2. ECOLOGICAL NETWORKS

2.1. INTRODUCTION

Ecological networks are a concept, which needs to be explored rather than a theory cast in stone. This concept is explored in this chapter. This chapter explores how this concept came to the fore, what the current perspectives on it are. This includes the components of an ecological network and why it is important. Why and how the concept arose and why it is important, tie the beginning and the end of the chapter together.

Changes that humans effect in the geosphere (lithosphere) are mostly reversible given enough time (millions of years) but the effect of some anthropogenic actions on the biosphere is irreversible (Williams, 2000). ("The biosphere is a hydrocarbon derivative of geological fractionation where lithosphere, hydrosphere and atmosphere meet." (Briggs *et. al.,* 1997, pg31)) When a species becomes extinct it cannot recover, it is gone forever. That niche, which the specie filled, is now left vacant – changing the careful balance of their specific ecosystem and thus the biosphere. These changes are most obvious on remote oceanic islands (Steadman, *cited in* Williams, 2000), as they are highly endemic. Take for example that Ca. 50% of all bird species have gone extinct on various islands (Sarukhan, 1998). Now, consider that all the landmasses on Earth are islands of varying sizes (Williams, 2000). Thus the same changes, specifically the extinction or extirpation (a taxon that is eliminated locally from a specific area) of species, are occurring across the globe at varying rates, accelerated hundreds or even thousands of times (Williams, 2000) above normal. The biodiversity of the planet – life on Earth (Wilson, 1992; Leakey & Lewin, 1995; Anderson, 1999) is under siege by the rapidly increasing human population, especially due to our continuing modification of the systems that constitute Earth as well as a result of our collective activities. (Sarukhan J. 1998; Craighead, 1999; Anderson, 1999)

As the *Homo sapien* population of the earth escalates (fig. 2.1), biodiversity diminishes. This may continue to epic proportions until such a point where the planet – Earth – will be inhabitable for almost all present occupants. Unless there is a paradigm shift in our behaviour this will continue. This has already been achieved, for some, due to the previous five mass extinctions. However the sixth is not inevitable (Morell, 1999). There are some initiatives to stem this extinction, such as: the work of the Gondwana Society; the work before, during and after the Earth summits; Environmentalist groups raising awareness of the problem; besides these there are also various other developments, research and changes in approaches to conservation and development. One such approach is Ecological Networks.

Ecological networks arose out of the realisation that past conservation strategies were/are not effective enough. The wide-open expanse of land, which used to be available for wildlife are

becoming increasingly pressurised due to increased human population with their associated need for resources. Resulting in the reduction or alteration of the available habitat, so that the populations living in the area are no longer viable. The protection of individual species is not viable as these require an environment to live in, a network of space. Species cannot function on their own as they draw on others to sustain their livelihood, a web of life. It is no longer possible to approach this problem from a narrow-minded approach, as these solutions are not proving to be good enough.

