Appendix H

Index of Environmental Integrity for MAIA Estuaries 1997

Environmental managers require information in a form they can understand and use in their decision-making. The challenge to scientists is to distill the vast complexity of information about the environment into something that is useful to and understandable by managers. Information on individual indicators collected in MAIA Estuaries in 1997-98 is discussed in the main body of this report. The summarization, or "integration", of the information on the individual indicators is in the form of an environmental report card. This report card is similar to the environmental report cards in the MAIA resource reports (Jones, et al. 1997; USEPA 1998; USEPA 2000). Multimetric approaches, which are intended to make it easier for managers to use ecological data in their decision-making, are also being explored as an additional way of integrating information from individual indicators (Paul 2002).

Multimetric approaches are used to combine information in the environmental report card into an overall assessment. This is driven by the desire of managers for information which can be used for comparative assessments and evaluation of conditions for geographic regions. To do this, a common basis for comparison is needed. Therefore, an index of environmental integrity (IEI) for the mid-Atlantic region has been developed for conducting multiresource assessments, i.e., to evaluate the overall condition of the region (Paul 2002). The index starts with information in the environmental report cards for individual resources. This information is then aggregated across indicators, spatial scales, and resources. An hierarchical multimetric approach is used to construct the index. It is assumed that individual metrics that make up the index respond to stress. Uniform scaling is applied to the individual metrics in the index. The index is then constructed by simple averaging of the metrics at each level of aggregation.

The IEI builds upon the tenets of the Index of Biotic Integrity (IBI) approach developed by Karr (Karr 1981; Karr and Chu 1999): it is a simple sum of individual metrics that respond monotonically to environmental stress; it scales the metrics uniformly; and it retains the information from the individual metrics. The index also relies on the scientific validity of the indicators underlying the environmental report cards. However, there are three differences from the IBI: the IEI assumes that the stress-response relationships for the metrics have been established and validated, whereas the IBI develops explicit dose-response relationships; the IEI responds to anthropogenic and natural stress, while the IBI deals with only anthropogenic stress; and the IEI is based not only on biological information as the IBI, but includes information on habitat and human use, making it an environmental index.

Paul (2002) used the environmental report cards for estuaries in the mid-Atlantic (USEPA 1998) and wadable streams in the mid-Atlantic Highlands (USEPA 2000) to illustrate the IEI approach. IEIs for estuaries were constructed straightforwardly, by first aggregating spatially within each watershed and then across the watersheds. Data for IEIs of streams could be aggregated only across watersheds and ecoregions; they could not be aggregated across states because of the limited coverage in Maryland and Virginia.

The report card presented in the summary chapter was used to construct IEIs for MAIA-E based on the 1997 information. The indicator information for eutrophication, sediment contamination, and benthic condition were used to construct the index. Values of 5, 3, and 1 were assigned to each indicator for each geographic area in the report card according to the percent area for the indicator exceeding 40%, between

20 and 40 %, or less than 20%, respectively. Here, 5 is used for good condition, 3 for fair, and 1 for poor. For example, if 21% of the area of a system exhibited bottom dissolved oxygen ≤ 5 mg/l, then a value of 3 was assigned. The result of the assignment of values for the indicators in all of the geographic areas, based on the data in Figure H-1, is shown in Table H-1.

Table H-1. Assignment of Scores to Geographic Areas for Each Indicator Based Upon Percent Area Exceeding Thresholds: less than 20% impairment = 5; 20% to 40% = 3; more than 40% impairment = 1.

