SELECTION, CATEGORIZATION,SIZE AND ZONING IN THE WORLD'S PROTECTED AREAS

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Summary

The mechanisms underlying the selection, categorization, size extension, and zoning of the protected areas in the world are shortly presented and discussed. After a screening of literature cases, this chapter is primarily based upon a series of procedures and methods, from the biodiversity estimation to iterative and information-based systems. The categorization that is currently utilized follows the most recent classification given by the IUCN and includes internationally recognized categories that range from strictly protected areas destined only for scientific uses to managed areas. The size of the protected areas is variable: from one side it depends on the area's original designation, especially in the case of long-existing reserves; alternatively, it depends on the process used to define the area itself. In general, it should be taken into account which taxa or ecosystems must be protected inside the area, taking also into consideration that an area of limited size is often characterized by a drastic loss in biodiversity, with a consequent extinction of animals with large home range extensions. The zoning is then an instrument to calibrate the intervention within the protected area, and it is rather flexible in the recently constituted reserves. A case study for a biodiversity "hot spot," Madagascar, is also provided. On this large island, the habitat alteration and deforestation rate are extremely severe, and the protected area network is among the few means (together with education and development) to preserve and possibly reverse this trend.

1. Introduction

Protected areaslegally established sites managed for conservationare evident means for protecting biodiversity. Worldwide, something more than 8000 protected areas cover over 750 million hectares of marine and terrestrial ecosystems, amounting to 1.5% of Earth's surface or 5.1% of national land area.

The protected areas have long been considered as territories where the nature is to be protected and where "normal" use of the land is to be suspended. This is the philosophy that underpins every protected area, due to the historical perspective upon which the first parks and national reserves were based between the end of nineteenth and beginning of the twentieth centuries.

The basis for the definition of the national parks and their management was finalized on the occasions of the London (1933) and Washington (1940) international conventions. According to the final resolutions, the term "national park" designated an area (a) placed under the public control, and whose borders must not be changed; (b) specifically designated for the propagation and conservation of wildlife and for safeguarding elements of aesthetic, geological, prehistoric, historical, archaeological, and scientific interests, and for public recreation; (c) where hunting activities (i.e., the killing or capture of the wild fauna) as well as the destruction and collection of flora are forbidden, excepting for the initiative or under the direction and control of the park's authorities.

In this chapter, the most important aspects regarding the processes of selection, categorization, size, and zoning in the protected areas are sketched. This exposition is necessarily synthetic, drawing largely from exhaustive arguments developed in specialized treatises as well as in dedicated papers published in journals of conservation, habitat management, and ecology.

2. Selection Process 

2.1. Methods to Select a Protected Area

Historically, most national parks and other areas that implicitly are thought to protect biodiversity are selected for reasons other than those that are biological. Although a variety of methods for evaluating the conservation worth of areas has been suggested, few have attempted to provide a cost-effective means for evaluating biodiversity at the scale of the ecoregion. The first reserves to be created were designated on ad hoc basis in an effort to conserve some species. This is still an important objective (sometimes still adopted to address area conservation), but it is evident that it is suboptimal for protecting biodiversity. Several criteria are used to identify such areas; these include biodiversity parameters, rarity, population abundance, and site area. In the case that data are accurate, it is possible to identify areas of high specific diversity ("hot spots") for certain taxa, focusing on threat level or biogeographical status.

Although biodiversity is often claimed to be a powerful tool for identifying and selecting areas for protection, aside from easily surveyed taxa (such as birds, large mammals, and butterflies) it is evident that for many groups a diversity estimate is often difficult. In general it should be stressed that the most suitable groups are those that can be rapidly censused. This is the main aim of several surveys carried out since the 1980s. It is not unlikely that the diversity for certain groups of species (or higher taxa) may not be coincident with that of others. Regardless, there is the tendency to utilize some "indicator taxa," which, for their facility in being surveyed, are taken into consideration in a general sense. This occurs for some vertebrate and invertebrate groups. However, the correlations between the indicator and the indicated taxa are quite variable and, in a general sense, questionable

Where knowledge of existing species distributions is inadequate for reserve planning, other

approaches might be attempted. It is worth noting the application to the protected areas' management of MacArthur and Wilson's (1967) island biogeography theory. In this case, the reserve is selected on the assumption that a larger reserve hosts a higher number of species, and, consequently, a higher biodiversity. However, no satisfactory resolution has come from the well-known debate over the relative benefits of a single large reserve versus several small reserves.

A comprehensive biodiversity plan needs to evaluate the sufficiency of these and other protected areas for conserving biodiversity. Gap analysis appears to be a useful instrument toward this goal. Gap analysis uses geographic information systems (GIS) to identify "gaps" in biodiversity protection that might be filled by the establishment of new preserves or changes in land use practices. Gap analysis consists of three primary data layers. These are (a) the distribution of actual vegetation types delineated from satellite imagery, (b) land ownership, and (c) distributions of terrestrial vertebrates as predicted from the distribution of vegetation. Within the GIS, overlays of animal distribution and ownership can be used to estimate the relative amount of protection afforded vertebrate animals. Gap analysis functions as a first-pass approach for organizing biological information. Depending on the database, the database can be used to springboard into other, more detailed studies and is meant as a proactive rather than reactive management tool. Gap analysis is a method of identifying gaps in the protection of biodiversity at state, regional, and national scales. Although designed to identify "gaps" in the protective network, the data collected for gap analysis can serve numerous other purposes. In one sense, the data represent the first systematic biodiversity compilation that transcends political boundaries. As such, the data are a useful starting point for other efforts designed to protect biodiversity. Some important applications include the ability to note temporal and spatial change in the extent and distribution of vegetation types.

2.2. Case Studies of Ugandan Reserves and South African Coastal Fishes

In the late 1980s the Ugandan Government decided to dedicate one-fifth (~3000 km^2) of the country's 15 000 km^2 forest estate to management as "strict nature reserves" for biodiversity protection. A program of biological inventory work was undertaken between 1991 and 1995. It was decided to survey those areas most likely to support viable populations of most species in the long term (namely the larger reserves exceeding 50 km^2), and any smaller reserve in which a particular vegetation type was uniquely represented.

