Mass extinction—profound problem, splendid opportunity

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A major extinction spasm is under way, threatening to eliminate millions of species. Fortunately *we still have time—although only just—to slow and stem the tide of extinctions that is washing* over earth's biotas. We cannot stop the mass extinction altogether; the processes of broad-scale habitat depletion have generated too much momentum to be halted overnight. But there is still much we can do to contain the scale of extinctions. In short, the prospect of a broad-scope depletion of earth's biodiversity is all too real: a profound problem. All too real also is the scope for an expansive effort to limit the phenomenon, and to save species in their millions: a splendid opportunity.

A mass extinction under way

There have been many recent prognoses of a sudden and massive increase in the rate of extinctions (Myers, 1979 and 1987; Ehrlich and Ehrlich, 1981; Club of Earth, 1986; Soule, 1986; Raven, 1987; Western and Pearl, 1988; Wilson, 1988). Generally speaking, these assessments agree that (i) the present rate is an average of several species per day (or at least one thousand times more than the background rate during the prehistoric past); (ii) this rate may well accelerate to several species per hour by the year 2000; and (iii) we may well lose anywhere from one-quarter to one-half, and conceivably a still greater share, of all species by the time the extinction spasm abates several centuries hence (i.e., after delayed-fallout effects, or processes of 'ecological equilibriation', have worked their ultimate impact).

Those who question the data base for these prognostications may care to consider a sample calculation from three areas (Myers, 1988). In the tropical forests of Madagascar, Atlantic-coast Brazil and Western Ecuador, before large-scale clearance began, there were 26,000 recorded vascular plant species, 12,400 (48 per cent) of them being endemics. For every plant species, there were probably at least 20 animal species (possibly several times more), making a minimum of 520,000 animal species, 250,000 being endemics. Forests in the three areas now cover less than 10 per cent of their original extent, or will do so by the end of the century if not sooner. The findings of island biogeography reveal that when a habitat loses 90 per cent of its area, it can support only 50 per cent of its original complement of species. Thus recent or near-future extinctions in these three areas alone could well total some 6200 plant species and at least 125,000 animal species. If, as is likely, the great majority of these extinctions will have occurred during the last 50 years of this century, there will have been eliminated an average of one plant species every three days, and several animal species, possibly as many as five species, every day (Table 1).

When we consider 10 other areas in tropical forests—the Colombian Choco, uplands of western Amazonia, Rondonia/Acre States in Brazilian Amazonia, the Tanzania/Kenya montane forests, the Eastern Himalayas, the Sinharaja forest in Sri Lanka, Peninsular Malaysia, northwestern Borneo, the Philippines and New Caledonia—we find that more than 18,000 higher-plant species, and at least

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360,000 animal species, are likely to have been eliminated already or to be on the verge of extinction. These plant species constitute just over 7 per cent of all such species on earth, in 0.3 per cent of earth's land surface.

There is solid empirical evidence, in tropical forests alone, then, to support the prognosis of a mass extinction episode. We face a situation where the earth's biotas appear set to become depleted to an extent that may well exceed that of the mass extinction at the end of the Cretaceous Period, 65 million years ago, when the dinosaurs and associated assemblages of animals disappeared. Today, however, there are more species extant, so the total in question this time is greater. A further difference is that the late-Cretaceous depletion probably spanned several thousand, if not more, years. The present extinction episode will occur largely within a single century, and wholly within a few centuries.

Impoverishing impact on the future of evolution

Even more importantly, the present episode may have uniquely severe repercussions for the future course of evolution. The forces of natural selection can work only with the species stocks available, and if these stocks are drastically reduced, the result is likely to be a depletion of evolution's speciation capacities, persisting far into the future. The geological record indicates that 5–10 million years elapsed after the dinosaur crash before there emerged a set of diversified and specialized biotas to match what was there before. The evolutionary outcome this time could prove still more severe. The present depletion will involve all major categories of species, since wildlife habitats are being eliminated wholesale. This contrasts sharply with what happened in the late Cretaceous, when not only placental mammals survived, but also birds, amphibians and many non-dinosaurian reptiles.

