Spatial Data Applications to Science Programs at CCEHBR

White Paper

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May 1999

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This paper outlines an approach to integrating spatial data, quantitative spatial techniques, and spatial statistics into research activities at CCEHBR at Charleston. Specific recommendations as to how GIS and spatial analysis can enhance the programs within CCEHBR and our role within NOS are proposed. A library of spatial environmental data for coastal research, along with appropriate analysis techniques, will provide a foundation for applying this approach across programs.

Goal: Given that natural phenomena can often be better understood in a spatial context, spatial data and analysis methods will be integrated into coastal investigations - from study design to final analysis.

Background: The effective use of spatial data to better understand natural phenomena holds great potential. While many private and government entities have developed GIS applications to store and visualize spatial data and manage their product (anything from forest resources to banking facilities), applying GIS to model environmental phenomena and better understand coastal ecosystem processes has not been fully developed. Specific research questions regarding the function of ecological systems can be better understood by retaining the spatial component of environmental data. Issues of location - proximity, spatial interaction of landscape components (both aquatic and terrestrial), range of influence, spatial distribution of resources, and synergy among environmental variables - play a role in determining environmental responses and habitat selection. Therefore, methods for quantifying these spatial characteristics and relationships are vital to interpreting ecological processes and provide a sound basis for land use planning and protection of species and habitats. As the use of spatial data in coastal applications increases, it is important that the availability and efficient use of this data be addressed. Likewise, the interpretation of spatial data requires that applicable tools be integrated into design of studies and interpretation of results.

Several CCEHBR program areas already incorporate GIS and spatial analysis tools into their research programs to varying degrees. For instance, the Marine Mammals Program has identified a need to track the spatial distribution and movement of animals in relation to factors that may affect their use of habitats and reduce anthropogenic stresses. The Ecotoxicology group has developed a sizable amount of spatial data related to land use changes and contaminants for southeast coastal environments. Models that incorporate spatial data and retain relationships among environmental factors could be developed to predict the impact of human activities on the coastal environment. The Biotoxins Program could gain by identifying specific goals related to plans at the NOS level to develop real time, high resolution data systems to monitor ocean conditions. This information could be used to link environmental parameters occurring at a very short temporal scale with harmful algal blooms.

Preliminary steps toward building a GIS/relational database library of coastal environmental data have been initiated by the Risk Analysis and Information Management Branch. The Shellfish Information Management System (SIMS) project has taken on the challenge of building a system of shared environmental spatial data that is generated and used by diverse state and federal programs. SIMS will provide information on state shellfish harvest area classification and related coastal environmental data useful to state partners and federal agencies, such as FDA, involved in shellfish

safety issues. State shellfish program data will also be useful to NOS and others for analyses of national trends related to shellfish resources, habitat, and water quality. The SIMS project will allow access to spatial data within a shared relational database, such that users can directly query and analyze data in a manner that suits their needs. Similarly, a relational database of spatial environmental data would provide core information on coastal ecosystems to be integrated into various research programs at CCEHBR. Whether a science program focuses on the distribution of biota or the role of landscape characteristics in the occurrence of contaminants, the GIS/relational database model (using a spatial data engine (SDE) and the Oracle relational database management system) will serve as a framework for sharing common environmental data. This type of shared data system has recently received greater attention as agencies realize the necessity of allowing access to extensive spatial datasets to a variety of users. This model is relatively new and many agencies and organizations are keenly interested in following the lead of those who successfully implement this concept.

Application to Science Programs

Need. Individual program areas at CCEHBR have begun to realize the potential benefit of GIS. However, these applications have not taken full advantage of the spatial analysis techniques and modeling potential to quantify and test hypotheses about environmental processes. In addition, spatial data products developed for specific research may be duplicative of other program area efforts to acquire and process similar data.

Solution. By integrating GIS, spatial modeling, and spatial statistics into research activities, the interrelatedness or spatial arrangement of factors affecting ecosystem health can be addressed. Rather than summarizing environmental phenomena as a single descriptive statistic, spatial analysis retains locational information. As these techniques are applied to a variety of studies, the development of common spatial data layers should be coordinated. This will reduce duplication of effort and serve as a library of baseline data that would be available for specific analyses.

Potential outcome. Examples of research areas that would benefit from a library of common environmental spatial data and the integration of spatial analysis techniques include marine species, biotoxins, and ecotoxicology. Tracking the locations of marine species is an integral part of understanding habitat usage and variations in abundance. The potential for relating the location of marine mammals or biotoxins to water temperature, salinity, currents, landuse characteristics, and human impacts may provide insight into the relationship between these species and the environmental parameters regulating their distribution. Ecotoxicology studies that examine the interaction between land use and estuarine contaminants provide information on the potential impacts on biota and environmental health. An emphasis on spatial statistics and mathematical modelling tests and confirms these observations to identify important impacts that are spatially driven. In addition, analysis of spatial patterns (eg. phytoplankton distribution) can suggest hypotheses about the underlying processes (eg. turbulence) driving these patterns just as delineating environmental parameters (salinity) may lead to predictions about the occurrence of diseases affecting marine organisms (eg. *Perkinsus*).

Implications and expected benefits. The approach proposed here would increase CCEHBR's role within NOS and NCCOS as a leader in environmental modeling and spatial analysis of coastal ecosystems by expanding our expertise in shared data models, GIS and environmental modeling,

quantitative methods, and spatial statistics. This also would increase the validity of the science produced at CCEHBR by integrating quantitative and statistical spatial methods. In addition,

- Research programs would directly benefit from an efficient, easily accessible library of common environmental spatial data and expertise in spatial analysis techniques.
- Fundamental environmental data (plant and animal distributions, the spatial distribution of contaminants, landscape characteristics, etc.) would provide the foundational material on which to build models that address specific ecological questions.
- Addressing issues of location and spatial interaction would provide additional insight into the relationship between toxins and organisms and environmental factors regulating their distribution.
- Spatial statistics and mathematical modeling would be applied to test and confirm these observations and identify important impacts that are spatially driven.
- This approach would compliment wider NOS efforts, such as the Spatial Data Synergy Project, by making use of and contributing to that data development effort. CCEHBR would be developing useful coastal datasets (eg. shellfish) that would support the NOS goal of providing its customers with coastal and ocean spatial information. CCEHBR could also provide direction and input into future technological and large scale data collection efforts so environmental data generated at the NOAA and NOS levels support scientific research of coastal environments.
- The spatial data library would serve as a model of the integration of GIS and relational databases. As with the SIMS project, a GIS/RDBMS model facilitates the exchange, update, and query of common types of spatial data developed by separate investigators. This capability at CCEHBR will link us technically and programmatically with similar support activities within NOAA/NOS and provide a common ground for building relationships among other agencies and partners interested in shared data systems.

Summary

As the use of spatial data and analysis increases, the exchange of environmental data across disciplines will build a quantitative basis for understanding the spatial relationship of these elements within the ecosystem. Whether a program focuses on health and distribution of biota or the role of landscape characteristics in the occurrence of contaminants, the GIS/relational database model supports these research efforts. This approach brings together both data and techniques that are traditionally developed in the context of ‘stand alone’ computing. In this new model, CCEHBR program areas collectively build the database, access it for their specific program needs, and apply appropriate spatial analysis methods. The successful application of this approach to science programs at CCEHBR will enhance our mission as coastal stewards by merging our first hand knowledge of coastal research needs and applications of environmental data with the technological advances that support scientific research.