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Thomas E. Lovejoy

World Wildlife Fund, 1601 Connecticut Avenue, NW, Washington, D.C. 20009

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THE EPOCH OF BIOTIC IMPOVERISHMENT

Thomas E. Lovejoy

ABSTRACT.—1978 was the first year in the history of man that legal power to eradicate a species was established. It is one of a number of signs of rapidly accelerating rates of extinction which may result in reduction of biological diversity by one-seventh to one-fifth, with a parallel reduction in the planet’s capacity to support man and a permanent reduction in the potential body of biological knowledge. Species loss of such a degree would warrant designating the close of the Recent epoch and the opening of a new one of Biotic Impoverishment. A great deal of the extinctions will occur in the tropical forest areas of the globe but with possible environmental effects extending into the temperate regions. It will fall to science to help slow the rate of extinction, to decide on which species and ecosystems to concentrate conservation efforts, and to communicate the importance of biological diversity to government and society.

It is an encouraging sign for conservation that during this first week of December 1978, both this symposium and the first meeting of private conservation organizations in Central America are taking place. It is interesting that the latter is occurring in Guatemala, a country which honors the Quetzal, a trogon of extraordinary beauty, in three ways: as its national bird, as its monetary unit, and with a statue in Guatemala City. At the same time the travel route many of us followed here takes us through Salt Lake City, where stands one of the few other statues in honor of a bird: the gull which rescued the Mormons from orthopteran plagues, and the specific identity of which is probably lost forever in history.

But 1978 will also be remembered as the year when, for the first time in the history of civilization, the power to exterminate a species other than a pathogen was legally established. This certainly was not arrived at in any particularly intelligent manner, and its full meaning in the history of the biological degradation of the planet was and is appreciated by few: it is the first indication in the body of law that we are not going to save, or try to save, the full array of species in the biota, and raises the terrifying questions of which and how many species will be written off. The new Endangered Species Legislation takes a step toward answering those questions by according lower-class status to the faunal majority represented by the invertebrates, as opposed to those lucky enough to have spinal columns.

At first, species will wink out one by one like city lights as night deepens, but soon there will be a rushing torrent of extinction. This year also saw all but the last remnant of natural forest on Bali cut over, leaving little natural habitat for the Rothschild’s Mynah, which fortunately does thrive in zoos. As far as I know, nobody has answered the question of how many extinctions the Bali forest destruction represents. It carries special meaning when we reflect on how much was learned about how the world works when Alfred Russell Wallace crossed the narrow strait between Bali and Lombok and began to conceive of the science of zoogeography and, later, of natural selection. He grasped natural selection independently of Darwin, yet so effectively that he propelled Darwin into publishing the volume which so greatly changed man’s view of his place in nature. It is indeed likely that some of the recent extinctions on Bali were of species actually described by Wallace, a sad tribute to a man who did so much to advance knowledge.

One little-appreciated aspect of the recent and forthcoming extinctions is the implication for the future growth of knowledge (Lovejoy 1978). An extinct species is one

about which we can learn little, either in terms of its specific biology or role in nature, except what can be gleaned from the sad remnants of information held by museum specimens—remnants which are nonetheless valuable and deserving of more appreciation. Many species will, in fact, disappear without even a mention of their existence in the chronicles of science.

While there certainly is some knowledge to be gained from the response of biological systems to destructive manipulation, it remains negligible when compared to what can be learned from living biological systems over the long time available when species continue to exist. Indeed one might think of human knowledge, whether in general or about biology in particular, as a growing n-dimensional hypervolume, with a volume $V_e$ at any point in time. Whether there is a total potential body of knowledge is probably a question for lengthy discussion, but for the moment and for the sake of argument, let us assume that there is such a definable body, and that it can be represented by another hypervolume, $V_p$, which contains, and is many orders of magnitude greater than, $V_e$ (Fig. 1).

Until relatively recent times, it can be said that throughout human history society has striven to enlarge $V_e$, deriving considerable benefit from doing so, and essentially driving $V_e$ to approach $V_p$. The effects of the relatively small number of man-generated extinctions up to this moment have been minor, but now, as we enter the epoch of Biotic Impoverishment, which probably deserves to be treated as an epoch distinct from the Recent, we are allowing $V_p$ to shrink and to approach $V_e$. Yet, as living organisms, surely we must realize that biology is the most important branch of knowledge for human welfare.

Most of us, even endangered species biologists, tend to underestimate the extent of the impoverishment of the biota that may lie before us. Here in the United States, already a highly developed nation with a human population now predicted to peak at a mere 253 million, it is possible to entertain the notion that we can have our fauna and flora and the sybaritic pleasures of the consumer society as well. There are occasional problems with endangered species and public works projects in conflict, but it seems possible to at least dream about having both.

