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Biodiversity is the array of populations and species on Earth, and the communities, ecosystems and landscapes of which they are component parts. Extinction may threaten local populations or entire species. While attention has focused on the problem of species loss, in many parts of the worlds the loss of local populations may be the most important aspect of the degradation of biodiversity. This paper discusses the importance of population extinction relative to species extinction, offers a preliminary assessment of its importance, and examines policy implications.

Defining Species and Populations

Nature at any given moment presents a "snapshot" of the process of diversification of populations. It is not always possible to have fixed guidelines for defining species and subspecies. A species is usually defined by breeding isolation --members of the species do not breed with members of other species. But local populations may also be defined by geographic isolation. The millions of known species may represent billions of genetically distinct populations, contributing to a pattern of biodiversity which varies across tropical, temperate, subarctic, and arctic regions. While there is less species diversity in non-tropical zones, species in temperate, subarctic, and arctic regions have larger ranges, and therefore almost certainly more local populations per species.

Rates of Population Loss

Considering only species extinctions may greatly underestimate the rate of loss of organic diversity. Species extinctions, especially in tropical areas, have gained attention, but population extinctions, which predominate in the temperate zone, are often ignored. In Britain, for example, changes in land-management practices since 1940 have led to a drastic decline in butterfly populations. Paving over of habitat, drainage of marshes, replacement of deciduous woodlands with conifer plantations, and use of fertilizers, herbicides, and insecticides, as well as climate change and acid rain, have contributed to a general decline of the butterfly fauna. Six percent of species have disappeared, and an additional 29% have suffered massive population extinctions.

Britain, as well as much of Europe, is now "biologically depauperate". Most of temperate Asia, especially China, is in even worse condition, and North America is traveling the same course.

Physical habitat destruction and modification, as well as importation of exotic species, are major causes of the imperiled status of 150 North American bird species and subspecies, as well as the population declines of other species not yet recognized as threatened.

The Significance of Population Extinctions

Why does it matter if populations become extinct? There are moral considerations surrounding the spreading destruction of the natural world. Loss of aesthetic value affects both those who are aware of the loss, such as naturalists and birdwatchers, and also those who suffer the opportunity cost of never experiencing or developing an appreciation for natural beauty. The direct economic value of fish and other harvested species is lost. In addition, population loss reduces genetic diversity, leaving species and ecosystems more vulnerable to environmental change. Reduction of genetic diversity also means that medicinal and agricultural resources are lost. Genetic variability is the "raw material" for selective breeding. Interpopulation variability is a key component of this diversity, one which cannot be duplicated in zoos or botanical gardens.

Perhaps the most important reason to care about population extinctions, however, is the ecosystem services they provide. Carbon fixation, water retention, flood prevention, nutrient recycling, pest control, detoxification of wastes, and many other services depend on natural populations of fauna and flora. An example is provided by the salinization of Australian wheatlands. In southwestern Australia, transpiration by native trees and shrubs maintained groundwater at relatively low levels. When the native species were cleared for wheat cultivation, the groundwater level rose, bringing with it salt concentrations that killed the wheat.

Dependence of ecosystem productivity on local populations is often subtle, yet crucial. The productivity of lakes, for example, is determined by the precise species balance of small crustacea and other organisms. Ecologists are just beginning to understand the degree to which extirpation of a population of one species can lead to a cascade of extinctions. In one case, removal of a predatory starfish allowed one mussel species to outcompete and exterminate numerous other species. Species interactions are often complex. Swallow species in Colorado depend on the co-occurrence of aspen trees, willow trees, red-naped sapsuckers, and a fungus that attacks aspens. The sapsuckers excavate nest cavities in fungus-affected aspens, which then become available as nest sites for the swallows within reach of food sources provided by the willows. Loss of species diversity in an area disrupts the web of species connections, causing a loss of "ecosystem plasticity" or adaptability.

The Economics of Preservation

The literature on the economics of species preservation is well-intentioned but unsatisfactory, since the uncertainties associated with valuation of existing species are overwhelming.[1] Further, in a context of rapid global change it is extremely difficult to determine the minimum viable population levels of species. Economic evaluation of the benefits and costs of conserving any single species is an exercise in "crackpot rigor" -- detailed mathematical analysis without ecological foundation. Analysis of population losses brings in additional uncertainties

regarding the uniqueness of the population, the reversibility of the loss, and the impact on the viability of the species as a whole.

The solution to this dilemma is for both ecologists and economists to focus on the overall values of ecosystems, and to eschew analysis of the costs and benefits of extinctions. Populations of species in an ecosystem are analogous to rivets in an airplane wing. Some are more critical than others in maintaining system function, but the continued deletion of populations, like continual popping of rivets, will eventually lead to collapse. "Both the great uncertainties in how much biodiversity is required to maintain humanity's life support systems and the irreversibility of any mistakes call for an extremely conservative approach. The burden of proof should be shifted to those who promote the loss of biodiversity for short-term gains. In addition, economists should focus on strategies to monetize the known values of ecosystems so that ways can be found to internalize them." (67)

Policy Implications

Habitat preservation is crucial both to saving biodiversity and to preserving ecosystem function. No destruction or fragmentation of habitat should be taken lightly. The population extinctions resulting form habitat loss and fragmentation should be considered at least as important as species losses. Legislation should provide for the maintenance and restoration of habitat. Emphasis should also be placed on restoration ecology -- restoring degraded lands and increasing population diversity. Urban and regional planning should focus on ways to reduce the human "footprint" on the planet, and to maximize the areas that can be devoted to the preservation of population, species, and ecosystem diversity. "The health of the human ecosystem must be assumed to depend as much or more on the maintenance of population diversity as it does on the maintenance of species diversity. Any other assumption amounts to taking a gigantic gamble with the future of civilization." (67)

Notes

1. See R.C. Bishop (1978).