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Designation of Supplementary Protected Areas in the Valle del Cauca, Colombia

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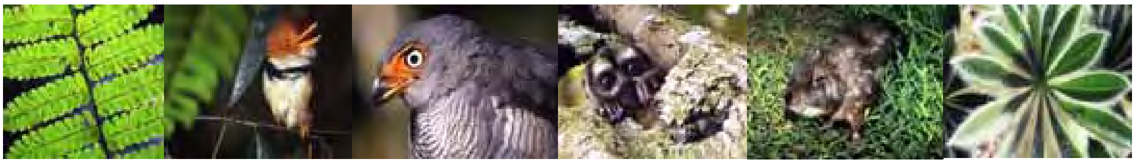

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DECLARATION OF ORIGINALITY

"I declare that the work presented in this report is my own work, except as acknowledged in the text, and that I have not submitted it, either in whole or in part, for a degree at this or any other university."

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Abstract

This research study dealt with the prioritization of candidate sites for addition to a largely *ad-hoc* designed protected area network within the Valle del Cauca, one regional department of Colombia believed to hold an exceptional share of the country's total biodiversity recourses while at the same time being heavily impacted upon by deforestation in favour to agricultural production. Although the methodology was essentially based on findings and recommendations brought forward by international researchers, investigations were yet considerably limited due to a restricted amount of accessible data, especially in regards to information about occurring species, therefore only allowing for a simplified gap analysis and the examination of species abundance and diversity within different ecosystem types according to sampling events and distributional modelling. In relation to the fine-scale investigation of ecosystem types and the highly fragmented character of a major section of the department, the selection of candidate sites in proportion to their content of ecosystem types currently underrepresented in the existing protected area network proved to be difficult. The fact that the ecosystem types distinguished by the most extreme reductions in cover extent were located in form of insignificantly sized fragments, dispersed within a landscape matrix dominated by agricultural land use, presented an important impediment to the creation of viably sized and at the same time representative protected areas.

Moreover, it was found that the at present protected sites of the department appear to be unexpectedly successful in including ecosystem types identified as providing valuable habitat to those bird and mammal species which were granted elevated importance as for their respective conservation status. Consequently, the chosen candidate sites for complementation of the existing protected area network in most cases failed to enclose under-protected ecosystems while simultaneously covering areas with assumed high incidences of bird and mammal species occurrence. In respect to the unsuccessfulness of designated supplementary sites in protecting small remaining fragments of dry forests, which had been attributed particular national conservation significance, besides the general necessity of physical amendments to the study area in the light of a holistic landscape management approach, the need for further conservation measures such as the implementation of private reserves and the construction of corridors was highlighted.

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1. Introduction

1.1. The General Situation regarding Biodiversity Conservation in Colombia

This research project, conducted in Colombia, a country which has been classified as 'megadiverse' and is recognized as one of the 'global hotspots' for biodiversity (Armenteras et al. 2002), deals with the design of protected areas within one of the most fragmented areas of the country, the Valle del Cauca. Despite of Colombia's extraordinary wealth of biodiversity, past research efforts towards the conservation of the country's ecosystems have been considerably limited as for the general lack of available funds for scientific investigations. Due to the absence of effectively implemented conservation strategies, the rate of ecosystem transformation has continued to accelerate in recent years, and consequently has the loss of biodiversity been dramatic in many parts of the country, especially within the central Andean region and the lowland landscapes of the Amazon, Caribbean and Pacific (Cavelier and Tobler 1998).

The design and implementation of conservation measures, such as required for a national network of protected areas that is based on sound ecological and biological principles, has been proven to be of especially difficult nature in Colombia, not only because as a developing country Colombia simply lacks essential financial resources for conserving biodiversity, and its numerous poverty-stricken small farmers are relying on the unsustainable exploitation of their lands to continue, but the enactment of environmental policies and conservation plans is further complicated and often hindered by the ongoing armed conflict within the country and the proportionate high presence of guerrillas in remote areas that are often characterized as holding high shares of biodiversity resources. As a result of serious safety concerns, areas assumed to be highly biodiverse are considered as being largely inaccessible, and even if necessary funds are obtainable, methodical species and ecosystem inventories often fail to be conducted (Alvarez 2002).

Although a total of 35 protected areas have been created in Colombia, covering an approximate 12 percent of the country's entire land area, therefore exceeding the recommendation made by the World Conservation Union (IUCN) to assign ten percent of land area to protected areas, the designation of protected areas has in the past been mainly based on social and political opportunities rather than scientific data (Arango et al. 2003). The currently existing network of protected areas, designed mostly using *ad-hoc* approaches, leaving a substantial amount of the country's various ecosystems fully unprotected, is consequently being regarded as being incapable of conserving a representative sample of the country's biodiversity (Armenteras et al. 2002; Arango et al. 2003). Some areas have in the light of ineffectively implemented conservation measures become more fragmented than others, depending on their location and environmental characteristics having favoured past settlement and agricultural opportunities. Because of the limited availability of reliable scientific data, a high level of uncertainty is associated with any estimates about the number of species of different taxa present in the country. According to a recent study from Wyngaarden and Fandino-Lozano (2005), as few as an estimated 10 percent of species have been described.

Despite this percent number appearing to be noticeably low, and it is impossible to verify what is unknown, because of the significantly high variations in ecosystem types due to large dissimilarities in altitudinal and climatic conditions, it is assumed that actual species numbers substantially exceed the current estimate. However, even with species inventories being incomplete, Colombia's documented plant species diversity (45,000 species) is second only to Brazil, while it not only harbours the world's richest avifauna (1766 species), but is also distinguished by providing habitat to the highest number of amphibian species (583 species). The country also contains a significant number of reptile and mammal species (475 species and 454 species respectively), whereas no approximate data on invertebrate abundance exists (Instituto Alexander von Humboldt 2002).

Colombia is at great risk of massive species extinctions, principally as a result of habitat destruction through deforestation and pollution. For instance, the list of threatened plants in Colombia comprises almost 1,000 species, and in relation to animal species, the International Union for Conservation of Nature (IUCN) registered 89 mammals, 133 birds, 20 reptiles and 8 fish species as being of endangered or critically endangered status, while no reliable information about the conservation status of Colombia's amphibian species is currently obtainable. This does not include a significant number of flora and fauna species which are on the verge of extinction, but have not yet been reported (Instituto Alexander von Humboldt 2002). It has to be kept in mind that this data is likely to present a serious underestimate about the actual number of threatened or endangered species in this country, acknowledging that the at present available information concerning biodiversity is extremely limited, and that species extinctions are likely to undergo undocumented. Habitat destruction and landscape transformation processes that have been recognized as being the most important factors for the extinction of species worldwide (Miller et al. 1999) have also been determined as being the main causes for the present dramatic loss of biodiversity in Colombia.

The effects of habitat fragmentation, where large landscape patches are reduced to small remnants surrounded by areas dominated by human land use, have been well documented (Miller et al., 1999; Bentley et al. 2000; Primack 2002). Miller et al. (1999) explain biodiversity loss within small patches of a fragmented landscape with the application of the species-area curve and the general principle that species diversity will be necessarily greater in larger fragments, as with the addition of every new species to a particular landscape the required habitat area increases. Another important cause of biodiversity loss in a heavily fragmented landscape mosaic is the increasing distance between single remaining habitat patches, consequently limiting the movement of metapopulations between patches. The lack of patch migration isolates species' populations within 'island' patches of the fragmented landscape, and likely effects on the populations' gene pools, such as a rise in homozygosity possibly leading to inbreeding depression and a decreasing ability of a species to adapt to altered environmental conditions, have been described by Primack (2002).

Despite of these principles of conservation biology being recognized by the prominent research institutes and conservation organizations in Colombia, the overall awareness of conservation issues by the general public is very restricted. Yet is the situation slowly improving, especially through the rising interest of international conservation commitment to Colombia.

1.2. The Study Area 'Valle del Cauca'

As the result of the overall absence of strategic actions towards the protection of original vegetation cover, largely intact areas are today mainly found in areas characterized as being essentially inaccessible, whereas areas with high fragmentation levels are generally located in the proximity of large urban centres. An example of this is the Central Cordillera, the central Andean region, where only small fragments of montane forest remain. Although the history of tropical deforestation has a long history in the Colombian Andes, due to 70 percent of the population being concentrated in this part of the country, and has had especially severe impacts here (Cavelier and Tobler 1998), large-scale fragmentation has also occurred in many other parts of the country, both initiated through increasing population densities and correspondingly rising levels of agricultural exploitation, as through the production of illicit crops.

The department Valle del Cauca, divided into an Andean and a Pacific Zone, in close proximity to the country's third-largest city Cali (approximately 2,300,000 inhabitants), has undergone extensive clearing of its original vegetation cover, mainly for sugarcane production and cattle farming. Colombia's Pacific Zone, regarded as facing a major risk to its natural resources, is characterized by particularly high biodiversity indices, and moreover renowned for exhibiting the highest levels of precipitation of any tropical zone on the globe (Armenteras et al. 2002).

In the Valle del Cauca highly accelerated processes of ecosystem deterioration have been observed due to an excessive level of urban settlement and agricultural exploitation including soil degradation, erosion, habitat destruction and fragmentation, as well as loss of hydrological fluxes owing to unsustainable irrigation practices, while the ability of the ecosystems to recuperate from anthropogenic disturbance is restricted due to the region's poor and fragile soils that are easily eroded once the top soil is lost or soil disturbance occurs (Armenteras et al. 2002). As it is the case for the majority of regions and ecosystems in Colombia, data about species occurrences is scarce from the Valle del Cauca, although it has been suggested that the region provides habitat to numerous endemic species, and that, in addition, a variety of species are of endangered status.

Despite of the regions' high endemism, unique ecosystems and the existence of serious threats, the significance of the Valle del Cauca as an area with exceptional biodiversity values and the need for interference into the currently unsustainable level of ecosystem transformation has only been recognized recently. One reason for this is that in general the issue of deforestation has received more attention from researchers in Amazonia and the tropical montane forests because of the outstanding species richness of those ecosystems (Arango-Velez et al. 1997; Kapos et al. 1997; Rangel 1997; Cavelier and Tobler 1998; Restrepo et al. 1998). Due to the overall lack of funds for scientific investigations in the Valle del Cauca, the low conservation priority granted to the area, and the especially severe threat mechanisms impacting on the region initiated by a particularly high population density, the department today is classified as one of the most seriously fragmented regions in Colombia. Following a nationwide gap analysis that investigated the representativeness of protected areas in the country and informed about the extent of the remaining areas of original vegetation cover for the various different ecosystems, detecting major conservation shortcomings in the Valle del Cauca, particularly in relation to the protection of dry forests, the urgent necessity of finding and implementing measures to protect the remaining biodiversity in this region became even more apparent. Consequently, the aim of this research project is the design of representative and viable protected area sites that complement the existing reserve network of the department.

1.3. Objective of the Study and Research Questions

Overall Objective of the Study

- Prioritize supplementary sites for addition into the present network of protected areas of the department Valle del Cauca that have the capability of conserving unique and vulnerable ecosystem features of the area by protecting those ecosystem types that fail to be adequately represented within existing protected areas, and at the same time provide for the preservation of viable populations of bird and mammal species which have been prioritized according to their current conservation status

As the results of this research will assist the provision of advice to the Corporación Autónoma Regional del Valle de Cauca (CVC), the agency responsible for the implementation of the network of protected areas in the Valle del Cauca, it is sought to present a variety of options with varying individual reserve sizes, as not to impose one scenario on the end-user but to outline different scenarios, carefully ranking sites for reserve acquisition according to uniqueness, species occurrence, species habitat provision and level of threat imposed on the site.

Three research questions are attempted to be solved in the course of this project. These overall research questions have been formulated as follows:

1) Which are the ecosystem types expected to hold the highest proportional levels of remaining biodiversity in the region and to what extent do they occur within existing protected areas?
2) Which are the ecosystem types with the smallest remaining cover extents of the Valle del Cauca?
3) Which areas of the department are characterized as of vulnerable status due to the likelihood of their transformation within the near future in favour to agricultural or urban land uses being perceived as especially high?

1.4. Brief Description of the utilized Methodology and the Report Structure

Broad methodological approach

This study makes extensive use of Geographical Information System (GIS) techniques for prioritizing sites for reserve acquisition. Firstly, a map of different ecosystem types and their respective total cover extents within the department is produced using the most current data available. Furthermore, the vulnerability of remaining intact ecosystem fragments to transformation, taking into account their specific locations and past transformation trends is examined.

This analysis of ecosystem types is followed by a detailed investigation of pronounced differences between particular ecosystems in regards to bird and mammal species assemblages using the statistical package ‘Pattern’ (PATN). Observations obtained from the preceding analyses, in addition to distributional models depicting the range of occurrence of bird and mammal species that are selected according to their particular conservation status, with superior importance attributed to umbrella species, are employed in identifying prospective sites for reserve acquisition that are evaluated against each other in relation to their proportional content of ecosystems that at present fail to be appropriately protected, while differences between candidate sites are quantified in PATN. Furthermore, this study attempts to provide recommendations considering measures which implementation assist a holistic conservation approach in the Valle del Cauca.

Report Structure

The report is structured into seven individual chapters. The second chapter provides an overview of the general status of protected area planning worldwide and reviews the findings and recommendations of a variety of researchers on prioritizing areas for conservation. Chapter 3 analyses the specific situation of Colombia and the department Valle del Cauca, addressing aspects such as advances in protected area planning and management as well as socio-economic factors.

After the examination of previous findings and the conservation framework of the Valle del Cauca, a situation-specific methodology, making use of a variety of GIS techniques and statistical analyses, is outlined in Chapter 4. Chapter 5 presents the results of the studies and, synthesizing the findings from the various parameters that were subject to investigation, ranks single sites according to urgency to be included in the reserve network while considering different scenarios. Chapter 6 suggests further measures for implementation and management of the protected area planning system in the Valle del Cauca, while the overall findings are summarized in Chapter 7.

2. Literature Review:

2.1. Introduction

This chapter commences with providing an overview about the frequently observed shortcomings of protected areas worldwide. In subsequent sections it then discusses recent developments in regards to systematic planning procedures that present an alternative methodology, which is based on scientific theories, to the commonly applied *ad-hoc* approach of the past. The findings of a variety of authors in relation to systematic reserve planning are addressed in this chapter, and they generally consist of recommendations concerning the application of different sampling techniques, the prioritization between a set of candidate sites, and the physical requirements of protected areas to assure for reserve viability and to enable the reserve network to fulfil its two most important functions, namely the retention and persistence of biodiversity within its boundaries. Within the last section of this chapter, the in many countries occurring inconsistency of conservation actions in the field with the advancing theoretical knowledge brought forward from the wealth of international research towards representative, complementary and viable reserve design is illustrated, and the limitations of applying systematic planning procedures into real world scenarios are discussed.

2.2. The Global Bias in the Selection of Protected Areas and ad-hoc Reservation Planning

The necessity of creating and effectively managing protected areas as to conserve biological features and ecosystem services that are valued to be of great importance by humankind has been increasingly acknowledged in the recent past (Chape et al. 2005). This rising awareness is particularly influenced by the rapid speed at which ecosystems worldwide continue to be destroyed or transformed. Due to a generally growing worldwide recognition of the significance of maintaining global biodiversity, a land area equalling 12 percent of the earth's surface has been set aside for protected areas (Chape et al. 2005). The fact that the terrestrial land area occupied by protected areas has increased ten-fold since 1962 supports the notion of a greater global commitment to conservation (World Conservation Monitoring Centre 2005). Today, protected areas are characterized as one of the earths most important land use allocations (Chape et al. 2005). Despite of this seemingly continuing progress towards the protection of global biodiversity, according to recent estimates published in 'The State of the World's Protected Areas' (World Conservation Monitoring Centre 2005), the currently existing protected areas fail to represent an adequate sample of the known environmental heterogeneity of the various ecosystems they are aimed at conserving. The main underlying cause for this bias in reserve selection are the high acquisition costs of land that is considered to be suitable for alternative development opportunities and activities such as logging, grazing and agricultural production (Chape et al. 2005).

As for this reason, governments worldwide, striving to comply with the from the IUCN set target of conserving a minimum of ten percent of the individual country's total land area, are frequently observed setting aside reserve sites in remote areas of the country or regions that are deficient of commercially exploitable environmental resources and where human settlement is sparse or people are politically weak, as to keep the social, political and economic costs associated with the establishment of conservation areas to a minimum (Lunney et al. 1997; Margules et al. 2000; Pressey 1994). Consequently has the widely adopted *ad-hoc* approach for designing nature reserves created a bias towards infertile lands that are in addition often characterized by a high relief or steep rainfall gradients (World Conservation Monitoring Centre 2005).

The observed tendency to conserve residual landscapes that in most cases lack exceptional species diversity diminishes the ability of the global network of protected areas to facilitate retention and persistence of biodiversity in the course of human and natural disturbances, described by Cowling et al. (1999) as the desired outcome of setting aside predefined fractions of natural landscapes.

2.3. The Evolution of Systematic Planning Procedures

2.3.1. Gap analyses to detect Shortcomings of Protected Areas

Because of the establishment of protected areas being associated with substantial costs, firstly those arising from the required activities in regards to protection and management, and secondly the opportunity costs consisting of lost prospects of development and resource extraction, it has been recommended to employ planning approaches based on defensible scientific theories that enhance the efficiency and effectiveness of newly created protected areas (Brooks et al. 2004). An efficient and effective global network of reserves endeavours the protection of the highest proportion of biodiversity within the smallest possible land area, as to minimize the various types of costs occurring with its development and maintenance. In order to successfully implement this ‘minimum required size’ approach there is a global consensus about the urgent necessity of being able to correctly identify highly biodiverse landscapes and to prioritize conservation actions according to their reservation status and the level of exposed threat (World Conservation Monitoring Centre 2005).

Approaches that evaluated the environmental heterogeneity of individual landscapes for the purpose of establishing representative protected areas have nonetheless been very divergent in relation to the specific socio-economic and ecological circumstances that greatly vary between countries and regions. Despite of single methodologies being generally very different is the ‘ecosystem approach’ considered to be the most useful tool for evaluating landscape heterogeneity (Sattler and Williams 1999; Environmental Protection Agency 2002; Etter 1998), since it facilitates investigations in relation to the representativeness of existing protected areas, and is capable of detecting unique landscape features as well as conservation gaps.

Etter (1998) defines the ecosystem as ‘a functional unit present in a given territory, homogenous in its biophysical and anthropogenic characteristics, which result from the interaction between climate, geomorphology, substrate, biological communities and human use’. The vegetation cover of a particular ecosystem is, according to Arango et al. (2003), the result of the combined influence of the factors above.

Using vegetative cover as the method for classifying and differentiating single ecosystems to evaluate the level of adequacy of protected area systems, gap analyses that quantify the representativeness of single ecosystems in reserve networks have gained growing popularity in studies worldwide (Scott et al. 1993; Groves et al. 2002; Driver et al. 2003; Margules and Pressey 2000). One aim of the gap analysis approach is, through protecting a reasonably sized area of every single ecosystem type, to prevent the decline and endangerment of single species and, in doing so, to avoid the need for costly reactive management activities that are mainly aimed at conserving single species populations from extinction, and often are of limited success (Jennings 2000). The underlying assumption of a well-conducted gap analysis is that the protection on the ecosystem level consequently leads to the conservation of a variety of habitats and species (Scott et al. 1993).

Although the gap analysis is generally considered as being a beneficial contribution to conservation, especially due to the possibility of its relative rapid realization, one essential factor limiting the validity of gap analyses is the large number of features contributing to environmental heterogeneity that are not utilized in the course of spatial conservation planning, as they can not be mapped (Brooks et al. 2004). An example are biotic and abiotic interactions taking place in vegetative communities that might have an important influence on ecosystem dynamics but are impossible to be spatially illustrated. Moreover, Flather et al. (1997) pointed out that one serious shortcoming of the majority of conducted gap analyses is the failure to incorporate the error component or the notion of uncertainty into the studies, in contrast assuming the analysis giving an accurate picture of the actual situation. Accordingly, Flather et al. (1997), together with other researchers (Scott et al. 1993; Brooks et al. 2004; Lombard et al. 2003; Pressey 2004), drew attention on the need to include high-quality species data into ecosystem studies in addition to gap analyses.

One apparent problem when attempting to evaluate the representativeness of ecosystems within protected area networks using gap analyses is to obtain a consensus about the number of ecosystems noticeably present in one particular landscape. The difficulty here lies within the availability of so-called ‘coarse’ or ‘fine’ biodiversity filters (Rouget 2003; Warman et al. 2004), and different perceptions of researchers on what methodology to employ for distinguishing between different ecosystems. To illustrate this argument, a recent study from Colombia, conducted by Wyngaarden and Fandino-Lozano (2005), investigated the distributions of ecosystems within the country and differentiated between 337 different ecosystems, in contrast to earlier studies from the Instituto Alexander von Humboldt (1998) describing only 64 existing ecosystems, and the Instituto de Hidrologia, Meteorologia y Estudios Ambientales (1998) that confirmed the occurrence of just 24 ecosystems. The elaborated conservation priorities for the creation of protected areas therefore largely depend on the scale of ecosystem evaluation utilized in the particular gap analysis. Once conservation gaps have been detected from gap analyses or other means, it has to be decided about the percentage of specific attributes of a regional landscape to be included on the reserve system.

Although the setting of fixed percentages seems promising, since it has the potential to greatly facilitate the process of reserve creation, it has been argued that fixed percentages of regional ecosystems or other selection units are arbitrary as the fail to account for the need of giving increased attention to regions with higher species richness, exceptional levels of endemism, or biophysical rarity which require higher representation targets (Brooks et al. 2004; Pressey 2004). Similarly has the target proposed by the IUCN to include a minimum of ten percent of every country’s total land area into protected areas, and hereby reassuring the conservation of a fair share of global biodiversity encountered negative reactions. Consistent with the findings from Lunney et al. (1997), for instance, at least 20 percent of Australia’s land area has to be set aside in protected areas in order to provide for a representative conservation of Australia’s natural assets. It is expected that for Colombia, a megadiverse country like Australia, due to its exceptional ecosystem heterogeneity and altitudinal variation, a land area considerably greater than the equivalent of ten percent of the country’s total area is necessary to be adequately reflecting the country’s biodiversity.

The generalization of conservation targets for different countries appears to be impossible because of underlying individual environmental conditions greatly differing from country to country.

2.3.2. Investigating the Species Attributes of different Sites

As the conduction of gap analyses exclusively, for distinguishing between sites of high conservation potential, has been criticised for providing an incomplete picture of existing biodiversity, since comprising an insufficient level of detail, it has been recommended to include the highest amount of information possibly available in regards to species-richness, with a focus on rare or endemic species, into reserve design considerations. Oliver et al. (1998) suggest that ideally the species abundance and species diversity of vascular plants, invertebrates and vertebrates should be investigated before choosing sites for reserve acquisition. However, in the vast majority of international studies, which aim is to distinguish between candidate sites for inclusion into a network of protected areas, the amount of accessible species data is, if at all present, very restricted in the light of planning processes that are dominated by temporal and budgetary constraints. Therefore has the concept of using environmental surrogates in the absence of such data gained growing importance in international studies, and results obtained from studies employing environmental surrogates have been described by Pressey (2004) to be of significantly higher relevance compared to those developed from studies that failed to utilize them.

Surrogacy, as explained by Sarkar et al. (2005), is the relationship between an ‘indicator’ parameter and an ‘objective’ parameter, where the ‘objective’ parameter stands for what is aimed to be conserved, which in the context of protected area design is biodiversity, while the ‘indicator’ parameter is capable to be representative of the ‘objective’ parameter and can replace the latter in planning exercises. In order to be classified as ‘indicator’ parameters, the substituting environmental variables are required to be of quantifiable nature and at the same time easily and accurately obtainable from limited field surveys, remotely sensed data and theoretical models (Sarkar et al. 2005).

Using climatic and physiographic variables of a region as environmental surrogates, in order to model the relative probability of occurrence of different species, has become a significant tool for choosing the most valuable areas for conservation planning. For instance, Johnson et al. (2004) found that modelling species distribution according to environmental surrogates, together with the contribution of expert opinion, has lead to accurate results for the prediction of the presence of mountain caribou (*Rangifer tarandus*) populations in British Colombia, Canada. The increasing employment of spatial modelling, triggered by the greater availability of remote sensing and geographic information systems (GIS) technologies, has also be discussed by Boone and Krohn (2000) who emphasized the need for a cautious interpretation of results, as comparisons between predicted and observed distributions have detected major discrepancies, which the authors attributed to a lack of understanding of factors that impact on the range limits of single species.

Wilson et al. (2005a) showed that probabilistic modelling of presence and absence of species utilizing thresholds, set either a priori or a posteriori, proves to be very sensitive to the method of threshold selection, with the a posteriori threshold selection approach generally being more risk adverse, since it incorporates the specific data set characteristics as well as the range and spread of predictions. Moreover, the study from Wilson et al. (2005a) demonstrated that spatial distribution modelling for conservation planning is very sensitive to different modelling methodologies, not only in relation to defined thresholds, but also to the size of the selected planning units, emphasising that conservation planners have to be aware of the degree of uncertainty associated with their predictive modelling exercises, as to make informed decisions about which approach to use according to the risks involved, and to assist with the interpretation of results.

Because of the high amount of information required to determine the various factors influencing the distributional range of a single species, modelling the distribution of multiple species of different taxa appears to be an extremely difficult and time-consuming exercise. Consequently is the notion of utilizing modelled population dispersions of single species as surrogates for modelling presence or absence of other species, of the same or different taxon, an inviting one.

In order to do so, a distinct overlap in species ranges has to be established which can only be verified through extensive surveys. Such a survey from South Africa (Eeley et al. 2001) documented that areas identified as being exceptionally species-rich, or so-called ‘rarity hotspots’, for a species of a particular taxon, contained a high proportion of overall diversity of this taxon. However, the results of the same study also indicated that only very little or no overlap existed between areas of outstanding species richness and distributional ranges of rare species. Correspondingly, Ceballos et al. (1998) failed to detect an overlap of rare species distributions with areas generally identified as being very species-rich, areas containing a high proportion of endangered species, or areas characterized by a high level of endemism. In addition did the authors recognize very dissimilar species compositions in the three area types mentioned afore.

Nonetheless, even if not accounting for the presence of rare species, the use of umbrella species, species which habitat requirements are sympatric with a wide range of other species, has been described as being valuable for the setting of conservation priorities (Poiani et al. 2001; Fleishman et al. 2000). Fleishman et al. (2000) and Poiani et al. (2001) list as the main requirements for a species to be classified as being an umbrella species a significantly large number of co-occurring species, high sensitivity to anthropogenic disturbance, and a tendency towards site fidelity in order to facilitate surveys. Moreover, Poiani et al. (2001) state, drawing on the results of a butterfly study from the United States, that, although protecting rare species might lead to a great number of widespread species protected at the same time, while the protection of widespread species in contrast did not provide for the inclusion of rare species in reserves, the restricted range of rare species might make the sampling too difficult and considerably decrease the value of an umbrella species. It has been argued that mammals from high trophic levels serve in many cases as good umbrella species because meeting their minimum habitat requirements, which are large due to their raised metabolic needs, the necessary habitat conditions are simultaneously met for other biota (Boshoff et al. 2001). This assumption has been confirmed from Eeley et al. (2001) who found that a reserve in South Africa, which selection was exclusively based on surveys of mammals, comprised a high proportion of the total species richness of the remaining taxa, notably bird species of which 90 percent of species known to occur in the region was represented in the reserve.

Similarly, Oliver et al. (1998) detected a generally significant level of ‘assemblage fidelity’ among vascular plants, vertebrates and invertebrates, with assemblage fidelity being considerably lower among invertebrates and plants due to a high turnover of invertebrate species. For creating reserves in landscapes considerably impacted by fragmentation, it appears to be beneficial to select umbrella species in correspondence to their susceptibility to fragmentation, according to Bentley et al. (2000) species distinguished by being specialists rather than generalists and usually by large body sizes, low fecundity levels and proportionate low adult survival rates. Umbrella species that have been selected as for their exceptional sensitivity to anthropogenic disturbances consequently show the ability of providing information about the conservation status of a particular ecosystem and are therefore also referred to as ‘indicator species’ (Fleishman et al. 2000). Coppolillo et al. (2004) discuss the concept of using ‘landscape species’, which is inherently similar to that of umbrella species, presenting a methodology to choose such species taking into account factors in relation to its specific area requirements, habitat heterogeneity, ecological importance, vulnerability and socioeconomic significance, scoring these factors and nominating the species with the highest score, which requirements furthermore meet the requirements of all remaining species.

2.3.3. Additional Recommendations brought forward in relation to Sampling for Reserve Selection

Despite the general existing recommendation to obtain the maximum possible amount of data on species abundance of vascular plants, invertebrates and vertebrates, in order to aid the selection of areas for reserve acquisition (Oliver et al. 1998; Scott et al. 1993, Brooks et al. 2004; Lombard et al. 2003; Pressey 2004), Gaston and Rodrigues (2003) argued that, even if species sampling effort was low, reserve selection based on very restricted presence and absence data still has the potential to lead to highly representative results because the results of low-intensity sampling reflect peaks of abundances, including that of restricted range species. Gaston and Rodrigues (2003), comparing sampling efforts of different intensities, nonetheless found that the acquisition of the most extensive data sets supplying detailed information on abundances of individual species provided for the most valuable results.

It has also been suggested that, once species data has been collected from a landscape, to analyse the differences in species diversity and abundance with the additional use of various aspects of environmental data, in order to be able to identify the locations of topographic isolates and environmental gradients that are assumed to exert a strong influence on biodiversity levels (Environmental Protection Agency 2002). Similarly, Wiersma and Urban (2005) stated that environmental gradients significantly impacted upon beta diversity or the compositional turnover between different sites in Canada, and moreover pointed out the advantages of using measures of species turnovers and site diversity in assisting decision-making concerning the preferable number and spacing of protected areas in a particular region.

Another concept that essentially builds on the use of beta diversity is the existence of ‘biogeographic crossroads’, discussed by Spector (2002). Biogeographic crossroads are distinguished as locations within a landscape where biogeographic assemblages intersect, in other words where areas or sites characterized by high levels of beta diversity overlap, and the protection of such species-rich interconnecting locations is described by Spector (2002) as an effort-economic conservation tactic that, although focusing solely on comparatively narrow portions of the landscape, can support the creation of a representative and complementary protected area network, while it may at the same time preserve evolutionary processes such as speciation and co-evolution. The importance of taking into account past evolutionary processes has been emphasized by Cowling and Pressey (2001) who, utilizing as an example the Cape Floristic Region of South Africa, within which many plant lineages have undergone rapid diversification processes and ecological specializations, highlighted the need to consider both the pattern of current plant species as well as future possibilities of lineage turnover when planning reserves.

The sensitivity of systematic reserve selection procedures to scale-related variables, as comprehensively discussed by Rouget (2003), has already been addressed at an earlier stage of this review. Of special importance in this context is the question arising for the researcher of whether to employ a fine or a coarse biodiversity filter in a particular study (Rouget 2003).

Sarkar et al. (2005) found that coarser filters enhance the performance of environmental surrogates in predicting species occurrence, while according to Higgins et al. (2004), fine scale biodiversity filters are necessary for detecting irreplaceable biodiversity and habitat values as well as for the identification of specific requirements of rare and endangered fauna. Besides having to choose between different analyses scales, the conservation planner is also presented with the difficulty of establishing the appropriate size of selection units (Warman et al. 2004). Selection units are the portions of the landscape that are examined for inclusion into the reserve system and can be consisting of natural, administrative or arbitrary landscape subdivisions (Pressey and Logan 1998). Pressey and Logan (1998) found that an overrepresentation of common landforms within any reserve network, being composed of reasonably sized individual fragments, is inevitable, and that the representation efficiency of single features was superior when utilizing smaller selection units, whereas overrepresentation of features was more frequent with the use of larger selection units.

2.3.4. The ‘Landscape Approach’ in Conservation Planning

Generally, it is assumed that once a network of protected areas has been created within a specific region, the biodiversity values within these areas are successfully protected for an indefinite timeframe (Stolton and Dudley 2005). That this is not necessarily the case has to do with a variety of possible factors, mainly consisting of directly impacting threats to protected areas, including the continuing exploitation of protected areas due to a frequently observed deficiency in effective enforcement, and the often prevalent failure to employ a large-scale planning approach that focuses on the whole landscape rather than concentrating on the protection of small portions of the landscape that have been identified as containing high biodiversity values (Carrol et al. 2004; Stolton and Dudley 2005). The apparent lack of large-scale planning that incorporates the variety of dynamic processes taking place within a landscape matrix comprising individual vegetation patches of differing successional stages, is also revealed by the small sizes of currently existing protected areas worldwide, which have been characterized as being inadequate for conserving the significant components of biodiversity within their boundaries (World Conservation Monitoring Centre 2005).

Consequently, according to the World Conservation Monitoring Centre (2005), should the drastic growth in the number of protected areas worldwide, having occurred within the past 43 years, be considered with caution, not only because of the high employment of *ad-hoc* reserve design approaches that have lead to a lack in overall representativeness of ecosystems, but also in relation to their insufficient sizes for fulfilling their individual tasks. The fact that 59478 or 58.25 percent of the total 102102 recorded protected areas, contained within the 2003 UN list, comprise a land area of less than 10 km^2 emphasizes the global trend towards the reservation of smaller sites (World Conservation Monitoring Centre 2005). As a result has the total land area protected worldwide in reserves actually declined within the past 30 years, with the highest growth occurring between 1962 and 1972 (World Conservation Monitoring Centre 2005). According to the predominance of inadequately sized reserves, one could assume that the inclusion of larger remaining fragments of original vegetation cover into a reserve network could generally provide for viability of the network. Rothley et al. (2004) nonetheless found that, despite of the hypothesis of larger fragments including higher biodiversity levels being generally verifiable, not all conservation objectives can potentially be realized using the largest fragment approach, but that various other criteria have to be investigated in relation to multiple, often conflicting objectives, embraced in protected area planning.

In the context of a holistic ‘landscape approach’ to protected area planning, Magin (2005) argues that, as the total land area which dedicate individual countries to reserves is considerably limited, networks of protected areas have to be designed in such a way that the reserved sites are not isolated from the wider landscape dominated by human land use, but on the contrary are considered as ‘core sites’ within a sustainably managed landscape where off-reserve conservation mechanisms protect biodiversity and ecosystems. An important component of the wider landscape planning approach is the concept of metapopulations, referring to populations of a single species being dispersed over different patches of a landscape. The significance of identifying source and sink dynamics of metapopulations, in order to be capable of protecting the essential habitat requirements of particular species, has been discussed by Margules and Pressey (2000).

Possingham (2003) also drew the attention on the necessity to not only take into account patches occupied by metapopulations of certain species for reservation purposes, but also empty patches that might fulfil an important function in the dynamics of metapopulations.

The need for the existence of ecological corridors that facilitate the movement of individuals of metapopulations between patches of a fragmented landscape has been increasingly acknowledged in the holistic landscape planning framework, because of isolated ‘island’ fragments of a landscape matrix dominated by urban development or agricultural land use being likely to face a serious decrease in species numbers due to a variety of stochastically occurring processes, including inbreeding depression (Magin 2005). Watson and Wilkins (1999) highlighted the necessity of establishing continuos corridors, also referred to as ‘stepping stones’, that provide linkages and opportunities for movement among singular reserves within a protected area network, as well as connecting fragments of the same ecosystem type within large reserves or outside reserves. Using as an example a study from the South Coast region of Western Australia, Watson and Wilkins (1999) introduced the concept of ‘macro-corridors’, linear assemblages of mostly continuos vegetation, ideally exclusively composed of original and pristine vegetation cover, which function consists of both connecting different protected areas as well as supplying quality habitat to numerous species. Consequently, macro-corridors typically measure hundreds to several kilometres in width and tens of kilometres in length (Watson and Wilkins 1999). With reference to planning of ecological corridors in a highly fragmented or marginal landscape, it has been suggested to utilize transformed habitats such as tree plantations to connect intact areas, while it has been recommended that protected areas are located in close proximity to each other if the creation of corridors appears to be infeasible (World Conservation Monitoring Centre 2005).

In addition to biodiversity loss within protected areas, due to an unsustainable level of isolation decreasing the viability of protected area networks, external influences, infiltrating from reserve edges into the reserve interior, have the potential to significantly alter the biotic and abiotic conditions found in the intact reserve environment (Turton et al. 1997).

