Bats can reach 3626 m a.s.l. in Papua New Guinea: altitudinal range extensions for six rainforest bat species

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Abstract: Bats represent an important, but poorly known component of mammal diversity in Papua New Guinea (PNG). Our surveys in two altitudinal rainforest gradients recorded 43 bat species of which six (Dobsonia minor, D. praedatrix, Hipposideros calcatus, H. maggietaylorae, Miniopterus australis, Miniopterus sp.) fell outside of their known altitudinal ranges. This enlargement could reflect the lack of past sampling, or a genuine range extension, potentially in response to climate change. Our study highlights the importance of baseline data on the altitudinal distribution of vertebrates, including bats, in PNG for the monitoring of their response to climate change and anthropogenic disturbance.

Keywords: Chiroptera; montane; Mount Wilhelm; White-man range.

After more than 200 years of scientific exploration the knowledge of the unique, often endemic, vertebrate fauna of Papua New Guinea (PNG) remains seriously incomplete (Flannery 1995; Menzies 2006; Milá et al. 2021; O’Shea 1996; Pratt and Beehler 2014). Among the vertebrates, bats are one of the most diverse but least studied taxa in PNG (Aplin et al. 2015; Armstrong and Aplin 2011; Armstrong et al. 2015). Recent taxonomic reviews based on genetic and morphological studies (e.g. Appleton et al. 2004; Irwin 2017; Lavery et al. 2014) have made progress in clarifying bat taxonomy but more work remains on other aspects, including acoustic and molecular signatures of species, as well as their population genetics and ecology (Armstrong and Aplin 2011; Armstrong et al. 2015; Kale et al. 2018).

In addition to taxonomy, the knowledge of the geographic distribution of bats and data on their ecology is crucial for better understanding of their role in rainforest ecosystems, as well as to inform policies for their conservation (e.g. Bahir and Gabadage 2009; Hayward et al. 2015). Information on altitudinal distribution of bats could also form baseline data for the study on the effects of climate change on these species. PNG is exceptionally well suited to such studies as it has multiple altitudinal gradients extending from lowland rainforests all the way to the climatic forest limits at around 3700 m a.s.l. To our knowledge there have been very few published records on altitudinal range shifts or extensions after field guides by Flannery (1995) and Bonaccorso (1998). After the recent studies along altitudinal gradients (Anthony et al. 2001; Armstrong and Aplin 2011; Robson et al. 2012), we expand our current knowledge with four extensive field surveys conducted between 2014 and 2017, covering two rainforest altitudinal gradients in PNG. These surveys documented significant (>100 m) altitudinal range extensions of six bat species.

We surveyed bat communities along two altitudinal gradients in PNG (Figure 1). (1) The Mt. Wilhelm altitudinal transect (05°43’S, 145°03’E) stretches along the northern slopes of the Bismarck Range. Surveys were carried out at eight regularly spaced locations along the gradient between altitudes of 200 m and 3700 m. Each location was separated by an altitudinal distance of 500 m. (2) The Whiteman Range altitudinal transect (05°52’S, 150°32’E) is located on the island of New Britain. Four locations,
separated by an altitudinal distance of 200 m were surveyed between altitudes of 500 m and 1100 m. Both transects are covered by primary and to a smaller degree secondary rainforest vegetation (Supplementary Appendices S1 and S2 – details on field methods, bat calls analysis, and forest types along the gradients).

A total of 1203 bats, representing 28 species belonging to six families, were captured and handled throughout the surveys at the Mt. Wilhelm and Whiteman Range altitudinal transects. Acoustic surveys revealed 15 additional species, excluding calls of those captured (Supplementary Appendix S3). The total species count, including captures and those detected acoustically, represent more than 50% of all the 80+ species of bats known to occur in PNG. Our results showed that 94% of the recorded species fell within the known altitudinal ranges for their respective species, except for six bat species: Dobsonia minor, D. praedatrix, Hipposideros calcaratus, H. maggietaylorae, Miniopterus australis, and Miniopterus sp. (Figure 2).

