The Application of GIS to Conservation

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Summary

The potential for the application of Geographic Information Systems (GIS) technology for wildlife resource management is described. This description is provided for a number of reasons. Firstly, GIS technology encourages the adoption of ecological principles in landuse policy and management plan formulation. Secondly, GIS and computing technology encourage collaboration, which is essential in establishing comprehensive environmental databases. Finally, to raise the awareness of the existence of resident expertise in Abu Dhabi working on the establishment of flora, fauna and habitat GIS-databases and to invite the participation of data collecting groups and individuals in the development of these facilities.

This account is written jointly by a GIS technical specialist and an ecologist 'end-user'. The two are joined by a common thread which is the application of data for environmental management.

GIS can be used to create a computer model of the natural environment. The natural environment is modeled in a GIS by the use of spatial databases, in which species, habitats and all other factors can be stored. Equipped with comprehensive databases and geographical query, analysis and presentation functions the GIS forms an environmental management support tool. A key feature provided by GIS is predictive analysis, by which the likely impact of developments can be assessed before any change to the real environment is made. This facility is powerful since it allows various scenarios to be played out and options evaluated.

A fundamental prerequisite for any information system is data, the greater the amount of data the greater the power of the information system. There is a paucity of environmental data in the UAE, and that information which is collected is largely uncoordinated and dispersed. The role of GIS in overcoming these difficulties is discussed.

Key Words: *GIS; conservation; desert; biodiversity; landuse; environmental management; environmental databases.*

تناقش الورقة أساليب تطبيق نظم المعلومات الجغرافية (جي آي إس) على المحمية.

Background and Rationale

The United Arab Emirates supports a predominantly desert landscape, receiving an average annual rainfall of less than 250mm. Abu Dhabi is the largest Emirate of the UAE, covering some 67,342 sq. km. Much of the Emirate is sand desert and it is this ecosystem which is the primary focus of this discussion.

The Abu Dhabi-based Environmental Research and Wildlife Development Agency (ERWDA) maintains several environmental databases holding data collected from within Abu Dhabi Emirate. Collection of data and its entry into computers is routine and ongoing; data arising from systematic surveys as well as opportunistic sightings. Amongst vertebrate groups the avifauna is the best recorded. Distribution information is 'reasonable' for larger herbivorous mammals. Floral communities of the entire country have recently been comprehensively surveyed, (Böer.(*in prep.*).) The goal of such survey work within ERWDA is to have data, readily accessible, on which to base future landuse management decisions and as input to environmental impact studies.

The greater the amount of data held in any database the more meaningful will be any decisions derived from it. The natural environment is especially complex, with many inter-related mechanisms. If informed decisions are to be made about the environment then a great deal of data will be required to counteract its complexity. In the UAE, as in many parts of the world, there is a chronic data deficiency and that which there is often out-of-date*. A great deal of the known information has yet to be formally recorded, and what is recorded tends to be widely distributed and unavailable to others. A developer, for example, wanting to undertake a comprehensive (i.e. realistic) Environmental Impact Assessment (EIA) would be faced with a large data 'sourcing' task. Such obstacles tend to encourage token-gesture EIA's. The findings of an EIA usually restrict the activities of a developer; data deficiencies or accessibility problems can only support environmentally insensitive development. Effective environmental protection requires that these information difficulties be overcome. Providing a coordinated, collaborative environmental data repository is one of the primary aims of the ERWDA GIS programme.

*This does not however undermine the value of historical data as a basis for change detection.

Geographic Information Systems

GIS are computer database systems which facilitate the efficient storage, management, retrieval, analysis and display of location-referenced data and associated descriptive information. As a tool capable of manipulating complex, multi-theme datasets GIS have achieved a high level of refinement. Within the last decade GIS have achieved operational status; they are now considered an indispensable tool by a large and diverse range of organisations with a broad range of applications.

Properly applied GIS can lead to improvements in the completeness, objectivity and accuracy of analyses; this leads to greater confidence in their output and ultimately better-informed decision makers. Socio-economic issues, for example, which are critically important in the success of landuse policy initiatives, but which are frequently complex in nature, can be incorporated into analyses by the use of GIS tools. Environmental analyses, prior to GIS, were: 'long-handed' (often to the point of being impractical), necessarily simplistic, error prone, and lacked objectivity and so lead to results of questionable validity.