Laurance et al. (1997) argued that abiotic changes are in most cases limited to a maximum distance of 60 meters into the forest interior, while the steepness of decline is commonly described as the function of the age and aspect of the edge (Schlaepfer et al. 2001). Biotic edge effects can be exceptionally diverse and encompass factors such as the proliferation of secondary vegetation along forest margins, invasions of weedy and generalist plants and animals, alteration of ecological processes such as nutrient cycling and energy changes, and often have the potential to initiate other ecological changes (Laurance et al. 1997). Changes of abiotic variables, including solar radiation, temperature and moisture, impact significantly on biological processes such as photosynthesis, vegetation development, decomposition, and nutrient cycling (Turton et al. 1997). According to a study by Fox et al. (1997) that examined species richness and abundance in forest fragments, both variables were significantly higher in the forest interior compared to areas near edges. As a result of research advances in relation to the impact of edge effects on protected areas, the concept of an integrated buffer design that thoroughly examines the variety of different abiotic and biotic external influences before declaring a buffer zone, rather than choosing reserve buffers on an *ad-hoc* basic only taking into account a limited subset of external threats, has gained increased recognition (Peterson 2005).

2.3.5. Choosing between seemingly appropriate Candidate Sites for Reserve Acquisition

The previous sections of this chapter mainly discussed factors that should be taken into account when planning representative protected areas in relation to the variety of available sampling techniques and the suggested physical requirements of reserve networks. One difficulty the conservation planner is presented with is the prioritization between different sites which biodiversity values might appear to be of similar significance. The expression of clearly defined conservation goals as well as the setting of specific and quantifiable targets that are based on estimates regarding the necessary conditions for biodiversity persistence, has been identified by Pressey et al. (2003) to be highly beneficial to conservation planning.

Among the advantages of having a set of explicitly articulated objectives are the possibility of effectively monitoring and evaluating the performance of particular protected areas in successfully conserving biodiversity values, the prioritization of actions essential for the implementation and maintenance of reserves, and, most importantly, the ability to rank potential sites for inclusion into reserves according to their capability of contributing to the enhanced representation of particular ecosystems which conservation has been recognized to be of major importance as concluded from analyses of ecosystem maps (Pressey et al. 2003). The frequently arising problem with objective setting and reserve planning is that different reserves types are generally required for achieving multiple objectives (Rouget 2003) and that therefore the objectives have to be ordered in correspondence to their apparent imperative.

Consistent with the principle of representativeness, it has been recommended to focus conservation efforts on poorly conserved regional ecosystems of which currently less than ten percent of their total extent is found in protected areas, and to give even higher priority to those ecosystems that have experienced serious declines in their total coverage area, and that are at the same time severely underrepresented in existing reserve networks (Environmental Protection Agency 2002). In the light of an overall lack of funding the notion of 'irreplaceability' has become more important in conservation planning (Meir et al. 2004). Areas distinguished by high levels of irreplaceability, often in regard to their unique biodiversity characteristics or ecological remnant status, have to be necessarily included into a reserve system, as their future loss prevents the reserve system from meeting one or more conservation targets (Ferrier et al. 2000). In contrast, areas with a lower degree of irreplaceability are typically found having more replacements in a region, and the future loss of such areas is judged as not hindering the achievement of conservation objectives (Ferrier et al. 2000).

Moreover, it has been suggested, in addition to examining irreplaceability of candidate sites, to investigate their probable vulnerability, in other words the likelihood of future biodiversity loss within an area, and to take both of these factors into account for assigning selection priorities (Margules and Pressey 2000).

Useful techniques for recognizing the likely vulnerability of individual ecosystems to disturbance or destruction are vulnerability analyses that investigate the past pattern of land transformation and attempt to establish relationships between particular environmental variables and the magnitude of land exploitation. Studies predicting future forest conversion have been conducted in Chile by Wilson et al. (2005b) and in Colombia by Etter and Wyngaarden (2000). It has also been recommended to base the selection of additional protected areas in conformity with the magnitude of difference between the biodiversity characteristics of the new site and already existing protected sites (Pressey 1994; Wiersma and Urban 2005).

In order to assist systematic reserve selection, the use of algorithms that are capable of identifying minimum or near-minimum solutions to the problem of having to represent a wealth of biodiversity features, has become more widespread, especially in Australia (Pressey et al. 1997). While 'optimality algorithms' are solved simultaneously, often with the help of computationally intensive linear-programming methods, the use of typically iterative 'heuristic algorithms' is simpler, selecting sites at each iteration that provide the most complementary set of features to those already present within sites chosen in previous iterations (Csuti et al. 1997). Frequently utilized heuristic algorithms are 'richness' and 'rarity' algorithms, with the former accounting for the maximum number of species in the minimum number of sites, emphasizing the concept of complementary by adding sites that are species-rich but dissimilar in their composition from previously selected sites, while the latter firstly adds sites containing the rarest species, progressively choosing further sites with the rarest unrepresented features (Csuti et al. 1997). According to Pressey et al. (1997), the choice of the most effective algorithm for a particular reserve planning exercise depends on the individual circumstances, including the characteristics of the data set and the specific objectives of the reserve network.

Protected areas are in some cases solely designed with the purpose of protecting one or multiple species or entire taxa that have been recognized as being of critical conservation status, and to facilitate the conservation of such species or taxa their exact habitat requirements have to acknowledged (Environmental Protection Agency 2002).

For evaluating the spatial needs of species or entire taxa, it is commonly distinguished between core habitats, areas that have been judged to be of major importance for the species or taxa, independent of whether sightings have occurred or not, critical habitats, areas that, although the species or taxa have not yet been recorded within them, are believed to perform a significant function for their survival, and essential habitats, where individuals are present, corridors exist, or populations are found within adjacent sites (Environmental Protection Agency 2002).

When species information is scarce, the reliance on GIS technologies and the application of environmental surrogates correspondingly increases and, especially in relation to the protection of critically endangered or extremely rare species, it seems to be appropriate to generally base decisions on the precautionary principle (Flather et al. 1997). Before the implementation of a reserve design which individual components have been selected using a systematic planning approach, it has been considered as essential to take into account the landscape's long-term capability of sustaining populations (Carroll et al. 2004) and to thoroughly evaluate the chances of the protected area to persist (Groves et al. 2002). This can for example be assessed with the help of species' population viability analyses or studies that investigate the response of ecosystems to differing disturbance regimes (Groves et al. 2002), and through taking into consideration possible future difficulties concerning reserve management, influenced also by political matters.

2.4. The Discrepancy between the Theoretical Reserve Selection Process and its Application in the Real World

Although over the last few decades a considerable amount of resources and effort have been spent in developing approaches to effectively prioritize land areas for conservation, and to improve the potential viability of reserve networks through investigating the significance of ecological and biological processes, new findings from conservation researchers often fail to be incorporated into reserve design procedures in the field (Prendergast et al. 1999).

According to Prendergast et al. (1999), one reason for this is that within a majority of countries worldwide, especially in developing countries, an obvious dichotomy exists between academic conservation research and applied land use planning. If such a dichotomy is evident, land managers are frequently simply unaware of the results obtained from scientific research, or, in some instances, even a conflict arises between reserve managers and academic researchers due to reserve mangers showing a general unwillingness to have actions dictated upon them (Prendergast et al. 1999).

Similarly, an overall scepticism is often observed from reserve mangers towards the validity of academic findings, arising from the common perception that academic theories are only of limited utility for planning exercises in the real world (Prendergast et al. 1999). Cowling et al. (2003) detected great contradictions between reserve planning methods based on scientific approaches and the prioritization of conservation areas by protected area managers, with the new reserves created by the latter excluding a large number of vulnerable and currently inadequately protected habitats, as identified by systematic reserve selection algorithms. However, Cowling et al. (2003) recommended, despite the apparent inefficiency of selected area choice by park managers, to consider their opinions and area prioritizations, in order to provide for reality-suited protected area plans that facilitate management effectiveness and at the same time increase the likelihood of the reserve network's persistence.

Likewise emphasized Prendergast et al. (1999) the necessity of supporting a closer dialogue between academic researchers and reserve managers, firstly as to integrate the needs and aspirations of the land managers into scientific protected area research, and secondly for rising the awareness of park managers in relation to the availability and efficiency of systematic reserve planning procedures. Another evident problem in many countries is the existence of a large variety of different statutory, voluntary and private reserve owners, between which generally only very little scientific cross-referencing occurs, making a nationwide adoption of a universal reserve acquisition policy extremely difficult (Prendergast et al. 1999).

Because of landscape development being dominated by socio-economic factors and trends, optimal reserve acquisition solutions often have to be compromised, and the conservation planner in many cases has to ‘mainstream’ with other sectors while also showing a great amount of flexibility (Pressey 1999). The need to compromise and to design protected areas in conditions being far from optimal is especially prevalent in developing countries where reserves are mostly found in isolated regions, located far-off from roads and areas with intensive land use, because of enforcement measures lacking efficiency in controlling the ongoing land exploitation by the poverty-stricken population, which also prevents the concept of off-reserve conservation from being a feasible option (Arango et al. 2003).

2.5. Conclusion

This chapter highlighted the generally inadequate state of protected areas worldwide which in most cases fail to conserve a representative sample of a region’s biodiversity values, and moreover are judged to be incapable of providing for the continuing persistence of functioning ecosystems because of being mainly designed on the basis of an *ad-hoc* approach, not evaluating the ability of the reserve system to meet conservation objectives in the long term. In recent years, important advances towards the development of systematic planning procedures have been made, and despite the existence of a variety of different planning approaches brought forward by numerous researchers, a general consensus exists about the benefits of including both gap analyses as well as species data in design considerations. Traditionally, areas for inclusion into reserve systems have been prioritized according to concerns in relation to rarity, risk, representativeness, and viability. Regardless of the evident scientific progress in protected area planning, there are still significant gaps between the theory and practice of reserve design that have to be overcome with a higher level of communication between academic researchers and land managers, which can potentially lead to more valuable scientific research results for the real world.

Colombia and the particular area of interest of this research project, the Valle del Cauca, present a valid example of a conservation scenario where the application of theoretically protected area approaches is greatly limited by the real world conservation framework, as more thoroughly discussed in the next chapter.

3. The Conservation Framework of the Valle del Cauca

3.1. Introduction

While the previous chapter reviewed recent international research findings concerning the long-term sustainable design of protected areas, providing optimal solutions to issues such as representativeness, viability and comprehensiveness, the aim of this chapter is to inform about the environmental, social and economic situation of Colombia in general, and of the Valle del Cauca, which has to be acknowledged in the development of a circumstances-specific study design. This chapter commences with an overview about the country's unique environmental characteristics, followed by a summary of demographic and poverty features. Environmental problems arising from the evident lack of efficient policies protecting the environment, unsustainable levels of environmental exploitation, and the large-scale occurrence of illegal activities that in turn are strongly influenced by Colombia's socio-economic circumstances, are discussed before the description of current and past governmental responses to the continuously increasing deterioration of environmental resources, notably in form of a national system of protected areas.

Having examined the country's overall characteristics, the chapter then narrows its focus on the study area, the Valle del Cauca, giving an account of the department's biodiversity features and considering the existing protected areas within the department, consisting of national parks and forest reserves, and their ability to contribute to the long-term protection of biodiversity. The final part of the chapter discusses the socio-economic and political factors particular to the department Valle del Cauca that have in the past lead to the destruction of forest resources, and at the same time are assumed to cause difficulties for the implementation of an innovative protected area network.

3.2. *General Country Profile*

3.2.1. Colombia's Location and Environmental Characteristics

Colombia is situated in the northern part of South America and, covering a total land area of 1,038,700 km^2, it presents the only South American country with coasts on both the Pacific and Caribbean (Dydynski 2003). Bordering Countries include Panama, Venezuela, Brazil, Peru and Ecuador (Figure 3.2-I). Colombia is distinguished by a highly diverse physical geography, consisting of flat coastal lowlands, central highlands, high Andean mountain ranges and eastern lowland plains. According to these significant dissimilarities in physical geography varies the country's climate considerably between regions (Dydynski 2003). The country's climatic zones range from extremely warm coastal lowlands to very cold mountainous areas, while the Caribbean coast is generally characterized as exhibiting a hot and dry climate, in contrast to the Pacific coast that is distinguished by extraordinary high levels of precipitation (Dydynski 2003).

Figure 3.2-I Colombia and Neighbouring Countries

Source: (CIA 2004)

Colombia's terrestrial surface is classified into six regions, each differentiated by distinct geographical features, including an Andean Region composed of three prominent mountain ranges that are commonly referred to as 'cordilleras' and the inter-Andean valleys Valle del Cauca and Valle del Magdalena, two littoral regions, the Caribbean and Pacific region, an area containing both the plains of the Orinoquian district and the Amazonian forests, and the Insular Region of Colombia (Instituto Alexander von Humboldt 2002). Although the country encloses an exceptional array of mountain peaks of greater than 5000 metres, in addition to the world's highest coastal mountain range, the Sierra Nevada de Santa Marta, the majority of Colombia's terrestrial surface consists of lowland plains with an altitude of less than 500 metres (Dydynski 2003) (Figure 3.2-II). Colombia is characterized as being comparatively highly forested, with approximately 46 percent of its land area being covered by forests (Instituto Alexander von Humboldt 2002).

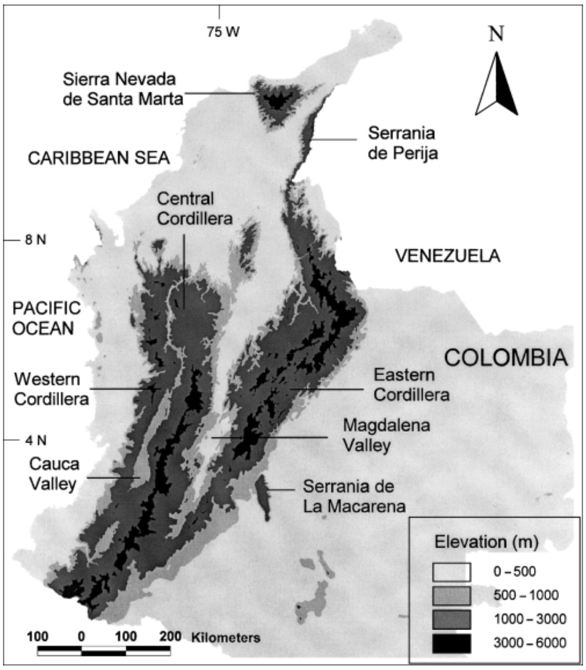

Figure 3.2-II Altitudinal Variations within Colombia

Source: (Kattan et al. 2004)

The majority of forests are located in Colombia's largely inaccessible south-eastern part where predominantly tropical Amazon rainforests are found, and in less significant magnitudes Andean and sub-Andean montane forests.

Besides, important remaining forest resources in form of humid lowland rainforests are situated in Colombia's northwest, extending from the western Andean mountain range to the Pacific coast in the west, and to the north into Panama (NDP 1996).

3.2.2. The Country's Demographics and Poverty Levels

Colombia presents the second most populous country in Latin America after Brazil, with an overall population density of 32 inhabitants per km^2 (Armenteras et al. 2002). Its population of 42.3 million (as of July 2003) is estimated to grow at an annual rate of 1.53 percent (NationMaster 2005). As it is the case in many developing countries, the migration from rural to urban areas has continued to rise over the past decades in Colombia, accelerated by the armed conflict that has had especially severe impacts on rural areas. As a result of this trend, the proportion of the country's total population residing in urban areas has increased from an estimated 57 percent to an estimated 74 percent between 1951 and 1994, while no current census is available (NationMaster 2005). In proximity to urban centres this trend has lead to serious environmental problems and, despite of population levels in many rural areas of the country having experienced stagnation or decline, these abandoned rural landscapes have lost a large part of their biodiversity values due to the prevalent increase of labour-intensive agriculture in rural areas (Etter and Wyngaarden 2000).

Colombia's problematic economic situation has further contributed to the country's rising population levels and environmental destruction. The country's economic condition considerably worsened in 1996 with the most serious economic crisis occurring since the 1930s, whereas up to this point Colombia had experienced relatively stable and sustained economic growth (World Bank 2002). An unsustainable increase in public spending during the latter half of the 1990s is thought to have initiated Colombia's economic downfall which lead to an extreme rise in unemployment levels (World Bank 2002). Accordingly has the amount of people living in poverty been increasing, with figures from 2001 giving evidence about a rise of up to 67 percent (percentage of the population living under the poverty line) from 60 percent in 1995 (World Bank 2002).

Moreover, inequality, the unfair distribution of financial capital between different social classes within the country, has considerably risen, with an approximate 20 percent of the population today being estimated to receive at least 34 percent of the country's total income. Rural poverty continues to be of significantly greater severity compared to urban poverty, and on overall contributes to a greater extent to Colombia's total poverty, important factors being the lack of education and access to the most basic social services, in addition to the wide-ranging unavailability of any employment opportunities (World Bank 2002).

3.2.3. Deforestation in Colombia

Colombia's deforestation rates are expected to be among the five highest in the world with an estimated minimum of 64 hectares of forests cleared annually (FAO 1999). Economic, political and social factors have been judged to bear the major responsibility for this dramatic forest loss, while government policies proved to act as facilitators. The nation-wide clearing of forests has in most cases been the result of sector policies in relation to development aspects such as infrastructure, agriculture, mining, energy, loans and colonisation, while management policies for the forest sector inadequately incorporated the conservation component. The destruction of forests in favour to agricultural use, combined with increasing colonisation rates, are responsible for the vast majority of forest loss within the country, as demonstrated in the list below outlining the most important factors leading to deforestation in Colombia.

Following are the major causes of deforestation in Colombia:

1. Expansion of agricultural frontiers and colonization (73%)
2. Timber production for industry and commerce (12%)
3. Wood consumption (11%)
4. Forest fires (2%)
5. Ilegal crops (2%)
6. Construction of infrastructure (e.g. roads)

7. Introduction of foreign species
8. Unsustainable use of flora and fauna

Source: (NDP 1996) and (Instituto Alexander von Humboldt 2002)

Despite the cultivation of illegal crops seemingly only having a marginal impact on deforestation rates (an estimated 2 percent), has illegal crop production in fact devastatingly affected Colombia’s remaining forests. Thousands of hectares of forests have been cleared for the cultivation of illegal crops such as cocaine, marihuana and poppy, with the Amazon and Andean ecosystems generally being considered as most seriously affected by illegal crop cultivation. It is commonly assumed that for the cultivation of one hectare of cocaine the destruction of two hectares of forest is necessary, while 2.5 hectares of forest are depleted for every hectare of opium cultivation (MARD 2002). An estimated 85 percent of poppy cultivation takes place in newly deforested lands on Andean slopes, and a large proportion of coca plantations are located in areas that have been cleared of montane forest (Alvarez 2002).

Although fumigation with herbicides for crop eradication has increased more than 80-fold since 1986, the total amount of illicit crop production within the country is believed to have multiplied 4.5 times according to recent figures, and in 2001 the total area of known illegal crop plantations had reached 140,000 hectares (Alvarez 2002). The growing number of farmers shifting from the production of legal crops to illegal crops represents a significant problem for the country’s agricultural scheme, and furthermore leads to severe ecosystem degradation, as well as accelerating biodiversity loss. Even though being the only tool of government control, one could argue that the fumigation of illicit plants amplifies the loss of biodiversity, as new areas of forest are cleared continuously and crop growers penetrate deeper into primary forests. Soils of abandoned poppy and coca plantations are characterized by an extremely low content of organic matter and by being severely deficient in nitrogen, phosphorous, and other nutrients, at the same time being highly acidic and aluminium toxic (Henkel 1995). Efficient government control and enforcement measures targeting illicit crop production often fail, due to the high degree of isolation of cultivated areas, and the armed conflict which is continuing within the country (Cavelier and Etter 1995).

Land use in Colombia is significantly affected by the armed conflict, as it frequently initiates the distress migration of local communities and environmental authorities from many regions, in addition to causing an overall decrease in frontier colonization rates (Alvarez 2002). Areas abandoned in the course of distress migration usually either regenerate into fallow or are consolidated into larger pasture areas by major regional landholders. A decline of overall agricultural productivity is generally the result of this ubiquitous trend, which moreover exerts increasing pressure on forest resources protected in Colombia's existing reserve system (Alvarez 2002). Just how severely the armed conflicts impacts on the country's remaining forest resources is highlighted by figures that give evidence about 33 percent of Colombia's total forest cover being situated within municipalities characterized by medium to high armed group activity, and about 20 percent of forest resources located within municipalities that are occupied by both belligerent leftist guerrillas and right-wing paramilitary groups (Alvarez 2002) .

3.2.4. Environmental Initiatives

Despite Colombia being a signatory member of the Convention on Biological Diversity (CBD), therefore formally obligating itself to the conservation of biological diversity and the development of sustainable use programs, does the government seemingly fail to give sufficient priority to environmental issues, as for the country's significant socio-economic problems and the existence of the armed conflict which the government is currently attempting to counteract with intense military campaigns. Another apparent obstacle complicating the development and implementation of strategic conservation actions is the comparatively high level of responsibility-sharing between different parties involved in the process of environmental planning and managing, and the frequently evident communication failures between those parties. An often noticeable unwillingness of different research institutions to cooperate and to participate in information-sharing, thereby facilitating the efficient conduction of various studies contributing to advances in the management of remaining biological resources, constitutes a major problem in Colombia.

In addition are protected areas mainly managed independently, even though a national system of protected areas was officially created in 1997 (Arango et al. 2003), making the systematic continued monitoring of combined biodiversity values difficult. Examples are arising difficulties when it is attempted to establish the conservation status of species which sub-populations are found in a variety of different parks, or the prioritization of conservation areas according to their floral or faunal characteristics, while it is unknown if those biodiversity features have been previously included in existing reserves.

Colombia's protected areas are currently composed of 51 national parks that are managed by the Special Administration Unit of National Natural Parks, a sub-section of the Ministry of Environment (Martinez 2005) (Figure 3.2-III). The amount of private nature reserves, concentrated mainly in the country's Andean region and privately owned and managed, has also grown over recent years (Dydynski 2003). Today there are more than 150 private reserves registered of which more than half are seriously impacted upon by insurgent groups (Dydynski 2003). A large proportion of national parks are also critically impacted upon by guerrilla activity, in addition of being affected by human settlement, logging, and ranching and poaching activities, due to high poverty levels in rural areas and insufficient availability of funding and skilled personnel to adequately guard the parks (Dydynski 2003).

According to figure 3.2-III which illustrates the existing protected areas in Colombia as of 2000, is the protection of natural ecosystems in the country strongly biased towards humid ecosystems, of which almost all are to some extent represented in the national system of protected areas (Arango et al. 2003). The national gap analysis, conducted in 2003, depicted severe conservation shortcomings, especially in the Caribbean and Pacific regions, principally in relation to dry ecosystems. Dry ecosystems were also found to be underrepresented within the Andean reserve system, representing the least protected ecosystems of the region. Additionally, the plains of the Orinoco basin showed serious conservation deficiencies having less than half of the occurring ecosystems located in protected areas. The Amazon region, in contrast, is distinguished by a more equitable representation of regional ecosystems; however, the few ecosystems that fail to be included in the reserve system are, consistent with the observations from other regions, mainly dry or hill top ecosystems (Arango et al. 2003).

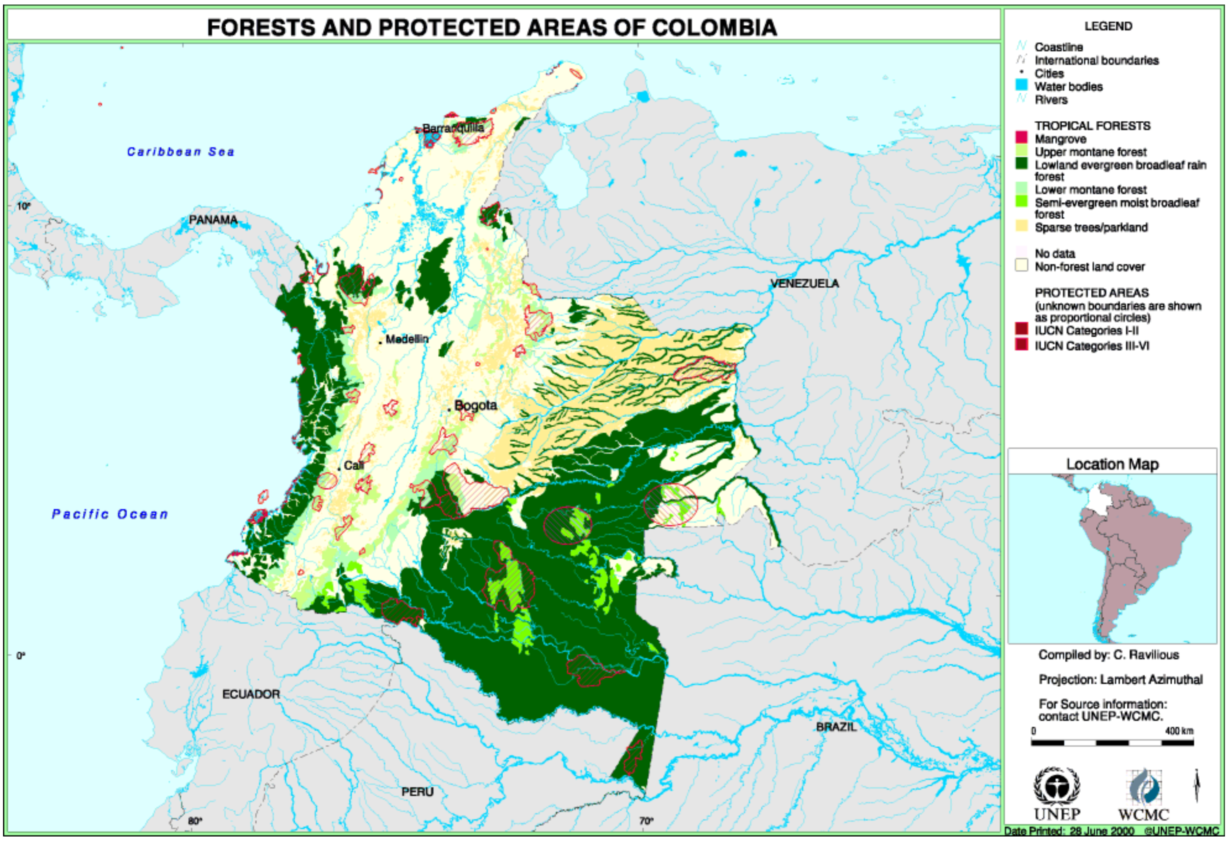

Figure 3.2-III Colombia and its Protected Area Network in 2000

Source: (UNEP World Conservation Monitoring Centre 2005)

Not only the obvious bias towards humid ecosystems causes the at present clearly perceptible conservation shortcomings, but inadequate locations and sizes of current protected areas make the long-term protection of the majority of Colombian ecosystems further unlikely. This argument is supported by figures stating that only about one third of Colombia's natural ecosystems are presented with at least ten percent of their total cover extent within protected areas, while the majority of the ecosystems with an adequate representation are located within the country's Amazon region. The overall results from the 2003 Gap analysis, depicting the representation of ecosystems in Colombia's national reserve system, are illustrated in Figure 3.2-IV. As discussed in section 2.31.of the previous chapter, the results of gap analyses often prove to be error prone and have in most cases to be considered with caution.

This study had it most serious limitations in that, as it was essentially based on the interpretation of satellite images, differentiations between degraded and well conserved ecosystems within existing protected areas were often difficult to undertake, and the representation of relatively intact ecosystems might actually be even lower than it is currently estimated.

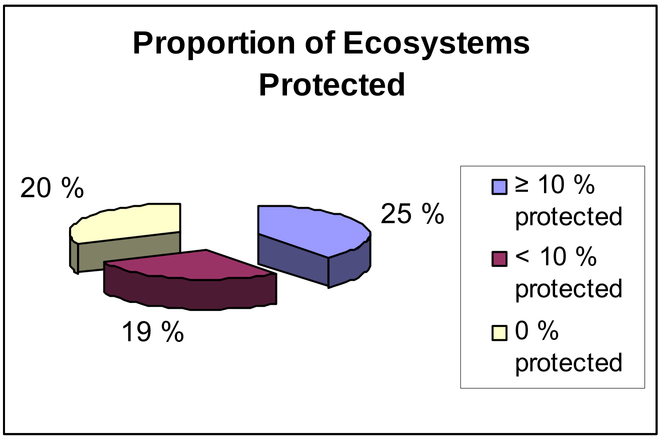

Figure 3.2-IV Representation of Ecosystems in Reserve Network

(Data Source: Arango et al. 2003)

Conservation strategies based on different scales usually lead to different conservation priorities, and the national government recognized in recent years that regional conservation initiatives might have the potential to enable the implementation of more effective conservation actions than feasible through protected area management on the national scale. One important current trend in reserve design is therefore the awarding of responsibility to regional administrative bodies, the regional autonomic organizations in Colombia. The Corporación Autónoma Regional del Valle de Cauca (CVC) is one of the first regional administrative bodies that is currently in the process of developing conservation priorities with the external input of scientific research.

3.3. *Description of the Valle del Cauca and its Conservation Status*

3.3.1. Physical Characteristics of the Valle del Cauca

The department Valle del Cauca, consisting of 42 different municipalities with Cali being the departmental capital, covers an approximate area of 20.629,3 km^2, equalling 1.9 percent of Colombia's total land area, and differentiates itself by containing both an apparent Andean and Pacific component (Figure 3.3-I). An extensive variety of natural environments are observed within the department, ranging from Pacific rain forests to high-altitude Andean mountain peaks.

Figure 3.3-I Location of the Valle del Cauca

Source: (Academica de Ciencias Luventicus 2005)

Significant deviations in relation to climatic conditions are found within the Valle del Cauca, consisting of extremely high precipitation levels throughout the year and an average temperature of 24 C on the Pacific Coast, two distinct short rainy seasons of moderate intensity and an average temperature of 28 C being recorded for the inland lowlands, and two longer rainy seasons of high intensity documented for the mountainous areas, while the coldest temperature zones composed of páramo ecosystems display the highest precipitation levels that continue to decline steadily with a decrease in altitude (Armenteras et al. 2002).

The susceptibility of gap analyses to alterations in scale is demonstrated by the greatly differing results obtained from studies with varying spatial detail (scales of 1:1,500.000 and 1:100.000 respectively). While the existence of a total of 20 ecosystems, of which 12 were classified as being essential in their natural intact state, and eight as having experienced large-scale transformation, was detected when measuring on the coarse-scale level, a sum of 61 ecosystems, including 48 relatively intact and 13 considerably transformed ecosystems, was obtained from the fine-scale evaluation (Armenteras et al. 2002). In contrast to the coarse-scale study of 1998, where 66 percent of the total extent of original ecosystem cover appeared to have been transformed (Etter 1998), the outcome of 53.3 percent attained from the more detailed assessment gave evidence about a slightly smaller proportion of ecosystems having been impacted by intense anthropogenic intervention.

As seen in many worldwide examples, the degree of ecosystem transformation in different parts of the department Valle del Cauca largely depends on variables such as relief, climate and accessibility. The majority of remaining intact forest cover is currently located in the Pacific region of the Valle del Cauca (74 %); while the cover extent of Andean forests is considerably lower (26 %). Humid sub-Andean forests constitute the main remaining ecosystem type with a total estimated cover extent of 160 hectares, followed by high-Andean and cloud forests that occupy an approximate 140 hectares, humid Andean forests approximately covering 122 hectares, and high-density Pacific forests that constitute an estimated land area of 109 hectares (Armenteras et al. 2002). The more detailed study derived to the same major conclusions but further subdivided the major ecosystems.

As a result of the wide variations in environmental conditions, the Valle del Cauca is described as containing an exceptional proportion of biodiversity within its departmental boundaries. In effect, the Valle del Cauca is recognized as one of the most biodiverse departments in the country and distinguishes itself on a global scale by outstanding species richness. According to the presently available data following species numbers have been registered:

818 bird species	(44 % of Colombia's bird species)
150 mammal species	(40 % of Colombia's mammal species)
160 reptile species	(34 % of Colombia's reptile species)
146 amphibian species	(30 % of Colombia's amphibian species)
161 freshwater fish species	(20 % of Colombia's freshwater fish species)

Source: (Corporación Regional Autónoma del Valle del Cauca 2005)

Considering that a substantial proportion of departmental regions yet has to be surveyed, notably a major part of the Pacific region that only recently was declared to be under the regional jurisdiction of the Valle del Cauca, and areas difficult to access dispersed over the entire department, it is expected that these figures significantly underestimate the true biodiversity values of this part of Colombia. A high level of endemism, evident throughout the entire extent of the department, but concentrated within several zones, further stresses the high conservation value of the area. The majority of thus far established zones of high endemism or 'national conservation hotspots' are located within lowland Pacific areas and are primarily distinguished by providing habitat to a large number of endemic bird species (Corporacion Regional Autonoma del Valle del Cauca 2005). However, as for the lack of appropriate field studies, it is assumed that a considerably greater number of zones with high endemism levels exist in other parts of the study area. Although plant diversity within the Valle del Cauca yet has to be thoroughly studied, a high presence of Colombia's most threatened plant families including *Orchidaceae*, *Ericaceae*, *Acanthaceae* and *Bromeliaceae* has been documented from the region, as well as the occurrence of many endemic subspecies of these families (Corporación Regional Autónoma del Valle del Cauca 2005).

3.3.2. The existing Network of Protected Areas in the Valle del Cauca

Three national parks are currently found in the study area with the park ‘Los Farallones de Cali’ being the most important one, as 99.8 percent of its entire land area of 206128 hectares is enclosed by the departmental borders of the Valle del Cauca. Encompassing a reasonable share of altitudinal and climatic ranges it is assumed that this park provides habitat to more than 600 bird species and a number of mammal species (Armenteras et al. 2002). However, the park’s effectiveness in protecting biodiversity within its borders is considerably diminished by the continuing presence of guerrillas within the park and coherent illegal activities.

The second largest protected area in the region is the park ‘Las Hermosas’, of which 43.8 percent of its total extent is located within the Valle del Cauca, covering an area of 44409 hectares. Being situated in the Central Cordillera, this park contains high altitude forests at elevations varying from 1.600 to 4.000 metres. The national park ‘Tatama’, with altitudes from 2000 to 4200 metres, is spread over three departments and merely 7.5 percent or 4703 hectares of its total area is located within the study area. Due to the park being extremely difficult to access, its fauna species attributes have been poorly studied, but it is nonetheless assumed that at least 85 species of amphibians and reptiles occur in the park, including 20 formerly unknown species, in addition to various mammal species (Armenteras et al. 2002).

Besides the three national parks are also forest reserves found in the study area, of which two of them have an approximate size of 8000 hectares and mainly include humid lowland ecosystems, while the remaining two are of very small size (821 hectares and 451 hectares respectively), protecting lake systems and lowland forests (Armenteras et al. 2002). Figure 3.3-II provides an overview about the currently existing network of protected areas in the Valle del Cauca. Although the present network of protected areas encloses an area equivalent of more than ten percent of the department’s total land surface, the gap analysis from 2003 demonstrated serious conservation shortcomings (Table 3.3-I).