Sixty-five of the country's principal forests were evaluated for biodiversity, focusing on five "indicator" taxa: woody plants, small mammals (of the families Cricetidae, Gerbillidae, Muridae, Mioxidae, and Soricidae), birds, butterflies, and large moths. Conservation priorities were established by comparing sites on the basis of species diversity and rarity, using directly comparable data sets. The first stage of the analysis was aimed at identifying areas with an unusually large number of species or high concentrations of rare species. Each site was scored for biological importance based on a measure of species diversity and the "rarity value" of the species (based on frequency of occurrence in Uganda's forests and known Africa-wide distributions) represented within the five indicator taxa at each site. Each site was then evaluated for various alternative land uses (e.g., timber production, local community use, recreational production, and local community use). In this way, scores were derived as objectively as possible using data on standing timber volumes, population, census statistics and so on, but more subjective assessments were also necessary to establish scores for certain criteria such as recreational potential. These scores were then combined in a single statistic used as a measure of each forest's overall suitability for designation as a reserve.

Usually prioritization for biodiversity conservation is based upon data occurring for the terrestrial habitats. A recent study analyzed available data sets of coastal fishes in South Africa. The 57 marine protected areas in that study have largely been designated by an opportunistic process, and currently only three of these are considered to offer substantial protection to coastal biota including fishes. The authors collated existing fish distribution data and applied and compared hot spot, biogeographical, and "complementarity" approaches to the selection of marine protected areas for the conservation of coastal fish diversity. First they examined the patterns of species and endemic species richness around the coast in order to understand whether any hot spot could be identified by the presence of fish. Then, they carried out a biogeographical analysis, based on zonation. They used a cluster analysis and multidimensional scaling that allowed the identification of major biogeographical zones. The final approach used complementarity analysis, which is a selective technique identifying how the target set of species can be conserved at the minimum number of sites. The study used a "rarity algorithm" that identifies sites scoring high on a scale of species rareness. This kind of selection produces high efficiency by leading to the selection of a minimum, or near-minimum, set of reserves that conserve all target species at least once.

3. Categorization and Denomination of Protected Areas

3.1. IUCN Categories

The main accepted purposes for managing protected areas are (a) scientific research, (b) wilderness protection, (c) preservation of species and genetic diversity, (d) maintenance of environmental services, (e) protection of specific natural and cultural features, (f) tourism and recreation, (g) education, (h) sustainable use of resources from natural ecosystems, and (i) maintenance of cultural and traditional attributes.

In 1978, the IUCN Commission on National Parks and Protected Areas (CNPPA) published a document regarding the new classifications of the protected areas, subdivided into 10 categories within three groups, as follows:

Group A. These categories are those for which the CNPPA and the World Conservation and Monitoring Center (WCMC) take responsibility to check the status of each area destined for conservation. They are (I) scientific reserve or strict nature reserve; (II) national park; (III) natural monument or natural landmark; (IV) natural conservation reserve, managed nature reserve, or wildlife sanctuary; and (V) protected landscape.

Group B. These categories are of particular importance to the IUCN, but not considered as essential within the formal structure of the CNPPA. Nevertheless, CNPPA and WCMC can check their conservation status and provide suggestions and experts. They are as follows (continuing the listing from Group A): (VI) resource reserve; (VII) natural biotic area or anthropological reserve; and (VIII) multiple-use management area or managed resource area.

Group C. The following categories are relative to areas that are already included in international programs and have a specific relevance for the nature conservation, although in some cases they are coincident with some of the former categories. The CNPPA and WCMC can provide their experience in cooperating with other institutions. These include (IX) biosphere reserve, and (X) world heritage site. Nonetheless, it was evident that this categorical system needed updating. In fact, the differences between some of these certain categories were not always clear, and the

treatment of marine conservation needed strengthening. Categories (IX) and (X) were not discrete management categories, and often the international designations are overlaid on other categories.

On the occasion of the IUCN meeting in Madrid (1984), only the first five categories were maintained, while categories VIX were abandoned (with the exception of the international designations, like Ramsar Site, Biosphere Reserve, and World Heritage, which were maintained). In 1994, the IUCN published the "Guidelines for Protected Area Management Categories," which were updated in 2000, with the proposition of six categories as follows:

Category Ia: Strict Nature Reserve. A protected area (of land and/or sea) managed mainly for scientific purposes, possessing some representative ecosystems that are available mainly for scientific research. It is usually not open to tourist access. The main objectives are (a) to preserve habitats, ecosystems, and species in an undisturbed state; (b) to preserve genetic resources; (c) to maintain and preserve ecological processes; (d) to safeguard structural landscape features or rock exposures; (e) to secure examples of the natural environment for scientific research, environmental monitoring, and education, including baseline areas from which all avoidable access is excluded; (f) to minimize disturbance by careful planning and execution of research and other activities; (g) to limit public access. The selection of these reserves is based upon the verification that the area is large enough to ensure the integrity of its ecosystems, is significantly free of human disturbance and intervention (and capable of remaining so), and the conservation of the area's biodiversity is achievable through protection and does not require substantial active management or habitat manipulation.

Category Ib: Wilderness Area. A large protected area managed mainly for wilderness protection, with unmodified (or slightly modified) land and/or sea, retaining its natural character and influence without permanent or significant habitation, and that is protected and managed so as to preserve its natural condition. The objectives are (a) to ensure that future generations will have the opportunity to experience understanding and enjoyment of areas that have been largely undisturbed by human action over a long period of time; (b) to maintain the primary attributes and qualities of the environment over the long period; (c) to provide public access at levels and of types that will best serve the physical and spiritual well-being of visitors and maintain the wilderness qualities of the area for present and future generations; and (d) to enable indigenous human communities living at low density and in balance with the available resources to maintain their lifestyle. The selection is based upon the verification that the area possesses high natural qualities, and a substantially absent human disturbance. Furthermore, the area should have outstanding ecological, geological, or other aspects of scientific, educational, scenic, or historic relevance. "Wilderness" is basically a human concept, not having an ecological implication; wilderness areas may include areas that were formerly exploited but have been abandoned and subsequently returned to natural succession. This subcategory was not yet reported in the 1978 system, but has been introduced following the IUCN General Assembly Resolution on Protection of Wilderness Resources and Values, adopted at the 1984 General Assembly in Madrid (Spain).

