Systematics, biodiversity science, and the conservation of the Earth’s biota

Systematik, Biodiversitätswissenschaft und Erhaltung der Vielfalt des Lebens auf der Erde

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Summary

Systematic biologists have described about 1.75 million species of organisms, and tens of millions remain to be discovered and described. Because of the continuing conversion of wildlands for human uses, it is certain that countless species are being lost. It has been estimated that the current extinction rate is 1,000 to 10,000 times the geological background extinction rate. This extinction is certain to result in profound consequences for all human societies inasmuch as these societies depend on these species for their ecological services, their contribution to the global economy (trillions of dollars in commerce each year), and their spiritual–esthetic benefits. Essentially all species and their habitats must be managed sustainably, but in order to do this much more biodiversity science will be needed. The move within the world’s great universities away from whole-organism biology and toward molecular–cell biology imperils humanity, because it is the study of organisms - through those disciplines constituting the biodiversity sciences- that provides the basis for managing the world’s species, habitats, and ecosystems.

Introduction

The Deutsche Zoologische Gesellschaft has a long, proud, and great tradition in organismal and evolutionary biology. This tradition gave Germany a leadership role in the comparative biology of life’s diversity during the 19th and 20th centuries. Over the last several decades, however, German biological science, like that in the United States and all other industrialized nations, has moved away from the study of whole organisms and toward molecular and cellular biology. This de-emphasis of whole-organism biology - or biodiversity science (Cracraft 1995) - in the world’s great universities is tragic. In fact, one might say it borders on being suicidal from the long-term perspective of the future of human societies. Fortunately many universities have begun to recognize the value provided by organismal biology and programs are expanding. But society’s need for knowledge about whole-organism biology is enormous, particularly in the developing world.

This paper will expand on this proposition and will make the case for promoting whole organism biology to a pre-eminent position within biological science. In doing this I would like to make the following major points:
- Earth’s biodiversity is largely unknown and it is all under threat.
- Scientists, as well as the general public, tend to underestimate the role biodiversity plays in sustaining all societies, and because of this the consequences of its loss are also not fully appreciated.
- Our lack of knowledge about biodiversity places profound limitations on the future well-being of human societies
- A substantial increase in our knowledge about biodiversity is fundamental for solving
societal problems and building a sustainable future. This last point can be made by discussing some of the findings and implications of the international systematics initiative, Systematics Agenda 2000.

Species diversity and extinction

According to the most recent estimate (UNEP 1995), there are about 1.75 million species of organisms known to inhabit the Earth. The actual number of species - most of which are insects and microorganisms - that constitute the vast number of habitats and ecosystems is much more than 1.75 million, of course, and estimates range from 10 to 100 million, with the most conventional of these values settling near 15 million (UNEP 1995). On a global scale, however, this latter figure is very likely much too low. Species richness in the marine realm has barely begun to be understood, and current evidence suggests that many millions of species remain to be discovered and described (Grassle and Maciolek 1992; Poore and Wilson 1993). Moreover, we have a paucity of knowledge about diversity within many of the poorly known ecosystems, starting with soils and going deep into the Earth itself (Pedersen 1993; West 1994), and no doubt those ecosystems harbor vast numbers of unknown species.

The fact that we cannot specify the global numbers of species to an order of magnitude, and the fact that we do not have a precise understanding of the patterns of distribution even for the vast majority of the species already described, limits our ability to quantify current extinction patterns and rates of loss with much accuracy. Most current thinking is that extinction rates are 1,000 to 10,000 times the historical “background” rate. Wilson (1992), for example, calculates that as many as 27,000 species a year are being lost from tropical moist forests. His estimate is derived from habitat loss and conversion of wildlands for human uses, which already had reached an average of 65% for all of Africa and 67% for tropical Asia in the early part of this decade (McNeely et al 1990). Wilson’s rates are based on rather conservative assumptions - that there are 10 million species in these tropical forests and that they are widely distributed. Yet, most of the biogeographic evidence suggests that species are rather narrowly distributed, and thus narrowly endemic. If true, then Wilson’s figure may be an underestimate of species loss. In any case, a very large number of species - mostly small, undescribed arthropods and microorganisms - are probably being driven to extinction with continued land transformation.

The values of biodiversity and the consequences of its loss

So what does it matter? What are the consequences of the loss of biodiversity? The answers to these questions should be immediately obvious to any educated person, yet many people - scientists who work on whole-organism biology included - often fail to see the true value and benefits of biodiversity and thus cannot imagine all the consequences that are associated with its loss. As others have noted, biodiversity is the lifeblood of human societies: it is the ecological support system that sustains us and provides for a quality existence. That is simple enough, but such a statement does not go very far in describing for the average person what, exactly, the benefits of biodiversity are. There are three broad categories of values to biodiversity: (1) ecosystem services, (2) utilitarian/use services, and (3) esthetic/spiritual benefits (see UNEP 1990, for a detailed discussion).

