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A process for comparing and interpreting differences in two benthic indices in New York Harbor

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A B S T R A C T

Often when various estuarine benthic indices disagree in their assessments of benthic condition, they are reflecting different aspects of benthic condition. We describe a process to screen indices for associations and, after identifying candidate metrics, evaluate metrics individually against the indices. We utilize radar plots as a multi-metric visualization tool, and conditional probability plots and receiver operating characteristic curves to evaluate associations seen in the plots. We investigated differences in two indices, the US EPA Environmental Monitoring and Assessment Program's benthic index for the Virginian Province and the New York Harbor benthic index of biotic integrity using data collected in New York Harbor and evaluated overall agreement of the indices and associations between each index and measures of habitat and sediment contamination. The indices agreed in approximately 78% of the cases. The New York Harbor benthic index of biotic integrity showed stronger associations with sediment metal contamination and grain size.

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1. Introduction

Observations of highly contaminated estuarine areas in the vicinity of New York City, New York from EPA's Environmental Monitoring and Assessment Program (EMAP; Strobel et al., 1995) brought much attention to the New York Harbor area. Based on coastal monitoring data collected from 1990 through 1993 from the Virginian Province (from Cape Cod, Massachusetts to the Chesapeake Bay, Virginia), the New York Harbor area was found to have higher than average sediment concentrations for all but one of the 59 chemicals measured.

Following the EMAP study, two investigations (one in 1993 and 1994 and another in 1998) were conducted by the US EPA Region 2 to evaluate water quality, sediment contaminants, and the benthic community structure of New York Harbor through a program known as Regional EMAP (REMAP). At the start of the regional monitoring program, the main tool used to evaluate benthic community condition for similar studies in the Virginian Province was the EMAP benthic index (EMAP BI; Paul et al., 2001). The regional office and their partners perceived a need for and developed an index specifically for the New York area (Adams et al., 1998). This, however, meant that two indices could be applied to the same data set.

Borja and Dauer (2008), observing the need for validating and intercalibrating multiple indices, recommended intercalibrations by assessing agreement between indices by using benthic expertise to assess benthic condition as was done by Weisberg et al. (2008) and by assessing the level of agreement when using multiple indices as was done by Borja et al. (2007, 2008).

Several questions arise from applying two indices to the monitoring data from the New York Harbor. First, how do they agree or disagree in their assessment of benthic condition? Second, how do we identify associations of other parameters (e.g. sediment metals and habitat characteristics) with those places of agreement or disagreement?

This paper describes a screening and evaluation process by which we can examine indices and their associations with environmental metrics. We utilize radar plots as a multi-metric visualization tool to screen for differences in water and sediment parameters, and conditional probability plots and receiver operating characteristic (ROC) curves to evaluate any apparent associations seen in the radar plots, and then apply this process to a case study in New York Harbor.

2. Materials and methods

2.1. Study area and data

Our study area was the New York Harbor system including the Upper and Lower Harbors, Newark Bay, and Jamaica Bay (Fig. 1).

