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Summer fish communities in northern Gulf of Mexico estuaries: Indices of ecological condition

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ABSTRACT

We used fish community data from trawl samples collected from >100 estuaries, bayous, and coastal lagoons of the Louisianan Biogeographic Province (Gulf of Mexico) to develop indicators of large-scale ecological condition. One data set, from which we derived reference values for fish community indicators, was based on bottom trawl samples collected from 367 randomly located sites during the summers of 1992–1994. A second trawl data set with similar geographic scope from 2000 to 2004 was used to test the robustness of the indicators derived from the reference data set to new data. We constructed a fish community index (FCI) from three basic indicators: number of species per trawl, total abundance per trawl, and an index of trophic balance among three common feeding guilds. The FCI was not correlated with salinity over a range from freshwater to marine and hypersaline conditions (0–52 psu). Direct correlations between the index and environmental variables generally were weak, although some were significant ($p < 0.05$). The FCI was negatively correlated with water clarity (secchi depth), water column depth, and sediment toxicity; correlations of the FCI with pH, sediment organic carbon, and sediment silt + clay content were positive. There was a hyperbolic relationship between dissolved oxygen and maximum values of the index, and no significant correlation with watershed land cover at the whole-estuary or estuary-complex scale. Values of all indicators increased between the two time periods. The FCI is a broad indicator of ecological condition for estuaries within the Louisianan Province, with data aggregated at scales ranging from large estuaries to the entire region. Sample density was insufficient to judge performance of the indicators or index at smaller scales.

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1. Introduction

The context for this study is expressed in the Report on the Environment (EPA, 2008). In posing the question, "What are the trends in the diversity and biological balance of the Nation's ecological systems?" (pp. 6–18), the report cites the lack of indicators for trends in coastal fish communities, among several other indicators required for more complete answers to this question. In developing indicators of coastal fish communities to fill this gap for one region of the United States, we took advantage of existing data sets from large-scale assessments of Gulf of Mexico estuaries. The Environmental Monitoring and Assessment Program (EMAP) has been developing, validating, and applying methods for assessing the condition of the Nation's major ecosystems since the early 1990s (McDonald, 2000). Comprehensive, probabilistic assessments of Gulf of Mexico estuaries were conducted from 1991 to 1994 as a component of EMAP, and later (2000–2006) through the National Coastal Assessment (NCA) Program (EPA, 2004a).

Fish community indices have been developed for a variety of freshwater habitats, especially wadeable streams, where indices of biotic integrity (IBI) have come into general use in many areas of the U.S. and elsewhere (e.g., Fausch et al., 1990; Barbour et al., 1995). Several published attempts to develop similar indices for estuaries have met with mixed success (Jordan et al., 1991; Chun et al., 1996; Deegan et al., 1997; Hughes et al., 2002; Meng et al., 2002; Harrison and Whitfield, 2004, 2006; Breine et al., 2007; Coates et al., 2007; Uriarte and Borja, 2009) There are several challenges in developing and applying IBI techniques to estuaries. Estuaries are open systems where fish are free to migrate widely within the range of their physiological tolerances; fish communities in these systems include a fluctuating mix of marine, freshwater, estuary-dependent, and estuarine resident species (Elliott et al., 2007). Complete sampling of the community, which can be achieved in streams with block nets and electrofishing, is virtually impossible in estuaries, similar to the situation in large rivers (Emery et al., 2003). Therefore, sampling typically is conducted with one or two gear types (e.g., seine and trawl nets) that are selective for certain species and size ranges of fish. Finally, unlike streams, small rivers, and lakes, where all or most of the species are year-round residents, temperate estuaries exhibit large

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seasonal variations in species composition, abundance, and other attributes of fish communities (Thompson and Fitzhugh, 1985).

Our primary objective for this study was to determine whether one or more indicators of fish community structure could be applied over the large spatial scale sampled in the EMAP and NCA programs. The data might appear to have limited utility for community analysis, because they are from a selective gear, with no information on seasonal variability, and each sample is taken from a dynamic community at a single time and place. Our analysis is based on the expectation that these potentially formidable drawbacks can be mitigated by consistent, spatially unbiased sampling over large areas and multiple years, and by employing indicators based on a few fundamental measures of community structure that are broadly associated with ecological condition. The fish community indicators presented here represent species richness, abundance, trophic balance, and a composite of these three properties. They are consistent with the concept of "...simple, robust indices of ecosystem state..." (Murawski, 2000, p. 655; see also Jordan and Houde, 2006) that communicate productivity, diversity, and variability.