Category II: National Park. A protected area managed mainly for ecosystem protection and recreation, protecting the integrity of one or more ecosystems, excluding exploitation or occupation contrary to the purpose of designation of the area, and providing a foundation for spiritual, scientific, educational, and recreational opportunities, all of which must be environmentally and culturally compatible. The main objectives are (a) the protection of natural areas of national and international significance for a series of purposes (e.g., spiritual, scientific, educational, recreational, or tourist); (b) the perpetuation of representative examples of biotic

communities, genetic resource, and species, meanwhile providing ecological stability and diversity; and (c) the elimination and prevention of exploitation. The area should contain a representative sample of major natural regions, features, or scenery where plant and animals species, habitats, and geomorphologic sites are of special significance.

Category III: Natural Monument. A protected area managed mainly for conservation of specific natural features, containing one or more specific natural or natural/cultural features of outstanding or unique value because of rarity, representative or aesthetic qualities, or cultural significance. Among the objectives are (a) to protect specific outstanding natural features because of their natural significance, unique or representational quality, and/or spiritual connotations; (b) to provide opportunities for research, education, and public satisfaction if in accord with the foregoing objectives; (c) to eliminate disturbing factors; and (d) to deliver to any resident population benefits as are consistent with the other objectives of management. In a general sense, the area should contain one or more features of outstanding significance (e.g., spectacular waterfalls, craters, caves, fossil beds, or sand dunes) and also should be large enough to protect the integrity of the feature and its immediate surroundings. In the 1978 system this category corresponded to the natural monumentnatural landmark.

Category IV: Habitat/Species Management Area. A protected area managed mainly for conservation through management intervention, subject to active intervention for management purposes to ensure the maintenance of habitats and/or to meet the requirements of specific species. The main objectives are (a) to maintain the habitat conditions needed to protect significant species, groups of species, biotic communities, or physical features of the environment where these require specific human manipulation for optimum management; (b) to facilitate scientific research and monitoring as primary activities associated with sustainable resource management; (c) to develop limited areas for public education and appreciation of the characteristics of the habitats concerned and of the work of wildlife management; (d) to eliminate and prevent exploitation or occupation inimical to the purposes of designation; and (e) to deliver such benefits to people living within the designated area as are consistent with the objectives of management. The areas should be important in the protection of nature and survival of species (including breeding areas, wetlands, coral reefs, estuaries, grasslands, forests, or spawning areas). They should also be those where habitat conservation is essential for locally important flora and fauna. The conservation of these habitats should depend upon active intervention and, when necessary, of habitat manipulation. In the 1978 system this category corresponded to the nature conservation reservemanaged nature reservewildlife sanctuary.

Category V: Protected Landscape/Seascape. A protected area managed mainly for landscape/seascape conservation and recreation, and where the interaction between people and nature has produced an area of distinct character with significant aesthetic, ecological, and/or cultural value, and often with high biological diversity. The preservation of the integrity of this traditional interaction is vital to the protection, maintenance, and evolution of such an area. Objectives are (a) to maintain the harmonious interaction between nature and culture, by means of the protection and the continuation of traditional land uses, building practices, and social and cultural manifestations; (b) to support lifestyles and activities that are in harmony with nature and the preservation of the social and cultural fabric of the communities concerned; (c) to maintain the diversity of landscape and habitat, and associated species and ecosystems; (d) to eliminate where necessary, and thereafter prevent, land uses and activities that are inappropriate in scale and/or character; (e) to provide opportunities for public enjoyment through recreation and tourism appropriate in type and scale to the essential qualities of the areas; (f) to encourage scientific and educational activities that contribute to the long-term well-being of resident

populations and to the development of public support for the environmental protection of such areas; and (g) to bring benefits to, and to contribute to the welfare of, the local community through the provision of natural products and services. The areas should therefore possess a landscape/seascape of high scenic quality and diverse associated habitats, together with peculiar fauna and flora, and unique or traditional land use patterns. The area should provide opportunities for public enjoyment through recreation and tourism within its normal lifestyle and economic activities. In terms of organizational responsibilities, this kind of area may be owned by a public authority, but it is more likely to include a mosaic of private and public ownership. In the 1978 system this category corresponded to the protected landscape.

Category VI: Managed Resource Protected Area. A protected area managed mainly for the sustainable use of natural ecosystems, containing predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, providing a sustainable flow of natural products and services. Objectives for management include (a) the protection of biodiversity and other natural values; (b) the promotion of sound management practices for sustainable production; (c) the protection of the natural resource base from being alienated for other land use purposes that would be detrimental to the area's biological diversity; (d) the contribution to regional and national development. The area should be at least two-thirds in a natural condition, although it may contain limited areas of modified ecosystems. Management should be undertaken by public bodies, in partnership with local communities. This category does not correspond directly with any of those reported in the 1978 system, although it is likely to include some areas formerly classified as resource reserves, natural biotic areasanthropological reserves, and multiple-use management areasmanaged resource areas.

3.2. International Important Sites

In the field of nature conservation there are two international conventions and one international program that include provision for designation of internationally important sites in any region of the world. These are the World Heritage Convention, the Ramsar (Wetlands) Convention, and the UNESCO Man and the Biosphere (MAB) program. While there is a wide range of other international conventions and programs, these cover only regions or small groups of countries. Both World Heritage sites and Ramsar sites must be nominated by a state that is party to the relevant convention. While there is an established review procedure for World Heritage sites (and nomination is not guarantee of listing), all nominated Ramsar sites are placed on the List of Wetlands of International Importance. Biosphere reserves are nominated by the national MAB committee of the country concerned, and are only designated following review and acceptance by the MAB Bureau. Each Contracting Party to the Ramsar Convention is obliged to nominate at least one wetland of international importance. However, a country can be party to the World Heritage Convention without having a natural site inscribed on the List, and may participate in the MAB program without designating a biosphere reserve.

