

GLOBAL BIODIVERSITY PATTERNS

Introduction

We've talked repeatedly about the large impacts humans have on the global environment and about the consequences those impacts have on contemporary rates of extinction. In particular, I argued that the impact of projected extinctions would be distributed unevenly among taxa, that we would tend to lose narrowly distributed endemic taxa and that they would be replaced with widespread cosmopolitan species, making a world that not only has fewer species but one that has fewer biotic differences among regions. What we haven't talked about are the cumulative effect of the individual losses on ecological communities. It probably won't come as a surprise that just as extinction affects some types of organisms more than others, some biomes will be more affected by changes forecast over the next century than others.¹

Projecting global biodiversity

Sala et al. [6] present scenarios for the status of biodiversity in 2100 for ten terrestrial biomes and the associated freshwater ecosystems.² These scenarios are based on:

- The five factors likely to have the largest impact on biodiversity changes over the next century:
 1. land use changes,
 2. the concentration of atmospheric CO₂,
 3. nitrogen deposition and acid rain,
 4. climate, and
 5. biotic exchanges, which they define as “deliberate or accidental introduction of plants and animals to an ecosystem.”

¹The following discussion is drawn largely from [6]

²They did not consider the freshwater ecosystems separately.

- Expected changes in these factors, “drivers”, in each biome between 2000 and 2100.
- The expected biodiversity impact of a unit change in each of those factors.
- Three possible ways in which the factors interact with one another in determining biodiversity change:
 1. *No interaction*: Each factor contributes independently to biodiversity change.
 2. *Antagonistic interaction*: Biodiversity change responds only to the factor that has the largest impact on it. The others have no effect.
 3. *Synergistic interaction*: Biodiversity change responds to the accumulated changes more than would be expected from an independent response to each factor by itself.

Expected changes in drivers

To forecast³ the state of global biodiversity in 2100, we need to forecast how the drivers will change between now and then. Sala et al. [6] use the “business as usual” scenario generated by global models of climate, vegetation, and land use. So what they provide is a *projection*, not a *forecast*. They tell us what will happen if we project current trends into the future. They don’t try to suggest how those trends might change. It’s a reasonable approach, and it illustrates again that knowing the direction we’re headed may be more important than knowing the final destination when trying to manage conservation problems. After all, the fact that we’re managing them at all means that we are at least considering changing directions. So we need to be able to project where we’ll arrive if we keep heading in the current direction and to compare it with where we would be if we changed our direction. You want a forecast when you can’t (or don’t want to) influence what’s going to happen. You want a projection when you do want to have an influence.

They ranked the amount of change for each of the five drivers on a scale of 1 (small) to 5 (large) (Table 1). Using the same scale (1 = low, 5 = high), they then ranked the biodiversity impact of a unit change in each of the five drivers in each of the ten biomes (Table 2), where one unit is defined as:

- *Land use*: conversion of 50% of land area to agriculture,
- *Climate*: 4°C change or 30% change in precipitation,

³Remember the difference between a forecast and a projection

	Arctic	Alpine	Boreal	Grass	Savanna	Med	Desert	N temp	S temp	Tropical
Land use	1.0	1.0	2.0	3.0	3.0	3.0	2.0	1.0	4.0	5.0
Climate	5.0	3.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
N deposition	1.0	3.0	3.0	3.0	2.0	3.0	2.0	5.0	1.0	2.0
Biotic exchange	1.0	1.0	2.0	3.0	3.0	5.0	3.0	3.0	2.0	2.0
CO ₂	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Table 1: Amount of change expected in each driver of biodiversity through 2100. 1 = low, 5 = high (from [6]).

	Arctic	Alpine	Boreal	Grass	Savanna	Med	Desert	N temp	S temp	Tropical
Land use	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Climate	4.0	4.0	3.5	3.0	3.0	3.0	4.0	2.0	2.0	3.0
N deposition	3.0	3.0	3.0	2.0	2.0	2.0	1.0	3.0	3.0	1.0
Biotic exchange	1.0	1.0	1.0	2.0	2.0	3.0	2.0	1.5	3.0	1.5
CO ₂	1.0	1.0	1.0	3.0	3.0	2.0	2.0	1.5	1.5	1.0

Table 2: Impact of a unit change in each driver by 2100. See text for description of what each unit corresponds to. 1 = low, 5 = high (from [6]).

- *Nitrogen deposition*: 20 kg ha⁻¹ year⁻¹,
- *Biotic exchange*: Arrival of 200 new plant or animal species by 2100, and
- *Atmospheric CO₂*: 2.5-fold increase (as projected) by 2100.

