Biomass, abundances, and abundance and geographical range size relationship of birds along a rainforest elevational gradient in Papua New Guinea (#39040)

First revision

Guidance from your Editor

Please submit by **22 May 2020** for the benefit of the authors .

Structure and Criteria
Please read the 'Structure and Criteria' page for general guidance.

Custom checks
Make sure you include the custom checks shown below, in your review.

Raw data check
Review the raw data. Download from the location described by the author.

Image check
Check that figures and images have not been inappropriately manipulated.

Privacy reminder: If uploading an annotated PDF, remove identifiable information to remain anonymous.

Files

Download and review all files from the materials page.

1 Tracked changes manuscript(s)
1 Rebuttal letter(s)
6 Figure file(s)
1 Raw data file(s)

Custom checks

Vertebrate animal usage checks

- Have you checked the authors ethical approval statement?
- Were the experiments necessary and ethical?
- Have you checked our animal research policies?

Structure and Criteria

Structure your review

The review form is divided into 5 sections. Please consider these when composing your review:

1. **BASIC REPORTING**
2. **EXPERIMENTAL DESIGN**
3. **VALIDITY OF THE FINDINGS**
4. General comments
5. Confidential notes to the editor

You can also annotate this PDF and upload it as part of your review

When ready submit online.

Editorial Criteria

Use these criteria points to structure your review. The full detailed editorial criteria is on your guidance page.

BASIC REPORTING

- ✓ Clear, unambiguous, professional English language used throughout.
- ✓ Intro & background to show context. Literature well referenced & relevant.
- ✓ Structure conforms to PeerJ standards, discipline norm, or improved for clarity.
- ✓ Figures are relevant, high quality, well labelled & described.
- ✓ Raw data supplied (see PeerJ policy).

EXPERIMENTAL DESIGN

- ✓ Original primary research within Scope of the journal.
- ✓ Research question well defined, relevant & meaningful. It is stated how the research fills an identified knowledge gap.
- ✓ Rigorous investigation performed to a high technical & ethical standard.
- ✓ Methods described with sufficient detail & information to replicate.

VALIDITY OF THE FINDINGS

- *i* Impact and novelty not assessed. Negative/inconclusive results accepted. *Meaningful* replication encouraged where rationale & benefit to literature is clearly stated.
- ✓ All underlying data have been provided; they are robust, statistically sound, & controlled.
- ✓ Speculation is welcome, but should be identified as such.
- ✓ Conclusions are well stated, linked to original research question & limited to supporting results.

Standout reviewing tips

The best reviewers use these techniques

Tip	*Example*
Support criticisms with evidence from the text or from other sources	*Smith et al (J of Methodology, 2005, V3, pp 123) have shown that the analysis you use in Lines 241-250 is not the most appropriate for this situation. Please explain why you used this method.*
Give specific suggestions on how to improve the manuscript	*Your introduction needs more detail. I suggest that you improve the description at lines 57- 86 to provide more justification for your study (specifically, you should expand upon the knowledge gap being filled).*
Comment on language and grammar issues	*The English language should be improved to ensure that an international audience can clearly understand your text. Some examples where the language could be improved include lines 23, 77, 121, 128 – the current phrasing makes comprehension difficult.*
Organize by importance of the issues, and number your points	*1. Your most important issue* *2. The next most important item* *3. …* *4. The least important points*
Please provide constructive criticism, and avoid personal opinions	*I thank you for providing the raw data, however your supplemental files need more descriptive metadata identifiers to be useful to future readers. Although your results are compelling, the data analysis should be improved in the following ways: AA, BB, CC*
Comment on strengths (as well as weaknesses) of the manuscript	*I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.*

Biomass, abundances, and abundance and geographical range size relationship of birds along a rainforest elevational gradient in Papua New Guinea

Katerina Sam Corresp., 1, 2 , **Bonny Koane** 3

1 Biology Centre of the Czech Academy of Sciences, Entomology Institute, Ceske Budejovice, Czech Republic

2 University of South Bohemia, Faculty of Science, Ceske Budejovice, Czech Republic

3 The New Guinea Binatang Research Centre, Madang, Papua New Guinea

Corresponding Author: Katerina Sam
Email address: katerina.sam@entu.cas.cz

~~Exceptions were noted in~~ the usually positive inter-specific relationship between geographical range size and abundance of local bird populatio he ority of the exceptions e described in tropical montane areas in Africa, where geographically-restricted bird species are unusually abundant. We ed how the local abundances of passerines and non-passerine of Mt Wilhelm elevational gradient in Papua New Guinea relate to their geographical range size. We collected ~~the~~ data on bird assemblages at eight elevations (200 – 3,700 m, 500 m elevational increment). We used a standardized point count at 16 points at each elevational study site. We partitioned the birds into feeding guilds, and we obtained data on geographical range sizes from Bird-Life International data zone. We observed a positive relationship between ~~the~~ abundance and geographical range size relationship in the lowlands. This trend changed to a negative one towards higher elevations. The total abundances o semblage showed a hump-shaped pattern along the elevational gradient , with passerine birds, namely passerine insectivores, driving the observed pattern. In contrast to abundances, the mean biomass of the bird assemblages decreased with increasing elevation (i.e., showed a different pattern than *mean abundances*). Our results show that montane bird species maintain dense populations which compensate for a smaller area available near ~~to~~ the top of the mountain.