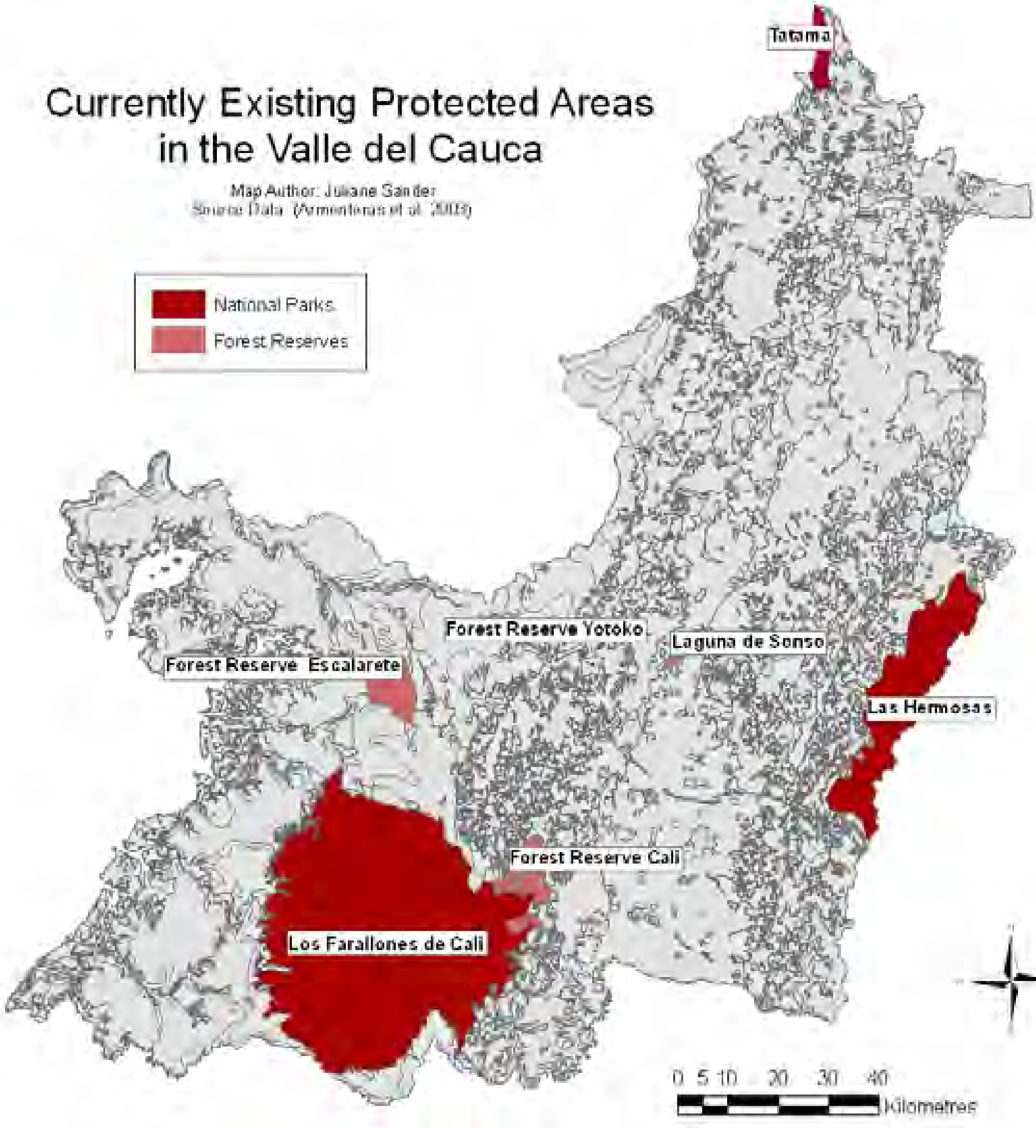

Figure 3.3-II National Parks and Forest Reserves in the Valle del Cauca

One obviously noticeable factor (Figure 3.3-II) is the concentration of protected area land use in the vicinity of the departmental capital Cali, due to the protected area with the evidently largest size, the national park ‘Los Farallones de Cali‘, in addition to one forest reserve, having been established in this region of the department. Taking into account the significantly high levels of ecosystem variation, biodiversity and endemism, the concentration of reserves within certain regions of the Valle del Cauca appears to be an inadequate approach towards conservation.

Ecosystem	Total Area of Ecosystem in Study Area (ha)	Area of Ecosystem protected in Study Area (ha)	Proportion of Ecosystem protected (%)
Humid Sub-Andean Forests	64899.1	11045.4	17.0
Medium-Density Humid Andean Forests	32542.9	3580.9	11.0
Medium-Density Andean Forests and High-Andean Oak Forests	11611.3	5044.2	43.4
Open High-Andean Humid Forests and Cloud Forests	228659.4	35593.1	17.3
Dry Forests and secondary xerotific Sub-Andean thicket	175611.4	0	0

Table 3.3-I Extent and Conservation Status of Forest Ecosystems of the Valle del Cauca

Source: (Arango et al. 2003)

Moreover, the fact that a considerably long period of time has passed since the most recent declaration of a protected area, the national park Tatama, in 1987, of which only a marginal fraction is contained within the department, while the largest national park 'Los Farallones de Cali' was created in 1968 and the two larger forest reserves 'Escalerete' and 'Cali' in 1983 and 1938 respectively (Armenteras et al. 2002), indicates the high probability of the existing protected areas having been principally established in the absence of any information in regards to biodiversity attributes of specific regions within the department, which is stressed by the fact that to date a large proportion of the department essentially remains unstudied.

Conservation failures of the current reserve network, detected in the nation-wide gap analysis from 2003 (Arango et al. 2003), documented in Table 3.3-I, reflect the biased representation of forest ecosystems of the Valle del Cauca, utilizing a coarse scale (1:1,500.000) for the analysis. According to more detailed evaluation of ecosystems (1:100.000) that was conducted by Armenteras et al. (2002) and gave evidence about a total of 61 different ecosystems in the Valle del Cauca, 31 of these 61 ecosystems fail to be adequately represented within the protected areas of the department.

On overall, the most striking observation obtained from both coarse and fine-scale gap analyses is the severe under-representation of dry forest ecosystems within the Valle del Cauca's reserve system, considered to be an extremely significant conservation deficiency because of many of these ecosystems failing to be protected to any extent throughout their occurrence range, which besides from the Valle del Cauca includes the Valle del Magdalena and the Caribbean Coast.

3.4. Factors complicating the successful Implementation of Conservation Strategies within the Valle de Cauca

The national importance of the Valle del Cauca as one of the country's centres for agricultural production, especially in relation to the production of sugarcane, coffee, rice and tobacco along with cattle farming, lets the concept of conservation in the region appear to be of only secondary importance. Exploitation of the environment in favour to agricultural activities proves to be particularly severe in the Valle del Cauca in comparison to other regions in Colombia, because of the existence of large-scale agricultural projects, notably regarding the production of coffee and sugarcane (Armenteras et al. 2002). Being one of the nation's leading departments in relation to agricultural productivity, the further expansion of agricultural areas into departmental areas currently distinguished by an essentially intact vegetation cover presents an immediate threat, especially for the Pacific regions where currently the vast majority of remaining forest cover is found, and species richness as well as species endemism is exceptionally high.

The continuing expansion of the road network within the Valle del Cauca, which is characterized as one of the nation's departments with the most thoroughly developed infrastructure, facilitates the access to today isolated areas and increases the probability of these areas to be affected by human settlement and agricultural exploitation. In addition to the threats of environmental destruction due to a rising level of agricultural activity, the department also experiences the consequences of Colombia's armed conflict.

In fact, the Valle del Cauca is presently of one the most seriously impacted regions by the conflict, suffering from a sizeable guerrilla force present in the department and ongoing fighting between the national army, guerrillas and paramilitaries (Martinez 2005). Violent roadblocks, often ending in kidnappings for ransom, are a daily reality within the department and incidences of killings and massacres targeting the civilian population have become more frequent within various municipalities of the Valle del Cauca. Besides the frequent occurrence of government-enforced disappropriation of small farmers in the course of large agricultural projects leading to the displacement of the rural population, a high proportion of cases of displacement arise due to the armed conflict and guerrillas intimidating small landholders.

While part of the department's rural population is fleeing the land, seeking refuge in urban centres, experiences the Valle del Cauca a continuing influx of immigrants from southern departments, located in closer proximity to the Ecuadorian border, that are impacted upon by an even higher level of violence (Martinez 2005). As a result of this immigration triggered by the displacement of the rural population in other departments, the growing accessibility of remote areas due to the continuing expansion of the department's road network, and emergent opportunities for agricultural exploitation, the Valle del Cauca today is distinguished as one of the departments with the highest level of population density in Colombia. Compared to the country's overall population density which averages 32 inhabitants per square kilometre, with a steadily rising population density of 181 inhabitants per square kilometre, while approximately 30 percent of the department's total population is confined to rural areas, the Valle del Cauca is typified as being densely populated (Armenteras et al. 2002).

Moreover, the department is differentiated by a high level of inequity, observed between its various municipalities. In contrast to the municipalities located within the industrialized zone of the Valle del Cauca, notably those in vicinity of the departmental capital Cali, where the standard of living is generally described as being comparatively high, the majority of the department's municipalities suffer from inadequate living conditions and the standard of living within the rural municipalities of the Pacific Coast is assumed to be one of the lowest in the whole of Colombia.

3.5 Conclusion

The Valle del Cauca is one of Colombia's most biodiverse regions and at the same time experiences many of the country's inherent problems, notably a high population growth, deforestation in favour to agricultural and industrial activities, and the armed conflict. Because of these significant and immediate threats to the remaining forests of the department and the inadequate representation of ecosystems, in particular dry ecosystems, within the existing reserve network, the design and implementation of additional protected areas is of urgent necessity. However, as for the only very limited knowledge about the biodiversity and endemism features of parts of the department, including the majority of the Pacific region, the development of new protected areas that cater for the requirements of a variety of species, therefore assuring their continuing existence, appears to be complicated. In order to effectively fulfil both tasks of alleviating currently occurring conservation gaps and meeting species requirements it is assumed that in addition to considering the necessity of including single ecosystems according to their unique biodiversity values and vulnerability, modelling of species' distributional ranges is required for prioritizing conservation areas, as addressed in the following chapter that provides a detailed outline of the study methodology.

4. Detailed Description of Methodological Approach

4.1. Introduction

The scope of investigations in this study, alike many other research studies conducted in developing countries, was considerably limited by the scarce availability of relevant data sets, while at the same time it has to be acknowledged that the quantity and quality of obtainable data was comparably high in the Valle del Cauca compared to the majority of national departments. Despite attempts to incorporate recommendations brought forward by international research into the study methodology, due to the particular data characteristics the possibilities proved to be limited.

This chapter essentially consists of three distinct section with the first describing utilized methods to assess the cover extent of remaining ecosystem types in the Valle del Cauca and their respective representativeness in existing protected areas, the second informing about employed GIS and PATN techniques to examine documented bird and mammal species occurrences in addition to modelling the probable distributional range of selected species, whereas the methodical approach regarding the creation of candidate sites, according to the observations attained from the preceding investigations, is dealt with in the final section of the chapter.

4.2. Assessment of Area Coverage and Protection Status of Ecosystems

For the examination of cover extents of the various ecosystem types, a relatively detailed map (scale: 1:100.000) of the study area was produced utilizing data provided from the Instituto Alexander von Humboldt (Armenteras et al. 2002). The projected coordinate system 'South America – Albers - Equal Area Conic' with the South American Datum 1969 was chosen for the entire range of GIS operations, since this projection allowed for the calculation of area sizes. As the data the ecosystem analysis is based upon originates from fairly recent remote sensing analyses, one underlying assumption of this study was that the cover extent of ecosystems remained essentially unchanged. Due to the limited amount of information, several ecosystem aspects which investigation could have lead to an increased accurateness and efficiency of the study failed to be evaluated. One of these aspects was the unfeasibility to identify the maturity state of a particular ecosystem type. Because of the recent acceleration of deforestation processes in the study areas it was generally presumed that remaining forest fragments to a large part were composed of mature primary forests and that from deforestation regenerating areas were covered by grass regrowth.

Another obvious constraint was the unavailability of plant species data which inhibited the incorporation of measures to conserve plant species of elevated conservation concern into considerations regarding the design of candidate sites as well as restricting the precision of bird and mammal species modelling.

The analysis of ecosystem cover extents, drawing attention on the ecosystem types with the proportionally largest area coverage in the study area, and also pointing out those that are today only represented with very small forest fragments, is followed by a clipping of the ecosystem layer with the layer illustrating the location of existing protected areas, while the information for the latter was likewise provided by the Instituto Alexander von Humboldt, as to calculate the proportions of particular ecosystem types protected. In addition, areas within the study region thought to be vulnerable to transformation processes in the near future, depending on their specific locations and analyses of past deforestation patterns were identified.

4.3. Analysis of Species Distributions

4.3.1. Mapping of documented Species Occurrences

Due to a deficiency of past exhaustive species surveys, only limited investigations could be performed making use of scarce and largely aged species data. Lists of bird and mammal occurrences were supplied by the Instituto Alexander von Humboldt that had compiled data sheets drawing on museum records and reports in the literature. The amount of documented bird occurrences clearly exceeded the sum of available mammal records and, due to the high availability of the former, solely bird species distinguished by a ‘Vulnerable’, ‘Endangered’ or ‘Critically Endangered’ status were included in the mapping exercises. The majority of available bird records were considerably outdated with sampling events dating back up to 50 years.

Despite of the aged nature of the majority of records, this data was nonetheless utilized, firstly due to the non-existence of more adequate data, and secondly since pilot mapping of occurrence events demonstrated that sampling events were mostly clustered in areas differentiated by seemingly intact vegetative cover. Moreover, it was assumed that extraordinary levels of biodiversity in particular regions of the department possibly provided an indication of current centres of biodiversity, even if composed of different species assemblages.

In contrast to the bird data, only mammal records documented from 1995 onwards were utilized for mapping purposes, since it was expected that the distribution of mammal fauna had undergone more pronounced changes, as pilot mapping exercises illustrated the centre of mammal abundance coinciding with the most heavily deforested areas of the department. Due to the sparse amount of accessible mammal data, species of all conservation statuses were incorporated into the study. In addition to the creation of maps illustrating the documented occurrences of bird and mammal species, information in regards to species' common names and conservation status was acquired. For bird species, owing to the existence of the 'Red Book of Colombian Birds' (Renjifo et al. 2002), the conservation status of species could be assessed country-specific, whereas for mammal species the IUCN status, evaluated on a global perspective, had to be adopted.
Furthermore, species' total abundances were examined and maps showing the distributions of critically endangered bird species and mammal species of elevated conservation concern were produced.

Not only the age of the data proved to be problematic for analyses assisting the prioritization of supplementary protected areas, but also other factors diminished its relevance, including the fact that the data mainly consisted of museum records which indicated the employment of biased rather than random sampling, with sampling being concentrated in those regions of the department where the probability of species' existence was perceived to be particularly high, in order to increase the easiness of specimens acquirement. According to Boshoff et al. (2001), sampling for museum records fails to provide for an accurate reflection of biodiversity values within a region since it only records the presence of individuals, falling short of distinguishing between the actual presence and absence of species in particular areas, as facilitated by random surveys. This spatial bias in sampling created negative uncertainties, areas where species could potentially occur but no sampling was conducted, as mentioned by Pressey (2004).

Another difficulty occurred with the apparent inaccuracy of many documented GPS measurements that became noticeable through large assemblages of individuals of the same or different species at single map coordinates.

Due to the high incidence of animal concentrations at single map coordinates, the number of bird and mammal species per coordinate is depicted in additional maps. A further limitation of the data was that it only contained records about bird and mammal species and excluded other animal taxa. However, it is believed that the protection of bird and mammal habitats potentially leads to the conservation of other taxa, especially through the protection of the latter, as for the high metabolic requirements of mammals.

4.3.2. Statistical Analyses of Species Assemblage Resemblance between Ecosystems

In order to investigate the level of similarity in relation to the assemblage composition of bird and mammal species among the different ecosystem types, a spatial join between the ecosystem and species layers was performed in GIS. Firstly, a comparison of values relating to species diversity and abundance of individuals was carried out to document differences in alpha diversity among ecosystems. This was followed by multivariate analyses in PATN to examine the relationships between ecosystem types based on species composition. Prior to the analyses both bird and mammal data was log-transformed. A Bray Curtis test for dissimilarity was used by constructing an association matrix that classified ecosystem types into groups by hierarchical agglomerative clustering and mapped the interrelationships into an ordination.

In addition to illustrating the degree of resemblance in assemblage composition between ecosystem types in the 3-dimensional space of the ordination, dendograms were produced to facilitate the interpretation of results. Because of the number of ecosystems with recorded bird occurrences being considerably greater than that obtained from the spatial join of the mammal and ecosystem layers, only the group centroids are depicted in the ordination explaining dissimilarities in bird assemblage composition, whereas due to the smaller number of ecosystems containing mammal records it was possible to create a minimum spanning tree demonstrating pair-wise associations between ecosystems.

Principal Axis Correlation (PPC) techniques as well as the Kruskal-Wallis one-way ANOVA on ranks were employed to examine relationships between species occurrences and ecosystem types and to determine which species exerted a high influence on the nature of the ordination. Furthermore, the level of assemblage affinity between selected species was investigated for both birds and mammals in dendograms developed through Bray Curtis tests.

4.3.3. Species Modelling

Because of the only limited significance of the species data due to its age and the obvious bias in sampling, it was necessary to additionally model the likely range of occurrence of selected species which was hoped to facilitate the protection of viable metapopulations. Only those species were considered for distributional modelling of which a reasonable amount of sampling events had been recorded and which were characterized as typically occurring in the study area, with the study area being described as constituting an important part of their habitat range. Furthermore, preference was given to species endemic to the region and, in regards to mammal species, those species distinguished by an elevated conservation concern.

For the modelling process the habitat requirements of the selected species were investigated as well as the ecosystem characteristics of the sampling locations taken into account, in order to make assumptions about the likely occurrence of metapopulations and the movement of species between forest fragments. To assist the design of distributional scenarios the literature was consulted for evidence about a species potentially occurring within an ecosystem type. In relation to bird species the necessary information could be simply inferred from the 'Red Book of Colombian Birds' (Renjifo et al. 2002), while the acquirement of details concerning the selected mammal species proved to be of considerably greater difficulty and a variety of online resources had to be utilized. It is important to note that for the modelling exercises only ecosystem types were considered which had been recognized to represent core habitat resources for the selected species, not including habitat types where species had been recorded seldom and in very low densities.

Moreover, two umbrella species were chosen from the selected set of bird species as well as two from the prioritized mammal species, while those species that had been documented relatively frequently and at the same time were characterized as being particularly susceptible to human interference and fragmentation was given preference. Maps demonstrating likely distributional scenarios were produced for every selected bird and mammal species. These single maps were then subsequently intersected in GIS operations to establish where modelled species distributions overlapped, which in turn assisted the identification of probable hotspots of bird and mammal biodiversity. An evident difficulty for the modelling process was the sole availability of information on respective ecosystem types and the inaccessibility of information including data on plants and abiotic or biotic factors which would have improved the efficiency of distributional modelling according to environmental surrogates. However, as for the relatively detailed ecosystem map, the results are judged to be substantially relevant for the reserve designation procedure.

4.4. Design of Candidate Sites

New layers containing prospective candidate sites were created according to visually assessing centres of overlap of previously produced species and ecosystem layers, outlining areas of conservation priority. Polygons of different sizes were drawn, with one layer being composed of larger candidate sites and the second layer enclosing smaller sites, frequently consisting of sub-divided larger candidate sites. Candidate sites were designed without providing for edge buffers and, in particular in regards to the smaller sites, correspond to the minimum size necessary for their future viability. The capability of single polygons to comply with previously assigned conservation priorities was distinguished by attributing a score value to every candidate site. This was followed by intersecting the new layers of candidate sites with the ecosystem layer in GIS and transferring the results of this operation to PATN. In addition to examining the ecosystem content of single candidate sites, Bray Curtis tests for dissimilarity were performed for both larger and smaller prospective protected areas, allowing for the construction of dendograms illustrating the degree of resemblance both among candidate sites and between candidate sites and existing protected areas.

Prioritized candidate sites were those that showed very low resemblance to current protected sites through minimal recurrence of already sufficiently protected ecosystems, and at the same time were differentiated by comparatively high score values. Moreover, the proportion of candidate sites consisting of assumingly intact vegetation cover was calculated as to favour the sites mainly containing intact ecosystem types. Generally, except for cases where smaller selection units more efficiently protected presently under-protected ecosystem types, larger candidate sites were initially prioritized before the provision of alternatives in form of similarly composed smaller sites.

4.5. Conclusion

Due to the vague and aged species data, the significance of species distribution data was limited. Probably the largest setback was the reliance on museum records obtained through biased sampling techniques which failed to provide adequate information about actually occurring biodiversity within the department. The availability of mammal data was especially poor with sampling events clustered in agricultural areas and in proximity to Cali. One diminutive advantageous characteristic of the species data was that it was composed of records assembled over numerous years, consequently not only giving a snapshot of species diversity affected by factors such as seasonality. A more pronounced benefit was the accessibility to relatively detailed ecosystem data that facilitated the differentiation between sufficiently protected and currently in the reserve system underrepresented ecosystems, therefore assisting the adequate prioritization of candidate sites, as well as supporting the modelling of species distributions. The results obtained from this formulated methodological approach are depicted in the following chapter.

5. Presentation and Discussion of Findings

5.1. Introduction

This chapter features the findings obtained from the variety of analyses performed with the utilization of GIS and PATN techniques. Firstly, the results from the examination of the study area's ecosystems including their respective cover extents are presented, followed by an illustration of the ecosystems that are currently protected within the Valle del Cauca. Afterwards, in two separate sections, the locations of bird and mammal sampling events are demonstrated in various maps, before dendograms and ordinations identify the degree of species assemblage resemblance between the various ecosystems. The characteristics of bird and mammal species selected for the purpose of distributional modelling are further explained in tables, and the level of overlap between the modelled distributions of the various species is depicted in maps. In the last section of this chapter, the actual task of designing new areas of reserve acquisition is illustrated, by the inclusion of two maps of differently sized candidate areas and a discussion of their respective characteristics. Lastly, the ecosystem features of the apparently most adequate sites are described, and a schedule in relation to the urgency of their acquirement is presented.

5.2. Analysis of Ecosystems of the Valle del Cauca

The ecosystem map, created utilizing data supplied from the Instituto Alexander von Humboldt, is illustrated in Figure 5.2-I. A total of 60 different ecosystem types were identified, consisting of 47 original cover forest ecosystems, one ecosystem type referred to as 'lakes and lagoons', and 13 transformed ecosystems with the majority being agro-ecosystems that at the same time represented the ecosystem types with the greatest proportional cover extents in the Valle del Cauca. The natural and transformed ecosystem types and their cover extents as of 2002 are listed within Table 1 of Appendix A while the fifteen ecosystems with the largest land coverage are presented in Table 5.2-I.

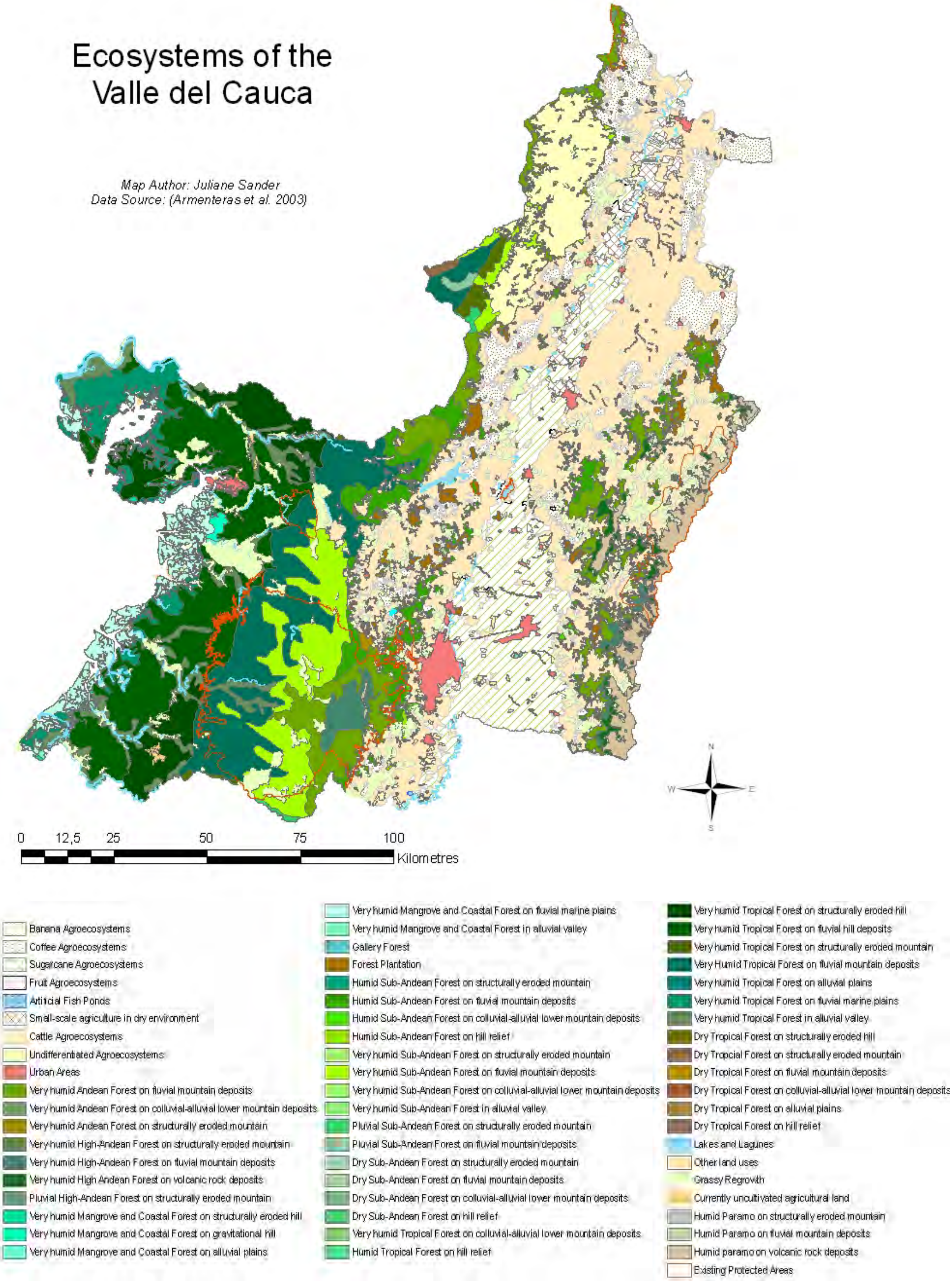

Figure 5.2-I Ecosystems of the Valle del Cauca

Ecosystem Type	Cover extent (ha)
Cattle Agro-Ecosystems	495508.85
Sugarcane Agro-Ecosystems	202112.30
Very humid Tropical Forest on fluvial hill deposits	162921.03
Very humid Tropical forest on fluvial mountain deposits	145527.87
Very humid Andean Forest on fluvial mountain deposits	118897.97
Grassy Regrowth	114999.39
Coffee Agro-Ecosystems	102398.61
Very humid Sub-Andean Forest on fluvial mountain deposits	95971.18
Undifferentiated Agro-Ecosystems	90547.97
Humid Sub - Andean Forest on fluvial mountain deposits	71860.68
Very humid Tropical Forest on structurally eroded hill	70990.70
Very humid Tropical Forest on fluvial marine plains	52345.87
Very humid Tropical Forest in alluvial Valley	49220.14
Very humid Mangrove and Coastal Forest on fluvial marine plains	4790.96
Humid Páramo on volcanic rock deposits	42596.36
Small Dry Agro-Ecosystems	30131.94

Table 5.2-I Ecosystems with the proportionally largest Cover Extent as of 2002

According to Table 5.2-I, the remaining natural ecosystems with the largest area coverage are very humid forest types on fluvial deposits. Both Table 5.2-I and Figure 5.2-I clearly exemplify the prevalence of tropical pacific forests in relation to comparative intact ecosystem cover types, while forest fragmentation, as in Colombia in general, has severely affected the Andean region. In this region of the department only small fragments of original vegetation cover remain. The ecosystem types occurring within the Valle del Cauca, of which the remaining cover extent has been reduced to less than 150 hectares, are listed within Table 5.2-II. The cut-off value of 150 hectares was chosen to highlight the very smallest ecosystem types that consequently are assumed to be exposed to an especially high risk of disappearance in the near future.

Ecosystem Type	Total Area (ha)
Very humid Sub-Andean Forest in alluvial valley	147.69
Dry Tropical Forest on structurally eroded hill	123.06
Humid Tropical Forest on colluvial-alluvial lower mountain deposits	117.69
Very humid Andean Forest on colluvial-alluvial lower mountain deposits	114.51
Dry Tropical Forest on alluvial plains	88.47
Dry Tropical Forest on hill relief	61.71
Humid Páramo on structurally eroded mountain	49.55
Dry Sub-Andean Forest on hill relief	39.34
Very humid Sub-Andean Forest on structurally eroded mountain	33.13
Humid Tropical Forest on hill relief	30.38

Table 5.2-II Ecosystems with the proportionally smallest Cover Extent as of 2002

As demonstrated in Table 5.2-II, among the ecosystems with the smallest land areas are four dry forest ecosystems, one páramo ecosystem, two humid forest ecosystems and three very humid ecosystems, with all these ecosystems being found within higher altitudinal ranges. Figure 5.2-II illustrates the extreme size reduction of the in Table 5.2-II included ecosystems. It is important to note that none of these small fragments are included in the currently existing network of protected areas and that therefore all these ecosystems should be considered for inclusion into the new network of protected areas.

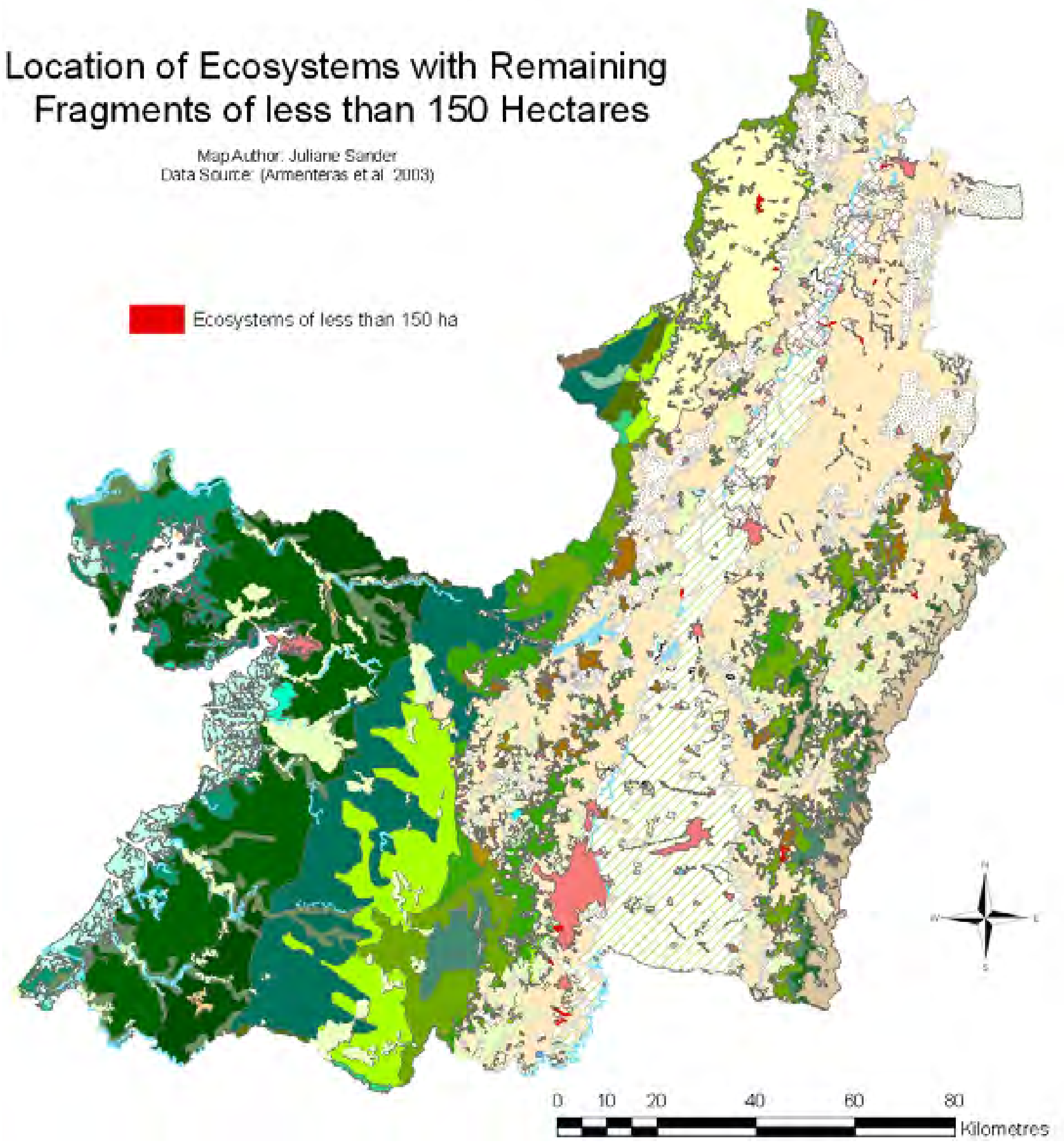

Figure 5.2-II Ecosystems with Fragments of less than 150 hectares

On this fine analysis scale, the ecosystem types with the highest level of representation within protected areas are 'Humid Páramo on volcanic rock deposits', 'Very humid High-Andean Forest on fluvial mountain deposits', 'Pluvial High-Andean Forest on structurally eroded mountain' and 'Humid Páramo on fluvial mountain deposits', having more than 50 percent of their total cover extent protected (Table 5.2-III). An additional important characteristic of the current reserve system is its proportionally large coverage of transformed ecosystems, especially cattle agro-ecosystems and areas that are presently in the process of rehabilitation and distinguished by grass cover. The GIS analysis arrived at slightly different results compared to the study by Armenteras (2002) as for the utilization of different data layers, however likewise proposing a very biased ecosystem representation.

Ecosystem Type	**Total Area (ha)**	**Area Protected (ha)**	**Proportion of Ecosystem protected (%)**
Humid Páramo on volcanic rock deposits	42596.36	35908.76	84.30
Very humid High-Andean Forest on fluvial mountain deposits	21038.87	16703.88	79.40
Very humid Tropical forest on fluvial mountain deposits	145527.87	101459.52	69.7
Pluvial High-Andean Forest on structurally eroded mountain	702.76	418.98	59.62
Humid Páramo on fluvial mountain deposits	3351.45	1992.47	59.45
Very humid Sub-Andean Forest on fluvial mountain deposits	95971.18	51294.01	53.4
Pluvial Sub-Andean Forest on structurally eroded mountain	3018.14	1295.33	42.92
Very humid High-Andean forest on structurally eroded mountain	615.94	199.85	32.45
Humid Sub - Andean Forest on fluvial mountain deposits	71860.68	23268.91	32.38
Very humid High-Andean Forest on volcanic rock deposits	18469.58	5217.93	28.25
Very humid Tropical Forest in alluvial valley	49220.14	11570.93	23.51
Dry Sub-Andean Forest on fluvial mountain deposits	5142.06	220.12	4.28
Very humid Andean Forest on fluvial mountain deposits	118897.97	5069.56	4.26
Lakes and Lagoons	14843.75	421.60	2.84
Very humid Tropical Forest on fluvial hill deposits	162921.03	4485.76	2.75
Very humid Tropical Forest on structurally eroded hill	70990.70	153.72	2.17
Forest Plantations	21353.10	794.9	0.37

Table 5.2-III Type and Cover Extent of Ecosystems protected

A total of 11 ecosystems were found to be represented with more than ten percent of their total cover extent in the existing protected areas. Consequently, these ecosystems will be given a reduced amount of priority in the development of the new reserve network. According to the present representation of ecosystems within protected areas, their specific location in the department and their remaining cover extent, Figure 5.2-III was produced that, solely in respect to gap and vulnerability analyses, provides a preliminary index about areas that should be considered for reserve acquisition.

