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Utility and limitations of species richness metrics for conservation planning

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Abstract

The appropriateness of species richness as an ecological indicator or decision variable for setting conservation and management priorities depends on many assumptions. Most critical is that current levels of species richness allow prediction of future contributions of various locations to biodiversity conservation and ecological function. Also important is the assumption that estimates of species richness can be compared among locations. Challenges arise because estimates of species richness are affected by area, scale and intensity of sampling, taxonomic grouping, estimation methods, and the dynamic nature of species richness. Nonetheless, species richness can contribute to prioritizing locations for biodiversity conservation provided it is not used in isolation—additional metrics, such as species composition, endemism, functional significance, and the severity of threats, are also required. The spatial domain of measurement also must be documented and justified. A multicriteria decision process is more likely to realize comprehensive conservation goals than prioritization of locations based on species richness alone.

Keywords: Biodiversity; Conservation planning; Hotspots; Scale dependence; Species richness

1. Introduction

Based on the number of publications reporting estimates of species richness, it is clear that biologists have a penchant for counting species. Counts are made to understand why locations differ in the number of species, what controls the number of species, and especially why some locations are more species-rich than others (Hutchinson, 1959). Biologists also hope to understand how number of species (hereafter species richness) is related to underlying environmental variables such as latitude, elevation, and land cover, and how species richness affects fundamental ecological processes such as primary productivity (e.g., MacArthur, 1972; Waide et al., 1999; Gaston, 2000; Lyons and Willig, 2002; Pimm and Brown, 2004). Among current principles used to guide conservation and management is that protection of locations with high species richness is an efficient way to conserve overall biodiversity and sustain key ecological

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functions (Scott et al., 1987; Myers et al., 2000). In other words, species richness is assumed to be an indicator of conservation value (e.g., Meir et al., 2004).

Because of inherent interest in patterns and processes associated with species richness, and because maintenance of species-rich locations is believed to protect multiple levels of biodiversity, ecologists have put considerable effort into documenting species richness and developing methods to identify potential predictors of species richness. However, at any one location, species richness is variable across time and depends on dynamic processes. Therefore, protection of locations that currently support a large number of species may not be a reliable long-term conservation strategy. Establishment of conservation reserves that support high levels of biodiversity and associated ecological processes over the long-term requires not only information on species richness but also complementary measures of ecological integrity (Karr, 1981; Smogor and Angermeier, 2001; Davis and Slobodkin, 2004) and resilience (Gunderson, 2000; Allison, 2004).

In this paper, we first examine the utility and limitations of species richness metrics from a conceptual perspective. We consider the extent to which protection of locations with a large number of species has been achieved in practice, and whether this strategy successfully has conserved biodiversity and ecological function. Next, we provide an overview of existing tools to make establishment of conservation priorities based on species richness a more exact science. In particular, we discuss methods for computing unbiased estimates of species richness to facilitate reliable comparisons among locations and for factoring temporal variability in species richness into land-use decisions. Finally, we address several integrative approaches for conservation assessment that build on species richness to increase the probability of achieving multiple-criteria conservation objectives.

2. Origin and application of the species richness paradigm

2.1. Motivation

For practical reasons, ''counts'' of species often are emphasized throughout the process of ecological assessment and monitoring. For many taxa of conservation concern, species are discrete entities that can be easily tallied. In addition, inexperienced observers may not have sufficient skills to collect unbiased data on abundance (Link and Sauer, 1998), especially for taxa with considerable variation in abundance within or between years. Using simple models based on land cover to predict presence/absence patterns (e.g., Scott et al., 1993, 2002; Caicco et al., 1995) also is more feasible logistically than collecting the detailed data on resource use or demography necessary to model habitat quality or viability. In addition, if sampling effort is standardized among locations, it may be possible to make inferences from count data about relative species richness even if it is not possible to infer absolute species richness (Link and Sauer, 1998).

A long history of counting species in ecosystems worldwide has yielded a large amount of comparative information. For example, available data clearly illustrate global (chiefly latitudinal) gradients in species richness, although the factors responsible are still strongly debated (Gaston, 2000; Pimm and Brown, 2004). Although some conclusions about coarse-grained patterns of species richness—e.g., tropical latitudes harbor more species than polar latitudes—may seem almost trivial, those conclusions have motivated searches for mechanistic explanations of species richness as a function of major gradients including elevation (Janzen et al., 1976), primary productivity or surrogates thereof (Hawkins et al., 2003; Hurlbert and Haskell, 2003), and urbanization (Pickett et al., 2001). The functional form of relationships between species richness and environmental gradients often depends on the resolution and extent of observation and on variation in disturbance regimes (Pickett and White, 1985).

Existing information on species richness has supported a range of high-profile conservation efforts, particularly when data on rarity or endemism were also available. For example, several major nongovernmental organizations have developed global maps of the richness of endemic species in conjunction with data on land use and land cover change. Areas with high concentrations of endemics and rapid or extensive land cover change commonly are known as ''hotspots'' (Myers et al., 2000), whereas areas with low species richness of endemics and more stable land