But such is certainly not the case in the tropical forest countries of the world, which are, with a couple of exceptions, all lesser-developed nations eager to ape our ways. The FAO estimate that tropical forest destruction currently occurs at 50 acres a minute is truly terrifying. These forests are a biological treasury, and the conflicts between traditional development projects and endangered species are many orders of magnitude greater than in temperate regions. I recently had the

![Fig. 1. The relationship of expected ($V_e$) and potential ($V_p$) knowledge.](image)
difficult task of producing for a presidential study an estimate of extinctions that will take place between now and the end of the century. Attempting to be conservative wherever possible, I still came up with a reduction of global diversity between one-seventh and one-fifth, principally because of what will happen to tropical forests. No doubt some of my colleagues think I am mad, but I would challenge them to produce a better estimate. If my estimate turns out to be too high it will either be because society has made considerable changes in its ways, or because it will take a bit longer to reach the same reduction in diversity. The U.S. example to the international community will be very important.

The problem of biotic impoverishment then is considerably greater than can be appreciated from an overview of endangered species here in the United States. Our American collection of endangered flora and fauna really represents but part of the forward contingent of a great rush to extinction. This all raises many questions for science and society, including the most terrible one of all, one which few are brave or foolhardy enough to ask: namely, can we continue to treat the value of a human life as a constant whatever the number of people may be? I am enormously uncomfortable even asking it, let alone trying to answer it, yet, even if ignored, it will in part be answered by the degraded capacity of the planet to support man if biotic impoverishment proceeds apace.

It is more comfortable to try and answer the scientific and technical questions raised by biotic impoverishment and it is these that this symposium is largely addressing. Certainly science has a critical role to play in efforts to reverse the tide, and it needs to be recognized that such science is as intellectually respectable and as useful to society as, for example, laboratory work on DNA hybridization.

In many cases it is a race with time. World Wildlife Fund is launching a major research program on the problem of the minimum critical size of ecosystems, or why and how ecosystems set aside in the midst of landscapes converted to man's purposes shed or lose species. How much more desirable it would be to have the results in hand now, because most opportunities to set aside a representative series of the planet's ecosystems will occur in the next two decades. Yet we have to make do with the situation.

It is important that universities and agencies recognize that conservation is an appropriate activity to which biologists should devote some of their time. Indeed it is probably correct to say that today a biologist can make as much of a contribution to science by helping to save species and ecosystems, and, therefore, future opportunities to study biology, as by more traditional scholarly pursuits.

To science should fall the terrible questions about which species and ecosystems to save and which not to save. Which of us would be comfortable about saying one species is more important than another? Yet it is clear that all will not be saved, and that it is preferable for scientists to address those questions rather than deferring to the less knowledgeable. Certainly we would be wise to try and avoid having to make such decisions in unthoughtful haste—but maybe the awful nature of the questions will drive us that much harder to keep the number of such decisions small.

There is another critical role for science, namely articulating the true meaning of biotic impoverishment for society. Too often both scientists and society in general focus on the individual species rather than on the recognition that the impoverishment of the biota represents a reduction of the planet's capacity to support man. Just on the basis of destroyed coastal wetlands it can be said that the fundamental capacity of the planet to support man is less today than a century ago. This erosion of our biological wealth has been masked by the constantly refined abilities of technology. Technology has fostered the illusion that we can get more and more from less and less, a dream that soon will be shattered; the cracks are already appearing.

Scientists must articulate the true meaning of endangered species as indicators of stressed ecosystems and as yet another sign of erosion of the basic quality of life. When the Devil's Hole pupfish was being endangered by a lowered water table, the real question was about the rights to reduce that natural resource base. It is not always easy to deduce the complete meaning for society of any particular endangered species, but it will always
be generally true that it will reflect deterioration of a biological system. When arguing the case, we cannot always expect the exploiters to play fair; poor human behavior with respect to questions of dwindling resources is all too familiar.

Our society is generally ignorant of the importance of biological resources and hence of endangered species. One Supreme Court judge harbored the view during the case of the Tellico Dam and the snail darter that the Endangered Species Act meant endangered species might be found behind already existing dams and it would be necessary to run around letting the water out. And a distinguished senator was concerned most of his state might be declared critical habitat for the grizzly bear; perhaps he was worried about their votes? It is really up to all of us to employ all our energies and intellects to correcting this dangerous state of ignorance. We should clearly make the case, for example, that dwindling biological resources are making a major contribution to problems of economic inflation.

