

Statement of
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My name is Gary S. Kleppel. I am Principal Investigator and Science Coordinator of the Land Use – Coastal Ecosystem Study (LU-CES). LU-CES is a multi-year, regional investigation of the effects of changing land use patterns and coastal development on the natural and economic resources of the salt marsh estuaries of the southeastern United States. The kinds of changes that we are concerned with are the result of human in-migration to the region, leading to increased urbanization and concomitant alteration of ecosystem structure (biodiversity) and function (performance) in ways that could significantly affect economic, aesthetic and cultural values. The goals of LU-CES are to develop an understanding of the mechanisms underlying these changes and to develop models and tools that can be used by decision makers, particularly at the local level to minimize and mitigate the negative impacts of changing land use patterns to coastal ecosystems. LU-CES is funded by the NOAA's Coastal Ocean Program (COP) and is managed by the South Carolina Sea Grant Consortium with input from Georgia Sea Grant. M.R. DeVoe, Executive Director of the SC Sea Grant Consortium, is co-PI of LU-CES.

The Problem -- For more than one hundred years after the end of the Civil War, the coasts of Georgia and South Carolina experienced minimal economic growth and development. During that time, population in the region actually declined. Land was used principally for agriculture and silvaculture, some manufacturing (particularly wood pulp products), and for the personal pleasure of a relatively few, wealthy, individuals. During that same period of time, the national trend in population movement was toward the coasts, a trend that continues today such that within the next 50 years, it is estimated that nearly 75 percent of the US population will live within 100 miles of a coastline.

Possibly as a result of the passage of the National Flood Insurance Program in the late 1960's (Becker 1998), population growth and development rates in the American Southeast have risen dramatically (Culliton et al. 1990), and currently are among the highest in the nation. The drivers of coastal development are the in-migration of retirees, and tourism. The impending retirement of 76 million Americans and the projected increase in population in the Carolinas and Georgia by 11 million by 2025 (US Census Bureau 2000) suggests that approximately 14 percent of the "post-WWII baby-boom generation" will ultimately reside in the region. About half of this growth will occur along the coastal plain. Quite clearly, this influx of new, permanent and seasonal residents, while stimulating a dramatic increase in regional economic development, is

also having enormous effects on coastal ecosystems and the human cultures that have developed in the Low County (as the coastal plain is called) during the past two centuries (Kleppel and DeVoe 2000).

Impacts of Changing Land Use Patterns to Coastal Ecosystems -- There is no shortage of evidence that urbanization, the principal form of land use change that will occur along the coasts of Georgia and South Carolina over the next three decades, negatively impacts ecosystems. Table 1 is a list of several papers, cited from memory, that support the hypothesis that urbanization degrades ecosystems.

Table 1. A list compiled from memory (volumes and page numbers added later) of papers that provide evidence that coastal ecosystems are degraded by urbanization.

- Ryther, J. & Dunstan, W. 1977. *Science* 171:1008.
- Valiela, I. and Teal, J. 1979. *Nature* 280:652.
- Sherr, E. & Payne, B. 1981. *Estuaries* 4:146.
- Brown M. et al. 1985. *Mar. Poll. Bull.* 16:236.
- Webb J. et al. 1985. *Wetlands* 4:75.
- Vernberg, F.J. et al. 1992. *Netherlands J. Sea Res.* 30:239.
- Rothschild, B. et al. 1994. *Mar. Ecol. Prog. Ser.* 111:29.
- Fulton M. et al. 1996. P. 477. In, Vernberg et al. *Sustainable development in the southeastern coastal zone.* University of South Carolina Press, Columbia.
- Lerberg, S. et al. 2000. *Estuaries* 23:838.

Research along the coast as part of NOAA COP's Urbanization and Southeast Estuarine Systems (USES) program has demonstrated that low density urban development, so-called suburbanization, characteristic of development patterns throughout the nation since the 1950's, reduces coastal ecosystem integrity in, often subtle, but definitive ways (Vernberg et al. 1996; Vernberg and Vernberg 2001, and references therein). Research at federal and state laboratories in the region generally supports this hypothesis (see Holland et al. 1996; Lerberg et al. 2000).

