Proposed Research Project
GIS and a Geodatabase for the Wildcliff Nature Reserve

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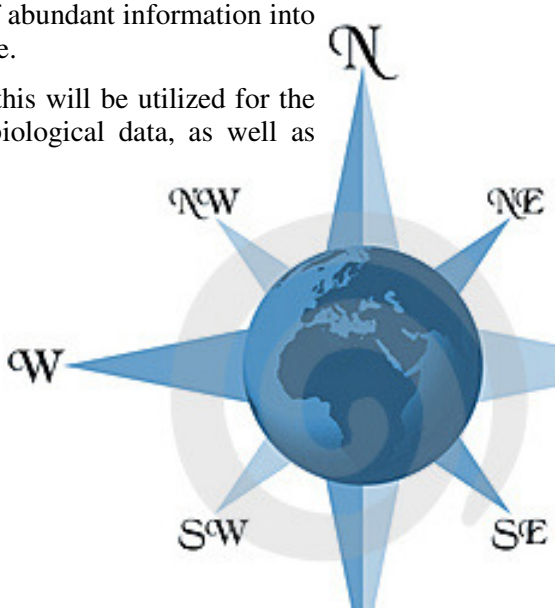
Geography is universal; all physical phenomena and many abstract ones demonstrate spatial differentiation. Virtually everything that happens, happens somewhere. It is for this reason that a greater knowledge of spatial relationships can serve as the basic framework for understanding our world and applying geographic knowledge to solve real-world problems. To aid in this process, we now have Geographic Information Systems (GIS) - powerful, state-of-the art technological tools used to manage, analyze and disseminate geographic knowledge.

A GIS is comprised of computer systems designed for storing, manipulating, analyzing, and displaying spatial data which are tied to a relational database, providing digital representations of information that would traditionally have been drawn on a map. It's this connection to a database that gives GIS much of its power; maps can be drawn from the database, data can be referenced from the maps, and when the database is updated, the associated map can be updated as well. But its not just about maps - GIS can perform complicated analytical functions and then present the results visually as maps, tables or graphs. Perhaps it's most important characteristic, however (particularly in regards to this study), is its versatility; GIS applications allow a vast array of data to be integrated and combined in a formal, logical manner on the basis of spatial relationships. If a problem or data has a spatial component, then a GIS allows it to be analyzed and interpreted spatially.

In this regard, GIS can serve as a useful tool for managing information on inventories of the earth's diverse flora and fauna species – it allows for the organization of a large collection of spatially referenced data by tying index maps into traditional bibliographic databases. Tabular data on each species characteristics, requirements, and status can be collected into a database and linked with the GIS to digitized maps. The relational power of the GIS allows data to be specifically maintained about each species at each site, such as its population and protection status at that site, in addition to separate tables depicting overarching characteristics of a species such as life history and detailed taxonomic classification. Once these links are made, it is then possible to conduct queries and prepare maps to answer spatial questions.

Recent advances in geographic technology such as GIS and global positioning systems (GPS) have enabled researchers all over the globe to collect environmental data at higher precision and accuracy than was previously feasible. The increasing precision of spatial data sets coupled with thorough collection data can facilitate the combination of abundant information into a system where the highest number of statistical operations can be made.

In regard to the proposed research, an inclusive GIS such as this will be utilized for the capture, storage, retrieval and manipulation of current and future biological data, as well as environmental systems and processes.



Study Area

The Cape Floristic Region is located at the southwestern tip of the African Continent and lies entirely within the borders of South Africa. The region spans 90,000 square kilometres, .05% of the earth's land area, yet contains roughly 3% of the world's plant species. Because of its distinct flora, it has been distinguished as one of the world's six floristic kingdoms and is known to have the highest species density in the world for equivalent sized areas.

Regrettably, the Cape Floristic Region has been critically threatened by a succession of human activities that have seen the Coast Renosterveld and Sandplain Fynbos, both lowland habitats, reduced by 48% and 83% of their original extent, respectively. On the whole, approximately 33% of the region has been transformed by agriculture, urbanization, and dense stands of alien plants (Rouget et al. 2003). Human activities on the land have resulted in major scars on the land and biodiversity is on the decline; land protection and restoration are therefore essential to safeguard the future of this irreplaceable resource.

