Global overview of the conservation of island bats: importance challenges and opportunities

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CHAPTER 16

Global Overview of the Conservation of Island Bats: Importance, Challenges, and Opportunities

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Introduction

Although constituting only a small percentage of earth's terrestrial land area, islands hold a disproportionate number of unique taxa and ecological communities. For example, Madagascar and the other Indian Ocean islands have high numbers of endemic species, reaching over 90% in mammals, amphibians, and reptiles (Goodman and Benstead 2003). Additionally, 12 out of the 20 areas containing the highest number of endemic birds are on islands (Orme et al. 2005), and 12 of the 18 hot spots of marine endemism surround islands (Roberts et al. 2002). Adaptations of island taxa include dwarfism, for example, three-toed sloths (*Bradypus*) on the Bocas del Toro islands, Panama (Anderson and Handley 2002); gigantism, for example, Komodo dragons (*Varanus komodoensis*) in the Lesser Sunda Islands, Indonesia (Jessop et al. 2006); and flightlessness or increased terrestriality, for example, the short-tailed bat (*Mystacina tuberculata*) of New Zealand (Riskin et al. 2006). These high levels of endemism, evolutionary adaptation, and specialization are caused by factors such as the size, distance, and period of island isolation from continents as well as island ecology and structure (Whittaker 1998).

Islands also represent some of the most naturally vulnerable habitats on the planet. Islands are limited in size and consequently only have finite natural resources, such as fertile soils and freshwater, and are highly susceptible to climatic changes and natural hazards such as tropical cyclones, droughts, and volcanic eruptions (CBD 2004; Wong et al. 2005). The main identified threats to island ecosystems are the introduction and establishment of invasive alien species, habitat change, and overexploitation of biodiversity resources, with climate change and pollution predicted to become increasingly serious threats (Mace et al. 2005; Thomas et al. 2004).

Unsurprisingly, given the natural fragility of island ecosystems, island biodiversity has been severely impacted both historically and currently by anthropogenic disturbance (Baillie et al. 2004; IUCN 2006; Mace et al. 2005; Orme et al. 2005; Steadman and Martin 2003). For example, most recorded vertebrate extinctions are on islands (Baillie et al. 2004; Mace et al. 2005), as are 60% of the hot spots of currently threatened birds (Orme et al. 2005). Human populations living on islands are also at risk and are vulnerable to historical collapse (Diamond 2005; Rolett and Diamond 2004), and Small Island Developing States (SIDS) are currently highlighted as the most vulnerable to projected global changes in the Millennium Ecosystem Assessment (Wong et al. 2005). Given the uniqueness of island biodiversity, its potential loss is especially important to global conservation efforts and priorities.

Bats are a major component of mammalian biodiversity and are often the only native island mammals, playing critical roles in seed dispersal and pollination. In particular, the role of frugivorous bats in localized seed dispersal and pollination in the South Pacific islands suggests that ongoing declines of these species may lead to a cascade of linked plant extinctions, especially on islands already depauperate in other vertebrate frugivores (Cox et al. 1991; Elmqvist et al. 1992; Rainey et al. 1995). Despite the apparent importance of bats to island ecosystem functioning, little is known about the global distribution and status of island bat populations, the effectiveness of current island conservation projects, and consequently where best to prioritize future conservation effort. In this chapter we use global data sets of mammalian species distributions, ecology, and threat (IUCN 2006; Jones et al. in press.; Grenyer et al. 2006) to investigate the conservation of island bat species and where effort should be focused to prioritize and increase the effectiveness of our conservation resources.

Distribution of Island Bats

We used data from Grenyer et al. 2006 to investigate the distribution of island bat species, following the taxonomy of Koopman 1993, as used in this data source (table 16.1). The distribution, taxonomy, and population status of all mammals were revised in October 2008 by the Global Mammal Assessment (GMA; Schipper et al. 2008), part of the International Union for Conservation of Nature (IUCN). The GMA's distributional data are based on the data source used in Grenyer et al. 2006 with additional input from experts from all over the world. The GMA also uses and adds to taxonomic information in Koopman 1993 and Simmons 2005, and includes the latest population status information, expanding that in IUCN 2006. However, at the time of analysis, the GMA's data were unavailable. So while we expect that the exact details of species distributions we present here will change with the outputs from the GMA, the overall global patterns are unlikely to be substantially different.

Table 16.1. Taxonomic distribution of island species within bats and all mammals

Clade	Total clade size	Proportion island-dwelling	Proportion island endemics	Proportion single-island endemics
All mammals	*4629*	*0.38*	*0.19*	*0.12*
All bats	*925*	*0.60****	*0.25****	*0.08****
Pteropodidae	166	0.86***	0.66***	0.19***
Emballonuridae	47	0.55	0.19	0.04
Craseonycteridae	1	0	0	0
Rhinopomatidae	3	0.67	0	0
Megadermatidae	5	1.00	0	0
Nycteridae	12	0.58	0.08	0
Rhinolophidae	130	0.68*	0.26	0.08
Myzopodidae	1	1.00	1.00	1.00
Thyropteridae	2	0.50	0	0
Furipteridae	2	1.00	0	0
Natalidae	5	1.00	0.60	0
Mystacinidae	2	1.00	1.00	0
Noctilionidae	2	0.50	0	0
Mormoopidae	8	0.88	0.38	0
Phyllostomidae	141	0.40***	0.09***	0.01***
Molossidae	80	0.49*	0.09***	0.08
Vespertilionidae	318	0.54*	0.14***	0.07
Threatened bats	225	0.61	0.50***	0.22***

Note: Island-dwelling species occur on islands and mainlands; island endemics occur only on islands; and single-island endemics occur on only one island. Proportions in each category were calculated against total clade size and tested against a binomial distribution with $P_{\text{Island-dwelling}} = 0.60$, $P_{\text{Island endemics}} = 0.25$, and $P_{\text{Single-island endemics}} = 0.08$ for tests among bat clades and $P_{\text{Island-dwelling}} = 0.38$, $P_{\text{Island endemics}} = 0.19$ and $P_{\text{Single-island endemics}} = 0.12$ for tests comparing bats with other mammals. Threatened bats are those classified by IUCN 2006 as vulnerable, endangered, or critically endangered.

$^{*}p < 0.05$ $^{***}p < 0.001$

How Many Bats Live on Islands?

For the purposes of these analyses, we define an island as any offshore island (discretely separated from a continent) or oceanic island, but do not include islands in lake or river systems. Following this definition, over half of all bats (60.3%) are island-dwelling (occur on islands and mainlands), 24.5% are island endemics, and 8% are single-island endemics. Interestingly, compared to the proportion found in all mammals, bats have significantly more island-dwelling and island-endemic species (using a binomial distribution and an expected mammalian frequency of 0.38 and 0.19 for island-dwelling and island-endemic species, respectively). This difference could be due to increased dispersal abilities of bats (through powered flight), facilitating long-distance dispersal and maintenance of small populations on islands. This idea is consistent with the observation that significantly fewer bat species are single-island endemics compared to other mammals (table 16.1).

Which Bats Live on Islands?

Bat families differ significantly in the proportion of their species living on islands. Some families are entirely or predominately island-living or endemic to islands, for example, the sucker-footed bats of Madagascar (Myzopodidae) and short-tailed bats of New Zealand (Mystacinidae); the majority of funnel-eared bats (Natalidae) are also endemic to islands of the Caribbean. Comparing the proportion of island-dwelling species in each family to that in all bats, we find the proportion in the families Pteropodidae (Old World fruit bats) and Rhinolophidae (horseshoe bats and Old World leaf-nosed bats) to be significantly greater (using a binomial distribution and an expected bat frequency of 0.60; table 16.1). Conversely, New World leaf-nosed bats (Phyllostomidae), free-tailed bats (Molossidae), and vesper bats (Vespertilionidae) have proportionately significantly fewer island-dwelling species than expected. A similar pattern is found in the distribution of island endemics and single-island endemics, with significantly fewer species of phyllostomids and more species of pteropodids living on islands than expected (table 16.1). Examples of single-island endemics in the Pteropodidae include the Mortlock Islands fruit bat (*Pteropus phaeocephalus*) endemic to the tiny Mortlock Islands (Micronesia) and the Aldabra flying fox (*Pteropus aldabrensis*) endemic to Aldabra (Seychelles).

Which Islands Are Important for Bats?

Bats occur throughout the islands of the world, being absent only from very small islands, the more inaccessible islands of the Pacific, and islands in the extreme Northern and Southern Hemispheres. We can investigate which islands host more bat species by using Geographic Information Systems, ArcMap 9.1 (ESRI 2005), to transform digital species range maps from Grenyer et al. 2006 into numbers of species in a global grid. Plate 11 plots extant bat species richness with available maps (894 species), using a 0.5 degree grid system where colors within each grid represent the number of species present. The highest richness of bat species occurs on tropical islands of the Indo-Pacific, such as Borneo (with a maximum of 73 species per grid square) and Java (58 species per grid), Sumatra (54), the Philippines (52), Sulawesi (48), and New Guinea (47). However, on a global scale, islands are not areas of high bat species richness (plate 11A). Continental areas contain a much higher density of species; for example, the richest areas or "hot spots" for bat species are in northern South America, with a maximum of 120 species recorded per grid square, Central America (102 species per grid), tropical Southeast Asia (especially peninsular Malaysia up through Thailand and Myanmar, with a maximum of 82 species per grid), and tropical Africa (79 species per grid; plate 11A). This overall pattern of species richness on continents rather than islands is largely congruent with other terrestrial vertebrate distributions examined to date, such as other mammals, birds, and amphibians (Baillie et al. 2004; Grenyer et al. 2006; Mace et al. 2005; Orme et al. 2005; Orme et al. 2006).