Societies in many regions of the world - rich and poor - are under severe stress because ecosystem services are breaking down. Poor water quality, loss of soils, exposure to disease agents, pollution, and other environmental impacts arise when ecosystem services are disrupted or lost, and at the local level this can cause considerable economic and
social hardship. At the global level, the increase in global warming is due, in part, to the loss of ecosystem services. Some broad categories of ecosystem services include (UNEP 1995, Myers 1996): climate regulation, maintaining biogeochemical cycles, controlling hydrological cycles, soil production and protection, pollination, biological control, among others. Ecosystem services underlying worldwide agriculture are alone worth trillions of dollars to the global economy.

Few people understand the magnitude of utilitarian uses supplied by the world’s species. In fact, those uses fuel the world economy. The utilitarian value of biodiversity cannot be accounted for solely in dollar terms but needs to be seen within the framework of how people use species to survive and maintain their standard of living. Globally, human beings use many tens of thousands of species each year (Groombridge 1992, UNEP 1995). Most of the world’s peoples are outside of the industrial-country mainstream of high-technology use of biodiversity. Most people, for example, rely on traditional medicines and are largely economically denied access to modern pharmaceuticals. Likewise, in many societies people rely heavily on food taken from the wild, in many cases using hundreds of species opportunistically each year. Thousands of species are traded locally and globally for food, shelter, medicines, pets, plant and animal byproducts, and a host of other uses. Thus, to understand the severe consequences of the loss of biodiversity, one must see how billions of people use these species in their daily lives, far from the commercial amenities provided to those of us living in the industrialized nations.

Finally, species have played traditional roles of symbolism and veneration in the religious life of many societies. Plant and animal species provide continuing solace, esthetic satisfaction, and comfort to people everywhere. People use species to maintain a connection to nature, but often take for granted what this connection means to them emotionally and psychologically. But ask a simple question of any urban dweller: would you go to a park to relax if that park were devoid of every species—no grass, no trees, or birds or mammals, no cool shade, no nothing? The answer would almost certainly be no. In fact, such a tract of land would not be a park anymore.

As biodiversity continues to be lost, the consequences of that lost will escalate and increasingly will exact a toll from societies everywhere. This is why it is imperative to make the connections between biodiversity and the benefits it provides. Once that is done, the consequences of extinction, local and global, become more tangible. Some of these consequences include:
- Accelerating deterioration of ecological services
- Accelerating decline of global human health
- Increased alienation of the human spirit and psyche from nature
- Increased poverty
- Greater overexploitation of increasingly scarce natural resources
- Increased warfaring/conflict
- More political/economic instability

The causes of biodiversity loss and its implications for biodiversity science

Figure 1, in a very simplified manner, attempts to identify some of the causal interconnections that can lead to environmental degradation and, eventually, the loss of biodiversity. The specific causal pathways shown in the figure have been discussed by many authors, and patterns of causation obviously vary from country to country. By and large, however, political and economic policy decisions are at the root of the causal chain of extinction (e.g., Chichilnisky 1996). These decisions, in turn, lead to a cascade of effects that result in environmental degradation, loss of habitat, and overexploitation of natural resources.

The point to be made here is that because of the complex factors leading to biodiversity loss, the solutions will be equally complex. The overriding conceptual approach
A MODEL FOR THE LOSS OF BIODIVERSITY

Fig. 1: A simplified causal model for the loss of global biodiversity. Understanding of the complexities of biodiversity loss reflects the myriad ways humans use biodiversity in their daily lives. It is only through such understanding that we can appreciate the complexities of the solutions that must be developed to preserve and sustainably use global biodiversity.

currently having political force among the world’s nations is the notion of sustainable development, which is a term laden with many meanings and nuances. Yet, by and large, there is little alternative except to attempt to increase people’s standard of living while at the same time striving to sustain the Earth’s natural resources for future generations. It is no secret that very few of those resources are currently being used sustainably. If this situation is to be reversed, much more attention will have to be paid to finding ways to bring about sustainability. Because of the ubiquitous global transformation of virtually every ecosystem on Earth, conserving those ecosystems will require that we manage them. It does not seem possible anymore, except perhaps in very rare cases, that ecosystems can be left inviolate and pristine without any human intervention whatsoever. This implies that all ecological systems will have to be managed.

The importance of systematics and the biodiversity sciences

Managing the Earth’s species and their ecosystems sustainably will require much more scientific information than is presently available, and most of that information will
necessarily have to be provided by the biodiversity sciences, that is, those disciplines focused on the biology of whole organisms (Cracraft 1995). Without increased knowledge from these disciplines—systematics, ecology, population biology and genetics, physiology, and behavior, and the other comparative sciences—the goal of sustainable development will remain only wishful thinking. This perspective is neither provocative nor wrong-headed, only common sense: natural resource management cannot take place in a vacuum of information about populations, species, and ecosystems.

