1. INTRODUCTION

"The last quagga died on 12 August 1883; she died not on the southern African veld, but was instead a solitary survivor that lay down and died in a cage in the Amsterdam Zoo in Holland!"

– Peter Hitchins
(chairman of the Game Rangers Association)

Environmentalists and Conservationists have been trying to conserve the natural environment since the early 1900's (Hitchins, 1994; 2), by putting nature in a "cage" and protecting it. The size of the cage varies but it is still a cage. Since its early beginnings, this idea of conservation has changed, it has progressed to a view that one can't just "cage" or fence off sections of the environment but one must also utilise it sustainably at varying degrees of intensivity as part of an integrative whole – the Earth.

The Earth houses many different components: atmosphere, lithosphere, biosphere, geosphere, which all work together to create a system in equilibrium. However as all nations strive for increasing socio-economic welfare, the increasing pressure on the earth's resources in turn causes pressure on the environment and its natural resources, beyond it's sustainable limits, disrupting the equilibrium. This has resulted in what earth and environmental scientists termed the 6th Extinction (loss of biodiversity) (Anderson, 2001; 1). The mere fact, that this is such a big issue, a real local, regional and global problem (Anderson, 2001; Leakey & Lewin, 1996; Hitchins, 1994), suggests that efforts in conservation (and the strife towards sustainability) are insufficient. They need to be changed or at the very least improved. One idea is to move from the "caged" environment to one of ecological networks, where the transfer and exchange of species is readily possible through a series of corridors linking already existing or new, core areas.

1.1. BACKGROUND

1.1.1. The Sixth extinction

The earth has been subjected to five earlier extinctions. The first was shortly after the evolution of the first land-based plants, 450 million years ago (Leaky & Lewin, 1995, Eldredge 2001). The second caused the formation of the coal forests approximately 350 million years ago (Leaky & Lewin, 1995, Eldredge 2001). This was followed by two mass extinctions in the Triassic period (250 – 200 million years ago) (Leaky & Lewin, 1995, Eldredge 2001). The fifth extinction occurred 65 million years ago at the end of the Cretaceous period, ending reptilian dominance of the Earth (Leaky & Lewin, 1995, Eldredge 2001)

"There is little doubt left in the minds of professional biologists, that Earth is currently faced with a mounting loss of species that threatens to rival the five great mass extinctions of the

geological past." (Eldredge, 2001). There is even less doubt that it is not some external force (Morell 1999) but *Homo sapiens* that are the direct cause (Morell,1999; Eldredge 2001) of the present mass extinction—the sixth. We have created a modern world where landscapes have been transformed through urbanisation and agriculture, species are being overexploited, pollution is rife and alien species are introduced at will. This is cause enough to disrupt that ever so precarious balance of nature — the Web of Life.

"We don't know, not even to the nearest order of magnitude" how many species there are on Earth, "the number could be close to 10 million or as high as 100 million" (E.O. Wilson, cited in Anderson & De Wit 2003) which constitute the Web of Life. Let alone their inter- and intra-actions with each other within their ecosystems and on Earth. And yet before significant studies take place, they are being changed and wiped off the face of the Earth.

This is not some mythical claim; there is sound evidence for this phenomenon. Around 70% of the area of the world's 25 most threatened diversity hotspots and 50% of the world's tropical forests have been eliminated, erased from existence (Wilson 1992, Mittermeier *et al.* 2000, Anderson 2001, *cited in* Anderson & De Wit 2002/2003). "In pushing other species to extinction, humanity is busy sawing off the limb on which it is perched."-Paul Ehrlich (5, 6, 7)

Even with this scary truth looming, real, imminent, and most certainly affecting large numbers of people in the long run, the majority turn a blind eye. Yet **"…the sixth extinction is not inevitable.** If humans are the cause, they can also be the solution." (Morell 1999)

