8. The Science of Amazon Conservation

THOMAS E. LOVEJOY
Vice-President for Science,
World Wildlife Fund,
1601 Connecticut Ave., N.W.
Washington, D.C. 20009, USA

A major problem in preparing an adequate conservation plan for the ten percent of the earth's biota thought to occur in the Amazon Basin is the minimal amount of knowledge about the natural history of the region. The least known of the earth's terrestrial biological formations, the majority of its species are unknown to science, and of those that are the details of their distribution and ecology are scantily known. Even the best recorded groups, such as the butterflies and birds, still produce surprises: for example, in 1969 I netted a pair of black-chested pygmy tyrant flycatchers (*Taeniotriccus andrei*) at Belem. This proved to be the first record of the species east of Santarem, some 625 km to the west.

Since the Amazon forest is not uniform in species composition throughout the basin, this rudimentary state of knowledge presents a challenge in choosing appropriate locations for national parks and other conservation areas. The current situation to the selection problem rests on an approach of analyzing the geographic distributions of well-known groups, such as birds (Haffer, 1969; Haffer and Simpson, 1978). In a series of publications Haffer (1969, 1970, 1974, 1978a, 1978b) noted that the distribution of species of forest birds of the Amazon included some which were relatively restricted and occurred in clusters —clusters of endemism. With insights derived from present rainfall patterns and information about past climates, he interpreted these clusters of endemics as representing those parts of the basin where rainforest persisted during periods of the Pleistocene when conditions were so cold and dry as not to allow a continuous forest cover. According to this view, new species and races of birds evolved during these periods of isolation, and when conditions once again favored forest cover over most of the basin, some of these did not spread throughout for a variety of reasons. The distributions of such birds, viewed today, in a sense represent ghosts of these past so-called Pleistocene refugia.

While this interpretation is generally accepted, it is far from proven fact. Fortunately, from the conservation point of view, it is not necessary to accept this interpretation of these geographic patterns in order to realize that such clusters of endemic species are indeed logical sites for parks and reserves. These species will only be conserved by establishing protected areas which include the areas in which they occur.

The current plan for a system of conservation units is based on this approach (Wetterberg *et al.*, 1976) and was accepted after discussion by the second meeting of the Intergovernmental Technical Group on Protection and Management of Amazon Flora and Fauna in August 1977. Maps of refugia as defined for birds (*vide* Haffer), butterflies (Brown, 1976), and reptiles (Vanzolini, 1973), as well as phytogeographic regions (a somewhat similar analysis) based on five families of woody plants (Prance, 1977) were superimposed. Those areas with the greatest degree of coincidence of 'refugia' as defined for the four taxa were given highest priority for conservation, and where there was the least degree of coincidence (i.e., a refugium for only one group) the least priority was given. Interestingly, some organisms seem to have more refugia than others, and not surprisingly, some of these do not coincide with all those for groups with fewer refugia. This is probably because a group such as butterflies which requires a small area could persist in a smaller forest patch (refugium) than could, for example, birds (Oren, 1982). This has important implications for conservation (Lovejoy, 1982).

As reassuring as the possibility of such an approach may be in the face of limited biological knowledge, it is nonetheless a doubtful assumption that conservation areas based on refugia defined for birds, two subfamilies of butterflies, reptiles, and only five plant families, will accom-

modate the rest (99 + %) of the Amazonian biota. It is the best we can do for the moment, but clearly there is a need to enlarge the data base on which such critical decisions depend.

At least two major efforts are afoot to do just this. The National Institute for Amazon Research (Instituto Nacional de Pesquisas da Amazonia, INPA) at Manaus has a joint effort with the New York Botanical Garden to enlarge the botanical data base. Existing data in the literature and herbaria have been assembled, and can be analysed once they are in a computer. At the same time, botanical expeditions are going to areas immediately threatened, or areas which have been largely neglected through remoteness, to fill in some of the blanks. Clearly there is a need for a Projeto Fauna to complement this Projeto Flora, although it is a much more difficult, an almost monumental task. Such a project was announced in 1981 by Brazil's National Research Council (CNPQ). Probably the first initiatives will be in western Amazonia where some of the funding will come from a research component of a World Bank loan.

Such an undertaking is so large as to require decades for completion, particularly in view of the limited trained scientific manpower available. Therefore it will be important to assess the results and their implication for conservation plans in five years or so. While in no way precluding the need for the larger and longer scholarly documents that should eventually emerge from such efforts, there is probably a need to consider preparation of preliminary atlases for some of the better known faunal taxa (e.g., various vertebrate groups and butterflies).

In the meantime, the reasonable thing to do is to proceed with conservation action based on current knowledge, as is happening. Since 1977 new protected areas have been established in Bolivia, Ecuador, Venezuela, and most notably, Brazil, totalling 118 300 km^2, an area larger than Austria (Wetterberg *et al.*, 1981). The Brazilian areas constitute close to 80 000 km^2.