The interpretation of ecological indicators typically involves establishing a reference condition (EPA, 1990; Gibson et al., 2000), which supplies a context for the indicators—is an observed indicator value equivalent to, higher than, or lower than a known condition? A common approach, used widely for indicators of fish and benthic communities, is to locate and sample one or more least-impaired, or relatively undisturbed sites (typically selected on the basis of professional judgment). The communities representative of these sites become the reference for other sites of known or unknown disturbance. Other approaches involve (1) historical (pre-disturbance) conditions, which seldom are known in quantitative terms and were not available for this study; (2) modeled reference conditions, which may incorporate ecological theory, knowledge of the faunal community expected under unimpaired conditions, and assumptions about the structure of unimpaired communities; (3) societally defined goals, targets, or benchmarks (Jordan and Smith, 2005); and (4) criteria based on the statistical distribution of indicator data (e.g., percentiles or cumulative frequency distributions; see Harrison and Whitfield, 2004 for an example of this approach). Each of these methods adopts the reference condition as a desired state for the community, and deviations from it as evidence of impairment or degradation. We have not attempted to define a least-impaired reference condition for Gulf of Mexico estuarine fish communities, or to interpret the data from a normative (qualitative) perspective (Lackey, 2007). Rather, we have used the statistical approach, with an internal reference: the distributions of ranked indicator data from consistent sampling of many randomly designated sites over 3 years.

We report the indicators at two spatial scales (Gulf-wide and for selected large estuaries), for two multi-year time periods, and explore correlations of the FCI with a variety of environmental variables, including geography, water quality, sediment quality, and land cover within estuarine watersheds.

2. Methods

2.1. Study area

Fish community indicators were developed from a reference data set: trawl sampling (two trawls per site) was conducted, along with water and sediment quality measures, during the summer months of 1992–1994 from the northern Gulf of Mexico as part of the U.S. Environmental Protection Agency's EMAP-Louisianan Province survey (Summers et al., 1993; Macauley et al., 1994, 1995, 1999). The 367 sampling sites (Fig. 1) and 734 trawls

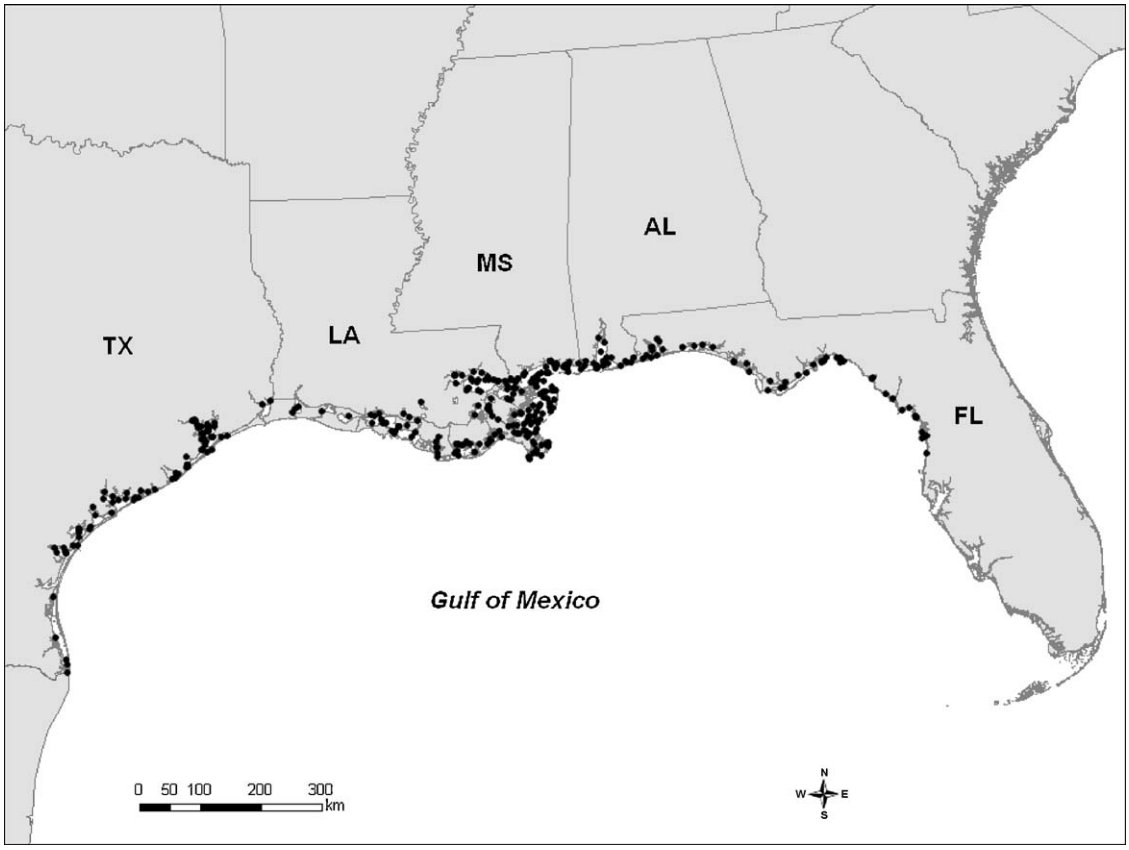

Fig. 1. Trawl sites in Gulf of Mexico estuaries sampled for the EMAP-Louisianan Province assessment, 1992–1994.