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The Present, Past and Future of Human-Caused Extinctions [and Discussion]

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The present, past and future of human-caused extinctions

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This paper re-evaluates whether we are really at the start of a mass extinction caused by humans. I consider the present, past and future of human-caused extinctions.

As regards the present, estimates of extinction rates based on *Red Data Books* underestimate real values by a large factor, because the books evaluate only those species that have attracted specific attention and searches. Especially in tropical areas with few resident biologists, many poorly known species go extinct without having been the object of specific attention, and others disappear even before being described. A 'green list' of species known to be secure is needed to complement 'red books' of species known to be extinct.

As regards the past, it is now clear that the first arrival of humans at any oceanic island with no previous human inhabitants has always precipitated a mass extinction in the island biota. Well-known victims include New Zealand's moas, Madagascar's giant lemurs, and scores of bird species on Hawaii and other tropical Pacific islands. Late-Pleistocene or Holocene extinctions of large mammals after the first arrival of humans in North America, South America and Australia may also have been caused by humans. Hence human-caused mass extinction is not a hypothesis for the future but an event that has been underway for thousands of years.

As regards the future, consideration of the main mechanisms of human-caused extinctions (overhunting, effects of introduced species, habitat destruction, and secondary ripple effects) indicates that the rate of extinction is accelerating. The basic reason is that there are now more humans than ever before, armed with more potent destructive technology, and encroaching on the world's most species-rich habitats: the continental tropical rainforests.

Introduction

Are we now at the start of another mass extinction, similar in magnitude to the greatest ones of the past, but differing in being caused by humans? I am not referring to the risk of a nuclear war, but instead to the risk resulting from effects (such as habitat destruction) that are already operating and that have already caused extinctions.

The answers offered to this question vary greatly. The *Red Data Book* of the International Council for Bird Preservation (ICBP) lists 88 Recent bird species as extinct and 283 as extant but endangered, about 1 and 3% of all Recent bird species, respectively. Many conservation biologists consider these numbers as gross underestimates, whereas many economists and developers consider them gross overestimates. How many species really have already become extinct through human causation? How many more are likely to become extinct in the next 50 years? If it is true that humans cause extinctions, so what? Aren't extinctions part of normal evolutionary history, with all species destined sooner or later for extinction anyway? Is an impending mass extinction crisis a hysterically exaggerated hypothesis, an event already underway or an already partly accomplished act?

To answer these questions, I consider the present, past and future of human-caused extinctions. I begin with an assessment of claims about the number of extinctions that have already occurred in modern times (i.e. since 1600). I then assess the number of extinctions that humans might have caused in recent millenia but were not witnessed by literate observers. Next, I discuss the number of extinctions likely to occur in the near future (e.g. by the year 2050), based on knowledge of mechanisms of human-related extinctions and on extrapolation of current trends. Finally, I return to the initial question of whether we are now in the middle of a mass-extinction wave.

The present

As a start, consider the claim in the ICBP Bird *Red Data Book* that about 88 full species of birds plus an additional 83 subspecies have become extinct since 1600 (King 1981). For a bird species to get on this list requires that it has been specifically searched for and not found for many years, despite ornithologists knowing where it previously occurred and having looked there. For some species and races that became extinct recently, ornithologists have watched a population dwindle down to the last few individuals and then followed the fates of those individuals in their last years. Thus it is very unlikely that species that pass the tests for inclusion on the ICBP list of extinct species actually still exist.

The occasional, well-publicized 'rediscoveries of extinct species' have instead involved birds that did not make it onto the ICBP list of species considered extinct. For example, when I rediscovered New Guinea's long-lost yellow-fronted gardener bowerbird (*Amblyornis flavifrons*) in 1981, the media cited it as an example of a species formerly considered extinct. In reality, no specimen had been collected of that bowerbird since its description in 1895, and there had been some speculation that it was possibly extinct, but the fact is that ornithologists did not know where the sole specimens had been collected. When I happened by chance on the bowerbird's range, New Guinea's previously unexplored Foja Mountains, the bowerbird proved reasonably common there (Diamond 1982).