The UNESCO MAB program was established to promote sustainable use of natural resources, and to protect natural habitats from incompatible developments in the immediate vicinity. Initiated in 1971, MAB was a consequence of the Biosphere Conference held in 1968 and the earlier international biological program of the International Council of Scientific Unions. The Man and the Biosphere program became operational in 1976, and provides for the establishment of "biosphere reserves" of various types throughout the world. Including 329 reserves, the MAB is an immense sample of sites housing invaluable land and marine ecosystems that are representative of specific biogeographical and cultural areas. Its objective is to combine environmental conservation and the sustainable development of the region, in conjunction with the study and monitoring of the environment on an international basis.

3.3. Other Kinds of Protected Areas

At the national level, a variety of designations are often used. The same designation may mean different things in different countries. And different designations in different countries may be used to describe the same category of protected area. This is one of the main reasons for using a system of categories at the international level that are identified by management objectives and does not depend on titles and denominations. Furthermore, the conditions for the establishment and management of protected areas may vary largely between regions and countries. For example, regions like Europe, with long-managed landscapes with multiple ownership are not, on the whole, as well-suited to the establishment of Category II areas. On the other hand, their circumstances are more conducive to the establishment of Category IV and V areas. In a general sense, IUCN does not favor different standards being used in the category application in different parts of the world, as this would counteract the value of having a defined standard.

A more functional term is the "marine protected area" (MPA), which is used, in slightly different senses, throughout the world. The IUCN, for examples, defines an MPA as follows: "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical, and cultural features, which has been reserved by law or other effective means to protect part of all of the enclosed environment." As the twenty-first century commences, there are almost 1300 marine protected areas around the world. The MPAs have been established by a growing number of countries and have been actively promoted by a variety of organizations such as the UNEP, IUCN, WWF, and UNESCO. The world leader in establishing marine protected areas is Australia, with 303 MPAs, including the Great Barrier Reef Marine Park, the largest marine reserve in the world.

It should also be noted that in Canada there are two further kinds of reserves that effectively conserve significant ocean and land areas: national wildlife areas (NWA) and migratory bird sanctuaries (MBS). The NWAs protect nationally significant habitats (especially for migratory birds) for the purpose of wildlife research, conservation, and interpretation. The MBSs try to conserve the diversity of migratory birds by controlling human activities within important areas that are managed for the protection of birds.

3.4. Multiple Classifications

Protected areas of different categories are often contiguous and sometimes one category "nests" within another. Thus many Category V areas contain within them Category I and IV areas; some will adjoin Category II areas. Similarly, some Category II areas may contain Category Ia and Ib areas. This is perfectly consistent with the application of the system, providing such areas are identified separately for accounting purposes. Although there are evident benefits in having the entire area within the responsibility of one management authority, this may not always be appropriate; in such cases, close cooperation between authorities is extremely important.

4. Size of Protected Areas 

4.1. How Big Should Reserves Be?

The size of a protected area should in general reflect the extent of land or water needed to accomplish the purposes of management. For example, for a Category I area, the size should be appropriate to ensure the integrity of the area to accomplish the management objective of

strict protection, either as a baseline area or research site, or for wilderness protection. On the other hand, for a Category II area, the boundaries should be drawn sufficiently widely that they might contain one (or more) entire ecosystems not subject to modification by human exploitation.

Size estimates are usually based on data from terrestrial habitat fragmentations, estimated minimum viable populations, and ecological needs of individual species. In all of the IUCN management categories there are 9869 sites larger than 1000 ha, protecting a total of 6.3% of the planets land surface. A large piece of this is Greenland, which contains the world's largest national park, 700 000 km^2, consisting mainly of snow. Protected areas in IUCN Categories IV now exist in 124 countries and in all of the world's biogeographical realms. However, 15 biogeographical provinces have no protected areas.

It is nevertheless difficult to specify how to select the size of a protected area. One possibility for establishing the size of a protected area lies with the exigencies of some (a few) species living within the reserve boundaries. A study on the home range requirements to estimate the area needed for eight grizzly bears (600 km^2), eight mountain lions (760 km^2), and eight wolves (600 km^2) concluded that only a few reserves in the United States are large enough to sustain eight individuals (600760 km^2) and that no reserves east of the Mississippi River were large enough to support the most transient of large carnivore populations. Other research suggests that two hawk eagles on the island of Java have home ranges of about 2030 km^2 and may not survive in forest smaller than 20100 km^2. Then, basing upon studies on birds, it was suggested that reserves should be 100 ha or larger. In any case, it is not believed that rain forests smaller than 2530 km^2 would be efficacious at conserving and protecting tropical birds, and indeed areas larger than 100 km^2 would often be needed.

Large predators are in general considered key focal species to define the size of a protected area, assuming that they have a large home range, and therefore smaller organisms would benefit from the larger protected area. Regardless of the specifics, it is obvious that the habitat and surface requirements of a vertebrate organism with a large home range are not necessarily coincident with that of other organisms. In habitat patches of 125 km^2 (this is the mean size of several small parks or nature reserves) the extinction rate in the first 100-year period would be 1050%. Extrapolating the data of mammal species present in the several land bridge islands of the Malay Peninsula to the protected reserves of East Africa, it was also noted that, after complete isolation, the "small" reserves will "collapse," loosing respectively 23% of their mammal species in 50 years, 65% in 500 years, and 88% in 5000 years.

4.2. Species Number, Area, and Distance

More species are usually present on larger islands regardless of which speciesarea hypothesis one uses to explain it. Studies of mainlands also demonstrate that the number of species increase with the size of the tract up to a point and increase less rapidly thereafter. Whether the species count ever completely levels off is controversial. We would expect species in habitat islands to become more numerous with increasing tract size due to area alone, although not all evidence conforms to this expectation. The decrease in number of species with increasing distance in islands is not well documented. The analogous consideration of nature reservesthat species on a habitat island will decrease with increasing distance from a source habitathas even less support.