The international systematics science initiative Systematics Agenda 2000 (SA2000) seeks to educate scientists, policymakers, and the public about the key role that systematic biology plays in supporting the conservation and sustainable use of natural resources (Systematics Agenda 2000 1994a, 1994b; Wheeler 1995a, 1995b; Cotterill 1995, Simpson and Cracraft 1995, Agenda Systematik 2000 1996), as well as to promote the importance of all the biodiversity sciences. Systematics is often a misunderstood science, being characterized frequently as stamp collecting. Yet without the discovery and description of species and an understanding of their phylogenetic relationships, modern agriculture and forestry (Miller and Rossman 1995, Rossman and Miller 1996), fisheries management (Vecchione and Collette 1996), human health services (Davis 1995, Oliver 1996, Balick 1996), and natural resources management (Cotterill 1995, Savage 1995, Prance 1995, McNeely 1995, Vane-Wright 1996) would not be possible. One only has to imagine a world in which we did not know the identity or geographic distribution of disease organisms, agricultural pests and pathogens, biological control agents, exotic (introduced) species, wild relatives of food crops, or any of the biotechnologically and pharmacologically useful species to begin to understand the magnitude of the importance of systematic biology.

Systematics Agenda 2000 proposes a global research initiative to inventory and describe the world’s species, understand their phylogenetic relationships, and to use the latter to construct a maximally efficient information system (Systematics Agenda 2000 1994a, 1994b; Agenda Systematik 2000 1996, Wheeler and Cracraft 1996). Society has gained vast benefits from having this information about a small percentage of the world’s species, and it stands to reason that knowledge provided by the discovery and understanding of new species will provide unimaginable benefits to future generations (see many of the papers cited above for examples).

It is the usefulness of scientific knowledge for managing natural resources that should be the primary impetus to expand systematic research and that of the other biodiversity sciences. It is often believed that technology will be capable of mitigating current environmental degradation and will have the capacity to compensate for what we might lose to extinction. Such a view is myopic, as a few simple examples will demonstrate:

1. Agriculture and forestry will collapse if insect pollinators are driven to extinction; technology cannot replace natural pollination processes. Nor will technology be capable, by itself, of replacing lost germplasms and biological control agents that sustain agroecosystems worldwide.

2. Global human health depends less on drugs created by pharmaceutical companies than it does on traditional medicines found in natural environments. Approximately 80% of the world’s peoples are economically excluded from most of the technologically-intensive health care services available in the industrial nations and instead obtain their health care through traditional sources. What happens to global health when the «environmental pharmacy» serving 80% of the population is lost? Thus, the single most important strategy for maintaining and improving global health care is not to put our expectations for survival on the shoulders of modern molecular medicine—important as that may be— but to conserve the world’s biodiversity. Medical technology is presently the most advanced it has ever been, yet paradoxically more people suffer from disease and more new diseases are emerging than ever before. Human health is inseparable from ecosystem health.

3. Technology cannot be expected to replace the myriad of ecosystems services cur-
rently provided by the ecological assemblages of the world's species. For most of the world clean water, clean air, soil formation and erosion protection, and other ecological services will continue to come from biological diversity not technological advances.

Conclusions

Many individuals, organizations, and international agencies have recognized the need for more systematic information about the world's species. At the same time, they have identified serious impediments to fostering systematics science, including the loss of systematic expertise for many groups of organisms, the inadequacy of training and education programs to generate that expertise, the deterioration of many of the world's natural history collections, the absence of these collections or of adequate collection support in most countries of the world, and the lack of an efficient information system linking systematics research centers around the world and to the users of systematic information (among many voices, see Oliver 1988, Parnell 1993, Patterson 1994, Seymour 1994, Wheeler 1995c).

Whereas these impediments exist in each of the industrialized countries, they are of far greater magnitude in the developing nations, where generally biological diversity is at its richest but science capacity is least established (Raven 1990, Cracraft 1995, and citations therein). Thus, SA2000 endorses the view that building systematics science capacity in the developing regions of the world—where the need for effective resource management is most critical—is an urgent priority. This will entail establishing natural history collections if none exist and creating research and curatorial positions to oversee and utilize those collections. These collections will thus become the locus for documenting the biological patrimony of that country, for training systematic expertise and support staff, and for educating the general public on the importance of their biological diversity (Cotterill 1995, Wheeler and Cracraft 1996).

In the developed countries there is a pressing need to re-establish or expand systematics research centers, not only in traditional natural history institutions such as museums or herbaria, but also in universities. Systematics research centers in universities are especially important for it is there that most professional training takes place. Some industrial countries have outstanding research collections, yet most of their universities have abandoned or reduced professional training, thus creating a crisis for the long-term maintenance of those collections and the quality of specimen-based research.

Finally, as SA2000 has stressed, it is essential that a global biodiversity information system, organized within the predictive framework of a phylogenetic classification scheme, be developed. An immense amount of biological knowledge is associated with the specimens housed in the world's natural history collections, in published systematic monographs and revisions, and in the systematic literature in general, yet relatively little of that information is electronically available worldwide to those who need it.

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