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Global Mapping of Ecosystem Disservices: The Unspoken Reality that Nature Sometimes Kills us

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ABSTRACT

Increasingly, we view nature through a utilitarian lens that leads us to attempt to measure and manage the services that species, habitats and ecosystems provide. Surprisingly, we have tended to consider only the positive values of ecosystems, their ecosystem services. In addition to providing our food and water, Nature also kills us, primarily through disease. If we are to effectively manage the terrestrial Earth, we need to also manage species, habitats and ecosystems so as to minimize such 'ecosystem disservices'. I consider what we know about the spatial pattern of one disservice, pathogen prevalence and how changes in habitat influence it. I consider the effects of habitat changes on pathogen prevalence and, consequently, ecosystem disservices. In the end, we need to weigh both the costs and the benefits of particular ecosystems, habitats and species – to consider the bad with the good. Doing so requires that we learn much more about the biota than we currently know.

Key words: Biophilia; biophobia; ecosystem disservices; ecosystem services; global pathogen prevalence.

IN MY PERSONAL EXPERIENCE, MOST CONSERVATION BIOLOGISTS CARRY OUT CONSERVATION because of an esthetic, moral or cultural fondness for wild species and places. The reasons behind conservation biologists' urges may not seem germane to conservation. Yet they are for the simple reason that, in beginning with a fondness for nature, we have missed an important reality—nature sometimes kills us. Tropical biologists, in particular, trade stories about cases of Leishmaniasis or Malaria and then, when it comes to tallying how much tropical forests are worth, only count the good stories. Or, in the peculiar logic of field biologists, botflies and their pestiferous kin can even come to seem like positives, the 'good' stories of adventurous days.

When ecologists and conservation biologists have set about to value nature, they have generated a list of kinds of values. These include esthetic, moral and cultural values, but also ecosystem service values (*e.g.*, water purification, pollination and carbon sequestration). Recent attempts have even been made to map such values globally and examine the extent to which key services show patterns similar to each other and to diversity (Naidoo *et al.* 2008). Yet rarely, if at all, in such efforts does one find the apparently unmentionable negative economic impacts of nature—ecosystem disservices.

Yet nature often harms and kills us. We were eaten in great numbers by predators (Hart & Sussman 2009) and killed in even greater numbers by pathogens (Magner 2009). We were bitten by venomous snakes, often mortally. We were besieged by flies, mosquitoes, ticks, fleas and bedbugs all carrying disease. We often still are. Predation was significant enough to shape our adrenal system (our fight and flight). We have both behavioral and physiological immune systems in large part to deal with infectious disease. In turn, the diseases we have been unable to effectively deal with shape genetic differences among populations as well as our cultural norms and economies (Navarrete & Fessler 2006, Thornhill *et al.* 2009). Deadly snakebites may have been common enough in our evolutionary past to have influenced our visual systems and fear modules (Isbell 2006). The influence of ectoparasite vectors of disease may have led to our hairlessness (Rantala 2007).

As we plan conservation and land management at the global scale, we need to account for ecosystem disservices. One can speculate as to why conservation tends to focus on positive rather than on both positive and negative attributes of species and habitats. Perhaps we ignore disservices because so large a percentage of the individuals valuing nature are distanced from the nature they are valuing. Ecosystems are, for example, valued in Washington, DC, while disservices accrue in Nigeria, where one can find more than 400 kinds of infectious diseases, many of them endemic (Dunn *et al.* 2010). Yet, regardless of how we arrived at our current perspective on the 'work' nature does, nature's disservices are real. More people died last year from wild species (most often diseases) than of all other causes combined (WHO 2008).

So how then do we consider such disservices and, more specifically, map them? Some disservices such as bites from venomous snakes are now rare enough to not require tallying for decisions, although even for snakes, exceptions may exist (Fayomi *et al.* 2002). We need to be careful to measure disservices on some common empirically grounded scale, whether in terms of lives or years of lives lost. Differentiating perceived disservices from actual disservices is key. One unambiguous disservice, at a global scale, is that offered by infectious disease via pathogens and their vectors.

