Improving estimates of biodiversity loss

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A R T I C L E   I N F O

Article history:
Received 26 August 2011
Received in revised form 29 January 2012
Accepted 31 January 2012
Available online xxxx

Keywords:
Agriculture
Countryside biogeography
Endemics-area relationship
Extinction rates
Species-area relationship
Population diversity

A B S T R A C T

Quantifying the magnitude of human-induced biodiversity loss is a critical yet daunting challenge. Recently, species extinction rate estimates using island biogeography theory have once again been called into question. Here we highlight two of the many factors making the traditional application of this approach problematic for measuring biodiversity loss: first, the extreme assumption that native habitats are surrounded by a sea of human enterprise largely incapable of sustaining native biodiversity and, second, the sole use of species-level extinction estimates, which always underestimates the loss of biodiversity. Here we show that a wide array of taxa make human-dominated, farming countryside their home beyond the borders of native habitats. With data on native tropical birds, we show how simple species numeration masks dramatic differences between habitat types in community composition (e.g. species diversity or functional diversity). Overlooking the countryside biota, coupled with a scientific paradigm that underestimates biodiversity loss by equating it with species extinction, will only exacerbate the ongoing crisis. This is especially true given the rapid expansion and intensification of agriculture threatening countryside biotas, and a persistent limited understanding of how population extinctions and changes in community composition after ecosystem functioning and services that support human life and wellbeing.

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Navjot S. Sodhi dedicated his life to understanding and reversing the biodiversity loss now sweeping the planet. Ecologists recognize Earth’s biota is now already experiencing the sixth great extinction wave, but nonetheless quantifying its pace mid-stride remains difficult. Problems of estimating biodiversity loss persist, partly because of the limitations and continued interpretation of species-area relationships (SAR) for estimating species extinction. The use of the SAR as the sole method for estimating biodiversity loss perpetuates the idea that only pristine habitats matter for conservation and dramatically underestimates biodiversity loss by ignoring population and community changes. We examine the conventional assumptions that human-dominated habitats and landscapes are largely incapable of sustaining native biodiversity and that the biodiversity crisis is best viewed by evaluating species extinction.

Thirty years ago, extinction rates were estimated using the classical framework of island biogeography (MacArthur and Wilson, 1967). The prevailing view was that the clues to the future of biodiversity were to be found in remnants of native habitat – Noah’s Arks floating in a hostile flood of human enterprise. The logic was that most organisms are highly adapted to their native habitats and that few would be able to exploit areas heavily modified by human activities. In general, those few species would not require or merit protection and efforts should concentrate on preserving ecosystems in their pristine forms removed from areas of high human activity.

A great deal of work has now reported that, to the contrary, human-dominated ecosystems (currently constituting 75% of the global land surface; Ellis et al., 2010) collectively host substantial biodiversity, and that this reservoir of biodiversity is under threat from rapid intensification of agricultural production systems and other factors associated with human population growth and consumption (Bignal and McCracken, 1996; Fischer et al., 2008; Haslem and Bennett, 2008; Hughes et al., 2002; Perfecto et al., 2009). New theory (Koh et al., 2010; Nelson et al. 2011; Pereira et al. 2004; Pereira and Daily 2006; and empirical study (Mendenhall et al., 2011) show how, for instance, many “tropical forest animals” can make their homes outside of native habitats, and their ability to do so varies with a range of species traits (Daily, 2001; Daily et al., 2001, 2003; Horner-Devine et al., 2003; Ricketts, 2001; Secercioglu et al., 2007). Moreover, different individuals within a population may use combinations of habitat that do not fit within the confines of the island paradigm (Fig. 1). Only a small fraction of the planet can be considered either pristine or completely inhospitable, with the vast majority of biodiversity existing in habitats located somewhere in between (Ellis et al., 2010). Understanding how to sustain biodiversity and ecosystem processes and services in these habitats requires much more attention.

There is tremendous opportunity to harmonize the conservation of biodiversity with human activities in biomes worldwide.
For example, in ancient human-modified landscapes, certain agricultural practices have sustained high biodiversity, as in the case of arecanut palm production in the biodiversity-rich Western Ghats of India. Despite continuous cultivation for over two millennia, the landscape has retained populations of some 95% of the bird species associated with native forest (Ranganathan et al., 2008). The scientific community continues to lack a clear understanding of how different types and intensities of human activity affect the components of biodiversity that drive ecosystem functioning, in part because of narrow concentration on species counts and species-level extinction.