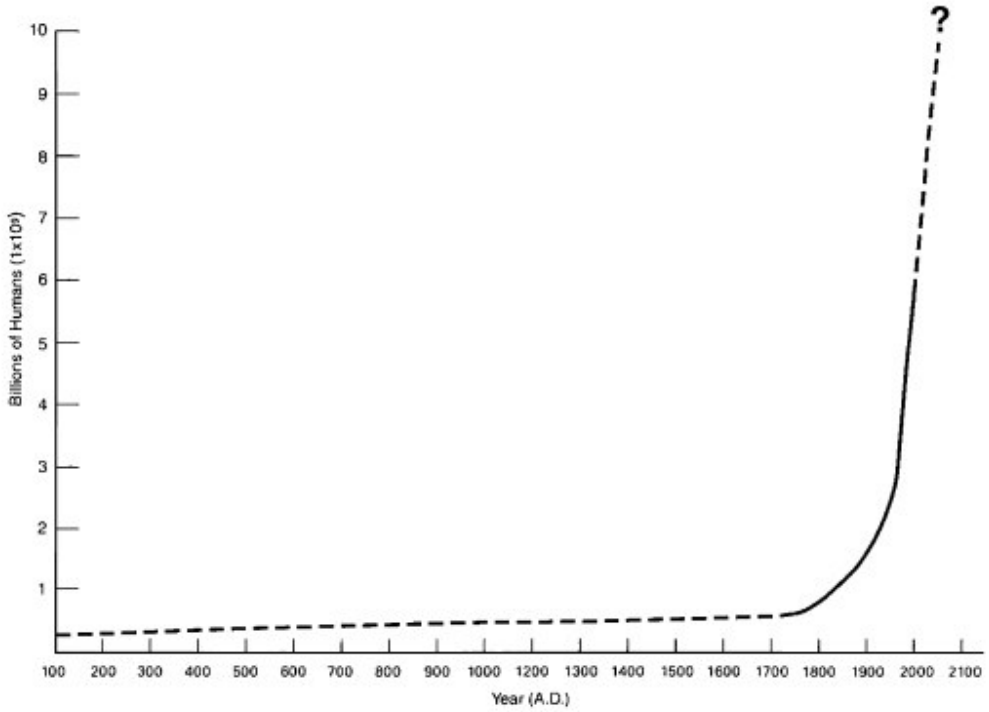

Figure 2.1: Increase in Human Population (from Williams, 2000)

Considering the various methods, approaches and ideas, why then the need to concentrate on Ecological Networks? The answer is simple. We need to stop putting the environment in “cages” and look at it holistically.

> “Sustainable land use planning and management require an holistic approach that integrates regionally significant environmental, economic and social issues. Planning and managing the wider landscape offers a mechanism by which this may be achieved. The concept of an "ecological network" seeks to maintain optimal conditions of ecological processes in the wider landscape and at the same time promote socio-economic viability. This concept is becoming increasingly important in European nature conservation. However, the models and tools to pursue wider landscape planning and management related to ecological networks have not yet been successfully demonstrated and evaluated.” (Lifeeconet, 2002)

Ecological networks are not a method cast in stone but more a concept which is highly flexible and thus adaptable to most situations. As such, this chapter is dedicated to exploring the concept of ecological networks.

2.1.1. Ecosystem – ecological

The ecosystem is characterised by a complex interrelation of abiotic and biotic factors. These are spatially organised in landscapes, which continuously change in time (Van den Berg & Stortelder, 2000). Making it a spatially dynamic multilevel system. As such it is no longer viable to select one individual aspect and protect it. The Ramsar Convention has realised this and has adopted the ecosystem approach, (Roch, 2002) as they realize that if they are to protect Earth's water & wetlands then whole ecosystems need to be protected. John Muir (nd) stated "Whenever we try to pick out anything by itself, we find it hitched to everything else in the universe." This is true of all ecosystems and trying to understand them. All the elements in the ecosystem are linked and interrelated like a complex network.

2.1.2. Networks

There are many thousands of networks present in the world today, from social networks, to road networks, to the Internet, to ecological networks. Wordnet of Princeton University defines a network as "an intricately connected system of things or people". The Earth comprises of numerous networks, which are interlinked – together, they form the system, Earth.

Ecology and the "web of life" are the small-scale networks in the system. The idea behind ecological networks, is to create a greater network of spatial structures, that will allow for the movement of species. Allowing the Web of Life, a network of space. This network needs to be both scalable and dynamic, enabling the existing processes to function at their required scales.

Together Ecosystems and Networks form a unique concept of linking the nodes of ecosystems into a complex functional system – Ecological Networks.

2.2. ECOLOGICAL NETWORKS

"Ecological Networks are more a concept than principal cast in concrete." (Centre Naturopa, 1998) This creates a flexibility (Centre Naturopa, 1998; personal communication Bennett, 2003; personal communication van der Sluis, 2003), which allows adaptation to a wide range of situations. However, this makes it difficult to define one set of rules to follow in the design and implementation of ecological networks, as it differs in most applications of the concept.

Bennett and Wit (2001) define an ecological network as:

> "an ecological network is regarded as a coherent system of natural and/or semi-natural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources."

