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High similarity between a bat-serviced plant assemblage and that used by humans

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ABSTRACT

Indigenous custodians manage important forest areas and have vital roles in biodiversity conservation in the Pacific, but their understanding of the role of bats in rainforest function is limited, and their perception of bats often negative, possibly compromising opportunities for conservation. To determine whether bat and forest conservation could be mediated by the identification of services provided by bats, we assessed similarity between bat-serviced (pollination and seed dispersal) and people-valued forest plants in Fiji. In nearly 500 diet samples from all four Fiji flying-fox species, we found 37 pollen morphospecies associated with *Notopteris macdonaldi*, *Pteropus samoensis*, and *Pteropus tonganus*. Thirteen morphospecies overlapped among bats, but were used in different proportions. No fruit was recorded in the diet of *N. macdonaldi*. Twenty-two fruit species groups (co-generic species that could not be distinguished) were recorded for *Pteropus* spp. A rainforest plant community represented by a survey of 2983 plants contained 75% of species groups valued by people (medicinal, cultural, economic uses), and bats serviced at least 42% of these species (96% valued by humans). The high similarity between bat and human resources (Sørensen's coefficient, $S_S = 0.68$) increased in a sub-sample of the 30 most abundant tree genera ($S_S = 0.80$). Plant endemism was high in the rainforest community (70%). Most endemic species were valued by people ($S_S = 0.78$ for abundant trees) and serviced by bats ($S_S = 0.77$). The great overlap between the plant assemblage benefiting from bat services and that valued by humans indicates that conservation approaches tailored to individual communities could be developed to promote bat conservation in traditionally-owned landscapes where negative perception of bats exists.

1. Introduction

Pteropodid bats (flying foxes) have crucial ecosystem roles in island ecosystems, primarily in the pollination and seed dispersal of rainforest plants (Fujita and Tuttle, 1991; Rainey et al., 1995). Nearly 80% of canopy-forming trees in Samoa depend on pteropodids for either pollination or seed dispersal (Banack, 1998); thus they provide considerable economic value to island forests (Fujita and Tuttle, 1991; Muscarella and Fleming, 2007). Bats are the only native terrestrial mammals throughout much of the Pacific, where they can track resources over large areas and among islands (Banack and Grant, 2002; Brooke, 2001; McConkey and Drake, 2007). However, many pteropodids are experiencing serious population declines (e.g. Brooke and Tschapka, 2002; Cousins and Compton, 2005; Craig et al., 1994; Scanlon et al., 2013a; Wiles, 1987; Wilson and Graham, 1992), threatening functional roles in seed dispersal (McConkey and Drake, 2006; see also review by McConkey et al. (2012)). Oceanic islands host a disproportionately large number of threatened bat species (Mickleburgh et al., 2002), but current research efforts poorly reflect conservation needs. For example, 24 of the 29 Critically Endangered bat species listed in Mickleburgh et al. (2002) are paleotropical (83%; 7% are neotropical and 10% from elsewhere), and 11 (38%) occur on small islands in the western Pacific and Indian oceans where comparatively very little research occurs.

Bats are threatened by lack of knowledge. In Fiji for example, a mix of abundant species (e.g. *Pteropus tonganus*, which is consumed and is considered an agricultural pest in some areas) and rare, poorly-known ones (e.g. Critically-Endangered *Mirimiri acrodonta*) presents a confusing situation for public understanding of bats (Scanlon et al., 2013a). Some communities value bats and have them as totems, but according to the NGO NatureFiji-MareqetiViti in Fiji, a leading impediment to conservation is that people generally do not value bats; people do not care for their presence, perceive them as detrimental to agriculture, and consider their

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only purpose to be a as potential source of food (K. Macedru, personal communication). Negative attitudes and/or misconceptions about pteropodid bats are widespread (e.g. Borneo: Struebig, 2009; Cook Islands: Cousins and Compton, 2005; Ghana: Ottou, 2011; Israel: Korine et al., 1999; Mariana Islands: Boland, 2010), and their conservation remains a problem in the Pacific region (see Wiles and Brooke, 2010). An approach used by Trewhella et al. (2005) to increase local awareness and understanding of bat conservation on islands of the western Indian Ocean was to create education programs linking human needs to ecosystem services provided by Critically Endangered bat species. Generally, bat awareness programs employ broad concepts, such as the pollination and seed dispersal roles of bats, but in order to change human perceptions of bats and have long-term impacts on forest conservation, we propose that specific, tangible examples of pollination and seed dispersal should be used where people use forest resources and have a reasonable knowledge of trees.

Pacific island rainforests have an extremely high biodiversity value (e.g. Kier et al., 2009; Myers et al., 2000). They are also increasingly threatened by agricultural intensification, forest conversion and logging, and invasive species (e.g. Keppel, 2006a,b; Lees, 2007; Reaser et al., 2007; Shearman et al., 2009). Current conservation approaches appear to be ineffective or failing in many Pacific countries (Hunnan, 2002; Keppel et al., 2012; Brodie et al., 2013). Better communication with government leaders, incorporation of indigenous knowledge and concepts into conservation strategies, participation of landowning communities and relevant stakeholders, local leadership (community and government), and a collaborative and coordinated approach with long-term goals are needed (Hunnan, 2002; Keppel et al., 2012; Lees, 2007). Customary ownership is the principal land tenure system across the South Pacific (AusAid, 2008), and traditionally owned areas support 57% of the world's Critically Endangered Pteropodidae (Mickleburgh et al., 2002). The Polynesia-Micronesia biodiversity hotspot (Mittermeier et al., 2008) contains some of the most endangered and rarest ecoregions (Gillespie et al., 2012; Olson and Dinerstein, 2008), and only about 11% of forests occur in protected areas (Gillespie et al., 2012). In Fiji, about 88% of all land is under customary tenure (AusAid, 2008), 47% has native vegetation cover, and just 2% of tropical moist forests are within formally protected areas (Gillespie et al., 2012). Thus indigenous custodians manage many important forest areas and have vital roles in biodiversity conservation in the Pacific.