Society worldwide has been rocked in recent weeks as the story of the charnal millefeuille of Jonestown emerged layer by layer in the media. How many of us recognize that we are well into the beginnings of a biological Jonestown? As in Jonestown, there will be human survivors once the epoch of biotic impoverishment passes. But their existence will be forever an impoverished and degraded one. The question of how degraded and how impoverished lies before science and society.

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Questions to Mr. Lovejoy

Q. It would be interesting to have a figure on that one-sixth of the species lost you have computed.
A. You mean in terms of numbers of species? If the total biota for the planet is estimated at lying somewhere between 3 million and 10 million species, which gives you some idea of how ignorant we are about the biology of the planet, and if one takes the more conservative figure of 3 million, the loss is on the order of 500,000 to 600,000. The actual home-work I went through to arrive at all of that is going to be published in the Global 2000 Study, which was requested by President Carter more than a year ago in his environmental address of 1977 and will emerge sometime in the coming September. That particular section will certainly stand out because a lot of the reviewers of that study who are not biologists and not particularly aware of what's happening in the tropical regions found it very difficult to believe and so it may be the only portion of that study with a name actually attached as an author.

Q. Would you explain your statement about fauna without vertebrates having less of a status in nature than vertebrates?
A. Well it's true. When it comes to invertebrates the secretary of interior has the ability to exempt certain public works projects from the Endangered Species Act without taking it through the long process to ultimately what some of us call the "Extinction Squad" setup in the new legislation. It really doesn't say flat out that the secretary of interior can allow a nonvertebrate to go extinct, but it says that he need not recognize discrete populations. Maybe some of the Department of the Interior people can explain it a little more fully than I, but there was a clear distinction drawn between the two.

Q. What are the strategies to address the problem of the destruction of tropical rainforests?
A. As currently treated, tropical rain forests are generally regarded as one-time use resources to be cleared and replaced by something else. That something else is often not economically viable in the long term. It's really a matter of proving that there are in fact considerably more gains from protecting as much of the tropical rain forests as we can than from converting them to short-time use.

Q. The recent modification of the Endangered Species Act was supported around the country. Some of the major conservation groups supported that modification. Now I understand that the World Wildlife Fund also supported the modification and I'd like to know if that's correct or what your position is.
A. During the period when the new endangered species legislation was being considered in recent months, some conservation organizations supported the modification. Was World Wildlife Fund one of these? It was not. The problem was that the biological reality and the political reality simply did not coincide. It is very clear, particularly from the Senate vote, which I think was something on the order of 94 in favor of modification, that there was little sympathy within the Congress for maintaining the Endangered Species Act as originally laid out. We, in fact, World Wildlife Fund and some other organizations, worked quietly behind the scenes to try and get as strong successor legislation as we could possibly get, but we simply were not about to go on record and condone anything that might lead to extinction. I think this was well understood by the staff of the Senate subcommittee in question.

Q. I have two comments to what you had to say today. First of all, forgive me if I have trouble thinking about tropical rain forests today. I deal in the area of management, which is where most of the problems
are being solved, at least in this country. If we set ourselves as biologists aside and say it's us against them, then two things may happen. First, we may become like a federal agency that I know of that says we have this pristine untouched piece of land and we're going to keep it pristine and untouched by allowing 10,000 people in and then it's going to stay somehow miraculously pristine and untouched. Second, which is more likely, the "other side" will win because they have more influence and more people. I think that we need to concentrate more heavily on the interface between the scientific community and the people and, in a democratic country, I think that is more appropriate.

A. I don't have any difficulty with that at all. In fact, I think in a sense that's what I was trying to say by saying we have to articulate what it all really means. But it's all in the best interests of all of us to be worrying about what is essentially the proper biological management, not only of the United States, but of the entire planet and that naturally falls into two distinct parts. One is making sure that you protect all the pieces—all the biological pieces—with a series of representative ecosystems properly designed so that they can be managed to protect their integrity, and I might add that it's getting harder and harder to protect an ecosystem anywhere without management of some sort. The other part is making the rest of the face of the planet biologically productive in a sustainable fashion and in a fashion that will in no way threaten the sort of species bank you've set aside. For example, we at World Wildlife Fund are taking a long shot at trying to talk to the last of the American billionaires, Daniel Ludwig, who has an operation in the Amazon about the size of Connecticut where he has cleared forest and is growing trees for pulp and rice. If I actually do get a chance to have a reasonable discussion with him, my point to him is not going to be that he shouldn't be doing what he's doing, because it is probably more intelligent than most of what's being done in the Amazon, but rather that the long-term security of his own operation depends on protecting the ecological integrity of the Amazon as a whole.

Q. You alluded to a correlation between biotic impoverishment and economic inflation. Would you care to elaborate on that subject?

