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The diversity and distribution of the fruit bat fauna (Mammalia, Chiroptera, Megachiroptera) of Danjugan Island, Cauayan, Negros Occidental, Philippines (with notes on the Microchiroptera)

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Abstract. Bats are the most diverse mammalian order in the Philippines and whilst many endemic and threatened species have been documented, they are also probably the least well-known order. Negros Island (central Visayas, Philippines) represents one of the ten highest-ranking sites globally for megachiropteran diversity, and is listed as a priority area for the establishment of protected areas for megachiropteran conservation. It is also listed as a priority site for survey work. The current study undertook mist-netting, roost and observation surveys of the bat fauna of Danjugan Island, off the west coast of Negros Occidental, to inventory the bat species present and to provide baseline ecological information to identify key areas of conservation concern. Eight species – five megachiropterans and three microchiropterans – were recorded over the course of the study, representing over 10% of the total Philippine bat fauna. Four of the species are new records for the island, and three are IUCN Red Listed. The results show that the island provides important cave- and tree-roosting areas for the local populations of several endemic and globally endangered species and sub-species. Already designated with reserve status, and with an environmental education programme established within the local communities, the island may be considered of national and global importance for bat conservation. Recommendations are given for future management.

Introduction

Bats (Order Chiroptera) often make up a large proportion of the mammalian diversity on small islands. Flying foxes (Pteropodidae) play a disproportionate role (over other frugivores) as seed dispersers, and pollinators, and thus in structuring the plant communities on islands (Rainey et al. 1995). Bats are the most diverse order of mammals in the Philippines with 25 megachiropteran and 48 microchiropteran species (Heaney and Regalado 1998). Of these, approximately 40% are endemic (Heaney 1986). However, the megachiropteran fauna

in the Philippines is also highly threatened (approximately 50%) as a result of large-scale deforestation and hunting (Mickleburgh et al. 1992; Mendoza and Mallari 1997). Consequently, island habitats in the Philippines and elsewhere have been identified as particularly important for bats and a priority for conservation efforts on a global scale (Mickleburgh et al. 2002). Mickleburgh et al. (1992) stressed (as one of twenty priority global projects) the urgent need to survey the Negros Island area (in the Philippines) which was ranked eighth highest in the world for megachiropteran diversity and was listed sixteenth globally for requiring the establishment of protected areas for world fruit bat conservation. However, the lack of basic survey information inhibits conservation efforts (Oliver and Heaney 1996; Heaney and Regalado 1998; Turner et al. 2002a) and there are concerns that several species may now be threatened and possibly extinct (Ingle and Heaney 1992). Heaney and Heideman (1987) reported that it has not been possible to estimate the number of species of bats in the Philippines that are extinct or endangered because of a lack of basic surveying information, and Negros remains a priority area for faunal surveys.

Danjugan Island lies just off the southwest coast of Negros Island and forms part of the Greater Negros, Panay Faunal Region of the central Philippines, the most threatened of the Philippines' five faunal regions (Heaney and Regalado 1998). There are at least 15 species of megachiropteran thought to be present within this faunal region, of which, approximately 20% are known to be endemic to the Philippines (Heaney et al. 1998). Bats are uniquely threatened due to their dependence on lowland forest. On Negros only 4% of the original tropical forest coverage remains (Heaney and Regalado 1998), and much of this is above 700 m elevation. Additionally, the restricted areas of forested habitat are still susceptible to local hunting pressure and limited logging operations (largely illegal) are on-going. In addition to the requirement for forest habitat, caves also provide important roost areas; but disturbance and destruction of caves has had a major impact on many species of bats (Utzurrum 1992). Danjugan Island however, represents a potentially important site for several bat species since it is still largely forested and boasts several limestone caves yet little is known of the bat species observed on the island.