Global effect of the changes

To determine the global effect of expected changes by 2100, they took the product of the numbers in Table 1 and Table 2 and scaled them relative to the largest impact (Figure 1). Using the biome level projections, allows us to make projections about how biodiversity in each biome is likely to change under each of three scenarios: (a) no interactions among the drivers,⁴ (b) antagonistic interactions among the drivers,⁵ and (c) synergistic interactions (Figure 2)⁶

⁴Algebraically, the sum of the projected impact from each of the five factors.

⁵Antagonistic interactions mean that the various changes cancel each other out. As a result, only the driver with the largest impact has an effect on the results. Algebraically, the value of the factor with the largest impact.

⁶Algebraically, the product of the projected impact from each of the factors.

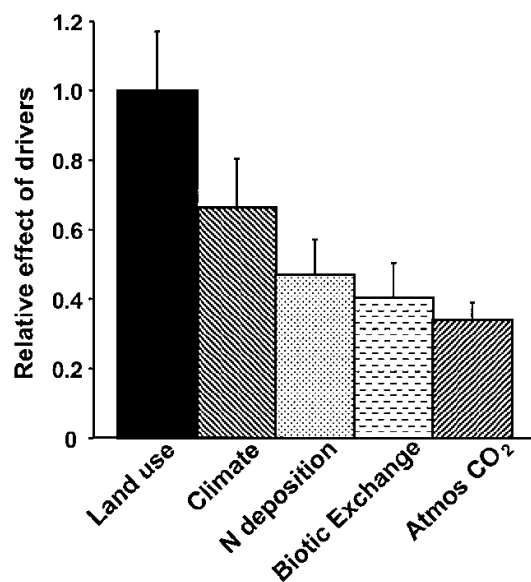


Figure 1: Relative impact of changes in five global factors affecting biodiversity. See [6] for details.

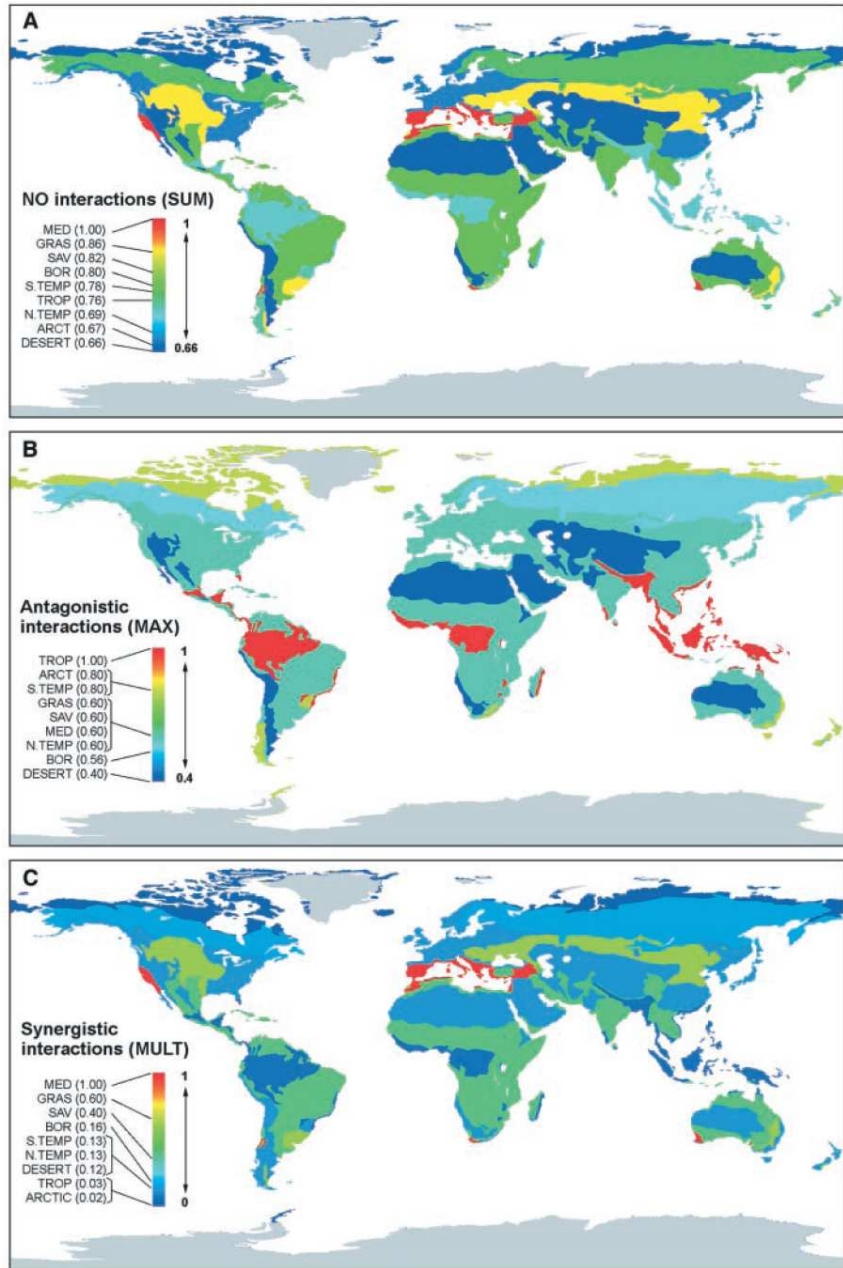


Figure 2: Projections of biodiversity change under three scenarios. See text and [6] for details.