Biomass, abundances, and abundance and geographical range size relationship of birds along a rainforest elevational gradient in Papua New Guinea

Katerina Sam[1,2], Bonny Koane[3]

[1] Biology Centre of the Czech Academy of Sciences, Entomology Institute, Ceske Budejovice, Czech Republic

[2] University of South Bohemia, Faculty of Science, Ceske Budejovice, Czech Republic

[3] The New Guinea Binatang Research Centre, Madang, Papua New Guinea

Corresponding Author:

Katerina Sam[1,2]

Branisovska 31, 370 05, Ceske Budejovice, Czech Republic

Email address: Katerina.sam.cz@gmail.com

Abstract

Exceptions were noted in the usually positive inter-specific relationship between geographical range size and abundance of local bird populations. The majority of the exceptions were described in tropical montane areas in Africa, where geographically-restricted bird species are unusually abundant. We tested how the local abundances of passerines and non-passerine of Mt Wilhelm elevational gradient in Papua New Guinea relate to their geographical range size. We collected the data on bird assemblages at eight elevations (200 – 3,700 m, 500 m elevational increment). We used a standardized point count at 16 points at each elevational study site. We partitioned the birds into feeding guilds, and we obtained data on geographical range sizes from Bird-Life International data zone. We observed a positive relationship between the abundance and geographical range size relationship in the lowlands. This trend changed to a negative one towards higher elevations. The

total abundances of assemblage showed a hump-shaped pattern along the elevational gradient, with passerine birds, namely passerine insectivores, driving the observed pattern. In contrast to abundances, the mean biomass of the bird assemblages decreased with increasing elevation (i.e., showed a different pattern than *mean abundances*). Our results show that montane bird species maintain dense populations which compensate for a smaller area available near to the top of the mountain.

Introduction

Many previous studi und a positive inter-specific relationship between geographical range size and abundance of local populations (Brown 1984; Gaston & Blackburn 2000; Gaston et al. 2000). The authors hypothesized that (1) species utilizing a wider range or more abundant resources become more abundant and widely distributed (Brown 1984), (2) that high population growth leads to higher abundances and to more occupied sites or that (3) intensive dispersal uce a positive inter-specific abundance-range size relationship (Borregaard & Rahbek 2010; Gaston et al. 2000). While there i tensive literature devoted to the patterns of species diversity along elevational gradients (McCain 2009; Rahbek 1995), these studies of species richness have been rarely combined with the study of bird abundance and biomass, arguably more important parameters when it comes to the impact of birds on other trophic levels (but see e.g., (Romdal 2001; Terborgh 1977). Even fewer studies have combined these attributes of bird communities with an estimate of available resources (Ding et al. 2005; Ghosh-Harihar 2013; Price et al. 2014) and/or available area along the mountain ranges (e.g., Ferenc et al. 2016; Price et al. 2014).

Many studies did not pay attention to potential differences between passerine and non-passerine species, or passerine species were considered only. Klopfer & MacArthur (1960) suggested that phylogenetically younger passerines should be relatively more abundant than non-passerines in unstable environments. They assumed that younger passerines have less limited central nervous capacity than non-passerines, making them capable of fitting changing environmental stimuli. In our work, we aimed to test an analogous hypothesis that the non-passerines will be more abundant in favorable tropical lowlands with stable climatic conditions compared to the higher elevations with less stable environments. In the Himalayas, the ratio of passerines to non-passerines increased very slowly between 160 and 2,600 m a.s.l., and abruptly between ca. 3,000 – 4,000 m a.s.l. (Price et al. 2014) (but note that not all non-passerines were surveyed). Similarly, passerine abundance increased relative to non-passerines with increasing elevation in the Andes (Terborgh 1977). Finally, ~~the~~ patterns of abundance or biomass in different feeding guilds with elevation have been rarely investigated in birds. However, they are essential for our understanding of ecosystem dynamics and function; arguably, s as such do not share many ecological functions (Sekercioglu 2006).

The ability of the species to occupy large geographical ranges might also affect their abundances within the range. Macroecologica dies have often revealed positive interspecific correlation between geographical range sizes and abundance of local populations (Brown 1984; Gaston & Blackburn 2000; Gaston et al. 2000). I~~t has been shown that m~~ost of the positive abundance range-size correlation ~~was~~ ~~demonstrated on~~ temperate region datasets (but see Blackburn et al. 2006). ~~Bird assemblages in African montane forest environments were showed to systematically violate the discussed rule (Ferenc et al. 2016, Reif et al. 2006~~ tropical Africa, the geographical range-restricted species are generally more abundant than species with large geographical ranges (Fjeldså et al. 2012). Several other recent studies of tropical montane taxa report that abundance is uncorrelated with (or negatively correlated to) geographical range size (Nana et al. 2014; Reeve et al. 2016) but see ~~(~~Theuerkauf et al. 2017). The only existing study on this topic from Papua New Guinea showed that abundance (capture ra was not related to range size (measured as elevational breadth; Freeman 2018).