Research interest and knowledge of bats in the Philippines has been steadily increasing (see Heaney and Heideman 1987; Heideman and Heaney 1989; Heaney 1991; Ingle and Heaney 1992; Utzurrum 1992; Heaney 1993; Heaney et al. 1998; Sedlock 2001) but with limited focus on the Negros–Panay Faunal Region, and virtually none on Danjugan. Work completed has focussed predominantly in Southern Negros, and on specific topics such as elevational zonation (Heaney et al. 1989) and the role of fruits bats in seed dispersal within sub-montane rainforest (Hamann and Curio 1999). Little work has focused on diversity, distributions and status of species in other areas of Negros. There is a clear need to survey areas of remaining habitat (forests and caves) that may still support significant bat populations, endemic or otherwise, and thus assess their conservation importance.

The Negros Rainforest Conservation Project (NRCP) is currently undertaking faunal inventories in the North Negros Forest Reserve (Turner et al. 2001; Turner et al. 2003) and recently completed similar work on Danjugan Island which lies just off the west coast of Negros Island. Danjugan is a potentially important area for bat conservation efforts since it is largely forested, boasts several limestone caves and is uninhabited. Only one previous (unpublished) survey has been completed on Danjugan and this estimated that the island was host to at least 6 species of megachiropteran bat (Maro 1994). The island has recently been designated reserve status as the Danjugan Island Marine Reserve and Sanctuaries (DIMRS) by the municipal government of Cauayan and provincial government of Negros Occidental in February 2000, and has been managed by the Philippines Reef and Rainforest Conservation Foundation Incorporated (PRRCFI) since 1995 (Ledesma et al. 1999). Therefore, in collaboration with PRRCFI and as part of the CCC Danjugan Island Biodiversity Survey (Turner et al. 2002a), surveys were carried out to determine the distribution and diversity of the bat fauna on Danjugan Island, in order to identify conservation concerns and to make management recommendations.

Aims

1. To complete an inventory of megachiropteran species on Danjugan Island.
2. To gather basic distributional and ecological data on each species.
3. To ascertain the local, national and global significance of the island with regards to bat conservation.
4. To identify key areas of conservation concern for the bat fauna of the island.
5. To make recommendations for the future management of the island with respect to bat conservation.

Materials and methods

Study Area

Danjugan Island is small (approximately 43 hectares) with a maximum elevation of 80 m. It is a coral fringed island covered in tropical forest, 3 km west of Negros just off the coast of Bulata in the Sulu sea (Figure 1), and is one of over 7000 islands that make up the Philippine Archipelago. The island has six lagoons, of which two are open to the sea and all but one are surrounded by diverse mangrove stands (King et al. 2002). There is however, no permanent standing fresh water on the island. The terrain is rugged and characterised by limestone geology, which has given rise to the formation of several caves

around the perimeter of the island. With respect to the islands flora, approximately 75% is forested and 50% of this area is secondary forest where some palms (*Areca catecho* and *Cocos nucifera*) and figs (*Ficus* spp) dominate. The average forest canopy height is approximately 10–15 m. The remaining forested area is dominated by coconut plantations in the south (Figure 1), and a mixture of beach/cliff forests, secondary scrub and grasslands (Figure 1, Table 1). A more detailed description of the Danjugan Island environment is given by Harborne et al. (1996) and Turner et al. (2002a).

Mist-net survey

Netting was carried out for 51 nights between June and September 2001. Mist-nets (two 10 m × 2.6 m and six 6 m × 2 m, 38 mm mesh) were used at 11 locations within three of the major habitat types (mixed species forest, coconut dominant forest and beach forest) present on the island (Figure 1, Table 1). As nets of 2 different sizes were used, and as they were open for variable lengths of time, net-effort for each location was calculated as hours per square-metre of net (Table 3). Single and a combination of nets were used at each location and

Table 1. Brief descriptions of the major habitat types on Danjugan Island (as illustrated in Figure 1).