The realization, that the earth's resources (biotic and abiotic) are both finite and essential for the survival of humans (7), has stimulated scientists and policy makers alike, into looking for any solution(s), which might work on the very limited time scale that is still available to us. These solutions range stem from concepts such as sustainable development; holistic multidisciplinary management; and reformation of agricultural and land use polices; saving genetic code; valuing biodiversity; reduction in CO_2 levels to name a few. These solutions are being researched and tackled on a large scale; having achieved critical mass. One such solution is the development of ecological networks (chapter 2). This is a relatively new concept. It is a spatial problem, which can benefit greatly from the use of Geographical Information Systems (GIS) (chapter 3). The spatial planning of ecological networks has not been well developed, GIS is the ideal tool to use for just this purpose. Thus the question remains how to plan, design and implement this concept effectively at various scales—the focus of this dissertation.

1.1.2. Ecological networks

Ecological networks are more a concept than principle cast in concrete. This creates a flexibility which allows adaptation to a wide range of situations. This makes it difficult to clarify

and implement, as it differs in most applications of the concept. However the basic concept is that of various core and buffer areas being linked to each other through a number of different types of corridors, to form a network. This network reduces the landscape fragmentation problems, which occur in so many areas of the world through the development of infrastructure (especially linear features such as trains & freeways) and urban areas. This means that the network allows interaction of species between the various core areas. In doing so, ensuring the survival of the meta population a set of local populations in an ecological network, connected by inter-patch dispersal and is sustainable if the chance to go extinct is less than 5% in 100 years (Shaffer 1994, Verboom *et al*. 2001 cited in van der Sluis *et al.* 2001). The exchange ensures that there is no stagnation of the gene pool, thus strengthening the species.

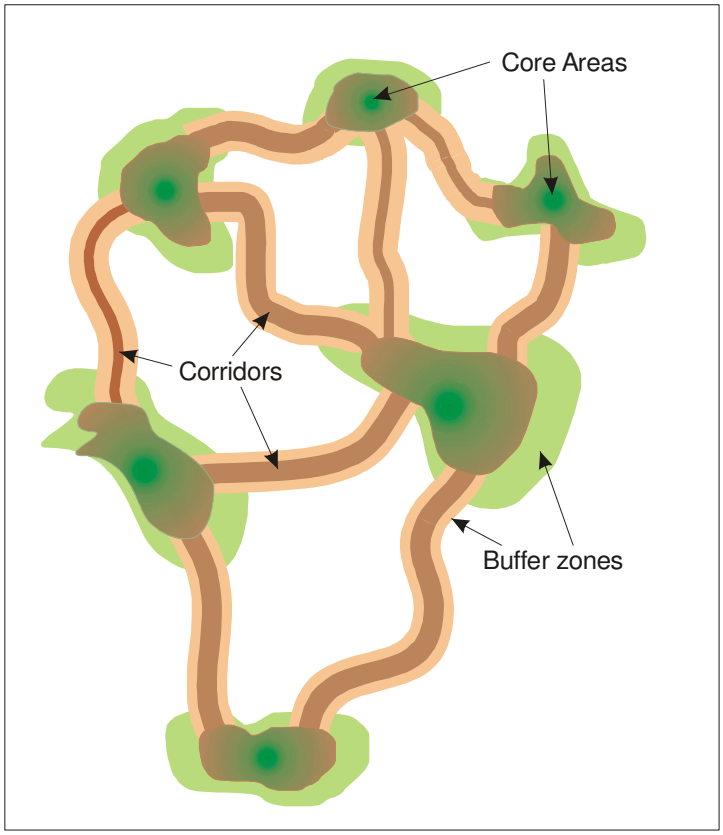

Figure 1.1: The Basic Elements of Ecological Networks

There are basically three elements to an ecological network, the core areas, the corridors, and the buffer zones as illustrated in figure 1.1

To define the ecological network function van der Sluis *et. al*. (2001) use an analysis method based on the theory of metapopulations and ecological networks. Whether an ecological network can sustain a persistent population or not depends on:

- Characteristics of a species: habitat preference, home range, dispersal capacity, the amount, shape and area of habitat patches in a landscape,
- Connectivity of the landscape, which defines how easily species can move to other habitat patches (spatial configuration of habitat patches).