The lengthy evaluation required for each species considered for inclusion in the *Red Data Book* meant that the books were widely recognized as out of date at the moment of publication. As Collar & Andrew (1988) of the ICBP aptly express it, 'With only limited resources to finance the evaluation and documentation of species at risk, there is inevitably tension between the urgency imposed by their plight and the responsibility of making the analyses as thorough and hence as truthful as possible'. The inevitable incompleteness of the *Red Data Books* attracted criticism that resulted in a new ICBP volume listing bird species considered to be at risk of global extinction and entitled *Birds to Watch* (Collar & Andrew 1988). This book lists 1029 bird species at risk of global extinction, and an additional 637 species considered near-threatened. Adding these two catagories to the 88 species that had already passed rigorous evaluation as being extinct yielded a total of 1754 bird species, or about 20% of the world's approximately 9000 Recent bird species, at risk of extinction or already extinct.

However, in the areas that I know best as a field ornithologist – New Guinea, Melanesia and Indonesia – some of those species that *Birds to Watch* lists as threatened are in fact surely extinct, because they occur on small islands and have not been seen in 50 years by residents of those islands who knew the species well. How could this renewed ICBP effort list extinct species as merely threatened? The basic problem is that even this latest effort continues to place the

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burden of proof on documenting that a species is extinct or threatened. Those species that get into the book are ones for which someone suspected danger and gathered supporting evidence. It is not the case that the status of all the world's bird species was evaluated and that those species found to be in danger were then listed.

This distinction between 'probably extinct' and 'positively known to be extinct' means little in Europe or North America, where there are millions of fanatically devoted bird-watchers. All species of European and North American birds are repeatedly monitored every year. The rarer they are, the more diligently they are monitored. No European or North American bird species could possibly become extinct without having been known to be in danger, and having been sought after, for many years.

However, most of the world's species occur in the tropics, where there are few resident trained naturalists and few specific searches for possibly endangered species. We don't even know how best to identify many tropical species alive, and we don't know where they were collected. All that we have may consist of specimens, sometimes from an uncertain locality, dating back to the 19th century. Thus if the burden of proof were on showing that a species is still extant in healthy numbers in a non-threatened habitat, many more species would fail that test than the ICBP now lists as extinct or threatened.

Some recent studies emphasize the gulf between 'proved extinct' and 'not proved extant' (Diamond 1987). In the Solomon Islands, a tropical southwest Pacific archipelago where I have done much fieldwork, the *Red Data Book* (King 1981) listed one extinct bird species. However, when I tabulated what species had actually been reported alive since 1953, it turned out that there were no definite records for 12 of the Solomon's 164 bird species, even though some of these species were formerly described as common. Most of these missing species are ground birds susceptible to introduced predators, and Solomon islanders specifically told me that some of them had been exterminated by introduced cats.

Still, the Solomon Islands are a mild example, because they have fewer native species to begin with, fewer introduced predators and more intact natural habitat than most other tropical areas. More typical of the world's tropics is lowland Malaysia, which is rich in species and has been extensively deforested. A recent four year search for the 266 species of primary freshwater fishes that had been described from the Malay Peninsula was able to find less than half (only 122) of those species (see Mohsin & Ambok 1983). The remainder have either become extinct, endangered or rare as a result of habitat changes.

Many other tropical habitats rich in endemic species, like Peninsular Malaysia, have already been extensively damaged or destroyed, but differ from Peninsular Malaysia in that no biologist has troubled to look for the habitat's former species. Other habitats have been destroyed even before they were surveyed by biologists. For example, a botanical survey of one forested ridge in Ecuador discovered numerous previously undescribed species of plants, just before those species were exterminated by logging at the ridge (Gentry 1987). That ridge's insects, and the plants of innumerable other logged ridges, were never described before being exterminated.

For these reasons the ICBP is shifting its emphasis from 'red books' of species proven to be extinct towards 'green lists' of species proven to be extant and secure (Imboden 1987). When one considers that most of the world's species live in tropical habitats now under siege and rarely visited by biologists, it becomes unlikely that as many as half of the world's Recent species will qualify for the Green List.

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The past

So far, I have confined my discussion to extinctions that occurred in modern times and that were recorded by literate observers. But many other Recent species are known only from fossil or subfossil bones and were never recorded by literate observers. Famous examples include the moas of New Zealand, the elephant birds of Madagascar, the flightless geese of Hawaii, and the mammoths of the Americas and Eurasia. There has been a long-standing debate over whether these extinctions too were caused by humans.