Wildcliff Nature Preserve

In 2007, after more than 160 years of use as agricultural and grazing land, the Wildcliff Nature Reserve was founded by the Wild Cape Nature Trust, a group of individuals dedicated to plant and wildlife conservation in South Africa's Cape Floral Kingdom. It contains 955 hectares along the Langeberg mountain range of South Africa's Western Cape. The reserve provides an exceptional example of the region's rich diversity; mountain fynbos enriching high meadows and afro-montane forests inhabiting the steep canyons support an abundance of plant and wildlife species.

The goals of the Wild Cape Nature Trust, aside from contributing to the preservation of an important part of the region, include furthering knowledge and understanding of the flora and fauna in the CFR by supporting a research program. Major headway has been made in attaining this goal since the inception of the reserve; completed and ongoing research projects span from comprehensive surveys of various flora and fauna groups to behavioral studies of the native baboon troops and investigations into the ecological history of the land.

Imperative to the goals of the Wild Cape Nature Trust and an essential step in re-establishing the ecosystem to its natural state is to formulate baseline data of the land's state of biodiversity. This involves documentation of the abundance, distribution, and ecology of the plants and animals on the preserve so that informed decisions can be made regarding the course of its restoration and preservation. By identifying the species that inhibit the land and their interrelationships between each other and the environmental conditions with which they interact, we can gain inclusive knowledge about the ecosystem in its entirety.

Despite its fairly recent incorporation, a large number of dedicated conservation-minded researchers have contributed to the task of surveying the plants and wildlife on the preserve, leading to a collection of inventories including birds, flora, mammals, reptiles, amphibians, invertebrates and fish. As these researchers come from down the road and around the world to

take part in the work at Wildcliff, their contributions will continue to expand upon this data and enrich the knowledge of the land and those that utilize it.

Aims and Objectives

The primary objective of the proposed project is to consolidate all of the wildlife and vegetation inventory data from previous and ongoing research at Wildcliff into a GIS compatible format which will allow for uniformity of data entry, well organized information storage, and easy retrieval of data.

Another goal includes taking the geographical component of each of the individual research studies completed or underway at Wildcliff and place them into a GIS framework so that they can be layered, related and interpreted. An organized geodatabase of tables and shape files specific to the projects will facilitate easy retrieval of detailed information pertaining to individual research objectives and activities, leading to greater convenience and uniformity for other project designs which add to or compliment previous endeavors.

Methods and Organization of Proposed GIS Project

To aid in the usefulness of this project, a basic GIS to be created in a separate study will supply baseline environmental layers such as hydrography, soil types, road and stream locations, elevations, slope, and aspect.

This proposed project will entail compiling existing spatial data into attribute tables along with their observational records and linking them with spatial data stored as map features in the reserve's GIS. The organization of this system will differ slightly between projects and in regards to the preserve-wide inventory geodatabase, but will provide a basic framework for the collection of future data in order to ensure seamless integration without the need for excess data manipulation.

Digital Wildcliff Flora and Fauna Species Inventory

Flora and fauna inventories such as those underway at Wildcliff result in point locations, area estimates, and census counts of a species, focusing which species, when it was seen, where it was seen, and how many were seen. The Wildcliff species inventory GIS is intended to store the core of these survey efforts, taking account of the what, when, and where aspects data collected.

This inventory data will be organized into tables for species, sites, and observations, all related by common fields. Microsoft Excel will be used for data entry in the species and collections tables, and will be subsequently saved in the .dbf file format. Sites data will be entered in the attribute table of the collection sites shapefile, which is automatically saved into a separate dBase file by ArcMap.

- Species Tables: The species tables will contain indexed taxonomic and common names of species known to exist within the Wildcliff Nature Preserve, organized into separate tables for mammals, reptiles, amphibians, birds, invertebrates, fish and flora. Predetermined fields for these tables will include:

    - *(Mammal/Reptile/Amphibian/etc)ID* – Indexed identification number assigned to each discrete species, formatted as R001, R002, R003, etc. for reptiles, M001,

M002, M003, etc. for mammals, and so on. Flora ID numbers will begin with 'P' (plants) and fish ID numbers will begin with 'F'. This field is used as the primary key of the table, so there will be no repetition of records.
    - *Family* – Taxonomic family name of the plant, as a text string. This field may have duplicates.
    - *Genus* – Taxonomic genus name of plant, as a text string. This field may have duplicates.
    - *Species* – Taxonomic species name of plant, as a text string. This field will not have duplicates.
    - *Common* – Common name of plant species, as a text string. This field does not have duplicates.
    - *Distribution* – Endemic, native, or exotic classification of the species.
    - *Notes* – Relevant notes such as those regarding the known range or origin of the species.