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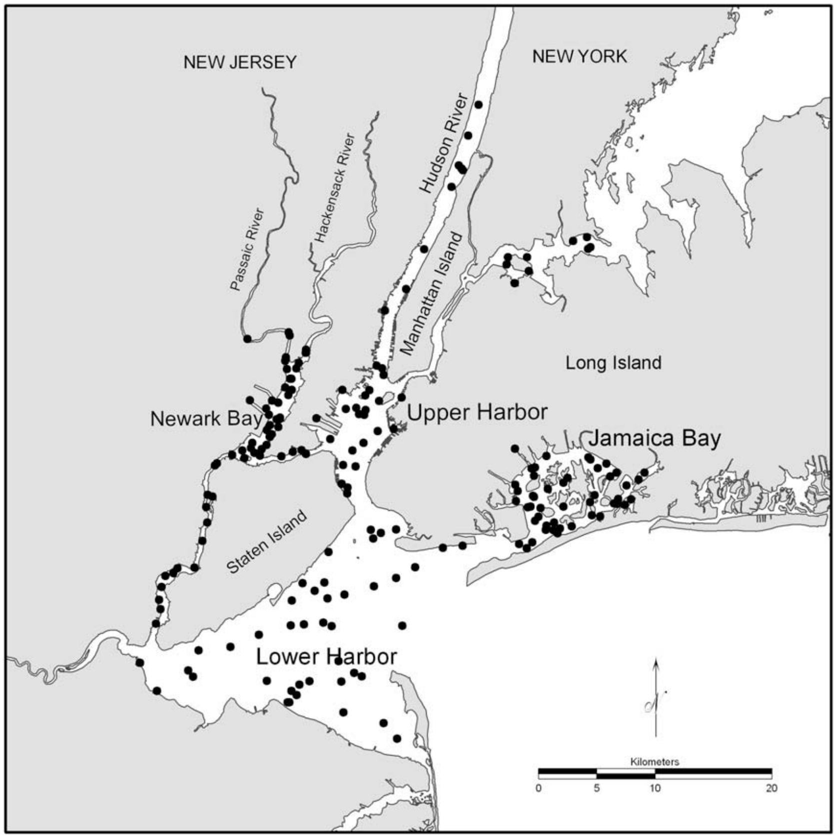

Fig. 1. Map of the New York/New Jersey Harbor showing sampling stations for the 1993/1994 and 1998 data.

We acquired data from the 1993/1994 and 1998 REMAP studies in New York Harbor designed to document the baseline conditions of water quality, sediment contamination, sediment physical characteristics, and benthic community structure (Adams et al., 1998; Adams and Benyi, 2003). For our study, we extracted data on physical characteristics of the sediment (percent silt–clay, total organic carbon), characteristics of the environment (bottom dissolved oxygen and bottom salinity), and sediment metal concentrations (Ag, Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Sn, and Zn). For a detailed description of the data and collection methods see Adams et al. (1998).

2.2. Benthic indices

To illustrate our screening and evaluation process, we compared two benthic indices: the New York Harbor benthic index of biotic integrity (B-IBI) and the EMAP BI for the Virginian Province. The B-IBI, developed specifically for New York Harbor, utilized an approach similar to that of the index of biotic integrity for freshwater benthos and other estuarine indices (Kerans and Karr, 1994; Weisberg et al., 1997; Adams et al., 1998; Llanso et al., 2002). The B-IBI incorporated five metrics of benthic invertebrates (number of species, abundance, biomass, and the abundance of taxa that either indicate or are sensitive to pollution) into a single value that described the condition of the benthos. Scoring for each metric was adjusted based on salinity and grain size. The index was calculated by scoring each metric as 5 (most similar to the reference site), 3, or 1 (most dissimilar to the reference site), and averaging the score of the five metrics. Index values less than or equal to 3 indicate poor condition. For further details of the development of the B-IBI see Weisberg et al. (1998) in Appendix C of Adams et al. (1998).

The EMAP BI, developed for the east coast of the United States from Cape Cod to the mouth of Chesapeake Bay, used linear discriminant analysis to incorporate three measures (salinity-normalized Gleason's *D* for infaunal and epifaunal species, the expected number of tubificids normalized for salinity, and the abundance of spionid polychaetes) into the index (Strobel et al., 1995; Paul et al., 2001). The index is a continuous function that is interpreted as binary with values greater than 0 indicating good condition and values less than or equal to 0 indicating poor condition. For further details of the development of the EMAP BI see Paul et al. (2001).

2.3. Assessment of agreement

We assessed agreement between the B-IBI and EMAP BI using an error matrix which is a tabular representation of agreement and disagreement between two categorical classifications of condition (good and poor; Table 1). From the error matrix we calculated the percentage of overall agreement.

2.4. Screening and evaluation process

We outlined a process to use radar plots, conditional probability analysis (CPA), and receiver operating characteristic (ROC) curves to assess index response to metal concentrations and habitat

Table 1
Matrix of index classifications for the New York Harbor area.

	B-IBI Good	B-IBI Poor	Total	
EMAP BI good	17	21	38	
EMAP BI poor	18	124	142	
Total	35	145	180	Total agreement 78.3%

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