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Global Change, the Future of Biodiversity and the Future of Zoos

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THIS IS AN ACCOUNT of what happens to thinking about the composition, function, and future of a zoo when a tropical biologist becomes a zoo director. It is an essay in the evolution of a concept. That evolution can only be understood, and explained, by reference to the environment in which it occurred. That environment is the unique Smithsonian Institution. The Institution, founded in 1846 for "the increase and diffusion of knowledge," is the world's largest assemblage of public exhibits and research entities under one intellectual roof. Its present mandate ranges from modem art to the history of the Precambrian, from the space shuttle to presidential memorabilia, and in its research entities, from the study of supernovae to research into Black History. It will shortly add a Native American museum to its range of subject matter. There is nothing quite like it anywhere.

I came to Washington committed, by twenty years of living and studying in the tropics, to the realization that they were the scene of unparalleled devastation, and incipient, if not actual, species loss. I was also totally convinced, by personal history, that zoos were a source of fascination and had an enormous potential for biological education in the broadest sense. Add to this a lifelong interest in aviation, resulting from spending impressionable years in Europe during World War II, and I was ripe for looking at zoos in an unconventional way. The Smithsonian environment tipped the scale. The first realization that we needed a new kind of bioexhibit to replace the zoo came through visits to the National Air and Space Museum. Here was something that I found endlessly fascinating, the most heavily visited museum on earth, a gallery of great masterpieces of human ingenuity and beautiful objects. But, I realized, it drew no parallels between man-made flying objects and the infinitely more ancient phenomenon of flying animals. Nor did our zoo's glorious bird house refer to heavier than air flying machines. With this came the realization that the Smithsonian made little or no effort to cross-refer its collections. Finally, I came to see that zoos also represented an unnatural excerpt of the living world. They dealt only with animals and the vertebrate minority at that. This, it seemed, was a ridiculous fragmentation. The living world is not so divided, plants and animals are totally and inextricably intermingled and interdependent. The ecology of life on earth cannot be conveyed by exhibits of the charismatic megavertebrates. So, laboriously, came the concept of the BioPark, the successor to the zoo, where holism could be restored. This and its relation to the environmental crisis is the subject of this essay. Essentially I will try to answer the questions: What are the causes of the Biodiversity crisis? What roles can the once and future zoo play in helping to maintain Biodiversity? What form will this new kind of bioexhibit take?

THE BIODIVERSITY CRISIS

The biodiversity crisis has been widely publicized in recent years. In particular, Wilson (1988) brings together a wide range of attitudes and analyses, from participants in the comprehensive Smithsonian Institution/National Academy of Sciences forum on Biodiversity. There have been many excellent individual treatments of this theme. Robinson (1989a) gives a recent lead into the extensive literature on biodiversity, and also on the unique and special nature of tropical biology. Because the problems confronting us have been so extensively discussed, the basic arguments do not need reiterating here. However, there is an exceptional matter that does need emphasis and re–emphasis. It concerns the extent of the problem of species-loss in the tropics. There is now no question that the tropics, and particularly the tropical rain forests, are the center of concentration of the substantial majority of the world's plant and animal species. Previous estimates by ttopical biologists (for instance, NRC 1980), that perhaps 60 percent of species were located in the tropics have been made to look extraordinarily conservative by Erwin's (1982, 1983) calculations

on the number of insect species on earth. He states that there may be as many as 30 million species, and regards this as conservative (T. Erwin, pers. comm.). Even the low end of his range of estimates is 15 million species. This is ten times the standard (and widely used) textbook figure of 1.5 million. Even if this new estimate is as much as three or four times too big, which I doubt (see also May 1986 for a calculation of the number of insect species, made on a totally different basis, that puts them at 10 million), then **at least 90 percent of all existing animal species are in the tropics.** This kind of conclusion has not been made sufficiently explicit in discussions on threats to biodiversity. It is clearly implicit in Erwin's (1982, 1983) calculations, since they are based on rain forest sampling, and on assumptions involving the distribution of insect species among tropical tree species and about the total number of tropical tree species. One need only do the arithmetic with the figures for species of other invertebrates and the vertebrate minority to realize how overwhelming is the tropical preponderance in species diversity. Realizing that 90 percent of animal species are in the tropics puts an entirely new complexion on our view of the biodiversity crisis. Since a substantial number of the species at risk are forest canopy residents, concern about species-loss due to the disturbance, degradation, and destruction of tropical forests is strongly reinforced. The extent of the forest losses has been widely discussed. In the ensuing arguments ecologists stressing destruction have generally been opposed by economists doubting their data (see, for instance, Myers 1988a, b, versus Simon 1980, 1986). All doubt seems to me to have been put to rest by recent satellite-derived information from the Brazilian Amazon (Fearnside & Salati 1985, Malingreau & Tucker 1988). A recent exhaustive survey of a wide variety of sources (Myers 1990) suggests that tropical deforestation rates have increased by 90 percent between 1979 and 1989. The forests are being rapidly destroyed, there is a biodiversity risk. The question remains: what are the causative agents?