Examining the richness pattern on islands at a finer resolution, the islands in the Caribbean are relatively species poor (plate 11B), although some recent taxonomic changes have split some island populations as distinct species

(Simmons 2005). Richness ranges from 27 species per 0.5 degree grid square on large islands such as Cuba, 20 species on Jamaica, 18 on Hispaniola, and 15 on Puerto Rico, to smaller numbers on the islands of the Bahamas and the Lesser Antilles (plate 11B). It is possible that these islands have already seen a number of bat extinctions, thereby reducing present species richness, in line with other mammals in this region (MacPhee and Flemming 1999; Morgan 2001). Similarly, European and African islands also contain relatively few species, with the highest richness on coastal islands such as Zanzibar and Pemba with a maximum of 21 and 12 species, respectively, and large islands such as Madagascar hosting 28 species (plate 11C). Interestingly, Madagascar has similar species richness to that of the much smaller Cuba, suggesting that Madagascar has been inadequately surveyed for bat biodiversity. Smaller oceanic islands in the African region have fewer bats, for example, a maximum of 5 species are found on the islands of the Seychelles and only 3 species on the Comoros and Mascarene islands (plate 11C). Despite the Indo-Pacific region containing the highest island species richness, there is a general decline in species richness away from the tropics, with lower species richness found on the more northern east Asian temperate islands such as Japan (containing a maximum of 20 species). The more isolated islands farther east in the Pacific Ocean are also relatively species poor (1–7 species; plate 11D).

Family composition of bats on islands and island regions varies greatly (fig. 16.1). Family-level richness is concentrated in islands of Southeast Asia (8 families are present in this region), Madagascar, and islands in the Caribbean (7 families each). Some families are confined to particular islands or island regions (e.g., sucker-footed bats, Myzopodidae, in Madagascar and the short-tailed bats, Mystacinidae, in New Zealand), while others are more cosmopolitan (the free-tailed bats, Molossidae, are found in all islands and island regions considered here except New Zealand). Island species richness of sheath-tailed bats (Emballonuridae) is concentrated in New Guinea and on other islands in Southeast Asia, as is the richness of Old World fruit bats (Pteropodidae) and horseshoe bats and Old World leaf-nosed bats (Rhinolophidae).

An examination of the environmental, ecological, and geographic correlates of these island richness patterns is beyond the scope of this chapter. However, important factors in determining island species richness are likely to be island area and degree of island isolation (e.g., island age and distance from mainland; MacArthur and Wilson 1967). Other factors such as island ecology and topology (Brown 1995; Rolett and Diamond 2004; Steadman and Martin 2003), climate and energy availability (reviewed in Clarke and Gaston 2006), and historical processes (Cardillo et al. 2005; Stevens 2006) are also likely to influence island species richness. Quantifying these processes will be an exciting area of future research (Lomolino et al. 2006), although care is needed when interpreting these richness patterns because the underlying data (species extent of occurrence maps) are subject to a number of possible errors. These errors include

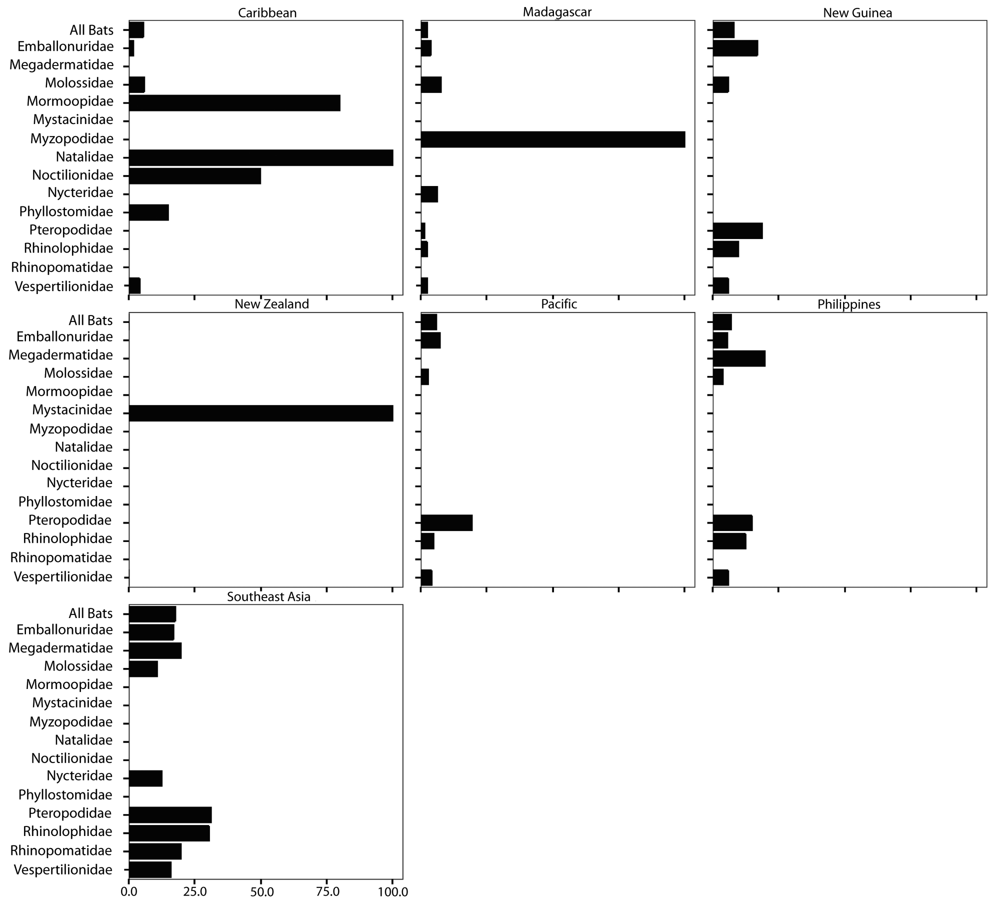

Figure 16.1. Number of bat species (as a percentage of total clade size) present within seven islands or island regions for all bats and within each family. Note that Vespertilionidae is also present in New Zealand (a very low proportion of total clade size).

the maps reflecting current distributions and not historical ranges (which can often be different; Ceballos and Ehrlich 2002), lack of underlying knowledge of species' habitat preferences, the data not reflecting temporal variation within species ranges (e.g., in migratory species), and biases toward areas and species that are more heavily sampled (Reddy and Dávalos 2003).

Extinction Risk in Island Bats

Evidence for a number of different taxa suggests that island living is a significant factor promoting decline and extinction at the population and species level (Fisher and Owens 2004; Jones et al. 2003; Purvis et al. 2000). Limited distributions result in populations being more susceptible to extinction due to stochastic events (e.g., hurricanes or fires), random demographic effects, the potential negative effects of limited genetic variability, or simply because threat processes such as habitat loss, exploitation, or introduced species are more likely to drive to extinction a species that is restricted in distribution or has a small total population (Fisher and Owens 2004; Lande 1993; Mace et al. 2005; Purvis et al. 2000).

Bats on islands seem to be no exception to this susceptibility, as the majority of extinct species were island-dwelling or island endemics (table 16.2). However, there is considerable disagreement as to which species of bats are actually extinct, because of the difficulties in documenting the final disappearance of very rare species and their poor subfossil record due to their size and ecology (see discussion in MacPhee and Flemming 1999). Examining the species considered as extinct in at least one of the critical treatments (i.e., IUCN Red List 2006; MacPhee and Flemming 1999; Simmons 2005), 14 out of these 15 species occur on islands (table 16.2). The remaining continental species (Tanzanian woolly bat, *Kerivoula africana*), although considered in MacPhee and Flemming 1999 as extinct, is reported as having been recently rediscovered (IUCN Red List 2006). Island extinctions are concentrated in the Caribbean islands, islands of the Indian Ocean, and Indo-Pacific islands (plate 12A).

Current risk of extinction also seems to be higher in island species than within bats generally (table 16.1). For example, the proportion of threatened bats (vulnerable, endangered, and critically endangered in IUCN Red List 2006) that are island endemics (0.50) or single-island endemics (0.22) is significantly higher than the proportion within all bats (0.25 and 0.08, respectively, testing against a binomial distribution). The most threatened bat species that live on islands (designated as critically endangered in IUCN Red List 2006) are listed in table 16.3. The majority of the most threatened island species are Old World fruit bats (Pteropodidae), followed by vesper bats (Vespertilionidae) and sheath-tailed bats (Emballonuridae). These species are classified as critically endangered mostly on the basis of severe declines in their populations (threat criterion A), with declines in ranges and small population sizes also playing an important role (threat criteria B and C, table 16.3). Interestingly, Old World fruit bats are on the whole more globally endangered than other bat families and have undergone more historical extinctions (Jones et al. 2003), which may be due in part to their tendency to live on islands where they may be easier targets for the wildlife trade (see below).

Which Islands Have Most Threatened Species?

The richness of threatened species is calculated for 0.5 degree grid squares across the globe (plate 12). Many islands contain threatened species, for example, the majority of the Caribbean islands (plate 12B, especially Guadeloupe, which contains four threatened species), the African coastal and oceanic islands (Canary Islands, Azores, São Tomé and Principe, Pemba, Seychelles, Comoros, Mauritius, Réunion, Rodrigues, and Madagascar), and a number of European islands (Sardinia, Corsica, and Sicily; plate 12C). However, threatened island species richness is concentrated in Southeast Asia (plate 12D), with grid squares in New Guinea containing up to eight threatened species and the Philippines containing up to six species on some islands. High threatened species richness is also found in Java, Solomon Islands, and Fiji (four species) and other islands in the South Pacific. For example, Santa Isabel in the Solomon Islands has three species listed as vulnerable (IUCN Red List 2006): the large-eared sheath-tailed bat (*Emballonura dianae*, Emballonuridae), flower-faced bat (*Anthops ornatus*, Rhinolophidae), and Sanborn's flying fox (*Pteropus mahaganus*, Pteropodidae) and the critically endangered Guadalcanal monkey-faced bat (*Pteralopex atrata*, Pteropodidae). The distributions of critically endangered island species are shown as crosses in plate 12C–D. These species reflect the overall pattern of threatened species richness but are specifically clustered on islands around Madagascar (Rodrigues, Réunion, Aldabra), islands of Micronesia (Chuuk, Mortlock, and Pohnpei), and the Solomon Islands (Guadalcanal, Bougainville, Choiseul; see table 16.3 for details).

