7: DISCUSSIONS AND CONCLUSIONS

7.1. INTRODUCTION

In concluding this thesis the key question must be answered. How to plan, design and implement this concept, of an ecological network, effectively at various scales?

The planning and implementation of an ecological network is very much the responsibility of the organisational "body in charge". As seen from the cases studies the approaches vary greatly from organisation to organisation. This is a very much political sphere. It is the design of ecological networks, which can be and is optimised by the Ecological Network Design Model (ENDeM). ENDeM provides a process and structure to design an ecological network. Aiding in preventing an organisation from reinventing the wheel.

The model can be used at any scale from local to global. The scale is dependent on the scale of spatial data used as input criteria. All the calculations are relative to distances measured from the spatial data. Except, if they are absolute values such as maximum distances or minimum viable populations, which are independent of scale.

The development of the Ecological Network Design Model has opened the door to some avenues for new research in the environmental and geographical information science fields. These are explored in the discussion and recommendations in this chapter. These are followed by the conclusions.

7.2. DISCUSSIONS AND RECOMMENDATIONS

There are four main points of discussion. Three of which are generally about the model, the last is some discussion surrounding three specific the criteria.

7.2.1. General

The ENDeM model has been based on an extensive literature review and a series of digital interviews (for a full explanation see Appendix 2), with designated experts. This concept was translated into the cartographic ENDeM model as it now stands. This model is based on the ideal and not on available data. Naturally these models can and need to be adapted to the available data. The initial inputs were selected in as basic form as possible. Once the feature data standards are developed for data and data classifications then these should be applied to the model, defining the data inputs. For this model the data is assumed to be available and in the correct format. As such this model cannot be considered conclusive, but should rather be considered the starting point.

Taking the ENDeM model as a starting point, it should be discussed and validated by a panel of experts, to ensure its validity and correctness. This process should include a series of stringent tests, to align the results as closely as possible to the ideal. This validation process is essential before the model can be used and be widely accepted.

Despite this validation process there are a few areas, which require further research and refinement to help improve the model.

- In the corridors sub-model, a network-optimising algorithm was necessary to optimise the network. From the research it became apparent that little has been done in designing optimal networks in a GIS. At this stage, existing networks have only been modelled in GIS. In contrast a substantial amount of work has been done in the optimisation of utility networks. However this work tends to disregard the spatial component. Further research should be done into the optimisation of the designing networks with GIS.

- The criteria that are repeated between sub-models may cause some conflict. This is most likely to occur between the suitability indices. In order to resolve this conflict, the use of multi-objective land allocation techniques may be beneficial. This procedure utilises heuristic decision making to resolve conflicts, which occur (Eastman, 2001). This would require the ranking or automated ranking of the criteria raising conflict e.g. ranking the suitability indices. It may be especially beneficial in combining the suitability indices of the core areas, corridors and buffer areas within the main model. However the real benefits of this would need to be investigated further.

7.2.2. Criteria

The criteria have been selected from extensive literature reviews and expert opinion. There are three specific criteria, which should be highlighted in the discussion. These are barriers, species and urban development. Let us consider species first.

In the case of key species, the literature stresses (Foppen *et. al.,* 2000; Bennett and Wolters, 1996) the importance of key species, while expert opinion ranks key species in the group of less important criteria. Thus the two sources contradict each other, warranting further investigation. From the study it is clear that species as a criteria cannot be ignored, but the effectiveness of key species is as yet unclear. Other than providing a quick method for developing an ecological network, due to the lack of comprehensive data on all species. This returns the attention to an earlier discussion, where it was mentioned that, Wilson (1992) states that we have yet to identify even a tenth of species currently on earth. Thus the use of key species is necessary but care must be taken not to assign too much weight to such key species.

Other criteria, which are dependent on species, are those of minimum viable population, and the aerial extent needed to sustain these viable populations. Minimum viable population has been defined previously (see chapter 6). However the correlation between minimum viable population and the minimum aerial extent is yet to be fully understood. In planning it is essential to know the spatial extent necessary, to be able to allocate the required space. Thus it is apparent that to refine ENDeM further, further research needs to be done into the relationship between the minimum viable population and the space (aerial extent) needed to sustain this.

Barriers are linked to species too. A barrier to one species is not necessarily a barrier to the next species (see section 5.3.5 Further considerations). It may only be a semi-permeable barrier. More than that, barriers are dependent on the type of motion and the direction of that motion. For example a seldom used, light railway has almost no barrier effects, where as a high-speed, frequently used, railway has a large barrier effect, especially to those species whose *type of motion* is walking. If the *type of motion* is flight, the barrier effects in both cases will change to minimal. If the direction of the motion is parallel to the railway, then there is no barrier effect. However, if the direction of motion is perpendicular to the railway, then there is a barrier effect, the extent of which is yet to be understood. The characteristics or behaviour of a feature, have an effect, as explained in the example above.

It is understood that barriers have an effect. How to measure that effect is poorly understood. Further research is necessary to develop an effective measure of the extent of the effect barriers have. This would be a measure of permeability in relation to the species, direction of approach and characteristics of the feature posing as a barrier. This would more than likely take the form of some kind of matrix, possibly a three-way matrix. However it may take another form entirely with the advent of object orientated and behavioural GIS.

