NOAA FISHERIES
Science & Technology

Estuaries are highly productive and critically important ecosystems that are prone to modification by human activities. In this study, we describe the development of a standard approach to (1) compare estuary condition relative to anthropogenic stressor gradients; and (2) identify key stressors and the scale at which they exert the most influence. Our approach uses the presence and abundance of fishes and invertebrates as indicators reflecting the condition of the local habitats where they live, feed, and reproduce. We demonstrate an approach whereby statistical models are used to systematically evaluate species sensitivities to stressors originating from the estuary shoreline, in the coastal watershed, or within the entire upstream river basin. Then we show how information about the species-level responses to stressors can be used to compare conditions between estuaries, and identify the influence and scale of stressors. Critically, we also identify stressor thresholds across which changes to species and ecosystems occur. We demonstrate our approach for 45 estuaries in the northern Gulf of Mexico, using a large trawl survey data set spanning 30 years. Specifically, we describe screening tools that were developed to rapidly assess 100's of possible species and community metrics to identify a subset that are most responsive to environmental stress and amenable to modeling. These candidate indicators were then used to model species and multi-species response to stress, and to map inter-estuary biological condition. This work is part of a national effort to assess the status of estuarine and coastal fish habitats throughout the United States in cooperation with the National Fish Habitat Partnership. We thus describe ways to scale-up the assessment to compare all estuaries in the country. Our approach yields results that offer important insights to decision makers at the regional and national level and is readily replicated in other places.

A Standardized Framework to Assess the Condition and Stresses of Estuary Ecosystems at Regional Scales: A Case Study of the Northern Gulf of Mexico

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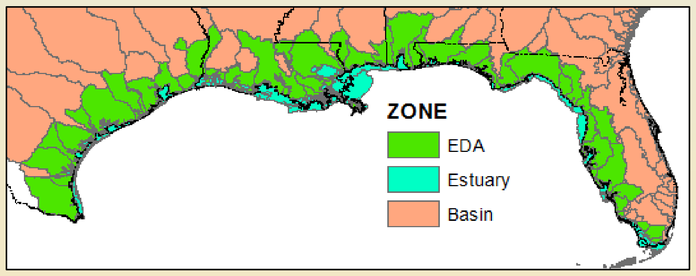
1. Spatial Framework

We developed a hierarchical spatial framework for the northern Gulf of Mexico to catalog and analyze georeferenced data.



Spatial analysis units included:

- Estuaries: Shoreline to 4m depth cutoff
- Shorelines: 500m buffer around estuary edges
- Estuarine drainage areas (EDA): Lowest 8-digit HUC
- Basins: To the top of the watershed divide

2. Data Compilation

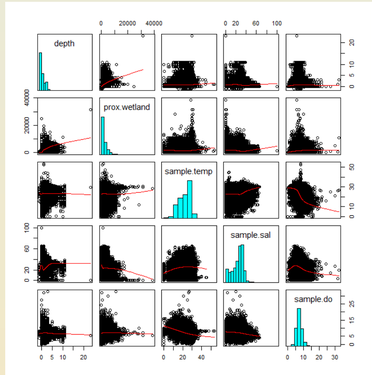
We compiled data sets from a number of sources to support the analysis. Although we explored many different kinds of data sets, the three primary types included were:

- Landscape environmental data: land use and land cover, population density, SPARROW-modeled N/P loads, NPDES and TRI site density, National Estuary Eutrophication Assessment scores, and estuary hydrogeomorphic class (Engle et al. 2007)
- Local habitat and disturbance data: depth, temperature, salinity, DO, secchi depth, turbidity, and pH
- Fish community data: national and state trawl survey sampling programs

We used up to a 40-year time series of data, where available, to investigate changes over time.

3. Evaluate Data

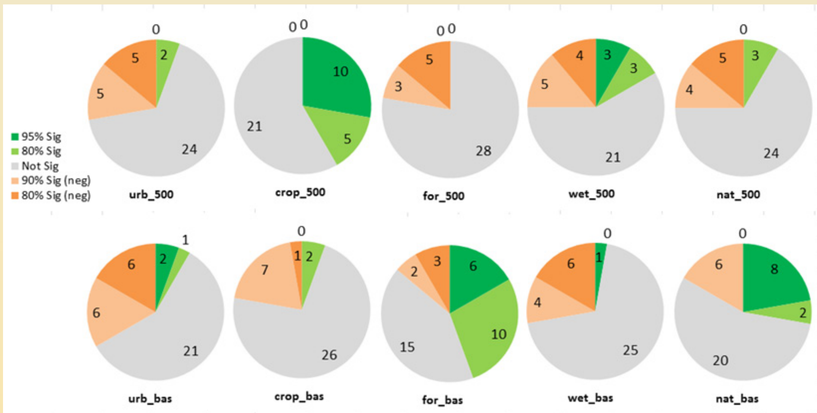
We used histograms, scatter plots, and other methods to look for outliers, points with high leverage, and suspicious patterns that could indicate errors in the data. We also investigated data distributions, skewness, and collinearity among predictors, and made decisions about where to clamp ranges or exclude values where necessary.

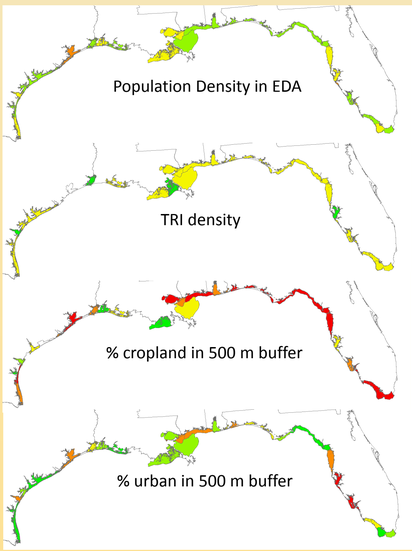


4. Indicator Screening Models

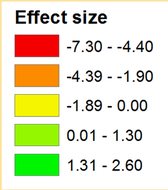
We used indicator screening to rapidly evaluate 100's of candidate indicators with the goal of identifying a subset with strong sensitivities to stressors, and identifying stressors and scales that have the greatest effects on biota. The pool of candidate indicators included both species abundances and a variety of fish community metrics.

A number of significant relationships were found between species presence/absence and land cover variables (graphs at right). These results should be interpreted with caution, because 1) a large number of species, with varying life history characteristics, were considered; 2) relationships only suggest causal effects; and 3) the models inverse-logit transformation results in a nonlinear response that cannot be simply characterized. However, many species appear to be related to multiple land cover variables, suggesting that more complex modeling could be beneficial. In particular, shoreline crop cover and basin forest and natural cover appear to be important to estuary species.





In addition to identifying the indicators with significant relationships to stressor variables, this step also provides initial estimates of the effect sizes of different stressors (see maps at left), and can be interpreted as a preliminary index of relative disturbance.



5. Species and Community Tolerance Models

Using the indicators identified in the screening step as sensitive to landscape anthropogenic disturbance, we are further investigating species and community tolerances to stressors using hierarchical zero-inflated Poisson (ZIP) regression models. These models deal with the difficult statistical problem of many zeros by allowing us to calculate the probability that a species has been locally extirpated (versus present but not sampled) along a stressor gradient. We also use ZIP models to identify stressor levels that lead to changes in species presence or community structure.

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