IMPLEMENTING GEOGRAPHICAL INFORMATION SYSTEMS TECHNOLOGY AT ARCHBOLD BIOLOGICAL STATION

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We dedicate this paper to the memory of Richard Archbold on the 50th Anniversary of the founding of the Archbold Biological Station.

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ABSTRACT

Archbold Biological Station (the Station) is a private ecological research facility dedicated to long-term ecological research and conservation. located in south-central Florida Research is conducted by Station staff and research associates and by visiting scientists from many institutions in the United States and abroad.

The primary objective of the Station's research program is to contribute to a better understanding of the natural ecosystems of Florida and of such basic ecological problems as mechanisms of population regulation and evolution of adaptations.

The basics of GIS are presented including preliminary considerations for implementation. Essential considerations about gis discussed include Map Themes and Multiple Attributes, Resolution and Registration, and Spatial Accuracy. Details of GIS implementation at the station including hardware and software, personnel and training and integration into research are given.

ARCHBOLD BIOLOGICAL STATION

Archbold Biological Station (the Station) is a private ecological research facility located in south-central Florida at the southern end of the Lake Wales Ridge, near the town of Lake Placid. The Station was founded in 1941 by Richard Archbold, and today it is operated by Archbold Expeditions, a non-profit foundation. Facilities include an excellent library, laboratories, reference collections, a Geographical Information System, plus dining and housing facilities for visiting investigators.

The primary function of the Station is research. Other major parts of the Station's mission include education, land management, and conservation. Educational programs emphasize research internships for undergraduate and graduate students and formal environmental instruction for grade school children. The Station plans and conducts prescribed burns to maintain fire-dependent plant and animal communities. Other aspects of land management include fencing, control of research use of the land, active removal of any exotic organisms that may occur, and making base maps.

The Station owns 5,000 acres (2,000 ha) of pristine habitat, and was designated a National Natural Landmark in 1987 by the U.S. Department of the Interior. The Station contains one of the highest concentrations of threatened and endangered organisms in the United States. Study and management of endangered species forms a dominant research theme of Station staff.

In 1988 the Station became proprietor of a nearby 10,300 acre (4,200 ha.) prairie cattle ranch (Buck Island Ranch) through a major grant from the John D. and Catherine T. MacArthur Foundation. The ranch became the John D. MacArthur Agro-ecology Research Center, operated as a division of Archbold Biological Station. The Center conducts and fosters long-term research on the ecological relationships between cattle ranching, citrus production, and the native environment.

RESEARCH AT THE STATION

The Station is dedicated to long-term ecological research and conservation. Research is conducted by Station staff and research associates and by visiting scientists from many institutions in the United States and abroad.

The primary emphasis of staff research is on the ecology of the unique Lake Wales Ridge, and adjacent central Florida, one of the most distinctive and endangered biotic regions of the southeastern United States. The distinctive habitat types together with well-equipped laboratories and other facilities combine to make the Station an ideal site for in-depth, long-term ecological investigations. The focus of the field research program is on 1) vegetation patterns and succession as related to soils, climate, fire, and animal activities, and 2) the life histories and population dynamics of plants, invertebrates, and vertebrates of the Station and environs.

The primary objective of the Station's research program is to contribute to a

better understanding of the natural ecosystems of Florida and of such basic ecological problems as mechanisms of population regulation and evolution of adaptations. Station research also provides base-line data needed to detect and monitor changes in natural ecosystems resulting from man's activities. Many species being studied are on endangered species lists, and the success of conservation efforts for these species is strongly dependent upon detailed knowledge of their life history and ecology.

The Station is used extensively by visiting scientists for research in areas covering the entire spectrum of modern biology. Many scientists have established long-term studies and return annually. Usually the research is conducted on or in the vicinity of the Station. Some investigators use the Station as a base of operations for work done elsewhere in the state.

