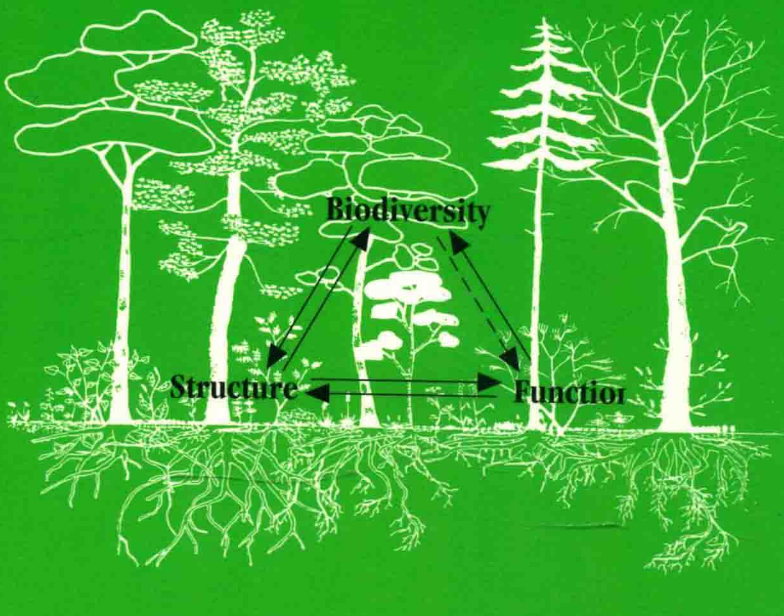
SPRINGER STUDY EDITION

E.-D. Schulze · H. A. Mooney (Eds.)

Biodiversity and Ecosystem Function



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Preface

The biota of the earth is being altered at an unprecedented rate. We are witnessing wholesale exchanges of organisms among geographic areas that were once totally biologically isolated. We are seeing massive changes in landscape use that are creating even more abundant successional patches, reductions in population sizes, and in the worst cases, losses of species. There are many reasons for concern about these trends. One is that we unfortunately do not know in detail the consequences of these massive alterations in terms of how the biosphere as a whole operates or even, for that matter, the functioning of localized ecosystems. We do know that the biosphere interacts strongly with the atmospheric composition, contributing to potential climate change. We also know that changes in vegetative cover greatly influence the hydrology and biochemistry of a site or region. Our knowledge is weak in important details, however. How are the many services that ecosystems provide to humanity altered by modifications of ecosystem composition? Stated in another way, what is the role of individual species in ecosystem function? We are observing the selective as well as wholesale alteration in the composition of ecosystems. Do these alterations matter in respect to how ecosystems operate and provide services? This book represents the initial probing of this central question. It will be followed by other volumes in this series examining in depth the functional role of biodiversity in various ecosystems of the world.

This effort is a result of a program co-sponsored by the International Union of Biological Sciences (IUBS), the Scientific Committee of Problems of the Environment (SCOPE), and the Man and the Biosphere Program (MAB) of UNESCO. The Scientific Steering Committee of the Ecosystem Function of Biodiversity component consists of D.L. Hawksworth, B. Huntley, P. Lasserre, E. Medina, H.A. Mooney (Chairman), V. Neronov, E.-D. Schulze, and O.T. Solbrig.

A symposium held near Bayreuth, Germany, between October 1–4, 1991, was the beginning of this volume. Most of the contributors to this effort were present at the meeting which was financially supported by IUBS, SCOPE, MAB, Electric Power Research Institute, German Science Foundation (SFB 137), and German Ministry for Technology and Research (BMFT) through the Bayreuth Institute of Terrestrial Ecology (BITÖK).

Bayreuth and Stanford

E.-D. Schulze
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Foreword
Biodiversity and Ecosystem Function: Need We Know More?

P. R. Ehrlich

The answer to the question posed in the title, from the viewpoint of science, clearly is "yes"; from the viewpoint of taking action to preserve biodiversity, the answer is equally clearly "no".

Let us consider the "yes" first. There is a great deal of uncertainty about the way in which the diversity of the populations and species in an ecosystem is related to the functional properties of the ecosystem. More research is badly needed; the lack of understanding is a major lacuna in our picture of how the world works.