Twelve or thirteen species of moas – large, flightless, ostrich-like birds confined to New Zealand – have been described from subfossil bones. It was long argued whether the moas died out before or after the Maori colonization of New Zealand around 1000 A.D., hence whether the extinctions of the moas were from natural or human causes. The argument has now been settled, because bones of almost all moa species have been found in close association with humans: namely, in Maori ovens and butchering sites, where moas were cut up and eaten (Anderson 1984, 1989). The estimated number of moa skeletons at the sites exceeds 100000. Radiocarbon dates show that the moas became extinct within about 500 years of human arrival. Hence there is now no doubt that the moas were exterminated as a result of human activity. Many other New Zealand bird species, as well as lizards and frogs, became extinct at the same time because of overhunting or habitat destruction, or commensal mammals that arrived with the Maoris.

Madagascar, like New Zealand, had giant flightless birds known as elephant birds, abundantly attested by subfossils and especially by eggshells. More recently, archaeologists have unearthed on Madagascar the bones of a dozen large species of lemurs up to the size of a gorilla, plus giant land tortoises and a hippopotamus. Madagascar, too, suffered the extinction of this whole megafauna soon after humans arrived around 500 A.D. (Dewar 1984).

Since 1982 more than 50 species of now-extinct subfossil birds have been found in Hawaii at sites postdating colonization by Polynesians, including a radiation of flightless geese. This mass extinction removed more than 50% of Hawaii's original avifauna (see Olson & James 1982; James *et al.* 1987). Similar reports of extinct birds are coming in from archaeological sites on all other investigated Pacific islands, including Tonga, the Marquesas, Cooks, Chathams, Bismarcks, Tahiti, Henderson, Fiji, Tikopia and New Caledonia (Steadman 1989).

All these oceanic islands – New Zealand, Madagascar, Hawaii and other Pacific islands – have in common the fact that they were initially not inhabited by humans. Their faunas collapsed quickly after human arrival, because the island species had evolved in the absence of human hunters and of introduced predators such as cats and rats. In particular, virtually all oceanic islands studied by palaeontologists have yielded one or more species of flightless rail, mostly now extinct. When one extrapolates from the studied islands to unstudied islands, one estimates that about one fifth of the species of birds that existed in the world a few thousand years ago have disappeared as a result of human activities on oceanic islands (Olson 1989).

These recent extinctions of 'naïve' island species (i.e. ones without experience of humans) are now widely accepted as human caused, because the extinctions are recent enough to be accurately datable, because of their close coincidence in time with human arrival, and because no natural environmental change even remotely adequate to account for them has been found. Still controversial, however, are extinctions of the naïve species that also existed on the continents not occupied by humans until the late Pleistocene: North America, South America

and Australia. In North America and South America, respectively, 73 and 80% of large mammal genera became extinct around the time of appearance 11000 years ago of Clovis hunters, who are considered by many to be the first human occupants of the New World (Martin 1984). Some of the extinctions are dated to within a century or two of the arrival of the Clovis hunters (see Mead *et al.* 1986). For a few of the extinct species, notably mammoths, evidence of human hunting is available in the form of butchered kills. The large mammals of the Americas may thus have been exterminated by humans, and Mosimann & Martin (1975) proposed that this occurred by a rapid 'blitzkrieg' that decimated naïve prey, as now widely accepted for the megafauna of oceanic islands. However, the cause of these late-Pleistocene extinctions of large American mammals is still debated, because there were major changes in climate around the same time; the exact time relation between extinction and human arrival is not established for most species, and evidence of human hunting has been obtained for only a few species.

The remaining continent that humans occupied only late in the Pleistocene, Australia, also lost most (86% (Martin 1984)) of its large mammal genera, plus some large flightless birds and giant lizards and snakes, after human arrival around 50000 years ago. Many native mammals of Mediterranean and West Indian islands, including all large species, also became extinct in the late Pleistocene or Holocene, though the exact time relation to arrival of humans is uncertain. Eurasia and Africa, where humans coevolved with large mammals for a million years or more, did not suffer such mass extinctions. However, a few species of large mammals, such as Eurasia's mammoths and woolly rhinoceroses, and Africa's giant buffalo, did disappear in the late Pleistocene as human hunting skills improved (Klein 1983). In all these cases, the debate continues as to whether these extinctions of large mammals were due to effects of humans or of climate.