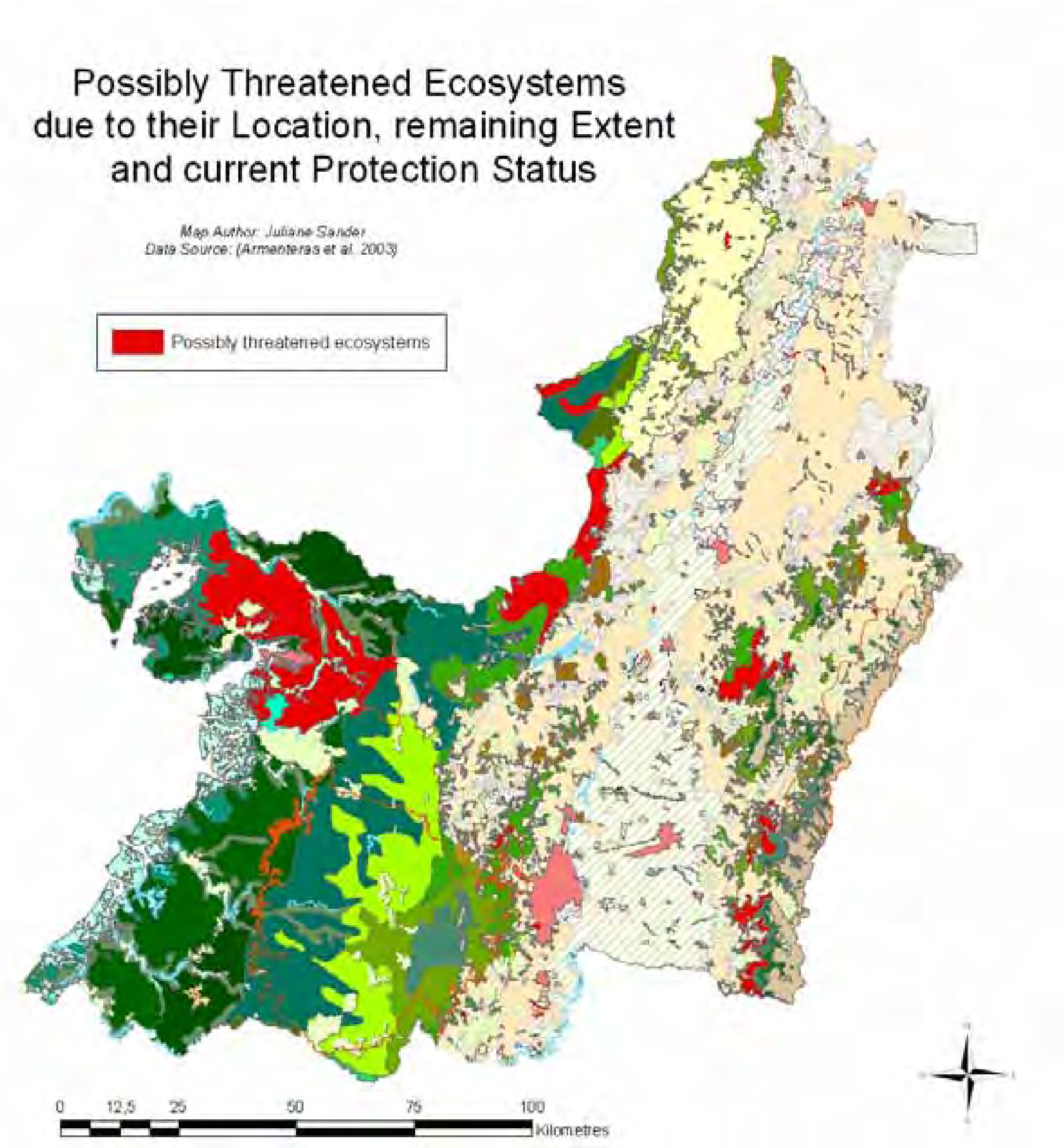

Figure 5.2-III Vulnerable Ecosystems

The so-called priority areas shown in the map are composed of ecosystems that are currently insufficiently protected or fail to be protected altogether, are either situated in close proximity to urban or agricultural development centres, or are distinguished by an extremely low remaining total cover extent. Similarly were areas with altitude levels exceeding 3000 metres excluded from the classification to priority areas, due to a study on the transformation of Colombian ecosystems, conducted by Etter and Wyngaarden (2000), implying that transformation rates were significantly reduced for ecosystems at altitudes higher than 3000 metres. The classification of tropical forest in the Pacific zone as priority area might come as a surprise considering the up to date relatively intact state of Pacific forests, however, the forest was judged to be likely to be transformed in the future as of its close proximity to the growing population centre and most important national port Buenaventura.

Both the examination of existing ecosystems and their respective sizes, detecting a high number of ecosystems which area coverage had been reduced to an insignificant amount of small fragments dispersed throughout the Andean region of the department, as well as the extremely biased representation of ecosystems within the present network of protected areas, indicated that prioritization of new sites for reserve acquisition according to the gap analysis methodology is associated with considerable difficulties. The task to represent all of the 36 ecosystems which vegetative cover has been characterized as being largely in its original state, and of that 32 currently fail to be to any extent protected, while of the remaining four less than five percent of their total area coverage is located within the reserve network, is assumed as being essentially impossible to realize, since this would require a vast number of very small-sized single reserves dispersed throughout the department with emphasis on the highly fragmented Andean region. Such a network put into practice, irrespective of the fact that its implementation seems to be exceedingly unlikely due to administrative and practical difficulties, is expected to be incapable of supporting the preservation of species diversity, as the existence of small protected areas surrounded by agricultural use will eventually lead to the reduction of genetic diversity through inbreeding, population reductions, and possibly extinction events. Not only isolation of protected areas appears to be problematic, but also the failure of small reserves to meet the habitat range requirements of species.

Consequently, as this fine-scale gap analysis appears to assist the protected area prioritization process only to limited degree, the analysis of bird and mammal species distributions, as well as the modelling of species' populations, will be given increased importance in deciding what larger fragments ought to have given especially high conservation priority.

5.3. Assessment of Species' Distributions

5.3.1. Bird Species – General Data Characteristics

A total of 56 bird species or 2319 individual animals of 'Vulnerable', 'Near Threatened', 'Endangered', or 'Critically Endangered' conservation status were recorded in the study area. Of these 56 species, 16 were included as 'Near Threatened', 22 as 'Vulnerable', 12 as 'Endangered' and six as 'Critically Endangered' in Colombia's red list of birds. A full list of sampled bird species, specifying their common name, conservation status in Colombia, and sampling abundance can be found in Appendix A (Table 2). The mean number of individuals per bird species was 41. Sampling abundances varied significantly, with 17 species or almost 31 percent of the total occurring species having been recorded only once or twice in the study area, while a further 12 bird species, approximating 21 percent of total verified species diversity, had been documented less than ten times.

The low sampling frequency of the majority of species had been expected, as solely species of conservation concern were included in this analysis. As of their considerable small numbers and although because information on the exact dates of sampling was unavailable, therefore making it difficult to assume their continuing presence in the Valle de Cauca, these species with exceptionally low sampling frequencies will not be considered for distribution modelling. Some other species, in contrast, were recorded with proportionally large abundances and dominated the overall sampling results.

The species with the undoubtedly greatest abundance was the Multicoloured Tanager *Chlorochrysa nitidissima* (626 individuals), followed by the Cinnamon Teal *Anas cyanoptera* (319 individuals), the Cauca Guan *Penelope perspicax* (238 individuals), and the Southern Pochard *Netta erythrophthalma* (173 individuals). The fact that *Netta erythrophthalma*, a bird species of critically endangered status, was found in comparatively large abundances in the Valle del Cauca highlights the importance of the Valle del Cauca as a national conservation region for birds. All bird species sampling events are illustrated within Figure 5.3.1-I.

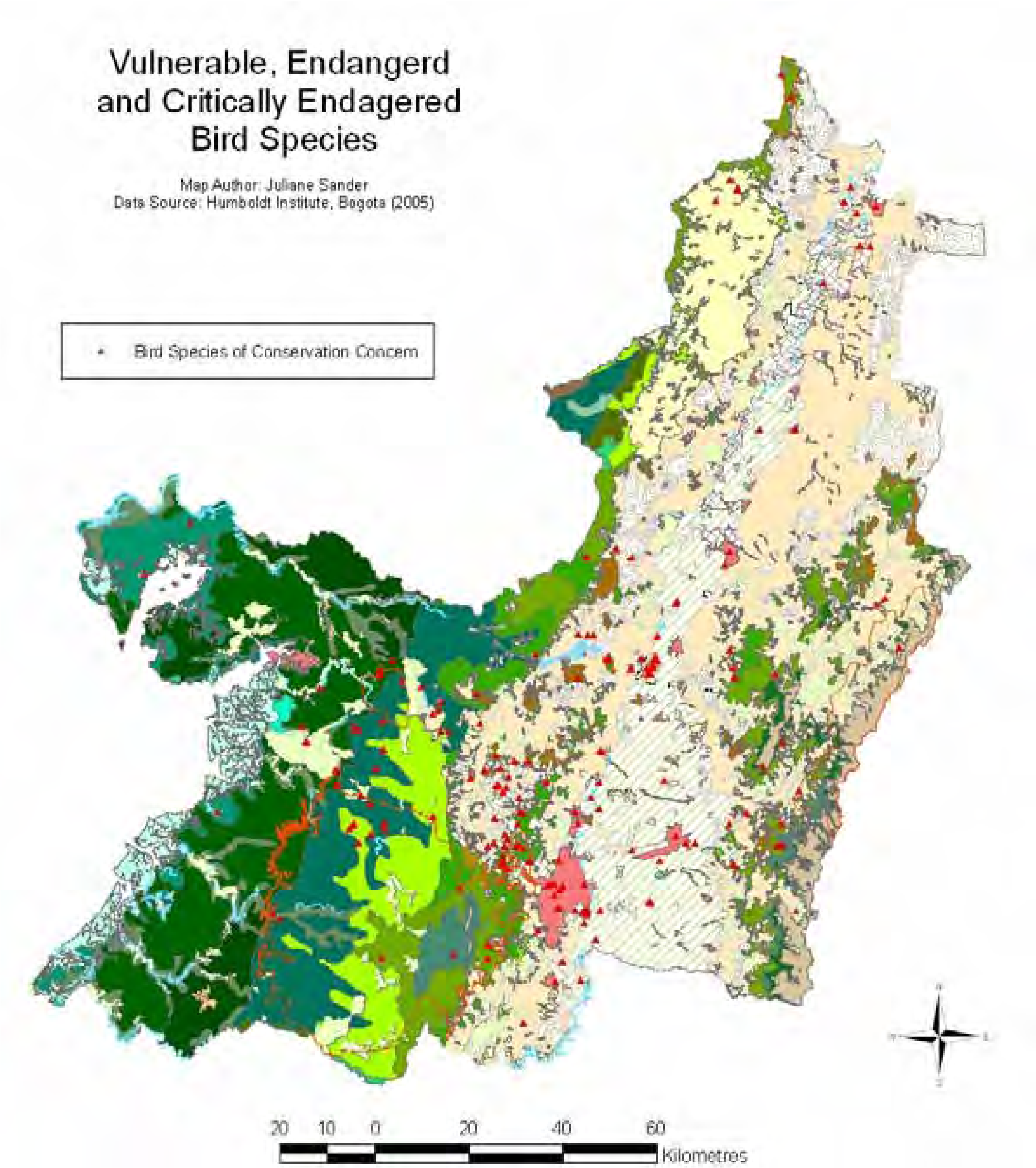

Figure 5.3-I Bird Sampling Events

The map shows an accumulation of bird records in the Andean region and in the vicinity of Cali, with the remaining majority of data records originating from sub-Andean and tropical regions that are situated in close proximity to the other population centre of the department, the port Buenaventura. Scattered species records were however available from almost all regions of the department while, in relation to remaining natural forest ecosystems, only a minor amount of bird records were obtained from the tropical forest regions stretching towards the Ecuadorian border and to the west of Buenaventura. In addition, data records were significantly sparse from the coastal region.

An examination of data values detected the clustering of sampling events on certain map coordinates. One single mapping coordinate was distinguished by a value as high as 87 individual birds, all from the species *Penelope perspicax*. In contrast to this extreme high value which represented an exception, the occurrence of up to ten individuals on one map coordinate was considerably more common. Not only clusters of single species were found, but assemblages of differing bird species were observed frequently. Examples of individuals of different species frequently recorded communally were groups consisting of the Yellow-winged Sparrow *Ammodramus savannarum* and the Cinnamon Teal *Anas cyanopteras*, groups of the Multicoloured Tanager *Chlorochrysa nitidissima* and the Turquoise Dacnis-Tanager *Dacnis hartlaubi*, as well as groups composed of the Grey-Breasted Mountain Toucan *Andigena hypoglauca* and the Golden-plumed Parakeet *Leptosittaca branicki*. Obviously this observation of individuals being recorded on the same map coordinates has to be considered with caution, especially in the more extreme events with values of more than fifty individual animals on one singly coordinate, as it is highly likely that this clustering could be attributed, at least to some part, to a certain sampling inaccuracy. Sampling events indicating assemblage fidelity between individuals of the same species or individuals of different species are demonstrated in Figure 5.3-II that informs about the approximate number of species on every recorded coordinate.

Two of the six bird species that have been classified as being of critically endangered conservation status only occurred with one or two specimens within the data set.

These species were the Tumaco Seedeater *Sporophila insulate* and the Yellow-eared Parrot *Ognorhynchus icterotis*. The White-chested Swift *Cypseloides lemosi*, another critically endangered bird, was recorded with ten individuals clustered on one map coordinate, making the drawing of further conclusions on the overall habitat range of the species therefore also difficult. One reason for the low sampling frequency of this bird probably were the only very limited available records from tropical regions, as *Cypseloides lemosi* is largely restricted to humid tropical forests at altitudes from 400 metres to 1400 metres.

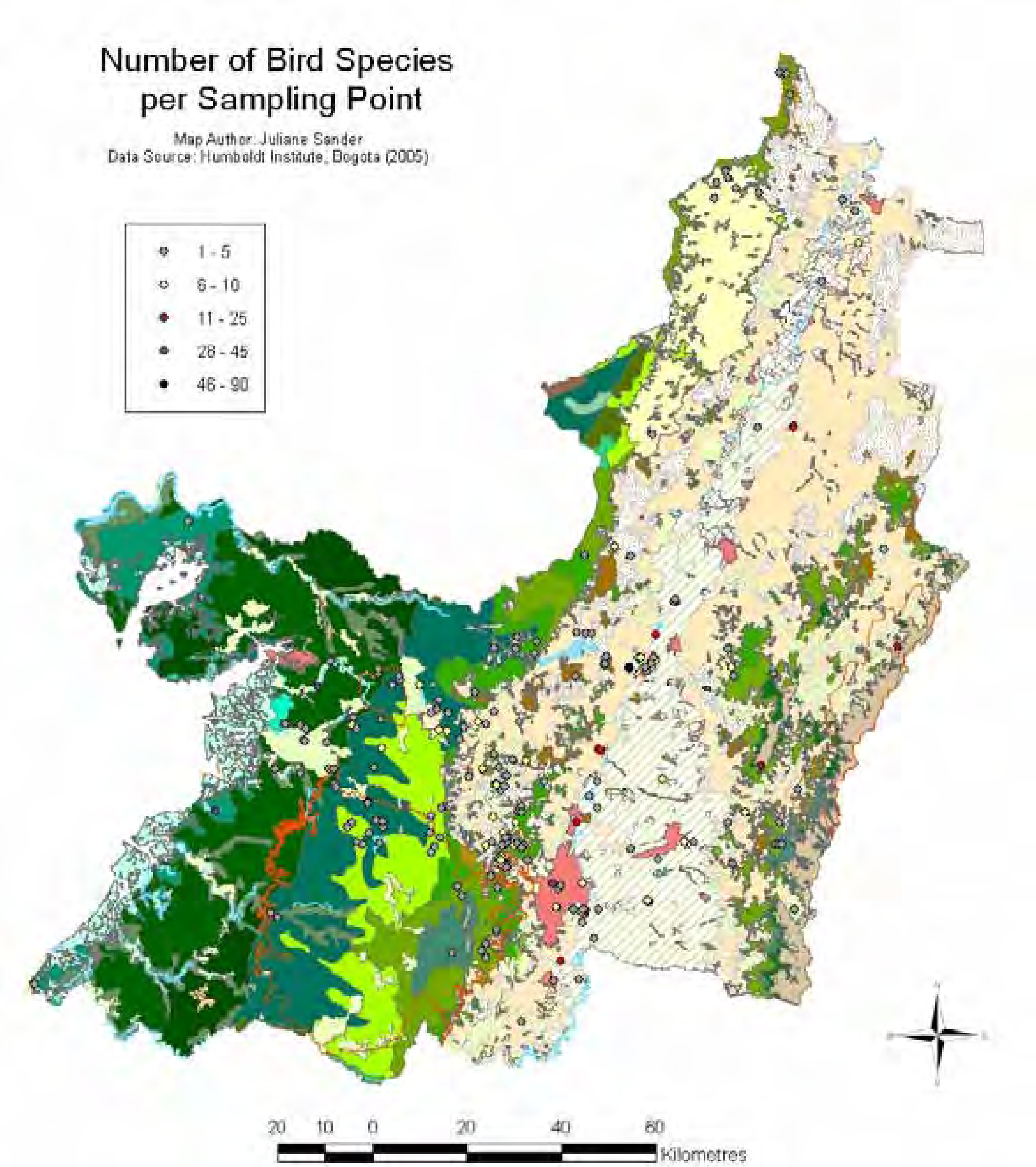

Figure 5.3-II Number of recorded Birds Events per Sampling Location

The Tanager Finch *Oreothraupis arremonops*, having lost at least 60 percent of its original habitat range, and distinguished by a current distribution that is restricted to only very few locations east of the Andes, including the Valle del Cauca, with altitudes ranging from 1200 metres to 2600 metres, was found with 20 individuals at 16 different map coordinates.

In contrast to those critically endangered species with only limited presence within the data set were the remaining two of the same conservation status characterized by a proportionally frequent occurrence, considering the overall mean number of individuals of all bird species, their very limited remaining habitat ranges in Colombia, and the low and fragmented distribution of residual populations of these species. The distribution of the Yellow-winged Sparrow *Ammodramus savannarum caucae*, a subspecies of *Ammodramus savannarum*, is known as being almost entirely confined to the Valle del Cauca, with only small documented habitat locations overlapping with adjacent departments to the north and south of the Valle del Cauca. No records of this species have been obtained in the recent future and its continuing existence could not be verified. However, complying with the precautionary principle this species was included in statistical analyses. Of substantial importance for conservation areas considerations were the relatively numerous records of the Southern Pochard *Netta erythrophthalma* that, although not endemic to Colombia, is of extremely critical conservation status as its population is assumed to only consist of 2500 individuals scattered throughout South America. The sampling events of these six critically endangered bird species are illustrated in Figure 5.3-III.

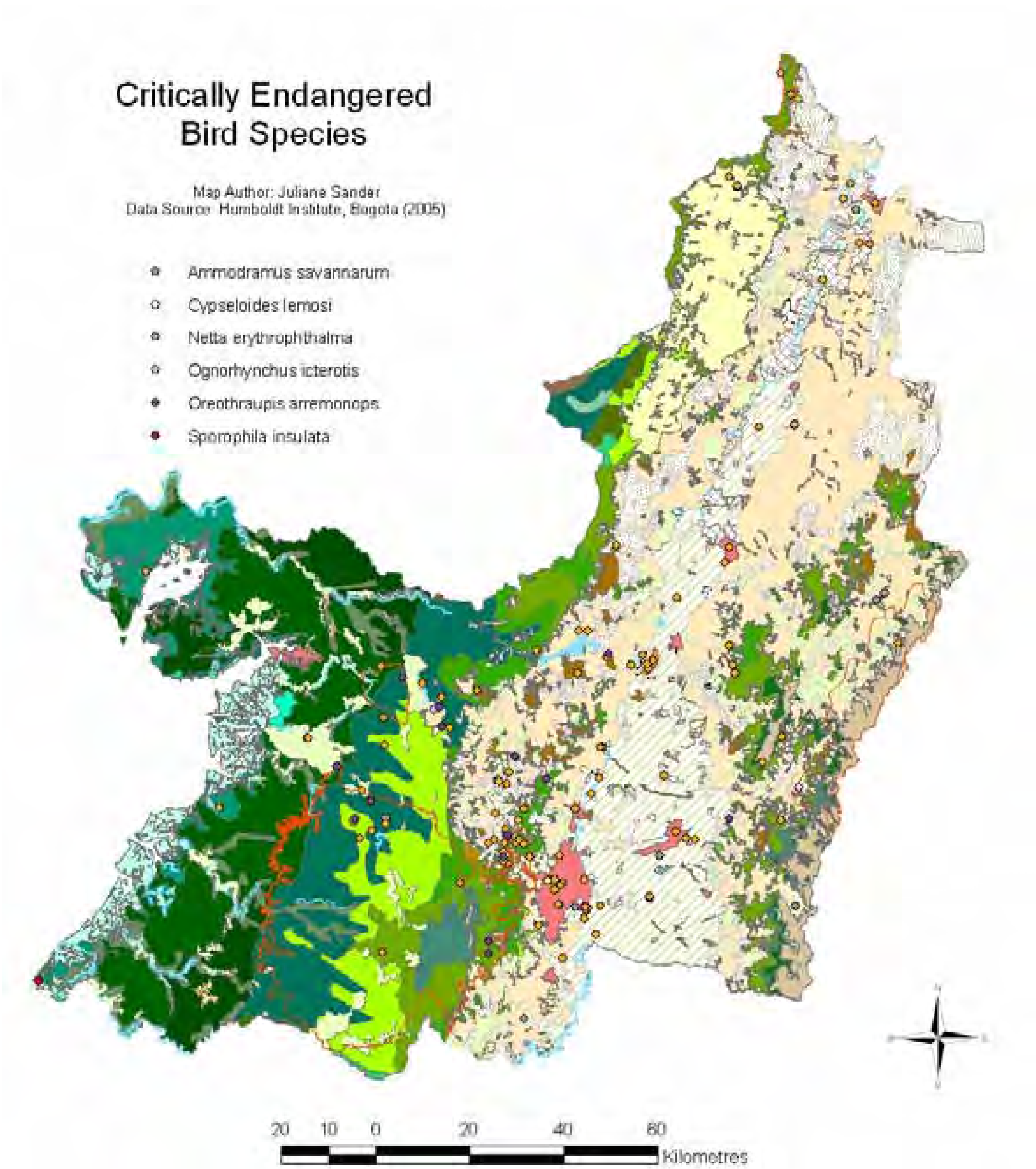

Figure 5.3-III Sampling Locations of Critically Endangered Bird Species

5.3.2. Bird Species Diversity in Ecosystems

After joining the bird distribution layer with the ecosystem layer the ecosystems containing the highest number of bird species could be identified. The results of this spatial join are presented in Table 5.3-I.

Ecosystem Type	Number of Species	Number of Individuals
Humid Sub - Andean Forest on fluvial mountain deposits	32	427
Sugarcane Agro-Ecosystems	21	305
Cattle Agro-Ecosystems	33	304
Urban Areas	25	285
Very humid Tropical Forest on fluvial mountain deposits	29	161
Undifferentiated Agro-Ecosystems	15	86
Lakes and Lagoons	16	86
Grassy Regrowth	19	76
Very humid Tropical Forest on fluvial hill deposits	19	72
Coffee Agro-Ecosystems	18	69
Very humid Andean Forest on fluvial mountain deposits	19	64
Very humid Sub - Andean Forest on fluvial mountain deposits	20	61
Dry Sub - Andean Forest on fluvial mountain deposits	19	57
Other land uses	14	49
Small Dry Agro-Ecosystems	11	44
Very humid Tropical Forest on fluvial marine plains	10	38
Humid Páramo on volcanic rock deposits	10	28
Very humid High - Andean Forest on fluvial mountain deposits	10	22
Very humid Tropical Forest in alluvial valley	9	22
Very humid High - Andean Forest on volcanic rock deposits	8	18
Forest Plantations	11	18
Dry Tropical Forest on fluvial mountain deposits	6	10
Fruit Agro-Ecosystems	6	8
Pluvial High - Andean Forest on structurally eroded mountain	7	8
Dry Sub-Andean Forest on colluvial - alluvial lower mountain deposits	7	8
Very humid Mangrove and Coastal Forest on fluvial marine plains	1	1

Table 5.3-I Number of Species and Abundances of Bird Individuals in Ecosystems

The table specifies the concentration of bird diversity in the ecosystem type characterized as ‘Humid Sub-Andean Forest on fluvial mountain deposits’, while sugarcane and cattle agro-ecosystems also demonstrated great levels of bird diversity, followed by the tropical ecosystem type ‘Very humid Tropical Forest on fluvial mountain deposits’. This table and the subsequent analyses using PATN have nonetheless to be regarded with caution, as for the considerable amount of bias evident in the data due to the nature of sampling that was concentrated in the Andean region. An example is the extremely low value of solely one species for the ecosystem type ‘Very humid Mangrove and Coastal Forest on fluvial marine plains’, which is supposed to be largely the result of a low sampling effort in this region.

Conspicuous, however, was the proportional large bird diversity in ecosystem types such as ‘Very humid Sub-Andean Forest on fluvial mountain deposits’ and ‘Dry Sub-Andean Forest on fluvial mountain deposits’ that, despite of only containing a fraction of the number of bird individuals of the ecosystems listed in the top rows of the table, were characterized by a remarkable species diversity. The Bray and Curtis Association measure of the statistic package PATN that was utilized with the agglomerative hierarchical fusion classification strategy incorporating the flexible UPGMA technique and a beta-value set at -0.1, including all ecosystems except ‘Very humid Tropical Forest on fluvial mountain deposits’, resulted in an ordination stress value of 0.1465 which was judged to be acceptable in regards to the highly differing species diversity characteristics between ecosystems. The dendogram, picturing the relationship between ecosystems clustered into five different groups according to the nature of bird species assemblages, is included as Figure 5.3-IV.

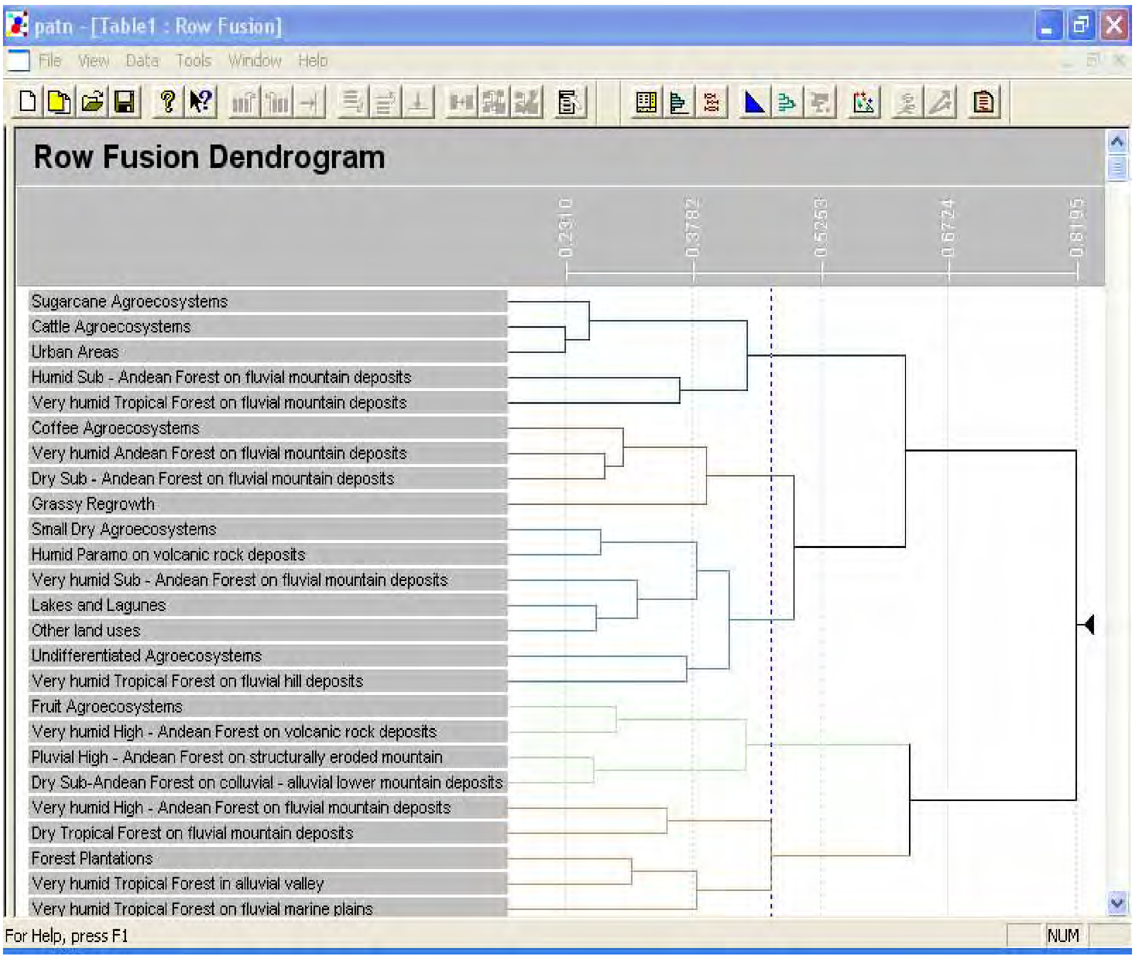

Figure 5.3-IV Dendogram of Relationships between Ecosystems in regards to Bird Biodiversity

‘Cattle Agro-Ecosystems’ and ‘Urban Areas’, which were then fused with ‘Sugarcane Agro-Ecosystems’, demonstrated the greatest similarity in relation to bird species assemblages of all ecosystem interrelationships. Group 1 was composed of the transformed and natural ecosystem types distinguished by containing the largest amount of individual birds, possibly due to the fact that large assemblages of overall abundant bird species were located in all of these ecosystems. However, the assemblage composition of other ecosystems with a relative large number of bird species appeared to significantly differ, with ‘Undifferentiated Agro-Ecosystems’, ‘Lakes and Lagoons’ and ‘Very humid Tropical Forest on fluvial hill deposits’ (Group 3) seemingly having a very different species composition compared to ‘Grassy Regrowth’, ‘Coffee Agro-Ecosystems’ and ‘Dry Sub-Andean Forest on fluvial mountain deposits’ (Group 2), while ‘Very humid Andean Forest on fluvial mountain deposits’ (Group 4) was illustrated as comprising the most differing species assemblage. Group 4 and Group 5 were generally characterized by the most unique species compositions, though only containing a small number of individuals. The conservation of the ecosystem type ‘Very humid Tropical Forest on fluvial marine plains’ (Group 5) appears to be important, as it is characterized by the most unique species assemblage.

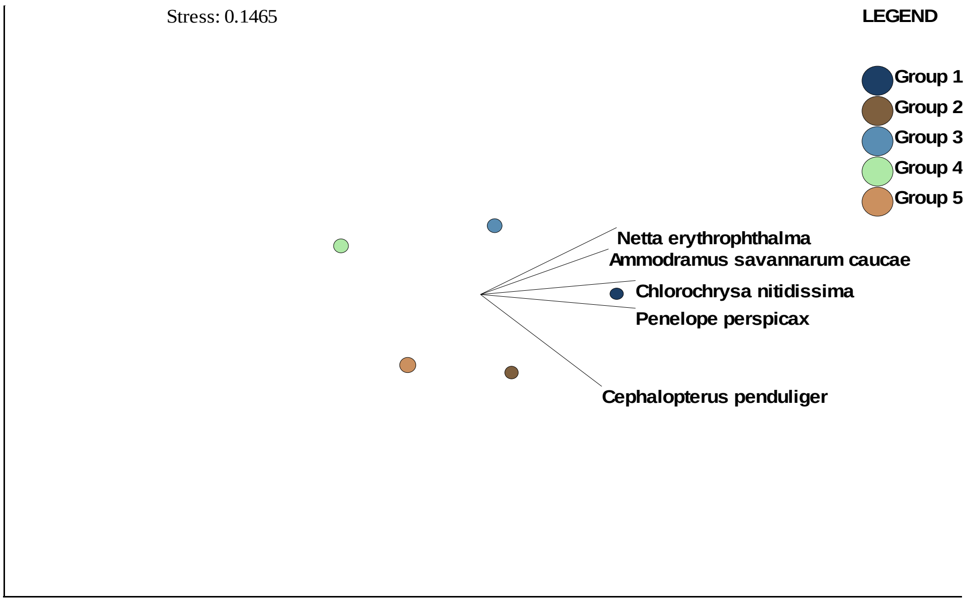

Figure 5.3-V Ordination with Group Centroids

Figure 5.3-V shows the distribution of group centroids in the ordination space, highlighting the distinctiveness of Group 4 and Group 5, and at the same time demonstrating that the species with the most significant correlation vectors were those with an overall large level of occurrence, with the exception of *Cephalopterus penduliger* of which only 60 specimens had been recorded in total, and that those species had a strong association with Groups 1 and 2. Both correlation vectors and Kruskal – Wallis test values were in contrast low for species associated with Groups 4 and 5. Generally, a factor diminishing the relevance of the association matrix appeared to have been the great difference in the magnitude of species data between different ecosystems, despite of the log-transformation, which is highlighted by the observation of almost all ecosystems with low bird numbers being members of Group 4 or group 5. Figure 5.3-VI presents an ordination incorporating exclusively untransformed ecosystems. The significant correlation vectors showed a slightly less pronounced bias towards Groups 1 and 2. Worth noting is also the increase in significant correlation vectors after the exclusion of transformed ecosystems with the addition of the Cinnamon Teal *Anas cyanopotera* and the Black-and-chestnut Eagle *Oroaetus isidori*.

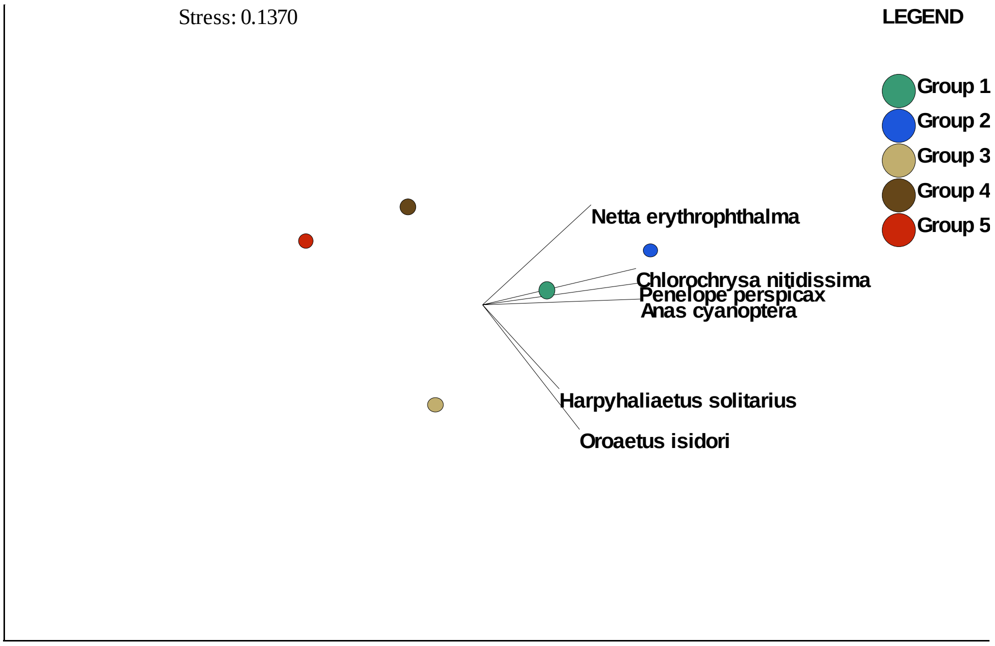

Figure 5.3-VI Ordination including only untransformed Ecosystems

Only species that were sampled with more than 20 individuals were included into the column-based analysis that investigated the assemblage affinity between different species (Figure 5.3-VII). The dendogram highlighted the close association between species sampled with the highest number of individuals, simultaneously being most significant correlation vectors in the ordination and related with Groups 1 and 2. These species formed the first and largest group of the dendogram. The second group, composed of three species of which two are included in the second ordination above, showed a considerably greater resemblance to Group 1 than the other three groups, while the last group was solely composed of the Toucan Barbet *Semnornis ramphastinus cacae.*

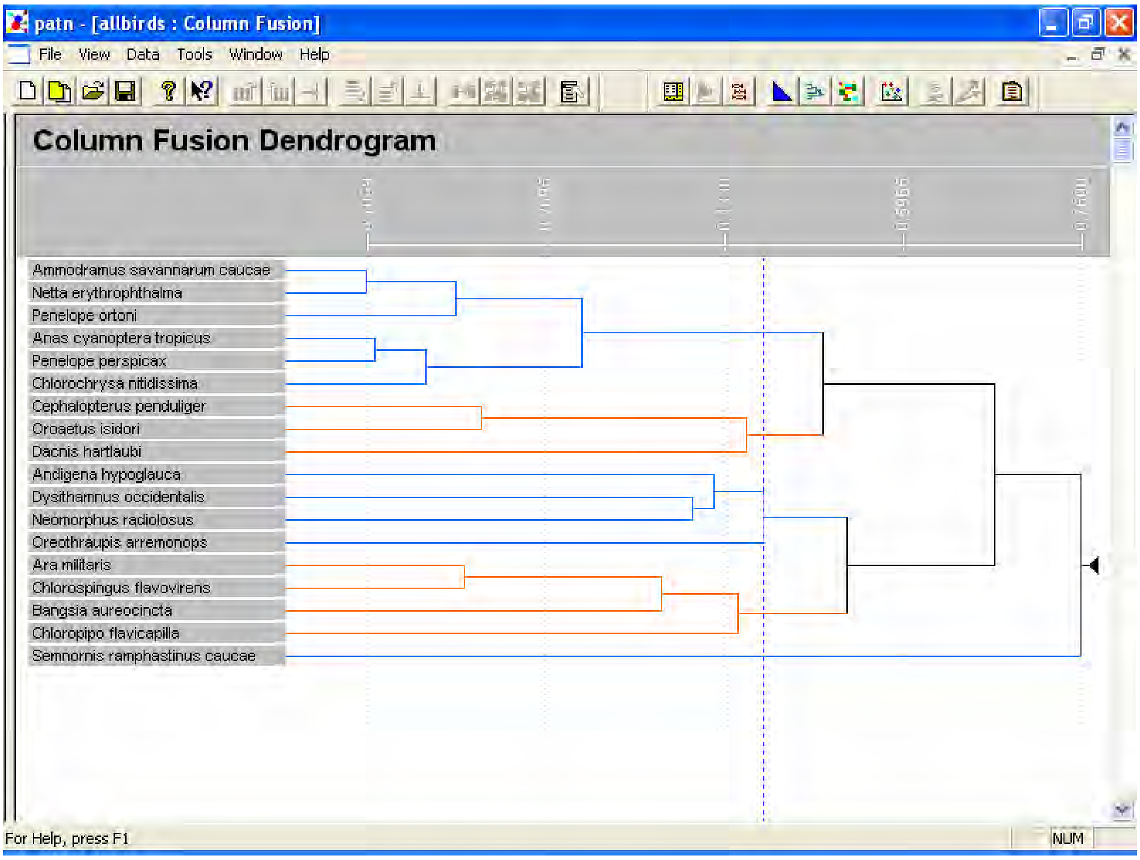

Figure 5.3-VII Dendogram of Associations between Bird Species

5.3.3. Modelling of Bird Species' Distribution

For the creation of species distribution models according to ecosystem availability, exclusively species of which at least 20 individuals occurred in the data set were taken into consideration, consequently leaving 17 species for selection. From these 17 species 10 species were chosen that simultaneously fulfilled the requirement of being of at least vulnerable conservation status, therefore excluding species that were classified as near threatened, and which distribution was furthermore either entirely confined to the Valle del Cauca, or where the Valle del Cauca presented one of the last important strongholds for the species, while another requisite for the species to be included into the modelling process was that it had been observed within various sampling locations and natural ecosystems in order to assist the formulation of well-founded predictions about the probable distribution of species. In addition, species which physical and life cycle characteristics, as well as habitat requirements, considerably differed among each other, were preferably chosen as to incorporate widely varying habitat needs into the reserve planning exercise. A brief description of the selected species is presented in the below table (Table 5.3-II).