The 1976 analysis of conservation priorities took note of the problem of what size parks and reserves should be. This is a problem all over the world because it is now widely recognised that an isolated fragment of once continuous natural habitat invariably loses species after isolation (Lovejoy and Oren, 1981). Habitat fragments go through an ecosystem decay process rather reminiscent of radioactive decay, progressively losing species in the process of approaching a simpler and somewhat stable state. This problem really calls into question whether any park or reserve in the world will ultimately fulfill the purpose for which it was originally established, as well as being of fundamental importance for almost any management goal for a habitat fragment.

The Amazon approach has been, once again, to use the best available information, namely Terborgh's estimate (1975), but also to work toward improving the state of knowledge about the problem. So while a minimum size of 2500 km^2 is being followed in the establishment of new areas, a major research effort is underway to study the problem. A joint US–Brazil effort involving the World Wildlife Fund-US and INPA is studying this problem taking an experimental approach (Lovejoy, 1980).

Brazil has a law that 50% of the land in any Amazon development project must remain in forest, and authorities of the Manaus Economic Free Zone (SUFRAMA) have agreed to arrange the 50% in the Distrito Agropecuaria north of Manaus to provide for the long-term study. On a number of cattle ranches (Fig. 8.1) researchers are being permitted to pick out a series of forest reserves while the forest is undisturbed but which will eventually be isolated. They will comprise a size series of reserves ranging from one to 1000 hectares in size, with replicates in each size class, plus one single large reserve in excess of 10 000 hectares and perhaps as much as 16 000. There are two 'controls' for the experiment. Firstly the data collected by studying the fauna and flora of the reserves while still part of an intact forest prior to isolation will provide a reference point. Secondly comparative data will be available from the single large area, which although most probably less than minimum critical size, will nonetheless be changing so slowly relative to the smaller reserves that it can essentially be considered mostly unaffected by the ecosystem decay function.

The purpose of the size series is twofold. One is to provide data to demonstrate whether forest patches of similar size tend to end up after species loss with similar species composition. The second is to provide a series of increasingly complex and more time consuming approximations of the species loss process. The smaller reserves will yield some quick and very simple insights into species loss and the larger reserves a slower but deeper understanding. Of course in addition there probably are certain factors which loom greater in importance in small reserves than larger ones. Further, the results of the research program (Fig. 8.2) are intended not only to make some approach to defining minimum critical size for Central Amazonian forest, but also to provide a basis for managing a reserve of lesser dimension to hold more and/or certain species which it otherwise would not.

Fig. 8.1. Cattle ranch near Manaus (Photo credit: Dr E. J. Fittkau).

A one and a ten-hectare reserve have already been isolated and have yielded new insights into the ecological dynamics of forest fragments (Lovejoy, Bierregaard and Schubart, 1982). It has been found that there is a major increase in the rate at which birds are netted in the reserve the instant the surrounding understory is destroyed. This may be due to truncated territories of some bird species resident in the reserve (i.e., no new individuals) but also probably includes an influx of birds from the surrounding devastated area. This overpopulation problem is superimposed on the basic species loss process. Within less than a year the capture rate in the one-hectare reserve had fallen to a level lower than prior to isolation, and species discovery functions (beginning with a series of successively later dates) calculated for the ten-hectare reserve indicated sampling of an increasingly impoverished bird community. In addition, the margins of the reserves were affected markedly by increased temperature and humidity fluctuation and showed an elevated susceptibility to tree blow down from increased exposure to wind. Both the influx and margin problems are of greater importance the smaller a reserve.

Amazon conservation, of course, must also take cognizance of the full variety of vegetation types, and particularly of the freshwater systems. Of special note in this regard is the remarkable relationship recently documented in considerable detail by Goulding (1980) about the relationship between many Amazon fish and the floodplain forests. Many fish swim into these forests at the time of high water and feed on fruits and seeds and other living matter which fall into the water. This transfer of nutrients from the terrestrial to the aquatic ecosystem permits a higher fish biomass than would otherwise be possible. This is of enormous significance in relation to the attraction of floodplain soils for agricultural development because of the annual deposition of silt. Any gain for agriculture through deforestation of the floodplain would be accompanied by a loss of fishery productivity. Since the Amazon fishery is a major source of animal protein (50%) for the Amazon populace this is a serious concern.

In additon there is a need for some parks or reserves of floodplain areas with accompanying portions of river to protect the associated fish community. These may be terribly difficult to design, and are not only important from the

Fig. 8.2. Minimum Size project—base camp (Photo credit: Dr E. J. Fittkau).

strictly biological point of view, but also are important in that they would in essence provide an undisturbed fish community so that the management of harvested and otherwise disturbed fish communities may be assessed.

Finally, much of the effort based on the above will fail unless cognizance is taken of the implications of the forest/rainfall relationship so elegantly illuminated by Salati and his colleagues (c.f. Salati, 1978; Salati *et al.*, 1978; Lovejoy and Salati, 1982). Through a variety of approaches, including isotopic analysis of rainfall across the Amazon Basin (which has an essentially unidirectional airflow from the Atlantic to the west), Salati *et al.* (1978) have demonstrated conclusively for the first time that forest can generate rainfall, and that in the case of the Amazon Basin, something of the order of 50% of the rainfall is generated within the basin itself and largely by the forest. This was the subject of a workshop at Piracicaba in November, which outlined the research necessary to define the precise dimensions of the Amazonian hydrological cycle so that appropriate land use recommendations can be made to avoid triggering an irreversible drying trend (Salati *et al.*, 1983).

