ECOLOGY, BIOLOGICAL CONSERVATION AND POLICY

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Contents

Summary

Conservation biology is one of the fastest-growing fields of modern scientific research. It is an applied discipline that integrates principles of natural and social sciences with

the objective of achieving the long-term persistence of biodiversity on Earth. Conservation biologists seek to understand the impact humans have on biodiversity and hope this understanding will provide guidelines for minimizing those negative effects on the persistence of biodiversity. In this chapter we illustrate how ecological theory is applied to real world conservation situations.

Our carefully chosen, illustrative case studies range from the creation of a national park in Madagascar, and Sudden Oak Death as an emerging disease, to novel tools for the conservation of endangered species and their habitats.

But conservation biologists also have an obligation in ensuring that their results reach a broader audience, the media, the general public and decision makers, and that their findings are translated into environmental policies.

The time has come to move from a reactive science to a proactive one. Only with great honesty and responsibility can we begin to tackle the huge issues facing our planet.

1. Conservation Biology as a Crisis-oriented, Interdisciplinary Science

There is little doubt left in the mind of professional biologists that we are in the middle of a mass extinction of biodiversity**.** Only this one differs from the prior five in two ways: First, this extinction event is happening in hundreds, not hundreds of thousands or millions of years. Second, though the cause of the prior extinctions is up for debate, all were the result of natural phenomena. This is the first time that one species - *Homo sapiens* - is the direct cause of the extinctions.

In the 1970s, books such as "The Population Bomb" and "Limits to Growth" proposed that growth trends in world population, food production and consumption of non-renewable natural resources were unsustainable.

The impact (I) of any population can be expressed as the product of three characteristics: the population size (P), its affluence or per-capita consumption (A) and the environmental damage (T) inflicted by the technologies used to supply each unit of consumption. One technique for measuring I is the Ecological Footprint, a tool for estimating the resources required to sustain humans, by determining the land area required to support the resource demands and absorb the wastes of a given population.

While most of population growth is occurring in developing countries that harbor 90% of the Earth’s biodiversity, affluent countries, the US in particular, have a 10-30 fold greater impact on the Earth’s resources, and as a result, are major drivers of biodiversity loss and climate change.

The global human population is approaching 6.4 billion, with 80 million people added each year. This staggering growth reflects an average of 4.1 births and 1.8 deaths each second. Human activities, including the clearing of forests, the spread of agriculture, the introduction of animals into new environments, and the pollution of air, water, and soil, account for almost all of the extinctions of the last several hundred years. The Earth is currently losing between 10^3 and 10^4 species per year - which breaks down to the even more daunting numbers of 3 to 30 species per day!

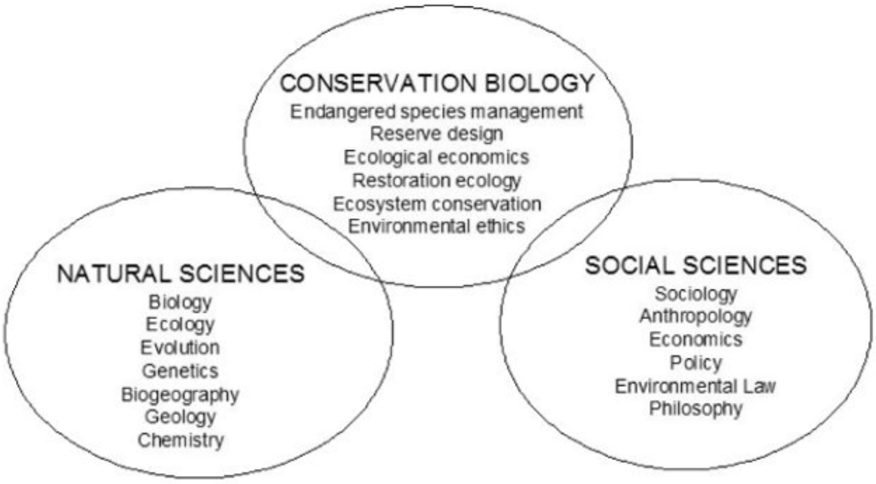

Figure 1. The interdisciplinary nature of conservation biology merges many traditional fields of natural and social sciences (Adapted from Meffe & Carroll 1997 Principles of Conservation Biology, p.23).

Conservation biology is a relatively young, multidisciplinary science that has developed to confront the dramatic reductions of biodiversity caused by human influences on the planet. It applies the principles of ecology, biogeography, population genetics, economics, sociology, anthropology, philosophy and other disciplines to the maintenance of biodiversity throughout the world (Figure 1). The goals of conservation biology are to develop the scientific and technical means for the protection, maintenance, and restoration of life on Earth: species, ecosystems, and the processes that sustain them. This chapter with its diverse array of case studies emphasizes the creative and effective conservation tools, analyses and techniques that have been developed to address these problems.