One can gain a sense of the scale of the impact of urbanization on ecosystem structure (biodiversity) by considering the classic "species-area" (S-A) relationship, described by Arrhenius (1921), popularized by MacArthur and Wilson (1967), and still very much of interest to theoretical ecologists (Plotkin et al. 2000). The S-A relationship suggests that as the area (originally of an island, but now), of any landscape increases, the number of species that occurs within that space increases according to a power law, such that,

$$S = cA^z, \quad (1)$$

where c is a constant that relates to density dependence and z reflects, among other factors, the complexity of the landscape. Using benthic invertebrate species richness data from tidal creeks draining urbanized and undeveloped watersheds in coastal Charleston

County, SC (Lerberg 1997; Lerberg et al. 2000), Kleppel et al. (2001) observed that as the area, A , of watersheds bordering to tidal creeks increases, S does indeed increase according to a power function.. However, tidal creeks in urbanized watersheds support about half as many species as do tidal creeks in undeveloped watersheds (Fig. 1).

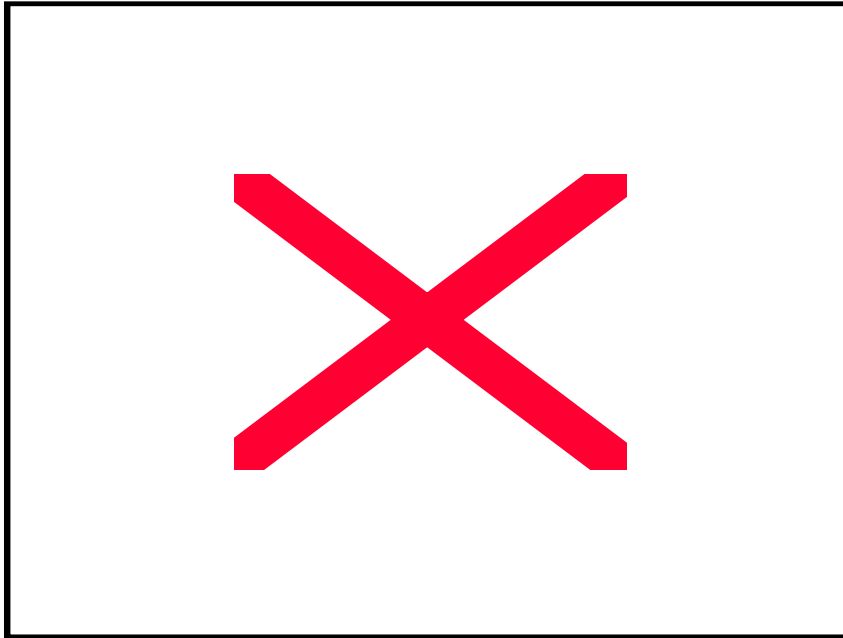


Fig. 1. Species richness of benthic macroinvertebrates in tidal creeks in undeveloped (S'_U) and developed (S'_D) watersheds in Charleston County, SC, expressed as a power function of watershed area.

Data are from Lerberg (1997) and Lerberg et al. (2000). Analysis is from Kleppel et al. (2001).

Kleppel et al. (2001) went on to estimate, from Census Bureau projections of future growth along the coast and estimates of average population densities in suburban and traditional urban areas, that if the current pattern of low density urban development continues, with the average population density being approximately 6 people hectare, then in the fastest growing coastal counties, as much as 12% of the benthic macroinvertebrate species in the tidal creeks may be lost (Fig. 2). Scaling the same population to the dimension of traditional small towns and cities would change the impact considerably. Now, the averages suggest a considerably smaller impact, the average loss being fewer than two species per watershed in even the fastest growing coastal counties. Although it is not unexpected that S - A relationships depicting correlations between the landscape and aquatic species richness would be quite noisy, the result leads to an important conclusion. It appears that while, urbanization degrades ecosystems (Table 1), the manner in which the population is distributed, may affect the impact that development of the coasts has on the ecosystems of the coastal Southeast. Thus, if all types of urban development were equally degrading to ecosystems, then there would be no need for science. The solution to population growth would need to be based completely on regulation. The findings of Kleppel et al. (2001), however, suggest that different scales of development have different impacts on ecosystems. It therefore becomes necessary to understand how changing the way land is used alters ecosystem integrity. This argument validates the Land Use-Coastal Ecosystem Study.

LU-CES, Interdisciplinary Conceptual Framework -- LU-CES is not a scientific research program *per se*. Rather, it is a research program with the stated intent of applying the results of scientific inquiry to the development of decision-making tools and

