COMMENTS

Disappearing forests and biodiversity loss: which areas should we protect?

M. CARDILLO

Division of Biology, Imperial College London, Silwood Park, Ascot SL5 7PY, U.K.

Email: m.cardillo@imperial.ac.uk

SUMMARY

Minimising biodiversity loss in the face of large scale deforestation relies heavily on protecting selected areas of habitat within reserves. However, limited funding means it is necessary to prioritise areas for protection. Most current prioritisation schemes aim to protect the greatest amount of threatened biodiversity possible within a limited area. Here I describe a complementary approach, based on the systematic identification of areas in which species tend to be inherently extinction-prone. This is a more forward-looking approach to global conservation planning that should allow planners to anticipate and prevent future species declines in many parts of the world that still retain much of their original forest cover.

Keywords: biodiversity, prioritisation, extinction risk, hotspots, conservation areas

Disparition des forêts et perte de la biodiversité: quels secteurs devrions nous protéger?

M.CARDILLO

Minimiser la perte de la biodiversité au cours du déboisement à grande échelle dépend principalement de la protection de zones selectionnées d‘habitat à l‘intérieur des réserves. Cependant, les budgets limités rendent nécessaire la protection de certaines zones en priorité. La plupart des projets mise en priorité visent à protéger la plus grande quantité de biodiversité possible au sein d‘une zone limitée. Je décris ici une approche complémentaire, basée sur l‘identification systématique des zones dans lesquelles les espèces ont tendance à être susceptibles d‘extinction de façon inhérente. C‘est une approche à la conservation globale davantage tournée vers l‘avenir, et qui devrait permettre aux créateurs de projets de de prévoir et d‘empécher les futurs déclins des espèces dans de nombreuses régions du monde qui gardent encore aujourd‘hui une grande part de leur couvert forestier originel.

Desaparición de bosques y pérdida de biodiversidad: ¿Qué áreas deberían ser protegidas?

M. CARDILLO

El hacer que la pérdida de biodiversidad sea mínima frente a la gran escala de deforestación, depende en gran parte de la protección de las zonas de hábitat dentro de las reservas seleccionadas. Sin embargo, la financiación limitada significa que hay que dar prioridad a la protección de ciertas áreas. La mayoría de los esquemas de prioridades apuntan a la protección de la gran parte de biodiversidad posiblemente amenazada dentro de un área limitada. Este artículo describe un enfoque complementario basado en la identificación sistemática de áreas en las que las especies tienden a estar expuestas a la extinción de una manera inherente. Este enfoque de la planeación de la conservación global es más avanzado y debería permitir a los organizadores el prevenir la desaparición de especies en muchas partes del mundo que aún conservan la superficie original del bosque.

INTRODUCTION

Forests are the most biodiverse terrestrial habitats on earth. Despite a growing awareness that biodiversity and properly-functioning natural ecosystems make a crucial contribution to human wellbeing (Rashid *et al*. 2003), deforestation is proceeding at a rapid pace throughout much of the world. In Brazil, for example, more forest was lost in the 16 years up to 2004 than in all the preceding centuries. With massive investments in roads, dams and other economic infrastructure on the drawing board, it is predicted that 40% of remaining forest in the Amazon basin will be lost by 2050 (Soares-Filho *et al*. 2006). In other heavily-forested countries, such as Indonesia and Papua New Guinea, deforestation rates are also at historically high levels (FAO 2006).

The destruction of forests and other habitats is the single most important cause of biodiversity loss (IUCN 2004), and it is inevitable that the massive loss of forests that will occur over the next few decades will result in widespread extinctions. The magnitude of this impending extinction event can be estimated, roughly, using the species-area relationship. The species-area relationship describes the increase in species richness (S) with area of habitat (A), which can usually be modelled as a power function of the form $S = cA^z$, the value of z indicating the slope of the increase. The expected loss of species from time t to t+1 can therefore be estimated as a function of habitat loss, using the equation $S_{t+1}/S_t = (A_{t+1}/A_t)^z$. Using this method it has been predicted, for example, that endemic mammal species richness in the Brazilian Amazon could be reduced by 5-18% under different modelled scenarios of forest loss to 2020 (Grelle 2005).