CAUSES OF TROPICAL HABITAT DESTRUCTION

The causes of environmental perturbation, like many phenomena, are divisible between ultimate and penultimate factors. This statement is not simply, or even mainly, a piece of sophistry. The understanding of the nature of the principal ultimate causes is crucially important to a balanced analysis. Many biologists, and others concerned about human activities that have major environmental impacts, ignore the fact that manmade environmental change is the single detectable indicator of our emergence from a long period of ecological identity with the rest of the animals. Until we domesticated plants and animals our effects on the environment were highly localized and largely indistinguishable from those of any other large, social, omnivore (for an extensive discussion of the environmental effects of prehistoric humans see Goudie 1990). Hunter/gatherers may produce clothing, dwellings, tools, language and so on, and eventually use fire in hunting, but in the ultimate sense they depend on the carrying capacity of an unaltered environment. This was our status for 99 percent of our history as a species. (The anthropological term hunter/gatherer, however useful within that discipline, tends to confound the issue of our ecological status. In all probability our preagricultural ancestors were not very distinct in their ecology; probably just slightly more carnivorous than the present-day great apes.) Only when we started herding animals and cultivating plants did we start the process of massive environmental conversion. We drastically modified a relatively small number of other organisms as we altered environments. Our civilization, science, and culture is built on this double transformation process. The changes resulting from agriculture were inexorable; slow at first, and then increasing in momentum as populations grew and technologies advanced. Pollen analysis shows that "temperate forests were removed in Mesolithic and Neolithic times and at an accelerating rate thereafter" (Goudie 1990). We may think that the destructive effects of prehistoric humans were limited by their relatively inefficient stone tools. However, we now know from interesting and imaginative experiments that, crude as the tools were, they greatly enhanced human power to change forests. Three men, using a stone ax from a museum, were able to clear 300 square meters of modern European forest in four hours, more than 100 trees were felled with one ax head that had not been sharpened for about 4000 years (Cole 1970). Metal tools extended our destructiveness; huge changes occurred in Europe very early in the agricultural revolution. But the great phase in deforestation in central and western Europe was from AD 1050 until around 1250 (Darby 1956). Recent deforestation in the New World is a highly significant case. Indigenous peoples had coexisted with the native environment with relatively minor effects on forests. Then came the settlement of Europeans with a comparatively advanced technology.