However, the basic concept focuses on conserving biodiversity at different levels of scales (the ecosystem, landscape and regional scales) (Bennett & Wit, 2001) using a structure of various core and buffer areas being linked to each other through a number of different types of corridors (figure 2.2), to form a network (Jongman, 1995; Centre Naturopa, 1998; Jongman & Kristiansen, 2001). Some authors (Jongman, 1995; van Opstal, 1998; Bouwma et. al., 2002) also include nature restoration–development areas in their structures of ecological networks. This network attempts to reduce the landscape fragmentation problems (Centre Naturopa, 1998), in strengthening ecological coherence (Bennett & Wit, 2001), which occur in so many areas of the world though the development of infrastructure (especially linear features such as trains & freeways) and urban areas. This means the 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) (Van der Sluis *et. al.,* 2001). This exchange ensures that there is no stagnation of the gene pool.

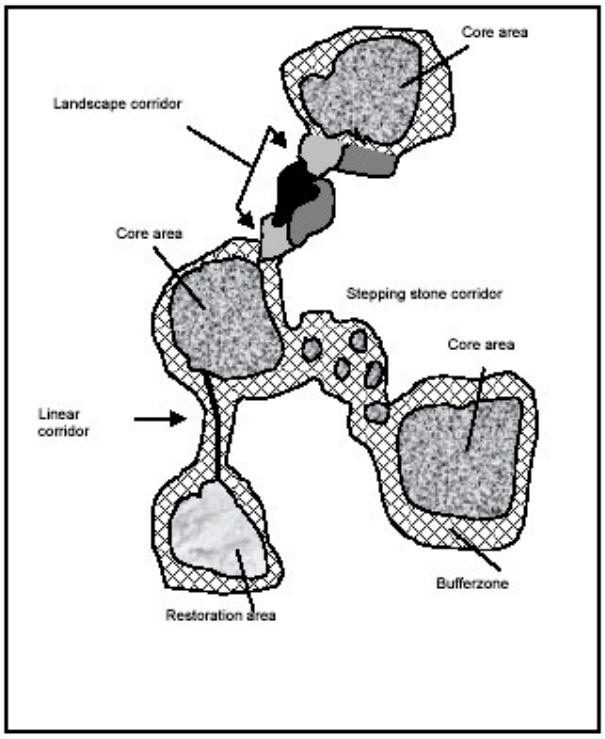

Figure 2.2: A schematic representation of an Ecological Network. (from I. M. Bouwma, *et. al.* 2002)

Virtually all the initiatives surrounding ecological networks aim to conserve species and habitats, and the majority also aim to facilitate the sustainable use of natural resources (Bennett & Wit, 2001). Less common objectives are the conservation of ecological and evolutionary processes and the conservation of cultural heritage. (Bennett & Wit, 2001) Ecological networks are tools used to achieve ecologically sound and globally stable landscapes (Miklos, 1998).

According to the Centre Naturopa (1998) ecosystems have five main requirements: appropriate physical environmental characteristics;

appropriate biotic conditions; minimum environmental quality; minimum spatial requirements for each species and sufficient opportunities for interaction between organisms. To meet these needs, an entire range of habitat types should be conserved (Centre Naturopa, 1998); small areas should be able to be interconnected (Centre Naturopa, 1998); and the environmental quality should be buffered against external influences (Centre Naturopa, 1998).

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. According to them, whether an ecological network can sustain a persistent population or not depends on:

- Characteristics of a species: habitat preference, home range, dispersal capacity, and 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).

They 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.

Many of the present initiatives in Ecological Networks, especially those in Europe, are based on policy objectives (Jongman, 1995), which coincide to the conservation and protection of areas of high natural values. However, due to different strategies, different networks arise.

2.2.1. Systems and Processes involved

There are basically three elements to an ecological network, the core areas, which for example may be nature reserves, areas of high natural value & quality, low intensity land use; corridors which are areas linking the core areas to one another either in the form of stepping stones, linear features or a combination of landscapes, low – medium intensity land use; and buffer zones bridging the gaps between low/medium intensity land and the areas of high intensity land use, which fall outside the ecological network (figure 2.2).