Island areas constitute a large part of the pattern of threatened bat species richness on a global level (plate 12). Other areas rich in threatened species include the Andes in South America (8 species per grid), southern Mexico (6 species), southern Mediterranean and eastern Europe (7 species), the Ivory Coast of West Africa (5 species), and the Atlantic coastal forest of Brazil (4 species). A low congruence has been found between the areas of threatened species richness across vertebrate groups (see example comparing birds, mammals, and amphibians, Grenyer et al. 2006). Areas of threatened bat richness are also likely to follow this pattern, meaning that areas with the most threatened bats are unique and that the distribution of extinction-prone species in other groups cannot act as a surrogate for bats when conservation decisions are being made.

Table 16.2. Bat species considered extinct in at least one source

Family	Species name	Distribution	Comments
Mormoopidae	Giant ghost-faced bat (*Mormoops magna*), 1	Trinidad (Cuba)	Extinct in Simmons 2005 but disqualified by MacPhee and Flemming 1999, as the extinction is considered to have occurred <1500. Not listed in IUCN Red List 2006.
Mormoopidae	Pristine mustached bat (*Pteronotus pristinus*), 2	Cuba, Florida (USA)	Extinct in Simmons 2005 but disqualified by MacPhee and Flemming 1999, as the extinction is considered to have occurred <1500. Not listed in IUCN Red List 2006.
Mystacinidae	New Zealand greater short-tailed bat (*Mystacina robusta*), 3	Big South Cape Island (New Zealand)	Extinct in all sources.
Phyllonycterinae	Puerto Rican flower bat (*Phyllonycteris major*), 4	Puerto Rico	Extinct in Simmons 2005 and IUCN Red List 2006 but disqualified by MacPhee and Flemming 1999, as the extinction is considered to have occurred <1500.
Pteropodidae	Panay golden-capped fruit bat (*Acerodon lucifer*), 5	Panay Island (Philippines)	Extinct in IUCN Red List 2006, but synonymized by MacPhee and Flemming 1999 and Simmons 2005 into the extant golden-capped fruit bat (*Acerodon jubatus*).
Pteropodidae	Negros naked-backed fruit bat (*Dobsonia chapmani*), 6	Cebu, Negros Islands (Philippines)	Extinct in MacPhee and Flemming 1999, but a living population was discovered in 2000 and is now listed in Simmons 2005 and IUCN Red List 2006.

Pteropodidae	Nendo tube-nosed fruit bat (*Nyctimene sanctacrucis*), 7	Santa Cruz Islands	Extinct in all sources.
Pteropodidae	Dusky flying fox (*Pteropus brunneus*), 8	Percy Island (Australia)	Extinct in all sources.
Pteropodidae	Large Pelew flying fox (*Pteropus pilosus*), 9	Palau, Caroline Islands	Extinct in all sources.
Pteropodidae	Dark flying fox (*Pteropus subniger*), 10	Réunion, Mauritius (Mascarene Islands)	Extinct in all sources.
Pteropodidae	Guam flying fox (*Pteropus tokudae*), 11	Guam (Mariana Islands)	Extinct in all sources.
Vespertilionidae	Tanzanian woolly bat (*Kerivoula africana*), 12	Tanzania	Extinct in MacPhee and Flemming 1999 but extant in Simmons 2005 and IUCN Red List 2006.
Vespertilionidae	Lord Howe Island long-eared bat (*Nyctophilus howensis*), 13	Lord Howe Island (Austrialia)	Extinct in Simmons 2005 and IUCN Red List 2006 but disqualified by MacPhee and Flemming 1999, as the extinction is considered to have occurred <1500.
Vespertilionidae	Thomas's big-eared bat (*Pharotis imogene*), 14	SE New Guinea (PNG)	Extinct in MacPhee and Flemming 1999 but listed as extant in Simmons 2005 and IUCN Red List 2006.
Vespertilionidae	Sturdee's pipistrelle (*Pipistrellus sturdeei*), 15	Bonin Islands (Japan)	Extinct in Simmons 2005 and IUCN 2006, but MacPhee and Flemming 1999 consider this species extant.

Sources: IUCN Red List 2006; MacPhee and Flemming 1999; Simmons 2005.

Note: Numbers after each species name refer to their distribution, plotted plate 12A.

Table 16.3. Critically endangered island bats

Family	Species name	Distribution	Range size (km^2)	Threat criteria	Threat processes
Emballonuridae	Seychelles sheath-tailed bat (*Coleura seychellensis*), 1	Seychelles	151	C2a(i,ii)	1, 2, 10
Pteropodidae	Bulmer's fruit bat (*Aproteles bulmerae*), 2	New Guinea	66,663	B1+2c	1, 3, 10
Pteropodidae	Negros naked-backed fruit bat (*Dobsonia chapmani*), 3	Negros (Philippines)	13,075	A2cd	1, 3, 10
Pteropodidae	Philippine tube-nosed fruit bat (*Nyctimene rabori*), 4	Negros (Philippines)	17,815	A2c	1, 10
Pteropodidae	Fijian monkey-faced bat (*Pteralopex acrodonta*), 5	Fiji	440	A1c, B1+2c	1, 10
Pteropodidae	Bougainville monkey-faced bat (*Pteralopex anceps*), 6	Buka, Bougainville, & Choiseul islands (Solomons)	7,319	A1c	1, 10
Pteropodidae	Guadalcanal monkey-faced bat (*Pteralopex atrata*), 7	San Isabel & Guadalcanal (Solomons)	9,345	A1c	
Pteropodidae	Montane monkey-faced bat (*Pteralopex pulchra*), 8	Guadacanal (Solomons)	728	A1c	
Pteropodidae	Aldabra flying fox (*Pteropus aldabrensis*), 9	Aldabra Island (Seychelles)	123	C2a(ii)	8, 9

Pteropodidae	Chuuk flying fox (*Pteropus insularis*), 10	Chuuk-Islands (Caroline Islands)	73	A1cd	1, 3, 9, 10
Pteropodidae	Comoro black flying fox (*Pteropus livingstonii*), 11	Comoros	639	A4c	1, 7, 9, 10
Pteropodidae	Caroline flying fox (*Pteropus molossinus*), 12	Mortlock & Pohnpei islands (Caroline Islands)	350	B1+2ce	1, 3, 10
Pteropodidae	Mortlock flying fox (*Pteropus phaeocephalus*), 13	Mortlock Island (Caroline Islands)	1	B1+2e	1, 3, 7, 10
Pteropodidae	Bonin flying fox (*Pteropus pselaphon*), 14	Bonin & Volcano islands (Japan)	72	B1+2ce	1, 3, 10
Pteropodidae	Rodriguez flying fox (*Pteropus rodricensis*), 15	Rodrigues & Round islands (Mascarene Islands)	112	B1ac(iv)	1, 7, 9, 10
Vespertilionidae	Gloomy tube-nosed bat (*Murina tenebrosa*), 16	Tsushima & Ryukyu Islands (Japan)	451	B1+2c, D	
Vespertilionidae	New Guinea big-eared bat (*Pharotis imogene*), 17	New Guinea	440	B1+2c, C2b	1, 10
Vespertilionidae	Lesser yellow bat (*Scotophilus borbonicus*), 18	Madagascar, Réunion (Mascarene Islands)	2,554	A1c	1, 10

Source: IUCN 2006.

Note: Threat processes: 1 = habitat loss; 2 = invasive species; 3= harvesting; 7 = natural disasters; 8 = changes in species dynamics; 9 = intrinsic factors; 10 = disturbance. Threat criteria: A = species classified because of population declines; B = reduction in geographic ranges; C = populations based on less than 250 individuals; D = populations based on less than 50 individuals (for further details see http://www.iucnredlist.org/). Range sizes were measured from digital range maps (Grenyer et al. 2006) using ArcMap 9.1 (ESRI 2005) with an equal area projection. Number after species names refer to their distribution plotted as crosses in plate 14C–D.

Threats Facing Island Bats

The main current threats listed for critically endangered island bats are habitat loss and human disturbance, with harvesting of major concern for many of the Old World fruit bats (Pteropodidae; table 16.3; Racey, Goodman, and Jenkins, chapter 13; Wiles and Brooke, chapter 14; O'Donnell, chapter 15; all in this volume). The same patterns emerge when the incidence of these processes is compared to all threatened island endemics (fig. 16.2). The main threatening processes facing all threatened bat species (as well as island species) are habitat loss, intrinsic factors (including reproductive population dynamics, dispersal capability, and range restriction), harvesting, human disturbance (tourism, civil unrest, research, transport, fire), natural disasters (cyclones, volcanoes), invasive species, and persecution (mainly pest control). Interesting patterns emerge when the proportions of threatened island endemics affected by the different processes are compared with all threatened bats. Although habitat loss is the overriding threat, a significantly smaller proportion of island species are threatened by this process than in all threatened bats (tested against a binomial distribution with $P_{\text{All threatened bats}}$ 0.35; fig. 16.2). The same pattern holds for the incidence of human disturbance and persecution in threatened island endemics compared to all threatened species (although not significant for the latter process). On the other hand, the threats caused by harvesting, intrinsic factors, and natural disasters are significantly more influential for threatened island endemics compared to all threatened species (fig. 16.2). Invasive species as a threatening process also follows the same pattern but is not significantly different in threatened island endemics compared to threatened bats overall. We discuss some of the factors that differentially affect island endemics below in more detail.