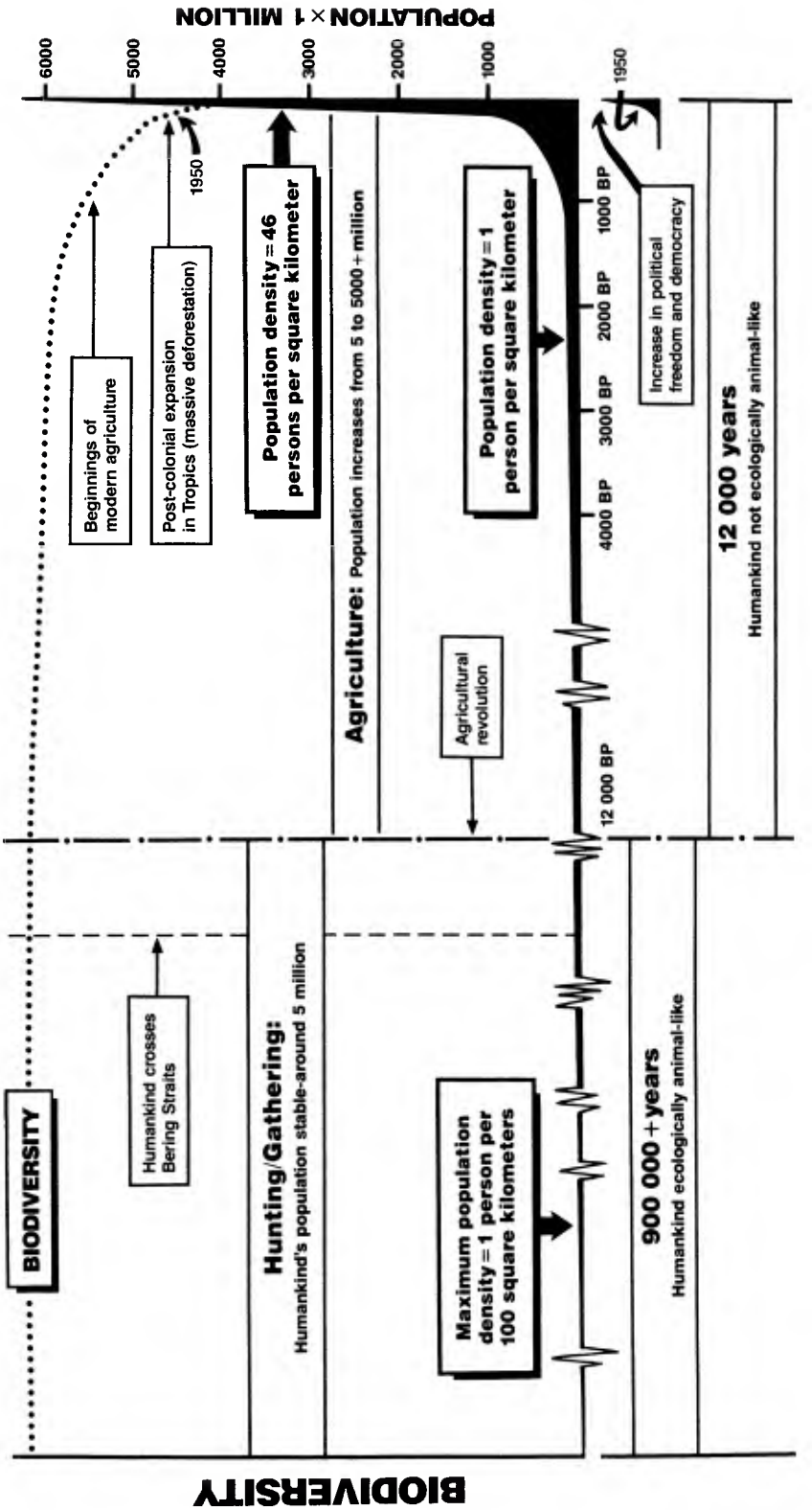

FIGURE 1. Relationships between population growth, biodiversity, origins of agriculture, and some other events. All except biodiversity curve based on published estimates.

In North America deforestation after this settlement was particularly brutal. More woodland was then lost in 200 years than was lost in Europe in 2000 years (Williams 1989). When the first settlers arrived the forest originally occupied around 170 million hectares; today only about 10 million hectares remain; this is a huge reduction.

From the beginnings of civilization there were changes in population, as the agricultural revolution advanced, populations increased slowly at first, but growth was inevitable as we increased the carrying capacity of the land. Change has accelerated massively, since the industrial revolution gave us greatly enhanced power. Animal power changed the world, but engines change the world very rapidly indeed.

The point of this argument is to give emphasis to the fact that the changes being enacted today in the tropics are a continuation of the very process that made civilization possible. They are exactly analogous, in ecological effect, to the changes carried out millennia earlier in the North Temperate and Mediterranean Regions, and then in North America (see Fig. 1). Only the scale of the consequences differs, the ultimate causation is the same; the process was merely delayed in the tropics, particularly in Africa and the Americas, by a great many factors not relevant here. (For an analysis, idiosyncratic, heterodox, provocative, and largely ignored, of some of these factors, see Darlington 1969, 1978.)