2.2.1.1. Core Areas

Core Areas generally provide the optimal environmental conditions and ecological space (Bennett, 1998; Wenger, 2000) to protect and conserve those landscapes, ecosystems, habitats and species considered important (Centre Naturopa, 1998; The Pan-European Biological and Landscape Diversity Strategy, *cited in* Foppen *et. al.,* 2000) or threatened. According to van Opstal (1998) core areas are coherent as regards soil composition, hydrology and climate; are ecologically integrated (functional as regards the main ecosystems of the core area); and are built up of natural, almost natural semi-natural or multi-functional ecosystems (or a mosaic of these ecosystems). These areas need to be of ecological value to the area, to make them viable.

Core Areas can take on any shape, mostly identified by traditional nature conservation policies (Jongman & Kristiansen, 1998). Often, already existing nature / conservation areas, are used as core areas and incorporated into the network. This occurs, especially if there is a history of conservation, within the particular country or area. If these areas do not already exist, they need to be designated, to be able to be used as the basis of the network.

Van Opstal (1998) defines core areas as areas, which sustain "…the vital functions that contribute to a viable population of a species that is of value to [a particular] area." For the purposes of this thesis this definition of a core area will be used.

In Europe, core areas are often too small to support viable populations without the support from other unprotected areas (Jongman, 1995); hence, the expansion of protected areas is crucial in the design of Ecological Networks. In other regions, USA (Jongman, 1995) and Southern Africa, the core areas or possible core areas, (mostly national parks, or hotspots) may be more than large enough to sustain viable populations. These core areas are traditionally fenced and thus isolated from external influences, both positive and negative. If these areas can be linked by corridors in such a manner that they can provide refuge for those species which fall outside of the park, as well as allow movement of species but still be buffered from negative external influences, the core areas would then benefit from the positive influences of an ecological network. What then are these corridors and buffers?

2.2.1.2. Corridors

Corridors generally create the appropriate interconnection between core areas (Nowicki, 1996; Bennett, 1998; Wenger, 2000), so that species would benefit from the opportunity to migrate and disperse, (Centre Naturopa, 1998) facilitating the diversification of the gene pool. They permeate the landscape, maintaining and re-establishing natural connectivity (Jongman and Troumbis, 1995 *cited in* Jongman and Kristiansen, 2001). Corridors are ideally placed where they improve the coherence of the natural systems (The Pan-European Biological and Landscape Diversity Strategy, *cited in* Foppen *et. al.,* 2000).

To exactly define a corridor is difficult, as many different authors use their own definition, which more often than not, are not clearly defined. Saunders & Hobbs (1991, *cited in* Bouwma *et. al.,* 2002) define a corridor as a linear feature of vegetation, differing from the surrounding vegetation and connecting at least two different patches (core areas), which were connected in historical times. However, this is not always what a species requires. Some research has been done into the dispersal patterns of forest birds. This shows that the birds require a mosaic of vegetation types (a stepping stone type corridor) (Bennett, 1999, *cited in* Bouwma *et. al.,* 2002; Brooker *et. al.,* 1999, *cited in* Bouwma *et. al.,* 2002). Bennett (1999) goes so far as to suggest a different term—linkages—to clarify the concept. In this thesis a corridor is defined after Foppen *et. al.,* (2000) in the broad sense as "a linkage between

resource habitat of a species consisting of landscape structures … resulting in a favourable effect on the exchange of propagules of the species (individuals, seeds, genes)." Its interpretation and implementation is flexible and easily adaptable to many different situations. The theoretical background for the functionality of corridors in maintaining viable population networks, stems from the island theory, the concept of metapopulations (Foppen *et. al.,* 2000) and island biogeography.