2. Ecological Theory and its Application to Conservation Biology

The multidisciplinary nature of conservation biology simply does not allow us to cover all topics in depth, and unfortunately many will receive little or no mention here. The focus of the following section is on the ecological theories that have guided the design of reserves networks.

2.1. Theory of Island Biogeography

The first systematic approaches to examining the design of nature reserve systems originated in the application of the Theory of Island Biogeography to fragmented landscapes. This theory postulates that the number of species on islands is the result of a dynamic equilibrium between the processes of extinction and colonization, such that as island size increases, extinction rate decreases, and as distance from the mainland increases, colonization rate decreases. As a result, small islands located far away from the mainland will achieve a smaller equilibrium number of species than large islands located near the mainland (Figure 2).

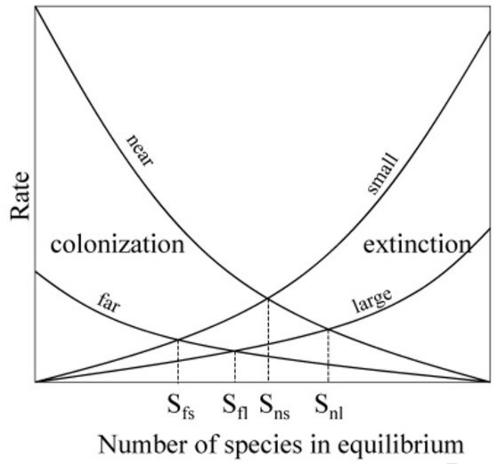

Figure 2. The Theory of Island Biogeography predicts that the number of species in equilibrium for small islands located far away from the mainland is smaller than for a large island located near the mainland (Adapted from B. A. Wilcox Insular ecology and conservation, in M. E. Soulé and B. A. Wilcox, Eds., Conservation Biology: an Evolutionary-Ecological Perspective, pp. 95-118)

With increasing habitat fragmentation and land-use changes in surrounding areas, nature preserves become habitat "islands" and may effectively decrease in size (e.g. due to edge effects) while increasing in degree of isolation from the matrix of habitat that once included them. The Theory of Island Biogeography predicts that the equilibrium number of species in habitat islands should decrease until either the effective size of the nature reserve stops decreasing, or, the effective distance from sources of immigrants stops increasing.

2.2. The Single Large or Several Small (SLOSS) Debate

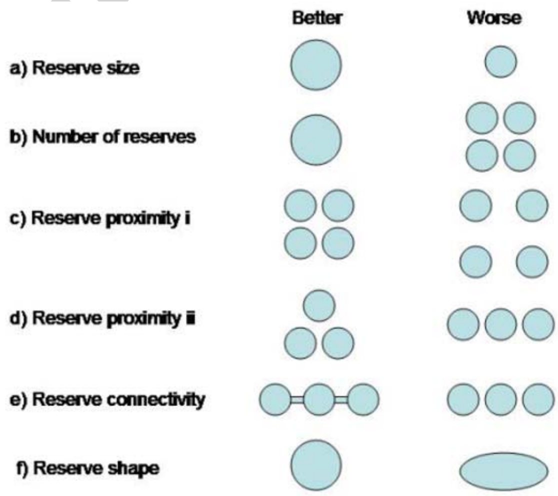

Figure 3. Reserve design guidelines: a) a large reserve is better than a small one; b) a single large is better than several small; c) and d) reserves that are closer together are

better than those farther apart; e) reserves that are connected by wildlife corridors are better than unconnected reserves; a compact (circular) reserve is better than an elongated reserve (redrawn from Biological Conservation, Volume 7, J. M. Diamond, The island dilemma: lessons of modern biogeographic studies for the design of natural reserves, pp. 129-146, ©1975, with permission from Elsevier Science).

The theory further suggests ways in which we can design nature reserves to maximize their ability to maintain diversity. The application of the underlying principles of island biogeography to the design of nature preserves (Figure 3), spawned the "single large or several small" – or "**SLOSS**" debate. The main point of contention was whether the conservation of biodiversity in a particular area was better served by one large reserve or by several small ones. Advocates of "single large" argue that contiguous areas are better able to preserve intact communities of interdependent species. Furthermore, large vertebrates tend to persist only in expansive areas of relatively undisturbed habitat. However, "several small" reserves can cover a wide variety of habitats, and, as a result, protect locally endemic species with small ranges. Multiple reserves are also less likely to be simultaneously devastated by a single random event – such as fire, flood, disease outbreak, etc – whereas a single large reserve might be destroyed by one such disaster. Early arguments on both sides of the issue failed to recognize that the answer to the SLOSS question depends on the conservation target. Different species have different habitat requirements; therefore, the spatial arrangement of habitat patches, i.e. the distance between them as well as the environmental conditions of the surrounding matrix, is important in determining the risk of extinction or decline of a species.