Habitat Type	Description
Undisturbed mixed-species forest	Undisturbed mixed-species forest, with high canopy and an abundance and diversity of *Ficus* spp.
Selectively-logged mixed-species forest	Mixed-species forest with reduced density of large trees due to history of selective-logging. Species composition influenced by local topography, but generally with abundance of *Ficus* spp.
Exposed mixed-species forest	Mixed-species forest with low canopy due to exposure to wind and sea-spray, with fewer Ficus but an abundance of Sterculia spp., Pandanus spp., and a Mimosoideae sp.
Coconut-dominated forest	Even-aged stands of remnant coconut plantations, with areas of other planted species such as mango, banana and a Mimosoideae sp. Secondary forest regenerating rapidly in most areas, but with low, scrubby undergrowth on ridges and other exposed areas.
Coastal-cliff scrub/forest	*Pandanus* dominated scrub on steep exposed coastal areas. Also *Terminalia*, *Sterculia* and cycads. *Pemphis acidula* abundant near sea-level.
Beach forest/scrub	Low forest/scrub bordering beaches, with extensive coconut, *Pandanus*, *Terminalia* and *Barringtonia*.
Beach	Beach areas with no vegetation.
Cultivated fruit garden	Grassy clearing between mixed-species forested slopes, with planted species such as banana, tea and figs.
Bare-rock islands	Small off-shore rock islands with little or no vegetation.
Lagoons	Salt-water lagoons with variety of mangrove habitats.

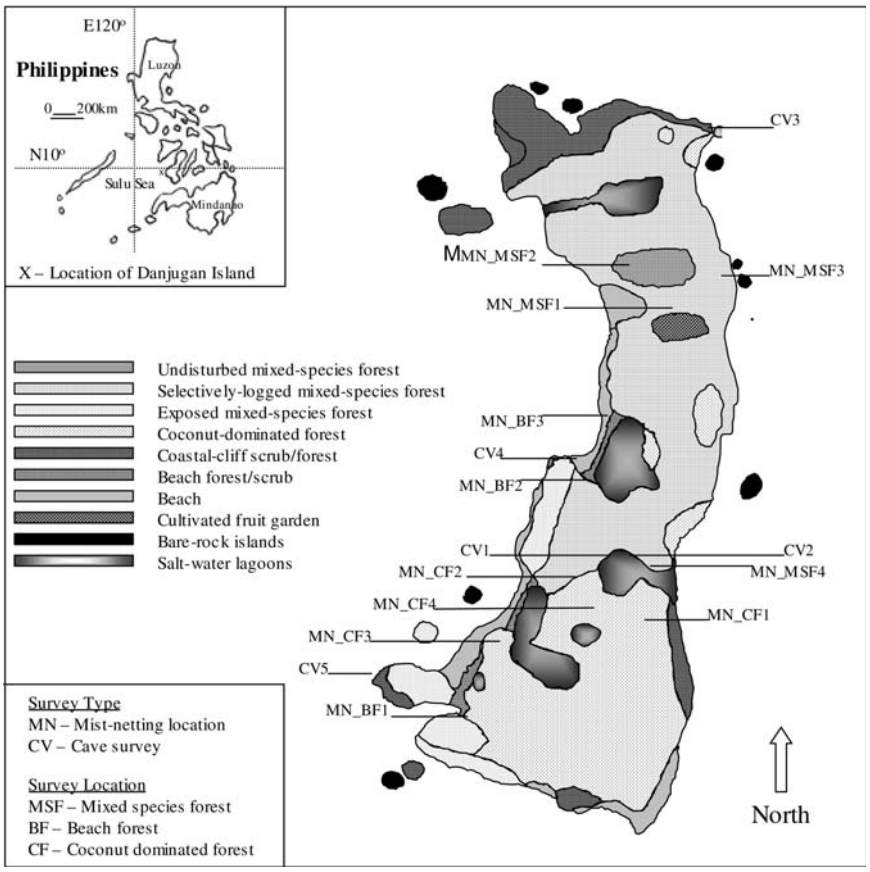

Figure 1. Location of the Danjugan Island Marine Reserve and Sanctuary, Philippines (Ledesma et al. 1999). The map also details the distribution of major habitat types as described in Table 1 (derived from Turner et al. 2002b) with the location of each survey site.

sampling effort has been summarised in mist-net hours: beach forest (MN_BF) sampled for 77 mist-net hours; coconut-dominated secondary forest (MN_CF) sampled for 43 mist-net hours; and mixed-species forest (MN_MSF) sampled for 38 mist-net hours (see Figure 1 for site distributions). A single net was also set just above the sea level at the entrance of a lagoon (L3). Other habitat types, such as mangrove and cliff forests, were not sampled due to problems of access at night.