Corridors can have different functions; such as ensuring that species can move between nesting and foraging sites (commuting corridors); ensuring that species can migrate and move seasonally (migration corridors); allowing the expansion of existing populations in their natural habitats and into areas within their natural range currently unoccupied (dispersal corridors); besides these, ecological corridors can also perform other landscape functions, such as climate regulation and prevention of erosion (Bouwma *et. al.,* 2002). Foppen *et al.* (2000) consider these functions important when setting up the topology of corridors. During the planning of corridors careful consideration must be given to barriers or features with barrier effects. A corridor may exist but not function until a barrier is removed.

Three different types of corridors (based on function) have been defined (Foppen *et. al.,* 2000; Bouwma *et. al.,* 2002), largely based on the type of movement of species. The first being the *migration corridor* which is based on the prominent biological process of migration. The most commonly known migration is that of annual migration of birds, fish and the buffalo in the African plains of Tanzania (Bennett, 1999) and Kenya. The second being that of *commuting corridors*. These are based on the daily/weekly "short" distance movements between breeding and foraging grounds. The third being *dispersal corridors* which create the linkage between habitat patches to facilitate exchange of dispersing individuals or by transporting seeds (Foppen *et. al.,* 2000).

Dispersal is considered the key process for sustainability (Opdam, 1990 *cited in* Foppen *et. al*., 2000) in that it can supplement declining populations, safeguard populations against inbreeding and allow for recolonisation after extinction (Foppen *et. al.,* 2000). The dispersal corridor can be subdivided into three categories.

1. *One-step dispersal corridors*—corridors which allow those individuals (mostly juveniles) to fulfill that innate 'urge' or pressed by density dependent effects, to leave the site of birth—this can be tens of meters as in the case of field mice (Foppen *et. al.,* 2000) or hundreds of kilometers in the case of large birds (Foppen *et. al.,* 2000).
2. *Reproduction corridors*—those, which allow more than just dispersal (this is part of its function) but filling the gap between networks and making one coherent network. Often the dispersal distances are too large for an individual, thus it is essential to have intermediary "habitat patches" sufficient for reproduction (Foppen *et. al.,* 2000). It may

however be more efficient to enlarge a habitat patch (core area) to reach a viable population.

3. *Range expansion corridors*—those that allow for evolutionary changes: due to amongst others—climate change (Bennett, 1999 *cited in* Foppen *et. al.,* 2000). However the general consensus at this stage is that the expected climate change is much faster than those that occurred historically (Anderson, 1999). Most vulnerable species, especially plants will not be able to adapt fast enough by changing their distribution. For this to be possible vast tracts of continuous natural land need to be available. Much uncertainty still surrounds this. Presently this does not seem like a feasible option (Foppen *et. al.,* 2000).

Jongman & Troumbis (1995), Bennett (1999) & Foppen *et. al.,* (2000) distinguish three different types of corridor, based on physiognomic structures. The first being that of a linear shaped linkage (*linear corridors*) between two core areas, which is generally continuous, depending on the species, in terms of what barriers can be crossed. Secondly that of *stepping stone corridors*, which consist of discreetly located habitat patches (intermediary, smaller than optimum, core areas). These patches can be of any shape and are generally located within an inhospitable area, allowing temporary or permanent (depending on the organism) refuge. (Foppen *et. al.,* 2000). Lastly a corridor, which consists of a mosaic of patterns with different qualities, is considered a *landscape corridor*. These are multifunctional, offering very low resistance to species with no absolute barriers (Foppen *et. al.,* 2000) and are illustrated in figure 2.2.

Miklos (1996, cited in Jongman & Kristiansen, 2001) describes the corridor types used in Slovakia. These are defined in terms of shape, position and structure. Thus differing somewhat from those types described above.

Corridors can be defined at many scales, for example at the local or microscale where the movement of carabids, and the foraging pattern of badgers is important; at the regional or mesoscale where the dispersal of larger carnivores, and fish migration feature; and at continental or macro scale where the migration flyways of swallows is the major criteria (Bouwma *et. al.,* 2002). What may be described as a stepping stone corridors for some species may be considered core areas for others.