In computing terms what comprises a GIS implementation varies tremendously. A GIS may be a single workstation running a single computer programme but equally it may comprise a heterogeneous mixture of wide-area networked computers running a diverse suite of software packages. GIS are differentiated from conventional database systems by their ability to operate upon geographically referenced data; their provision of spatial analysis tools and the use of map-based user interfaces. In short, they work on spatial data using geographical concepts and techniques.

Typically, organisations hold a great deal more spatial data than they realise. Spatial data may take the form of a map but this format is not mandatory. Any data that is related to a named place (area, or other feature) or coordinate can be readily incorporated into a GIS database.

Many GIS projects have failed because they did not live up to the unrealistic expectations of senior management who were initially over-sold on the technology (and under-sold on the timescales involved) by enthusiastic technical personnel who typically overlook the overriding issue - data, specifically the cost of its acquisition and conversion into computer format. Various studies have shown that typically (depending on the application) between fifty and eighty percent of the total cost of a GIS system (including labour costs) is spent in capturing data and making it usable.

Relational databases

Most modern database systems are of the relational type. This type of system stores data in tables where individual tables contain information about single concepts. Data about related concepts, held in separate tables, can be brought together on the basis of a common link. Where GIS bring benefit over other relational database systems is that in addition to linking tabular data through common columns GIS-enabled datasets can be related through their location. It is thus quite possible for two quite different datasets, collected at different times, for different purposes but which share a relevance to some conservation issue to be brought together on the basis of their geographic relationship; for example adjacency, separation or containment.

Shared databases - realising data synergy

One of the great benefits of GIS is its ability to integrate diverse datasets, from, for example, unrelated surveys. Data from different scales, coordinate systems and so on can all be incorporated and brought into a common display and analysis environment. For species distributions only the species name and its geographical location (and preferably observer and date of observation) are a minimum requirement, although clearly the more information the better the modeling potential.

A key factor in the concept of all relational databases, including GIS, is that the datasets do not have to be held in a single physical database. The database can be distributed, meaning that data can be physically held on different computers at entirely different (indeed remote) locations. The GIS thus becomes an *interface* to dispersed data. This is extremely important for a number of reasons. Possibly the most important factor in establishing a collective 'pool' of data, especially when there are multiple contributors, is to retain control of data with its 'owners'. If data collectors/recorders are required to handover data and relinquish control over it they are unlikely to cooperate. Modern computing technology readily facilitates on-line access to remote databases. Psychologically the collectors and recorders of data are likely to be much happier to share their data than to simply hand it, and thus control of it, to another body. In this kind of arrangement the 'owners' of data feel their data is contributing to a broader understanding of the environment without compromising the original purposes for its collection or their status as collector/coordinator.

The ability to access, display and analyse combinations of datasets which individually may pre-date the GIS and which primarily belong to another organisational function or indeed another organisation is one of the main advantages of this type of information system.

Remote Sensing - a partial solution to habitat data deficiencies

Remote Sensing is the name given to the technology of electronic imaging of the Earth, usually by satellite or aircraft. This technology offers many benefits to conservation, and is especially relevant to desert and marine studies. The high rate of change in the landscape (desert mobility) in regions like the Gulf states means that conventional maps are out of date almost as soon as they are produced. Management decisions are thus based on old information. Remote sensing data, especially from satellites, provides a cost effective way of obtaining regular updates on the state of the environment.

Conventional cartographic methods for representing the surface of the Earth have limitations in areas such as the Gulf countries. Traditional cartography requires that features of interest are delineated and represented by points, lines and areas. Themes of environmental interest, and desert landscapes in particular, can rarely be so clearly defined since one characteristic often merges into the next over some distance. The digital images provided by remote sensing instruments are matrices of reflectance measurements. Since these images are quantitative measurements of the Earth's surface they are not subject to the cartographic abstraction of conventional maps.

Satellite imagery combined with other habitat characterising datasets (e.g. topography, soil-type, distance from human activity) in a GIS provides a powerful tool for habitat characterisation, delineation, measurement and monitoring. The ERWDA GIS department employs sophisticated image processing software to delineate and map habitat units. This information will be combined with species distribution information to establish species-habitat associations.