In terms of protecting biodiversity, there are two basic responses to the current situation. The first is to attempt to mitigate the underlying causes of deforestation by addressing the social, political and economic factors that allow forest destruction to prevail over sustainable management (Geist and Lambin 2002). The second is to accept that deforestation will continue at high rates for the foreseeable future, and concentrate on conserving the species and habitats that remain. These are of course not mutually exclusive alternatives, but in this article, I focus on the second of these responses. Because of limited resources, planning for conservation is largely an exercise in prioritisation. I examine some of the approaches that have been taken to global conservation prioritisation, and describe a new approach based on the identification of areas where many species appear particularly extinction-prone.

PRIORITISING AREAS FOR PROTECTION

Conservation of species and ecosystems relies heavily on the prevention of ongoing habitat loss, usually by the establishment of protected areas. To date, this has generally been done in an ad-hoc, opportunistic fashion, with the result that protected area networks are often inadequate to meet conservation goals. Furthermore, the funds available for establishing and managing protected areas are a fraction of what is needed to adequately represent all remaining ecosystems and to secure populations of all remaining species. Acceptance of these limitations has led to the gradual development of a systematic approach to conservation planning, based on the prioritisation of areas according to measures of their relative conservation worth (Margules and Pressey 2000). This has been done not only at regional and national levels, but also globally. Identifying global conservation priority areas is more than just an academic exercise: increasingly, biodiversity loss is recognised as a global problem and conservation decisions are taken at an international level. There are now a number of schemes that use different criteria to identify and map global biodiversity "hotspots", which are proposed as high-priority areas for conservation. For example, Conservation International's Biodiversity Hotspots (Mittermeier *et al*. 2005) include the 25 areas of the world that have at least 1500 endemic vascular plant species, and where at least 70% of the original habitat has been lost. Birdlife International's Endemic Bird Areas (Stattersfield *et al*. 1998) include 218 areas with at least two bird species of restricted distribution (<50000km^2). Other global conservation priority schemes include Conservation International's High-biodiversity Wilderness Areas (Mittermeier *et al*. 2005), Birdlife International's Important Bird Areas (BirdLife International 2004), WWF's Global 200 Ecoregions (Olson and Dinerstein 1998) and the Alliance for Zero Extinction's Conservation Areas (Ricketts *et al*. 2005).

The principal aims of global prioritisation schemes such as these are firstly, to conserve as much biodiversity as possible, and secondly, to conserve a sample of biodiversity that represents the broadest possible range of species and ecosystem types. The emphasis is largely on those parts of the world deemed to have the most biodiversity to lose, or where species are perceived to be under the most immediate threat of extinction. These aims are a natural response to a crisis situation of rapid habitat loss and species declines, combined with limited funding available for conservation. But relatively little attention has been paid to systematic forward planning for extinctions. Many parts of the world still retain large areas of intact habitat. In these areas, what is the most effective way to avoid a future rerun of the widespread extinctions that have already occurred in more heavily-modified regions? One way is to identify and prioritise areas where species appear to be especially sensitive to human disturbance.