D. minor occurs only on New Guinea mainland. Prior to our study, it had only been recorded from sea level up to 600 m a.s.l. (Bonaccorso 1998). We captured a mature female in a mist net set at a fallowed food garden (S 05°43’40.8″; E 145°15’28.8″; 711 m a.s.l.). D. praedatrix is endemic to the island of New Britain. Its previous altitudinal records range from sea level to 300 m. We captured a sub-adult female in a mist net set at 941 m a.s.l. (S 05°58’875″; E 150°31’033″). The occurrence of two Dobsonia species recorded at much higher elevation than their previous maxima did not come as a surprise to us. This is supported by the fact that D. minor and D. praedatrix predominantly occur in lowland forests but could easily move upslope to lower montane forests because of similarity in floristic diversity and structure (Ashton 2003; Johns et al. 2007a; Supplementary Appendix S2). Bat movements can also be related to how close their roosting sites are. D. minor has a home range of 1.5 ha and can travel distances up to 1150 m (Bonaccorso et al. 2002). However, given that D. minor is an understory bat, it will likely not fly straight upslope but rather commute from one spot to another in search for food and better roost sites (Bonaccorso et al. 2002). Similar movement patterns can also be expected in D. praedatrix, another understory bat. H. calcaratus and H. maggietaylorae have previously been recorded from sea level up to 600 and 300 m,
respectively (Bonaccorso 1998). We captured individuals of both species in the Whiteman Range at altitudes of 1092 m (\(H. \text{calcaratus}\)) and 1112 m (\(H. \text{maggietaylorae}\)). \(H. \text{calcaratus}\) and \(H. \text{maggietaylorae}\) are obligate cave dwellers. Records at altitudes above 1000 m infer closeness of bat caves. The \(H. \text{maggietaylorae}\) specimen collected in New Britain was ammonia-bleached giving its fur an orang–brown coloration (Figure 2). This fur color condition happens in bats spending long time in torpor in caves, lactating in maternity roost caves (Kunz 1982).

Two individual \(M. \text{australis}\) were captured at Mt. Wilhelm transect in mist nets set at 1718 m (S 05°45’23.4″; E 145°14’11.0″) and 2117 m a.s.l. (S 05°45’30.7″; E 145°10’58.5″). Both records are altitudinal range extensions superseding the previous record of 1500 m a.s.l. (Bonaccorso 1998). Morphometric measurements and body mass of the captured individuals are provided in Table 1. Our record of \(M. \text{australis}\) at 2117 m a.s.l. (617 m higher than previous record) was expected because of the similarity in floristic structure between the altitudes 1000 m and <3000 m (Johns et al. 2007c). This bat was mist-netted in a closed canopy, primary forest where the net was set along a human made track.

The bat call we recorded at 3200 m a.s.l. (S 05°48’07.2″; E 145°04’11.3″) and 3626 m a.s.l. (S 05°47’21.7″; E 145°03’36.8″) is the most significant of our altitudinal records. This call is frequency modulated, with steep linear pulses ending with quite a steep curve, and a characteristic frequency around 53 kHz (Figure 2). Such short, steeply decreasing, broadband frequency sweep at 53+ kHz had previously been recorded throughout PNG at altitudes <3000 m (Armstrong and Aplin 2011). Due to the lack of a combined genetic, morphometric, and acoustic data, Armstrong and Aplin (2011, 2014) decided to attribute this unidentified call type to ‘\(M. \text{australis}\) sp.3’. In the absence of improved knowledge on the taxonomy of \(M. \text{australis}\)
species occurring in PNG we attribute the more reserved ‘Miniopterus sp.’ to the call we recorded, whilst knowing that this call could also belong to an undetected species of Pipistrellus, which also has similar call characteristics (Armstrong and Aplin 2014). The two pipistrelle species that have been recorded at altitudes over 2000 m in PNG are P. collinus and P. angulatus, which have characteristic frequencies around 40 and 44 kHz, respectively (Armstrong and Aplin 2011; Robson et al. 2012). P. angulatus recorded at Manus Island had a much higher characteristic frequency of 48 kHz (Armstrong et al. 2015). While the call we recorded fell within the ranges of M. australis and M. schreibersii in terms of characteristic frequency and peak frequency, respectively (Collen 2012), attributing either of the names to this unconfirmed call would be incorrect and misleading as the taxonomy of Miniopterus species occurring in PNG is still unresolved (Appleton et al. 2004; Armstrong 2016; Armstrong and Aplin 2014).

Our record for Miniopterus sp. came as a complete surprise because we recorded it well above the timberline which is usually an alpine zone. The vegetation above 3500 m a.s.l. is a mosaic of alpine grassland with forest patches composed of relatively short trees and with tree ferns scattered throughout (Johns et al. 2007b). The minimum temperature at the alpine grasslands towards the peak of Mt. Wilhelm gets close to zero degrees Celsius (Mcalpine et al. 1983). The bat we detected acoustically is probably using the timberline only as a forage area and might be expected to traverse even higher in the timberline.