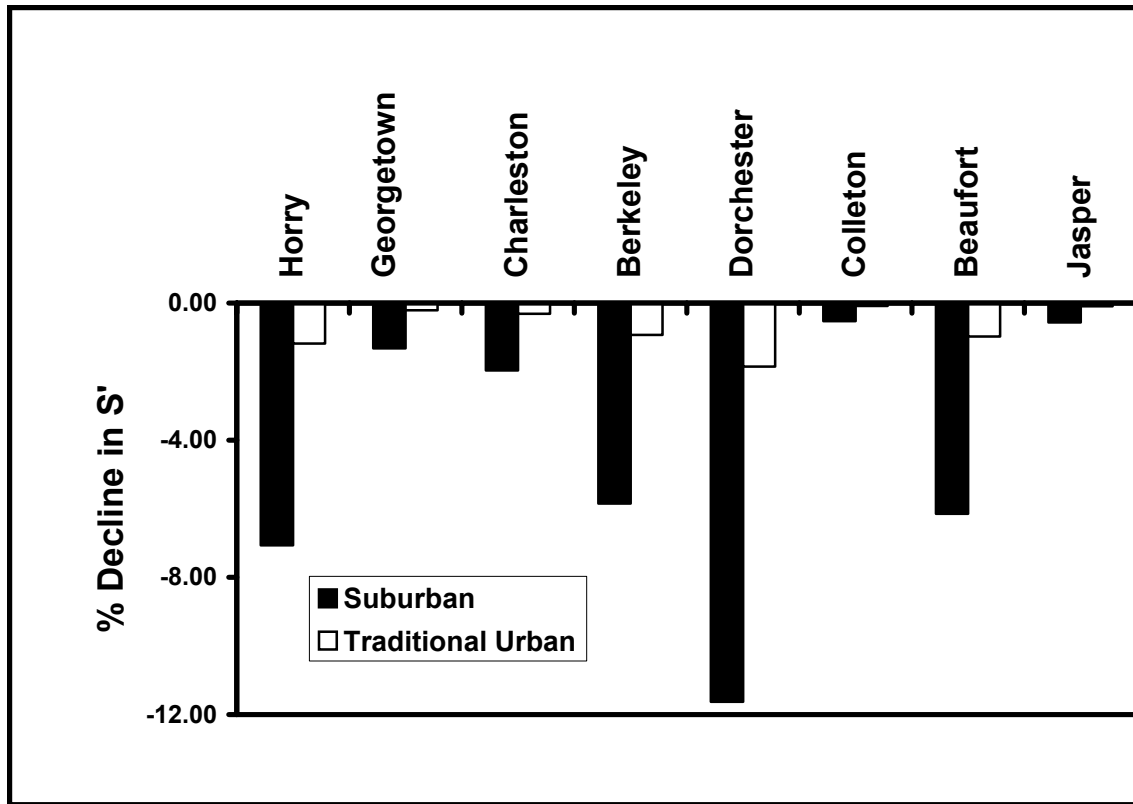


Fig. 2. Estimated changes in species richness (number of species) as a function of two types of urban development: low density (suburban) and higher density (traditional).

From: Kleppel et al. (2001)

guidance for policy makers. The program is seeking to respond to key challenges identified by state and local resource managers in South Carolina and Georgia as critically affecting sustainable use of fisheries and other resources, and protection of these resources and the ecosystems upon which they depend from contamination and degradation. LU-CES, therefore, addresses both scientific and policy issues as part of its mission.

Scientific Issues. Documenting the consequences of changing land use patterns to coastal ecosystems has been complicated by the enormous spatial and temporal variability associated with the coasts and estuaries of the South Carolina and Georgia (D. Porter pers. comm.). Thus, traditional tools for evaluating and predicting impacts, based largely on the correlative approach are difficult to apply, and in any case, do not resolve causation. In LU-CES, we have taken a mechanistic approach, seeking cause-effect

explanations for the ecosystem response to land use change. LU-CES supported an initial effort to identify the key issues and problems pertinent to the program mission and to determine the state of knowledge on these issues. Nine State of Knowledge Reports have been produced and are available on the LU-CES website (www.lu-ces.org). In general, the key issues fall into two major categories are:

1. ***Linking transport of forcing functions (e.g., contaminants), determining their fates (where do they end up) and identifying their effects on living resources.*** It is perceived that the hydrosystem provides the principal transport from land to the estuary. Much of that transport may occur below the surface. Relatively little is known about ground water and interstitial flows in this region dominated by highly permeable soils and significant aquifers (Joye et al. 1998). Further, on reaching the estuaries and saltmarshes, dissolved and particulate material distributions are not predicted simply by tidal fluxes. Rather, local asymmetries in the transport regime influence the fates of materials in the system (Blanton 1998). As such, eutrophication, microbial contamination and uptake of toxic contaminants by estuarine biota are linked to the local physical regime as well as the nature of the materials themselves (i.e, particulates, colloids, etc)(Fletcher et al. 1998; Shaw and Chandler 1998).
2. ***Spatial scaling.*** Processes occurring over an enormous range of scales – from the size of the drainage system to scale of molecules determine the impacts of land use change on coastal resources. It is impossible to observe and study the entire range of processes. Therefore, LU-CES has sought to identify interfaces between system compartments, such that information generated on the saltmarsh-tidal creek scale is translated to larger scales relating to urbanization of the region, and vice versa.