Of special interest to humanity is the relationship of biodiversity to the variety of services provided by ecosystems and, in particular, to the stability of the flow of those services, such as the maintenance of the gaseous composition of the atmosphere, preservation of soils, recycling of nutrients, and provision of food from the sea. Ecologists generally accept the viewpoint expressed in the "rivet popper" analogy (Ehrlich and Ehrlich 1981) that a policy of continually exterminating populations and species eventually will dramatically compromise ecosystem services. It remains impossible to specify when "eventually" might be, as was emphasized in the original analogy:

> Ecosystems, like well-made airplanes, tend to have redundant subsystems and other "design" features that permit them to continue functioning after absorbing a certain amount of abuse. A dozen rivets, or a dozen species, might never be missed. On the other hand, a thirteenth rivet popped from a wing flap, or the extinction of a key species involved in the cycling of nitrogen, could lead to a serious accident. (pp. XII–XIII)

This volume surveys the present state of knowledge about biodiversity and its influence on some aspects of ecosystem functioning and suggests research agendas that could improve our understanding. It is conceivable that some general rules for the potential impact of population/species extinction on the properties of ecosystems will eventually be attained.

Scientifically, the effort to uncover such rules is very important. But to turn to the "no," we already know enough about the manifold values of biodiversity (of which involvement in biogeochemical cycles is just one) *to take action now.* Detailed studies of natural and perturbed systems to yield information on ecosystem responses to extinctions are not required for developing a sound conservation policy.

The rivet popper analogy suggests what the proper overall policy should be: It is essential that biodiversity be preserved (and restored) wherever possible. No more relatively undisturbed natural systems should be cleared to make way for development, which should be confined to areas already strongly altered by humanity. Rates of global change should be slowed so as to give natural ecosystems more time to adjust. Such a conservative conservation policy is mandatory even from the standpoint of major ecosystem processes, no matter what the level of redundancy in the functioning of different populations or species in biogeochemical cycles or other ecosystem processes. That is because the roles played by various organisms in communities (and thus in ecosystems) are often not at all transparent; either one of two herbivores or two insectivores do not necessarily have equivalent impacts on the ecosystem functioning. Detailed knowledge of relationships among the organisms of an ecosystem is required before one could be reasonably secure in declaring that the removal of a given component population or species will have no significant detrimental impact on the functioning of the system, and that information is usually not available.

Three examples from community ecology illustrate how difficult it may be to draw conclusions on ecosystem impacts without detailed knowledge of the system. Observations taken over a short interval (a "snapshot") will often miss essential elements, as will a lack of understanding of keystone roles. In the first instance, some years ago Charles Birch and I searched in vain for caterpillars of *Cactoblastis cactorum* on isolated clumps of imported *Opuntia* cactus in Queensland, Australia. If we had not known the story, we would never have concluded that one small herbivore, an introduced biological control agent, was responsible for removing almost all the *Opuntia* from 25 million hectares of Queensland and New South Wales and for keeping the area free of serious infestation (DeBach 1974). In the *Opuntia* case, there is no question that important ecosystem services were altered first by the importation of the cactus and then by the importation of the moth – indeed, agriculture was made impossible and natural ecosystems were transformed over some 12 million hectares until the cactus was brought under control.

In contrast, our group has observed several natural extinctions of Bay checkerspot butterfly (*Euphydryas editha*) populations, whose caterpillars are usually much easier to find than those of *Cactoblastis*, and those extinctions have not resulted in discernable increases in populations of the butterfly's foodplants or changes in the functioning of the serpentine grassland ecosystems in which they occurred. The reasons for the different ecosystem impacts of these two lepidopterous herbivores are well understood but would not have been obvious from short-term studies by a scientist unfamiliar with the two ecosystems.