More significant still, the present extinction spasm looks likely to eliminate a sizeable share of terrestrial plant species, by contrast with mass-extinction episodes of the prehistoric past when terrestrial plants survived with relatively few losses (Knoll, 1986) and thus supplied a resource base on which evolutionary processes could start to generate replacement animal species forthwith. If this biotic substrate is markedly depleted within the foreseeable future, the restorative capacities of evolution will be diminished all the more.

We must also anticipate the elimination of many key environments—tropical forests, coral reefs, wetlands, estuaries and other biotopes with exceptional richness of species. These environments

Table 1. Three critical areas: Madagascar, Atlantic-coast Brazil and Western Ecuador

Area	Original forest (sq km)	Remaining primary forest in 1987 (sq km) and per cent of original	Total of original plant species	Total of original plant endemics and per cent of original species	Total of plant species eliminated or on verge of extinction*†	Remaining forest area as proportion of earth's land surface	Total of original plant species as proportion of all earth's plant species
Madagascar	62,000	10,000 (16%)	6000	4900 (82%)	2450‡	0.00675%	2.4%
Atlantic-coast Brazil	1,000,000	20,000 (2%)	10,000	5000 (50%)	2500	0.0135%	4.0%
Western Ecuador	27,000	2500 (9%) at most	10,000	2500 (25%)	1250	0.0017%	4.0%
Total	1,089,000	32,500 (3%)	26,000	12,400 (48%)	6200	0.02%	10.4%

*In light of the findings of the theory of island biogeography.
†The number of animal species in a similar situation can be roughly estimated by multiplying the number of plant species by 20, thus supplying a minimum estimate. According to the calculations presented here, the total number of animal species in question is 124,000. The actual total could be several times higher.
‡That is, when remaining Madagascar primary forest declines to 10% of original extent, which is likely within the next decade at most.

have served in the past as 'powerhouses' of evolution, having generated many more species than other environments (Mayr, 1982). By losing them, the biotic underpinnings of many basic evolutionary processes will have been severely degraded and depleted. It will be enduring damage, to the extent that it will not permit a compensatory outburst of speciation until after a longer delay than has been the ostensible case in the past. Whereas a 'bounce back' period following the late Cretaceous extinctions lasted only a few million years, this time the delay could be much longer, possibly twice as long or more.

For these diverse reasons, we face the prospect of an impoverishing phenomenon for earth's biotas that may well prove to be the greatest single setback to biodiversity since the beginning of life almost four billion years ago. It will mostly occur within a single century, or 0.000025 per cent of the time that earth has featured life. It will also take place largely within the lifetimes of biologists and conservationists now alive.

A global experiment, entirely unplanned

In short, we are unwittingly conducting an experiment of global scale and unprecedented import. While its results cannot be anticipated in detail, we can be sure its overall outcome will be wholly irreversible. Thus, it is remarkable that today's evolutionary biologists conduct their enquiries almost entirely with a retrospective approach, seemingly indifferent to the tumult of evolutionary activity that is gathering with every passing day. Is this not, in some senses at least, a uniquely fortunate time to be an evolutionary biologist, when there are abundant opportunities for research, and research of a radically pioneering kind?

Consider, for example, Lake Malawi in East Africa. This 29,600-sq-km lake has more than 500 cichlid fish species, 99 per cent of them endemic. This contrasts with the Great Lakes of North America, eight times larger, yet supporting only 173 fish species, less than 10 per cent of them endemic. The recent evolution of Lake Malawi has featured much explosive speciation, producing an exceedingly rich fish fauna with greater differentiation than in any other tropical lake. Indeed, Lake Malawi, together with a chain of other lakes in Eastern Africa (harbouring almost 1000 endemic chichlids altogether, plus more than 100 other endemic species), must be far more significant for the study of evolution than the Galapagos Islands (Greenwood, 1984). Yet the basic biology of Lake Malawi, the leading lake in the chain, has yet to be elucidated, and there is next to no scientific programme for long-term systematic research. What is worse, Lake Malawi is imminently threatened with pollution from industrial installations.

There are many other such ecosystems in the tropics: exceptionally rich and interesting, exceptionally unexplored, and exceptionally threatened by our global experiment.