In practical terms, corridors generally follow existing landscape patterns (van der Sluis *et. al.,* 2001) and are usually multi-functional (Jongman and Kristiansen, 2001). Some natural elements lend themselves to being ideal corridors, such as watercourses. These form natural corridors: used by both animal species and humans, with their great natural wealth, connecting numerous elements within the corridor, both longitudinally and laterally (Wenger, 2000). Others such as those in agricultural areas do not form such obvious corridors and require research and careful planning.

At present, there is ongoing research into the concept of corridors due to a lack of clarity surrounding various aspects, especially how to effectively insure the connectivity that a corridor is to provide. This is primarily due to the fact that traditional conservation techniques focused on protected areas (Foppen *et. al.,* 2000). However, much has been said and written about corridors since the seventies, especially in the last few years since the idea of corridors and ecological networks has taken off. However, not all research has been positive.

There are some negative effects that corridors can have on conservation, which must be considered. Part of a corridor's aim is to decrease the isolation of a given population, however, if this population is exposed to a more competitive one, it could result in the decline of numbers; and the possible spreading of diseases & exotic species (Noss, 1987, *cited in* Jongman & Kristiansen, 1998, 2001; Noss, 1987, *cited in* Bouwma *et. al.,* 2002; Saunders *et. al.,* nd, *cited in* Plummer & Mann, 1995; Simberloff, nd, *cited in* Plummer & Mann, 1995; Bennett, 1999). Corridors could possibly facilitate the spread of fires and abiotic disturbances as well as the disruption of local adaptations (Noss, 1987 *cited in* Jongman & Kristiansen, 1998, 2001; Noss, 1987, *cited in* Bouwma *et. al.,* 2002; Bennett, 1999, *cited in* Bouwma *et. al.,* 2002). Could the potential negative effects of a corridor outweigh the conservation value (Foppen *et. al.,* 2000)? Besides, these corridors are often touted as ways to increase genetic diversity among populations, but they might actually decrease it, due to genetical homogenising of the metapopulation as a whole (Simberloff, nd, *cited in* Plummer & Mann 1995). Other areas of criticism are: whether or not there is enough scientific evidence to demonstrate the potential benefits of corridors (Foppen *et. al.,* 2000), especially since very few ecological networks have actually been implemented and others are only reaching implementation at this stage and whether corridors are cost effective in comparison to other conservation methods (Foppen *et. al.,* 2000).

Simberloff (nd, *cited in* Plummer & Mann, 1995) states that both the positive and negative effects of corridors remain largely theoretical. Primarily, due to the huge difficulties in conducting empirical research on corridors (Harrson, nd, *cited in* Plummer & Mann, 1995; Hanski, nd, *cited in* Plummer & Mann, 1995), as a result it remains an "unproven scientific concept" (Plummer & Mann, 1995).

Murphy (nd, *cited in* Plummer & Mann, 1995) is of the opinion that corridors should be given the benefit of the doubt. "Given what we know about the dispersal of species and the persistence of populations, [he thinks] the burden of proof should fall on those who would deny corridors to a reserve system, not on those who lobby for them." Stemming out of this, this thesis only sets out to develop a spatial planning facility, for the development ecological networks of which corridors are part and not to prove or disprove that they are indeed as

beneficial as some authors (Bennett & Wolters, 1996; Jongman & Kristiansen, 1998, 2001; Bennett, 1999; Foppen *et. al.,* 2000; Bouwma *et. al.,* 2002) would make out.

2.2.1.3. Buffers

The concept of a buffer zone is an old one (Wright & Thompson, 1935 *cited in* Bouwma *et. al.,* 2002). UNESCO has used the concept of buffer zones in the structure of their Biosphere reserves (MAB, 2002) since their origin at the "Biosphere Conference" organized by UNESCO in 1968 (MAB, nd). Buffer zones are implemented to protect both the core areas and the corridors from potentially adverse external influences; (Bennett, 1994, *cited in* Jongman and Kristiansen, 1998; Bennett, 1998; Centre Naturopa, 1998; The Pan-European Biological and Landscape Diversity Strategy, *cited in* Foppen *et. al.,* 2000; Wenger, 2000) such as pollution, land drainage (Centre Naturopa, 1998) or over-exploitation. The buffer zone concept maybe implemented practically through zoning activities at provincial or government level. The Council of Europe (2000, *cited in* Bouwma *et.al.,* 2002) suggests three main objectives of a buffer zone:

- Protection, to protect from harmful human activities;
- Interaction, to sustain positive landscape interactions;
- Diffusion, to sustain natural and man-made flows in the landscape.