Since the promotion and maintenance of plant–animal interactions are key for conserving island biodiversity (Kaiser-Bunbury et al., 2010), we examined how forest use by bats could be matched to specific benefits that local people could relate to immediately. We (1) identified flower and fruit diets of coexisting pteropodid bats in remnant tropical moist forest habitat on Vanua Levu and Taveuni Islands, Fiji; (2) assessed bats' potential roles in rainforest pollination and seed dispersal; (3) identified the value (medicinal, cultural, economic) of forests to traditional land managers; and (4) assessed similarity between plant communities serviced by bats (pollination, seed dispersal) and those valued by people. This project represents the first step in a larger program aiming to guide and implement bat conservation in the Pacific region. Such an aim may be facilitated by motivating bat–plant conservation in traditionally-owned landscapes. Our objective was to identify tangible benefits of bats to forests and people.

2. Materials and methods

2.1. Study site

We worked on two islands (Vanua Levu and Taveuni) in priority rainforest conservation areas (Olson et al., 2009) within Cakaudrove Province. On Vanua Levu we worked in primary and secondary low- and mid-elevation rainforest (50–550 m) and on Taveuni in montane cloud forest (900–1300 m) (see Ash, 1987; Scanlon et al., 2013a; see also Appendices 1 and 2 for plant species lists from Taveuni and Vanua Levu, respectively).

2.2. Study species

Fiji has six bat species, four in the family Pteropodidae and two insectivores that are now restricted to very small populations (*Chaerephon bregullae* and *Emballonura semicaudata semicaudata*). All species but one are threatened (Scanlon et al., 2013a). The flying foxes comprise three large species (adult mass from Fiji; IUCN (2012) listing): *P. tonganus* (315–570 g; Least Concern), *Pteropus samoensis* (302–438 g; Near Threatened), and *M. acrodonta*, syn. *Pteralopex acrodonta* (Helgen, 2005; 222–362 g; Critically Endangered; Flannery, 1995; Scanlon et al., 2013a). The fourth pteropodid is the smaller free-tailed nectarivorous bat *Notopteris macdonaldi* (50–89 g, Vulnerable; Scanlon et al., 2013a). *M. acrodonta* has one of the most restricted distributions of any bat. It is found only in montane cloud forest on Taveuni (Flannery, 1995; Hill and Beckon, 1978; Scanlon et al., 2013a). Two subspecies of *P. samoensis* occur in the Pacific (*P. s. nawaiensis*, Fiji; *P. s. samoensis*, Samoa) (Flannery, 1995). *P. tonganus* is one of the most widespread flying foxes (current distribution from Papua New Guinea to the Cook Islands), with *P. t. tonganus* occurring from Fiji to the east (Flannery, 1995).

On Vanua Levu, *P. tonganus* formed annual maternity camps in the dry season in 2009 and 2010. The camps consisted of about 300 females with pups. Juvenile animals were captured there year round. Non-maternity camps consisted of 300 to several thousand animals. *P. samoensis* and *N. macdonaldi* also reproduced there year round. *P. samoensis* is solitary, or roosts in small groups (<30 animals), sometimes within larger camps of *P. tonganus* (Scanlon et al., 2013a). *N. macdonaldi* is a cave-obligate species. It was netted shortly after dusk at the study site, indicating that cave roosts occur nearby, but despite extensive searches with local guides, we were unable to locate a cave within our study site on Vanua Levu (see Scanlon et al., 2013a for survey details). On Taveuni, pregnant (Scanlon et al., 2013a) and lactating (Flannery, 1995) *M. acrodonta* were recorded in May. Little information is available on the ecology of this elusive bat.

Banack (1998) found broad fruit diet overlap between *P. tonganus* and *P. s. samoensis* in American Samoa. Use of floral resources increased seasonally (in February, October, and November). Observations were diurnal and nocturnal, and focused mostly on fruiting trees and fruit ejecta, with little emphasis on flowers. Diet partitioning in these species is not well understood. The diets of *N. macdonaldi* and *M. acrodonta* have not been studied.

2.3. Dietary samples

We netted plant-visiting pteropodids on Vanua Levu from 2009 to 2011 ($n = 22$ months; 2553 mist-net-hours, MNH, standardised as in Kalko and Handley, 2001); four surveys were completed in the cloud forests of Taveuni in 2009 (1887 MNH; see Scanlon, 2009; Scanlon et al., 2013a). Net heights were between 2 and 20 m. Excluding *M. acrodonta*, little difference in capture height (Scanlon and Petit, 2013) or vertical stratification of resources via isotopic analysis (Scanlon et al., 2013b) occurred among species. Locations were chosen independently of flowering and fruiting tree hotspots or roost sites, and at least 10 locations were used at each site and rotated so that the same site was not used in two consecutive months/surveys. Upon capture, we swabbed fur for pollen using the paper stem of a cotton applicator humidified with distilled water. The applicator was brushed from the nostrils up to