The precise amount of Amazonian deforestation that has taken place is unknown and estimates of the current rate of forest loss are imprecise (Carvalho, 1981; Fearnside, 1982). Luckily it has not progressed to the extent that there have been many extinctions, or that the forest/fishery and forest/rainfall relationships have been destroyed. Consequently, there is still the opportunity to plan Amazon development scientifically so as to protect its incredible biological riches. There appears to be a good chance that this will actually happen.

References

Brown, Jr., K. S. (1976) Centros de evolução, refugios quaternarios e conservação de patrimonios geneticos na região neotropical: padroes de diferenciação em Ithomiinae. *Acta Amazônica*, 7 (1), pp. 75–137.

Carvalho, J. C. de M. (1981) The conservation of nature and natural resources in the Brazilian Amazonia, *Revista Companhia Vale do Rio Doce (CVRD)*, 2, pp. 1–48.

Fearnside, P. M. (1982) Deforestation in the Brazilian Amazon: How fast is it occurring?, *Interciencia*, 7, pp. 82–88.

Goulding, M. (1980) *The Fishes and the Forest*, University of California Press, pp. i–xii, 1–280.

Haffer, J. (1969) Speciation in Amazonian forest birds, *Science*, *165*, pp. 131–137.

Haffer, J. (1970) Art-Entstehung bei einigen Waldvogeln Amazoniens, *J. Ornithol.*, *111*, pp. 285–331.

Haffer, J. (1974) *Avian Speciation in Tropical South America*, Nuttall Ornithol. Club, Cambridge, Massachusetts, i viii, 390 pp.

Haffer, J. (1978a) Quaternary biogeography of tropical lowland South America. In W. E. Duellman (ed.), *The South American Herpetofauna: Its origin, evolution, and dispersal*, Univ. of Kansas.

Haffer, J. (1978b) Distribution of Amazon forest birds, *Bonn. Zool. Beitr.*, *29*, pp. 38 79.

Haffer, J. and Simpson, B. (1978) Speciation patterns in the Amazonian forest biota, *Ann. Rev. Ecol. Syst.*, *9*, pp. 497 518.

Lovejoy, T. E. (1980) Discontinuous wilderness: minimum areas for conservation, *Parks*, *6* (2), pp. 5 10.

Lovejoy, T. E. (1982) Designing refugia for tomorrow. In G. T. Prance (ed.), *Biological Diversification in the Tropics*, Columbia University Press, pp. 673 630.

Lovejoy, T. E., Bierregaard, R. O. and Schubart, H. O. R. (1982) Ecological Dynamics of Forest Fragments. Manuscript for Tropical Rain Forest Symposium, University of Leeds, England.

Lovejoy, T. E. and Salati, E. (1982) in E. Moran (ed.), *The Dilemma of Amazonian Development*, Westerly Press.

Oren, D. C. (1982) Testing the refuge model for South America: a hypothesis to evaluate discrepancies in refuges number across taxa. In G. T. Prance (ed.), *Biological Diversification in the Tropics*, Columbia University Press, pp. 601 607.

Prance, G. T. (1977) The phytogeographic subdivisions of Amazonia and their influence on the selection of biological reserves. In G. T. Prance and T. S. Elias (eds.), *Extinction is Forever*, New York Botanical Garden, pp. 195 213.

Salati, E. (1978) Recycling of water in the Amazon Basin: an isotopic study, *Water Resources Research, Richmond*, *15* (5), pp. 1250 1258.

Salati, E., Marques, J. and Molion, L. C. B. (1978) Origem e distribuicao das chuvas na Amazonia, *Interciencia*, *3*, pp. 200 205.

Salati, E., Lovejoy, T. L. and Vose, P. B. (1983) Precipitation and water recycling in tropical rain forests with special reference to the Amazon Basin, *The Environmentalist*, *3* (1), pp. 67 72.

Terborgh, J. (1975) Faunal equilibria and the design of wildlife preserves. In F. B. Golley and E. Medina (eds.), *Tropical Ecological Systems: Trends in Terrestrial and Aquatic Research*, Springer-Verlag, pp. 369 380.

Vanzolini, P. E. (1973) Paleoclimates, relief, and species multiplication in equatorial forests. In B. J. Meggers, E. S. Ayensu and W. P. Duckworth (eds.), *Tropical Forest Ecosystems in Africa and South America: A comparative review*, Smithsonian Institution Press, Washington, D.C., pp. 255 258.

Wetterberg, G. B., Padua, M. T. J., de Castro, C. S. and de Vasconcellos, J. M. C. (1976) Uma analise de prioridades em conservacao da natureza na Amazonia, *PNUD/FAO/IBDF/BRA-45 Serie Tecnica No. 8*, pp. i iv, 1 62.

Wetterberg, G. B., Prance, G. T. and Lovejoy, T. E. (1981) Conservation progress in Amazonia: a structural review, *Parks*, *6* (2), pp. 5 10.