BASIC CONSIDERATIONS ABOUT IMPLEMENTING GEOGRAPHIC INFORMATION SYSTEMS

Preliminary Considerations

Geographic Information Systems (GIS) require an investment in technology, new methodologies, project planning, base map preparation, and computer applications not encountered in more familiar computing environments. GIS is normally installed on workstations or mini computers and the transition to these more powerful and intricate computers represents a large step for groups who have traditionally used personal computers. Therefore, conducting a formal assessment of user needs is an essential part of GIS planning.

Spatial data bases present a new approach to research and data management at ecological research facilities. These databases, the approaches to analysis, and complexity of system design are fundamentally different from other computer applications. Research scientists should work closely with the GIS specialist in the design of the spatial databases as the specialist will likely be the only individual with advanced training in spatial database design and in the integration of base maps for analysis.

The primary advantage of GIS technology in research is its ability to analyze spatially related environmental phenomena. Maps of environmental features can be analyzed to examine where statistically significant patterns occur. Statistical models can be produced and the results of the analysis presented in map form.

GIS Basics

GIS is classified into two basic categories, vector-based and raster- or cell-based systems. Vector-based systems record information as cartesian x-y coordinates. Computer-screen images are constructed from points, lines, and polygons which represent the locations of individual landscape features such as a tortoise burrow, a

scrub jay territory, or a fence line around a preserve. Vector-based systems rely upon topology as a means to spatially reference these features to each other.

Raster systems are based on a matrix of rows and columns of cells which represent areal positions on the ground. Normally square, the cell size is held constant for each set of spatial data. Statistical analysis of neighborhood characteristics, proximity models, contagion distributions, diffusion and gravity models, landscape fractal dimension, trend surface models, spatial autocorrelation, and other powerful multivariate models are much easier to compute from raster data systems than from vector-based systems.

ESSENTIAL CONSIDERATIONS ABOUT GIS

Map Themes and Multiple Attributes

Maps, satellite images, and aerial photographs are the most common sources of baseline data sets integrated into GIS. Field studies, like those conducted at the Station, often require the development of several study tract maps such as ground water surface elevations, topography, soils, a species' territories, or vegetation communities. Advanced GIS software allows multiple attributes to be assigned to each polygon in a map. For example, a soils map may require the assignment of several soil attributes (organic matter content, pH, cation exchange capacity, permeability, total available nitrogen, texture classes, etc.) to each polygon or cell represented on the map.

Resolution and Registration

The resolution at which data are collected for map themes is important when a base map is converted to GIS because maps of multiple scales are often consolidated into a common geographic information data set. At the Station, the scale for ecological mapping is large (1:1200) to medium (1:24000), and for regional conservation maps is medium to small (1:100000). Small scale maps are typically used in GIS for regional planning, biogeographic studies, and landscape investigation, but the ecological grain at the Station is so fine that larger scale mapping is required.

Disregard for registration standards will result in poor spatial registration among the diverse data sets maintained in the GIS. For example, soils maps must be registered with the same accuracy as topography and habitat maps. Otherwise, lakes represented on a habitat map may be spatially registered to the same geographic positions as an upland soil on a soils map. While many GIS applications have integrated large and small scale maps in a database, mixing extremely different map scales should be avoided. The accuracy of digitizing equipment in combination with the scale of maps will influence the geodetic registration control of each map included in the database. National mapping standards are maintained by federal agencies and in Florida by regional planning agencies and water management districts. Research stations planning regional mapping projects must consider the geodetic registration

compatibility of in-house maps with those produced by these agencies.