2.3. Minimum Population Size (MVP) and Population Viability Analysis (PVA)

During the mid-1980s there was a shift from the theory of island biogeography which places an emphasis on the equilibrium of species richness, to that of populations, which focuses on individual species. Many ecological studies during this time were being conducted to determine minimum viable population (MVP) size for threatened and endangered species. This concept addresses individual species and their long-term probability of population persistence in habitat patches of various sizes in the face of foreseeable demographic, environmental, and genetic stochasticity and natural catastrophes. The minimum viable population size is typically defined as the minimum size required for an isolated population to have a 99% chance of remaining extant for the following 1000 years in a particular habitat. The tool used by conservation biologists to evaluate the likelihood that it will persist for a given time into the future is called a population viability analysis (PVA)**.**

Usually applied for the conservation and management of rare and endangered species, it focuses on principles of population ecology to assess the species' chance of survival. It explores the interactions between different known factors, such as life-history, ecology, environmental variation, and the effects of various types of threats, and assesses the likelihood that a population will become extinct within a specified time frame and under particular circumstances, using stochastic simulations. PVAs can be used to plan research and focus data collection, to assess **vulnerability** and to rank various management options.

2.4. Metapopulation Dynamics

Human alteration of the landscape frequently leads to the fragmentation and isolation (insularization) of once contiguous wildlife habitat. A single population that formerly was dispersed throughout the continuous forest may be isolated into several smaller patches of habitat. These smaller populations may interact if individuals disperse among the remaining habitat patches. Thus, a metapopulation refers to the range of species composed of geographically isolated patches, interconnected through patterns of gene flow, extinction and recolonization. This paradigm assumes that each population cycles in relative independence of the other populations and may eventually go locally extinct as a consequence of demographic stochasticity**,** but because there are other populations that survive, individuals can disperse back into the area where the population went extinct. In principle at least, metapopulation dynamics provides a framework for conservation biologists dealing with the persistence of species in fragmented landscapes. Furthermore, the development of this theory in conjunction with source-sink dynamics emphasizes the importance of connectivity between geographically separate populations.

2.5. The Importance of Connectivity

Protecting large cores of wild habitat is essential to healthy ecosystems. Cores are areas where human activities are limited and the maintenance of biodiversity is the primary goal. Surrounding the core are buffer zones where human impacts are permitted, but which can also support many wild species. UNESCO's Man and Biosphere reserves are designed after this principle. The Wildlands Project (TWP) has added one additional important component to the design of reserves: Wherever possible, core reserves are linked within and between regions by wildlife corridors that allow natural movement – including dispersal of wide-ranging species for genetic exchange between populations and for the migration of animals in response to climate change (Figure 4).

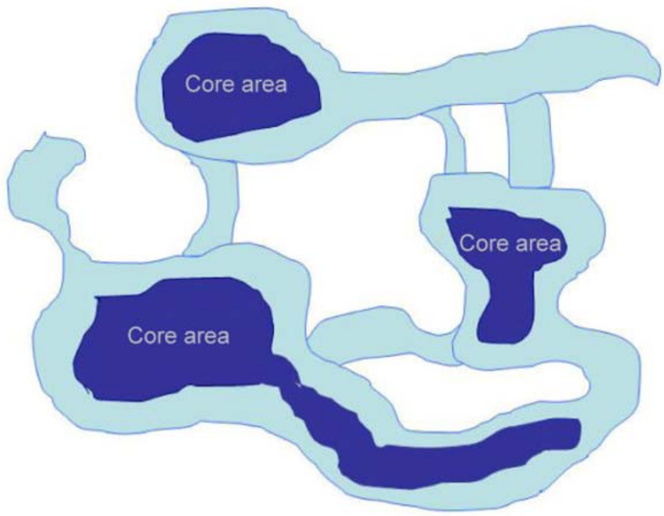

Figure 4. A regional reserve network: core areas and smaller reserves are connected by corridor habitat through which wildlife species can travel (Adapted from Soulé & Terborgh 1999).

Climate change **(***See Global Ecology***)** ranks highly alongside other recognized threats to biological diversity and is predicted to have profound effects on the environmental conditions at the regional level. Model outputs of expected changes in species ranges and ecosystem dynamics have indicated that rapidly changing climatic conditions could significantly affect existing protected areas at a regional scale. For example, many of the National Parks in the United States may lose up to 20% of their species and thus be unable to meet their conservation mandate. The uncertainty of what effect climate change will have on ecosystems and biodiversity emphasizes the need for regional reserve networks with a high degree of connectivity at regional scales.