Appendix B contains the modelled distribution maps of these species (Figure 1 – Figure 10). Moreover, *Andigena hypoglauca* and *Chlorochrysa nitidissima* were chosen as umbrella species, since they were described as being highly susceptible to fragmentation, their often occurred simultaneously with other bird species, and their habitat requirements considerably varied from each other. Accordingly will the predicted distributions of these species be attributed especially high importance in the course of reserve design. The level of overlap between estimated ranges of occurrence of single species is illustrated within Figure 5.3-VIII A clear concentration of bird species was perceptible in the region east of Cali where sub-Andean forests descend into tropical forests.

Species	Common Name	Conser-vation Status	Characteristics
Anas cyanoptera	Cinnamon Teal	EN	Species has experienced a decline of 92 % of its geographical distribution in Colombia as of the loss or pollution of shallow water resources. Remaining population in Colombia is extremely reduced, declining and fragmented. Today found in the vicinity of shallow pools within a variety of altitudinal ranges.
Andigena hypoglauca	Grey-breasted Mountain Toucan	VU	Species has lost an approximate 61 % of its habitat through the destruction of Andean forests and is highly susceptible to fragmentation. Occurrence is concentrated within Andean forests of 2700 - 3100 m altitude but found between 2400 - 3400 m.
Bangsia aureocincta	Gold-ringed Tanager	EN	Endemic to Colombia, restricted to few south-eastern departments with a very localized distribution, after having lost > 60 % of suitable habitat. Found in Sub-Andean forests from 1500 – 2195 m altitude.
Cephalopterus penduliger	Long-wattled Umbrellabird	VU	Occurs in south-eastern Colombia and eastern Ecuador, rare species with localized distributions, main habitat are humid and very humid forests of 500 – 1400 m altitude, has lost > 30 % of its potential habitat
Chlorochrysa nitidissima	Multicoloured Tanager	VU	Endemic to Sub-Andean forests at 1300 – 2200 m altitude of the Central and Western Cordilleras. Mainly found in three departments, including Valle del Cauca. Being very susceptible to fragmentation this species has lost > 81 % of its potential habitat.
Dacnis hartlaubi	Turquoise Dacnis-Tanager	VU	Endemic to Colombia, has lost 73 % of suitable habitat, distinguished by very localized, declining and fragmented distributions. Mainly sighted in humid Sub-Andean forests from 1300 -2200 m altitude, but also in young regrowth and agricultural areas.
Neomorphus radiolosus	Banded Ground-Cuckoo	EN	Endemic to Colombia, only found in very few locations of the Western Cordillera in High – Andean forests or sub-páramo and páramo habitats in extremely localized and fragmented populations.
Netta erythrophthalma	Southern Pochard	CR	In western South America < 2500 individuals estimated, very localized and fragmented distribution. Mainly found near lakes and lagoons at altitudes < 2600 m.
Oroaetus isidoria	Black-and-chestnut Eagle	EN	Occurs in undisturbed large humid forest tracts from 1600 – 3000 m, has lost > 63 % of its habitat and 30 % of its population within 3 generations, only 740 -1480 individuals remaining in Colombia.
Penelope perspicax	Cauca Guan	EN	Endemic, population concentrated in Sub-Andean forests of the Valle del Cauca, mainly from 650 – 2200 m. Estimated < 1000 individuals found in population fragments, extremely susceptible to stochastic extinction as for the low population numbers.

Table 5.3-II Description of selected Bird Species for Distribution Modelling

Source: Renjifo et al. (2002)

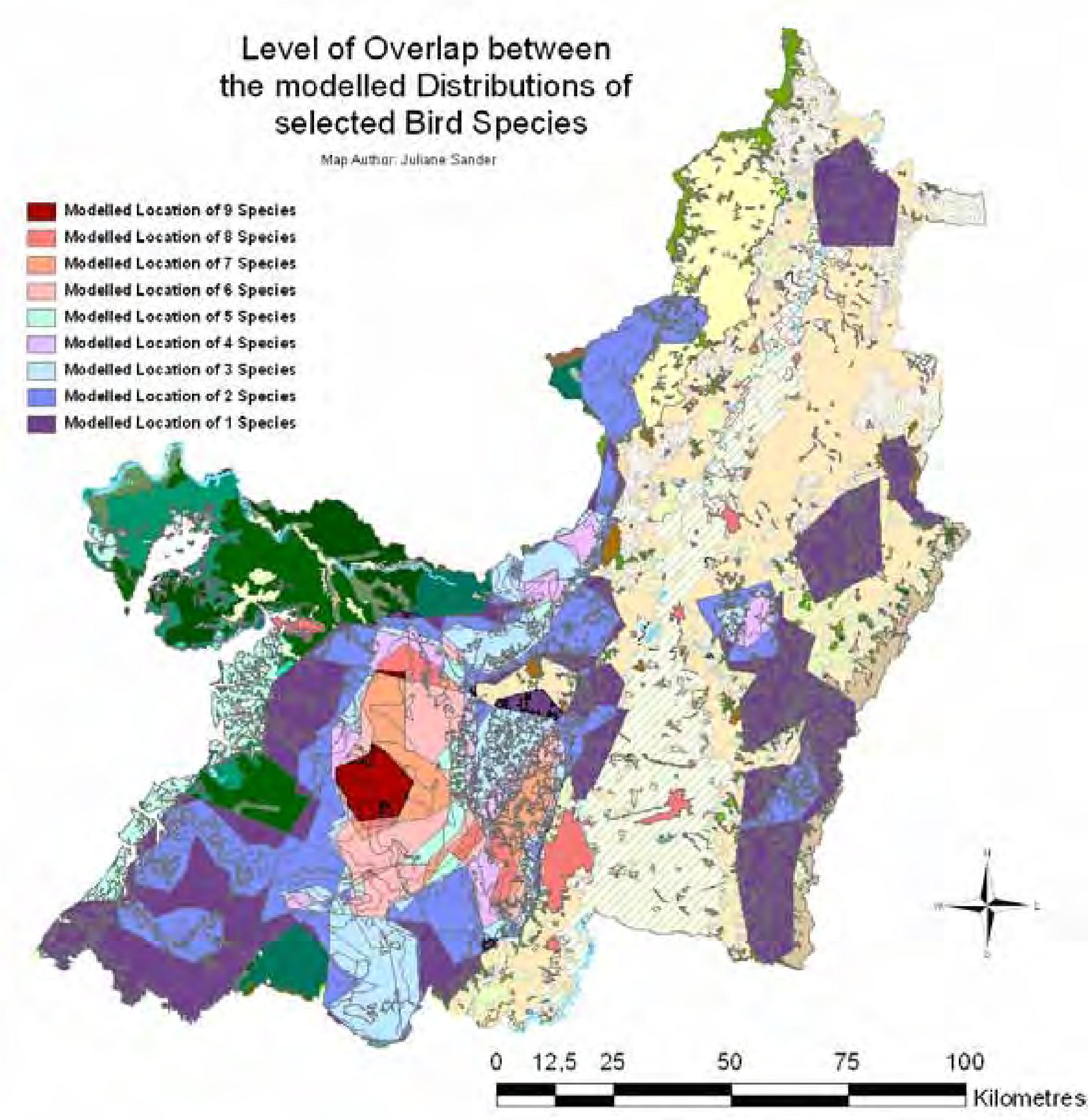

Figure 5.3-VIII Overlap of Modelled Bird Distributions

5.3.4. General Mammal Data Characteristics

A total of 67 mammal species, represented by 318 individuals, was documented. Table 3 in Appendix A contains the complete list of sampled mammal species, inclusive of information in relation to the common name, IUCN conservation status and the observed abundance of single species. The vast majority of species was not categorized by the IUCN as being of elevated conservation concern.

Only the Colombian Night Monkey *Aotus lemurinus* was classified as vulnerable while another five species were distinguished as being of ‘Lower Risk – near threatened status’ and for a further two species the lack of information was that pronounced that their conservation status could not be evaluated and their status was described as ‘Data Deficient’. Four of the remaining 58 species were of ‘Least Concern’ status and the large majority of species was categorized by the IUCN as of ‘Lower Risk-least concern’ status. In regards to the apparent absence of mammal species with elevated conservation concern, which, in the light of the heavily fragmented landscape of the Valle del Cauca and the generally as high assumed susceptibility of mammals to fragmentation, was unexpected, it has to be kept in mind that, in contrast to the country-specific conservation status evaluation of birds, the status of mammals was assessed according to the global situation of the species. Moreover, the data was differentiated by a general absence of medium to large-sized mammals, and by being largely dominated by small mammal species such as bats and rodents.

In contrast to the bird data, the mammal records failed to be biased towards a small number of species but abundances were similarly low for all species. 21 species or an approximate 31 percent of species only occurred with one individual and a further 35 species, equalling 52 percent of all species, were recoded less than ten times. The observed abundance of the Silky Short-Tailed Bat *Carollia brevicauda* consisted of 21 individuals, making it the most common species. Bats, represented with a diversity of 29 species, accounted for more than 42 percent of total species variety, whereas small rodents, mainly present in the form of wild mouse species, with 22 species constituted a further approximate 33 percent of species diversity. Figure 5.3-IX illustrates the sampling locations of mammals within the Valle del Cauca.

The map shows the dispersion of mammal species throughout the high-altitude Andean area of the department to the east and north of Cali, at the same time possibly explaining the overall lack of medium to large-sized mammal species, as of the absence of sampling events from larger forest fragments where residual populations of larger-sized mammals are assumed to be concentrated.

Figure 5.3-IX Mammal Sampling Events

It is believed that the lack of data from larger tracts of tropical and sub-Andean forests west of the departmental capital, where a concentration of bird species assemblages was detected, is the result of selected sampling that was influenced by more effortless opportunities for observing the mainly cryptic and nocturnal mammals in vast open deforested spaces as opposed to densely forested areas.

Despite of the high sampling bias obvious within the mammal data set, the data is nonetheless expected to contribute with valuable additional information to the reserve design process, as it indicates which areas in the highly fragmented part of the department warrant specific conservation attention.

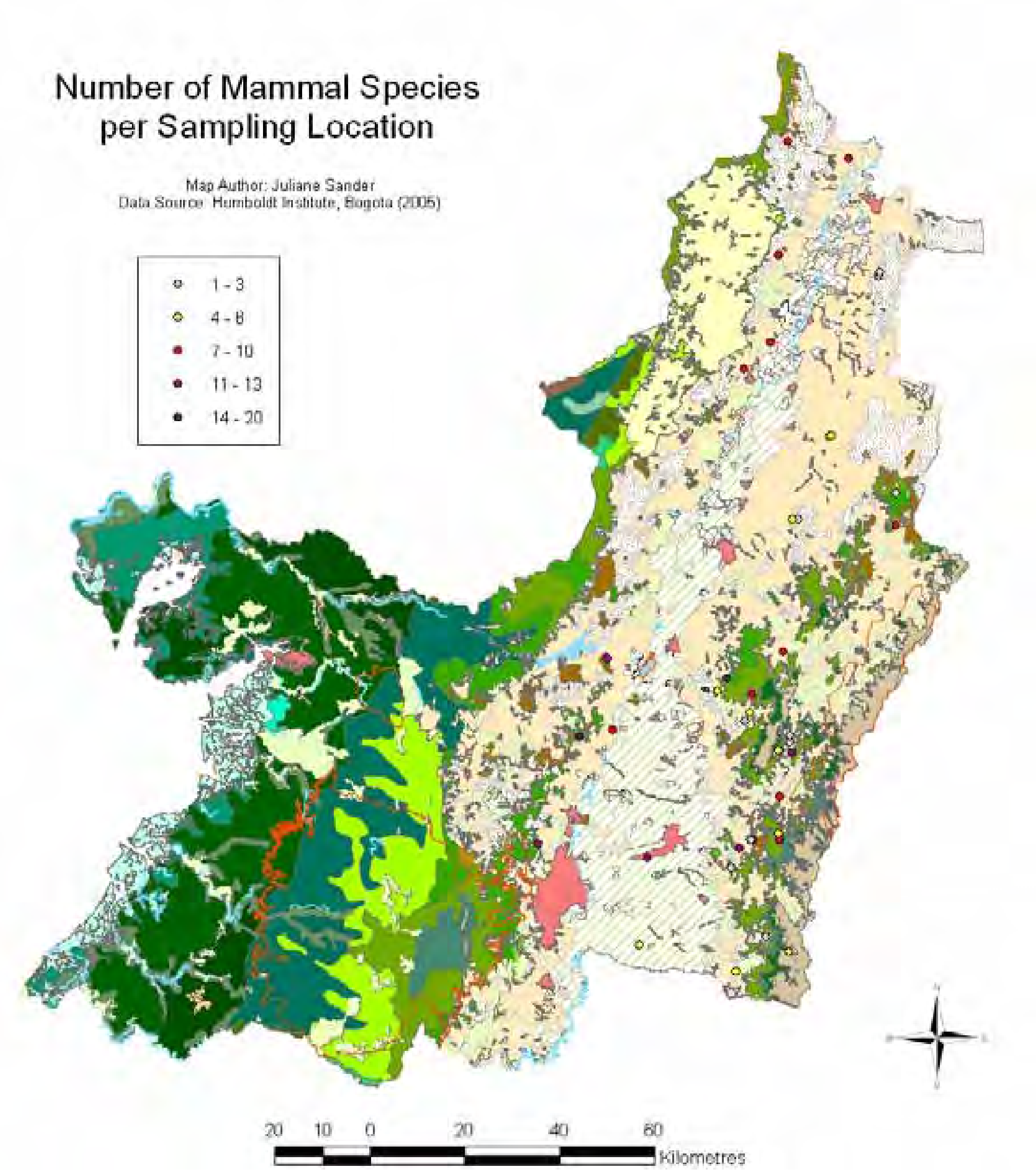

Figure 5.3-X Number of recorded Mammals per Sampling Location

As it was the case for the bird data, a clustering of individuals at certain map coordinates was also observed within the mammal data. The number of individuals per mapping coordinate is illustrated in Figure 5.3-X. Assemblage fidelity between different species was observed especially frequently in regards to bat species.

As of the absence of endangered or critically endangered mammal species, mammals of ‘Vulnerable’, ‘Lower Risk - near threatened’ or ‘Data deficient’ status were declared of being of especial conservation priority and, as to obtain more information for the purpose of distributional modelling, occurrences recorded before 1995 were additionally included in Figure 5.3-XI that demonstrates the sampling locations of these eight species.

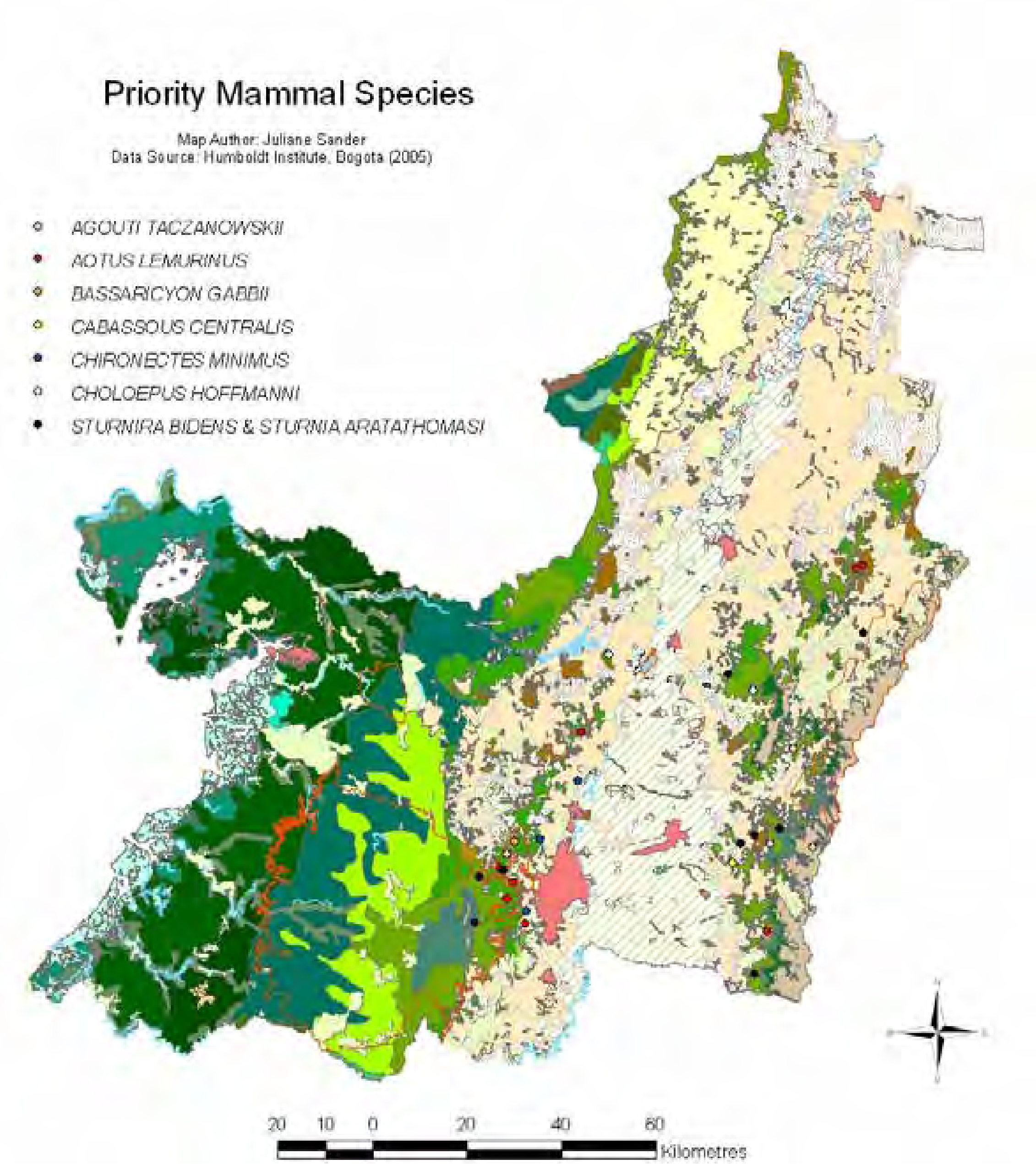

Figure 5.3-XI Sampling Locations of Mammal Species of elevated Conservation Concern

Despite of the inclusion of additional data points the number of map coordinate records remained considerably low, and apart from the Night Monkey *Aotus lemurinus* and the Bidentate Yellow-Shouldered Bat *Sturnia bidens* that were both represented with 14 records each, less than five records were documented per species. The Aratathomas Yellow-Shouldered Bat *Sturnia aratathomasi*, sampled only on three occasions, occurred exclusively in congruence with *Sturnia bidens*.

5.3.5. Ecosystems associated with Mammal Occurrences

The spatial join between the ecosystem and species layers gave evidence of mammals occupying a total of 12 ecosystems (Table 5.3-III). With 188 individuals of 54 different species, accounting for almost 60 percent of total mammal abundance, cattle agro-ecosystems contained the vast majority of sampled specimens.

Ecosystem Type	Number of Species	Number of Individuals
Cattle Agro-Ecosystems	54	188
Very humid Andean Forest on fluvial mountain deposits	18	21
Forest Plantations	18	19
Grassy Regrowth	18	19
Urban Areas	17	24
Coffee Agro-Ecosystems	10	10
Very humid High-Andean Forest on fluvial mountain deposits	10	10
Sugarcane Agro-Ecosystems	5	5
Very humid Sub-Andean Forest on fluvial mountain deposits	5	5
Humid Páramo on volcanic mountain deposits	5	5
Undifferentiated Agro-Ecosystems	3	3
Tropical Dry Forest on fluvial mountain deposits	1	1

Table 5.3-III Number of Mammal Species and individual Animals per Ecosystem Type

In relation to natural ecosystems, solely the ecosystem type ‘Very humid Andean Forest on fluvial mountain deposits’, including 18 different species, followed by the ecosystem type ‘Very humid High-Andean Forest on fluvial mountain deposits’, was characterized by a considerable species diversity.

However, in regards to the over-proportional mammal diversity in cattle agro-ecosystems, the extremely small sizes of remaining forest fragments in this landscape matrix dominated by cattle farming have to taken into account, as well as the fact that a large proportion of mammal sampling events took place in close proximity to small forest fragments of ecosystem types such as ‘Very humid Andean Forest on fluvial mountain deposits’, ‘Humid Sub-Andean Forest on fluvial mountain deposits’, ‘Very humid High-Andean Forest on fluvial mountain deposits’, as well as ‘Lakes and Lagoons’. Merely one species, the Northern Naked-Tailed Armadillo *Cabassous centralis*, occurred in one of the last remaining small fragments of the dry forest ecosystem type ‘Tropical Dry Forest on fluvial mountain deposit’, therefore excluding this ecosystem type from the following statistical analyses.

Making use of the same analysing procedures in PATN as further explained in the analysis of bird species assemblages, an ordination stress value of 0.1286 was obtained. A dendogram consisting of the eleven ecosystems organized into four different groups is presented within Figure 5.3-XII.

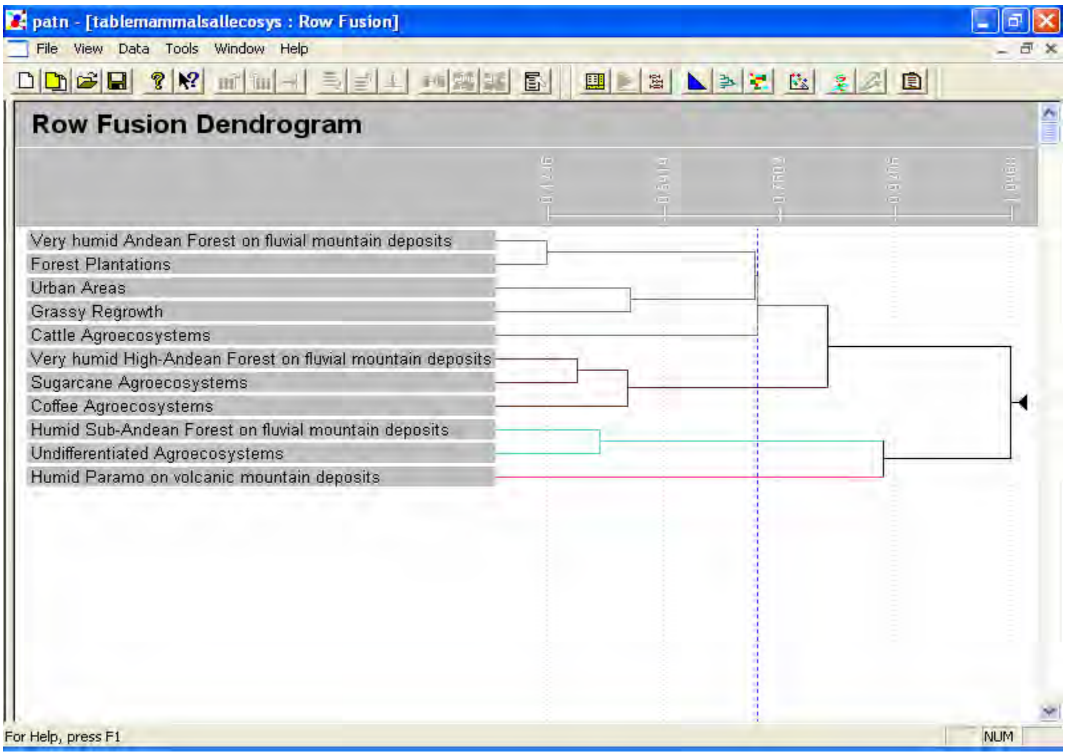

Figure 5.3-XII Dendogram of Ecosystem Associations according to Mammal Species

Interestingly, the greatest similarity in relation to species composition existed between a natural and transformed ecosystem, namely the ecosystem types ‘Very humid Andean Forest on fluvial mountain deposits’ and ‘Forest Plantations’. These two ecosystem types are included in the first and largest group, composed of five ecosystem types, while only one of these ecosystems is not classified as transformed. Although the significance of the dendogram is diminished by the distinct differences in species numbers within the relevant ecosystems, the perception of natural ecosystems closely associated with transformed ecosystems, not only as observed in Group 1, but also through the close relationship between ‘Very humid High-Andean Forest on fluvial mountain deposits’ and ‘Sugarcane Agro-Ecosystems’ in Group 2, as well as between ‘Very humid Sub-Andean Forest on fluvial mountain deposits’ and ‘Undifferentiated Agro-Ecosystems’ in Group 3, is noteworthy, and stresses the importance of those forest fragments as part of the habitat range of species that were sampled in closely located agricultural areas. The ecosystem type ‘Humid Páramo on volcanic mountain deposits’, although one of the ecosystems with the smallest faunal assemblage, is distinguished by the most unique species composition.

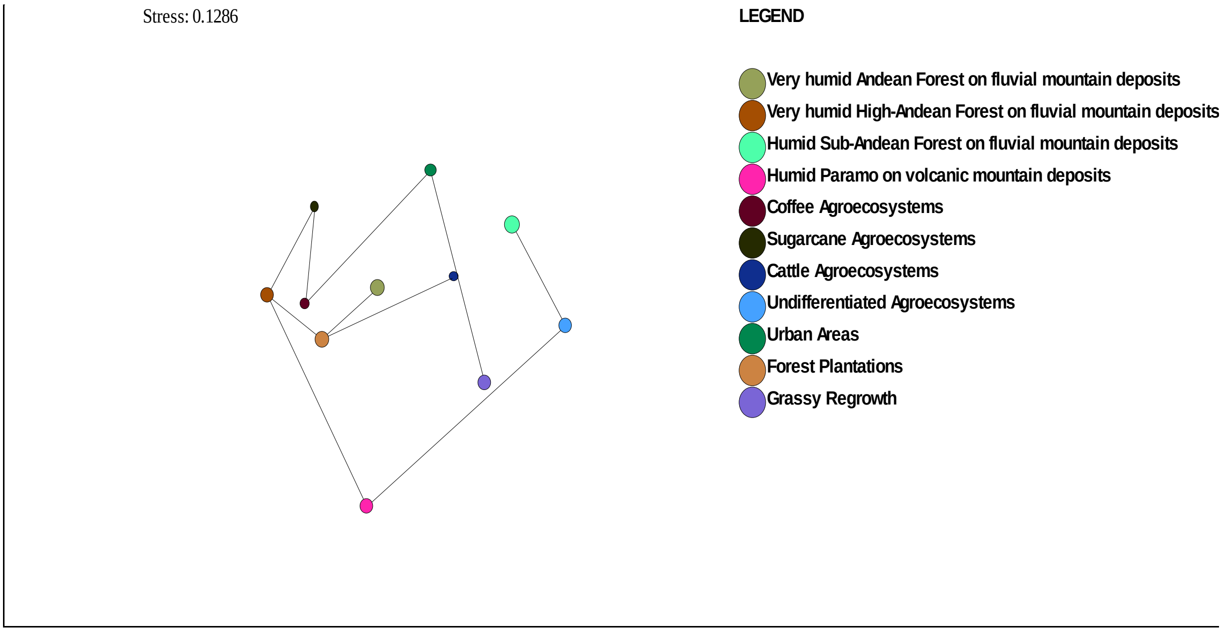

Figure 5.3-XIII Minimum Spanning Tree of Ecosystems

The relationships between ecosystems are further described with the use of the minimum spanning tree (Figure 5.3-XIII) that outlines the pair-wise associations between ecosystems. When comparing the pair-wise distances between ecosystems, 'Humid Páramo on volcanic mountain deposits', 'Urban Areas' and 'Grassy Regrowth' appeared to be the ecosystems with the most distinct faunal composition.

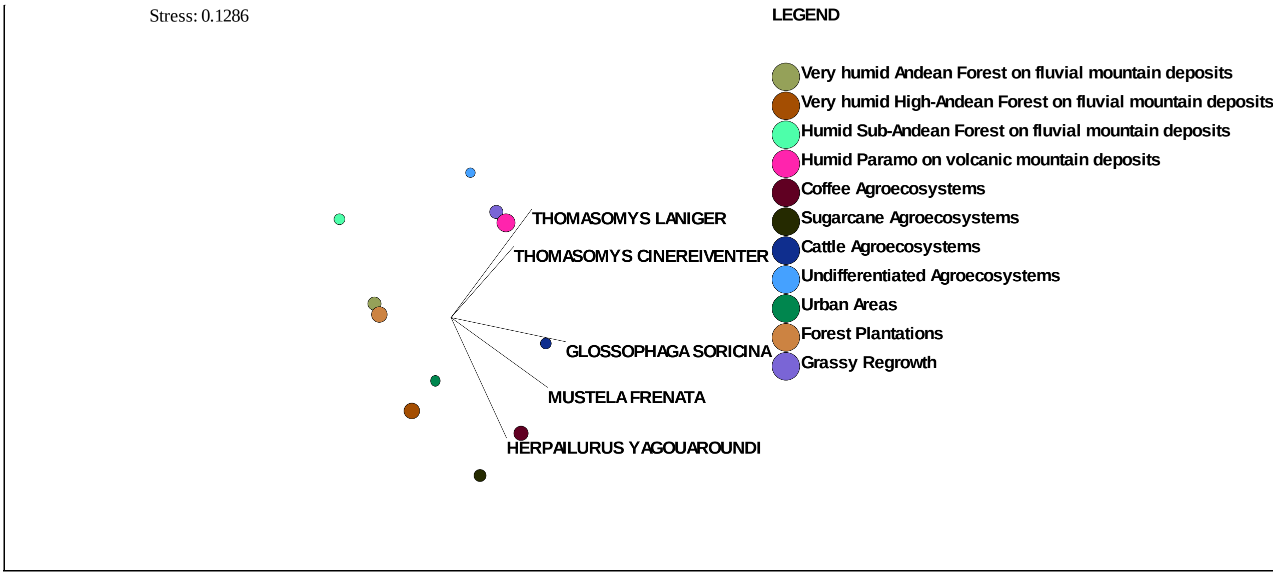

Figure 5.3-XIV Ordination with extrinsic Vectors

Figure 5.3-XIV demonstrates the main correlation vectors in the ordination. In comparison with the major correlation vectors of the ecosystem ordination according to bird species, these correlation vectors were less significant and, apart from the Nectar or Long-Tongued Bat *Glossophaga soricina*, consisted of species that were observed relatively rarely. The Ashy-Bellied Oldfield Mouse *Thomasomys cinereiventer* and the Oldfield Mouse *Thomasomys laniger* were closely associated with the páramo ecosystem type and greatly contributed to its distinctness from other ecosystems. The dendogram in Figure 5.3-XV illustrates the level of habitat resemblance between mammal species that were sampled with more than ten individuals, categorized into three groups.

Differences in sampling locations of these species were not very significant, already indicated by the ordination where only one of these more abundant species proved to be a significant correlation vector. *Glossophaga soricinas'* significant influence on the correlation is confirmed in the dendogram where it is attributed an own group.

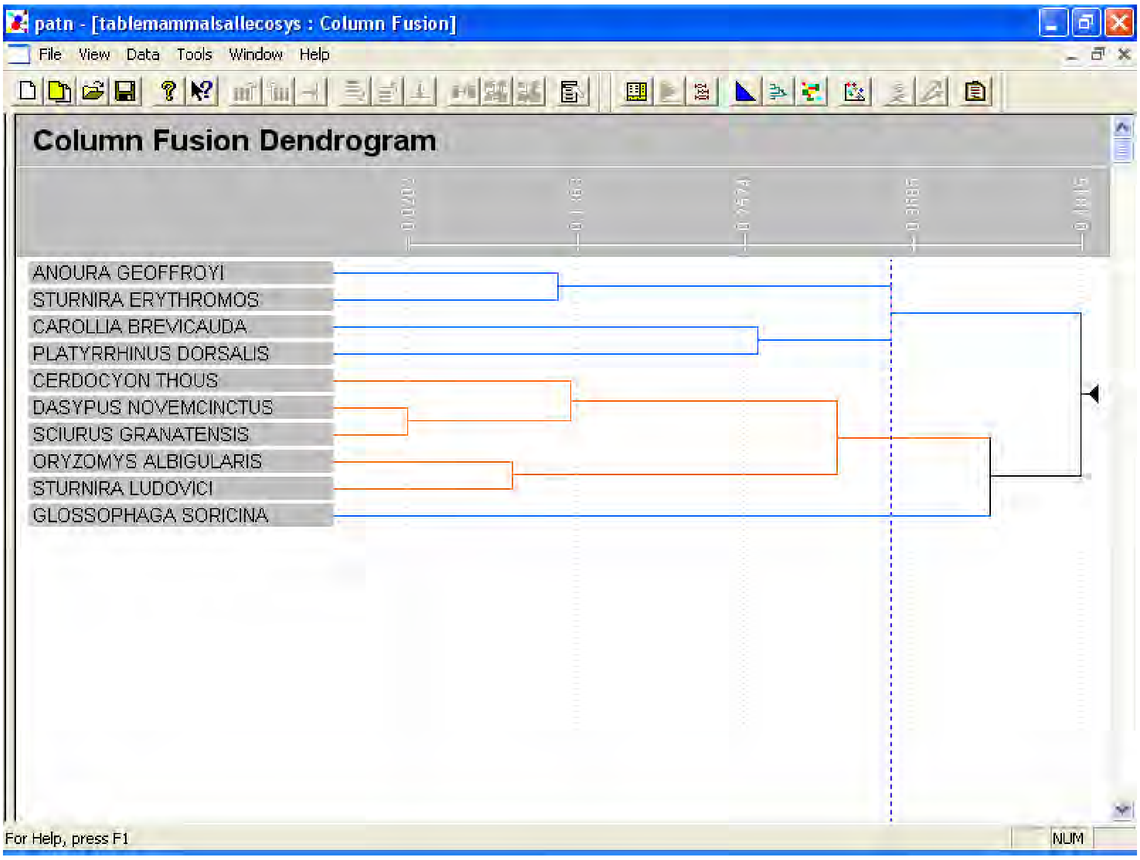

Figure 5.3-XV Level of Assemblage Fidelity between Mammal Species

5.3.6. Distribution Modelling of Mammal Species

The distributions of the eight species of elevated conservation concern which sampling locations are illustrated in Figure 5.3-XI were modelled according to the available information in relation to their habitat preferences. The modelled distribution maps of single species are included in Appendix B (Figure 11 - Figure 17) while Table 5.3-IV briefly summarizes the distinct characteristics of the modelled species.