My own evaluation of the evidence is that most of these debated late-Pleistocene extinctions of large mammals were indeed caused by humans. Proponents of climate-based theories have failed to explain why large species became extinct in each part of the world after the first arrival of humans but did not become extinct in other parts of the world with similar climate changes at the same time or in the same part of the world when similar climate changes had occurred in the past (Martin 1984; Diamond 1989).

Thus at least the evidence from oceanic islands makes clear that human-caused mass extinctions are not a hypothesis about something that could happen in the future, but instead a proven event that has already overtaken one fifth of the world's Recent avifauna. Depending on one's evaluation of the continental evidence, human-caused mass extinction may also have already befallen half of the world's Recent large mammals.

The future

Is the peak of the current human-caused extinction already passed, or is most of it still to come? Let us try to answer this question by considering the possible mechanisms by which humans exterminate species, and the possible remaining victims. Four mechanisms stand out (Diamond 1984*a*).

The first and most obvious mechanism of extermination is overhunting. This is the mechanism that played a large role in the extinctions of New Zealand's moas, the 50 species or subspecies of large mammals exterminated since 1600, and possibly the large mammals that

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became extinct in the late Pleistocene. Hence one might wonder whether, after tens of thousands of years, we have already hunted out any species that we are likely to be able to hunt out. However, many species of large mammals survive in Africa, Eurasia and the oceans, and a smaller number survive in the Americas and Australia. Improved hunting technology is rapidly reducing populations of surviving large mammal species. Obvious candidates to disappear in the near future are most large mammals of Africa and southeast Asia (at least outside of zoos and game parks) and the larger cetaceans.

A second mechanism of human-caused extinction involves effects of introduced species on native species: effects as predators, grazers, browsers, competitors and vectors of disease. Introduced predators such as cats and rats have been the dominant cause of bird extinctions on oceanic islands, whereas introduced mammalian herbivores such as goats have been the main cause of reduction of island vegetation. Famous dramatic examples include the extinctions of native birds within a few months or years after rats arrived at Lord Howe Island in 1918 and at New Zealand's Big South Cape Island in 1964 (Atkinson & Bell 1973; Diamond 1984*a*). The reason for the susceptibility of island species is of course that they evolved in the absence of species functionally equivalent to the introduced ones. Hence island birds had evolved no behavioural defences against mammalian predators, whereas island plants had evolved no chemical and mechanical deterrants to mammalian herbivores.

Again, one might wonder: hasn't most of the damage already been done, and haven't cats and rats and goats spread around the world? Perhaps surprisingly, the answer is 'no'. The decimation of Australia's small native marsupials and rodents by introduced cats and foxes is sufficiently recent that some native species still survive to provide likely future victims. Oceanic islands still rich in endemic birds, lacking *Rattus rattus* and *R. norvegicus*, and hence candidates for a rat-caused extinction wave, include Rennell and Little Barrier (Diamond 1984*b*). What may ultimately prove to be the biggest modern extinction wave caused by an introduced predator has just started in Africa's Lake Victoria, whose hundreds of endemic species of cichlid fish are now in the process of being exterminated by a predatory fish, the Nile perch, introduced in a misguided effort to establish a new fishery.

A third mechanism is habitat destruction, which is now becoming the leading mode of human-caused extinctions. In the past, habitat destruction has accounted for about half of the extinctions of bird species on continents (King 1980). In this case the worst is surely yet to come because of accelerated destruction of the world's most species-rich habitats, the continental tropical rainforests (Myers 1980). At current rates of logging and forest destruction, rainforests that are rich in endemic species and that may be largely cleared within the coming decade include the Atlantic forest of Brazil, the forests of Madagascar, and those of lowland Malaysia, whereas those of Borneo and the Philippines are expected to follow soon thereafter. By the middle of the next century, large blocks of rainforest are unlikely to survive outside Amazonia and Zaire. Nor is it necessary to destroy a habitat completely to exterminate many of its species: reduction and fragmentation of habitats also cause extinctions (Diamond 1984*c*).