Spatial Accuracy

The exacting requirements of GIS for spatial accuracy is by far the least understood issue about geographic data. Cartography imposes the highest degree of data standards used in the GIS data base, and cartographic data standards will always exceed the resolution at which field data are collected. When ecological data are mapped a discrete spatial characteristic is implied. Errors in the geographic location associated with the graphic data can be as critical to the overall accuracy of the data base as the error associated with attributes represented. For example, in the Station's long-term population study of the Florida scrub jay, a vegetation map of the study tract (600+ ha) designed by mapping vegetation patches as small 5 meters on a side includes over 1200 polygons. This fine scale is necessary to describe the grain of the habitat meaningful to scrub jays. To capture this resolution in a spatial data base, the habitat map was digitized with a registration error approaching 1 meter.

GIS AT THE STATION

Hardware and Software

The variety of research objectives and mapping projects at ABS requires the use of two GIS software packages, ARC/INFO (a vector based system) and ERDAS (a raster based system), both purchased through two recent, matching grants ($15,000 and $162,000) from the National Science Foundation. When fully implemented, two Sun Microsystems SPARCstations and a 386-PC will provide access to the GIS software, statistical analysis packages, and image processing and plotting equipment. All Station data sets will be developed using the ARC/INFO digitizing and editing capabilities. Most data will be converted to either ARC/INFO's GRID module or to ERDAS for analysis, because raster data are more efficient than vector data in overlay procedures and statistical analysis.

Personnel and Training

Currently one GIS specialist is responsible for all data preparation, automation, and analysis at ABS. Some maps have been digitized by part-time research interns, but the need for training and previous computer experience indicates that a full-time technician is required to run a GIS facility efficiently.

The varied scope of GIS applications at a field station requires the GIS specialist to gain knowledge in the areas of science related to the station's research focus. Additionally, the changing nature of GIS software and technology requires a commitment to continuing formal training in GIS related topics.

INTEGRATION OF GIS AT THE STATION

The three major uses of GIS at the Station are: 1) management of facilities and habitats, 2) analysis of ecological research data, and 3) regional conservation planning.

Management Uses of GIS

GIS applications will improve two vital management activities at the Station and the Ranch, or at any other terrestrial field-research facility: making base maps and controlling research use of station lands.

Base maps are essential to all field station operations. Maps delineate property boundaries and fire management zones and mark locations of utilities, structures, fences, roads, trails, water features, and environmental monitoring sites. All of these aspects change through time, especially when new property is acquired, and the maps can be updated promptly with GIS. Once the base maps are created, attributes for utilities and structures such as material, cost, and age can be added to the data base.

Mapping research sites and study plots located on Station lands is essential. As the Station becomes home to more research projects, potential conflicts exist between long-term and short-term projects, between monitoring and experimental projects, and between staff scientists and visiting investigators. GIS provides a unified data base for organizing these studies in space.

Not only do GIS base maps and research maps serve as management tools, they are also electronic archives of these important aspects of a station's land-use history. The value of some site-related, ecological data is diminished if land-use history is lacking.

Research Use of GIS

At the Station, long-term ecological research on native plants and animals covers many topics including; effects of different fire regimes on plant and animal populations, gopher tortoise burrow use and home range, Florida scrub jay reproductive success and population dynamics, and small mammal movements and population dynamics, among others. All of the many Station ecological projects share a common theme--space. Space or spatial relationships are major components of the interactions between soil, vegetation communities, fire intensity, and habitat use by animals.

The importance of GIS analysis for ecological research is exemplified by the study of Florida scrub jay (*Aphelocoma coerulescens*) demography and population ecology. Florida scrub jays are sedentary, permanently monogamous, extremely habitat

specific, and vigorously defend family territory boundaries the year round. Spatially-related data collected on a 2 square mile demography tract for 25-30 families include annual nest sites and territory maps for each of 23 years, and for the past 4 years; monthly census of available food (arthropods and small vertebrates, 60 sites), monthly foraging watches of 30-40 birds (500 hours/yr), and annual acorn production and vegetation transects (200 sites). Each of these data sets represents one to several additional data themes that will be used in overlays onto standard Station map themes for topography, soils, and fire history (30 years). Complex relationships probably exist between reproductive success or territory size and fire history, vegetation communities, and food resources. Only with the fully integrative capacity of GIS can these relationships be defined and studied.