4.3. Population Size and Protected Areas

The effective population size is an "ideal" number of individuals whose decrease in genetic variation due to genetic drift equals that of the actual population studied. The drop of a population of some species to 50 individuals may threaten their short-term fitness, in terms of fecundity, viability, fertility, and the disease resistance desired by animal breeders. Further considerations suggest that 500 individuals are needed for long-term fitness in a population to prevent the eventual erosion of genetic variation. A population of fewer than 50 individuals induces more than one percent loss of heterozygosity instead of the two to three percent loss that animal breeders usually tolerate. In general, the major goal of genetic management is to avoid genetic deterioration of populations, to preserve the species' potential for adaptation, and thereby reduce the chances of extinction. Problems that require genetic management span the entire range from inbreeding depression to hybrid breakdown in fitness. Small populations run the risk of genetic deterioration through the effects of inbreeding and genetic drift. Both processes can lead to homozygosity, which frequently results in reduced fertility in adults and increased juvenile mortality. The recommendation of 500 individuals is based on the assumption that the loss of genetic variation will be balanced by gain through mutation. The minimum effective population size to retain genetic diversity of vertebrates in captivity is said to be 250500. Thus a population of 500 was suggested for long-term conservation regimes. The rough guideline of 50 individuals as a lower threshold is based (although with slim concrete data) upon the work of animal breeders, and it is recommended for maintenance of short-term fitness to park and other reserve managers.

4.4. Habitat Shape and Size, and Species Number

Contrary to some interpretations, the theory of island biogeography does not directly address the question of shape of reserves. In fact, several observations suggest that as large a perimeter as possible should be oriented towards a species source, to increase immigration. Edges between different vegetation types are known for their tendency to contain more species than the central part of a vegetation type. The ecotone concept also applies to the natural transition area between any two ecosystems. The edge contains more animal species from both adjacent vegetation types, as well as species that thrive best at the edge itself. The "island" model applies here, since real islands have edges, as do habitat islands. Therefore, increases in species number in habitat islands and nature reserves could be related not only to larger area, but also to edges, whether on the perimeter or between two interior zones of the nature reserve. A classical example is that regarding the Barro Colorado Island (Panama). The creation of the Panama Canal and Lake Gatun by damming the Chagras Rivers, changed many hilltops into islands within the lake. The best studied of these islands is Barro Colorado. A study published in 1974 demonstrated that 45 of the original 209 breeding forest bird species on Barro Colorado disappeared during 19231971. In all likelihood, some species disappeared also for other reasons, such as forest maturation, although it is almost assured that the overall lowering of species count is due to an area effect.

4.5. Species Loss in Protected Areas

Local extinctions are also known in some protected areas. The extinction of 13 mammalian species in Mount Rainier National Park (Washington) since the 1940s was said to be a function of reserve size and insularity. Moreover, it was claimed that Everglades National Park (Florida) was already somewhat isolated, while a continued decline of some mammalian species in the park was at least consistent with (although not necessarily a direct result of) the hypothesis of decline due to progressive isolation. The four mammalian extinctions in Mkomazi Game Reserve (KenyaTanzania) since 1975 were consistent with the isolation model, although

specific causes could be loss of permanent water, cattle grazing, and illicit hunting.

5. Zoning and Differential Use in the Protected Areas

5.1. International Zoning Classifications

One of the primary purposes of management is to determine the category to which an area is assigned, and management plans often contain management zones for a variety of purposes that take local conditions into account. In order to relegate an area to the appropriate category, minimally three-quarters of the area should be managed for the primary purpose; and the management of the remaining area must not be in conflict with this primary purpose. Whereas the former view of protected areas provided the safeguard of "concentric" areas, with internal zones of high protection moving outward to zones of partial protection and ultimately to zones of greater freedom of action, the new park models tend not only to apply zoning but also a more holistic view of environmental utilization.

There is an obvious relationship between the classification of the categories of protected areas and the objectives that underlie an alternative typology of protected areas adopted by IUCN. In an FAO document published in 1976 and later adopted by IUCN, there were indications of a zoning scheme applicable to certain geographical topologies that differ substantially from those encountered in European regions. In fact they identified: (a) zones in a primitive state of scientific interest ; (b) zones of historicalcultural interest; (c) zones in a pristine state; (d) zones subject to recovery interventions; and (e) special-purpose zones.

A IUCN document published in 2000 included a full inventory (United Nations List of National Parks and Protected Areas) of the worlds protected areas categorized along the following dimensions of concern:

- integral protection: strict nature reserve, wilderness area
- conservation of the ecosystems and recreation: national park
- conservation of the specific natural elements: national monuments
- conservation by means of active management forms: area for the management of habitats and species
- conservation of the landscape and recreative activities: protected landscapes
- sustainable use of the natural ecosystems: protected area for the management of resources

For each of these categories there are primary, secondary, and tertiary objectives. Although extent differs, human intervention is not only allowed but sometimes lends an element of conservation and protection, opposite the result with the former IUCN classifications. Thus it is expected that in addition to zones devoted to the primary objective, there might be other zoning rules applied in an effort to achieve lower level objectives and that take into account the local conditions. Furthermore, the same IUCN document indicates that protected areas should not be isolated territorial units. Management planning of protected areas must be incorporated within regional plans and supported by politics that address wider geographic areas.

In any event, the categories of the proposed system are not so rigidly defined as to exclude spatial overlap or mutuality; thus, members of some wider categories, such as protected landscapes (Category V) or national parks (Category II), can include in their borders natural reserves (Category Ia), wilderness areas (Category Ib), natural monuments (Category III), or

areas for the management of habitats and animals species (Category IV).