Harvesting

There is growing concern about the potential impact of harvesting on a range of animal species, especially for the burgeoning wildlife trade (Fa et al. 2005; Robinson and Bennett 2000). Attention has historically focused on primates and other large mammals in Africa and the New World (e.g., Bowen-Jones and Pendry 1999; Peres 2000), and until recently there has been little information on bats. Hunting and the consumption of bats have been recorded on a number of islands, and there is evidence that these activities are having a significant impact on bat populations in the Indo-Pacific islands (Wiles and Brooke, chapter 14, this volume; Mickleburgh et al. 2002; Mickleburgh et al. 2009; table 16.4). The majority of harvested bat species on islands are Old World fruit bats (Pteropodidae), with *Pteropus* species most often reported (Mickleburgh et al. 2009). Species from the genera *Acerodon*, *Dobsonia*, *Cynopterus*, and *Rousettus* are also harvested on a number of islands (e.g., Moluccan naked-backed fruit bat, *Dobsonia moluccensis*, from New Guinea; Cuthbert 2003b, 2003a). Bats from other families are also occasionally eaten, especially on Madagascar, the Philip-

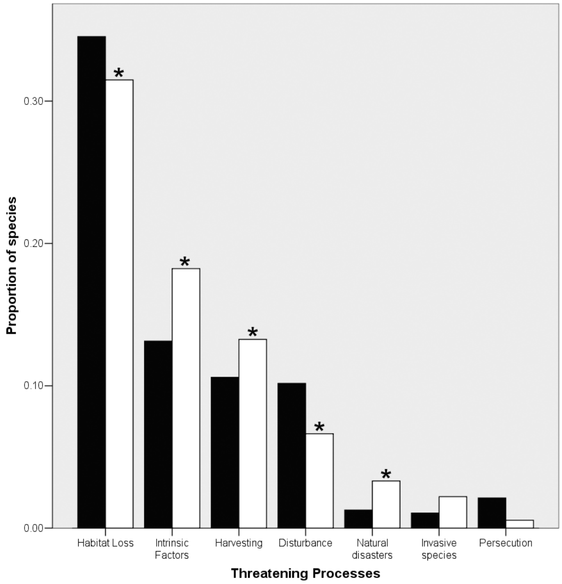

Figure 16.2. Number of species threatened by each of the main processes (expressed as a proportion of the total number of species threatened at a species or subspecies level) for all threatened bats (*black bars*; n = 472 species) and threatened island endemics (*white bars*; n = 181 species). *Asterisks* represent the significance ($p < 0.05$) of the difference of the proportions in threatened island endemics compared to the proportion in all threatened bats from a binomial distribution.

pines, and New Guinea (Mickleburgh et al. 2009). For example, the northern mastiff bat (*Chaerephon jobensis*, Molossidae) is eaten on Fiji (Flannery 1995) and Schreibers's long-fingered bat (*Miniopterus schreibersii*, Vespertilionidae) on New Guinea (Craven 1988). Most of the species reported to be eaten on islands are large (median mass around 300 g), although there is a wide range from 8.7 g of the small bent-winged bat in New Guinea (*Miniopterus pusillus*; Craven 1988) to 1,090 g of the golden-capped fruit bat in the Philippines (*Acerodon jubatus*; Shively 1997). Harvested species are mostly fruit or nectar feeders, and over 40% of those referred to by (Mickleburgh et al. 2009) are either listed as vulnerable, endangered, or critically endangered (IUCN 2006). It is thought that overhunting, along with snake predation and habitat loss, contributed to the extinction of the Guam flying fox (*Pteropus tokudae*; Mickleburgh et al. 2002; table 16.2).

Harvesting for bats on islands is mainly for food, although in regions such as Malaysia, Java, and the Philippines, bats are also important in traditional medicine and there is considerable demand from international markets (Fujita 1988; Fujita and Tuttle 1991; table 16.4). Chapter 14 (Wiles and Brooke, this volume) gives a detailed account of the impact of harvesting on bat populations on islands in the Pacific and Southeast Asia. The impact of harvesting on

Table 16.4. A review of island bat harvesting

Island or island region	Purpose and impact	Sources
Madagascar	Food. Important bushmeat taxa in rural areas. Trade is local or regional. Harvesting levels are probably too high to be sustainable.	MacKinnon et al. 2003; Racey, Goodman, and Jenkins, chapter 13, this volume.
Rodrigues	Food. Traditionally important but now less popular.	B. Carroll, pers. comm.
Mauritius	Food and sport. Traditionally important but now less popular.	B. Carroll, V. Powell, pers. comm.
Seychelles	Food. Common supermarket and restaurant item.	Cheke and Dahl 1981; Dusoulier 2003; Hutson 1997; Racey 1979; J. Gerlach, pers. comm.
Comoros	Food. Only occasionally eaten.	P. Reason, K. Rodriguez-Clark, W. Trewhella, D. Waters, pers. comm.
New Guinea	Food. Important bushmeat taxa with estimates of up to 10% of game hunted. Harvesting levels are probably too high to be sustainable, but mixed evidence.	Bonaccorso 1998; Craven 1988; Cuthbert 2003a, 2003b; Flannery 1990; Hladick et al. 1993; D. Wright, R. Cuthbert, pers. comm.
Andaman and Nicobar Islands	Food. Only occasionally eaten. Harvesting levels are probably too high to be sustainable.	B. Aul, pers. comm.
Indonesia	Food and medicinal use. Common in bushmeat markets. Harvesting levels are probably too high to be sustainable on some islands (e.g., Sulawesi). Bats known to be traded on Java, Lombok, Sangihe Islands, Sulawesi, Talaud Islands, and Togian Islands.	Bergmans and Rozendaal 1988; Fujita and Tuttle 1991; Hill 1991; Kitchener et al. 1990; Lee 2000; Lee et al. 2005, Owen et al. 1987; Riley 1998, 2002a, 2002b; Waldman 1998; Whitten 1992; S. Heinrichs, pers. comm.
Malaysia	Food, medicinal use, sport, and pest control. Trade is local, regional, and international.	Fujita 1988; Fujita and Tuttle 1991; Gregory 2004; Mohd-Azlan et al. 2001; G. Davison, T. Kingston, K. Olival, N. Patel, C. Shepherd, M. Tuttle, A. Zubaid, pers. comm.
Philippines	Food, medicinal use, and sport. Important bushmeat taxa. Trade is local or regional. Harvesting levels are probably too high to be sustainable.	Heaney and Heideman 1987; Lacerna and Widmann 1999; Shively 1997; Stier 2003; Binhi sang Kauswagan Foundation, A. Cariño, E. Curio, C. Dolino, N. Ingle, T. Mildenstein, L. Paguntalan, S. Stier, P. Widmann, pers. comm.
Guam & Mariana Islands	Food. Important bushmeat taxa. Trade is local. Harvesting levels are probably too high to be sustainable and has already caused extinction.	Wiles and Brooke, chapter 14, this volume; Harrison 1985; Lemke 1986; Stinson et al. 1992; Utzurrum et al. 2003; Wheeler 1980; Wiles 1987, 1990; Wiles and Payne 1986.

Table 16.4. (*continued*)

Island or island region	Purpose and impact	Sources
New Caledonia	Food. Important bushmeat taxa.	Flannery 1995; F. Brescia, A. Goarant, pers. comm.
Solomons	Food. Important bushmeat taxa.	Bowen-Jones et al. 1997; Richardson 1996.
Vanuata	Food. Important bushmeat taxa.	Chambers and Esrom 1991.
American Samoa	Food and worship. Important bushmeat taxa.	Cox 1983; Brooke 2001; Craig et al. 1994a; Craig et al. 1994b; R. Utzurrum, P. Craig, pers. comm.
Cook Islands	Food. Important bushmeat taxa. Harvesting levels are probably too high to be sustainable.	Brooke and Tschapka 2002; Wodzicki and Felten 1980.
Niue	Food. Harvesting levels are probably too high to be unsustainable.	Brooke and Tschapka 2002.
Fiji	Food. Important bushmeat taxa.	Palmeirim et al. 2005; J. Palmeirim, D. Watling, pers. comm.
Palau	Food. Eaten fairly often	Wiles et al. 1997; G. Wiles pers. comm.
Federated States of Micronesia	Food. Eaten fairly often on Yap.	G. Wiles, pers. comm.

Source: Adapted from Mickleburgh et al. 2009.

island bats seems variable. For example, on Guam bats are considered a great delicacy, and historically this demand has caused bat populations to decline severely there and on surrounding Pacific islands that supplied the Guam market (Wiles and Brooke, chapter 14, this volume). This trade was largely eliminated following the listing of all *Pteropus* and *Acerodon* species on CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) appendices I and II in 1989. On Sulawesi, the Philippines, and New Guinea, bats are also heavily hunted, and this has severely impacted their populations (Mickleburgh et al. 2009). On some islands, harvesting and the consequent impacts have been much less (e.g., Caroline islands Falanruw and Manmaw 1992). Reports from Niue, where hunting restrictions have been enforced, suggest flying fox populations are resilient and may recover relatively quickly once hunting ceases (Brooke and Tschapka 2002).

Intrinsic Factors

With their low reproductive outputs and long life spans, bats are naturally adapted to a low extrinsic mortality (Jones and MacLarnon 2001). Natural catastrophes and harvesting have always been factors in the lives of bats living on islands, and the recovery ability of populations may depend in part on their ability to move between neighboring islands, a broad diet, a lack of predators on many islands, and social habits. However, with increased depletion of populations through harvesting in recent years, natural catastrophes that were once of little long-term consequence may now be more significant due to modified population structures.