Nowicki (1996) states that buffers are site specific and that an extensive knowledge of the ecological interrelations within the landscape structure, is necessary. Thus, one cannot arbitrarily assign a buffer, but one needs to research its plausible effects or necessity. Kati *et. al.* (nd) state that for Orthoptera, the core areas of the reserve [they studied] have a limited conservation value, but the buffer zone is very important. The Buffer area helps to sustain ecosystem health and the rich local biodiversity (Schultze and Mooney, 1993 cited in Kati *et. al.,* nd), which are factors that support high populations and guarantee long-term survival (Kati *et. al.,* nd).

2.2.1.4. Barriers

In delineating core areas and corridors, the effects of barriers (e.g. roads) (van der Sluis *et. al.,* 2001) should be considered, as these will most likely have a major impact on the network and movement characteristics of the organisms. In a study where cougars were tracked with radio collars, it was found that the cats followed the same paths between habitat patches even if they crossed through golf courses and highway underpasses, but they did not venture into a tract of homes (Beier, nd, *cited in* Plummer and Mann, 1995). In this case the houses acted as an impenetrable barrier where as the golf course did not. The highway underpasses acted as a break in the barrier thus making the highway barrier semi penetrable, as it could only be crossed at certain points.

It is very easy if you have a study to guide you as to the paths that a certain species follows and what are or are not barriers during their movements. This however, is hardly ever the case and planning has to be undertaken to preserve as many of these corridors and paths as possible. Another important consideration is that of ownership and the construction of fences for the demarcation of this ownership. For example, the presence of fences in the Veluwe National Park in the Netherlands. However there are a few cases where this does not happen, where a group of owners form consortia without fences.

2.2.2. Importance of Scale

Just as it is difficult to translate a study about the movements of cougars to that of impala, so to is it difficult to transform a study at a small scale into one of a large scale. It remains to be seen if findings at a species level (large scale) can be extrapolated to the levels of a nation or even a continent (Foppen *et. al.,* 2000). There is a relationship between the needs of a species, the dimensions of the corridors and the scale level under consideration (Foppen *et. al.,* 2000). As already alluded to: what is considered a core area for one species may only be a stepping stone for another species. The key species (if one considers the corridor species specific) determines the dimensions of the corridor and minimum area for core areas. However the scale level determines which species will benefit (Foppen *et. al.,* 2000). At a local scale the corridor might be between 10 meters and a few hundreds of meters benefiting the smaller species with less mobility. Where as at a global scale the corridors will be thousands of kilometres, which will benefit migratory birds and fish species. In Europe the mean interpatch distance was analysed using Corine Biotope sites. The distance arrived at was between 13 and 32 kilometres (Foppen et. al., 2000). This is not the only consideration, the great range in dispersal capacity, determines the scale of the ecological network as well as the size of the areas required for core populations (Butovsky *et. al.,* 1998).

2.3. DESIGNING AN ECOLOGICAL NETWORK

In planning an ecological network many aspects need to be considered. The European Centre for Nature Conservation (ECNC) developed a database on Expertise in Ecological Networks, which lists 119 specific fields covering approximately 44 general fields of expertise (ECNC, 2000b). From this and other aspects mentioned above, it is clear that the design of an ecological network is an immensely complex task. It was been suggested that this could be the key to the very survival of a species, perhaps our own! Hence it is a task, which should not be taken lightly.

It is therefore useful to have a broad guide as to how to design an ecological network, even better a system, which allows the inputs of variables, analyses it and returns various solutions to the problem.