The last criterion that warrants further consideration is that of urban development. This is considered an important criterion when developing an ecological network (chapter 5). This criterion forms part of the compound criterion “barriers” (chapter 6); and plays a part in calculating the natural areas (Appendix 3). In appendix 3, a method of calculating urban development is explained. This method will capture urban development as it currently stands (at the date of the satellite image). However, if ecological networks are to be planned to remain sustainable and effective for years to come, then future urban development needs to be taken into consideration. Utilising time series analysis together with principal component analysis to consider the direction and speed of urban development, will give a better indication of urban sprawl and it’s future possible encroachment on the environment. Allowing the ecological network to remain effective.

7.3. CONCLUSIONS

This thesis attempts to defy the confined ways of thinking, in order to help towards solving a global problem—the Sixth Extinction. It uses the concept of Ecological Networks with the technology of Geographical Information Systems (GIS) to accomplish this.

However there is still a gap between ecologists and GIS specialists (Schneider-Jacoby, *Pers. Comm.* 2003). More often than not GIS is only used as a map-making tool. Its full capabilities are not utilised in ecological planning let alone in the design of ecological networks. However, there is a move towards utilising this technology as seen with the PEEN and Life Econet initiatives. One of the problems faced by such projects is the lack of human resources, who have an excellent knowledge of both ecology and GIS (Schneider-Jacoby, *Pers. Comm.* 2003).

Regardless of this gap, the process of solving a problem is the same in both disciples. In this thesis an effort is made to close the gap, but further discussion and research is necessary to accomplish this task.

In this thesis determining the criteria and their relative weights was discussed in chapters 2, 4 & 5. It is assumed that the necessary data is available and obtainable. The model is created for the ideal dataset. Thus the model is not tested (at this stage) due to lack of available data. As such the actual data transformation, calculations and combinations cannot be shown. However the process is modelled and described in full. Describing the stages from data transformation through to basic elements, to combining the elements to provide possible solutions. It is exactly these stages of the problem solving process, which the model seeks to address. Providing a solution to the problem of designing ecological networks in an effort to stem the sixth extinction.

The ENDeM model is the result of addressing the problem of discovering:
What is an effective means to utilise GIS for the development and implementation of ecological networks at local, national and multinational scales? It is the transcription of those “means” to design an ecological network. The good part about this model is that it is in fact adaptable to all scales, through the scale of the input data. This is apparent in the design of the relationships, as all dimensional calculations are calculated on the fly and are not predetermined. One thing, which detracts from the model, is that the required input data may not be available. Appendix 3 details this input data, some of which has not been collected before. Other of the entities are yet to be understood; difficult to measure or calculate, let alone capture as data for input into the model.

The design of an Ecological Network is a highly complicated process. Especially as the scientific community are yet to understand fully how the system works. Through the research it became apparent that the design of ecological networks can be split into three basic units, that of the design of core areas, corridors, and buffer zones. Each of these can be a research topic own its own. However it is the combination of these, which results in the Ecological Network. The model is created such that it can be divided into three sub-models, to calculate the three basic units and then combine these into a possible design for an Ecological Network.

Each of the sub-models (Core Areas, Corridors and Buffer Areas) can be utilised separately if necessary, lending to the model's flexibility. Allowing its application in a number of different places and frames of reference. If, for example the core areas already exist and function effectively, then only the corridors and buffer area sub-models need to be run to provide possible solutions to completing the ecological network.

Some criteria, which form the input to more than one of the sub-models, such as the suitability index and the land use intensity index. The utilisation of these differs in each sub-model. As the research progressed so the model was adapted to adhere to the findings.

At the outset of the thesis it was proposed to create a generic model, primarily excluding species. It became apparent that it is not possible to exclude species entirely. Species is inextricably linked to the purpose of an ecological network—the protection of species, and ensuring their sustainable existence.

It is not possible to define corridors or core areas without looking at species and their migratory patterns. It is pointless to define a corridor, which will not be utilised by migrating animals. Some might eventually utilise such a corridor. But some species e.g. elephant (*Loxodonta africana* (Skinner and Smithers, 1990)) use the same paths across generations and have home ranges of between 426,5 km^2 and less (Skinner and Smithers, 1990). This cannot be changed overnight, if ever, just to suit the planning. As such it is not possible to define corridors or core areas without looking at the migration patterns and home ranges of species respectively.

Species along with ecosystems have been included in a generic way, where the decision maker only needs to select the species (or possible key species). It is assumed that the data associated with the species is available. It is in some cases (e.g. *Loxodonta Africana)* but mostly it is not available. This is an area for further research for ecologists, zoologists and botanists. An effort was made to keep the model as generic as possible to allow for its adaptation to numerous different situations and locations. As such, many of the dimension calculations of the elements are relative.

Mackey (nd) states “Most species will become extinct before their habitats can be defined, let alone their intra-species, population-based diversity is examined.” This statement by Mackey shows just how mammoth the task is of protecting species. This model aims to prevent exactly that extinction. Bringing conservation a little bit closer to protecting the environment. Bringing GIS and Ecological Networks together to allow the web of life, a network of space.