Species	Common Name	Conser-vation Status	Characteristics
Agouti taczanowskii	Mountain Paca	LR-nt	Ample distribution within the neotropics ranging from Southern Mexico to Paraguay. Found in a variety of forest types but concentrated in humid forests with altitudes < 3000 m. Hunted for subsistence food. (Escuela de Ingeniería de Antigua 2005)
Aotus lemurinus	Colombian Night Monkey	VU	In Colombia found mainly in Andean forests which are either primary forests or consisting of remnant and older secondary forests with high species diversity. Extremely susceptible to human interference and fragmentation. (Wikipedia 2005; Primate Info Net 2005)
Bassaricyon gabbii	Bushy-Tailed Olingo	LR-nt	Occurs from Nicaragua to Ecuador in tropical forests at altitudes < 2000 m. Arboreal animal that depends on hollow trees and mature forests. (Comparative Mammalian Brain Collections 2005)
Cabassous centralis	Northern Naked - Tailed Armadillo	DD	Observed in areas east of the Andes from northern Argentina to Colombia and from Panama to Honduras. Lives in burrows and prefers areas with dense ground vegetation such as dry forests with xerotific thickets and grasslands. (University of Michigan Museum of Zoology 2005)
Chironectes minimus	Water Opossum	LR-nt	Found from southern Mexico to north-eastern Argentina with a declining extent of occurrence. Associated with permanent bodies of water (streams, rivers, shallow pools) in humid forest habitats and open woodlands > 1600 m altitude. (Ojeda and Giannoni 2000)
Choloepus hoffmanni	Hoffmann's Two-Toed Sloth	DD	In Colombia mainly occurs in Andean forests. Largely arboreal animal depending on hollow trees Females associate in groups while males are typically solitary. Females outnumber males by a ratio as high as 11:1. (University of Michigan Museum of Zoology 2005)
Sturnia aratathomasi	Aratathomas Yellow - Shouldered Bat	LR-nt	Representing Colombia's bat variety which is the richest in South America. Decline of bat species evident and associated with the loss of forest habitats, especially in arid areas in close proximity to riverine habitats. (IUCN 2005)
Sturnia bidens	Bidentate Yellow - Shouldered Bat	LR-nt	

Table 5.3-IV Distinct Characteristics of Mammal Species selected for Distributional Modelling

Annotations to the table: LR - lc = Lower Risk – least concern
LR - nt = Lower Risk – near threatened
LC = Least Concern
DD = Data Deficient

Aotus lemurinus, the Colombian Night Monkey, was classified as an umbrella species, as the species is distinguished as being extremely susceptible to human intervention and fragmentation, and its habitat requirements are thought to resemble those of a variety of other primate species occurring in the Valle del Cauca. Likewise declared as an umbrella species was Hoffmann's Two-Toed Sloth *Choloepus hoffmanni* as for its high metabolic requirements, low fecundity rates, and its dependency on hollow trees which is observed in a variety of species from the study area.

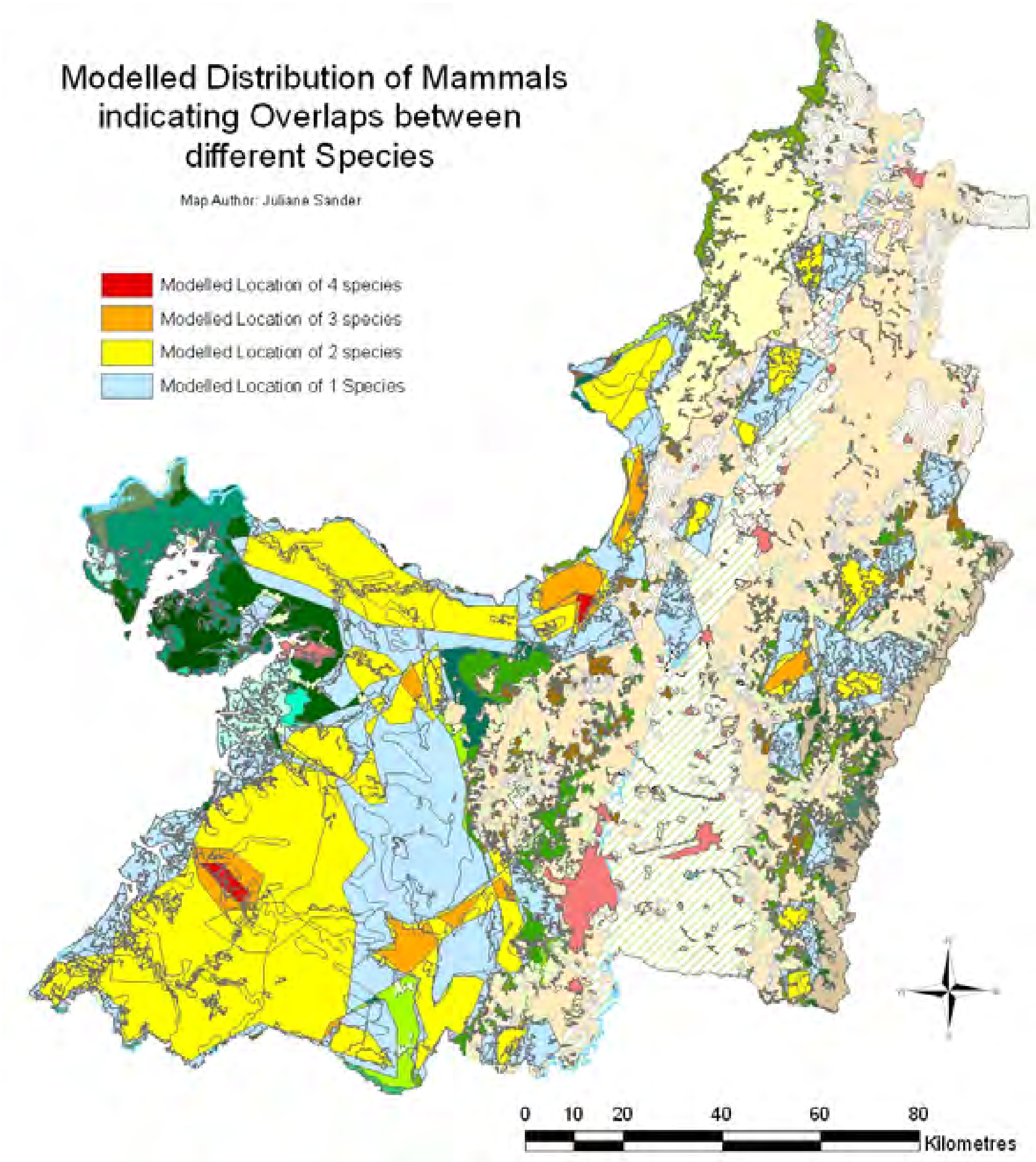

Figure 5.3-XVI Overlap of modelled Mammal Distributions

Figure 5.3-XVI depicts the level of overlap between the singular modelled mammal distributions which, compared to the bird species, is less pronounced due to the more particular habitat requirements of the selected mammal species.

5.4. Designation of Protected Areas

5.4.1. The 'Larger Area Option'

12 Polygons containing candidate sites were created according to a visual assessment of the study area map illustrating ecosystem characteristics including vulnerability status and uniqueness of species assemblage composition as assessed in PATN, as well as species' distributions. Figure 5.4-I shows the location of these larger candidate sites. Despite this new layer of protected areas being classified as of 'larger' size, it consisted of comparatively small polygons with the mean size amounting to 12058 hectares. Although the creation of relatively small-sized areas was influenced by several factors, including the greater likelihood of succeeding in protecting a larger range of currently underrepresented ecosystems with a wider range of smaller selection units, and a higher probability of effective management of these newly established protected areas, the most significant factors were the exceedingly fragmented state of the study area and the department's extensive road network making the design of larger areas, especially in the Andean region east and north of Cali, impossible.

Every polygon was attributed a score value that was calculated from overlaying the new protected area layer with the various species and ecosystem layers created in previous sections. The candidate site was given one point per bird or mammal species which modelled distributional range included the polygon, a score between two to ten points for containing a specific number of documented bird species sampling events (see Figure 5.3-II) while the polygon was awarded with the same number of points when it comprised a certain number of mammal sampling events (see Figure 5.3-X).

Furthermore the candidate site was attributed two and a half points when, according to distributional models, it provided habitat for a bird or mammal umbrella species, two points for each critically endangered bird species and one point for each priority mammal species which was sampled within its borders. When a site was classified as being vulnerable to transformation in the near future or contained ecosystems with less than 150 hectares cover extent remaining, it was awarded with ten points. If the candidate site comprised ecosystems that were characterized as enclosing unique mammal or bird species assemblages, as established in the preceding PATN analyses, it was given five points.

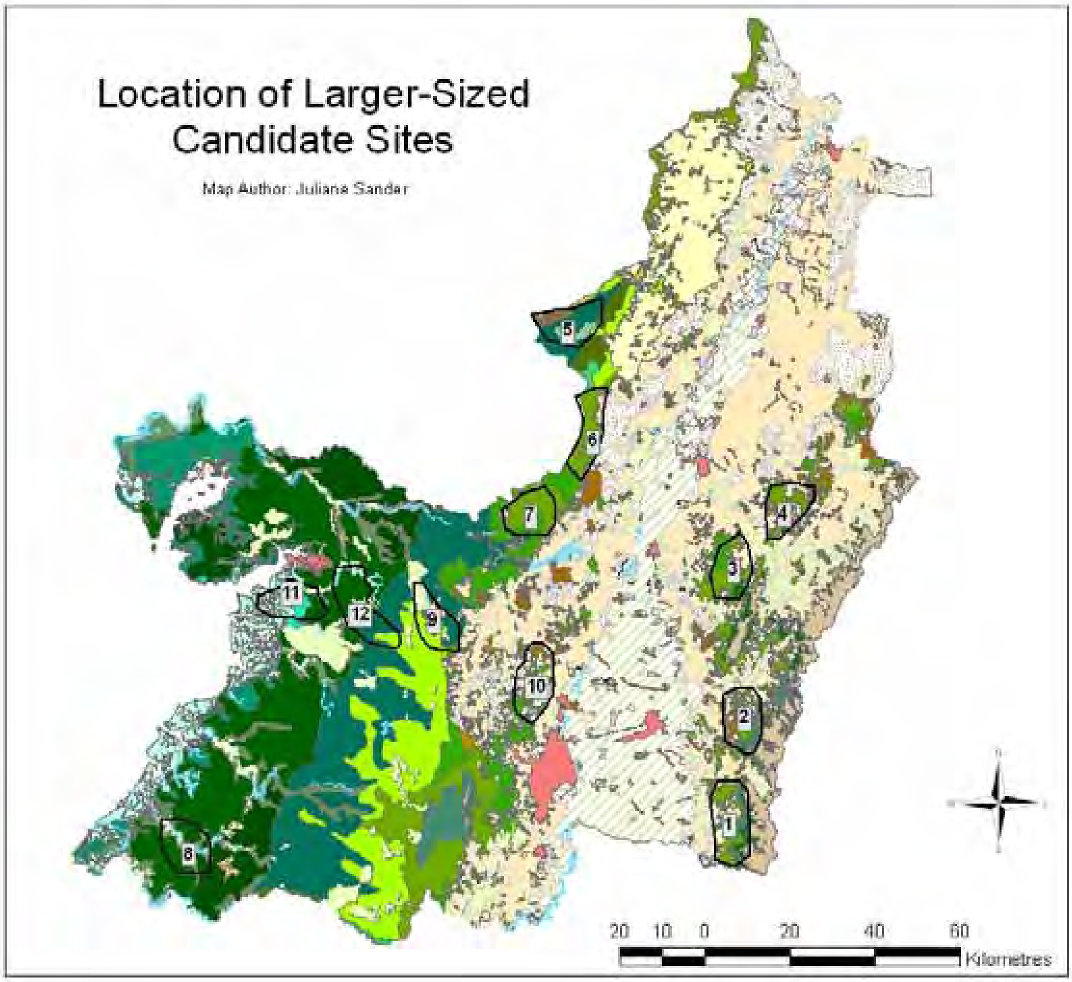

Figure 5.4-I Larger-sized Candidate Sites

Table 1 of Appendix C provides an overview of the individual candidate site scores from the overlay analyses. The maximum score consisted of 51 points while the mean value amounted to 27 points.

In addition to examining the ecosystem characteristics of every candidate site, the agglomerative hierarchical fusion classification strategy from PATN, producing five groups composed of the 12 candidate sites and already existing protected areas with the Bray Curtis association measure that resulted in an ordination stress value of 0.1482, assisted in prioritizing sites taking into account the level of dissimilarity both among sites and between sites and existing protected areas. The dendogram picturing those interrelationships is depicted in Figure 5.4-II.

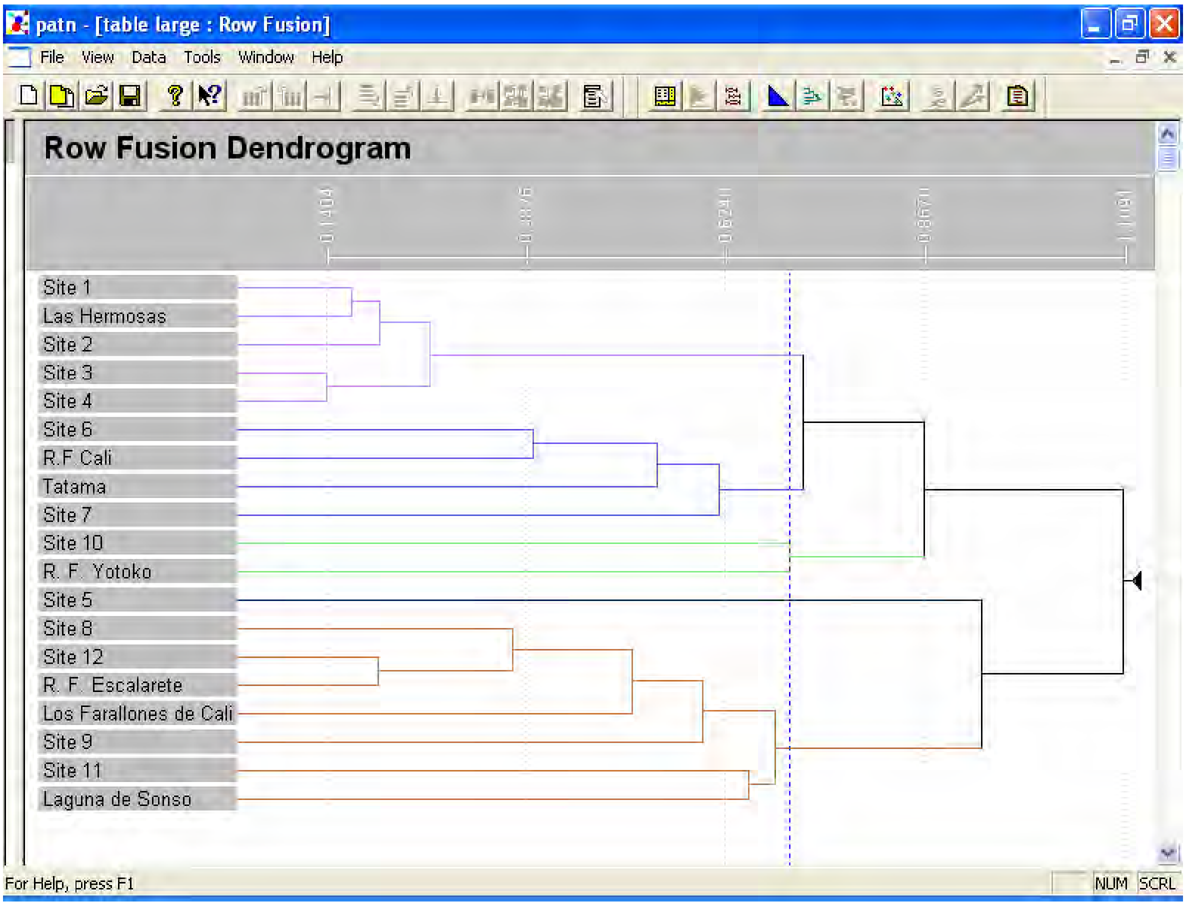

Figure 5.4-II Dendogram demonstrating Associations between larger Candidate Sites

When investigating the ecosystem characteristics of candidate sites, the sites with the highest scores were found to show a significant resemblance to already protected sites. These sites were organized from PATN into the dendogram's first group.

Among these sites, the most appropriate site for reserve acquisition was Site 2, not only because it was distinguished by the highest score of all larger candidate sites, but also as it represented the only candidate site including an ecosystem type which cover extent had been reduced to less than 150 hectares, by enclosing the ecosystem type 'Very humid Andean Forest on colluvial-alluvial lower mountain deposits'. However, the fact that it mainly protected high-Andean and páramo ecosystem types that are severely overrepresented in existing protected areas, and moreover merely an approximate 55 percent of its total area was characterized as consisting of intact ecosystems, since in order to allow the inclusion of the small ecosystem remnant, situated a slight distance apart from the centre of the site, nearby agro-ecosystems had to be incorporated into the polygon, decreased its conservation value.

Site 5 appeared to have the most unique ecosystem characteristics of all larger sites in the dendogram and a closer inspection of its contents detected a relatively high representation of the ecosystem type 'Pluvial Sub-Andean Forest on fluvial mountain deposits' that currently fails to be protected to any extent. Nonetheless was almost 60 percent of the total area of this site occupied by the already heavily overrepresented ecosystem type 'Very humid Tropical Forest on fluvial mountain deposits', hence diminishing the value of this site for reserve acquisition. Both Site 6 and Site 7 protected large portions of the ecosystem type 'Very humid Andean Forest on fluvial mountain deposits' that is at present underrepresented in reserves, while at the same time PATN analyses indicated the significance of this ecosystem type in providing habitat for a variety of bird and mammal species. Site 7, although comprising a higher proportion of the overrepresented ecosystem type 'Humid Sub-Andean Forest on fluvial mountain deposits', was evaluated as being of superior value for conservation because it enclosed a large fragment of the at the moment seriously underrepresented ecosystem type 'Very humid Tropical Forest on structurally eroded hill' and also showed a higher dissimilarity to already protected areas. Moreover, Site 7, in contrast to Site 6 of which 25 percent of its total area had been transformed into agro-ecosystems, exclusively was composed of unmodified ecosystems and had a slightly higher point score. Furthermore, Site 6 had a round shape, its core therefore expected to be less susceptible to edge effects, and consequently was judged as being of superior adequacy compared to the elongated-shaped Site 6.

Site 8, if only having a low point score, included reasonable proportions of the presently underrepresented ecosystem types ‘Very humid Tropical Forest on fluvial hill deposits’ and ‘Lakes and Lagoons’, with the latter ecosystem type having been established as providing important habitat for unique bird and mammal assemblages in PATN. This site was assessed as being more valuable than the similarly structured Site 12, as Site 8 contained smaller portions of overrepresented ecosystem types while simultaneously protecting a larger extent of freshwater habitat, and also demonstrated a greater level of dissimilarity to existing reserves. Site 9 and Site 10 were considered as being of lower priority for inclusion into the reserve network as they to the most part consisted of extensively protected ecosystems.

On the contrary, Site 11 was regarded as an important addition to the reserve network, due to its capability of protecting the underrepresented ecosystem type ‘Very humid Tropical Forest on fluvial hill deposits’ and a substantial portion of mangrove and coastal forests that currently fail to be protected altogether, notably the ecosystem type ‘Very humid Mangrove and Coastal Forest on fluvial marine plains’. The conservation of mangroves for the continuing functioning of coastal processes was perceived as being of utmost importance, consequently, despite of the low point score of this site, justifying the need for its protection.

5.4.2. The ‘Smaller Area Option’

Because of the heavily fragmented state of the study area it was expected that smaller selection units had the potential to present a viable alternative to the proposed larger areas. A total of 30 areas, frequently located in close proximity to each other and occasionally intersecting, were selected utilizing the same selection process as further described in the course of designing larger areas. The mean size of these smaller areas amounted to an approximate 2205 hectares, with the maximum point score accounting to 41, and the mean point score of 21 being considerably lower than the value of 27 obtained from examining the larger areas.

Figure 5.4-III demonstrates the location of single sites while Table 2 of Appendix C informs about their individually obtained score values.

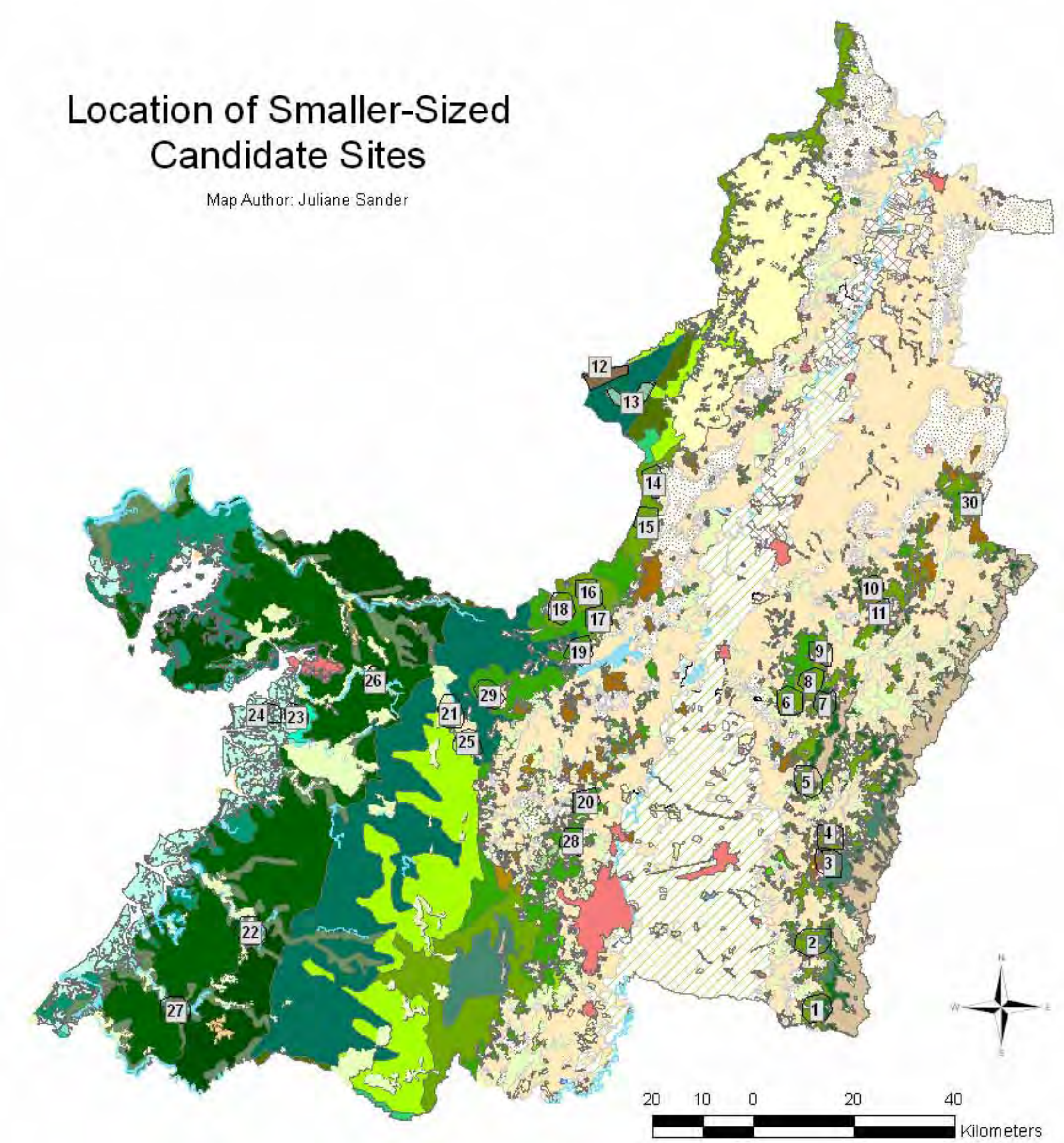

Figure 5.4-III Smaller-sized Candidate Sites

An assortment of sites, including Sites 4, 5, 9, 20, 21, 25, 28, 29 and 30 was, after an assessment of the proportion of untransformed ecosystems within particular polygons, excluded from further suitability analyses, due to the natural ecosystem content of these sites constituting less than 65 percent, and in most cases less than 50 percent of the total polygon area.

A large portion of these ecosystems that were nonetheless characterized by comparatively high score values, consisted of areas covered with young grass regrowth. The dendogram, produced choosing the same options in PATN as in the comparison of large candidate sites, outlining the level of association between small candidate sites and their similarity in ecosystem composition to existing protected areas, is presented in Figure 5.4-IV. When organizing the candidate sites into 7 groups an ordination stress level of 0.1465 was obtained.

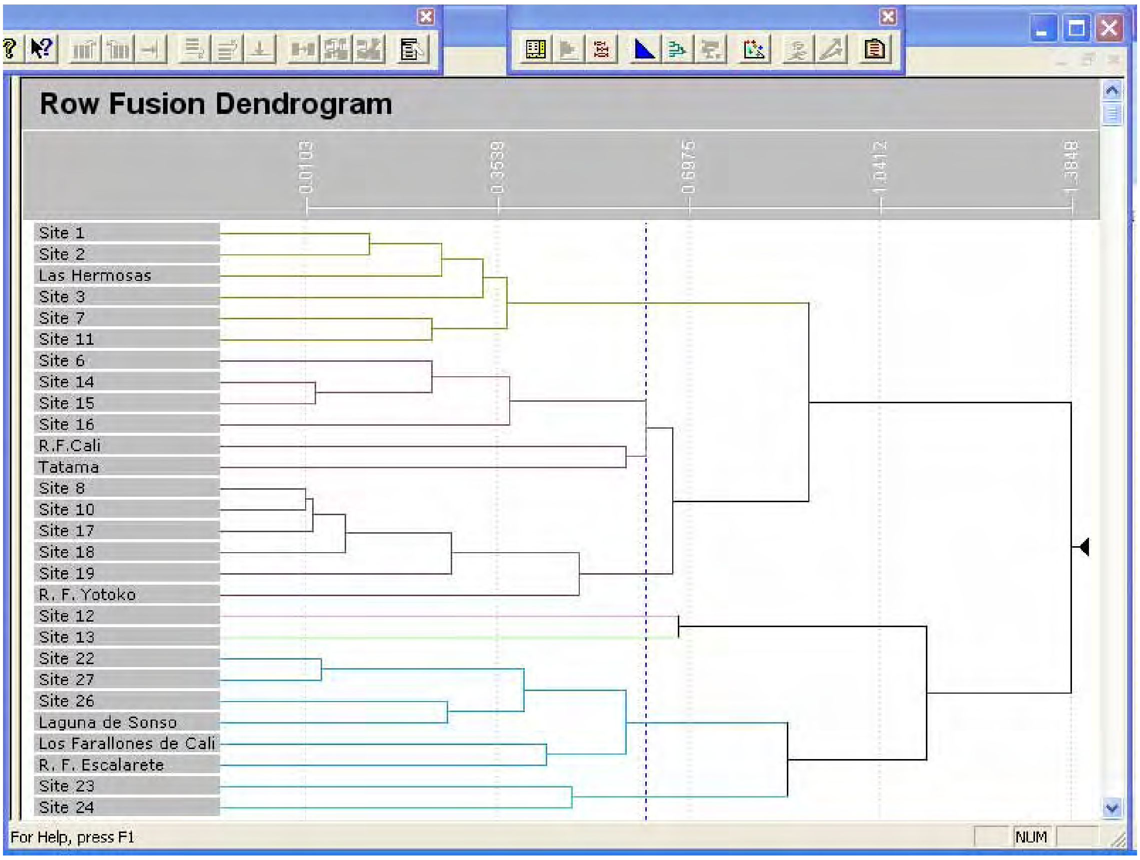

Figure 5.4-IV Dendogram describing Relationships between smaller Candidate Sites

Sites 1, 2, 3, 7 and 11, members of the first group of the dendogram, mostly consisted of high-Andean and páramo ecosystems that are already overrepresented in the reserve system. The second group of the dendogram was composed of sites that almost exclusively contained ‘Very humid Andean Forest on fluvial mountain deposits’ while sites clustered into Group 3 enclosed both ‘Very humid Andean Forest on fluvial mountain deposits’ and sub-Andean Forest types that did not require additional protective measures.

Among the sites included within Group 2, site 16 appeared to be the most adequate one for conservation purposes because it was entirely made up of the ecosystem type 'Very humid Andean Forest on fluvial mountain deposits' and failed to comprise transformed ecosystems. Site 18 presented a less efficient alternative to site 16, although distinguished by a higher point score, as ten percent of its total extent was occupied by transformed ecosystems. These adjacent sites showed very similar species and ecosystem characteristics, with the solitary dissimilarities being the modelled presence of one additional bird umbrella species in site 18, in addition to site 16 being part of the modelled distributional range of one extra bird species. Site 12 and site 13 both formed their own groups and a further examination of their contents indicated that their conservation values were indeed very high, even though only achieving low point scores. Furthermore, site 12 was considered to be of especially urgent conservation priority due to almost entirely being consisting of the ecosystem type 'Dry Tropical Forest on structurally eroded mountain', in the light of the extremely critical nationwide conservation status of dry tropical forests.

However, candidate site 13 was also granted high priority for inclusion into the reserve system, since it predominantly covered the currently to any extent unprotected ecosystem type 'Pluvial Sub-Andean Forest on fluvial mountain deposits'. For the protection of freshwater habitat the neighbouring sites 22 and 27 of Group 6 were taken into consideration because they showed less similarity to existing protected areas compared to the remaining group member, site 26. While both sites 22 and 27 only attained low score values, the conservation value of site 27 seemed to be superior, despite of encompassing slightly less freshwater habitat, as not only its proportional content of overrepresented ecosystems was considerably lower than observed in site 22, but also due to its coverage of large fragments of the presently severely underrepresented ecosystem types 'Very humid Tropical Forest on structurally eroded hill' and 'Very humid Tropical Forest on fluvial hill deposits'. Among site 23 and site 24, the sole members of Group 7, site 23 was regarded as of higher relevance for reserve acquisition, since its point score was superior due to its vulnerable status, in addition to enclosing two different mangrove and coastal forest types, in contrast to site 24 that only comprised one of these.

5.4.3. Proposed Schedule of Site Acquisition

Generally, it is recommended to give preference to the larger sites of which the conservation value has been established to be considerable, since the capability of larger-sized areas to protect inter- and intra-species interactions and complex ecosystem processes is assumed to be superior, and larger areas were moreover observed of achieving higher point scores, hence accomplishing more conservation goals at once. Consequently, it is suggested to firstly declare one of the large areas, site 7, as a protected area due to its high point score and the urgent necessity of protecting a large additional portion of the vulnerable ecosystem type 'Very humid Andean Forest on fluvial mountain deposits' that contains a large share of the departments biodiversity. If the acquisition of this site appears to be infeasible, large site 6 presents a slightly less adequate alternative, and in case only a smaller area can be reserved small site 16 should be taken into consideration with small site 18 representing a viable alternative. Even though only being one of the smaller sites, site 12, consistent of dry tropical forest, should be attributed particularly high conservation priority.

Site 8 is recommended as the next large site for inclusion into the protected area system due to the vital need of conserving additional freshwater habitat, influenced by the presence of freshwater resources dependent endangered bird species such as *Anas cyanoptera,* in addition to the varied bat fauna of the department for which the conservation of these ecosystems is essential. Small site 27 represents a diminutive substitute. Afterwards, large site 11, comprising important coastal and mangrove habitats, should be incorporated into the reserve network, with small site 23 being the small-scale option. Lastly, it is proposed to add small site 13 to the protected area system as to facilitate the protection of a currently unprotected ecosystem variant of pluvial sub-Andean forest. The adjacent small sites 12 and 13 could certainly be combined into one large site, which would however diminish their efficiency in exclusively protecting underrepresented ecosystems, as seen in the case of large site 5 that covers this specific location. Figure 5.4-V shows the selected areas and indicates the proposed order of their acquirement into the protected area network while Table 5.4-I provides detailed information about the types of ecosystems protected in the site addition process, taking into account the different alternatives.

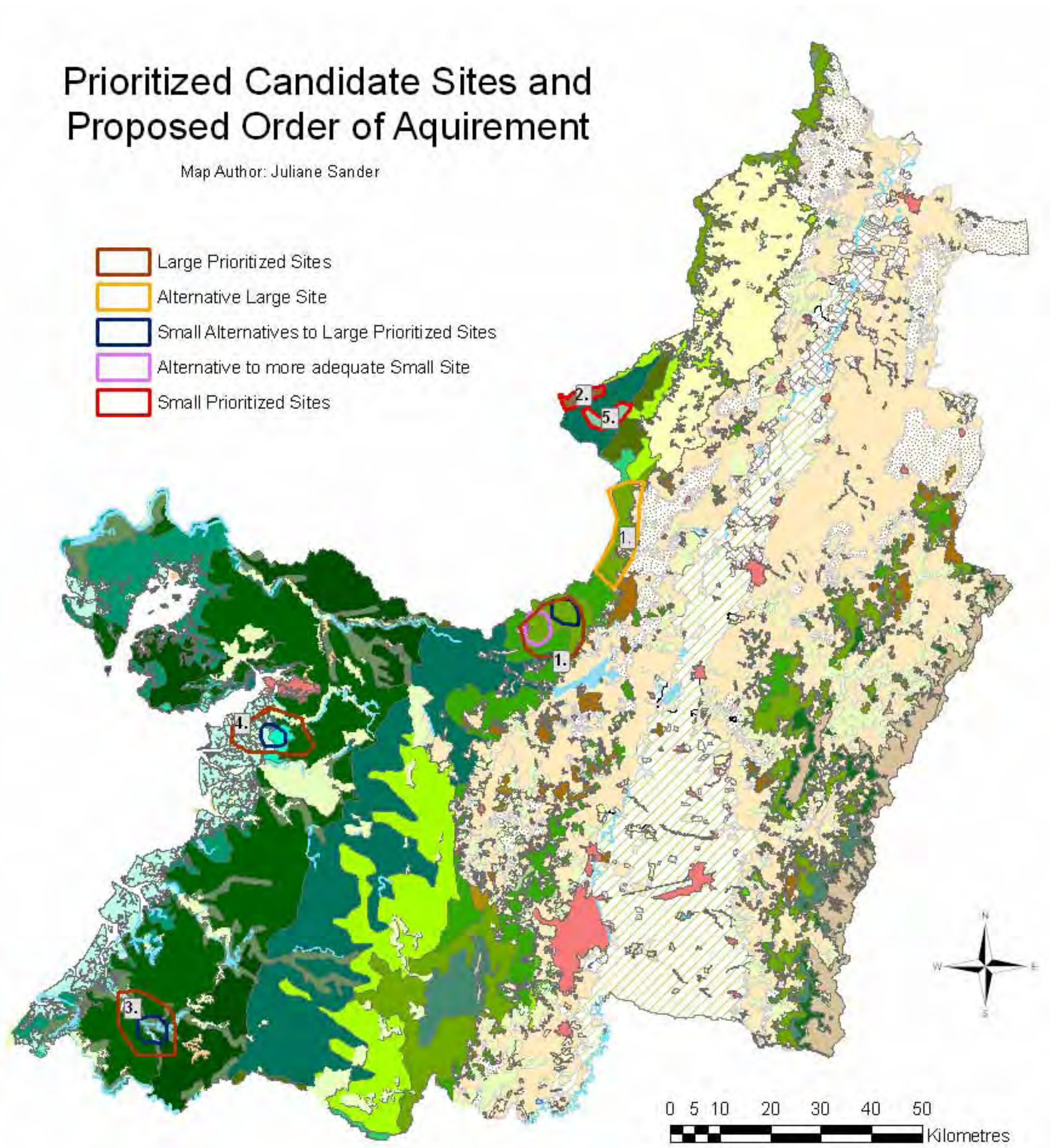

Figure 5.4-V Suggested Additional Protected Area Sites

Site Added	% of currently under-protected Ecosystems protected	% of currently overprotected Ecosystems protected	Area Size (ha)
Large: 7	6.8 % ' Very humid Andean Forest on fluvial mountain deposits' 1.9 % ' Very humid Tropical Forest on structurally eroded hill'	2.7 % ' Humid Sub-Andean Forest on fluvial mountain deposits' 0.1 % ' Very humid Tropical Forest on fluvial mountain deposits' 0.57 % ' Very humid Tropical Forest in alluvial Valley'	10429.11
Alternative **6**	6.4% ' Very humid Andean Forest on fluvial mountain deposits' 0.4 % ' Lakes and Lagoons'	0.1 % ' Humid Sub-Andean Forest on fluvial mountain deposits' 1.2 % ' Pluvial Sub-Andean Forest on structurally eroded mountain'	10429.11
Small: 16	1.8 % ' Very humid Andean Forest on fluvial mountain deposits'	----	2138.68
Alternative **18**	2,1 % ' Very humid Andean Forest on fluvial mountain deposits'	----	2726.32
Small: 12	91 % ' Dry Tropical Forest on structurally eroded mountain'	0.1 % ' Very humid Tropical Forest on fluvial mountain deposits'	2055.33
Large: 8	3.9 % ' Very humid Tropical Forest on fluvial hill deposits' 3,6 % ' Lakes and Lagoons'	5.5 % ' Very humid Tropical Forest in alluvial Valley'	11978.30
Small: 27	2.0 % ' Very humid Tropical Forest on structurally eroded hill' 1.3 % ' Lakes and Lagoons'	2.5 % ' Very humid Tropical Forest in alluvial Valley'	2541.27
Large: 11	8.5 % ' Very humid Mangrove and Coastal Forest on fluvial marine plains' 1.8 % ' Very humid Tropical Forest on fluvial hill deposits' 0.4 % ' Very humid Tropical Forest on fluvial marine plains'	----	10701.44
Small: 23	23 % ' Very humid Mangrove and Coastal Forest on gravitational hill' 1.5 % ' Very humid Tropical Forest on fluvial marine plains'	----	1751.62
Small: 13	93 % ' Pluvial Sub-Andean Forest on fluvial mountain deposits' 0.2 % ' Very humid Tropical Forest on fluvial hill deposits'	----	2385.88

Table 5.4-I Types and Proportions of Ecosystems added within the Reserve Acquisition Schedule

5.5. Conclusion

Attempts to combine the modelled distribution centres of bird and mammal species into protected areas, at the same time containing in the existing protected area system seriously underrepresented ecosystem types, proved to of extreme difficulty as of the highly fragmented state of the study area which made it impossible to include ecosystems of exceptionally reduced cover extents into reasonably-sized protected areas considered as having the potential to conserve a fair share of ecosystem processes. The analyses showed that small new reserve sites were distinguished by a higher level of capability to protect highly size-reduced ecosystem types, as they were characterized by a superior efficiency due to a lower or non-existent proportional content of ecosystem types already overrepresented in the reserve network. However, candidate sites were generally typified by enclosing a relative high proportion of the most abundant ecosystems in existing protected areas, while in addition large natural ecosystem sections of some were already used for agricultural purposes, and many contained considerable-sized areas covered with young grass regrowth. It seems that even smaller selection units would be required for reducing the problem of over-repetition of already sufficiently protected sites. However, the generally observed lower viability of smaller sites objects this idea.