Van der Sluis and Chardon, (2001) propose the following design steps:
First, *defining the problem* in terms of choice of species and the type of ecosystem. Secondly *selecting the species* or species group (ecosystem) concerned, the strategic choice of which can result in more benefits. It then follows to *spatially analyse* the current habitat, based on quality, quantity and potential for a viable population. The corridors and core areas (and reserves) must be defined according to species requirements and land assessment, which form the backbone of the network. This comprises the *functional analysis* of the network. The defined habitats require zoning and projection, for the *consolidation of the ecological network*. To strengthen the network, strategic development considering specific species migration patterns can improve the spatial cohesion of the network. Finally the functionality of the network can be assessed. In these proposed steps, the design of an ecological network is broadly defined in five steps. These steps and the criteria for designing an ecological network will be discussed in detail in chapter 5.

2.3.1. Criteria

The results from these steps need to be defined and analysed using criteria which describe the variables or factors in the ecological network. Basically the important factors (and criteria) in designing an ecological network are:

- dispersal distance of a species or deemed number of key species (representative of the ecosystem) (Jongman, 1995; van Opstal, 1998);
- spatial coherence of the area (Jongman, 1995);
- habitat (quality and size, carrying capacity) (Jongman, 1995; van Opstal, 1998);
- land use (type and intensity) (Geneletti, 2002);
- proximity to man-dominated landscapes (Geneletti, 2002).

It is important to consider what van Opstal (1998) states "…the challenge is to formulate criteria that will encompass existing national and internationally used criteria". It is the criteria that determine what the ecological network will look like and how it will function if at all. Thus the selection of the criteria is crucially important. To formulate effective criteria, the criteria used in a number of case studies are examined in chapter 4. These are evaluated by an expert knowledge base in chapter 5. Determining criteria for an ecological network is a sound scientific task. But the question remains as to why are ecological networks so important.

2.4. THE IMPORTANCE OF ECOLOGICAL NETWORKS

Human development spreads its tentacles into the rural/undisturbed/ natural areas. The landscape is transformed from continuous undulating hills of the African savannah to a patchwork of strips of land divided by road (figure 2.3), rail and utilities (figure 2.4)—the people are pleased, they are now connected. The ecosystem they utilise has been "disconnected" or fragmented.

Figure 2.3: Fragmentation of the African Savannah

But what does this mean?

As fragmentation of the landscape increases, the ecological coherence and interconnectivity decreases. This decreases the aerial extent available for the ecosystem (species and habitat) (Geneletti, 2002), reduces the opportunities for interaction between organisms (Centre Naturopa, 1998), decreases their resources especially in terms of available food, and increases their exposure to external disturbances (Geneletti, 2002). That is, fragmentation and disturbance of the natural balance. These effects can lead to the decline in the biodiversity of the area, as well as the stability and ability to recover from disturbances (Sanders *et. al.,* 1991) including the overall quality of the environment.

Up until now conservation and protecting biodiversity has been about putting “a fence around it” and keeping the adverse effects out. This has been successful up to a point. However this approach has its shortcomings, as it too fragments the landscape into core areas, with “barren” areas in between and restricts the mobility of those species, which require it. In spite of national and international cooperation to protect nature there is still a continuous decline of species as well as their habitats (Jongman, 1995).

Ecological networks attempt to combat the effects of fragmentation, in that they aim to improve the ecological coherence and inter patch connectivity of the area, by creating various corridors between habitat patches (core areas) and buffering them to reduce the adverse negative influences. It is a more holistic, multidisciplinary approach to the management of the environment.

Figure 2.4: Fragmentation and disturbance of a rainforest.

2.5. SUMMARY

As all species compete for space and resources on earth, so the need to utilise what is available, efficiently and sustainably becomes paramount. Thus looking at the bigger picture, approaching the problem holistically and utilising the technology available, may just help to stem the sixth extinction.

> "*Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself*." Chief Seattle

In finding solutions to the mass eradication of species which scientists call the sixth extinction, we are protecting our species from extinction. Especially considering that man is totally dependent on the resources of Earth (at this stage).

Ecological networks are a concept, which will help to protect these resources, provided that we can find a good method or process to plan and implement this concept in a sustainable and workable way. In the next chapter the spatial technological side of developing this method or process will be discussed.