Like Navjot S. Sodhi, we urge ecologists to broaden their conceptualization and quantification of biodiversity loss by including within it population extinctions and changes in community composition (e.g., species diversity and functional diversity) (Ceballos and Ehrlich, 2002; Hughes et al., 1997; Sekercioglu et al., 2004; Sodhi et al., 2004). Our research has shown the shortcomings of the sole use of species richness, the fundamental unit of the SAR, to measure biodiversity’s response to human impacts. For example, after extensive deforestation (about 70% of original forest cover) in the 1960s and 70s in the canton of Coto Brus, Costa Rica (ca. 950 km²), only four bird species (1.4% underwent local extinction (none of which are globally extinct; Daily et al., 2001, Appendix A and B). Additionally, the number of bird species is equally distributed among habitat types (agricultural plots, semi-native habitats, and native forest) (Fig. 2). From a species extinction perspective, very little biodiversity change has occurred.

Considerable differences between habitat types arise from changes in species community composition, however, at a fine scale along a gradient from native to more human-impacted habitats. A dramatic shift in species community composition occurs within 70 m of small forest elements scattered throughout the countryside (Mendenhall et al., 2011). It remains an open question if these differences in species community composition reflect changes in functional diversity, biological filtering between habitats, and/or population losses. Moreover, we have little knowledge of how such changes in community composition affect ecosystem functioning or the provisioning of biodiversity-driven services to society, nor at what spatial or time scales (Balvanera et al., 2006; Cardinale, 2011). Considering the complexity of the issues, there obviously remains much work to understand how ecosystems respond to human-induced environmental change at levels deeper than species richness (Tscharntke et al., this issue).

Currently the biodiversity crisis measured in units of species extinction only accounts for a cusp of biodiversity loss. The extinction of a species is the culmination of many populations perishing and indicative of immense disruption, reorganization, and restructuring of biological communities, often over huge areas. Our current understanding of the size and gravity of biodiversity loss is crippled by overlooking habitats beyond the island paradigm of hospitable and inhospitable, and the loss is dramatically underestimated because we ignore population extinctions and community change over such large areas. To gain a better sense of the ongoing biodiversity crisis, we must direct our attention toward research efforts to forecast population diversity, community structure, ecosystem functioning, and ecosystem services in concert with estimates of species extinctions.

Acknowledgements

We thank Melinda Belisle, Luke Frishkoff, Rachelle Gould, Matthew Knope, John Harte, Daniel Karp, Guy Ziv, and two anonymous reviewers for helpful comments on the paper. We thank Federico Oviedo Brenes and dozens of field assistants in the collection of bird population data. Funding was provided by Peter and Helen Mendenhall, C.D., et al. Improving estimates of biodiversity loss. Biol. Conserv. (2012), doi:10.1016/j.biocon.2012.01.069

Fig. 1. Proportion of population inhabiting different countryside habitats for 148 native bird species censused using constant-effort mistnet sampling in the canton of Coto Brus, Costa Rica. Species’ forest dependency rank ranges from complete forest dependendency (rank 1) to complete forest avoidance (rank 148) and was determined by comparing relative abundance in natural forest (a 260 ha reserve; green) versus agricultural plots (deforested farm plots; yellow). The proportion of each species’ population in intermediate habitats (grey) is also shown. These habitats include 10–20-yr-old secondary forest fragments (50–75 ha), primary forest in small fragments (1–20 ha), and primary forest in thin riparian strips (10–100 m wide). Proportion of population was calculated by summing the individuals encountered during mist net sampling from 2007–2009 and controlling for sampling effort among habitat types. Data are depicted for 16,168 individual birds of commonly captured species (species represented by ≤5 captures are not shown). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Mean species richness values (with minimum and maximum values, from three locations) in six common habitat types in Coto Brus, Costa Rica. Species richness was estimated through constant-effort mist net sampling from 2007–2009. Data are shown for 148 native bird species represented by ≥5 individuals captured at 18 sampling locations. Species accumulation curves for all sites have reached asymptote. Each habitat type is represented by three sampling locations. Habitat descriptions match those in Fig. 1, except agricultural plots were split into low intensity (~25% tree cover on farms) and high intensity (~5% tree cover on farms) categories. Species richness was distributed among habitat types equally (one-way analysis of variance, F5,227 = 2.19, P = 0.12). When community composition was compared using Sørensen similarity coefficients, two distinct communities were observed: in agricultural plots (both low and high intensity) and all countryside forest elements (natural forest and intermediate habitats; one-way analysis of similarity, R = 0.756, P < 0.001 [Mendenhall et al., 2011]).
Bing, Ralph and Louise Haberfeld, the Moore Family Foundation, the Koret Foundation, the Mertz Gilmore Foundation, the Winslow Foundation, and a National Science Foundation graduate fellowship to C.D.M.

References