A. Probably, if one searched around, examples could be found. For instance, the price of fish is increasing as the supply dwindles and the demand stays high. I only began to think about this ten days ago, but certainly this process has to be occurring here and there. The problem is to sort it out from the incredible maze of vectors that comprise economics and really demonstrate what's happening—and that's part of the problem.

Q. Mammoth is now about $5 a pound. The summer Chinook is in very great danger; we might have to drain Grand Coulee Dam to save it. In one of your other statements, you said that we have to protect habitats that have been damaged or destroyed and renew them. No summer Chinook were caught this year, except for about 1,500 by the Indians. At one time there were billions of pounds of Chinook Crab is now about $5 a pound.

A. I'm really delighted to have that example. Well, in fact, if you probably start thinking about it, the price of lobsters and other marine products has certainly risen a great deal in recent years and that may be one of the more clear-cut situations. The world fisheries peaked about 1970. They made a slight recovery this year, I believe, but all along there has been an increasing catch effort, an increasing amount of actual fossil fuel energy going into the pursuit of these fish, and certainly the demand for them has been increasing too.

Q. Are there any calculations on how much of a decrease we are going to get in atmospheric oxygen if these tropical forests are destroyed?

A. The problem of tropical forests with respect to oxygen turns out to be no real issue. They, in fact, consume about as much oxygen as they produce. The real problem in terms of biogeochemical cycles may well lie in the carbon which is stored in tropical rain forests. Tropical rain forests represent the largest terrestrially stored pool of carbon, and it was estimated as long ago as 1954 by Evelyn Hutchinson that the increase in carbon dioxide in the atmosphere probably came equally from the burning of fossil fuels and the destruction of forests. The whole problem of global circulation of carbon and where the sinks are certainly isn't a clear matter, but we do know that CO₂ is increasing and that if we destroy two-thirds of the tropical forest (which is the estimate by 2000) we will release an enormous amount of carbon into the atmosphere. The question is how rapidly the natural sinks can absorb it and bring it back to normal level. If there is a pulse of carbon in the atmosphere, then we may get into problems of climatic change, change in rainfall regimens, and temperatures in the temperate zones. The tropical rain forests really aren't all that far away.

Q. It seems like we're expanding on the strategy of the common ideal. How can we deal with individual countries that are bent on destroying a habitat which may affect the rest of us?

A. If I had the answer to that I might be head of the U.N. There is no easy answer to it at the moment. Many, such as Roland Clement or I, work on a country-by-country basis. I endeavor to persuade the Brazilians, for example, that proper management of the Amazon is in their best interests as well as that of the rest of the world in terms of, say, carbon. On the other hand, there is increasing recognition within governments, even in Latin America, which people were despairing about for so long, that there are major problems. There is now an Amazonian pact among all the Amazonian nations which, at least in rhetoric, talks about proper management of the Amazon. There are some interesting questions involved in that. Take the example of the contributions of biological species to modern medicine, especially the importance of a primate species. Take a cure that comes from one of those species and it is very rapidly distributed around the world as an international resource, so we may be approaching the time when some biological resources, at least, are
recognized by the international community as being international resources, and pressure will therefore fall on some of the less well-behaved countries to clean up their act.

Q. Are people as much a problem as governments?
A. Oh, it certainly is both. Roland Clement is going to address problems of people.

Q. Is corruption ever a problem?
A. Well, corruption is a problem. I would guess that at least in Latin America, which is my major "beat," ignorance is a greater problem than corruption.

Q. Do you think there really is a middle ground between biotic deprivation and the goals of preservation of the biota?
A. I think there has to be. It's just a matter of how much we want to let it hurt before we really respond to it. I think it's as simple as that.

Q. What about the review board set up under the new endangered species legislation to make decisions on seemingly irresolvable conflict between endangered species and public works projects? How busy will they be, and how eager will they be to exercise that power?
A. We're really talking about a play of attitude and how that will affect the whole process. The Endangered Species Act up to the point where it was revised certainly involved thousands of cases of seeming conflict that were all resolvable at staff-level discussion with the Department of the Interior. The single exception was the Tellico Dam and snail darter, and that really became an exception only because the TVA was completely recalcitrant and refused to acknowledge that it was subject to the law. If one reflects on those figures, it might say that only rarely will the Extinction Squad have a nasty decision to make. If, on the other hand, agencies feel that the creation of the Extinction Squad has weakened the power of the Department of the Interior, they may feel less need to be pliable in discussion and they may get very busy up on top. I don't think they're going to be happy to do this at all. My own particular solution to the whole thing is to erect a large black marble slab on the mall in Washington so that we can engrave on it the name of the species exterminated and the names of the members of the squad at that time.

**Literature Cited**