Range extensions may either represent more accurate data on the existing geographic ranges of species, or reflect genuine changes in species distribution. In particular, the chances of recording rare species in one-off surveys using limited sampling methods are low. Repeated surveys combining the use of mist nets, harp traps, and acoustic devices greatly increase the chances of detecting all local bat species. Further, many studies tend to accumulate faunistic records from a suite of ad hoc study sites, rather than designing a systematic survey along altitudinal transects as in our study. In particular, the use of harp traps and acoustic recordings along altitudinal gradients in PNG has been very limited (e.g. Flannery and Seri 1990). Our range expansion data are therefore more likely documenting the original geographic ranges of the bat species concerned than any genuine range expansions. However, the importance of such data is increasing with future altitudinal changes to species distributions expected in response to climate change (e.g. Gang et al. 2013; Pecl et al. 2017). Thus, it is important to establish the base line data for climate impact monitoring.

A previous study (Amick 2016) showed that bats are concentrated mostly in the lowlands, with their distribution not reaching the timberline. This is different from birds that also have their greatest species diversity in the lowlands at Mt. Wilhelm, but the decline with altitude in species richness is not as rapid as in bats, with at least 35 bird species recorded in the timberline (Sam et al. 2019).

In conclusion, our study contributes altitudinal range expansions for six bat species as well as providing the highest elevational record of a bat in PNG. Our study demonstrates the need for further research on the altitudinal distribution of bats to ensure accurate baseline data is available for future comparative studies. These data is urgently needed across PNG to allow us to monitor potential changes in species distribution, particularly in relation to climate change.

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Table 1: Morphometric measurements and body mass of bat species recorded outside of their known altitudinal ranges. All species were either mist netted or captured in harp traps.

| Species                      | n      | FA (mm) x ± SD | HB (mm) x ± SD | Ear (mm) x ± SD | Mass (g) x ± SD |
|------------------------------|--------|----------------|----------------|-----------------|-----------------|
| Dobsonia minor               | 1,♀    | 839            | 1131           | 171             | 75              |
| Dobsonia praedatrix          | 1,♀    | 1136           | —              | —               | —               |
| Hipposideros calciratus      | 2,♂♀   | 556.5 ± 30.4   | —              | —               | 15.5 ± 6.4      |
| Hipposideros maggietaylorae  | 2,♀    | 556 ± 6.4      | 657 (n = 1)    | 19.7 (n = 1)    | 16 ± 5.7        |
| Miniopterus australis        | 2,♂♀   | 320 (n = 1)    | 406 ± 28.3     | 89.5 ± 13.4     | 9.5 ± 0.7       |
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**Author contributions:** PKA led the manuscript writing, analyzed data, and interpreted the results. KS, VN and PST conceived ideas and designed the study. PKA and GD collected the data. PKA, PST and GD managed the data. VN, KS and PST contributed to the text and interpretation of results. All authors gave final approval for publication.

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**References**

Amick, P.K. (2016). Composition, α- and β-diversity of bat (Chiroptera) communities along an elevational forest gradient in Papua New Guinea, PGD Science, thesis. Port Moresby, University of Papua New Guinea, Papua New Guinea.

Anthony, N., Byrnes, D., Foufopoulos, J., and Putnam, M. (2001). *Biological survey of New Britain Island, Papua New Guinea*. Falcon Art Media, Madison.

Aplin, K.P., Novera, J., and Armstrong, K.N. (2015). Mammals of Manus and Mussau Islands. In: Whitmore, N. (Ed.), *A rapid biodiversity survey of Papua New Guinea’s Manus and Mussau Islands*. Wildlife Conservation Society, Goroka, pp. 69–85.

Armstrong, K.N. (2016). Bats. In: Richards, S.J. (Ed.), *Biodiversity assessment of the forest in the PNG LNG upstream project area*, Southern Highlands and Hela Provinces, Papua New Guinea. Exxon Mobil PNG, Port Moresby, pp. 222–267.

Ashton, P.S. (2003). Floristic zonation of tree communities on wet tropical mountains revisited. *Perspect. Plant Ecol. Evol. Syst.* 6: 87–104.

Bahir, M.M. and Gabadage, D.E. (2009). Taxonomic errors and inaccuracies in Sri Lanka’s Red List, 2007: a cautionary note. *J. Threat. Taxa* 1: 525–529.

Bonaccorso, F.J. (1998). *Bats of Papua New Guinea*. Conservation International, Washington, D.C.