The present–day imperus to convert the tropics to agriculture (of some kind) is driven by the urgent striving to develop the economies of the so–called Third World. This drive dates, approximately, from the post-World War II decolonization process. It is clearly not a product of ignorance or stupidity but rather of human need and the political, economic, and social expressions of this need. The processes involved are hardwood extraction, slash and burn agriculture, cattle ranching and fuelwood extraction. Myers (1990) has suggested that the old term for slash and burn agriculturalists, "shifting cultivators," should be changed to "shifted cultivators." The prior term referred to the impermanence of their land usage, they moved into a forest area, cleared it, cultivated for several years and then moved on when the land's fertility was exhausted. Shifted cultivators, on the other hand, are "farmers who formerly made a living in long-established farmlands of the countries concerned, often in territories far distant from the forests. For various reasons—population growth, maldistribution of established farmlands, lack of agrotechnologies for intensive cultivation, and inadequate rural development generally—they have increasingly become squeezed out of their erstwhile homelands. Perceiving no alternative way to sustain themselves, they head for the only alternative lands available to them, viz. the tropical forests." (Myers 1990, 5–6). Not on this list of forces impelling shifted cultivators to the forest frontier are government policies of inducement to transmigration. The pressures on cultivators to shift have now reached such a stage that Myers (1990, 6), concludes: "With scant understanding of how to make sustainable use of forest ecosystems, these shifted cultivators now cause more destruction of forests than all the other agents of deforestation combined (Myers 1988a, b; Repetto & Gillis 1988, World Resources Institute and World Bank 1985)." This statement really emphasizes the pressures of poverty more than any prior analysis.

Population pressures that strongly drive shifted cultivation are likely to increase rather than decrease. In 1989 populations in 32 tropical countries increased by an average of well over 2 percent, their combined populations are projected to increase by 477 million by the year 2000, and by 1324 million by 2020 (Myers 1990, Table 8). By 2030, or thereabouts, 80 percent of the world's population will be living in the tropical forest countries; some 6.4 billion people out of 8 billion will surely extend capacities to provide food *in situ*. These increases will clearly put further stress on the forests, in fact there is a tendency for deforestation rates to increase faster than population growth. Thus, while the populations of tropical forest countries has increased by 15 to 36 percent in the 1980s, deforestation has increased by 90 percent during the same period (Myers 1990). All this is ominous in the extreme.

Despite the clear political and economic reasons for deforestation there is a widespread tendency to regard the environmental degradation in tropical nations as susceptible to the ameliorating effects of education. For instance, the World Conservation Strategy (IUCN 1980), despite pages of realistic analyses, states: "Lack of awareness of the benefits of conservation and of its relevance to everyday concerns prevents policy makers, development practitioners and the general public from seeing the urgent need to achieve conservation objectives." and "Until people understand why they should safeguard ecosystems and species they will not do so." (IUCN 1980: 30). Of course, multiply-edited consensus documents are inherently liable to this kind of confusion between their constituent parts, but this is really yet another instance of what I have called the "enlightenment fallacy" (Robinson 1985a, 1989a). This is a philosophical viewpoint that assumes that rational choice is possible in decision-

making. It ignores the pressures of short-term necessity that are certainly operative factors in the majority of Third World development decisions and policies. Thus, to comment on the above World Conservation Strategy statements, even if governments understand why they should protect ecosystems, can see the need for conservation objectives, and understand the benefits of conservation, they probably do not have the luxury of making pro–conservation choices when faced with the urgent necessities of providing adequate food, housing, medical care and so on for their peoples. Biologists who have worked in the tropics will recognize this source of these pressures. Education may help to prevent the worst absurdities where there are choices, but in my opinion it cannot solve the basic problem. What can?

There have been many proposals to deal with the biodiversity crisis. Some are contained in an entire section of the volume resulting from the S.I./NAS forum, referred to above (Wilson 1988). Gradwohl and Greenberg (1988) report on successful projects already accomplished in the tropics in their book "Saving the Tropical Forests" that resulted from a conference held at the National Zoo. Rubinoff (1983) has made a major proposal for subsidizing the conservation of rain forests through a levy from the developed nations, and so on. In essence, all these proposals call for either a slowing of the pace of destruction, or a moratorium on it. The long-range purpose of such a moratorium is frequently not articulated as clearly as the shott-term reasons for it. But almost always it is seen, dimly or clearly, as a means of buying time to do the research necessary to find "alternatives to destruction." This logical progression, from the idea of slowing or halting the present destruction, to that of finding development methods consistent with the preservation of biodiversity, begs the crucial question: How do we secure the implementation of such policies? Here is where I believe the function of the once-and-future zoo comes in. I believe that only if the developed world provides major financial support for Third World forest conservation can the time be bought for the research into alternatives. And here is something susceptible to the effects of education. In this case, I believe, education can result in public pressures on the governments of the economically advanced countries. They alone can provide the resources necessary to solve the day-to-day problems of urgent necessity that afflict the South (following the Brandt report, South is a convention for Third World). My view is that bioexhibits (a useful neologism for those public instirutions that exhibit aspects of biology) in the developed world have a central role to play in such an education of public opinion.

