Biological Conservation 198 (2016) 122–134

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Limited erosion of genetic and species diversity from small forest patches: Sacred forest groves in an Afrotropical biodiversity hotspot have high conservation value for butterflies

J.L. Bossart [a,*], Josephine B. Antwi [b]

[a] Department of Biological Sciences, Southeastern Louisiana University, SLU 10736, Hammond, LA 70402, United States
[b] Hermiston Agricultural Research and Extension Center, Oregon State University, Hermiston, OR 97838, United States

ARTICLE INFO

Article history:
Received 17 July 2015
Received in revised form 17 March 2016
Accepted 24 March 2016
Available online 5 May 2016

Keywords:
Sacred groves
Diversity–area relationships
Species–genetic diversity correlations
Forest fragmentation
Community conservation
Afrotropics

ABSTRACT

Sacred forest groves are often located in some of the world's hottest hotspots of biodiversity, and consequently have high potential conservation value. Recent efforts to quantify their value have focused nearly exclusively on a single component of diversity, species diversity within communities, which may or may not be an effective proxy for a second fundamental component of diversity, genetic diversity within populations. We studied fruit-feeding butterfly communities to simultaneously assess to what extent five small sacred groves have retained the level of species and genetic diversity found in two much larger forest reserves. We additionally evaluate whether measures correlate across habitat fragments to investigate how closely these two components of diversity mirror each other. We quantified the diversity and composition of the fruit-feeding butterfly communities at each site and also the haplotype diversity within three specific species that differ with respect to their sensitivity to habitat fragmentation. Of the multiple measures of species and genetic diversity computed, only rarefied species richness was correlated with forest fragment size and even in this case the relationship was weak. Importantly, the limited decline in species richness documented in the sacred groves was not due to species replacements, whereby common, broadly distributed, generalists supplanted more vulnerable species in these communities. Although similar processes are known to drive declines in both species and gene diversity, we found only limited evidence of positive species-genetic diversity correlations (SGDCs), and only in the species most sensitive to fragmentation. Thus, a conservation strategy that emphasizes species complementarity or richness may be ineffective at capturing other critical levels of biodiversity. Overall, our findings demonstrate that even very small forest patches can have a conservation value that rivals that of much larger forest reserves. The implementation of official national and international initiatives that preserve and strengthen existing community-based conservation practices is critically needed to ensure that indigenous conservation areas persist into the future.

1. Introduction

Sacred natural areas set aside and protected by indigenous cultures represent the earliest forms of environmental conservation in the world (Posey, 1999). Sanctions and taboos, which in many cases have been enforced over centuries, restricted entry to these sites except for a few specific individuals or limited groups, and only for specific events. Most sacred sites have their origins in religious or traditional belief systems, key historical events, or are royal burial grounds, and conservation *per se* was rarely the intended objective (Bharuch, 1999; Ntiamoa-Baidu, 2001; Dudley et al., 2009). Nonetheless, the traditional laws strictly enforced by local communities fostered the long term persistence of these natural areas and coincidentally also secured their role as repositories of local biodiversity and as *de facto* protected areas.

Although indigenous protected areas take on a wide variety of forms (Mgumia and Oba, 2003; Shen et al., 2012), sacred forest groves are a common type found widely throughout the forest zones of Africa and Asia (Lebbie and Freudenberger, 1996; Hughes and Chandran, 1998; Malhotra et al., 2001; Mgumia and Oba, 2003; Bhagwat and Rutte, 2006; Hu et al., 2011). Sacred groves are small areas of forest habitat that are allied with and hold special spiritual significance for local village communities. Their general abundance links to the historical practice of communities in close proximity of forests to hold initiation rituals and secret ceremonies within the boundaries of the forest, and to section off specific areas as burial grounds for chiefs and other village elites.

* Corresponding author.
E-mail address: jbossart@selu.edu (J.L. Bossart).

http://dx.doi.org/10.1016/j.biocon.2016.03.029
0006-3207/Published by Elsevier Ltd.

Most sacred groves currently exist as isolated forest remnants embedded within a transformed, non-forest landscape matrix. In some regions, these relict patches constitute the only remaining examples of what were formerly much larger, or even extensive, expanses of old growth forest (UNESCO, 2003; Cardelús et al., 2013).

Interest in the potential conservation value of sacred forest groves has increased markedly over the past decade (UNESCO, 2003; Bhagwat and Rutte, 2006; Verschuuren, 2010). This heightened conservation attention seems well-deserved given their long history of protection, their tight linkage with local communities and locally-administered management, and their prevalence in some of the world's hottest hotspots of biodiversity. But most sacred groves are very small (some are only a few hectares) and, consequently, expected to harbor reduced species and genetic diversity relative to larger tracts of forest habitat, owing to the multiple and interacting ecological, demographic, and evolutionary processes that promote loss of species and genetic variation from small, isolated habitat fragments (MacArthur and Wilson, 1967; Avise, 1994; Frankham, 1995; Rosenzweig, 1995; Turner, 1996; May and Stumpf, 2000). As such, their value may only be apparent when the biodiversity of multiple groves is considered collectively, when they happen to harbor relict populations of rare or declining species, or when they facilitate gene flow and connectivity of fragmented forest populations across the broader landscape.