Van der Sluis *et. al*. (2001) go further to say that the network function of a scenario / landscape can be tested on the basis of a number of species, which can be related to an ecosystem type.

Basically, the important factors in designing this network are the dispersal distance of a species or deemed number of key species (representative of the ecosystem); the spatial coherence of the area; habitat (quality and size, carrying capacity); and the land use (type and intensity). Environmental problems are not defined by political boundaries but might be adversely or favourably affected at a political boundary due to differing policies. As such, ecological networks should not be restricted by political boundaries.

> *The biggest issue is how to effectively and efficiently design and implement these ecological networks in a holistic sustainable and manageable way in a short period of time.*

In order to design and implement any ecological network, one requires an understanding of how the physical, ecological, social, economic and political systems (processes) involved work and how they interact. This in itself is a daunting task. Thus due to its complex nature, any "system" which might be used to model this and facilitate decisions (based on these processes and interactions), which can drive actions to reach a goal of implemented sustainable ecological networks, would be beneficial. Another major factor is scale. A core area for one species may only be a stepping-stone for another species. Processes, which occur at one scale, may not occur at another scale, making the systems scale dependent. This adds another dimension to the problem. However geographical information systems are equipped to handle specifically these kinds of spatial problems.

1.1.3. Geographical Information Systems (GIS)

Geographical information systems are not only a means of coding, storing, retrieving and analysing spatial data about the earth (Burrough, 1986). But have the ability to integrate biophysical and socio-economic spatial and non-spatial data (Eastman *et. al.* 2002). This is particularly useful and important in the effort to protect the environment. The environment consists of the biophysical and is affected either directly or indirectly by the socio-economic factors. All aspects of the environment occur at a location, be it above, below or on the surface of the earth. The idea behind GIS is to model the earth by relating everything to location and the objects and processes between them, thus modelling the environment. This enables the modelling of various scenarios, to ascertain the best solutions to the problem at hand or to possible problems in the future. A major part of the initial stage in developing an ecological network is its plausible locations. GIS can produce various scenarios using a variety of criteria and locations, providing a rating from ideal to most feasible to least feasible. It is also possible to adapt these scenarios according to various scales such as local, regional, national and even continental scales.

To produce these scenarios one requires a number of things, amongst which are hardware, software, spatial data, data management and analysis procedures (methods), people and

organisations; and most of all the problem or application area – ecological networks (Davis 2001, Heywood et al. 1998). This thesis will however not tackle all these aspects but rather focus on the analysis procedure (method). Some mention of spatial data is made as this may stipulate the initial method in the final model. Further explanations surrounding GIS and its applicability to the problem are discussed in chapter three.

GIS can be a catalyst in helping us understand these spatial relationships within the Environment, in terms of both quality and quantity. It gives us a handle to concepts quite difficult to come to grips with otherwise. Once we understand the inter- and intra- relationships and have a picture of what the current reality is all about, we can start to propose changes. To gain sufficient knowledge to create an accurate image of reality requires multidisciplinary interaction. These proposals can be modelled in terms of its effects on other species before actual implementation, therefore helping us to prevent costly mistakes. However, it is important to note that our models will only be as good as our understanding (Netterberg and van Wyk, in press), if this is limited - and it is, then so will be the model.

The abilities of GIS mentioned above and more, make GIS ideal for planning and designing ecological networks.

1.2. GIS AND ECOLOGICAL NETWORKS

GIS & Remote Sensing can help from design and planning an ecological network, by considering the variable location based information, to its implementation with powerful visualisation tools, to monitoring the network after it is functioning. It would seem that the combination of GIS and Ecological Networks would be extremely powerful. The question is what would be the best, most efficient way to exploit this combination to see ecological networks sprouting and giving new life to the planet.

GIS can benefit the development of ecological networks greatly to ultimately Stem the Sixth Extinction (Figure 1.2). The spatial and integrative abilities of GIS can help to plan Ecological Networks more effectively. Once the model has been tested and adjusted this process will be more efficient too. The key is that a solution to the Sixth Extinction needs to be found. This needs to happen quickly. This model may be one of those solutions.