Station management goals are combined with research goals by using GIS to model fire behavior and to study the responses of plant species to fire. Fire is a major ecological force in the pine and oak forests of southeastern United States. The Station uses prescribed burns to maintain fire-dependent plant communities in a fragmented landscape and for specific research goals. The Station's 30-year record of individual fire maps will be mapped with GIS. The spatial variables of each fire include patterns of intensity; the attributes of each fire include date of burn and ignition source.

Because the behavior of fuel types at the Station is not well-known, GIS will be used to analyze individual fire maps and model fire behavior. Many endangered plants of the Station (and the Lake Wales Ridge) depend on fire or other natural disturbances at various stages in their life histories. The GIS fire history maps will allow examination of the relationships between fire and the distribution of these species on the Station.

At the Ranch, agro-ecology research is just underway and long-term projects are being initiated. GIS will be used to analyze the effects of livestock exclosures on plant and animal communities and to study the effects on water quality of pesticide and fertilizer use in pastures and in the citrus grove.

Conservation Planning with GIS

The Station is actively involved in regional conservation because the remaining native xeric upland habitats on the Lake Wales Ridge are in danger of extinction. About 90% of these habitats have been destroyed for citrus cultivation and commercial development or subdivided for housing. Furthermore, the rate of destruction has not diminished and may be increasing. Accurate maps are essential to any regional conservation plans. The Station has completed a GIS map of the Lake Wales Ridge in Highlands and Polk counties, Florida, showing the original extent of xeric upland habitats (based on early 1940s aerial photographs) and showing tracts remaining in 1990 (Fig. 1). Species inventories for these remaining tracts will be integrated with the regional map. The finished map will be used by federal, state, and local governments for the design of an ecosystem preserve in a fragmented landscape. These maps can also be used for research problems in conservation biology such as species-area

relationships, distribution of patches for corridor design, and historical changes in patch abundance, distribution, and overall connectivity.

Future Plans for GIS

The Station plans to mount several GIS map themes (boundaries, man-made features, research study areas, topography, soils, vegetation, fire history) of the Station's 5,000-acre main property on a stand alone desk-top computer using ArcView software (Environmental Systems Research Inst.). This user-friendly system provides full integration with large GIS systems in the ARC/INFO format. It provides a wide range of features; visualization, spread sheet, spatial selection, logical manipulation, statistical tools, and plotting. With natural and intuitive icons and menus, scientists can easily query the map themes for their own individual research needs and then produce maps for field use or education.

The Station will soon make its GIS facilities available to the general scientific community for research in ecology and conservation biology.

HOW DOES GIS AFFECT A FIELD STATION LIBRARIAN?

GIS specialists active in a biological research setting typically hold graduate degrees from a variety of backgrounds including landscape architecture, planning, geology, geography, ecology, wildlife management, or soils science. As with any addition to the research staff of a field station, orientation to station research history is necessary for the GIS specialist. The station's librarian is often the central resource person in this capacity.

The GIS specialist will have great interest in the station's map resources, especially related to local research areas. Certain maps and historical aerial photographs will be in the station's holdings, while others will be ordered from a wide variety of places (agencies, commercial sources, other research scientists). Searching out sources of photographs can be new ground for the station's librarian. Another possible new area for the station librarian will be the need for access to outside computerized data bases related to geography or geographic data. The GIS specialist can locate some of these sources.

Like other members of the scientific staff, the GIS specialist will want to keep his/her professional skills current by reading GIS-related books, journals, newsletters, and trade magazines. GIS is a new field, only 20 years old, and although established earth-sciences and geography journals publish GIS articles, new journals devoted to GIS have appeared in the last decade. Therefore new GIS personnel will mean a new subject area for collection development and this will be part of the learning challenge for the station librarian.