- Sites Tables: The Sites tables will originate from the attribute tables for the collection/trap/survey site shapefiles. I will compile the shapefiles from various surveys pertaining to an individual group, so ideally there will be only one layer and corresponding table for each of the seven groups. Since not every study results in precise point locations for observed species, I will also include layers of transects and regional polygons (usually determined by vegetation or habitat type) where appropriate. Fields in this table will be organized roughly as follows:
    - *SiteID* – Indexed identification number assigned to each discrete collection/trap/survey site, formatted as 001, 002, 003, etc. This field has no duplicates, and is used as the primary key of the table.
    - *Location* – Description of the unique physical location of the site, as a text string.
    - Other fields may be later formulated to include information of relation to environmental variables such as distance from nearest water source

- Observation Tables: The observation tables will contain records relating collection sites per flora/fauna species (or signs of their presence such as nests or burrows). This data will primarily be collected from individual researchers and serve as a vital link that relates each species under study to its corresponding observation sites on the preserve. The organization of this table may vary depending on the shape of the site (point site observations of a single species vs observations within an area) , but will require a species ID, site ID, and date field. A basic organization of the fields will include:
    - *(Mammal/Reptile/Amphibian/etc)ID* – Individual species identification number, related to the field of the same name in the corresponding species table.
    - *SiteID* – Individual collection/survey/trap site identification number, related to the field of the same name in the sites table.
    - *AreaComments* – Description of the area of observation. Most sites are 'point sites', which mean that the SiteID number refers an actual point on the preserve. Other descriptive terms can include zonal identifiers such as 'along Krantz River' or 'around top dam'.
    - *Habitat type:* ID for habitat types in regards to the group in question (such as those outlined by Fust in his baboon study: AMF = Afro-Montane Forest, PF = Pine Forest, AMF/PA = boundary between Afro-Montane Forests and pastureland). A table will be included to serve as a legend for this field.
    - *Precipitation* – X = not recorded, 0 = none, 1 = slight, 2 = moderate, 3 = strong.
    - *ObsComments* – Identification of the observer and a description of the species observed (health, abundance, etc.)

- *DateObserved* – Date of the observation
- *TimeObserved* – Time of the observation

Wildcliff Research Project Geodatabase/GIS

The following information outlines some of the research from Wildcliff that will be included in this project and the methods that will be used to integrate them into a GIS compatible format. Species and sites tables from research projects will also be compiled into the Wildcliff inventory GIS and geodatabase where applicable.

- *Applying paleoecology to conservation and identifying 'natural' ecological conditions (James MacPherson)*: MacPherson argues in his proposal that palaeoecological information is needed for a full understanding of ecosystem dynamics at the Wildcliff Reserve. His research aims to investigate the use of palaeoecology in providing proxy data representing 'natural' ecological conditions by objectives such as establishing a history of vegetation though selected indicator species represented in sediment cores and collecting neo-pollen samples to calculate spatial representation of fossil pollen. Proposed GIS components of this project include:
  - A shapefile which will include sampling sites used during data collection
  - Tables of the vegetation found at these sites and any additional information provided by the researcher.

- *Small Mammal Survey (Richard Kempf and Amanda Amodeo)***:** The goal of this study was to form a baseline data set of the small mammals at Wildcliff through the use of live capture/release trapping at five trap line locations which represent different habitat types and several microhabitat sites within each trap line.
  - A species table will be created to include the eleven different species found during the course of this project. This table will also include will also contain links to the location of species photographs taken during the course of research. A trap site table (along with a corresponding shapefile) will include the five trap line locations and a description of each, and a collections table will include records of the 79 animals which were trapped (related to the species table by a species ID and to the trap site table by a trap ID).
  - The Simpsons Biodiversity Index will also be incorporated in the trap sites table due to its pertinence to this study. By including this, a rough map can be created to show the variance in biodiversity between the sites and across the preserve, with darker colors indicating higher small mammal biodiversity.

- *A Survey of Arthropods by Mickal Houadria***:** The researcher involved in this project sought to establish a database of some of the orders of insects at the reserve and compare the varying habitats for biodiversity. He created tables of the data and location of the different traps used as well as tables of inventory lists, separated by order.
  - For this inventory, I will generate a shapefile to show the location and types of the traps used and include the dates of trap installments in the attribute table. The inventory list provided will be formatted as the observation table for this project.