	Eutrophication			Sediment Contamination			Benthic Condition
	Surface Chlorophyll	Water Clarity	Bottom DO	Sediment Metals	Sediment Organics	Sediment Toxicity	Benthic Index
MAIA	3	1	3	3	3	5	3
DELAWARE ESTUARY	3	1	5	5	5	3	1
Delaware Bay	3	1	5	5	5	3	1
Delaware River	1	1	5	1	1	3	1
*Schuylkill River	3	1	5	1	1	1	1
*Salem River	1	1	3	1	1	5	3
CHESAPEAKE BAY	3	1	3	1	3	5	3
Mainstem	5	5	1	1	3	5	3
Choptank River	3	1	3	1	3	5	5
Patuxent River	3	1	1	1	3	5	1
Potomac River	1	1	3	1	1	5	1
Rappahannock River	1	1	3	1	3	5	3
York River	1	1	3	1	5	5	1
James River	1	1	5	1	1	5	3
*Severn River	1	1	1	1	1	5	1
*South River	1	1	1	1	1	5	1
*Eastern Bay	1	3	3	3	3	5	3
*Pocomoke River	5	3	1	3	3	5	3
*St. Jerome River	1	1	5	1	5	5	1
*Pamunkey River	3	1	5	1	3	3	5
*Mobjack Bay	5	3	3	1	5	5	3
*Cherrystone Inlet	1	1	5	1	1	5	1
COASTAL BAYS	5	1	5	5	5	5	3
Chincoteague Bay	5	1	5	5	5	5	5
*Sinepuxent Bay	1	1	5	5	5	5	5
*Va Coastal Bays	5	1	5	5	5	5	3
ALBEMARLE-PAMLICO	3	1	5	5	5	5	1
Chowan River	5	1	3	5	1	1	3
Neuse River	1	1	5	5	5	5	1

*system sampled spatially intensively

Aggregations across indicators were used for constructing IEIs. The aggregation for eutrophication-related indicators was done with only surface chlorophyll *a,* water clarity, and bottom dissolved oxygen (the indicators with impact thresholds). The aggregation for sediment contamination was done for metals, organics, and toxicity. A sediment-quality aggregation was done combining overall sediment contamination with benthic condition. Finally, an overall IEI for each system was the aggregation of the values for eutrophication and sediment-quality. These aggregations are shown in Table H-2.

Table H-2. Values for Index of Environmental Integrity for MAIA Estuaries Geographic Areas. Eutrophication index is the average of chlorophyll *a,* water clarity, and dissolved oxygen scores from Table H-1. Sediment contamination is the average of metal, organics and toxicity scores. Sediment quality is the average of sediment contamination indicators and benthic index. Overall, the index is the average of all indicators.

	Eutrophication	Sediment Contamination	Sediment Quality	Overall IEI
MAIA	2.3	3.7	3.5	3.0
DELAWARE ESTUARY	3.0	4.3	3.5	3.3
Delaware Bay	3.0	4.3	3.5	3.3
Delaware River	2.3	1.7	1.5	1.9
*Schuylkill River	3.0	1.0	1.0	1.9
*Salem River	1.7	2.3	2.5	2.1
CHESAPEAKE BAY	2.3	3.0	3.0	2.7
Mainstem	3.7	3.0	3.0	3.3
Choptank River	2.3	3.0	3.5	3.0
Patuxent River	1.7	3.0	2.5	2.1
Potomac River	1.7	2.3	2.0	1.9
Rappahannock River	1.7	3.0	3.0	2.4
York River	1.7	3.7	3.0	2.4
James River	2.3	2.3	2.5	2.4
*Severn River	1.0	2.3	2.0	1.6
*South River	1.0	2.3	2.0	1.6
*Eastern Bay	2.3	3.7	3.5	3.0
*Pocomoke River	3.0	3.7	3.5	3.3
*St. Jerome River	2.3	3.7	3.0	2.7
*Pamunkey River	3.0	2.3	3.0	3.0
*Mobjack Bay	3.7	3.7	3.5	3.6
*Cherrystone Inlet	2.3	2.3	2.0	2.1
COASTAL BAYS	3.7	5.0	4.5	4.1
Chincoteague Bay	3.7	5.0	5.0	4.4
*Sinepuxent Bay	2.3	5.0	5.0	3.9
*Va Coastal Bays	3.7	5.0	4.5	4.1
ALBEMARLE-PAMLICO	3.0	5.0	4.0	3.6
Chowan River	3.0	2.3	2.5	2.7
Neuse River	2.3	5.0	4.0	3.3

*system sampled spatially intensively

Caution must be emphasized in the interpretation that is placed on the IEI values in Table H-2. A limited number of indicators was used to determine the values. For example, only surface chlorophyll *a,* water quality and bottom dissolved oxygen were used to determine the eutrophication values. Additional indicators could be incorporated if clearly-defined thresholds are assigned to these additional indicators. For determining IEI values indicators, it is inappropriate to use thresholds that are based on percentiles of observed values. That is why total nitrogen and phosphorus were not used in the construction of the IEIs. A limited number of categories of indicators, was available with no indicators for human use. This means that the interpretation of the overall IEI score is restricted to aspects of eutrophication and sediment quality.