We close by emphasizing that GIS personnel represent information-

management colleagues. These colleagues are willing to educate station scientific staff in the data analysis and management capabilities of GIS. The first step in this process often begins at the librarian's office. GIS is another information-related learning challenge for librarians.

SUGGESTED READINGS IN GIS

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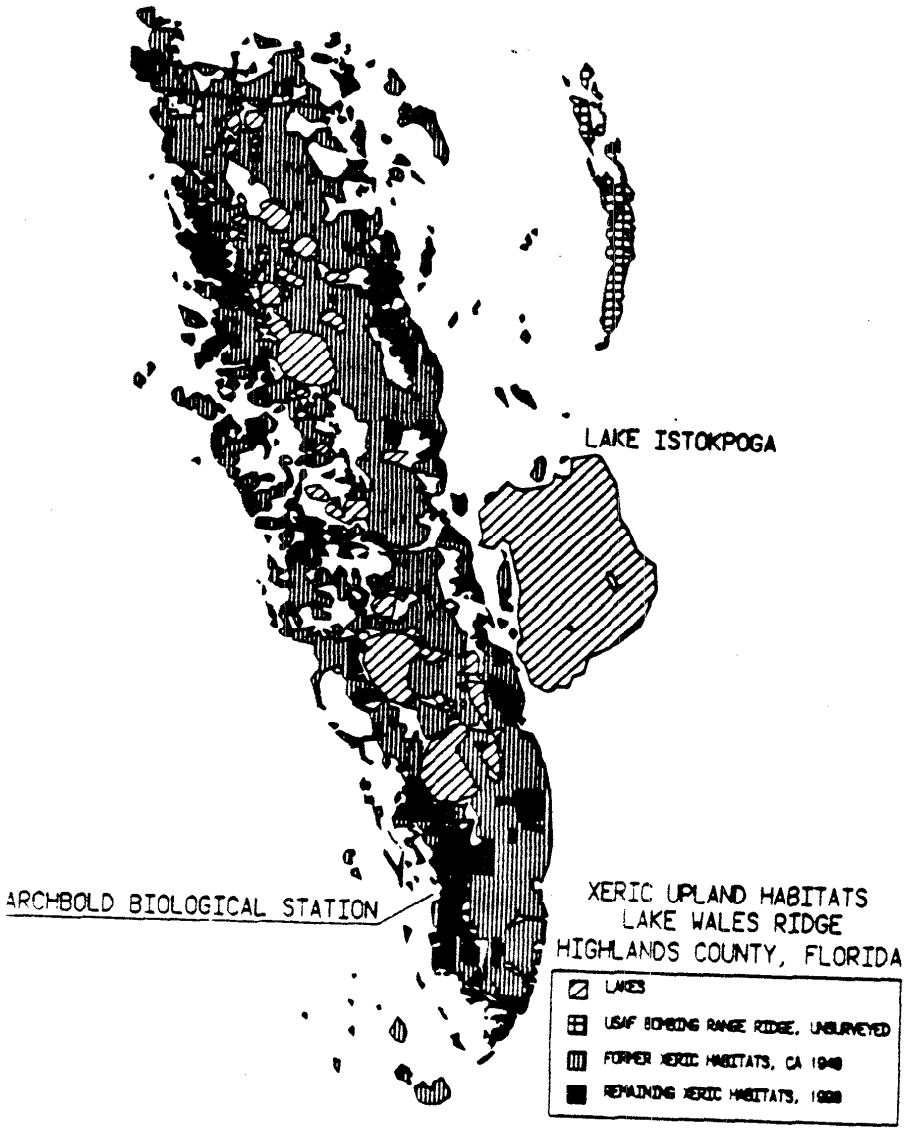

Fig. 1. Map of xeric, upland habitats on the Lake Wales Ridge in Highlands County, Florida, showing the original extent of these habitats and the tracts remaining in 1990.