In a more complicated example, Gretchen Daily and her colleagues (1992b) have found that in subalpine Gunnison County, Colorado, red-naped sapsuckers (*Sphyrapicus nuchalis*, a woodpecker that drills wells into shrubs and trees and feeds on the sap that flows from them) require willow clumps in close proximity to aspen stands in order to breed. The sapsuckers, by far the most abundant primary cavity nesters in the region, also make nest holes that are subsequently used by tree and violet-green swallows (*Tachycineta bicolor* and *T. thalassina*). If a patch of aspens lacks willows, sapsuckers will not breed there and neither will swallows. The sapsuckers appear to function as keystone herbivores (Ehrlich and Daily 1988) since they cause heavy mortality among the willows, provide nest cavities to a variety of secondary hole-nesting birds other than the swallows, and also supply sugary sap to a wide range of vertebrates and invertebrates that steal it from the wells. A more obscure keystone in the system is the fungus (*Fomes igniarius*) that causes heart-rot in the aspens. The sapsuckers appear able to excavate nests only in infected trees; if the fungus were wiped out, there would be no sapsuckers, no swallows, and no high-quality food supplements for many species (Daily 1992a).

The probable impact on the local ecosystem of the removal of a keystone component of the sapsucker complex from the subalpine community is difficult to predict. Perhaps most or all of the subalpine system's biogeochemical functions would remain unchanged, or perhaps increases willow survival (or some unexpected effect mediated by subsequent changes in populations of other organisms interacting with the sapsuckers) would have an effect on those functions over the long term.

In the *Opuntia* example, policymakers would be well justified in taking steps to conserve *Cactoblastis* or in reintroducing it if it should go extinct. Whether preservation of the red-naped sapsuckers could be justified on the basis of their contributions to the ecosystem services is not known – and the question could likely only be answered by allowing them to go extinct.

The rivet popper principle provides the scientific guidance to cover the sapsucker example; the birds should be protected because of the uncertainty over the effects of random deletions of populations or species from ecosystems and because of the near certainty of the effects of a policy of continuing deletions. Unless humanity is willing to run a planet-wide experiment to see how well depauperate communities will support ecosystem services (Ehrlich 1991), it generally should operate on the principle that all reductions of biodiversity are to be avoided simply because of potential threats to ecosystem functioning.

The incompatibility between current rates of destruction of that diversity and the acquisition of knowledge about its ecosystemic consequences also argues strongly for a conservative approach to setting broad policy. Of course, so do the nonecosystemic reasons – ethical, esthetic, and economic – for preserving our only known living companions in the universe (Ehrlich and Ehrlich 1981). All decision-makers should be informed of this broad policy recommendation, which should form the background for taking action in specific cases.

Research on specific cases to reduce the uncertainty can help significantly with the evaluation of alternative courses of action, the optimal allocation of limited funds to conservation efforts, and the relative merits of competing parties' interests. If ecologists are to persuade decision-makers to make biologically sound decisions, then they will often need the kind of detailed knowledge that can be generated by properly prosecuted research.

Ecologists find themselves in a difficult position. Given the funds to do the research, they can greatly improve the efficiency of decision-making about the preservation of biodiversity and ecosystem services in specific cases. This is true even in situations in which high levels of uncertainty persist. Sound scientific guidance can be given about decisions at a level of $P = 0.50$, just as it can about decisions at the level of $P = 0.99$ (even though many scientists have not yet learned to think in terms of providing policy advice with high levels of uncertainty).

A standard way for politicians to avoid taking unpalatable actions, however, is to call for and offer to finance more research. Ecologists must not permit inadequate funding of their field to cause them to concentrate on garnering research grants to the exclusion of pressing for action on the basis of knowledge already available. On the other hand, without much more research, many conservation efforts are likely to be carried out inefficiently, reducing the chances of their ultimate success. Our job is to push politicians to start acting now on the basis of present knowledge while they invest the necessary resources in the research required to increase the efficiency of their actions. We can no more afford to wait for more knowledge to start preserving ecosystem services than an earthquake-prone area can afford to wait for the ability to predict the time and magnitude of earthquakes precisely before starting to strengthen buildings, improve fire-fighting capabilities, and make plans for evacuation and disaster relief. Once preparations have been begun, research to develop a better predictive ability, better fire-fighting techniques, more secure structures, and so on will continue to pay dividends in lives saved and damage averted. Action and research should go hand in hand.

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