Another observed issue was the apparent ‘over-representation’ of ecosystems with seriously reduced cover extents in newly created small-sized protected areas whereas the majority of ecosystem types with the exception of ‘Very humid Andean Forest on fluvial mountain deposits’ were, after addition of the recommended new sites, further represented with less than ten percent their total area sizes. Examples are the inclusion of 93 percent of remaining cover extent of the ecosystem type ‘ Pluvial Sub-Andean Forest on fluvial mountain deposits' within small site 13 and the enclosure of 91 percent of the ecosystem type ‘ Dry Tropical Forest on structurally eroded mountain’ within small site 12. According to the distributional models of bird species and the analyses of actual sampling events in PATN, the preferred habitat of a vast majority of endangered bird species coincidences with protected areas or ecosystems on the outside of the reserve network that are nonetheless sufficiently protected.

Mammal species, in contrast, were mainly sampled within agro-ecosystems, making any inferences about their preferred ecosystem habitats difficult. The results of this section are more thoroughly evaluated in the following chapter.

6. Additional Recommendations concerning long – term Biodiversity Management within the Valle del Cauca

6.1. Introduction

This chapter commences with a review of the major observations obtained from the analyses in relation to ecosystem and species characteristics of the study area performed in the previous chapter, while questioning the assumption that the implementation of supplementary protected areas suffices in providing for an adequate protection of the area's biodiversity recourses. This is followed by additional suggestions that could potentially contribute to the successful long-term protection of biodiversity in the Valle del Cauca by acknowledging the need for a balanced conservation approach on the landscape level. Furthermore, recommendations are provided in regards to future management and maintenance of biodiversity in the study area.

6.2. Implications of Results

One initial observation of investigations carried out making use of both GIS and PATN procedures was that, according to the analyses, a large proportion of the ecosystems characterized by supplying important habitat for documented bird and mammal species in the study area was sufficiently represented in the existing protected area network. It seems to be, however, problematic to conclude that the protection of habitat for the majority of species is provided for, as for the extreme bias in sampling. Nonetheless, the results indicate that, despite being designed essentially on an *ad*-hoc basis, the existing reserve network is potentially capable of conserving a reasonable share of sampled biodiversity features of the area and that the upkeep and maintenance of the existing network should be attributed high priority.

This in particular necessitates a stricter enforcement of protected areas, especially in the northern part of the national park 'Las Farallones de Cali', due to the peak of modelled bird distributions being concentrated here, and the documented guerrilla presence in parts of the park.

The proposed additional protected areas are designed largely based on the 'precautionary principle', since they were generally distinguished by both relatively low species sampling events and modelled species occurrences. Nonetheless, it is assumed that species dependent on lower altitudes failed to be recorded in the first place due to high sampling bias. The general hypothesis of lowland areas serving as important bird habitat to some degree supports the decision of locating a sizeable proportion of newly designed protected areas in the lowlands of the department. Another beneficial aspect of the enlarged reserve system is that it supports the conservation of very humid Andean forest which, in PATN analyses, proved to supply significant habitat resources for both bird and mammal species while in addition representing the most important habitat type for a vulnerable mammal umbrella species, the night monkey *Aotus lemurinus*.

Yet do the results appear to be somewhat unsatisfactory as the expanded protected area system does not succeed in incorporating those ecosystem types that have been attributed with some of the highest national conservation priorities and highest levels of irreplaceability, namely dry forests. Because of their insignificant sizes, and their locations scattered throughout the highly fragmented part of the department, their inclusion into viably sized protected areas was unfeasible. Consequently, it is recommended to establish privately owned forest reserves at the site of these small fragments. To encourage this, the government could potentially offer economic incentives in the form of tax rebates or others to prospective landholders. Figure 6.2-I illustrates the location of these small fragments, while distinguishing between dry forests and other forest types that have undergone extreme reductions in cover extent, and the respective remaining cover extents of ecosystem types, with dry forests of less than 150 hectares total area size being awarded most urgent conservation priority. The depiction of the department's road network shows the close proximity of small dry forest fragments to roads, consequently further highlighting the necessity of urgent conservation actions.

One concluding remark of this particular reserve design scenario is that corresponding to the IUCN recommendations of protecting an approximate ten percent of every ecosystem's cover extent is an extremely difficult task, in this case caused by the notably high number of ecosystem types due to the fine-scale analysis, and the highly reduced cover extents of some of them, provoking their apparent 'overrepresentation' in the reserve system.

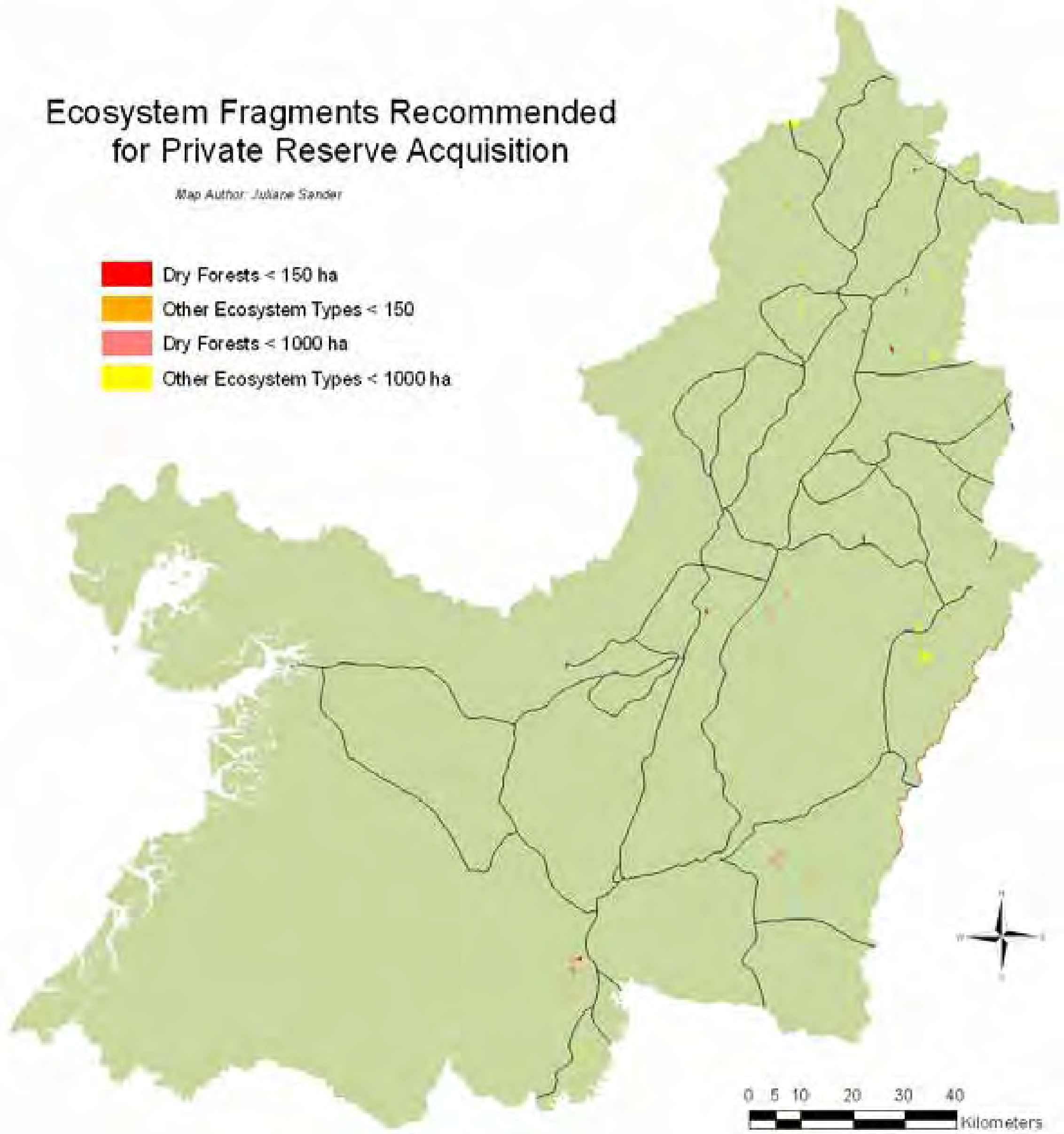

Figure 6.2-I Location of Small Fragments for Private Reserve Acquisition

It is also presumed that, despite of the CVC being one of the most committed regional authorities in relation to conservation matters, a further enhanced cooperation between major research institutions is likely to assist long-term conservation efforts.

There is a clear need for more current species research, in particular from lowland areas where no information on species occurrences exists at all, with the emphasis on the south-western part of the department, in order to protect possibly highly biodiverse areas from the impacts of the armed conflict that is prevalent in the area. Since this study has highlighted the significance of the department as habitat provider for a great number of endangered bird species, more funds could potentially be raised from government agencies and NGO's to assist these research efforts.

6.3. Proposed Amendments towards a Holistic Landscape Approach

The heavily fragmented state of the study area complicates a conservation approach that is based on species dynamics within the entire study area, rather than solely the protection of isolated areas. Due to the small remaining extent of the majority of ecosystem types and the expected high density of biodiversity within fragments, the provision of 'empty patches' that are sparsely used by species but nonetheless are characterized as of considerably importance for metapopulation dynamics proves to be difficult, and is assumingly solely provided for in the case of in the reserve system overrepresented ecosystem types. Because of the documented significance of establishing connections between intact fragments in the habitat matrix, the creation of corridors linking existing and newly designated protected areas as well as larger fragments that have not been prioritized for inclusion in the network is perceived to be of utmost importance.

Even in the event of currently intact large forest fragments covering the interspace between protected areas it is recommended to induce measures to guard these corridor spaces from future acts of land transformation. As the existing and supplementary protected area sites can be interconnected through intact forest fragments, a corridor has to be artificially constructed solely for the purpose of connecting two areas not part of the reserve system. Nonetheless is the effectiveness of corridors in many instances diminished by intersecting roads or areas of agricultural land use. The corridor linking the national park 'Las Farallones de Cali' with newly designated site 8 is regarded as the corridor the most uncomplicated to implement.

Despite the candidate sites created in the vicinity of the national park 'Las Hermosas' having demonstrated high resemblance to protected sites, it is recommended, due to a high concentration of recorded and modelled species occurrences, to establish an augmented species stronghold here through the expansion of 'Las Hermosas'. In this respect it is suggested to enlarge the national park with the incorporation of large candidate site 2 that attained the maximum point score among all candidate sites and which inclusion could be easily realized as for the absence of roads. The proposed interconnecting corridors are illustrated in Figure 6.3-I that also depicts the suggested site of national park expansion.

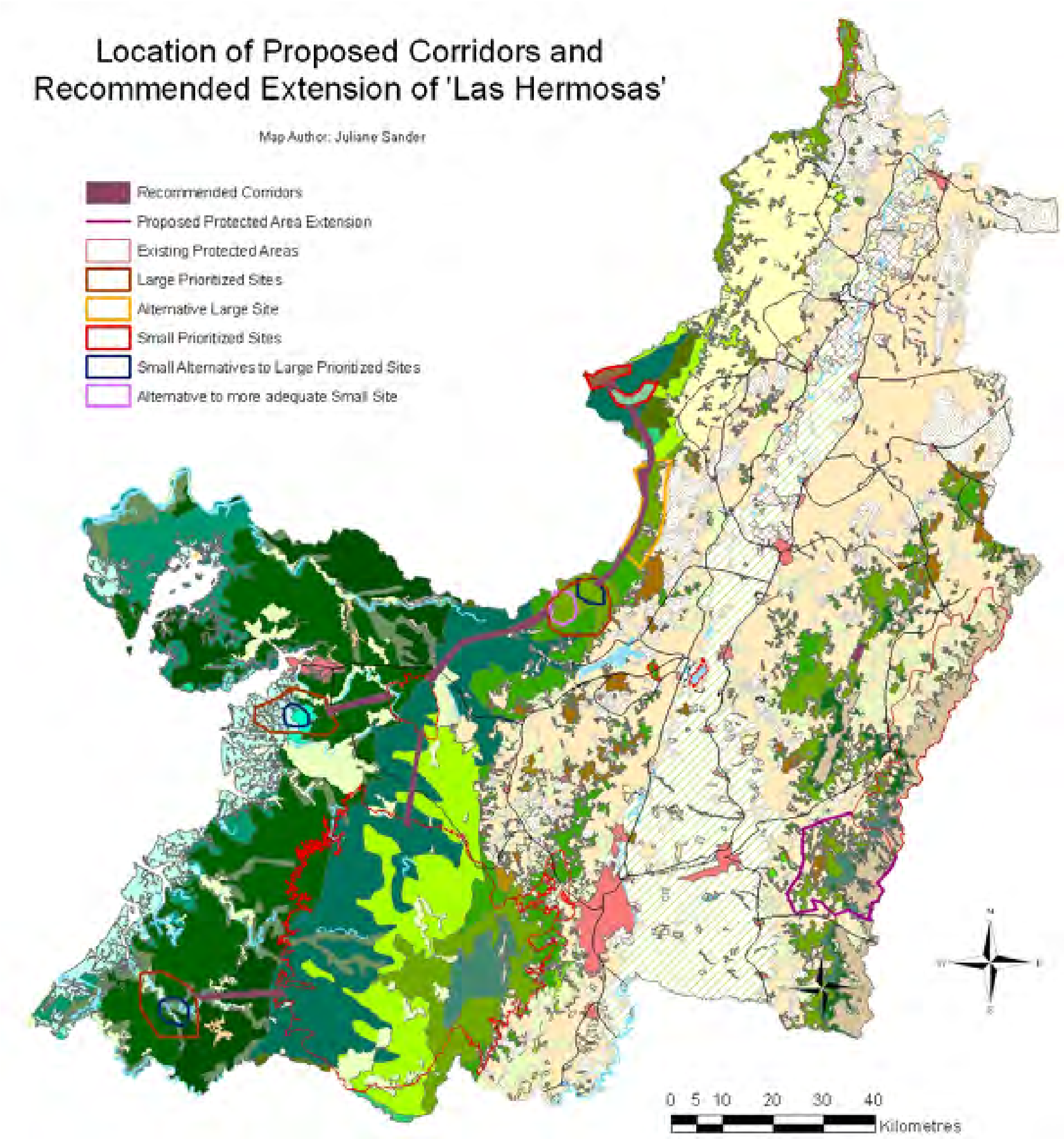

Figure 6.3-I Recommended Amendments to the Conservation Landscape

Furthermore, the close monitoring of future landscape transformation trends in the department appears to be very important in order to facilitate an adaptive management approach, in addition to providing assistance to farmers in regards to sustainable land use management that supports the long-term health of soil resources, leading to a reduced occurrence of abandoned fallows, and consequently potentially lessen the transformation rate of natural ecosystem types. The analysis of ecosystem cover types detected a relative large proportional cover extent of areas with young grass regrowth. It is expected that restoration measures such as the planting of fast-growing pioneer species could possibly shorten the regeneration process and improve the habitat quality of these areas. In addition could field surveys that focus on soil characteristics and determine the nutrient status of soils, and accordingly provide information on the need to artificially enrich their nutrient contents, prove to be useful for accelerating habitat regeneration. It might also be a realistic option to trigger the expansion and regeneration of heavily size-reduced ecosystem types by the adoption of innovative fire regimes, devised in compliance with the requirements of individual tree species.

Lastly, a very prominent observation was the high concentration of species within agro-ecosystems, implying that at least some species can continue to exist even after parts of the landscape have been transformed, as long as larger intact ecosystem fragments are conserved in close proximity to these agricultural land use areas. To further support species occurrence in agro-ecosystems, measures decreasing their hostility to species like the planting of adequate vegetation such as fruit-bearing trees for bird species should be considered. The education of farmers about this aspect and the possible provision of incentives for 'species-friendly agro-ecosystems' are factors to be taken into consideration in regards to this aspect.

6.4. Conclusion

This chapter critically evaluated the capability of the expanded protected area network to provide for the preservation of the department's biodiversity, highlighting the need for further conservation measures in addition to the acquisition of prioritized candidate sites into the protected area network.

The highly advanced fragmentation state of the study area caused the necessity for such supplementary conservation actions of which the inclusion of fragments of heavily size-reduced ecosystem types, in particular dry forests, into private reserves, clearly presents the most urgent one. In order to facilitate the accomplishment of at least a part of the recommended measures, large quantities of both financial funds and management dedication are required. However, as of the CVC's strong interest in biodiversity protection and demonstrated willingness to cooperate, the conservation prospects of this department appear to be a lot less bleak compared to other departments in Colombia.

7. Conclusion

The principal objective of this research study could only be partially achieved due to the appearance of considerable complications arising in conjunction with the specific characteristics of the study area and accessible data. Only in regards to one single currently under-protected humid Andean forest type, the creation of a new protected area that both accounted for the results of the gap analysis and the modelled distribution of prioritized species was realizable. The considerably low score values of the majority of remaining prioritized candidate sites signified an only weak accomplishment of the key objective. Main factors hindering the adequate representation of presently insufficiently protected ecosystems in newly designated sites were the highly fragmented character of a substantial part of the study area, with fragmentation processes having been concentrated within the right half of the department, and the high level of observed ecosystem heterogeneity due to the analysis having been conducted at a fine scale.

The most significant deficit of the extended protected area network is its failure to include those dry forest ecosystem types that have been reduced to insignificantly sized fragments and at the same time represent the most vulnerable and irreplaceable ecosystem types. Consequently, the conservation efficiency of the expanded reserve network is dependent on the implementation of supplementary mechanisms such as the establishment of private reserves.

Despite of national protected areas in Colombia being generally typified by substantially large sizes, and small reserves being usually owned privately, in the case of the attainment of private reserve proving to be infeasible in the imminent future, alternative actions on the public part have to be taken.

In contrast to many biodiversity hotspots in the developing world, the study area was differentiated by a comparably large-sized existing protected area network which, according to distributional modelling, was evaluated as being unexpectedly effective in covering important bird and mammal habitat while furthermore including ecosystem types that were also located within vulnerable locations in currently unprotected regions of the department. Consistent with the analyses performed in PATN and GIS, the ecosystem types distinguished by both a high species abundance and uniqueness of species assemblage composition were among those ecosystems already overrepresented in the *ad-hoc* designed reserve system. Since the sampling of bird species mainly took place inside protected areas or in close vicinity to, no information could be obtained about the occurrence of species which habitat requirements considerably differed from the in protected areas enclosed environments. Despite the assumption of lowland areas providing important bird habitat, it is nonetheless supposed that the concentration of species in humid sub-Andean forests to a certain extent is reflecting the real situation. This could be explained with the phenomenon of a 'biogeographic crossroad', assimilating both lowland and Andean species, with the literature effectively confirming the tolerance of a large number of endemic bird species to this habitat type.

The observation of numerous species, in particular mammal species, having been recorded in agricultural areas bordering with forest fragments, emphasizes the significance of ecotones in the Valle del Cauca, and the necessity to focus more conservation attention on these places of intersection. Similarly, the general high resemblance in species assemblage composition between transformed and natural ecosystems accentuated the need for a holistic landscape management that allows for the movement of species and decreases the habitat hostility of land use areas through instruments such as 'conservation islands'.

Lastly, the relatively large biodiversity potential of the Valle el Cauca, due to the mainly intact state of forests within the left half of the department, became apparent in this study, even with the use of only limited available and biased species data. At the same time the vulnerability of this departmental region, especially in relation to the continuing growth of the industrial centre Buenaventura, was revealed, as well as the importance of monitoring developmental trends and the need for a stricter enforcement of protected areas in the Valle del Cauca.

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Appendix A

Tables in regards to Cover Extents of single Ecosystem Types and Sampled Bird and Mammal Species

A.1. Study Area's Ecosystem Types

Ecosystem Type	Total Area (hectares)
Cattle Agro-Ecosystems	495508.851
Sugarcane Agro-Ecosystems	202112.296
Very humid Tropical Forest on fluvial hill deposits	162921.029
Very humid Tropical Forest on fluvial mountain deposits	145527.871
Very humid Andean Forest on fluvial mountain deposits	118897.969
Grassy Regrowth	114999.388
Coffee Agro-Ecosystems	102398.605
Very humid Sub-Andean Forest on fluvial mountain deposits	95971.184
Undifferentiated Agro-Ecosystems	90547.97
Humid Sub - Andean Forest on fluvial mountain deposits	71860.68
Very humid Tropical Forest on structurally eroded hill	70990.70
Very humid Tropical Forest on fluvial marine plains	52345.87
Very humid Tropical Forest in alluvial Valley	49220.14
Very humid Mangrove and Coastal Forest on fluvial marine plains	47970.96
Humid Páramo on volcanic rock deposits	42596.36
Small dry Agro-Ecosystems	30131.94
Urban Areas	29113.53
Forest Plantations	21353.10
Very humid High-Andean Forest on fluvial mountain deposits	21038.87
Very humid High-Andean Forest on volcanic rock deposits	18469.58
Lakes and Lagoons	14843.75
Very humid Tropical Forest on structurally eroded mountain	9433.35
Other Land Uses	6791.34
Dry Sub-Andean Forest on fluvial mountain deposits	5142.06
Fruit Agro-Ecosystems	4121.92
Very Humid Mangrove and Coastal Forest on gravitational hill	3895.08
Gallery Forest	3843.00
Humid Páramo on fluvial mountain deposits	3351.45
Dry Tropical Forest on fluvial mountain deposits	3109.96
Pluvial Sub-Andean Forest on structurally eroded mountain	3018.14
Very humid Mangrove and Coastal Forest in alluvial Valley	2985.67
Pluvial Sub-Andean Forest on fluvial mountain deposits	2272.86
Humid Sub-Andean Forest on colluvial-alluvial lower mountain deposits	2079.32
Dry Tropical Forest on structurally eroded mountain	2012.05
Currently Uncultivated Agricultural Land	1668.11
Very Humid Tropical Forest on alluvial plains	1529.02
Humid Sub-Andean Forest on hill relief	1399.27
Very humid Mangrove and Coastal Forest on alluvial plains	1167.12
Very humid Mangrove and coastal Forest on structurally eroded hill	1133.81
Pluvial High-Andean Forest on structurally eroded mountain	702.76
Very humid High-Andean forest on structurally eroded mountain	615.94
Dry Sub-Andean Forest on colluvial-alluvial lower mountain deposits	599.23
Humid Sub-Andean Forest on structurally eroded mountain	369.73
Banana Agro-Ecosystems	344.93
Dry Sub-Andean Forest on structurally eroded mountain	232.73
Humid Tropical Forest on colluvial-alluvial lower mountain deposits	190.01
Very humid Andean forest on structurally eroded mountain	167.54
Very humid Sub-Andean Forest on colluvial-alluvial lower mountain deposits	158.11

Very humid Sub-Andean Forest in alluvial valley	147.69
Dry Tropical Forest on structurally eroded hill	123.06
Humid Dry Forest on colluvial-alluvial lower mountain deposits	117.69
Very humid Andean Forest on colluvial-alluvial lower mountain deposits	114.51
Artificial Fish Ponds	104.16
Dry Tropical Forest on alluvial plains	88.47
Dry Tropical Forest on hill relief	61.71
Humid Páramo on structurally eroded mountain	49.55
Dry Sub-Andean Forest on hill relief	39.34
Very humid Sub-Andean Forest on structurally eroded mountain	33.13
Humid Tropical Forest on hill relief	30.38

Table 1 List of Ecosystems and their Area Coverage

A.2. Sampled Bird Species

Species	Common Name	Conservation Status	Number of Individuals
Ammodramus savannarum caucae	Yellow-winged Sparrow	CR	133
Ampelion rufaxilla antioquiae	Chestnut-crested Cotinga	VU	2
Anas cyanoptera septentrionales	Cinnamon Teal	EN	5
Anas cyanoptera	Cinnamon Teal	EN	319
Anas georgica spinicauda	Yellow-billed Pintail	EN	18
Andigena hypoglauca	Grey-breasted Mountain Toucan	VU	32
Andigena nigrirostris occidentalis	Grey-breasted Mountain Toucan	VU	6
Andigena nigrirostris spilorhynchus	Grey-breasted Mountain Toucan	VU	2
Ara militaris	Military Macaw	VU	51
Bangsia aureocincta	Gold-ringed Tanager	EN	28
Bangsia melanochlamys	Black-and-gold Tanager	VU	10
Bolborhynchus ferrugineifrons	Rufous-fronted Parakeet	VU	10
Cacicus uropygialis pacificus	Pacific Cacique	VU	14
Campylorhamphus pucherani	Greater Scythebill	NT	4
Capito quinticolor	Five-colored Barbet	VU	16
Cephalopterus penduliger	Long-wattled Umbrellabird	VU	64
Chauna chavaria	Northern Screamer	VU	4
Chlorochrysa nitidissima	Multicolored Tanager	VU	626
Chloropipo flavicapilla	Yellow-headed Manakin	NT	54
Chlorospingus flavovirens	Yellow-green Bush-Tanager	VU	60
Cyanolyca pulchra	Beautiful Jay	NT	4
Cypseloides lemosi	White-chested Swift	CR	10
Dacnis hartlaubi	Turquoise Dacnis-Tanager	VU	60
Diglossa gloriosissima	Chestnut-bellied Flowerpiercer	EN	2
Dysithamnus occidentalis	Bicolored Antvireo	EN	20
Glaucidium nubicola	Cloud-forest Pygmy-Owl	VU	10
Grallaricula cucullata	Hooded Antpitta	NT	4
Harpyhaliaetus solitarius	Solitary Eagle	EN	10
Hypopyrrhus pyrohypogaster	Red-bellied Grackle	EN	2
Iridosornis porphyrocephala	Purplish-mantled Tanager	NT	2
Leptosittaca branickii	Golden-plumed Parakeet	VU	9
Leucopternis semiplumbea	Semiplumbeous Hawk	NT	2
Melanerpes chrysauchen	Golden-naped Woodpecker	VU	2
Micrastur plumbeus	Plumbeous Forest-Falcon	VU	2
Myadestes leucogenys	Rufous-brown Solitaire	NT	2
Neomorphus radiolosus	Banded Ground-Cuckoo	EN	29
Netta erythrophthalma	Southern Pochard	CR	173
Nothocercus bonapartei intercedens	Highland Tinamou	NT	4
Ognorhynchus icterotis	Yellow-eared Parrot	CR	4
Oreothraupis arremonops	Tanager Finch	CR	20
Oroaetus isidori	Black-and-chestnut Eagle	EN	50
Oryzoborus crassirostris	Large-billed Seed-Finch	NT	8
Otus colombianus	Colombian Screech-Owl	NT	6
Penelope ortoni	Baudo Guan	VU	137
Penelope perspicax	Cauca Guan	EN	238
Pionopsitta pyrilia	Saffron-headed Parrot	VU	1
Polystictus pectoralis	Bearded Tachuri	NT	1
Ramphastos ambiguus	Black-mandibled Toucan	NT	2

Saltator cinctus	Masked Saltator	VU	2
Sarkidiornis melanotos carunculatus	Comb Duck	EN	9
Semnornis ramphastinus caucae	Toucan Barbet	NT	29
Spizastur melanoleucus	Black-and-White Hawk-Eagle	NT	1
Sporophila insulata	Tumaco Seedeater	CR	1
Tangara johannae	Blue-whiskered Tanager	NT	1
Tinamus tao	Grey Tinamou	NT	2
Total			**2317**

Table 2 Bird Species documented as occurring in the Valle del Cauca

A.3. Sampled Mammal Species

Species	Common Name	IUCN Status	Number of Individuals
Agouti taczanowski	Mountain Paca	LR-nt	1
Akodon affinis	Colombian Grass Mouse	LR-lc	6
Akodon bogotensis	Bogota Grass Mouse	LR-lc	2
Alouatta seniculus	Red Howler Monkey	LC	2
Anoura caudifera	Tailed Tailless Bat	LR-lc	5
Anoura geoffroyi	Geoffroy's Tailless Bat	LR-lc	12
Aotus lemurinus	Colombian Night Monkey	VU	2
Artibeus glaucus	Silver Fruit Eating Bat	LR-lc	3
Artibeus jamaicensis	Jamaican Fuit Bat	LR-lc	4
Artibeus lituratus	Greater Fruit Eating Bat	LR-lc	6
Artibeus phaeotis	Pygmy Fruit- Eating Bat	LR-lc	2
Artibeus toltecus	Toltec Fruit- Eating Bat	LR-lc	1
Bassaricyon gabbii	Bushy-Tailed Olingo	LR-nt	1
Cabassous centralis	Northern Naked -Tailed Armadillo	DD	1
Caenolestes fuliginosus	Silky Shrew Opossums	LR-lc	1
Carollia brevicauda	Silky Short-Tailed Bat	LR-lc	21
Carollia Castanea	Chestnut Short-Tailed Bat	LR-lc	5
Carollia Perspicillata	Seba's Short Tailed Bat	LR-lc	7
Cerdocyon thous	Crab-eating Zorro	LC	13
Echinoprocta rufescens	Stump-Tailed Porcupine	LR-lc	3
Conepatus semistriatus	Striped Hog-Nosed Skunk	LR-lc	1
Chiroderma salvini	Salvin's Big-Eyed Bat	LR-lc	1
Chironectes minimus	Water Opossum	LR-nt	1
Choloepus hoffmanni	Hoffmann's Two-Toed Sloth	DD	2
Dasypus novemcinctus	Nine-Banded Armadillo	LR-lc	13
Desmodus rotundus	Vampire Bat	LR-lc	4
Didelphis albiventris	White-Eared Opossum	LR-lc	2
Didelphis marsupialis	Southern Opossum	LR-lc	7
Eira barbara	Tayra	LR-lc	1
Eptesicus brasiliensis	Brazilian Brown Bat	LR-lc	2
Glossophaga soricina	Nectar or Long-Tongued Bat	LR-lc	12
Herpailurus yagouaroundi	Jaguarundi	LC	5
Heteromys australis	Southern Spiny Pocket Mouse	LR-lc	5
Histiotus montanus	Small Big-Eared Brown Bat	LR-lc	1
Lasiurus blossevilli	Western Red Bat	LR-lc	5
Lutra longicaudis	Neotropical Otter	LC	1
Melanomys caliginosus	Dusky Rice Cat	LR-lc	2
Microryzomys altissimus	Highland Small Rice Cat	LR-lc	1
Mustela frenata	Long-Tailed Weasel	LR-lc	6
Myotis keaysi	Hairy- Legged Myotis	LR-lc	1
Myotis nigricans	Black Myotid Bat	LR-lc	9
Nasua nasua	South American Coati	LR-lc	2
Neacomys tenuipes	Narrow - Footed Bristly Mouse	LR-lc	1
Neusticomys monticolus	Montane Fish - Eating Rat	LR-lc	1
Noctilio albiventris	Lesser Bulldog Bat	LR-lc	1
Oryzomys albigularis	Tome's Rice Rat	LR-lc	16
Oryzomys alfaroi	Alfaros's Rice Rat	LR-lc	6
Platyrrhinus dorsalis	Thomas's Broad-Nosed Bat	LR-lc	13

Platyrrhinus helleri	Heller's Broad – Nosed Bat	LR-lc	2
Platyrrhinus vittatus	Greater Broad-Nosed Bat	LR-lc	4
Potos flavus	Kinkajou	LR-lc	7
Reithrodontomys mexicanus	Mexican Harvest Mouse	LR-lc	1
Rhipidomys latimanus	Broad - Footed Climbing Mouse	LR-lc	1
Rhipidomys venustus	Charming Climbing Mouse	LR-lc	1
Sciurus granatensis	Red-tailed Squirrel	LR-lc	12
Sturnia aratathomasi	Aratathomas Yellow - Shouldered Bat	LR-nt	1
Sturnia bidens	Bidentate Yellow -Shouldered Bat	LR-nt	7
Sturnia erythromos	Hairy Yellow-Shouldered Bat	LR-lc	17
Sturnia lilium	Little Yellow-Shouldered Bat	LR-lc	9
Sturnia Ludovico	Highland Yellow-Shouldered Bat	LR-lc	17
Sylvilagus brasiliensis	Forest Rabbit	LR-lc	5
Thomasomys aureus	Golden Oldfield Mouse	LR-lc	2
Thomasomys cinereiventer	Ashy-Bellied Oldfield Mouse	LR-lc	4
Thomasomys laniger	Oldfield Mouse	LR-lc	2
Thyroptera tricolor	Spix's Disk-Winged Bat	LR-lc	1
Vampyressa pusilla	Little Yellow-Eared Bat	LR-lc	1
Zygodontomys brunneus	Brown Cane Mouse	LR-lc	4
Total			318

Table 3 Mammals species sampled in the Valle del Cauca

Annotations to the table: LR - lc = Lower Risk – least concern
LR - nt = Lower Risk – near threatened
LC = Least Concern
DD = Data Deficient