The IEI values indicate that eutrophication is of major concern in the Chesapeake Bay, with sediment quality of concern in the other major systems. Of the intensively-sampled systems, the Schuylkill River has the lowest value for sediment contamination, while the Severn and South Rivers have the lowest for eutrophication. Again, these interpretations are limited because of the small number of indicators that were used to construct the IEIs.

	Eutrophication						Sediment Contamination			Benthic Community
	Total Nitrogen	Total Phosp	Tot Org Carbon	Chl *a*	Water Clarity	Diss Oxygen	Metals	Organics	Sediment Toxicity	Benthic Index
MAIA	21	15	16	31	50	21	39	29	1	37
DELAWARE ESTUARY	23	31	7	29	51	1	16	18	2	36
Delaware Bay	11	20	3	24	45	0	6	6	0	36
Delaware River	100	100	28	63	89	11	76	100	15	38
Schuylkill River*	100	100	100	20	60	11	100	100	71	83
Salem River*	100	100	60	100	100	30	100	90	0	40
CHESAPEAKE BAY	17	11	12	29	46	38	56	38	0	35
Mainstem	5	0	15	16	17	55	45	31	0	30
Choptank River	25	25	33	25	50	25	60	20	0	0
Patuxent River	27	64	0	36	82	70	80	20	0	44
Potomac River	45	64	0	55	100	25	71	43	0	56
Rappahannock River	0	0	0	67	75	33	100	20	0	32
York River	0	0	0	50	75	38	100	0	0	52
James River	15	0	7	50	68	5	64	64	0	32
Severn River*	18	11	45	41	45	71	76	69	4	62
South River*	12	23	35	73	89	56	89	67	0	59
Eastern Bay*	30	0	0	70	40	30	33	22	0	33
Pocomoke River*	50	75	40	0	40	50	20	20	0	20
St. Jerome Creek*	20	0	0	50	100	10	60	0	0	60
Pamunkey River*	11	25	9	36	100	9	55	27	27	0
Mobjack Bay*	0	0	0	0	20	20	50	10	0	40
Cherrystone Inlet*	11	11	0	50	100	0	80	70	10	80
COASTAL BAYS	34	36	0	14	100	9	21	11	0	25
Chincoteague Bay	50	30	0	0	100	17	36	0	0	9
Sinepuxent Bay*	60	40	0	60	100	0	0	0	0	0
VA Coastal Bays*	0	20	0	0	100	0	18	9	0	30
ALBEMARLE-PAMLICO	25	16	24	37	54	3	21	20	1	41
Chowan River	0	0	70	0	70	40	70	60	80	40
Neuse River	9	1	33	41	51	9	41	9	0	50
Impaired when:	TN >1 mg/L	TP >0.1 mg/L	TOC >3%	CHL*a* >15 µg/L	SECCHI ≤1 m	DO ≤5mg/L	MET Exceed ERL/ERM	ORG Exceed ERL/ERM	TOX <80%	<0

* Intensively-sampled systems

Better conditions	(blue)	(green)	Less than 20% of the estuarine area exhibits high values or impairment
	(light yellow)	(yellow)	20% to 40% of the area exhibits high values or impairment
Worse conditions	(orange)	(red)	More than 40% of the area exhibits high values or impairment

Note regarding color schemes: The thresholds used to define assessment categories for TN, TP, and TOC are developmental and are under evaluation. Neutral colors are used to characterize these indicators, and interpretation as "high" or "low" may be more appropriate than "good" or "poor". Categories for other indicators are based on established criteria and may be interpreted as "impaired" or "unimpaired".

Figure H-1. Environmental Report Card for Mid-Atlantic Estuaries. Based on the percentage of estuarine area that exceeds the designated impairment threshold. Warm colors (red or orange) indicate a greater incidence of impaired conditions or excessively high concentrations of a substance. Numbers in cells are percentages of estuarine area impaired. Refer to Figure 7-1.