Limitations in Ecological Data

In ecological surveys there are limitations of manpower, time, accessibility and so on which have, and which continue to, determine survey methodology, survey duration and thoroughness. Rapid assessment faunal surveys, for example, have been undertaken using systematic methodologies but have also benefited from opportunistic observations. Geographical locations are now frequently determined using a Global Positioning System (GPS), but these have an instantaneous accuracy, in UAE, of only c.100 metres (Roshier *unpub.*). Furthermore, in Abu Dhabi data collection is only realistic in the cooler months, thus the data possesses certain temporal limitations. *(See also below and following paper.)*

Data Interpretation - Ecological considerations

Theoretical models may yield species distribution predictions which are at variance with observed patterns. This is not necessarily an error in the model but may be due to bias in observations, for example the arrival and presence of the observer is likely to effect sightings. Aerial photography, track, footprint and dropping observation and satellite and radio tagging may give improved information, but have their own financial and temporal constraints.

As stated above, in the Gulf states the climate certainly imposes a restriction on data completeness. For the seven or eight hot months of each year there is little or no field survey data so seasonal patterns may be difficult to determine with confidence.

Explanation of the distribution and density of different species or species assemblages may be correlated with habitat, for example a relationship between invertebrate diversity and plant biomass has already been established in Abu Dhabi deserts (Tigar *in prep.*). GIS with remote sensing data can be used to derive theoretical populations, carrying capacities or other non-directly measurable quantities by use of quantifiable parametric indicators. These estimates can then be calibrated against surveyed animal densities to predict actual populations in unsurveyed areas i.e. by ground-truthing. Disturbance levels appear to be of major importance to wildlife, particularly in open landscapes and it is possible to derive objectively, with the aid of a GIS, where this is greatest, least and so on (*see following paper*).

Fragmentation of plant or animal populations has long been recognised as a serious wildlife management problem. With GIS it is a straightforward exercise to reveal habitat fragmentation and design remedial actions. For example, given the mobility of a species and the likelihood of natural recolonisation, whether, if other measures were put in place, re-introduction would be necessary. Such concerns are particularly relevant in UAE for species such as gazelle, oryx and leopard.

Complete areal coverage by ground survey is generally not feasible in any habitat - deserts being no exception. When full areal coverage is not available there is a possibility that maps of animal distribution may simply reflect observer distribution (& often do just that). A GIS is able to generate a potential or theoretical range map based on numerous, disparate environmental factors; for example vegetation, climate, soil, disturbance, complimentary and competing species. When the data available for analysis do not permit accurate density estimates for individual species, prime or core areas may still be identifiable. Alternatively the analysis may reveal data deficiencies, or unexplained gaps in distribution, which the ecologist is then obliged to explain and possibly instigate remedial actions (especially if man-made).

Of course ground truthing, i.e. field survey, is fundamentally important and will locate sites apparently of higher quality than others. During the course of survey work by ERWDA in Abu Dhabi, certain distributional patterns have emerged between species and habitat types, for example, mountain gazelles *Gazella gazella cora* with sand sheets; cream-coloured coursers *Cursorius cursor* with gravel plains; Ruppell's fox *Vulpes rueppellii* with high dunes and ***dhub*** lizard *Uromastyx microlepis* with sandstone/limestone outcrops. Unrelated taxonomic groups may also be associated, presumably by similar habitat preference, for example gazelle, eagle owl *Bubo bubo acalaphus* and long-legged buzzard *Buteo rufinus* have been found to co-occur in ***ghaf*** *Prosopis cinerea* stands. GIS is able to cross-check to show if these purported associations are valid and perhaps identify previously unknown associations.

Although much can be deduced from the output of the GIS itself, it is clear that a sound understanding of the ecological processes and the many inter-relationships in operation are required to define the models and apply appropriate management action (*see following paper*). Hence GIS, like all other information systems, must be firmly put in their place - they are information tools, albeit very powerful ones. GIS are a means to an end, not an end in their own right.

Conclusion

GIS technology offers tremendous potential as a conservation and environmental management support tool. The technology of GIS is well proven. The limiting factor is data. Environmental data for the UAE is geographically and temporally 'patchy'. Any data about the flora, fauna and habitats of the UAE have an important value in environmental conservation. The ERWDA GIS and database programme welcomes data contributions and on-line access in its attempt to provide a single point of focus for environmental information. No attempt to take ownership of data is intended, modern computing technology (including the Internet) facilitates on-line access of datasets held in computers spread across the country, indeed the globe. The primary issue of concern is collaboration and coordination in environmental data recording. Technology is no longer a limiting factor, only staff - a GIS technical specialist and one or more ecologists are required by any environmental research organisation.

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