BIOPARKS AND BIODIVERSITY

I believe that most of the major problems facing the planet can only be solved if we have a biologically enlightened population. This may seem like the re-emergence of the enlightenment fallacy, but it is here stated as a precondition for sound decision-making in the next century, assuming widespread democracy where governments are susceptible to public pressures and have some freedom of choice in major policy decisions. Formal biological education seems to me as essential to our future as Latin, Greek, and Theology were once considered to be in medieval times. But extrascholastic, informal, biological education may be even more impottant. We have, if statistics on pets and house plants are any indicator, an urgent need for contacts with other living things. (As an old-fashioned ethologist I think that this may be a behavioral atavism.) In an urbanized society zoos, aquariums, parks, and gardens may be the only remaining places where such contacts can be made for the majority of people. Despite the extraordinarily high quality of natural history, wildlife and science programs, television's two dimensional—diminished—images do not really substitute for the fascination of "real" living plants and animals. At present more people visit zoos in the United States than attend all field sports combined. If we add visitors to botanic gardens, arborerums, and natural history museums, the size of the audience for bioexhibits is even more impressively extensive. Furthermore, new zoos and aquariums continue to open, and attract visitors, despite the omnipresence of television. Exploiting the potential of these resources for attitude-changing bioenvironmental education places a tremendous responsibility on us all.

CONTENTS OF THE BIOPARK

As stated in the introduction, the idea of a holistic, fully integrated bioexhibit emerged, for me, from the Smithsonian experience. The more I developed it (Robinson 1985b, 1986, 1987a, b, 1988, 1989c—an evolutionary progression) the more I became aware of its intellectual debts to progenitors, both narrowfield and broadconcept. In particular, I found that Boyden (1969), in an almost entirely ignored paper in the International Zoo Yearbook, had advocated the creation of a Biological Center

which was almost exactly what I had in mind. To amplify: the BioPark is not merely a habitat–based zoo, not merely a zoo with "naturalistic" exhibits, such zoos have been evolving since Hagenbeck's (1909) revolution in zoo design. Modern zoos reflect great and significant progress in husbandry, veterinary medicine, exhibitry, conservation, and education but they are still zoos, that is, places to see living animals. Zoological parks are parks focusing almost exclusively on the animal side of life's great equation. The idea of the BioPark is to emphasize the interactivity and interconnectedness of the living world by focusing on both the life of animals and the life of plants.

To do this well means illustrating processes, as well as specimens. It means exhibiting processes at all levels: intraspecific, social, interspecific, plant/animal, animal/plant and so on. It means progressing from using plants as a backdrop to animals (the convention for zoos), or as isolated organisms (the convention for gardens), to showing interactions involving both groups. Examples are numerous but some interactions are more complex, more wonderful, more exquisite for our purposes than others. The alpha list, for me, includes pollination, seed dispersal, defensive adaptations, predation, and a range of mutualisms. These are precisely those areas of tropical biology where coadaptations provide a glorious embarrassment of illustrative riches for the BioPark exhibit designer. I keep thinking that a bibliography of just Dan Janzen's papers could keep a BioPark designer busy for the next hundred years! I also imagine designing an exhibit on floral sex to illustrate Darwin's marvelous book "On the various contrivances by which Orchids are fettilised by Insects" (1877).

One of the biggest obstacles to clear thinking in popular conceptions of animal biology springs from anthropomorphism. This can affect so many attitudes that relate to public policies. As a result I feel strongly that an important aspect of biology that we need to emphasize in our BioPark is what can be called cognitive ethology. We need to somehow take the visitor into the animal's world. And of course there is not one animal's world but many different sensory worlds of many different species. Creating this new set of "viewpoints" is essential if we are to combat the anthropomorphisms that are rampant at present. These anthropomorphisms produce attitudes that distort our approach to nature as badly as the dominionistic attitudes that also abound. The lessons that emerged from the work of Tinbergen and Lorenz (Robinson 1989c) about the perceptions of animals are crucial to our perception of the living world that surrounds us. The message is that other creatures do not necessarily see, hear, smell, feel, or otherwise sense the world the way we do. They may not see colors at all, or see in sharp focus, or they may see colors that we cannot imagine, or see so sharply that the detail is unimaginable to us. We need to depart from the human eye view of the world that we propagate to our visitors. It is very important that we try to portray the differences. As a quick "for example," it would be very easy, with modern technology, to present a bee's eye view of flowers in the Hall of Floral Sex pollination exhibit. A TV camera adapted to "see" in the ultraviolet could show patterns on flowers that are invisible to us, but vital to insects. Of course, this would also make an essential point about the intricate fine–tuning achieved by evolution.