- *A Survey of Frogs by Kelly Sloan*
  - A shapefile will delineate the eight area site locations used during the course of this research. The results of the survey will be incorporated into an observation table,

linked to the site locations by a site ID but also including specific location notes provided by the researcher.

- *Microcrustaceans and Aquatic Beetles by Zsolt Gidó*
  - Because this is presently a preliminary report, data from this research will primarily serve as part of the Wildcliff inventory geodatabase/GIS through its contributions of species identification and relative observation locations.
- *Mongoose Presence at Wildcliff (Ariana Malone)***:** A study to collect baseline data for the three species of mongoose on the reserve. GIS data for this project will include:
  - An observation table containing a unique transect ID, species ID, time of day, weather type, habitat type, number of individuals seen, and behavior notes.
  - Transects will be compiled into a shapefile, as well as point locations for species observations, burrow locations, locations of animal signs (tracks, shelters, etc) and locations of feces recorded during scat surveys. The attribute tables for these files will include more detailed information regarding these locations.
  - Data from the survey report regarding the potential areas of mongoose occupancy at Wildcliff will also be included, most likely as polygon shapefiles representing likely inhabitance.
- *Herptiles - Keystone Species and Monitoring (Njal Rollinson):* The primary purpose of this study was to conduct surveys which asses the species diversity and relative abundance of lizards, snakes and frogs at Wildcliff.
  - A shape file will be created from the GPS locations of species observed during this project. From the attribute table of this shapefile I will generate a sites table which will include information to differentiate between trap sites and observation sites.
  - Tables for the frog, snake and lizard survey data will also include a species table and an observation table. The observation table will include a species ID, site ID (linked to the table derived from the sites shapefile), and data which was recorded in the field including time, date, habitat, and weather conditions.
  - As it is collected, links to the locations of species photographs and possibly even recordings of frog calls will be included in the observations table.

  The secondary purpose was to identify one or more keystone species on the preserve and develop long-term protocols for these species.
  - An observation table for this project will include a species ID (corresponding to the species ID of the Wildcliff inventory geodatabase), a site ID, and detailed information on the habitat features of the location (percent leaf cover, size of substrate, etc).
  - A shape file will also be created from the GPS coordinates of the capture sites. This will be linked to the data in the observation table by the site ID.
- *Predicted effect of Black Wattle Removal on Reptilian Species Diversity (Njal Rollinson):* For this study the researcher sought to compare reptilian species diversity in Black Wattle strands of various densities to areas where Black Wattle was absent, as well as to assess the level of species endemism in forested and non-forested areas. GIS/geodatabase information assembled for this research will include:
  - A shapefile of the 11 survey areas identified by the researcher, a survey site table (and shapefile), and a species observation table containing species ID, site ID, and information about the nature of the capture or identification including the time, date, number of cover objects flipped during the survey time, and any other notes.

- A second shapefile for the 2m x 2m plots within the survey areas will also be included. The vegetation measures taken by the researcher at these sites which were averaged across the survey areas will be included in the attribute table of the survey area shapefile (dominant plant, area in m2, # of species recorded, # of rocks sampled, % of rocks sampled, etc.)

- *Ants of the Fynbos (Marijke Wouters):* The researcher of this study will be investigating the diversity of local ant populations at Wildcliff as well as the presence of invasive ants, notably the Argentine ant which poses as a threat to native plants, ants, and other arthropods. Several sampling methods will be employed including hand collecting, litter leaf sampling, tuna bait trapping and pitfall trapping, therefore the organization of the geographical components will evolve as the data is gathered.

- *A Survey of Avifauna at Wildcliff Nature Reserve (Conan Guard):* This project involves tallying all of the birds observed at a fixed location during specific, repeated observation periods with the aim of providing the relative abundance and trends of the avifauna on the reserve. The species and survey point tables will follow the general outline of the other research projects included in this GIS, but the observations table will be made to include the bird's age and sex, time of the observation, and the bird's distance from the observer.

- *Baboon Studies at Wildcliff (Projects by Paula Pebsworth, Pascal Fust, Kelly Sloan, Cédric Sueur, and others)*: Multiple studies involve systematic monitoring of the foraging activities and other behavior of the Wildcliff chacma baboons. A large aim of this project is to compile data from several of these research projects into an all-inclusive geodatabase to allow for a detailed GIS based spatial analysis on the Wildcliff baboon troops. In order to avoid duplication of efforts, the extent of analysis included in this study will depend on the progress of various other studies.