Scope for action initiatives

What should we, as conservationists and biologists, do in response? I propose two main categories of action—a programme of research and a comprehensive species conservation strategy.

A programme of research

While we accept the profound significance of our experiment, we know all too little about its workings. We urgently need to identify and define the critical processes at work. As an indication of some priority items, we should consider the following.

(a) Differentiated extinction rates. Which categories of species are being most affected? Which ecotopes and biomes are being most rapidly depleted? Are we likely to lose most of the tropical forests before we lose most of any other biome—or might tropical coral reefs, since they are more limited in extent, be the first major biome to decline to its last 10 per cent?

(b) Linked extinctions. What prospect is there that a mass-extinction process will feed on itself through mechanisms that, by virtue of the integrative workings of ecosystems (especially of the more species-rich and complex ecosystems of the tropics), can trigger a domino effect of extinctions, and even precipitate 'cascades of extinctions' on a vast scale? In other words, how far

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could the linked-extinction phenomenon, well known at local level (Janzen, 1975; Gilbert, 1980; Terborgh, 1986), apply at a more macro level?

(c) Mass extinctions and survivorship. What more can the past tell us about the survivors of mass-extinction events? With a better grasp of the biological, ecological and geographical attributes that have enabled certain taxa to survive phases of biotic crisis during the paleontological past (Jablonski and Raup, 1986), can we gain a clearer insight into the probable makeup of biotas that appear best adapted to come through the present extinction episode?

(d) The greenhouse effect and other climatic dislocations. In view of the critical consequences of climatic dislocations for protected-area networks (Peters and Darling, 1985), what responses could we consider in the form of, for example, exceptional adaptiveness in wildland management? Also, what might be some repercussions for wildland plant communities arising from ozone-layer depletion?

(e) Diversity and integrity of nature. In light of the possible threat of linked extinctions in large numbers, should we consider switching our conservationist emphasis from seeking to safeguard the diversity of nature to trying instead to preserve the integrity of nature (Western, 1988)? In other words, should we also seek to safeguard ecological processes—even evolutionary processes?

(f) A triage strategy. Since we already practise triage, albeit unwittingly (Myers, 1983), how can we apply it in a more informed and methodical manner? This applies not only between species, but between communities, ecotopes, even biomes and regions. Should we not place much greater emphasis on the tropics, and on tropical forests in particular, even it this is to the detriment of non-tropical areas? In what other ways can we become more efficient in getting the best return from each scarce conservation pound and dollar?

These six issues are proposed as illustrative candidates for priority research. What other topics merit urgent consideration? For instance, what ecological thresholds of irreversible change may well occur? What synergisms are compounding the operational impacts of the experiment? These questions, and many more like them, warrant urgent methodical attention from the conservation-biology community. We still have no structured and systematized agenda for research to delineate the extinction crisis in its main critical dimensions. When priorities are established, we shall be further towards developing a discipline of conservation biology, with the predictive capacity that characterizes a coherent field of science. To date we have made a solid start: no less, and no more.

A comprehensive species conservation strategy

At the same time that we pursue this research programme, we should anticipate the time when political leaders recognize the need to tackle the extinction question. They may then turn to conservation biologists and ask 'What will it take to save the majority of all species at risk in the foreseeable future? In particular, what will it take in the way of institutional measures, professional expertise, scientific resources, on-ground safeguards, and whatever else is needed to do the job? Above all, what will be the likely cost? Could it be done for $2 billion over 5 years? Or $1 billion for each of 3 opening years, followed by $0.5 billion for each of another 3 years? Or a lot more still? Or (conceivably) a lot less?'

However unlikely it may seem now that conservation biologists will one day find themselves faced with such questions, they might consider that it is hardly too soon to start formulating an Action Plan, with budgetary estimates. In some quarters political leaders' thinking is advancing rapidly. When the World Commission on Environment and Development started its deliberations in late 1984, the notion that is should consider threatened species was dismissed with virtually no discussion. Within 2 years the Commission had come round to the idea that is should certainly address the issue, even with a chapter of its own in the Commission's report, thus placing it on a par with pollution, food, energy, population and climate. At one of the Commission's later meetings, there were informal discussions on what a species conservation campaign might cost—and the Commissioners were surprised that the conservation community has scarcely started on an overall analysis of the task. Rather it was still stuck for the most part with an approach of a panda population here, a bird community there, and a rain-forest patch somewhere else—a long way from the all-embracing approach that is required.