Another widespread misconception is about the nature of the wild environment. It is constantly counterposed to the zoo world as an antithesis of freedom against captivity or imprisonment. This picture of idyllic freedom is biological nonsense, as we all know, and is inimical to any appreciation of how the living world functions. We cannot act to save anything if we totally misunderstand the nature of Nature. For example, the popular concept of the nature of owls is probably closer to Walt Disney than to the reality of a superbly efficient killer of huge numbers of mice and "innocent" small furry beasties. Few people realize that in the "real" world most animal babies die slowly, painfully, or both. Predation, disease, parasitism, debilitating or lethal competition, sexual rivalry, and all the other aspects of "nature red in tooth and claw" are issues that zoos largely, and deliberately, ignore. There must be a way of presenting a true view in a nonoffensive way. The Microtheater of the Subvisible (below) may be one place to teach these lessons with high drama.

Of course, this is not all the BioPark can, or should, do. We can take visitors into the apparently magical world of the subvisible. The combination of a microscope, television camera and display screen can show living diatoms, foraminiferans, *Volvox, Vorticella* and *Stentor,* to wide audiences. This technology can take people to the fuzzy frontier between animal and plant and downscale even further to bacteria wriggling in their millions. The invertebrates in general are the largely overlooked majority of life on earth and they need to be shown as the prime movers of our living systems. We have done this at the National Zoo and the wide-ranging exhibit (Robinson 1989b) is extremely popular. When

we deal with our dependence on the living world we can first focus on things of immediate and obvious relevance and then move from the known to the less well-known, to the unknown. For example, we can show how plant defensive compounds can be used in our armory against disease, how Native Americans used them this way and from there on to the ancient links between our civilization and the living world. Domestic animals and their history are important parts of the story. Petroglyphs, hieroglyphs, and the cave paintings of Lascaux and Altamira belong in the BioPark. I have expounded the possibilities elsewhere (see Literature Cited), but I hope that this sample of suggestions starts you thinking of the possibilities. (If so, please write to me.) The domestication of plants can be told dramatically, too. This kind of holistic bioexhibitry, crowned by a rain forest exhibit that presents the system as it really is, a Bruegellian complex of small-scale interactions not the usual Henri Rousseau distortion, could be an immensely powerful educational tool. I hope that it will happen in time.

ZOOS AS ARKS

Zoos are often characterized as modern-day Noah's Arks where threatened species can be saved to be reintroduced when the waters of destruction have receded. This view is as unreal as the original myth of Noah saving the creation. *Ex situ* breeding efforts that have saved threatened species (Pere David's deer, the Hawaiian goose, the Golden Lion tamarin, the Guam rail; the Arabian oryx) are tributes to our incredible ingenuity and dedication. They are, generally speaking, noble efforts and a focus to promulgate concern but there is no way that the countless species now at risk can be saved *ex situ*. Even the great advances in cryopreservation, in vitro fertilization and the surrogation of maternity cannot do more than skim the surface of the problem. They will undoubtedly help to save some conspicuous and attractive vertebrates, and are, of course, important technologies well worth pursuing. But there are too many endangered species, even of the vertebrates, and the processes of both natural, and enhanced *ex situ* breeding are too expensive. We need to save habitats, and that can be accomplished only if we involve concerned people. That, I contend, is our true vocation. Let us go to it with a new approach, and let us do it in time.

REPRISE

Statistics of species diversity aside, the tropics are a biological treasure house of complexity, coadaptation, evolutionary fine-tuning, and absolute wonder. Putting a biologist in a rain forest, however briefly, is the experiential equivalent of transporting a 1903 air enthusiast to the present-day National Air and Space Museum, or Heathrow Airport, London. The extraordinary complexity of tropical ecosystems must be saved for many reasons. Not the least of these is the potential value of rain forests and their components to our own future. To save them in time, with the threshold of no–return rapidly approaching (Lovejoy 1988), will need every possible effort by a broad spectrum of people and institutions. Bioexhibits can play a major part in this, and a new kind of holistic entity, the BioPark, could contribute significantly more than its intellectual ancestors.

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