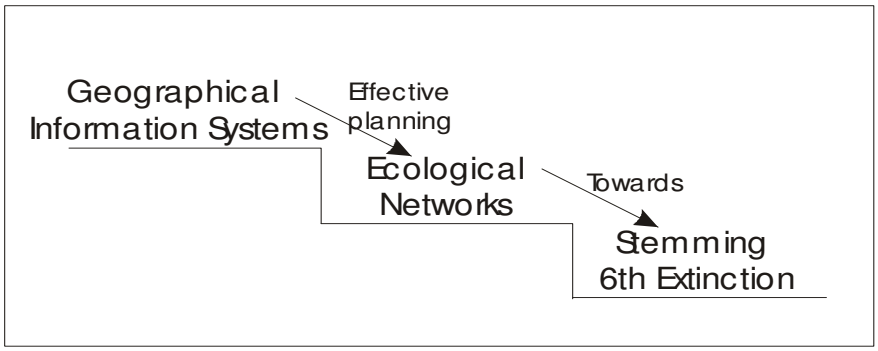

Figure 1.2: Working towards a solution.

1.3. PROBLEM STATEMENT

What is an effective means to utilise GIS for the development and implementation of ecological networks at local, national and multinational scales? Finally, to transcribe these "means" into a conceptual prototype which facilitates the design and implementation of such ecological networks.

1.4. OBJECTIVES

The object of the thesis is to create a conceptual prototype module of how best to spatially design ecological networks by utilising GIS.

1.5. AIMS

- Describe what methods in ecological networks and GIS & RS exist at local, regional and global scales?
- What are the chief differences between the different contexts both in terms of GIS and ecological networks. (looking at scale)
- Evaluate what works and what doesn't work in all contexts using examples as illustration.
- What can be learnt from this discussion?
- What problems still exist and need to be combated?
- Convert this research to system requirements for the conceptual *Ecological Network Design Model (ENDeM).*
- Create a conceptual prototype *ENDeM* .

1.6. OVERVIEW

To be able to achieve the above mentioned aims, one needs to access many different aspects of ecological networks and geographical information systems. To determine what is the most effective and useful methods utilised at present, one needs to examine various scenarios / Case studies. When working in conservation, issues of scale, development, social welfare, politics and available funds are very important. In GIS issues of scale, technology, development, available data, people and funding are also just as important. The thesis will be focusing on the issues of scale, this issue forms an umbrella over some of the other issues like welfare, technology, people and funding.

The size of the area concerned and scale of the project will always have a direct impact on the surroundings. It determines the level of management, effective legislation, extent of inputs and funding required. As in the case of the Netherlands, European legislation on conservation filters down and must be applied at national, provincial and municipal levels regarding all conservation matters. There have been cases where major projects (e.g. construction of a road) in the Netherlands, have been scrapped for conservation purposes as a direct result of European legislation (Personal Communication, Omtzigt N).

These aspects and more need to be considered in creating the spatial conceptual model of how best to plan design and implement ecological networks through the varying levels of scale. The utilisation of geographical information systems to spatially design ecological networks would seem to be the best mechanism to obtain this goal.

1.6.1. Structure of this thesis

Following this overview chapter, there follows discussions on the concept of Ecological Networks and GIS. These discussions take place in chapters two and three respectively. In chapter four, various case studies are discussed. These case studies were selected from global, meso and local scales. Only one global scale initiative is discussed. At both meso and local scales, two initiatives were selected, one from Europe and one from Africa. These case studies were used to develop a series of questions for digital interviews, which were sent to an Expert knowledge base. The methodology and the results from these interviews are described in chapter five. Culminating in a list of criteria, ranked according to importance, for the design of Ecological Networks. This list of criteria forms the basis for the systems requirements listed in chapter six. These in turn form the basis for the conceptual and cartographic models described in chapter six—the crux of this thesis. Chapter seven is a discussion of the recommendations and conclusions, placing all the pieces together to complete the puzzle. Taking one step closer to stemming the Sixth Extinction.