IDENTIFYING EXTINCTION-PRONE SPECIES

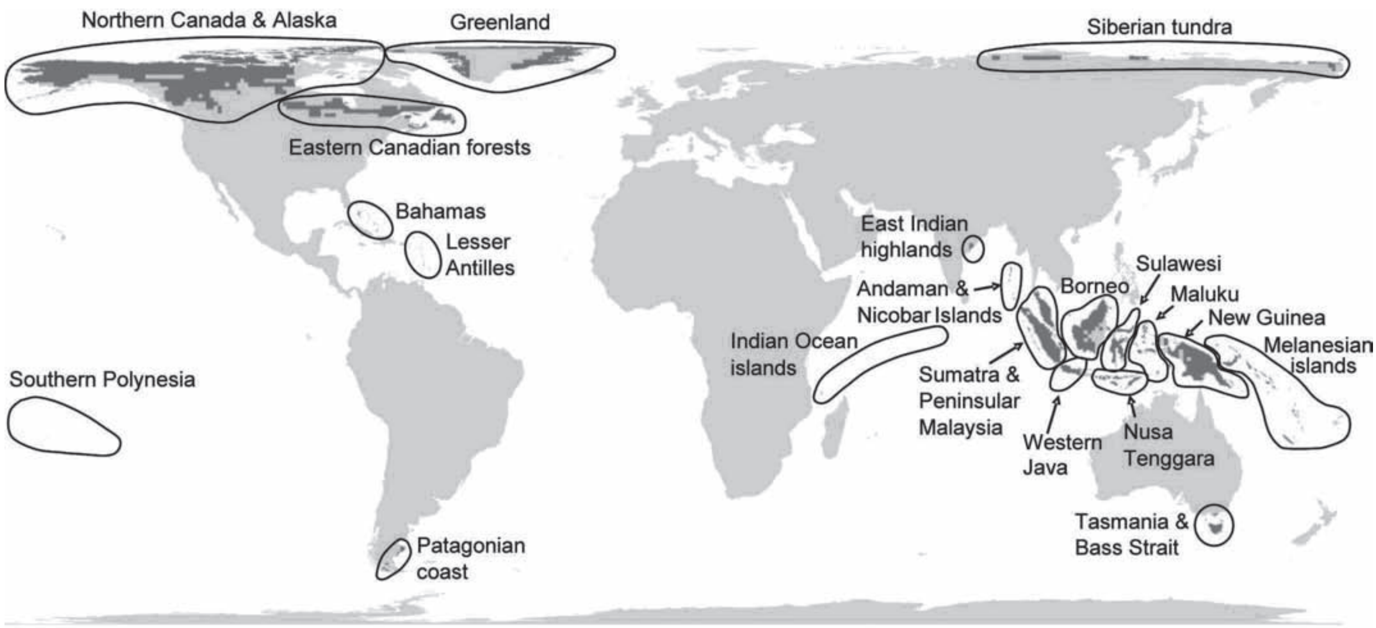
As we have seen, it is possible to use the species-area relationship to estimate the number of species expected to go extinct under projected scenarios of habitat loss. It is very likely that this will not be a random sample of the species found in a given region. Patterns of species decline and extinction are usually phylogenetically selective, with some taxonomic groups far more likely than others to suffer species losses (McKinney 1997). For conservation planning purposes, it would be very useful if we could move a step beyond simply estimating the number of impending extinctions, and predict which species, or at least what kinds of species, will be most sensitive to habitat loss. Consideration of species sensitivity is implicit in the definitions of some of the existing global prioritisation schemes. For example, the hotspots of Conservation International and the Endemic Bird Areas of BirdLife International include areas harbouring species of restricted geographic distribution. It is a reasonable assumption that such species will be more likely to go extinct if they suffer serious habitat loss (Cardillo *et al*. 2005). On the other hand, some species with very broad distributions have declined rapidly towards extinction (e.g., the Black Rhino *Diceros bicornis* and the Saiga antelope *Saiga tatarica*). A species' sensitivity to disturbance is influenced not only by the size of its geographic distribution, but also by a suite of ecological and life-history traits. For well-known groups such as mammals, therefore, sensitivity to disturbance can be estimated far more accurately using multivariate comparative models based on many different traits, than by simply assuming that species of restricted distribution are more extinction-prone (Fisher and Owens 2004, Purvis *et al*. 2005).

Comparative models often show that traits such as low population density, large body size and low reproductive rate, as well as a small geographic distribution, are associated with a high risk of extinction. Values of traits such as these represent a species' extinction-proneness: its inherent, biological sensitivity to human disturbances such as habitat loss. A species' current, or realized, extinction risk is not just a function of biology, but also has much to do with where a species lives and the levels of disturbance to which it is exposed. If we plot current extinction risk against risk predicted from biological traits, the positive association is usually very strong but there is nevertheless much scatter around the line of unity. Some of this scatter represents genuine statistical uncertainty, but we expect much of it to be associated with variation in the levels of disturbance experienced by different species. It is this scatter that several colleagues and I recently referred to as "latent extinction risk" (Cardillo *et al*. 2006). A species' latent risk is simply the extinction risk predicted from its biology minus its current extinction risk from the IUCN Red List (IUCN 2004), measured on a continuous numerical scale. Species that are overpredicted (predicted extinction risk is higher than current risk) have positive latent risk, and species that are underpredicted (predicted risk is lower than current risk) have negative latent risk. Positive latent risk implies that a species has the potential to become more threatened than it is at present: it has a biology that makes it relatively sensitive, but has probably not yet experienced high levels of human pressure.

HOTSPOTS OF LATENT EXTINCTION RISK

The concept of latent extinction risk was recently used to identify additional global priority areas for mammal conservation (Cardillo *et al*. 2006), to complement those identified under existing prioritisation schemes. To find areas where many mammal species have unusually high latent risk, the average latent risk of non-marine mammal species found in each 100 x 100km grid cell across the earth's surface was calculated, and cells with the top 10% of average latent risk values were identified. These cells show a strong tendency to be clustered into larger aggregate "hotspots" (Figure 1); this is not surprising, given the high degree of spatial autocorrelation in the composition of mammal assemblages. The 20 hotspots thus identified represent areas where there is considerable scope for the erosion of mammal biodiversity, and on this basis should be taken into consideration in global conservation planning efforts.