Appendix B

Maps of modelled Species' Distributions

B.1. Modelled Bird Species' Distributions

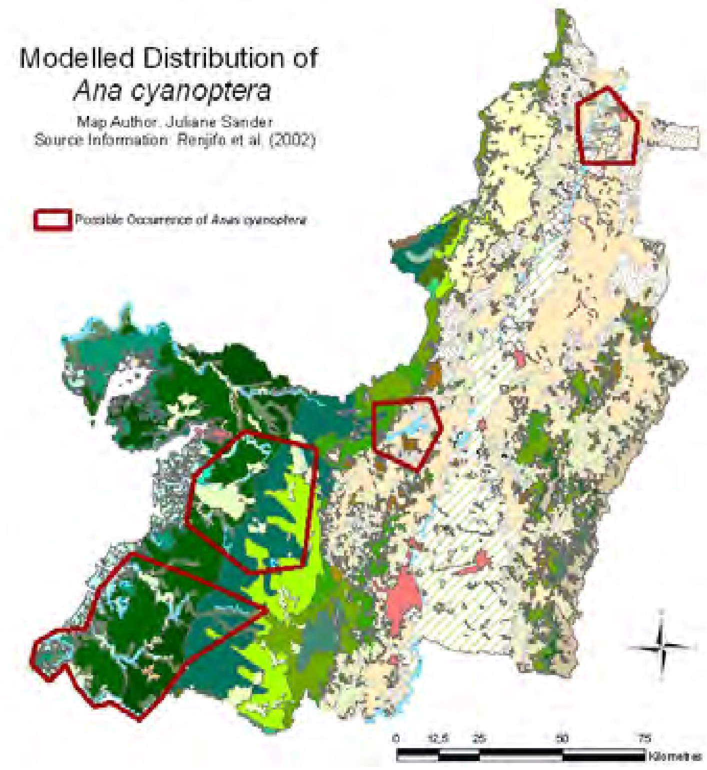

Figure 1 Cinnamon Teal *Anas Cyanoptera*

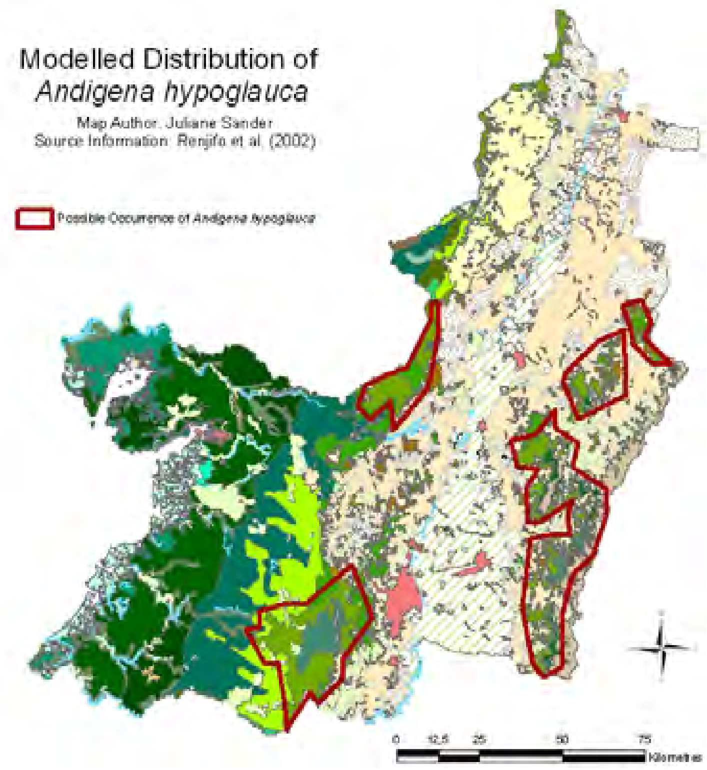

Figure 2 Grey-Breasted Mountain Toucan *Andigena Hypoglauca*

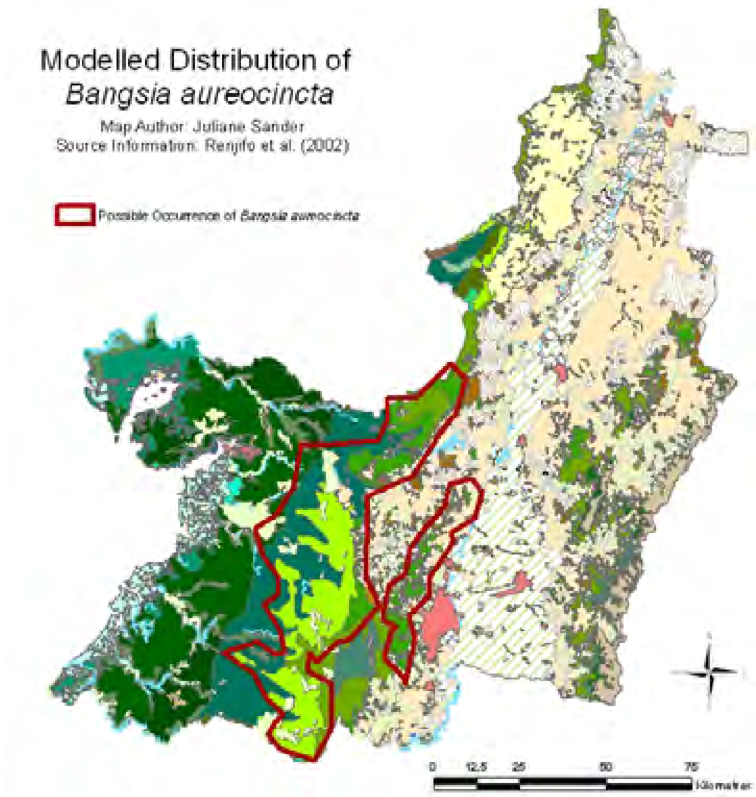

Figure 3 Gold-ringed Tanager *Bangsia aureocincta*

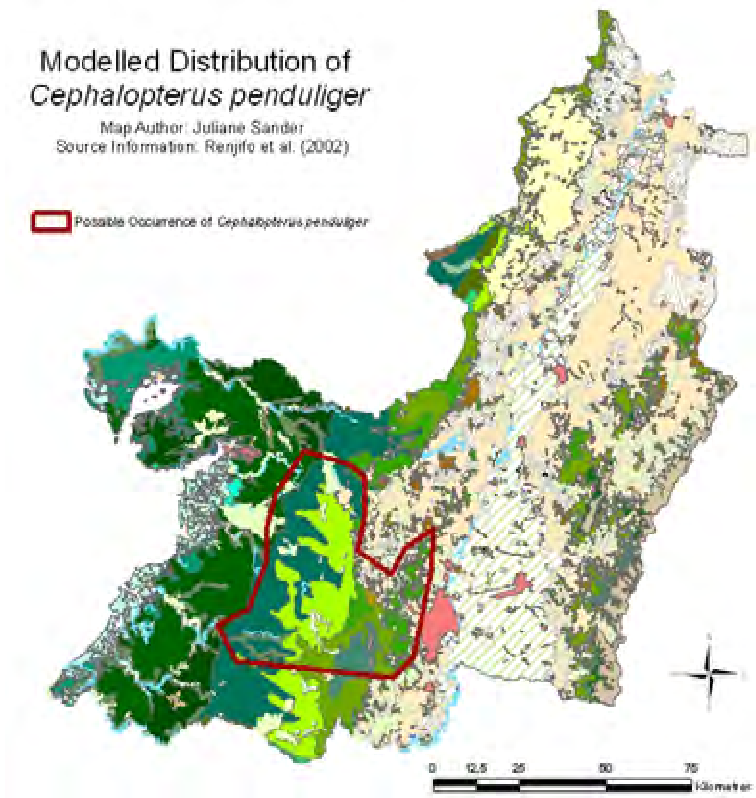

Figure 4 Long-Wattled Umbrellabird *Cephalopterus penduliger*

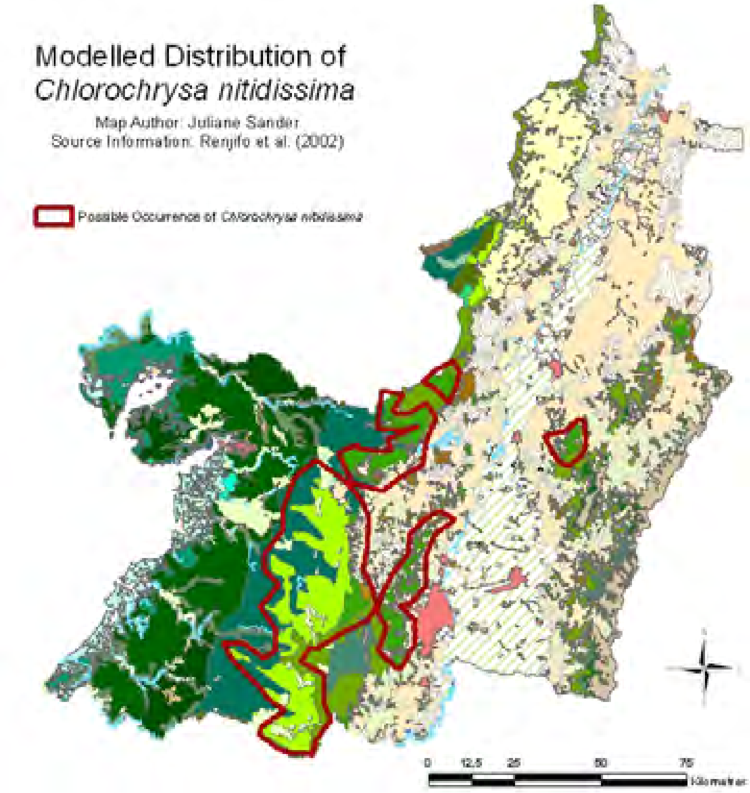

Figure 5 Multicolored tanager *Chlorochrysa nitidissima*

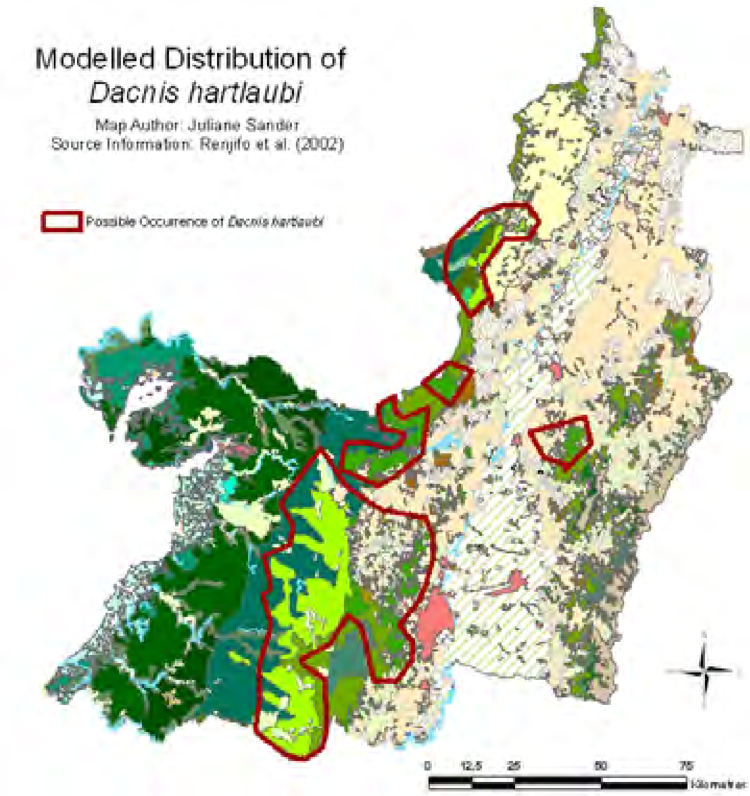

Figure 6 Turquoise Dacnis-Tanager *Dacnis hartlaubi*

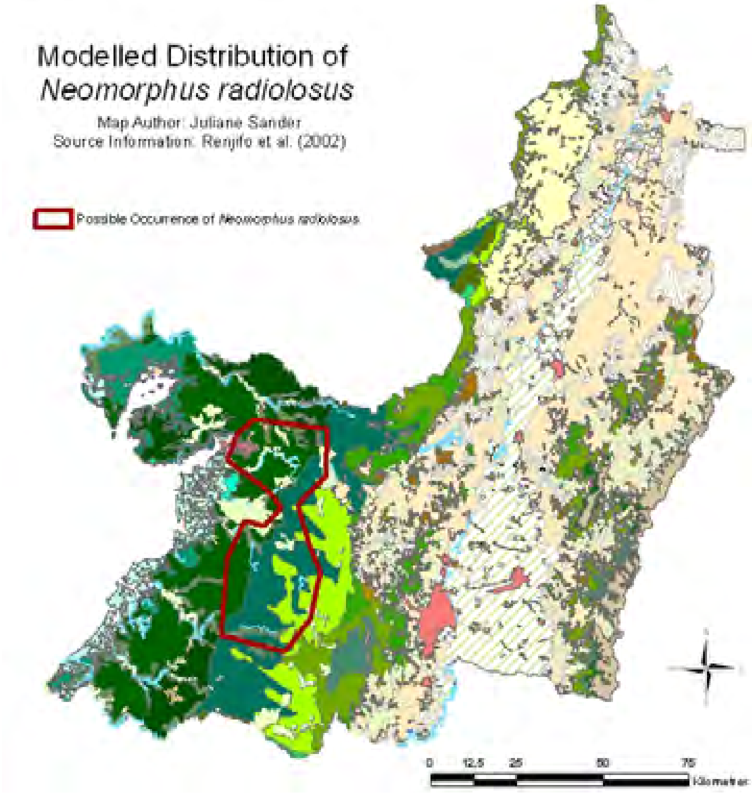

Figure 7 Banded Ground-Cuckoo *Neomorphus radiolus*

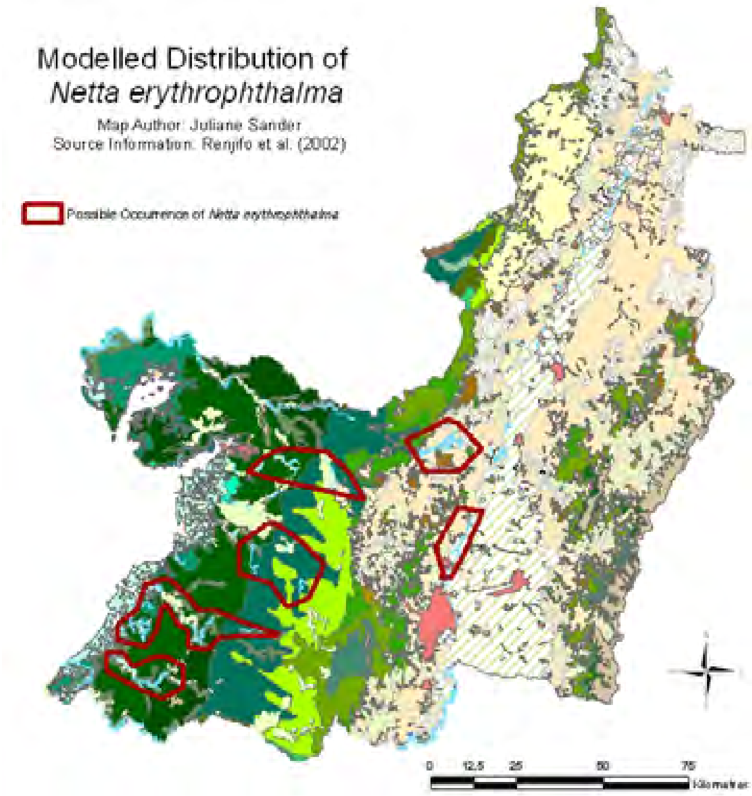

Figure 8 Southern Pochard *Netta erythrophthalma*

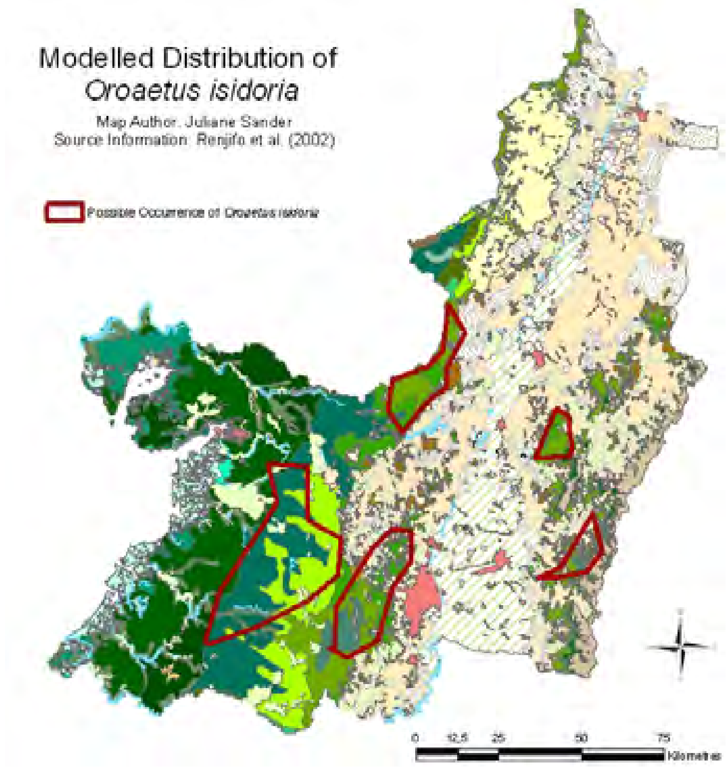

Figure 9 Black-and-chestnut Eagle *Oroaetus isidoria*

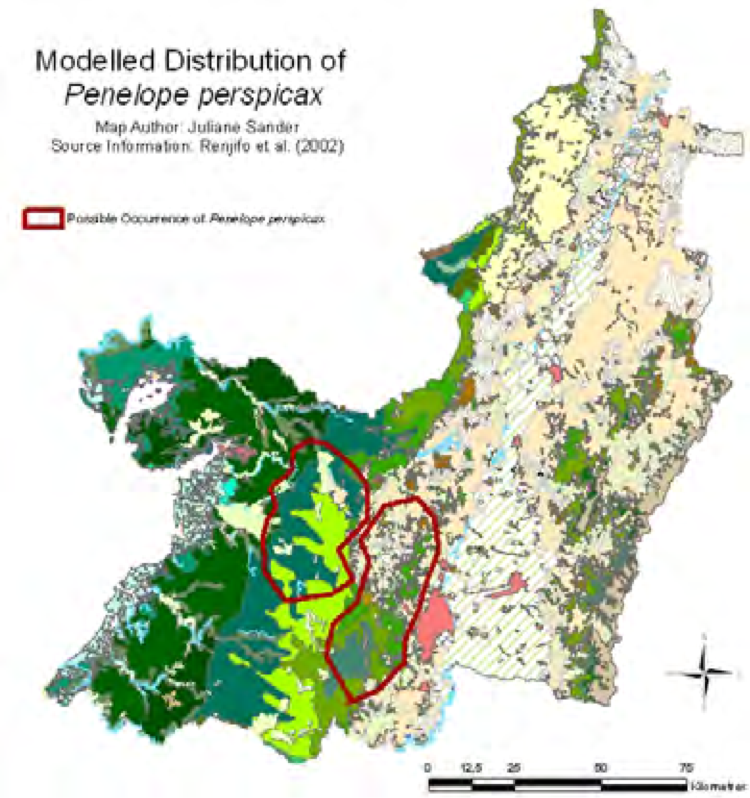

Figure 10 Cauca Guan *Penelope perspicax*

B.2. Modelled Mammal Species' Distributions

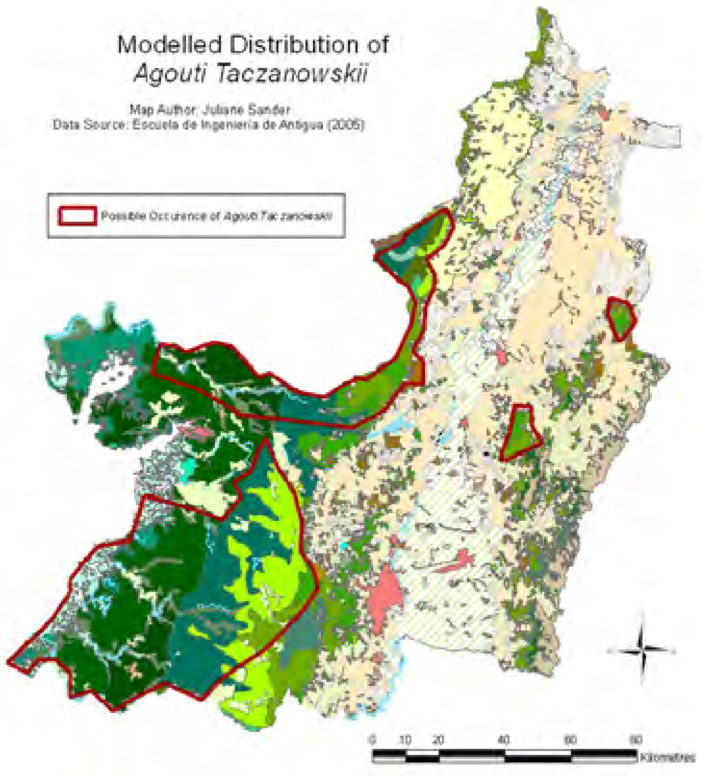

Figure 11 Mountain Paca *Agouti taczanowskii*

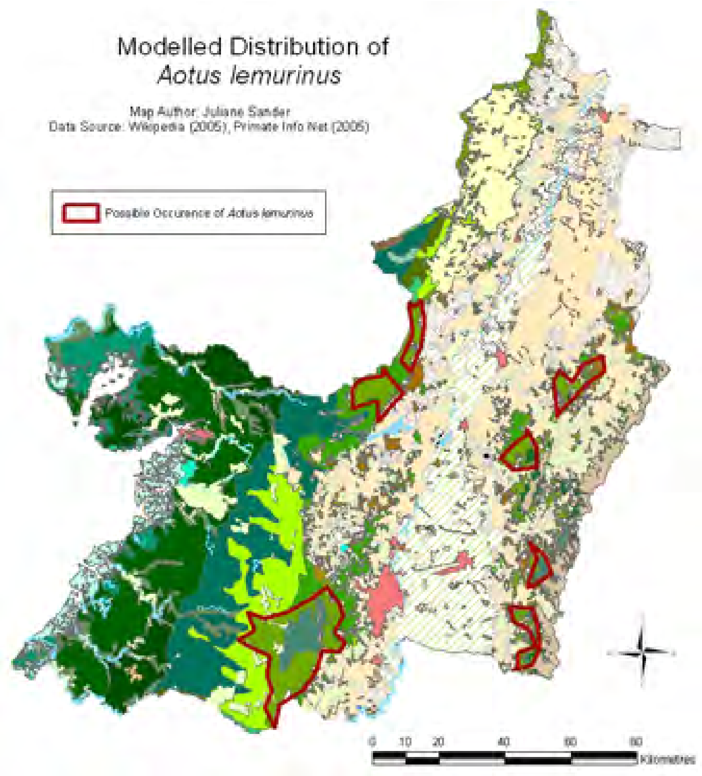

Figure 12 Colombian Night Monkey *Aotus lemurinus*

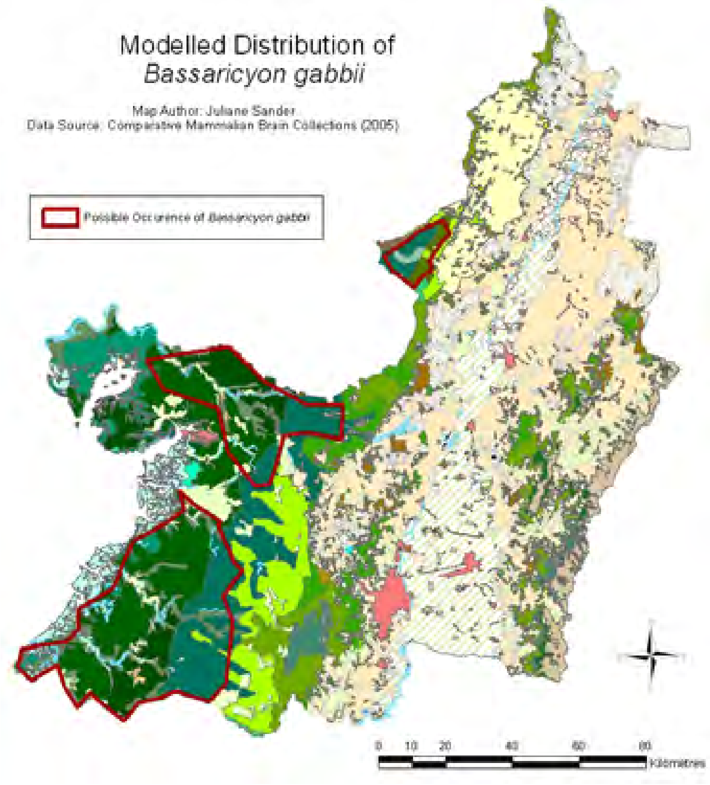

Figure 13 Bushy-tailed Oringo *Bassaricyon gabbii*

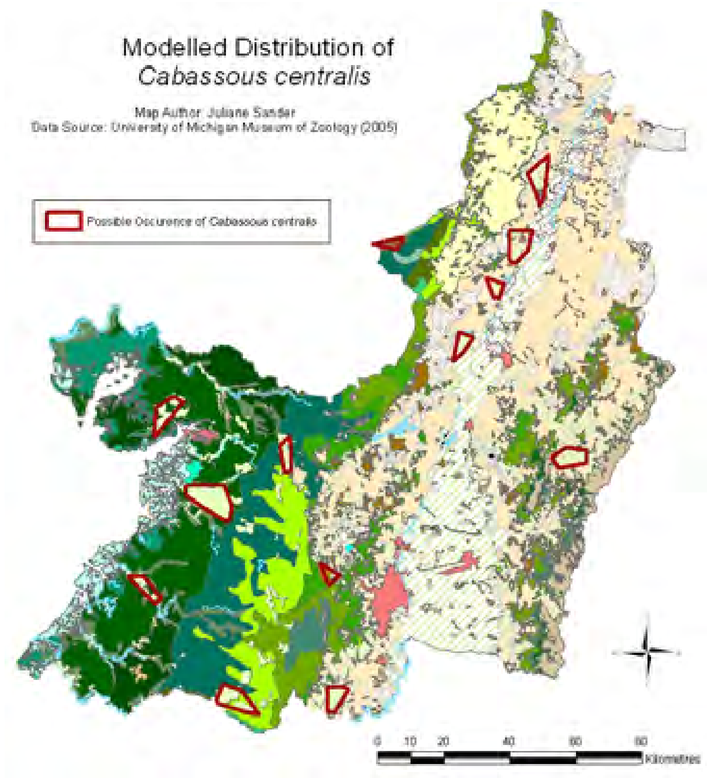

Figure 14 Northern Naked-Tailed Armadillo *Cabassous centralis*

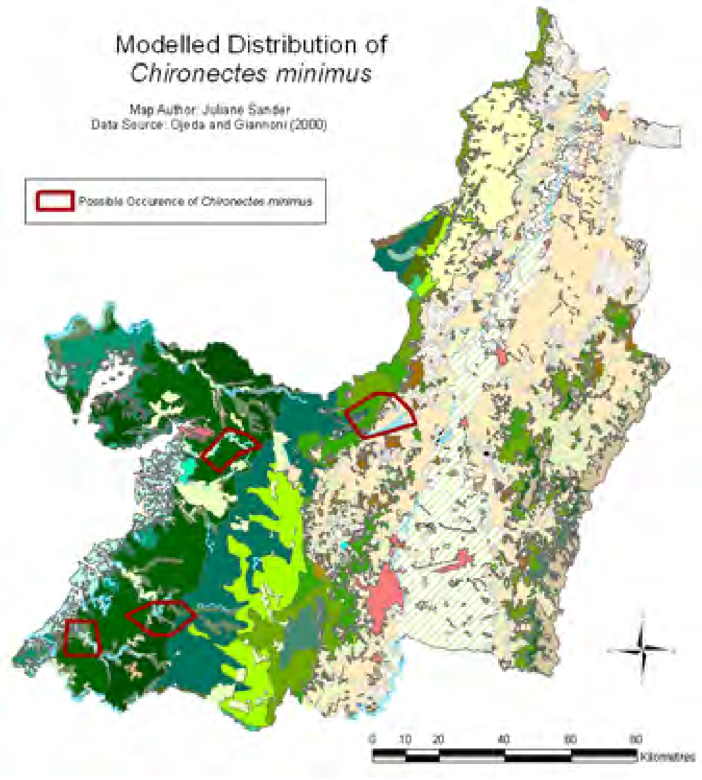

Figure 15 Water Opossum *Chironectes minimus*

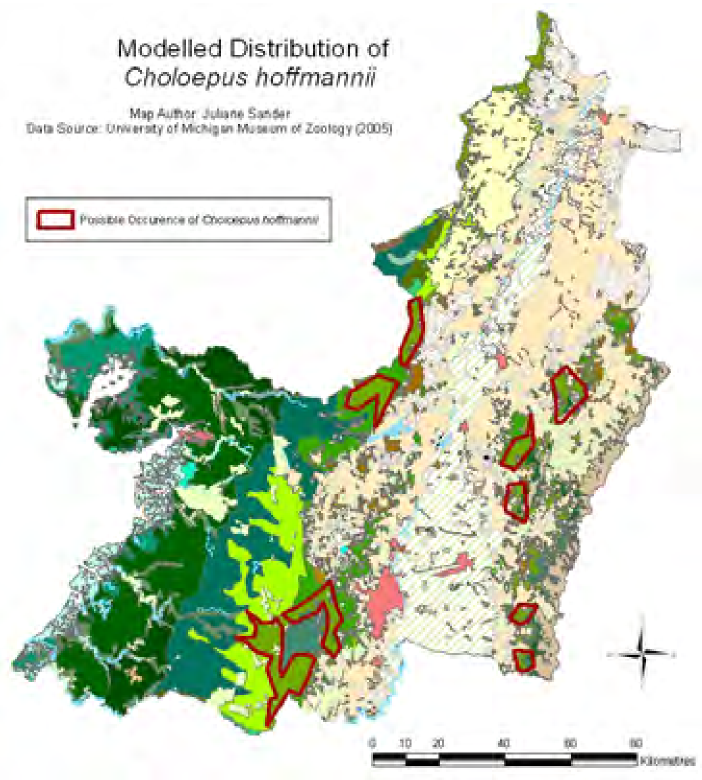

Figure 16 Hoffmann's Two-Toed Sloth *Choloepus hoffmanni*

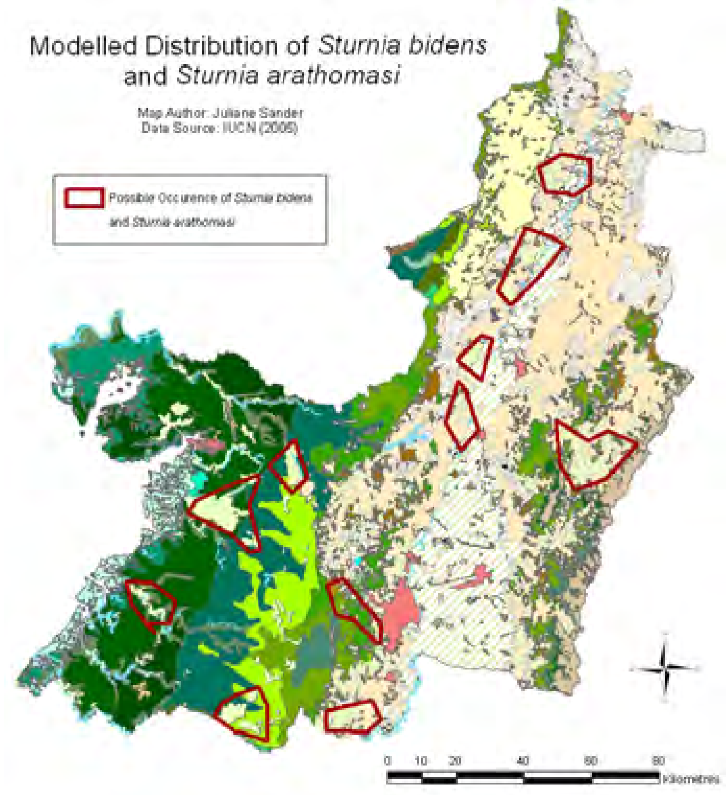

Figure 17 Bidentate Yellow-Shouldered Bat *Sturnia bidens* and Arathomas Yellow-Shouldered Bat *Sturnia arathomasi*

Appendix C

Score Evaluation of Single Candidate Sites

	No Bird Species Modelled	Umbrella Bird Species	No Individual Birds	No CR Bird Species	No Mammal Species Modelled	Umbrella Mammal Species	No Individual Mammals	No Priority Mammal Species	Vulnerable Location	Contains Ecosystems < 150 ha	Contains Bird Ecosystems prioritized through PATN	Contains Mammal Ecosystems prioritized through PATN	Score
Site 1	0	Ah	0	0	2	Al, Ch	7-10	3	YES	0	0	YES	35
Site 2	2	Ah	26-45	1	1	Al	7-10	1	YES	YES	0	YES	51
Site 3	4	Ah, Cn	0	0	2	Al, Ch	0	1	YES	0	0	YES	34
Site 4	0	Ah	0	0	2	Al, Ch	0	0	0	0	0	YES	16
Site 5	2	0	0	0	2	0	0	0	YES	0	YES	0	19
Site 6	2	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	31
Site 7	4	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	33
Site 8	2	0	0	0	2	0	0	0	0	0	YES	0	9
Site 9	8	Cn	11-25	3	1	0	0	0	0	0	YES	0	29
Site 10	7	Cn	11-25	3	1	0	0	0	0	0	0	0	23
Site 11	0	0	0	0	1	0	0	0	YES	0	0	0	11
Site 12	7	0	11-25	1	2	0	0	0	YES	0	YES	0	32

Table 1 Attributes and Scores of preliminary selected Larger-sized Protected Areas

Annotations to Tables 1 and 2: Ah = Andigena hypoglauca
Cn = Chlorochrysa nitidissima
Al = Aotus lemurinus
Ch = Choloepus hoffmanni

	No Bird Species Modelled	Umbrella Bird Species	No Individual Birds	No CR Bird Species	No Mammal Species Modelled	Umbrella Mammal Species	No Individual Mammals	No Priority Mammal Species	Vulnerable Location	Contains Ecosystems < 150 ha	Contains Bird Ecosystems prioritized through PATN	Contains Mammal Ecosystems prioritized through PATN	Score
Site 1	1	Ah, Cn	0	0	2	Al, Ch	0	2	YES	0	0	YES	32
Site 2	1	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	30
Site 3	2	Ah, Cn	11-25	0	1	Al	7-10	2	YES	0	0	YES	41
Site 4	2	Ah, Cn	0	0	0	0	7-10	1	YES	0	0	YES	30
Site 5	1	Ah, Cn	11-25	0	1	Ch	0	0	0	0	0	YES	22
Site 6	2	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	31
Site 7	2	Ah, Cn	0	0	1	Al	0	0	0	0	0	0	12
Site 8	4	Ah	0	0	2	Al, Ch	0	0	YES	0	0	YES	30
Site 9	4	Ah, Cn	0	0	1	0	0	0	YES	0	0	YES	26
Site 10	1	Ah, Cn	0	0	2	Al, Ch	0	0	0	0	0	YES	20
Site 11	1	Ah, Cn	0	0	2	Al, Ch	0	0	0	0	0	0	15
Site 12	0	0	0	0	1	0	0	0	YES	0	0	0	11
Site 13	2	0	0	0	2	0	0	0	0	0	0	0	4
Site 14	0	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	29
Site 15	2	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	31
Site 16	4	Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	30
Site 17	4	Ah, Cn	0	0	4	Al, Ch	0	0	YES	0	YES	YES	40
Site 18	3	Ah, Cn	0	0	2	Al, Ch	0	0	YES	0	0	YES	32
Site 19	5	0	0	0	1	0	4-6	0	0	0	YES	0	15
Site 20	6	0	0	0	1	0	1-3	0	0	0	YES	0	14
Site 21	7	0	6-10	1	2	0	1-3	0	0	0	YES	0	22
Site 22	2	0	0	0	2	0	0	0	0	0	YES	0	9
Site 23	0	0	0	0	1	0	0	0	YES	0	0	0	11
Site 24	0	0	0	0	1	0	0	0	0	0	0	0	1
Site 25	6	0	6-10	0	0	0	0	0	0	0	0	0	10
Site 26	2	0	0	0	2	0	0	0	YES	0	YES	0	19
Site 27	2	0	0	0	2	0	0	0	0	0	YES	0	9
Site 28	8	0	0	0	1	0	0	0	0	0	YES	0	14
Site 29	4	0	0	0	1	0	0	0	0	0	YES	0	10
Site 30	1	Ah, Cn	0	0	1	0	0	0	0	0	YES	0	13

Table 2 Attributes and Scores of preliminary selected small-sized Protected Areas