Bonaccorso, F.J., Winkelmann, J.R., Dumont, E.R., and Thibault, K. (2002). Home range of *Dobsonia minor* (Pteropodidae): a solitary, foliage-roosting fruit bat in Papua New Guinea. *Biotropica* 34: 127–135.

Collen, A. (2012). *The evolution of echolocation in bats: a comparative approach*. PhD. thesis. University College, London.

Flannery, T.F. (1995). *Mammals of New Guinea*. Australian Museum/Reed Books, Chatswood.

Flannery, T.F. and Seri, L. (1990). The mammals of southern West Sepik Province, Papua New Guinea: their distribution, abundance, human use and zoogeography. *Rec. Aust. Mus.* 42: 173–208.

Gang, G., Zhou, W., Li, J., Chen, Y., Mu, S., Ren, J., Chen, J., and Groisman, P.Y. (2013). Assessing the spatiotemporal variation in distribution, extent and NPP of terrestrial ecosystems in response to climate change from 1911 to 2000. *PLoS ONE* 8: e80394.

Hayward, M., Child, M., Kerley, G., Lindsey, P., Somers, M., and Burns, B. (2015). Ambiguity in guideline definitions introduces assessor bias and influences consistency in IUCN Red List status assessments. *Front. Ecol. Evol.* 3: 1–12.

Irwin, N. (2017). A new Tube-nosed fruit bat from New Guinea, *Nyctimene Wrightae* sp. nov, a re-diagnosis of *N. Certans* and *N. Cyclotis* (Pteropodidae: Chiroptera), and a review of their conservation status. *Rec. Aust. Mus.* 69: 73–100.

Johns, R.J., Shea, G., and Puradynatmika, P. (2007a). Lowland vegetation of Papua. In: Marshall, A.J. and Beehler, B.M. (Eds.), *The ecology of Papua*. Periplus Editions, Singapore, pp. 945–961.

Johns, R.J., Shea, G.A., and Puradynatmika, P. (2007b). Subalpine and alpine vegetation of Papua. In: Marshall, A.J. and Beehler, B.M. (Eds.), *The ecology of Papua*. Periplus Editions, Singapore, pp. 1025–1053.

Johns, R.J., Shea, G.A., Vink, W., and Puradynatmika, P. (2007c). Montane vegetation of Papua. In: Marshall, A.J. and Beehler, B.M. (Eds.), *The ecology of Papua*. Periplus Editions, Singapore, pp. 977–1024.

Kale, E., Armstrong, K.N., Amick, P.K., and Woxvold, I. (2018). A survey of the mammals of Uro Creek, Gulf Province, Papua New Guinea. An unpublished report, ExxonMobil PNG Ltd.

Kunz, T.H. (1982). Roosting ecology of bats. In: Kunz, T.H. (Ed.), *Ecology of bats*. Springer, Boston.
Lavery, T.H., Leung, L.K.-P., and Seddon, J.M. (2014). Molecular phylogeny of hipposiderid bats (Chiroptera: Hipposideridae) from Solomon Islands and Cape York Peninsula, Australia. Zool. Scripta 43: 429–442.

McAlpine, J., Keig, G., and Falls, R. (1983). Climate of Papua New Guinea. ANU Press, Canberra.

Menzies, J. (2006). The frogs of New Guinea and the Solomon Islands. Pensoft Publishers, Sofia.

Milá, B., Bruxaux, J., Friis, G., Sam, K., Ashari, H., and Thébaud, C. (2021). A new, undescribed species of Melanocharis berrypecker from western New Guinea and the evolutionary history of the family Melanocharitidae. Ibis 163: 1310–1329.

O’Shea, M. (1996). A guide to the snakes of Papua New Guinea. Independent Publishing, Port Moresby.

Pecl, G.T., Araujo, M.B., Bell, J.D., Blanchard, J., Bonebrake, T.C., Chen, I.-C., Clark, T.D., Colwell, R.K., Danielsen, F., Evergard, B., et al. (2017). Biodiversity redistribution under climate change: impacts on ecosystems and human well-being. Science 355: 1–9.

Pratt, T.K. and Beehler, B.M. (2014). Birds of New Guinea. Princeton University Press, Princeton.

Robson, S.K., Inkster, T.E., and Krockenberger, A.K. (2012). Bats of the YUS Conservation Area, Papua New Guinea. School of Marine and Tropical Biology, James Cook University, Townsville.

Sam, K., Koane, B., Bardos, D.C., Jeppy, S., and Novotny, V. (2019). Species richness of birds along a complete rain forest elevational gradient in the tropics: habitat complexity and food resources matter. J. Biogeogr. 46: 279–290.

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