FIGURE 1 *Hotspots of latent extinction risk for non-marine mammals. See text for a definition of the hotpots.*



The latent risk hotspots are found in a wide range of places – tropics, temperate zones and high latitudes, and all continents except Africa. With the exception of large areas of Arctic tundra and some small islands, the feature that seems to be common to most of these hotspots is that they are areas of forest habitat, whether the boreal forests of the arctic, the temperate rainforests and wet sclerophyll forests of Tasmania, or the tropical rainforests of Indonesia and Melanesia. Notably absent from the hotspot map are drier woodland, savanna and desert regions. Indeed, many of the driest parts of the world are areas of very low latent risk, where many mammal species have already become more threatened than would be expected from their biological characteristics. However, this does not necessarily lead to the generalisation that forests tend to support mammal species that are inherently more sensitive to disturbance. For one thing, some arid and semi-arid regions – southwest Africa, the Pacific coast of South America and Mongolia – have high levels of predicted extinction risk, because they support large-bodied mammal species with slow life histories and low population densities, traits which tend to be associated with extinction-proneness. Further, some large forested regions – notably the Amazon and Congo basins – are home to mammals with relatively low levels of predicted extinction risk, and thus they do not feature among the latent risk hotspots.

GLOBAL PRIORITISATION STRATEGIES: DIFFERENCES OF EMPHASIS

When the map of mammal latent risk hotspots is examined, it is clear that the outcomes of this approach to identifying priority conservation areas diverge substantially from those of existing approaches. The regions of highest mammal species richness – East Africa and the tropical Andes – do not appear as latent risk hotspots. Indeed, some of the most conspicuous of the latent risk hotspots, in the northern parts of North America, are relatively poor in both total and endemic species richness, notwithstanding their large size. The northern Canada and Alaska hotspot has only 96 non-marine mammal species, compared to at least 500 in the Andes and Amazon basin. Why should particular importance be given to conserving the habitats and mammal fauna of Canada and Alaska, and other relatively species-poor areas?

The fundamental aim of most existing prioritisation schemes is to retain the maximum possible number of species, worldwide. This is why there is a strong emphasis on areas of high endemicity, such as South Africa's Cape Province or the tropical Andes: loss of much of the habitat in these areas would mean the extinction of many species found nowhere else. But it could also be argued that preserving intact assemblages, even relatively species-poor ones, is just as important as the maintenance of worldwide species numbers. For example, if 50 mammal species were to go extinct from the Amazon basin and Andes, it would represent a relatively small proportion of that region's mammal fauna. Most of the region's mammal biodiversity would remain, and the contribution of mammal species to ecosystem functioning might not be greatly altered. On the other hand, if the same number of species went extinct from Canada and Alaska, it would mean the loss of nearly the whole mammal fauna across a very wide region, with potentially severe ecological consequences (Danell *et al.* 2003, Borrvall and Ebenman 2006). A species that is not quite extinct but has been reduced to 1% of its original distribution still appears on a global species inventory, but is effectively "ecologically extinct": it makes little contribution to ecosystem functioning and the provision of ecosystem services. The latent risk approach is consistent with the view that it is important to prevent extinctions of local populations, as well as entire species (Balvanera *et al.* 2001, Ceballos and Ehrlich 2002). Under this view, it is important to maintain intact species assemblages across as much of the earth's surface as possible.

Much of conservation planning is aimed at saving what we can in the current battlegrounds of conservation. In general, this is a sensible approach. The crisis of deforestation and species declines is immediate, and the need for conservation action is urgent in areas where forest loss is most rapid, particularly where such areas contain large numbers of endemic species. But focusing entirely on a damage-limitation conservation planning approach risks leaving too few resources available to protect the future battlegrounds of conservation: places which still retain much of their original forest cover, but where species may be especially prone to extinction in the face of disturbance. Anticipating and preventing extinctions before they occur is surely a more cost-effective and efficient way of protecting biodiversity, in the long term, than expensive (and often ineffective) attempts to rescue species from the edge of extinction. What is needed in conservation planning is a more "balanced portfolio" that both responds to the immediate extinction crisis and prevents the crisis continuing into the future.

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