To maximise capture efficiency, nets were established across likely flight-paths such as clearings, along ridges, or by water (Heaney et al. 1989), in a variety of combinations, such as 'Z' and 'T' formations (Kunz et al. 1996), and at heights ranging from 1 to 10 m above the ground. High nets were operated on a pulley system, and when possible were complemented by a low net positioned on the same pulley system (following Ingle 1993). Generally,

nets were opened before dusk and closed when captures ceased (or shut at midnight), depending on weather and personnel. The midnight to dawn period was sampled very rarely. All nets were checked at least every 30 min when open.

Bats captured were identified using Ingle and Heaney (1992), sexed by observation of genitalia and nipples, and aged (to adult or juvenile) by assessment of the ossification of the joints of the digits of the wing. Forearm length was measured using a dial calliper, and body mass using a spring balance. When new species were encountered, ear, hind-foot and total length were also recorded. All bats that were captured were subsequently released once biometric data had been recorded. No voucher specimens were taken.

For each survey night, the location, weather conditions and time the nets were operational was noted.

Cave survey

Caves were located by exploration on foot, and by touring the perimeter of the island by boat. Each cave was surveyed for evidence (visual or audible) of bat presence, either from the entrance or by entering the mouth of the cave. Numbers of bats within caves was estimated by direct observation during the day, or by counting the bats as they left the caves around dusk. Three researchers were located in different positions near the entrance to each cave and made independent counts of the emerging bats. Estimates were derived from the range of the counts for each cave. Actual mean counts are not presented since no level of accuracy could be assigned. Species present within caves were confirmed by trapping with a hoop-net just inside the cave. This followed the approach of Clyde et al. (1996) where only roosting individuals were caught, and then released once identification had been confirmed. Where it was not possible to safely employ this approach, a single mist-net was opened just outside the mouth of the cave. Where the cave was believed to contain a large number of individuals, the capture of unmanageable numbers of bats in the net was avoided by setting the mist-net outside the times of peak activity (determined by prior observation) and the net was set on bamboo poles held by two researchers, and lowered each time a bat was caught. Each bat captured was dealt with as for the general mist-net survey.

Results

A total of eight bat species were recorded on Danjugan Island during this study. Five were megachiropterans: Island Flying Fox (*Pteropus hypomelanus*); Little Golden Mantled Flying Fox (*Pteropus pumilus*); Cave Roosting Nectar Bat (*Eonycteris spelaea*); Common Short Nosed Fruit Bat (*Cynopterus brachyotis*); and Geoffroy's Rousette (*Rousettus amplexicaudatus*).

Table 2. Summary of total bat captures within each habitat type.

Species	Habitat		
	BF	CF	MSF
E. spelaea	32	6	50
C. brachyotis	30	104	13
[1]*P. pumilus*	3	6	3
R. amplexicaudatus	0	6	0
P. hypomelanus	0	8	0
M. macrotarsus	1	0	0
S. saccolaimus	0	0	4
Total	66	130	70

BF–Beach forest; CF–Coconut-dominated forest; MSF–Mixed species forest.
[1]Endemic species.

Table 3. B + ats captured per 100 net-effort units during mist-net survey (1 net-effort unit = 1 hour per square metre of net).

Habitat type	Beach forest			Coconut forest				Mixed-species forest				Total
Location code[1]	BF3	BF1	BF2	CF2	CF1	CF3	CF4	MSF2	MSF3	MSF1	MSF4	–
Net-effort units	700	540	45	75	56	514	438	300	33	607	63	3370
Net height[2]	L&H	L&M	M	L	L	L&H	H	L&H	M	L&H	Sea-level	–
E. spelaea	3.86	0.19	4.44	14.67	–	0.97	20.11	1.67	–	1.32	–	4.36
C. brachyotis	1.43	3.52	6.67	2.67	1.78	0.58	–	1.67	6.15	7.08	–	2.61
[3]*P. pumilus*	0.29	–	–	–	–	0.97	0.23	0.33	3.08	0.16	–	0.33
R. amplexicaudatus	–	–	–	–	–	–	1.83	–	–	–	–	0.24
P. hypomelanus	–	–	–	–	–	0.58	0.69	–	–	–	–	0.18
M. macrotarsus	–	–	–	–	–	–	–	–	–	–	6.38	0.12
S. saccolaimus	0.14	–	–	–	–	–	–	–	–	–	–	0.03
Total	5.71	3.70	11.11	17.33	1.78	3.11	22.86	3.67	9.23	8.56	6.38	7.86

[1]BF–Beach forest; CF–Coconut-dominated forest; MSF–Mixed species forest.
[2]Height of nets: L = 1–4 m, M = 4–7 m, H = 7–10 m.
[3]Endemic species.