To map the global disservices provided by pathogens and their vectors, we might begin by examining patterns in the diversity of human pathogens. One difficulty is that we understand far more about the spatial distribution of, say, woodpeckers than we do of pathogens and their vectors. The finest grain data available on pathogen distribution and abundance globally are at the scale of political regions. Data on pathogen vectors are even cruder, with thousands of mosquito species, for example, not yet described,

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much less mapped (Foley *et al*. 2007). At the coarse scale of political regions, the spatial concordance between mammal and bird diversity and human pathogen diversity is very, very strong (Dunn *et al*. 2010). You will find the most species capable of disservices in the same countries where the most species in need of conservation are likely to be found. Superficially, this result suggests conflict between biodiversity conservation and management to avoid ecosystem disservices. But we need to focus a little. It is not simply pathogen diversity that is a disservice but instead the number of infectious disease cases (prevalence) caused by pathogens.

Prevalence, it turns out, is only weakly correlated with bird and mammal diversity and, more importantly, varies as much within political regions as among them (Dunn *et al*. 2010). Within regions, it appears that it is the conversion of natural habitats to managed or disturbed habitats that tends to increase disease prevalence. Ironically (and maladaptively), we appear to make habitats worse for us in terms of their disservices (Schmidt & Ostfeld 2001, Vanwambeke *et al*. 2007). In some cases, ecosystem disservices may be an economically more viable reason for conserving wild lands than are the services. In this regard (and more so than for services), an argument might be made that we should not only map the current disservices associated with different habitats, ecosystems or regions but also the change in disservice resulting from changes to those habitats.

If disturbances to natural systems tend to increase the prevalence of pathogens, one might begin to map disservices by mapping disturbance and human population density (the latter, of course, directly linked to prevalence). Because the probability of any given disease increasing in prevalence must be a function of the number of diseases, the map should be weighted by pathogen diversity. If this crude cartoon model is correct, then the disservice provided by converting forest to other uses is a function of pathogen diversity, which is correlated with mammal and bird diversity. Perhaps the places one should avoid disturbance and disturbance-mediated ecosystem disservices may be the same as those where biodiversity is high. This may not be true, but such a possibility deserves investigation.

In the specific context of pathogens, another factor worth considering is the emergence of new diseases, which, if recent history is a model, can happen quickly enough to have global impacts on economies and life expectancies (Jones *et al*. 2008). Tropical rain forest species may someday yield useful drugs, but they may also yield new diseases. Most emerging diseases (at least those not due to antibiotic resistance) arise from either our domesticated animals or from wild vertebrates (Jones *et al*. 2008). In the latter case, apes appear many times more likely to be the sources of emergent diseases than are other primates, which are, in turn, more likely to be sources of emergent diseases than are other vertebrates (Wolfe *et al*. 2007). Given these realities, the potential disservices if forests with apes are disturbed seem fundamentally different than those without apes. But just how different? We do not know, but given what we do know about disservices from pathogens I suggest we avoid disturbing high diversity habitats. The disservices from emerging pathogens suggest that the high-diversity habitats we should most actively avoid disturbing are those in West Africa, where multiple ape species overlap in their distribution.

Conflicts between ecosystem services, disservices and conservation will arise. Some diverse habitats do and will offer disservices (wetlands, for example, provide habitat for malarial mosquitoes whether they are diverse or not) and we cannot ignore these disservices. They will affect us whether or not we build them into our equations. They find us and kill us or shorten our lives as they always have. What we need is to appeal neither to our innate fondness nor dislike for other species, but instead to empirical studies of species and what they do. Wilson (1984) has talked about our innate fondness for nature, our biophilia. We also have an innate biophobia, composed of our fear modules, our immune systems and perhaps other basic features to help us escape elements of nature. But our biophilia and biophobia evolved under the circumstances of our history, not in the context of managing the entire surface of the Earth. As we move forward, we must garden nature. We need to manage not only for habitats with fewer disservices, but also in such a way that individual species provide fewer disservices. The balance between disservice and service can be subtle and so requires a concerted, global effort to understand the species on Earth in as much detail as possible. Until we better understand the species around us, we must make do with rough estimates of the consequences of our actions. Those estimates must include both the pluses and the minuses, the bad with the good.

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