Natural Disasters

Islands in the Indian and Pacific Oceans are regularly affected by tropical storms, and severe storms have impacted island bat populations. For example, cyclones are reported as a major factor in the decline of Rodriguez flying fox (*Pteropus rodricensis*, Pteropodidae). For example, in 1979 Cyclone Celine II reduced the number of animals from 151 to 70 (Carroll 1984). Cyclone Namu caused large-scale population declines in Solomons flying fox (*Pteropus rayneri*) and Pacific flying fox (*P. tonganus*) on Malaita (Solomon Islands) in 1986 (Flannery 1989). Indirect effects of storms are also important. For example, evidence from the Mariana Islands, Samoa, and Vanuatu suggest that a major cause of mortality was increased hunting by humans after the storm hit (Pierson and Rainey 1992). Defoliation from the storm made roosting animals more visible, and a reduced food supply forced bats to forage diurnally, increasing human hunting success.

Invasive Species

On some islands the introduction of predators has been implicated in the decline or extinction of bat populations. For example, the accidental introduction of rats and subsequently owls to control the rats is thought to have led to the extinction of Lord Howe Island long-eared bats (*Nyctophilus howensis*, Vespertilionidae) on Lord Howe Island (Hutson et al. 2001). In New Zealand, the more terrestrial habits of New Zealand lesser short-tailed bat (*Mystacina tuberculata*, Mystacinidae) have made it especially vulnerable to introduced rats, feral cats, and stoats (Daniel and Williams 1984). On the islands of Guam in the Pacific and Christmas Island in the Indian Ocean, introduced arboreal snakes (the brown tree snake, *Boiga irregularis*, on Guam and the wolf snake, *Lycodon aulicus capucinus*, on Christmas Island) have had a devastating effect on resident bat populations. Observations of bat colonies between 1984 and 1988 on Guam indicated virtually zero survival of juveniles beyond 1–2 months, because of snake predation (Wiles 1987). On Christmas Island where the wolf snake has become established, it poses a serious threat to the native bat species, the black-eared flying fox (*Pteropus melanotus natalis*, Pteropodidae) and the least pipistrelle (*Pipistrellus murrayi*, Vespertilionidae) (Fritts 1993).

Climate Change

Although not listed as a threat process in IUCN 2006, global climate change and its effects on rising sea levels, altered tropical cyclone regimens, and changing plant phenology seem a likely threat for island bat populations. Although range extensions and shifts in elevational distribution of bats have been observed in Costa Rica and Canada (LaVal 2004; Willis and Brigham 2003), few studies have identified any direct links to climate change (see Robinson et al. 2005 for a review). Rising sea levels would reduce available habitat and refuges from human hunting on low-relief atolls in particular (accounting for many of the world's remote oceanic islands). In addition, sea-level rise may lead to mangrove forest declines along coastal zones of small islands, an important roosting habitat for *Pteropus* species (Rainey 1998). Additionally, predicted increases in the intensity and frequency of tropical storms would impact the long-term persistence of bat populations on small islands.

Island Bat Conservation

Islands have been the focus of a considerable number of bat conservation projects. The focal area for active projects in 2000–2006 and (where appropriate) the target species along with IUCN threat status are shown in table 16.5. While this is not an exhaustive list, we provide a review of the more significant projects compiled through contact with a range of international organizations providing funding opportunities. Bat conservation projects have been carried out in all the areas that we identified as hot spots for species or threatened species richness (table 16.5). A lot of effort has been focused on the islands off East Africa and Indian Ocean islands, where projects have been running the longest and are the most developed (e.g., Comores and Madagascar, Pemba, Rodrigues). Projects in Southeast Asia, Indo-Pacific islands, and the Caribbean are characterized by initial population surveys and identifying important conservation sites. Important exceptions of larger, longer-running programs are those projects under way in the Philippines, Sulawesi, Guam, and New Zealand. The United Kingdom has one of the longest-running conservation monitoring programs of all (table 16.5, and see below).

How successful have these projects been in conserving island bats? It is difficult to assess the success of a particular project, and an in-depth discussion of the ways of assessing success is beyond the scope of this chapter. However, we briefly outline a number of criteria that could be valuable in making such assessments, and we examine several projects that have achieved differing levels of success in order to synthesize effective conservation methods and make suggestions for future projects (also see Shilton and Whittaker, chapter 7; Racey, Goodman, and Jenkins, chapter 13; Wiles and Brooke, chapter 14; and O'Donnell, chapter 15; all in this volume).

1. *Meeting project objectives*. At a very simple level, a successful project is one that achieved the objectives originally outlined in the proposal. However, this may not be a good measure of conservation success, especially if the objectives have a very narrow focus. For example, a project may set out to assess population numbers, which in itself is useful but may be of little conservation

Table 16.5. A summary of some key bat conservation projects on islands, 2000–2006

Area	Projects
Africa/Indian Ocean	*Andaman and Nicobars*. A range of projects have been running since 2004, focusing particularly on ecology and conservation of the Nicobar flying fox (*Pteropus faunulus*, Pteropodidae; endangered, IUCN 2006).
	Comoros. See text.
	Madagascar. See text.
	Mauritius. Mauritius Wildlife Foundation is promoting bat conservation on the island and has focused on the foraging ecology of the Greater Mascarene flying fox (*Pteropus niger*, Pteropodidae; vulnerable, IUCN 2006).
	Pemba. A project focusing on the endemic Pemba flying fox (*Pteropus voeltzkowi*, Pteropodidae; vulnerable, IUCN 2006) began in 1995. Initially a population survey, it has since grown into a locally managed fruit bat conservation program including regular surveys, assessment of the threats from hunting, and community education.
	Réunion. A bat education and inventory project took place in 2004.
	Rodrigues. Projects have focused on the Rodrigues flying fox (*Pteropus rodricensis*, Pteropodidae; critically endangered, IUCN 2006), investigating their distribution, dispersal, and conservation, as well as community restoration of endangered forests and general fruit bat environmental education projects.
	Seychelles. Work has focused on the conservation of the Seychelles sheath-tailed bat (*Coleura seychellensis*, Emballonuridae; critically endangered, IUCN 2006).
	Sri Lanka. A field techniques training project was held on the island in 2006.
Southeast Asia	*Borneo*. A number of ongoing projects focus on hunting and trade in flying foxes, a bat survey in East Kalimantan, development of a bat training manual for future workshops, and a study investigating the population structure of flying foxes and the ecology of Nipah virus.
	Java. An ongoing project looks at the population structure of flying foxes and the ecology of Nipah virus. In 2001 there was a study of the distribution of cave-dwelling bats of the Gunung Sewu karst area.
	Krakatau. A recent study of seed dispersal by fruit bats after volcanic eruptions.
	Philippines. See text.
	Papua New Guinea. An ongoing program focuses on the conservation of flying foxes. Other projects have looked at the ecology of bats and figs and the ecology, systematics, and conservation of tube-nosed bats (Nyctimeninae, Pteropodidae).
	Sulawesi. A number of projects focus on the conservation of bats in north Sulawesi and on fruit bat feeding ecology at Tulabolo in Bogani Nani Wartabone National Park.
	Sumatra. An ongoing project looks at the population structure of flying foxes and the ecology of Nipah virus.

Table 16.5. (*continued*)

Area	Projects
Pacific Ocean	*American Samoa*. An ongoing project focuses on monitoring and roosting behavior of bats. In 2000 there was a study of foraging and nutritional ecology of fruit bats and in 2005 a survey of *Pteropus* (Pteropodidae).
	Fiji. See text.
	Guam and Commonwealth of Northern Mariana Islands. Ongoing work monitors the status of Marianas flying fox (*Pteropus mariannus*, Pteropodidae; endangered, IUCN 2006) on Guam. In 2004 there was a project looking at habitat use by the Polynesian sheath-tailed bat (*Emballonura semicaudata*; endangered, IUCN 2006) on Aguiguan in the CNMI.
	Hawaii. Ongoing research is looking into the Hawaiian hoary bat (*Lasiurus cinereus semotus*, Vespertilionidae).
	New Caledonia. Ongoing projects include an annual bat night.
	New Zealand. The Department of Conservation is involved in projects on the two native bat species, the long-tailed bat (*Chalinolobus tuberculatus*, Vespertilionidae; vulnerable, IUCN 2006) and the New Zealand lesser short-tailed bat (*Mystacina tuberculata*, Mystacinidae; vulnerable, IUCN 2006). This has included research into ecology in fragmented urban districts, modeling of distribution, and conservation in South Canterbuy (*C. tuberculatus*); and captive bat translocation on Kapita Island, modeling of distribution, and role in resproductive biology of native plants (*M. tuberculata*).
	Niue. Threats to bats from overhunting were surveyed in 2002.
	Taiwan. A project focused on population structure and conservation of Formosan lesser horseshoe bat (*Rhinolophus monoceros*, Rhinolophidae) in 2002.
	Vanuatu. There is an ongoing survey and inventory project.
Caribbean	*Cayman Islands*. A Cayman Islands bat conference was held in 2000.
	Guadeloupe. There are ongoing surveys, and a local NGO focuses on bats.
	Martinique. A bat inventory and education project took place in 2004.
	Trinidad and Tobago. A project looked at the impact of logging on bat communities.
Europe	*United Kingdom*. See text.

Sources: Aberdeen University, Bat Conservation International, BP Conservation Programme, Columbus Zoo, Department of Conservation (New Zealand), Disney Wildlife Conservation Fund, Fauna and Flora International, Houston Zoo, Lubee Bat Conservancy, Oregon Zoo, Organisation for Bat Conservation, Philadelphia Zoo, Paris Museum, Rufford Small Grants Programme, U.S. Fish and Wildlife Service, U.S. Geological Survey Biological Resources Division, Whitley Fund for Nature, Wildlife Conservation Society, and Wildlife Trusts.

value unless there is a plan about how these data can be used to guarantee the long-term survival of the species.

2. *Population stability or increase*. Halting population decline or increasing population numbers is particularly valuable on islands, where bat populations are often relatively small. Success could be measured by recording population trends over time, although declines due to stochastic events such as cyclones would have to be taken into account.