Eonycteris spelaea accounted for over half the 266 bats captured during the general mist-net survey, but exhibited high variation in catch-rates across the survey sites (Tables 2 & 3). This variation showed a high negative correlation ($r = -0.619$; $p < 0.01$; $n = 10$) with distance from a cave found to contain a roost of over 5000 individuals of this species (Table 5). This species was the most widely distributed species, being captured at all but one of the mist-net sites. *C. brachyotis* was recorded across all sites except CF4 and MSF4, with the species captured almost exclusively in low to mid-level nets (Table 3). This is in contrast to the other species, with *P. pumilus* and *E. spelaea* being captured in mid- and high-level nets, and *P. hypomelanus* and *R. amplexicaudatus* were

Table 4. [1]Megachiropteran and [2]Microchiropteran morphological data.

Species		Adult male		Adult female	
		Forearm (mm)	Mass (g)	Forearm (mm)	Mass (g)
[1]*P. hypomelanus*	range	123.0–141.7	385–410	120.5–131.4	240–360
	mean	132.35	397.50	124.60	284.00
	SD	13.22	17.70	5.91	65.90
	n	2	2	3	3
[1]*P. pumilus*	range	94.4–109.0	125–190	89.3–109.5	165–200
	mean	103.38	161.40	101.32	182.00
	SD	5.54	24.40	7.53	13.51
	n	5	5	5	5
[1]*R. amplexicaudatus*	range	80.6–85.5	70–120	77.3–89.3	65–75
	mean	83.05	95.00	83.28	71.25
	SD	3.46	35.36	5.67	4.79
	n	2	2	5	4
[1]*E. spelaea*	range	55.0–77.9	50–95	57.6–79.2	42–100
	mean	72.80	68.82	72.56	68.44
	SD	2.89	12.94	4.46	17.02
	n	30	30	27	27
[1]*C. brachyotis*	range	56.5–68.9	27–38	55.9–72.7	28–65
	mean	62.67	33.00	63.50	34.05
	SD	3.90	3.40	3.20	6.47
	n	10	10	40	40
[2] *T. melanopogon*	range	64.3–65.7	22.0–27.0	–	–
	mean	64.70	24.41	–	–
	SD	0.57	2.07	–	–
	n	5	5	–	–
[2] *M. macrotarsus*	Range	46.5–49.1	10.0–13.1	–	–
	Mean	47.73	11.67	47.2	12
	SD	1.31	1.53	–	–
	n	3	3	1	1
[2] *S. saccolaimus*	Range	–	–	–	–
	Mean	70.2	35	–	–
	SD	–	–	–	–
	n	1	1	–	–

only captured in high nets. For all adult individuals caught morphological data was recorded for each species (Table 4).

Five caves were located around the island (Figure 1) although only one contained significant numbers of *E. spelaea* (Tables 2 and 3). *C. brachyotis* was also found roosting in a cave, but in very small numbers and not in proportion to its relative abundance in the mist-net catches.

Daytime tree-roost searches found the two pteropodid species to be roosting singly or in small groups in the mixed-species forest in the northern half of the island, and to a lesser extent the exposed forest on the south-western corner of the island (see Figure 1). The majority appeared to be roosting north of site MSF1 (Figure 1). Daytime searches in the coconut and secondary growth southern region found no bats roosting.

Table 5. Summary of caves found to contain bat roosts during the study period (caves found not to contain bats have not been included).