Determining the importance of sacred groves for forest conservation has taken on an increased urgency. The traditional beliefs that have long protected these unique, community-based reserves have decayed in concert with the influx of western influences and immigration into local communities by those holding different value systems (Ntiamoa-Baidu, 2001; Dudley et al., 2010). Consequently, many groves are rapidly being degraded and/or lost. Despite their obvious and irreplaceable cultural significance, loss of the world's sacred groves may have limited consequences for conservation if, as predicted, the biodiversity they harbor is generally found to be much reduced to that in large expanses of forest or if their resident communities are largely dominated by widespread, common generalists. Although studies of sacred groves to date have tended to support this expectation of reduced diversity, these have been limited in number and in their geographic and taxonomic scope (e.g. UNESCO, 2003; Bhagwat and Rutte, 2006; Dudley et al., 2009; Shahabuddin and Rao, 2010) and may not reflect their conservation value more generally. Previous studies have also focused nearly entirely on species diversity, and often on only one measure, species richness, but species diversity is just one important element of biodiversity and may or may not adequately reflect other key levels of diversity.

Here, we quantify the extent to which small, individual forest groves retain the levels of butterfly biodiversity found in much larger forest reserves. To our knowledge, this study is the first that simultaneously considers both genetic diversity within species and species diversity within communities, the two most fundamental levels of biodiversity, to assess the value of indigenous conservation areas. We focus on a relatively understudied region of the world where a large number of sacred forest groves are known to occur, Ghana, West Africa. Diversity associated with five sacred groves was compared to that of two much larger governmental forest reserves. Species diversity was assessed by sampling the species-rich community of fruit-feeding forest butterflies associated with each forest fragment. The species diversity component herein extends Bossart et al. (2006), which was a more descriptive, less thorough characterization of species diversity in four sacred groves. Genetic diversity was assessed by characterizing the population genetic profiles of three co-distributed forest butterfly species that differ with respect to their relative sensitivity to habitat fragmentation. A second goal of the study was to investigate whether levels of species and gene diversity, which are influenced by similar processes (Vellend et al., 2014), were correlated within and between forest fragments. High correlation would imply that conservation evaluation could be streamlined as one measure of diversity could serve as an effective proxy for assessing the general conservation value of habitat fragments.

2. Materials methods

2.1. Study sites and sampling

Ghana lies at the eastern most extent of the Upper Guinean forests of western West Africa, a region that has been experiencing one of the highest rates of deforestation in the world (Myers et al., 2000; Poorter et al., 2004; FAO, 2009). Although estimates vary, by all accounts the large majority of Ghana's original forest cover has been converted to anthropogenically derived, farm-bush savanna. All substantial expanses of remaining forest habitat in the country have been set aside as forest reserves, most of which are actively managed for timber harvest, and some of which have essentially no forest remaining (Hawthorne and Abu-Juam, 1995). Only about 1% of old growth forest occurs outside the boundaries of existing reserves, and sacred forest groves account for the bulk of this off-reserve forest habitat. More than 1400 sacred groves are known to occur throughout Ghana's five physiographic regions, but this number is thought to reflect only a fraction of those actually present (Tufour et al., NCRC). Most (if not all) extant groves in the country remain as discrete patches dotting the non-forest landscape matrix.

Seven forest fragments were sampled; five sacred forest groves and two large forest reserves for comparison. Fragments ranged in size from 6 to 5000 ha (Table 1) and are all centered around Kumasi (6°41′ 21.85″ N, 1°37′24.93″ W), the capital city of the Ashanti administrative region in Ghana (Fig. 1). All seven fragments are representatives of the moist semi-deciduous forest habitat subtype. All are also completely surrounded by farm bush savanna, except for Owabi Forest Reserve, which adjoins the reservoir that supplies water for the city of Kumasi, and for Kajease sacred grove, where the once surrounding rural countryside is rapidly being completely supplanted by suburbanization.

Approximately 900 butterfly species are known for Ghana. The large majority of these are forest-associated species, about 1/3 of which are fruit-feeders from the family Nymphalidae. The guild of fruit-feeding forest butterflies has been beneficially exploited to study many aspects of tropical forest ecology in natural, managed, and degraded ecosystems (e.g. Kremen, 1992; Fermon et al., 2000; Stork et al., 2003; Bossart and Opuni-Frimpong, 2009; Hill et al., 2011). Member species can readily be collected via fruit-baited traps, which facilitates the systematic collection of species diversity data, and they display a wide range of relative sensitivities to habitat loss, fragmentation, and patch degradation, which makes them superb indicators of environmental change.

The fruit-feeding butterfly community of each forest fragment was sampled using typical fruit-bait traps. Traps were hung in the understory 8–10 cm above the ground. Three to four traps were installed at 80 m intervals along each of two to four 'straight line' transects in each forest fragment. Each transect was established by using a compass to set direction and a meter tape to determine distance. A machete was used where necessary to gain passage through the understory. Individual transects were located in discrete areas of the forest at least 300 m distant (and generally much more) from any other transect, except in the three smallest fragments where inter-transect distance was constrained by the small size and irregular shape of the forest patch. Traps were placed in similar micro habitats within areas of closed canopy forest. A total of 78 traps was installed across all sites; more traps were hung at larger sites, fewer at smaller sites (Table 1).

Trap sampling was initiated July 2005 and continued through May 2006. In general, samples were collected from each site on a 3-week rotational basis. Each sampling bout consisted of two sampling days. Traps were baited with mashed, fermenting banana, and butterflies collected the following day ~24 h later. Traps were then re-baited and left for an additional 24 h, after which trapped butterflies were again retrieved. All specimens captured in traps were retained for subsequent identification. Specimens were stored in a laboratory freezer at the Forestry Research Institute of Ghana, Fumesua, until shipment via DHL express courier to Carnegie Museum of Natural History (CMNH), Pittsburgh, Pennsylvania.