3. *Long-term monitoring*. To assess the conservation status of a species, a long-term monitoring system that extends beyond the life of the project must be in place.

4. *Sustainability*. Conservation activities can be sustainable in the long-term only if there is local support, ideally in the form of active local conservation organizations. Sustainability is often achieved through education programs and engagement of the local community in bat conservation actions and can be the key component in the ultimate success of any project.

5. *Government involvement and incorporation into local and national policy*. The project ultimately needs to lead to local, regional, or international conservation policy change and support. Changes in enforcement of legislation (such as protection of bats or their roosts, establishment of protected areas, and regulation of hunting) and the acceptance and implementation of species or habitat management plans can only be achieved with government support and local adoption of policy.

6. *Addressing the threat*. Improved species conservation status will be compromised if many of the threatening processes are still operating. Successful projects would recognize this and attempt to minimize or eliminate the threats over time.

Island Bat Conservation Projects

Action Comores

The Comoros include a group of islands (Grande Comore, Mohéli, and Anjouan making up the Union of the Comoros and Mayotte, part of France) at the head of the Mozambique Channel between the north of Madagascar and East Africa. Action Comores (http://ibis.nott.ac.uk/Action-Comores), running since 1992, initially was focused on the conservation of the critically endangered Livingstone's flying fox (*Pteropus livingstonii*, Pteropodidae) (Clark et al. 1997; Reason et al. 1999; Sewall et al. 2003a; Sewall et al. 2003b; Trewhella and Reason 1992, 1993, 1994). The project later expanded to the other two pteropodid species found on the islands, the Comores flying fox (*Pteropus seychellensis comorensis*) and Comores rousette (*Rousettus obliviosus*) (Sewall et al. 2003b; Trewhella et al. 1995).

How successful has this project been? We review the evidence according to our criteria for success outlined above: (1) *Meeting project objectives*. The various projects have all had clear and achievable goals and have currently achieved all their objectives. (2) *Population stability or increase*. Prior to 1992, there were thought to be between 50 and 150 *P. livingstonii* in the Comoros. The most recent estimate is 1,200 bats from at least 20 roosts, most of them on Anjouan. (3) *Long-term monitoring*. The project undertook its first survey in 1992, and in 1994 initiated a roost monitoring program that is ongoing. A program of biannual surveys by trained Comorian surveyors has helped to assess population numbers and, more importantly, has documented long-term trends. (4) *Sustainability*. Action Comores involves a network of both local and international nongovernmental organizations (NGOs) as well as the Comorian government. Partners include Action Comores; Bristol Zoo and the Durrell Wildlife Conservation Trust; IUCN Species Survival Commission Chiroptera Specialist Group; the Ministry of Production and the Environment, Union of the Comoros; Projet Conservation de la Biodiversité et Développement Durable aux Comores, a program funded by the Global Environmental Facility (GEF) and United Nations Development Program (UNDP); and Ulanga, an association of Comorian environmental NGOs. (5) *Government involvement and incorporation into local and national policy*. The government agency responsible for environmental issues has been heavily involved in the project, and an action plan has been produced to help guide future government policy (Sewall et al. 2003a). (6) *Addressing the threat*. One of the main threats on the Comoros is deforestation, and Action Comores has taken a multifaceted approach toward this issue. Although *P. livingstonii* is protected, much of the habitat it needs for feeding and roosting is not. Indeed, no terrestrial areas are protected in the Union of the Comoros, and habitat protection largely relies on the participation and involvement of local communities. Environmental education has been a major part of the work of Action Comores, and it has used bat identification sheets, videos, lesson plans for teachers, posters, and stickers to promote the habitat conservation message (Trewhella et al. 2005). Captive breeding has also provided a buffer against catastrophic loss of animals and their habitat. As of 2002, there were 42 bats in captivity at Jersey and Bristol Zoos in the United Kingdom. Importantly, these bats remain the property of the Comorian people.

Bat Count Philippines

The 7,100 islands that make up the Philippines contain high numbers of endemic and threatened bat species (Hutson et al. 2001; Mickleburgh et al. 2002). Bat Count Philippines was established in Subic Bay (Luzon Island) in 2002 to protect an area of forest that was home to a colony of large flying foxes (*Pteropus vampyrus*, Pteropodidae). The forest had benefited from being leased by the U.S. Navy but was threatened following the navy's withdrawal.

We assess the success of their project using our criteria. (1) *Meeting project objectives.* Although the initial focus of Bat Count Philippines was to protect the forest and a single species, the project expanded to include estimates of bat population numbers at key accessible roost sites of both *Pteropus vampyrus* and the golden-capped fruit bat (*Acerodon jubatus*, Pteropodidae; endangered and endemic to the Philippines) in other areas, their ecology, and their role in pollination and seed dispersal, alongside capacity-building projects with local communities, educational programs for tourists, and a national awareness campaign. Bat Count Philippines has also initiated training in wildlife management for protected-area managers, students, and local communities. (2) *Population stability or increase.* It is too early to judge the project's long-term impact. However, the project has identified that current estimates of the population size of the golden-capped fruit bat are overestimates (T. Mildenstein, pers. comm.). (3) *Long-term monitoring.* Long-term monitoring of the colonies has been running since 2003 using a network of volunteers from the local community and expanding to include more sites at a national level. (4) *Sustainability*. Bat Count Philippines has a high chance of long-term sustainability because it was founded from a need identified by the local community to protect their forest. Community involvement has been a key element of the project throughout. From the 45 people originally trained in flying fox monitoring in 2002–2003, the project has now trained hundreds of other volunteers, students, community-based organizations, and local government officials and staff. Bat Count Philippines currently works in partnership with a number of other organizations: Cebu Biodiversity Conservation Foundation, Center for Environmental Awareness and Education, the Friends of Flying Fox in Boracay, Biodiversity Resource Conservation Inc. of Panay, the local government units of Sarangani and Isabela provinces, and the cities of Sagay and Davao. (5) *Government involvement and incorporation into local and national policy.* The local government has cooperated with the project in extending environmental awareness programs so that projects in one area have a wider impact. For example, the focus on bats and bat conservation in the province of Negros Oriental in 2006 encouraged other municipalities and cities in the Visayas region to focus on specific flagship species in 2007. The project aims to expand what is a community-based project to the national level by collaborating with the national government. (6) *Addressing the threat*. The main threat to bats in the Philippines is habitat loss, and Bat Count Philippines is addressing this by working with communities and involving them in measures to protect the forest.

Madagasikara Voakajy

Madagasikara Voakajy, a national NGO established in 2005, specializes in undertaking a range of bat conservation projects in Madagascar, home to a large number of threatened and endemic bat species (Mickleburgh et al. 2002; Racey, Goodman, and Jenkins, chapter 13, this volume). Their projects have focused on a number of different species, including the vulnerable Madagascan flying fox (*Pteropus rufus*, Pteropodidae), the Madagascan straw-colored fruit bat (*Eidolon dupreanum*, Pteropodidae), the Madagascan rousette (*Rousettus madagascariensis*, Pteropodidae), and the sucker-footed bat (*Myzopoda aurita*, Myzopodidae).

Projects have focused on issues such as hunting, the role of bats in seed pollination and dispersal, reducing bat-human conflicts, education, and raising awareness among different stakeholder groups.

Using our criteria, we assess the project's success. (1) *Meeting project objectives*. Each project within Madagasikara Voakajy has met their clear objectives as well as addressing the overall mission of the organization. (2) *Population stability or increase*. It is too early to judge the project's long-term impact. (3) *Long-term monitoring*. Members of the team have contributed to the latest population status and threat assessments of Madagascar's bats as part of the IUCN's Global Mammal Assessment. The first stage in establishing a baseline from which long-term monitoring can begin has been accomplished through monitoring of key roost sites in the Alaotra-Mangoro region and is continuing. (4) *Sustainability*. Madagasikara Voakajy has developed an extensive national network including staff and students at the universities of Antananarivo and Toliara, the National Association for the Management of Protected Areas (ANGAP), and a local grassroots flying fox NGO (Arongampanihy Culture, Communication, and Environment). The bat monitoring project has also established "dinas" or social contracts with communities in the Alaotro-Mangoro region. The local communities have agreed to dinas that conserve the Madagascan flying fox (*Pteropus rufus*) living in patches of forest in steep valleys where it was impossible to extract the trees when the primary forest was cleared. Such social contracts are particularly effective because they tend to be more readily observed by local communities when compared to government legislation. This work shows the importance of engaging local communities on their own terms. (5) *Government involvement and incorporation into local and national policy*. The activities of Madagasikara Voakajy have already raised the profile of bat conservation in Madagascar, where research and conservation priorities have consistently excluded bats, despite their threatened status. (6) *Addressing the threat*. Hunting and habitat loss are the major threats to Malagasy bats. Madagasikara Voakajy is using a number of novel and successful approaches to address these. Examples of success include halting forest clearance near roost sites and setting up buffer zones. The use of dinas is also a particularly useful technique that binds communities more closely into a long-term conservation plan.

Fiji Islands Bat Conservation

Fiji presents a significant challenge for bat conservation, as there are over 300 islands and a total land area of 18,272 km^2. While it has a small bat fauna (6 species), most are threatened, and one species (*Pteralopex acrodonta*, Pteropodidae) is critically endangered. In 2000 a number of bat conservation projects were initiated that aimed to contribute to the knowledge and conservation of the Fijian bat fauna (Palmeirim et al. 2005).