Location code	Location	Species	Number trapped	Estimated numbers	Comment
CV1	Lagoon 3 cave	*E. spelaea*	53	> 5000	largest cave, near lagoon 3, with water-filled base; presence of *R. amplexi-caudatus* unconfirmed (see text)
CV2	Lagoon 3 cave 2	*C. brachyotis*	3	10	smaller cave near lagoon 3, with water filled base and roosting sites in shafts
CV3	NE sea cave	*T. melanopogon*	1	300–500	2 inter-connected caves on Northwest corner of island, exposed to the sea
CV4	Turtle beach cave	*T. melanopogon*	4	9	small sea-cave at south-ern-end of Turtle Beach, with seaward and beach entrances
CV5	SW sea cave	*T. melanopogon*	0	8	sea-cave on Southwest coast of island, with westward-facing en-trance; back galleries closed by storm debris during study-period

Discussion

The four-month survey found a total of eight bat species and provided the first biometric data for these species at this location. Of the five megachiropterans recorded, one species, *Pteropus hypomelanus*, had not previously been recorded on the island. Maro (1994) found Jagor's Dog-faced fruit bat (*Ptenochirus jagori)* to be present but this species was not located by the current study. Several of the species captured on Danjugan Island are of significant conservation concern, based on levels of endemism and global status. Although taxonomic research was out of the scope of this study, the importance of subspecific differentiation of polytypic species when conserving endemic biodiversity has previously been stressed for other taxonomic groups on Negros Island (Brooks et al. 1992; Turner et al. 2002b).

Although unconfirmed during this study (due to permit restrictions on collection) distribution data suggests that the *E. spelaea* population on Danjugan Island is the sub-species *glandifera* (Corbet and Hill 1992; Mickleburgh et al. 1992; Heaney et al. 1998); a sub-species listed as globally 'vulnerable' by the IUCN (grade 4 on a scale of 1–11 where 1 = Extinct, and 11 = Not threatened) (Mickleburgh et al. 1992). Therefore this roost of over 5000 individuals

in a single cave could be of significant global conservation value. This species was only found in one roost and the choice of roost site could be attributed to the size of the cave at the Lagoon and this species' preference to roost in large numbers, or the fact that the many other caves on the island are coastal caves and are much more exposed. Another factor that may affect cave roost choice is a probable preference in Philippine roosts for caves with some penetrating light (Mickleburgh et al. 1992).

There is also a possibility that the presence of *C. brachyotis* on Danjugan may in fact represent an endemic sub-species, since Kitchener and Maharadatunkamsi (1991) and Schmitt et al. (1995) considered populations of this species from the Philippines and Sulawesi to represent a separate species, *C. luzoniensis*. However, Corbet and Hill (1992) and Koopman (1993) place *luzoniensis* as a sub-species of *C. brachyotis*; further study is needed. In agreement with previous studies (Mickleburgh et al. 1992) our data suggests that this species is not limited to cave roosts as it was found in all areas of the island not just areas local to the cave roosts. It is known to roost in disturbed habitats and is likely to be distributed across the island. *C. brachyotis* was the most widely distributed species, being captured at all but two of the mist-net sites. The absence of *C. brachyotis* at these sites is probably due to the fact that high nets were operated, with the species captured almost exclusively in low to mid-level nets at the other mist-net sites.

The unconfirmed sighting of *R. amplexicaudatus* in the cave at the lagoon close to site MSF4 is probably accurate since *R. amplexicaudatus* is commonly found roosting with *E. spelaea* but tends to roost further back, in the darkest regions of caves (Corbet and Hill 1992). *Rousettus* is the only known genus of megachiropteran that has the ability to echolocate that enables it to navigate in complete darkness. The capture of eight *R. amplexicaudatus* at CF4 occurred after 21:00 hrs. This could be an indication of a later timing of departure from the cave. Further mist-netting work outside the cave entrance could confirm these observations.