I have reasoned so far about human-related factors impinging directly on target species. However, almost every species is dependent on other species for food, habitat structure, pollination, seed dispersal or other necessities. Thus each extinction is likely to cause a cascade of secondary extinctions. For example, human removal of top predators (jaguars, pumas and harpy eagles) on Barro Colorado Island caused a population surge in medium-sized predators (monkeys and coatamundis) on which the top predators normally prey, and that surge of

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medium-sized predators then led to extinctions of ground-nesting birds on which humans had no direct effects (Terborgh & Winter 1980). Similarly, the disappearance of coyotes from southern Californian canyons turned out to result in declines rather than increases in populations of native birds, because coyotes prey on cats and foxes that prey more heavily on birds than do the coyotes themselves (Soule *et al.* 1988).

Finally, recall that our exclusive focus up to this point has been on extinctions of species. But there are other types of losses of biological diversity, such as extinctions of genetically distinct populations (subspecies) and losses of genetic diversity within a population. Some species that have recovered after passing through severe population bottlenecks, such as elephant seals (Bonnell & Selander 1974) and Cheetahs (O'Brien *et al.* 1983), are now virtually homozygous at all loci studied electrophoretically. In the long term, such species are less able to adapt to altered environmental conditions, and in the short term their survival may be jeopardized by inbreeding depression.

Coda

Among the questions with which I began this article was a common observation disparaging the significance of current human-caused extinctions. 'Extinctions are occurring normally all the time, and it is the fate of all species eventually to become extinct, so what is so different about human-caused extinctions?'

There are three things wrong with this reasoning. First, it is not the fate of all species to go extinct: the existence of tens of millions of species today shows that many species of the past survived to evolve into chronologically distinct species.

Second, the current rate of conservatively documented extinctions is far above the background rate: e.g. one or two bird species per year, sufficient to eliminate the world's entire avifauna in 4500–9000 years. My consideration of the main mechanisms of human-caused extinctions, and our extrapolation from current trends, led me to the conclusion that that current rate of human-caused extinctions will increase. Basically, this is because there are more humans alive now than ever before, armed with more potent means of destruction, and now beginning to assault the most species-rich areas on earth.

Third, in other spheres of life besides conservation biology humans do not simply accept whatever Nature or their own deeds deal to them. Instead, we make choices and alter the course of events around us. To dismiss the current extinction wave on the grounds that extinctions are normal events is like ignoring a genocidal massacre on the grounds that every human is bound to die at some time anyway.

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Discussion

N. P. Ashmole (*Department of Zoology, University of Edinburgh, U.K.*). The picture that Professor Diamond has painted is a very gloomy one, but perhaps we can take a little comfort from the fact that what we have heard in this meeting, and know from previous studies of the fossil record, suggests that episodes of extinction are typically followed by rapid evolution and adaptive radiation. It seems likely that the mass extinction caused by humans will in due course result in exciting evolutionary changes and proliferation of new species: the only trouble is that we may not be here to see it!

P. E. Purves (35 *Morgan House, Tachbrook Street, London, U.K.*). Professor Diamond, during your talk on man-related extinctions you referred to a number of marine mammals that have received your attention. I was surprised, however, that there was no mention of the near extermination of the largest animal that has ever existed on this earth, namely the blue whale, *Balaenoptera musculus*.

During the years immediately before World War II, blue whales were being killed at a rate of 37 000 annually. By 1966 the southern blue whale stock was estimated at less than 1000 animals and therefore no longer commercially viable.

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The whaling companies then turned their attention to the second largest of the baleen whales, the fin whale, *Balaenoptera physalus*. These in turn were systematically slaughtered until they too, became so rare as to be not worth hunting.

At present, only the smallest of the baleen whales, the minke whale, *Balaenoptera acutorostrata*, remains a viable resource. The large baleen whales have become so widely dispersed that recovery of the whale populations seems very doubtful. The Government of the U.S.A. has placed a total embargo on the hunting of Californian grey whales and thankfully the population of grey whales is increasing by approximately 12% per annum.

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