Using our criteria we assess the project's success. (1) *Meeting project objectives.* The project's aim was to assess the distribution of bats in the Fijian archipelago, assess the status of bat species, and identify key conservation sites and potential threats. The project achieved all of these objectives. (2) *Population stability or increase.* This project is providing a baseline survey and cannot yet be judged on this criterion. (3) *Long-term monitoring.* As with 2, this is just the first part of the process of establishing a long-term monitoring scheme. (4) *Sustainability*. The long-term sustainability will depend on the attitude of government and local people. Part of the project involved lengthy negotiations with local communities to gain access to land. In Fiji there is a traditional village hierarchy that needs to be respected when undertaking such survey work. This system does provide ample opportunity to engage communities about their bats, and in general, village Fijians are sensitive to conservation issues. The attitude of government is a different issue, and it remains to be seen if it will act upon the recommendations of this survey. (5) *Government involvement and incorporation into local and national policy.* The outputs from this project have given the government an ideal platform to commence a bat conservation program. It now has detailed information on distribution and status and know which sites they need to protect. It will probably take efforts from within Fiji to ensure that the government acts on this information. (6) *Addressing the threat.* The main threat is the lack of information about the population status of Fijian bats, which this project has addressed. Caves have been identified as an important habitat (of the nine sites earmarked as in need of protection, eight were caves). The major issue now is to tackle the threats to those sites and to bats generally. This will need the support of local Fijians and the establishment of networks and groups like those in the Comoros. This project is the first step in a long process.

The United Kingdom's National Bat Monitoring Program

There are 17 bat species in the United Kingdom. Since legislation was passed in 1981 to protect these species, there has been a significant increase in bat conservation activities. In 1996 the Bat Conservation Trust (BCT) set up the National Bat Monitoring Program (NBMP) to provide long-term population trends for a range of U.K. species and a statistically robust assessment of the impact of various bat conservation measures that are being undertaken.

Again we evaluate the project's success against our criteria. (1) *Meeting project objectives*. The NBMP has always had a simple and clear objective, to provide long-term population trends, which they are building with ongoing data collection and analysis. (2) *Population stability or increase*. In 2006 BCT produced *The State of the UK's Bats*, which showed statistically significant increases in the populations of four species: lesser horseshoe bat (*Rhinolophus hipposideros*, Rhinolophidae); Natterer's bat (*Myotis nattereri*, Vespertilionidae), Daubenton's bat (*M. daubentoni*), and common pipistrelle bat (*Pipistrellus pipistrellus*, Vespertilionidae). (3) *Long-term monitoring*. The NBMP was established as a long-term monitoring program that began collecting data in 1996. (4) *Sustainability*. The NBMP relies heavily on a network of volunteers to implement a range of surveys looking at feeding areas, summer roosts, and winter hibernation sites. Volunteer involvement with the project has continued to rise since it was established. (5) *Government involvement and incorporation into local and national policy*. Since 2001 the NBMP has received financial support from the Joint Nature Conservation Committee, a government conservation body. Information from the NBMP is fed into the Biodiversity Action Plan (BAP) process that is part of the U.K. government's response to the Rio Earth Summit in 1992. Currently there are BAPs for six U.K. species: greater and lesser horseshoe bat (*Rhinolophus ferrumequinum* and *R. hipposideros*, Rhinolophidae); Bechstein's bat (*Myotis bechsteinii*), mouse-eared bat (*M. myotis*), common pipistrelle bat (*Pipistrellus pipistrellus*), and western barbastelle (*Barbastella barbastellus*, Vespertilionidae). (6) *Addressing the threat*. The NBMP has addressed the issue of a lack of statistically robust information on population trends. The information on trends is being used to drive government policy and is helping to focus on species that are especially in need of conservation attention.

Lessons Learned

Successful projects have objectives that are easily achievable and establish long-term species and habitat management plans. Projects involve the government from the outset, and build local support through interaction and education (local people are the key to their long-term success). These projects are often multifaceted in their approach and focus on a range of issues and collaborate with other island bat conservation groups, especially to learn from their experiences. Due to the remoteness of many islands and the lack of knowledge of the status of species on islands, many projects have been short surveys. The long-term success of the project has often been dependant on whether there has been the commitment of a dedicated bat biologist to spark longer-term conservation programs. Those that have continued and grown in stature over a period of years have several aspects in common: (1) highly motivated local advocates for bats, (2) attachment to local infrastructure and/or development of a center from which conservation, training, and education projects in the surrounding region can be led, (3) multiple funding and project partners engaged over time, (4) stewardship through involvement of islanders in bat-roost monitoring programs and environmental education programs, (5) a succession of linked projects that search for smaller win-win situations where both the local environment is protected and islanders receive some tangible benefit for doing so.

Future Island Bat Conservation

Understanding the elements that make projects successful is only one part of planning future island bat conservation. Given finite conservation resources, projects need to focus on particular areas or species of concern and respond to newly emerging threats. However, there are many ways of setting conservation priorities. For example, species-rich islands could be targeted for conservation efforts (i.e., those illustrated in plate 11), or areas with the largest family-level diversity (fig. 16.1), or islands with the highest number of threatened species (plate 12), or those containing the most critically endangered species (table 16.3, plate 12C–D), or islands facing overwhelming threats (e.g., unsustainable hunting, table 16.4). Focusing on areas that have had historical extinctions (plate 12A) or that previous projects have neglected or underdeveloped might be more appropriate (table 16.5). Other measures of interest might be islands with the largest number of rare species or highest amount of evolutionary diversity (Grenyer et al. 2006; plate 13). For example, the islands with the highest number per grid square of rare bat species (defined here as those species with range sizes of less than 41,685 km^2, following Grenyer et al. 2006) are the Solomon Islands (11 species per grid square), Lesser Antilles (7 species per grid), Bismarck Archipelago (5 species per grid), and the Moluccas (4 species per grid; plate 13A). Areas with highest mean evolutionary diversity per grid square for island bats are New Zealand (with its unique short-tailed bats in the family Mystacinidae), New Guinea, and the Caribbean (plate 13B).

A combination of different biodiversity measures might be appropriate, for example, species that are both "Evolutionarily Distinct" and "Globally Endangered" (or EDGE species; Isaac et al. 2007). Species are given a ranking depending on their evolutionary distinctiveness and their threat status (Isaac et al. 2007). Bats that fall within the top 100 ranked EDGE mammals are plotted as circles on figure 16.2B. Islands that contain bats in the top 100 EDGE species include Madagascar (sucker-footed bat, *Myzopoda aurita*, Myzopodidae), Seychelles (Seychelles sheath-tailed bat, *Coleura seychellensis*, Emballonuridae), Iriomote (Imaizumi's horseshoe bat, *Rhinolophus imaizumii*, Rhinolophidae), New Guinea (Bulmer's fruit bat, *Aproteles bulmerae*, and New Guinea big-eared bat, *Pharotis imogene*, Pteropodidae), and New Zealand (New Zealand lesser short-tailed bat, *Mystacina tuberculata*, Mystacinidae).

Other area-based priority-setting criteria can also be used to indicate where best to focus conservation efforts, or where these efforts miss important bat conservation areas. For example, the Alliance for Zero Extinction has highlighted 595 discrete sites that contain the majority of the population of at least one endangered or critically endangered species (mammals, birds, reptiles, amphibians, and conifers; Ricketts et al. 2005). Similar criteria have also been used to select Conservation International's 25 biodiversity hot spots (Myers 2003; Myers et al. 2000), BirdLife International's endemic bird areas (Stattersfield et al. 1998), and WWF's Global 200 Ecoregions (Olson and Dinerstein 1998). Any integrated approach to bat conservation must carefully consider where bats fit into these schemes to maximize the effectiveness of conservation measures and use of resources (Whittaker et al. 2005). Another growing area to consider is using models of climate change and human development to understand which areas are most likely to be impacted by future change and to focus on those (Mace et al. 2005; Thomas et al. 2004).

Whatever area-based or species-based priorities are selected, the rationale and objectives need to be clear from the outset. Currently island bats rarely receive attention from international conservation organizations or local planners despite dramatic declines being observed for a number of Indo-Pacific island species. A major first step for the future of island bat conservation is to raise the profile of bats on the conservation agenda and to examine the effectiveness of currently protected areas for bats. A recent analysis suggests that the network of currently protected areas may be inadequately representing islands and island species (Rodrigues et al. 2004). For example, 14% of threatened species and 7.2% of threatened genera are omitted by the network of currently protected areas. A majority of those taxa occur on islands and tropical mountains that are outside protected areas and within centers of endemism. Additionally, only 4% of the Ramsar sites and approximately 15% of established biosphere reserves are located on islands (Mace et al. 2005). We hope this chapter goes some way toward achieving the recognition that island bat conservation deserves, and provides the necessary tools for setting priorities and carrying out effective island bat conservation in the future.

Conclusions

Islands, representing some of the most vulnerable habitats on the planet, are important habitats for bats, with 60% of species living on islands. Overall, island bat species and family richness is concentrated in a few areas, with most of the diversity on tropical Indo-Pacific islands. Island living seems to be an important factor in determining extinction risk in bats, with the majority of all historical extinctions on islands and island species currently disproportionately more threatened. When compared to threatened bats in general, island species seem to be significantly more threatened by harvesting, intrinsic biological factors, invasive species, and natural disasters. Out of the conservation projects focused on island bats over the last 30 years, the most successful have implemented long-term species and habitat management plans involving local and governmental support. Future island bat conservation should take a complementary approach to priority setting, integrating different measures of biodiversity, and focusing where existing conservation programs do not currently cover.