5.2. Zoning in "Man and the Biosphere" Reserves

In the "Man and the Biosphere" (MAB) reserves, the biosphere encompasses a core zone that represents one of Earth's major ecosystems and is large enough to permit *in situ* conservation of its genetic material. These core zones are meant to be undisturbed by human activity, except for scientific research. Multiuse buffer zones are intended to surround the core, and these should be managed for the economic benefit of local populations. As an example, in the Canary Islands, with the aim of reaching an adequate balance between natural values and the use of natural resources, the MAB reserves are divided into three related zones: (a) core area, which comprises the most carefully preserved ecosystems; (b) buffer zone, which surrounds the core area and is part of its sphere of influence (those activities carried out in these areas should not be an obstacle to the conservation of the core area); and (c) outer transition area, which usually receives the greatest human influence.

6. A Case Study: the Protected Areas Network in Madagascar

6.1. Biodiversity of Madagascar

Madagascar, with a land area of 594 180 km^2, is the planets fourth largest island after Greenland, New Guinea, and Borneo. Because of its large size, diverse relief, geology, climate, and vegetation types (Figures 13), it is in many respects best viewed as a microcontinent. Its separation from continental Africa, approximately 140 million years ago, allowed the evolution and differentiation of unique forms of fauna and flora, absent in other parts of the world. Recent estimations indicate that at least 80% of all species of plants and animals on Madagascar are endemic, exceeding 90% for the forest species.

Figure 1. Rain forest of the eastern coast of Madagascar
(Photo by F. Andreone.)

Figure 2. Bushsucculent forest of southwestern Madagascar
(Photo by F. Andreone.)

Figure 3. Mangroves at Sahamalaza, northwestern Madagascar
This peninsula is currently included within the forthcoming new protected areas, due to its variety of marine ecosystems and the presence of a conspicuous *Eulemur macaco flavifrons* population.
(Photo by F. Andreone.)

The process of deforestation and exploitation of many forests in the world has a dramatic negative effect on Malagasy forests (Figure 4), where the application of the slash-and-burn agriculture ("tavy") has devastating effects on the original forests. It is in fact anticipated that, if this process is not inverted, in a few years 99% of Malagasy rain forests will disappear, together with most of their peculiar fauna and flora. Facing the increasing deforestation and exploitation of many Malagasy habitats, a network of protected areas has been announced by the Malagasy Government.

Figure 4. "Tavy" (slash-and-burn agriculture), a deforestation practice applied in much of Madagascar
(Photo by F. Andreone.)

In the context of an analysis of the selection, categorization, size, and zoning processes of the worlds protected areas, it is of particular relevance to understand what has been done in one of the most critical regions in terms of biodiversity. The preservation of Madagascar, indeed a unique natural heritage, must be therefore considered a world priority. The present treatise is based upon the ideas, concepts, and projects formulated by the Association National pour la Gstion des Aires Proteges (ANGAP) in the "Plan de Gestion du Rseau National des Aires Proteges de Madagascar."

6.2. Protected Areas in Madagascar

The protected areas of Madagascar currently number 46 (updated at April 2000, Figure 5) and are divided into three distinct categories:

(a) *Reserve Naturelle Intgrale* (RNI; strict nature reserves). An area that represents a peculiar ecosystem, with the aim of safeguarding the fauna and flora within a certain perimeter. Current occupied surface area, 3755 km^2; total number of such reserves, seven. The RNIs can be included in the IUCN's Category Ia.

(b) *Parc National* (PN; national park). An area with the aim of protecting and conserving an original natural or cultural patrimony, while also providing a recreational and educational complex. Current occupied surface area, 10 382 km^2; total number of such parks, 16. The PNs can be included in the IUCN's Category II.

(c) *Rserve Spciale* (RS; special reserve). An area created mainly to protect an ecosystem or a specific site where there exists a peculiar vegetal or animal species. Current occupied surface area, 17 103 km^2; total number of such reserves, 23. The RSs can be included in the IUCN's

Category IV.

Some of the reserves, such as the PN d'Ankarafantsika, the RNI de Lokobe (Nosy Be), Bemaraha, de Tsaratanana, Zahamena, and Tsimanampetsotsa, were created in the 1920s. A second wave was established in the 1950s and 1960s. In this period, there was official protection of many areas, such as the RS d'Analamera, Anjanaharibe-Sud, Nosy Mangabe, and the PN de la Montagne d'Ambre. More recently, the status some of these areas (e.g., Marojejy, Zahamena, KirindyMitea, and ZombitseVohibasia) was changed into national parks. One national park (Mananara-Nord) is currently classified as an MAB site, another (Bemaraha) is included as a UNESCO World Heritage Site. Furthermore, Madagascar ratified the Ramsar Convention in 1998, and included the Lac Tsimanampetsotsa and the Manambolomaty Complex in the list of Ramsar sites. This convention is retained as very important by ANGAP and stimulated efforts to identify and conserve exceptional wet areas in Madagascar. In fact, the first new site that will be integrated in the national network of protected areas will be most likely the Manambolomaty Complex.

In terms of size, the protected areas of Madagascar span a broad range: the RSs go from 520 ha (Nosy Mangabe) to 60 050 ha (Ambatovaky), the RNIs from 740 ha (Lokobe) to 85 370 ha (Bemaraha), and the PNs from 10 000 (Mantady) to 230 000 (Masoala).

Figure 5. Map of Madagascar, with the existing protected areas (updated at May 2001)

Protected areas in Madagascar: national parks, green; marine parks, blue; strict nature Reserves, yellow; special reserves, red; province border, dotted line.
(From "Plan de Gestion du Rseau National des Aires Proteges de Madagascar, by ANGAP (2001).)

6.3. National Plan of Environmental Action

Madagascar authorities understood the importance of the application of coherent actions for the protection of the essential natural resources. This led to the adoption, at the beginning of the 1990s, of a *Plan National d'Action Environnementale* (National Plan of Environmental Action; PNAE), which is the first of this kind elaborated in Africa. The PNAE was applied as a consequence of the December 21, 1990, law 90-033. With a duration of 15 years, it has two main objectives: (a) to stop and possibly reverse the general environmental degradation and promote the durable utilization of the natural resources, and (b) to create an atmosphere for environmental considerations to integrate other aspects of the macroeconomic management.