So we need to prepare an overall strategy to save the bulk of threatened species. We should give attention not only to biological and ecological factors but also to economic and political constraints. Thus there is need to bring economists into the effort, notably those who have worked at the issue with sound purpose already; see, for example, Bishop, 1980; Fisher, 1982; and Pearce, 1983.

Some comparative costs

We should bear in mind that an Action Plan of proper scope will not be a case of 'the same as before, only more so'. Even 'much more so' will not do the job, at least in conventional terms. We need an order-of-magnitude shift in our thinking. Since its origin in 1961 the World Wildlife Fund (via all its national appeals) has raised $130 million, an average of $5 million a year. Magnificent as this achievement is, it should be compared with the estimated costs of an expanded conservation campaign in tropical forests alone: $90 million a year for the first 5 years (Food and Agriculture Organization *et al.*, 1987).

While a species conservation effort could theoretically be mounted in its own right, in practice it would need to be integrated with programmes tackling a host of related problems in the developing tropics—this being the zone with the greatest numbers of species and with the greatest threats. One cannot ensure animal species a future without ensuring an improved future for the human communities who live in the tropics. Otherwise we shall witness growing throngs of impoverished peasants spreading into every last corner of wildlife habitats.

To put a save-species budget into context (UNICEF, 1987), let us note that to promote intensified agriculture by 150 million subsistence farmers (with their families, they total around 1 billion people, including 250 million slash-and-burn cultivators) would cost roughly $10 billion a year—and this measure would serve to stem the flood of landless farmers into wildlife habitats. To halt the spread of deserts would cost $5 billion a year. To counteract the decline of tropical forests would cost almost $2 billion a year. To supply increased family-planning services throughout the Third World would cost $4 billion a year. To provide clean water plus sanitation to 1.5 billion of the Third World's poorest people—a major measure to reduce infant mortality, hence to reduce the incentive for large families—would cost $46 billion a year. (Note: these estimates of some basic costs take no account of measures to tackle other environmental and development problems, such as programmes to slow the greenhouse effect and to halt depletion of the ozone layer).

This all amounts to $67 billion a year—less than twice as much as current development aid. So even if a species conservation programme in itself were to cost several billion dollars a year, this would not be out of line with other major efforts on the part of the global community. Indeed, since species contribute to modern drugs, agricultural crops, industrial materials and energy supplies, it would reinforce the vastly greater investments in human welfare via public health, agriculture and so forth.

The question to be asked is not 'Can we afford to do it?' It is 'How can we afford not to do it?'

A unique challenge

In principle, then, an effort to stem the extinction spasm is not beyond our means. The funding should not be impossible to mobilize, supposing the political leaders, policy makers and budget slicers are made aware of what is at stake. While there is a great deal to be learned scientifically and technically about the issue, we could readily correct that deficiency by mounting a methodical research programme; but if we continue with our present research 'strategies', we may not come up with the key answers until after millions of species have been eliminated. When there are so many urgent research questions to be investigated, do we need yet more research on the white-tailed deer in the United States? The species flourishes, yet it has absorbed more than $10 million of research funds since 1950.

In short, we *can* do the job. Surely we do not lack the will to do it. So why do we not rise more conclusively to the challenge? Could it be that we fall short on a sense of vision? Or, by vaguely perceiving a tremendous need, do we become prone to a kind of frozen horror at the prospect of a task of such vast scale?

Herein lies the true challenge. The first step is to grasp the intrinsic character of the challenge facing us, to apprehend the size of the task, and to comprehend the costs of undertaking it (together with the concealed costs of not undertaking it). If the prospect of a suitable-size response seems daunting, let us bear in mind that the first great waves of extinctions are only beginning. There need be nothing inevitable about a mass extinction in the long run: the unwitting experiment can still be controlled and eventually contained. A profound problem indeed, but even more a splendid opportunity.

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