  Although some of these projects do not have an explicitly spatial component in their analysis, the quantification of spatial patterns recorded during the course of research can facilitate inferences about the causation of behavior, such as movement or foraging behavior.

  In a completed study of the function and use of cheek pouches of the baboon population, Fust recorded information regarding age, social rank, sex, group size, and aspects of habitat and resource utilization. This data will be imported to serve as an observation table. With the exception of project-specific fields such as degree of fullness of cheek pouches, this table may serve as a template for future recorded baboon observation data so that units and parameters coincide, which would aid in future analysis at a temporal scale.

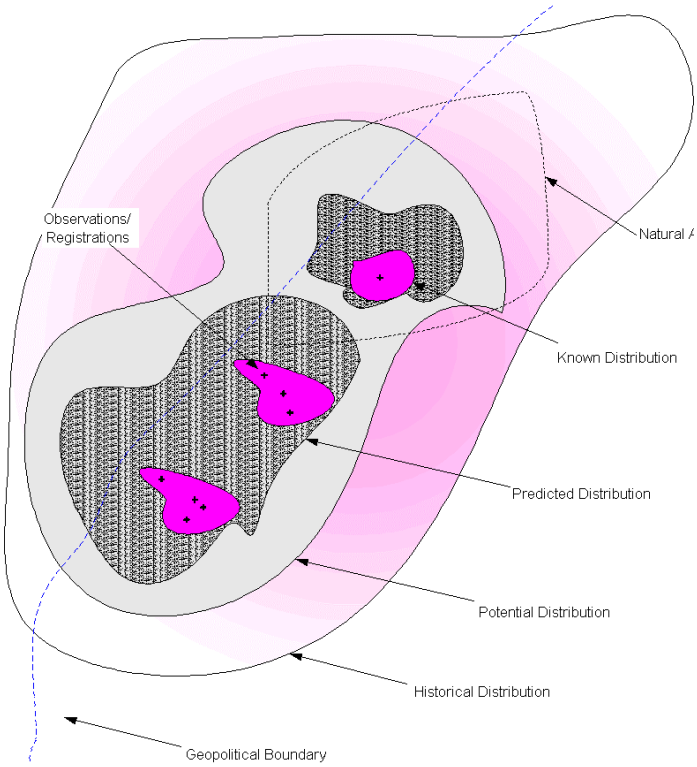
  A study proposed by the Baboon Research Unit at the University of Cape Town aims to collect spatial data and to perform a detailed GIS based spatial analysis on the Wildcliff troops. They will achieve this using year round GPS data recorded by tracking collars and seasonal observational data collected by various field biologists. GPS collars will provide an extensive time slice of positional data that answer broad scale questions of area use.

  This study will coincide with that of Paula Pebsworth, who will be gathering behavioral observations beginning in November 2008 as a part of a long term project which will provide baseline data on food and habitat selection and answer questions regarding home range, habitat type, movement patterns, diet selection, parasites, and possible medicinal plant use.

Expected Results

Examples of GIS outputs for these projects will include:

- A land use map of the troops' home range
- Maps of seasonal troop movement patterns
- Stored shapefiles depicting other movement patterns
- Various overlay maps depicting attributes that are shown to determine the intensity at which different areas of the home range are utilized
- Maps of habitat suitability indices for the baboon troops
- General baboon troop distribution map showing historical, known, and predicted distributions (right)



Conclusion

Not only will this GIS and geodatabase system make it possible to see basic distribution patterns, but researchers can also select and combine distribution data sets, perform spatial statistics on the distributions, retrieve the metadata (i.e., the collection data and attributes of the specimen associated with points on the map), or overlay species distributions onto maps of soils, climate, and other environmental variables.

The resulting GIS and geodatabase will serve to the benefit of research objectives at Wildcliff by simply providing an up to date spatial and temporal record of research projects, study sites, and results for use in future research and management.

Cited:

Rouget, M., D.M. Richardson, R.M. Cowling, J.W. Lloyd, and A.T. Lombard. 2003. "Current patterns of habitat transformation and future threats to biodiversity in terrestrial ecosystems of the cape floristic region." *Biological Conservation* 112, 63–85.

Giddy, I. (2008). 'Wildcliff Nature Reserve'. www.wildcliff.org. Accessed 8/12/08.