The PNAE is divided in three phases. The first phase (*Programme Environnemental 1* (PE 1): 19901997) focused on some specific objectives, including the new forestal politics and the law on the management of resources by local communities. The PE 1 stressed the importance of the reinforcing capacity by means of the creation of new environmental entities (e.g., the ANGAP). Furthermore, one such entity, the *Office National pour l'Environnement* plays an

important and fundamental role in the application of the PNAE, of which it is the organization providing management, coordination, and support.

The second phase of PNAE (PE 2) started in July 1997 and has several components. Under the coordination of the *Ministre de l'Environnement*, the ANGAP works in collaboration with several partners, such as the *Conseil National de lEnvironment* (the consultative body charged to control the general environmental orientation), the *Comit Interministriel pour lEnvironnement* (the consultative body that warrants effective integration of environmental management imperatives for durable development), the *Office National de lEnvironnement* (for the management and coordination of PNAE), the *Ministre des Eaux et Forets* (responsible of the development of forest politics and management of natural resources), the *Association Nationale dActions Environnementales* (for financing the preparation and application of microprojects on soil management and slope basins), the *FoibenTaosaritanini Madagasasikara* (National Cartographic Institute, which characterizes and archives cartographic data), the *Direction Gnrale du Domaine et de la Scurisation Foncire*, and the *Centre de Formation aux Scienxes de lInstitut Gographicque Environnementale*.

6.4. Ecoregional Approach

The two-pronged approach usually adopted to define a national network of protected areas in Madagascar is (a) to identify distinct ecoregions, and (b) to assure that each is minimally represented by a protected area. This represents only a partial solution in Madagascar for the following reasons: the scientific information available is still limited concerning the biodiversity characteristics of most taxonomic groups, the composition of habitats and species vary considerably within the remaining natural habitats, with the consequence that several biological communities are present over a short distance, and the available information indicates that the main taxonomic groups show different characteristics in terms of biodiversity. Therefore, a single ecoregion classification scheme would not likely be valid for all relevant groups.

Since the terrestrial habitats of Madagascar are severely altered and fragmented, there are the following consequences: (a) in most cases, the protected areas are of relatively small size; (b) a relatively high number of protected areas is necessary to represent local endemicity and geographical variations; (c) some additional measures, such as the ecoregional programs of conservation and development, as well as the promotion of protected areas, are necessary to maximize the surface area available for plants and animals.

Several classifications were used to identify the terrestrial ecoregions of Madagascar. These are, for example, those proposed in 1921 by Perrier de la Bathie, later refined by Humbert and Cours Dame (1965), Faramalala (1995), and Du Puy and Moat (1996). The current terrestrial ecoregions, as accepted by the ANGAP, are as follows (Figure 6): (1) the northern mountains; (2) the east; (3) the center; (4) the west, (5) the south. A sixth ecoregions includes the isolated and transitional habitats.

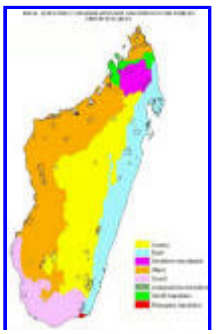

Figure 6. Ecoregions of Madagascar
Center, yellow; East, blue; Northern mountains, purple; West, brown; South, pink; Analavelona transition, marsh green; North transition, light green; Ranopiso transition, red.
(From *Plan de Gestion du Rseau National des Aires Proteges de Madagascar* (ANGAP 2001).)

6.5. Intervention Within the Protected Areas

Three types of intervention were identified for the conservation of the protected areas in Madagascar: (a) zoning, (b) measures of conservation adapted to the specific needs of a protected area, and (c) restoration.

Zoning. Zoning has been intended as a useful tool to assess the conservation of a protected area. Within each protected areas it is possible to identify up to five different zones: (a) The "conservation zone" represents the "hard nucleus" within a protected area where strict management is enacted, including scientific research and surveys. (b) The "research zone" represents the region reserved for ecological/biological surveys. (c) The "buffer zone" is situated just beyond the "hard nucleus" and includes three subzones: the *zone doccupation controle* (zone of controlled occupation), the *zone dutilisation controle* (zone of controlled use), and the *zone de service* (service zone). It should be stressed that the zone of controlled use has a special significance for the coast, marine, and wetland areas, where long-term traditional utilization has occurred. In these regions, the zone of controlled use represents the majority of the protected area. The service zone serves as a locus for specific activities regarding the management of the protected area. (d) The "protection zone" is just beyond the protected area and is created to give the ANGAP control of the sites outer reaches to prevent inappropriate utilization that could potentially produce negative impacts on the protected area. (e) The "peripheral zone" is represented by external areas that are managed by local communities.

Conservation Measures Adapted to the Specific Needs of a Protected Area. The parks and reserves have been classified by priority rank, and, secondly, a series of measures has been defined for each priority. To classify the level of priority, the protected areas have been ranked for their biodiversity. As a definition, all of the protected areas are considered as necessary to represent the Malagasy biodiversity. Then a distinction has been made between areas exhibiting high levels of biodiversity and those with an exceptional biodiversity level. This last category is useful to distinguish the protected areas that cover ecosystems, habitats, or species assemblages and/or endemicity centers or with an exceptional biodiversity. The classification is therefore "exceptional" if the representation of the biodiversity given by the site is not found in other protected areas. Thus, the second step relates to the threat level. The consequent matrix (Table 1 and Figure 7) identifies the priority level given to each park or reserve.

Table 1. Classification of the existing and proposed protected areas for the conservation measures
Town names appear in italics; remaining entries are names of protected areas.

Restoration. Some protected areas (such as Fort d'Ambre, Manombo, and Andranomena) are so degraded that the main (and likely unique) strategy applied is that of habitat restoration. This process includes the following steps: (a) adequate surveillance to stop any further degradation; (b) physical protection of the areas at high risk when this is necessary; (c) marking of the borders; (d) natural regeneration; and (e) restoration by means of reforestation and soil

conservation. Since this degree of restoration is relatively complicated and expensive, it is reserved for habitats that are seriously endangered or naturally rare, as is the case for transitional forests, high-altitude environments, and eastern littoral forests. An interesting case of forest restoration concerns the attempt to recreate forest corridors between the main blocks that constitute the Masoala National Park.