Analysis

I'm not going to write down what I think here.⁷ I'm hoping to provoke some discussion and comment in class. We'll see if we can come to a consensus there. Points to consider include:

- How reliable are the indices of change and impact?
- How reliable is the method used for combining them?
- What limitations does the analysis have?
- Do the limitations invalidate the analysis?
- Is there a way that the analysis could have been done better?

Biodiversity hotspots

Sala [6] provides us with a way to say something about what areas of the world are likely to suffer the greatest changes in biodiversity as a result of changes projected through 2100. But we all know that some regions of the world are more diverse than others. Most groups of organisms have far more species in the tropics than they do in the temperate zone or in higher latitudes. As a result, a lot of the focus on the extinction crisis has been associated with loss of tropical rainforests. Because the numbers are so daunting, many conservationists have focused on identifying those places with the highest amount of diversity, “biodiversity hotspots” as Norman Myers [3] called them. Myers et al. [4, p. 853] argue that because “the number of species threatened with extinction far outstrips available conservation resources . . . this places a premium on identifying priorities”, which they propose to do by identifying “areas featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat.” Their analysis suggest that “as many as 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to hotspots comprising only 1.4% of the land surface of the Earth” (Figure 3).

Because the definition of “hotspot” Myers et al. [4] used included “exceptional loss of habitat” and because land use changes are the biggest driver of biodiversity loss [6], it shouldn't be surprising that several of the hotspots correspond with areas identified in the Sala et al. analysis as areas where the greatest biodiversity changes are expected, notably the Mediterranean climate regions: the Mediterranean basin itself, the Cape Floristic Province, southwest Australia, central Chile, and the California Floristic Province.

⁷Obviously, I think it's worth discussing this paper, or I wouldn't have spent this much time talking about it.

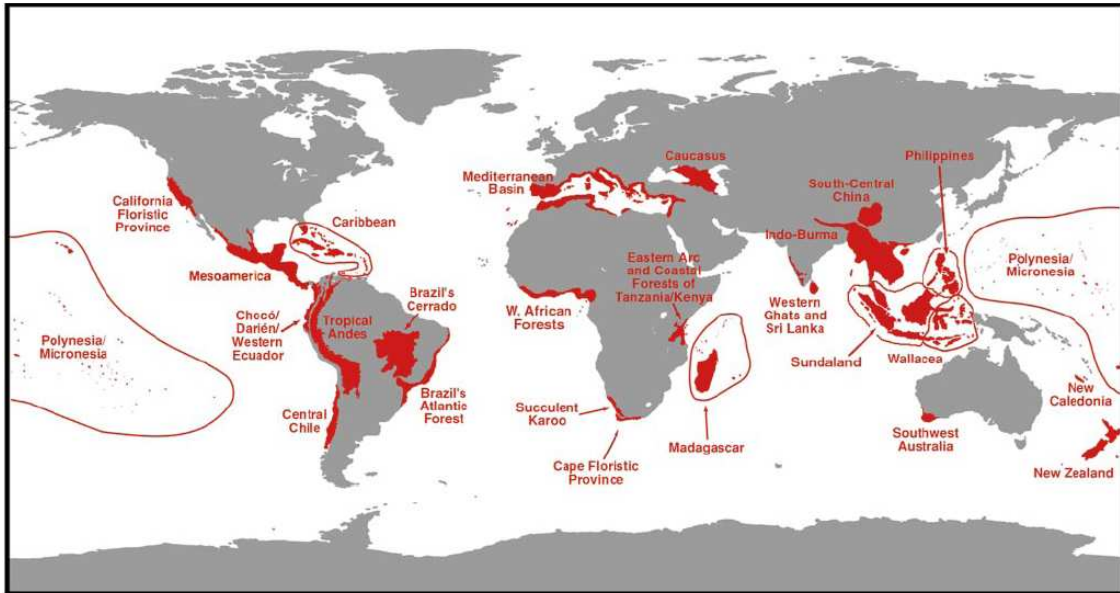


Figure 3: The 25 biodiversity hotspots identified by Myers et al. [4].