The presence of *P. pumilus* within the Danjugan Island reserve is very encouraging as it is considered globally vulnerable by the IUCN and is fourth on the conservation priority list for Philippine fruit bats (Mickleburgh et al. 1992). Whilst none were observed roosting in the southern region of the island, an ability to settle in disturbed areas may be essential to its future survival considering the rate of forest destruction in the Philippines. *P pumilus* are known to frequent small islands where it is usually associated with primary and well-developed secondary forest (Heaney et al. 1989) and uncommon to rare on larger islands (Heideman and Heaney 1989; Utzurrum 1992). Catch data suggests that densities are quite low although this species forages high in the canopy and therefore it may be more abundant on the island than current data suggests. Although more frequently captured at the sites in relatively undisturbed mixed-species forest, the species was also netted in both the beach forest and the coconut-dominated secondary forest. However, it was observed roosting only in the mixed forest.

The other species of this genus recorded on the island, the common island flying fox (*Pteropus hypomelanus*), is likely to be of the sub-species *P. hypomelanus cagayanus* (Mickleburgh et al. 1992), a sub-species endemic to the Philippines. Although captured in low numbers, large numbers were observed dispersing from the island at dusk, and the species appears to be more abundant on the island than the catch-rates suggest due to a tendency to fly high above the netting reach.

The Pallid large-footed Myotis (*Myotis macrotarsus*) is currently listed as near-threatened (Hutson et al. 2001). Philippine populations of *T. melanopogon* were formerly separated as *T. philippinensis*; however Heaney et al. (1998) consider the latter to be a sub-species of this widespread species (Corbet and Hill 1992; Koopman 1993). The two other microchiropteran species caught are both from the Emballonuridae (Sheath tailed bats) family. The Black-bearded Tomb bat (*Taphozous melanopogon*) and the Pouched bat (*Saccolaimus saccolaimus*) are both widespread across Southeast Asia although not much is known about the latter. *T. melanopogon* was found roosting in three sea caves, one of which contained large numbers (Table 5).

Conclusion

Whilst further survey work on the island would give a clearer indication of the distribution and roosting sites of all species, and an estimate of relative abundances, this preliminary survey demonstrates that Danjugan Island's bat fauna is relatively diverse given the small size of the island, in comparison to other islands in the Philippines (see Heaney et al. 2000). Further research may also bring clarification to the presence of endemic sub-species of *C. brachyotis*, *E. spelaea*, *P. hypomelanus* and *T. melanopogon*.

Considering that the seven priorities for the conservation of global bat fauna given by Mickleburgh et al. (2002) include focusing efforts on endemic species, islands, caves, education and legal protection, this study has shown that Danjugan Island is of major national and global significance for bat conservation and offers an opportunity to develop an education program. The island supports a cave-roost of over 5000 *Eonycteris spelaea*, probably of the globally vulnerable sub-species *E. spelaea glandifera*, while the extensive primary and secondary forest provides roosting areas for *Pteropus hypomelanus cagayanus*, and the globally vulnerable *Pteropus pumilus*, both endemic to the Philippines. These roosting sites are utilised not only by individuals that forage on the island itself, but also for large numbers of bats that forage on mainland Negros. Further caves support roosts of *Taphozous melanopogan* (presumably the endemic *philippinensis* sub-species)

The island has already been designated as the Danjugan Island Marine Reserve and Sanctuaries (DIMRS), and therefore offers protection to a roosting area utilised by large numbers of the local populations of these endemic or endangered species, safe from human interference and the hunting

pressures experienced by bats on Negros. Further, under the guidance of PRRCFI, a local education programme (largely marine) is already well established as part of the integrated community-based approach to the management of the reserve and its environs (Ledesma et al. 1999).

Thus, given that the island is already managed in a manner sympathetic to marine wildlife conservation and sustainable resource-use, steps to ensure the conservation of the bat fauna should also be taken. These should include continued development of environmental education in the local communities, including issues of bat conservation. Management should also focus on the protection of key habitat areas, including the extensive forest cover that provides roosting areas for *Pteropus pumilus* and *P. hypomelanus*, and protection and minimal disturbance of all cave-roosts. Additionally, there is still scope for additional research such as undertaking fully quantitative long-term surveys of the island's bat populations and researching patterns of dispersal to the mainland of *P. pumilus*, *P. hypomelanus* and *E. spelaea*. Finally, in order to assess the conservation value of the island for bat fauna the sub-specific placement of the *E. spelaea* population, and also of *C. brachyotis*, *P. hypomelanus* and *T. melanopogon* needs to be confirmed.

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