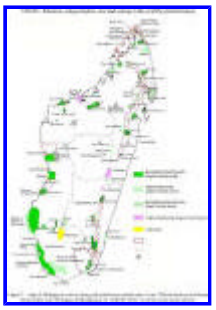

Figure 7. Map of Madagascar with existing and potential protected areas
Level of conservation priority: exceptional biodiversity (higher threat level), dark green; high biodiversity (higher threat level), light green; exceptional biodiversity (lower threat level), dotted; high biodiversity (lower threat level), pink; unknown, yellow; existing or potential areas for the ecoregional programs (lower threat level), red line; province borders, dotted line. Borders are given for existing protected areas; colored areas depicted without borders refer to future protected areas.
(From *Plan de Gestion du Rseau National des Aires Proteges de Madagascar* (ANGAP 2001).)

6.6. Strategic Value of the Protected Areas Network

The future network is based upon a consensus between scientists, members of ANGAP, and representations of the partners implied in the PNAE. Good information on biodiversity is only now beginning to appear in a synthesized form, treating an entire ecoregion or the whole country. One of the best examples is the recent evaluation of conservation priorities for birds that has been established at a national scale. It is evident, however, that the structure proposed for the future network will require modification according to the availability of national data as well as of knowledge of global biodiversity.

6.7. Future Steps for the Valorization of Protected Areas in Madagascar

The most important objective of the protected areas network in Madagascar is to create an enduring structure for species and habitat conservation. This requires institutional stability and a clear idea of the aims and adequate resources to follow through on those intentions. The four columns upon which the ANGAP develops its strategy are as follows: (a) the confirmation of clear mandatory objectives by means of the application of a "protected areas code," which stresses the authority of ANGAP in the management of the protected areas; (b) the definition of the territory that should constitute the national network as presented in the *Plan de Gestion du Rseau National des Aires Proteges*; (c) the organizational examination of the ANGAP to evaluate its pertinence at the level of its structure, systems, and competence; and (d) the elaboration of the plan to bring about enduring biodiversity, which will establish a precise management orientation and the needs that apply to both the short and medium terms.

The propositions formulated upon the basis of the biogeographic examination include (a) the change in status for two protected areas (the RS du Tampoketsa d'Analamaitso and the RS de

Bora are changed to zones of community management, due to the persisting ecological degradation and lowering of biodiversity representation); (b) the evaluation of new proposed sites and creation of new protected areas (the new parks and potential reserves can be integrated in the national network or can be managed as protected areas by another entity, such as an autonomous region); and (c) evaluation of the possibility to extend the existing protected areas (regarding, for example, the RNI de Tsimanampetsotsa, the RS de Kalambatritra and Ambohijanary, and the NP de (Kirindy Mitea).

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Related Chapters

Related Links will be activated soon!

Glossary

ANGAP: Association National pour la Gstion des Aires Proteges (National Association for the Management of Protected Areas). A nongovernmental organization that manages the protected areas in Madagascar.
Biodiversity: Propriety of each living being to be various (i.e., to show more than one way to be itself). In a general sense it indicates the variety of species and/or other taxa in a given surface unity. The evaluation of biodiversity does not necessarily imply only the number of represented unities (i.e., richness), but also the relative frequency of each of them (i.e., evenness).
Biodiversity hot spots: Regional concentrations of species that have been of interest to biogeographers since the early 1800s, and are now widely used by conservationists to provide easy (and hopefully efficient) identification of sites for biodiversity preservation.
Biotic community: There are several different concepts of ecological communities. Here, the term community is intended as an assemblage of species populations that occur together in space and time.
CNPPA: Commission on National Parks and Protected Areas (a commission of IUCN).
Ecotone. A habitat created by abutment of very different habitats, or a transition area between them.
FAO: Food and Agriculture Organization.
GIS: Geographic Information System.
Heterozygosity: Condition of an individual that has different alleles at one or more loci and therefore produces gametes of two or more different kinds (the opposite of homozygosity).
IUCN: International Union for Conservation of Nature and Natural Resources, also known as the World Conservation Union.
MAB: Man and the Biosphere. This designates the homonymous UNESCO program and "Biosphere Reserves" of various types throughout the world.
MPA: Marine protected area.
PNAE: *Plan National d'Action Environnementale* (National Plan of Environmental Action (in Madagascar)).
Tavy: Type of agricultural practice used in Madagascar (and in many regions of South America

and Africa), consisting in cutting small areas of forested land, burning off the vegetation to release the nutrients into the soil, and then cultivating the area with rice and other crops for a short period. The site is then abandoned, and the people migrate to another site where the cycle is started again. Known as "slash-and-burn agriculture," it is one of the main causes of dramatic deforestation and soil erosion in Madagascar and elsewhere in developing countries.
UNEP: United Nations Environment Program.
UNESCO: United Nations Educational, Scientific, and Cultural Organization.
WCMC: World Conservation and Monitoring Center.
WWF: World Wide Fund for Nature.

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Biographical Sketch

Franco Andreone is PhD and Zoological Curator at Museo Regionale di Scienze Naturali in Torino (Italy). He carries out research on many zoological aspects, mainly related with herpetology. He is currently a member of the Conservation Committee of the Societas Herpetologica Italica, of the IUCN SSC (Species Survival Commission), "Amphibians and Reptiles of Madagascar and Mascarenes" and Country Liaison Representative for Italy and Madagascar of the journal *Amphibian and Reptile Conservation*. He has published approximately one hundred scientific papers, served as a referee for several international zoological journals, and is currently a member of the editorial board of the international batrachological journal *Alytes*. His main interests include the conservation, ecology, and taxonomy of amphibians and reptiles of Madagascar, where he conducts regular field survey activities. Furthermore, he collaborates with several nongovernmental organizations to carry out studies to be applied to habitat management and protected areas valorization, both in Italy and in Madagascar.