The coldspot challenge

The hotspot idea is attractive because it recognizes a real challenge facing conservationists. We *have* to make choices. It is not possible, it may not even be desirable in terms of human welfare, to prevent large-scale changes in land use in many parts of the world. Moreover, the number of species threatened with extinction is so vast that we cannot possibly devote our attention to saving each one individually. We must identify areas in which they can persist⁸ and leave them to fend for themselves. So we have to identify the areas where we will focus our attention as wisely as possible.

If our goal is to prevent as many species from going extinct as possible, then focusing on biodiversity hotspots is an obvious way to move forward. But is preventing extinction of as many species as possible our only goal? Is it even our primary goal? If it is, why are conservationists so worked up about drilling in the Arctic National Wildlife Refuge? The diversity of bryophytes and lichens may be reasonably great in the Arctic tundra, but for most other groups of organisms, the diversity in the Brazilian Atlantic forest or Madagascar (to pick just a couple of examples) is probably far greater.

Kareiva and Marvier [1] point out several reasons why we preventing extinction of the

⁸Or in which we *hope* they can persist.

maximum number of species might not be our only conservation goal. We might be interested in:

- Maintaining functioning ecosystems,
- Providing the greatest variety of plant, animal, and microorganism lineages for evolutionary innovations in the future,
- Preserving spectacular wild landscapes that inspire the human spirit, or
- Protecting biodiversity values in a way that complements and sustains human welfare.

These interests are not contradictory with preventing species extinctions, but they are not identical with preventing species extinctions, nor are they identical to one another. Consider the example of Montana and Ecuador that Kareiva and Marvier use:

- Montana and Ecuador are of roughly equal size.
- Ecuador: 19,362 vascular plant species and 2466 vertebrate species — total 21,828
- Montana: about 2,600 species
- Suppose we focus only on the number of species and set 20,000 as a target, and consider three scenarios:
 1. Ecuador 18,000 species; Montana 2000 species
 2. Ecuador 19,000 species; Montana 1000 species
 3. Ecuador 20,000 species; Montana 0 species

All have the same outcome in terms of total number of species, but the fraction of Ecuador's diversity that is protected ranges from a low of 82% to a high of 92% while the fraction of Montana's diversity protected ranges from 0% to 77%. Are those outcomes really equivalent?

If you answer that question “No”,⁹ it means that there are some other aspects of biodiversity or wild systems that you value beyond simply the number of species that they contain. Notice, however, that this answer involves a judgement of value, i.e., it involves bringing in some ethical or aesthetic judgment that isn't subject to experimental verification.

⁹And I suspect that you probably will.

To see this, imagine that you went through the above calculations with me and I told you at the end “I think all three scenarios are equivalent. There’s no reason to prefer one to the other (unless one costs a lot less money, and saving species in Ecuador is probably cheaper than saving them in Montana, so forget Montana).” How would you go about convincing me I’m wrong?

The problem of indicator taxa

Kareiva and Marvier [1] allude to another limitation of the hotspot approach that Myers et al. [4] explicitly acknowledge and attempt to address. The hotspots Myers originally identified were based entirely on the distribution of vascular plants. Those identified in [4] are based on a more extensive database, but they are based on species lists of vascular plants, mammals, birds, reptiles, and amphibians—no fish, no insects, no arachnids, no fungi, no lichens, no mosses, no microorganisms. Unless the distribution of species in different major groups of taxa corresponds to a high degree, it’s possible that the hotspots Myers et al. identified are hotspots for vascular plants and tetrapods, while the hotspots for insects or microorganisms would be found in very different places. Their data suggest a fairly high degree of congruence between vascular plants and tetrapods, but their analysis can’t tell us how well their approach would work for the vast array of species not included in their analysis.

Data on the coincidence of invertebrate and plant distributions at a global level is hard to come by.¹⁰ Unfortunately, at smaller scales the coincidence doesn’t appear to be particularly great. Consider, for example, an analysis of biodiversity changes associated with forest modification in the Mbalmyo Forest Reserve (south-central Cameroon). No one group is a good indicator for changes in species richness in other groups [2]. The groups were birds, butterflies, flying beetles, canopy beetles, canopy ants, leaf-litter ants, termites, and soil nematodes. Similarly, Prendergrast et al. [5] found a very low coincidence of species hotspots among five groups surveyed through the island of Britain.

References

- [1] Peter Kareiva and Michelle Marvier. Conserving biodiversity coldspots: recent calls to direct conservation funding to the world’s biodiversity hotspots may be bad investment advice. *American Scientist*, 91:344–351, 2003.

¹⁰At least I don’t know of any.

- [2] J. H. Lawton, D. E. Bignell, B. Bolton, G. F. Bloemers, P. Eggleton, P. M. Hammond, M. Hodda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stork, D. S. Srivastava, and A. D. Watt. Biodiversity inventories, indicator taxa, and effects of habitat modification in tropical forest. *Nature*, 391:72–76, 1998.
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