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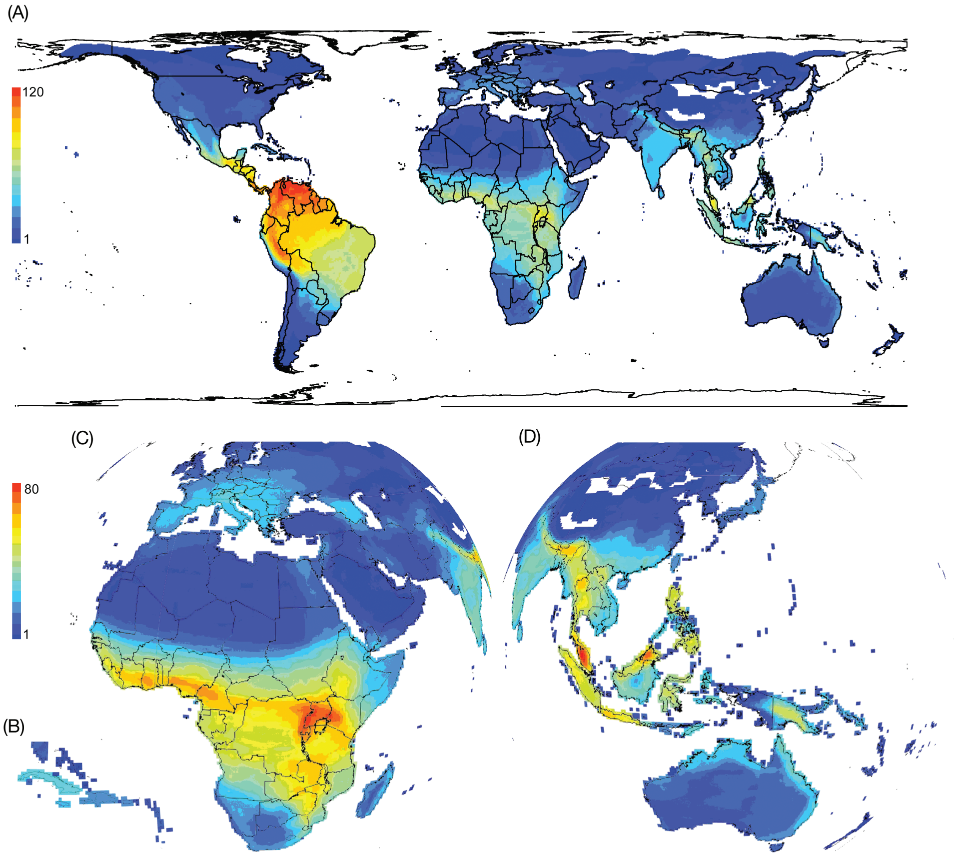

Plate 11 Richness of extant bat species (n = 894 species) plotted onto 0.5 degree grids using ArcMap 9.1 (ESRI 2005) (color gradients are linear with respect to species number) for (*A*) the global extent, (*B*) the Caribbean, (*C*) European and African islands, and (*D*) Indo-Pacific islands.

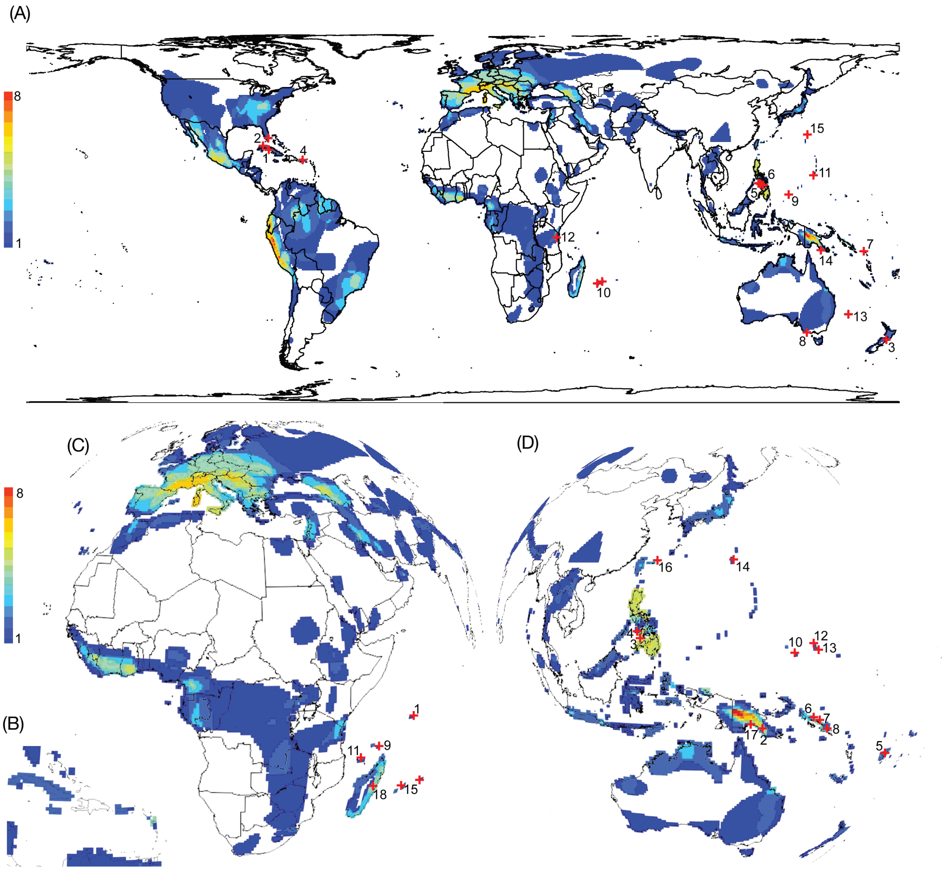

Plate 12 Richness of threatened bat species (n = 219 species, defined as vulnerable, endangered, and critically endangered following IUCN 2006) plotted onto 0.5 degree grids using ArcGIS 9.1 (color gradients are linear with respect to species number) for (*A*) the global extent (*crosses* represent historical extinctions; see table 16.2 for key), (*B*) the Caribbean, (*C*) European and African islands, and (*D*) Indo-Pacific islands (*crosses* represent critically endangered species; see table 16.3 for key).

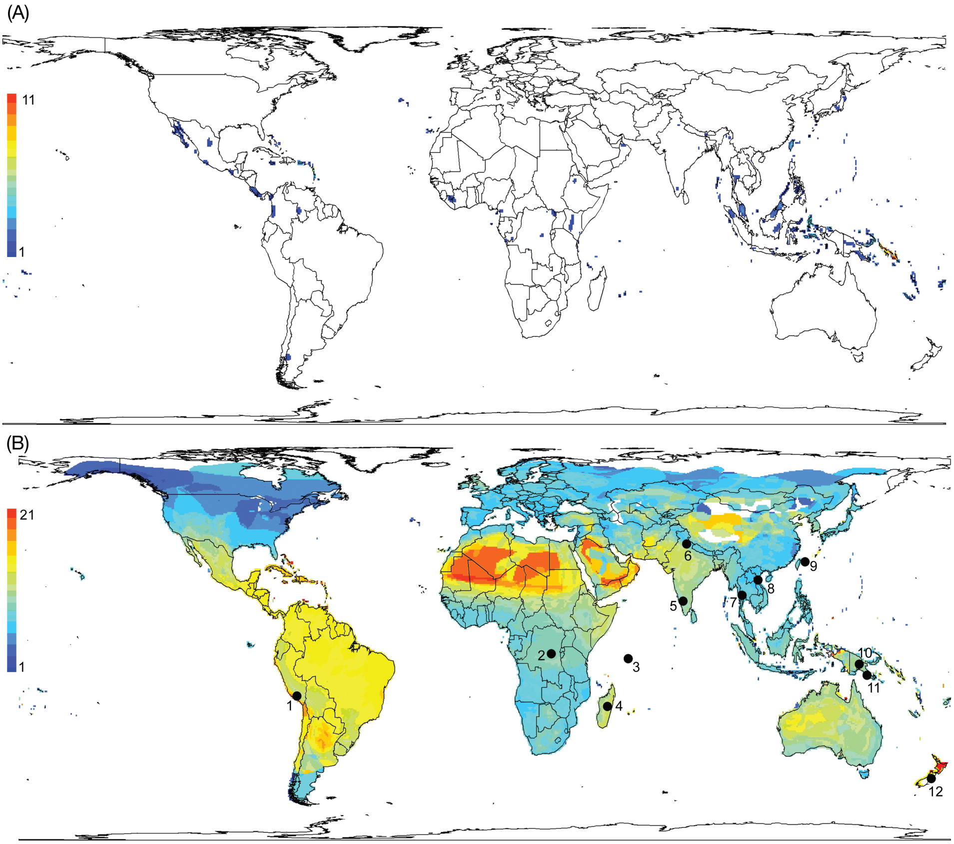

Plate 13 Richness of (*A*) rare species (species with geographic ranges of less than 41,685 km^2 following Grenyer et al. 2006; 159 species) and (*B*) mean phylogenetic diversity of bats (894 species), plotted onto 0.5 degree grids using ArcMap 9.1 (color gradients are linear with respect to species number). Phylogenetic diversity was calculated following Isaac et al. 2007. Circles represent bats in the top 100 EDGE (evolutionarily distinct and globally endangered) mammals.*1*, blunt-eared bat (*Tomopeas ravus,* Molossidae); 2, Gallagher's free-tailed bat (*Chaerephon gallagheri*, Molossidae); 3, Seychelles sheath-tailed bat (*Coleura seychellensis*, Emballonuridae); 4, sucker-footed bat (*Myzopoda aurita*, Myzopodidae); *5*, Wroughton's free-tailed bat (*Otomops wroughtoni*, Molossidae); *6*, Peters's tube-nosed bat (*Murina grisea*, Vespertilionidae); *7*, hog-nosed bat (*Craseonycteris thonglongyai*, Craseonycteridae); *8*, Vietnam leaf-nosed bat (*Paracoelops megalotis*, Rhinolophidae); *9*, Imaizumi's horseshoe bat (*Rhinolophus imaizumii*, Rhinolophidae); *10*, Bulmer's fruit bat (*Aproteles bulmerae*, Pteropodidae); *11*, New Guinea big-eared bat (*Pharotis imogene*, Vespertilionidae); *12*, New Zealand lesser short-tailed bat (*Mystacina tuberculata*, Mystacinidae).