Policy and Outreach Issues. LU-CES was not conceived as a fundamental science program. Instead, the research products are intended to be used to enhance the abilities of decision makers and resource managers to address the key resource management challenges accruing from rapid coastal development during the first half of the 21st Century.

To this end, LU-CES has helped to create a series of unique partnerships between academic and government scientists, and between federal, state and local resource management and planning agencies. The partnering process will eventually link to the private sector. The approach that is being taken to accomplish these goals is represented as a combination of large scale predictive modeling, data compilation and scenario modeling that will provide tools that will be useful to the public and private sectors in resolving specific issue. LU-CES is not attempting to solve each problem that the management community has with respect to coastal development. Instead, the program will provide a data that can be accessed in a variety of ways, at several levels of technical expertise, in a format designed to inform the decision making process. We are currently working with our partners in the public sector to define the information delivery system.

To accomplish these goals, LU-CES has already or will soon:

1. ***Convene a Resource Manager/User Panel***, composed of planners managers and decision makers to participate in the development of the program and to comment on and guide program progress through the life of the program.
2. ***Develop a virtual website for access to data and modeling tools***. The website will have resources geared to several levels of technical competence.
3. ***Project regional growth patterns on the landscape scale***. This aspect of LU-CES is modeled on already successful growth projection models for the Charleston area.
4. ***Work with local planners, governments and ngo's*** to translate LU-CES products for potential users, ensuring maximal application of data products and outreach resources.

Conclusion -- LU-CES is a unique experiment in applying fundamental scientific information to help reduce pressure on economic, cultural and aesthetic resources created by rapid development and alteration of land use patterns. The program is interdisciplinary and cross cutting in terms of its approach to regional problems. The initial field year has yielded interesting data suggesting the sensitivity of the system to local physics, the importance of interstitial flow in the transport system, and the occurrence of “interface zones” in the system where convergent transport regimes concentrate materials (e.g., nutrients) potentially traceable to specific land uses within the estuaries.

Of at least equal significance is the experiment that LU-CES represents in terms of the relationship between academic science, local, state and federal governments and society at large. The lessons learned about how to apply federal resources to local problems through the application of scientific expertise may be among the most important contributions of the LU-CES effort.

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Dr. Gary S. Kleppel is the Principal Investigator/Program Director of the Land Use Coastal Ecosystem Study (LU-CES), a position he shares with M. Richard DeVoe, Executive Director of the South Carolina Sea Grant Consortium. LU-CES is a multi-year study, funded by the NOAA Coastal Ocean Program, of the impacts of changing land-use patterns on coastal ecosystems of the southeastern United States, brought about by high rates of human in-migration to the region. Dr. Kleppel is the Chief Scientific Officer of LU-CES and, as such, is responsible for development of the conceptual scientific framework and research design for the program. He works closely with the financial coordinators of the program and is actively involved in efforts to take the science from LU-CES to the public with a variety of outreach activities and coordinated efforts at designing scientifically informed natural resource and community-based planning tools.

Dr. Kleppel obtained his PhD in Biology in 1979 from Fordham University, where his dissertation focused on primary productivity in the lower Hudson River estuary. His post-doctoral work was conducted as a Fellow of the Allen Hancock Foundation, of the University of Southern California, between 1981 and 1986. Dr. Kleppel joined the Faculty of Oceanography of Nova Southeastern University in 1987, moved to the Department of Environmental Health Sciences, University of South Carolina, Columbia in 1996 and to the Department of Biological Sciences of the University at Albany, State University of New York in 2000. Currently, Dr. Kleppel is Associate Professor and Director of the Biodiversity, Conservation and Policy Program in the Department of Biological Sciences. He is also Associate Director of the Institute for Health and the Environment at the University at Albany.

Dr. Kleppel's research interests have, throughout his career, centered on estuarine and coastal ecosystems. However, the direction and focus of his work has changed several times. Though trained in algal physiology, Dr. Kleppel gravitated toward zooplankton research early in his career. He began investigating zooplankton feeding and by the mid-1990's had produced several important papers on zooplankton diet and nutritional physiology. In 1994, Dr. Kleppel began working with the group that organized LU-CES and he has been PI/PD of the program since the program's funding in 1995. His current research focuses on the "scaling" of human communities to create a sustainable presence in the ecosystem. The work combines elements of classical ecology (where Dr. Kleppel is working to develop metrics for quantitative assessment of ecosystem function), social science, law and architecture.