2.6. Different Strategies for Protecting Biodiversity

The purpose of conservation areas is threefold: 1) to preserve large and functioning ecosystems that deliver ecosystem services (watersheds for flood control, wild bees as crop pollinators) and retain the biodiversity and ecological processes; 2) to preserve biodiversity; and 3) to protect particular species or groups of species of special interest (see Box A for an example of the creation of a National Park that takes all of these factors into account). Therefore, one would ideally develop a series of reserve design options for a region each reflecting a different emphasis (e.g. species of special concern mapping, representation analysis, area-dependent species analysis), compare the outputs and base the final decision on the research results, time and available funds.

Conservation biologists are rarely faced with the luxury of being able to fully design reserves. Rather, they must choose where to efficiently allocate the scarce resources for protecting biodiversity in order to get "the most bang out of the conservation buck". For example, WWF pursues eco-region conservation and has identified the Global 200, the most biologically distinct terrestrial, freshwater, and marine eco-regions of the planet, Conservation International's Hotspots hold especially high numbers of endemic species that are under extreme threat and have lost at least 70% of their original habitat, and, Birdlife International's Endemic Bird Areas seek to protect regions of range overlap of range-restricted endemic species.

We've come a long way since the Theory of Island Biogeography was first applied to the design of protected areas. The shift in focus from protected areas to entire regions grew out of the knowledge that protected areas were too small and too isolated from one another to preserve their species. Simultaneously, there was a shift in emphasis from single species to biodiversity in all its components resulting in an increase in the scale of planning for conservation work.

2.7. The Concept of Complementarity

All of the strategies mentioned above have one common goal: they seek to maximize the representation of the known biological diversity and ecological patterns and processes of an area. Their principle is that of complementarity. Its application in site selection ensures that as many new attributes as possible will be added to an existing reserve system. The attributes can be all species, **endemics**, rare species, landscape units or eco-regions. The well-known **Gap Analysis**, pioneered by Australian scientists in the 1980s, and popularized by U.S. governmental agencies in the decade that followed, is an example of such an approach for selecting conservation areas. It is based on assessment of the comprehensiveness of existing protected area networks and identification of gaps in coverage.

However, representation of biodiversity within protected areas is no guarantee that these species will persist. Furthermore, the presence of a set of target species does not assure that their parasites, predators, prey, or mutualists are included, or that other unrelated species groups will be represented as well.

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Biographical Sketches

Tatjana Good works as a Research Associate for the IUCN Global Mammal Assessment (GMA), through the University of Virginia’s Department of Environmental Sciences. The GMA is a global initiative undertaking comprehensive assessments of the conservation status of all 5,000+ mammal species, thereby improving mammal species' data in the IUCN Red List of Threatened Species, and pioneering new approaches to identifying conservation priorities. Tatjana Good received her MSc in Wildlife Ecology and Conservation Biology at the University of Zűrich, Switzerland and completed her PhD in Behavioral Endocrinology in the Department of Ecology and Evolutionary Biology at Princeton University, USA. Due to her passion for conservation biology and her interest in its interface with public policy, she acquired a certificate in Science Technology and Environmental Policy from the Woodrow Wilson School of Public and International Affairs at Princeton University. She is particularly interested in the conservation of biodiversity and the design of conservation reserve networks, which utilize tools such as Geographical Information System (GIS), species range modeling and reserve design algorithms.

Jon Paul Rodríguez wears many hats: he is a researcher at the Centro de Ecología, Instituto Venezolano de Investigaciones Cientificas (IVIC), Caracas, Venezuela; the Chair of bioDISCOVERY, one of DIVERSITAS’ core projects, and the president of PROVITA, a Venezuelan NGO to mention but a few. He received his PhD in the Department of Ecology and Evolutionary Biology, and his certificate in Science Technology and Environmental Policy from the Woodrow Wilson School of Public and International Affairs at Princeton University (USA). His main research interests are the temporal and spatial patterns of species distributions and abundances, the use of sound science in making environmental policies, and the conservation of endangered species and ecosystems. His projects reflect his interdisciplinary way of thinking, ranging from topics such as: “Present status and future perspectives of Venezuelan fisheries” and “Neotropical Migratory Birds and Mangrove Restoration in Venezuela’s Coastal Wetland” to “Gap analysis of protected areas and biodiversity of the Andean region (Bolivia, Peru, Columbia, Ecuador and Venezuela)” and “Threatened Psitacids of Margarita Island: Symbols for Conservation Education about Venezuela’s Insular Biodiversity”.