Drivers of high abundances of montane forest species are unknown. However, several mutually non-exclusive hypotheses ~~were~~ discu (Ferenc et al. 2016). These are: (1) Long-term ~~eco-~~climatic stability allows specialization of new ecological forms, which then leads to high local abundances of species at mountain tops (Fjeldså et al. 2012). (2) Species-poor communities compensate for density at high altitudes which then leads to high abundances of montane bird species (MacArthur 1972). (3) Locally abundant tropical montane species have higher chances to survive despite their small range sizes. While insuffi ly abundant species get extinct (Johnson 1998).

To investigate the relationship between abundance and area in different regions, we focused on bird assemblages along the elevational gradient of Mt. Wilhelm in Papua New Guinea. Our goals were to investigate (1) trends in abundances of birds along the elevational gradient, (2) changes in relative abundances of different groups of birds (passerines and non-passerines, various feeding guilds), and (3) effects of geographical range sizes on the abundance of individual species.

Materials & Methods

The study was performed along Mt Wilhelm (4,509 m a.s.l.) in the Central Range of Papua New Guinea (Figure 1a, b). The complete rainforest gradient spanned from the lowland floodplains of the Ramu river (200 m a.s.l., 5° 44'S 145° 20'E) to the treeline (3700 m a.s.l., 5° 47'S 145° 03'E; Fig. 1). We completed the study along a 30 km long transect, where eight sites were evenly spaced at 500 m elevational increments. Because of the steep terrain, elevation could deviate by 50 m within each study site. Survey tracks and study sites at each elevation were directed through representative and diverse microhabitats (e.g., ridges, valleys, rivulets; ≥ 250 m from forest edge). In the lowlands, average annual precipitation is 3,288 mm, rising to 4,400 mm at 3,700 m a.s.l. A distinct condensation zone is at around 2,500 – 2,700 m a.s.l. (McAlpine et al. 1983). Mean annual temperature typically decreases at a constant rate of 0.54°C per 100 elevational meters; from 27.4°C at the lowland site (200 m a.s.l.) to 8.37°C at the tree line (3700 m a.s.l.). The habitats of the elevational gradient could be described as lowland alluvial forest (200 m a.s.l.), foothill forest (700 and 1,200 m a.s.l.), lower montane forest (1,700 – 2,700 m a.s.l.), and upper montane forest (3,200 and 3,700 m a.s.l.; according to Paijmans (1976). Plant species composition of forest (Paijmans 1976), general climatic conditions (McAlpine et al. 1983) and habitats at individual study sites (Sam & Koane 2014) are described elsewhere.

Data on bird communit ere collected in 2010, 2011 and 2012 during the wet and dry seasons, using a standardized point-count at 16 points per elevation (Sam & Koane 2014; Sam et al. 2019). The surveys were conducted in the mornings between 5:45 and 11:0 . Each of the 16 sample points had a radius of 50 m (area 0.785 ha per point, which makes 12.56 ha per elevational study site). Points were located 150 m apart to lower the risk of multiple encour f the same individuals. We visited each point on 14 days (8 times during dry season and 6 times during season). The order of the points was altered during each re-survey, to avoid biases due to daytime. Birds were detected for 15 minutes during each visit at each point. This resulted 240 minutes of daily surveys. During the point-counts, we used a distance sampling protocol. The birds were recorded in five 10-m e radial distance bands (Buckland et al. 2001). Detection adjustments, however, proved to b plicable with significant problems in tropics~~.~~ (Banks-Leite et al. 2014). Therefore, we used the observed abundance only estimates instead of the distance sampling-based estimates in the analyses (see similar reasons and discussion by Ferenc et al. 2016). To evaluate the consistency in our data, we (1) compared abundances of birds observed during point-counts (reported here) and from mist-netting conducted at the same sites during the same surveys (Sam et al. 2019), (2) we run all the analyses reported here also with mist-netted data, and we (3) we compared the abundances of the birds recorded during point-counts done in wet and dry season (Figure S1-S3). The data showed that abundances obtained by mist-netting and by point-counts and by point-counts in wet and dry season are well correlated, and that the t remain unchanged, when only mist-netting data are used (Figure S1-S3).

We recorded the number of individuals of each species at any of the 15-min intervals and summed them across all 16 points of each survey day at the certain elevation. Then we averaged these daily abundances across the 14 days (or 6 days of wet season and 8 days of dry season respectively at each elevation). Hereafter we call this measure “*mean elevational abundance*” of a given species at a certain elevational site. After that, we averaged *mean elevational abundances* across the elevations where the bird species was present to calcu “*mean abundance*” of the given species at the elevational gradient. To summarize abundances of bird assemblages at a given elevation (hereafter “*total abundance*”) we calculated the sum of *mean elevational abundances* of all species present at site (i.e. at 16 points within 4 hours long survey). Elevations between minimal and maximal range where birds were missing were not considered, i.e., data were not extrapolated, and the birds were given zero abundance at this elevation. The taxonomy used followed the International Ornithological Congress World Bird List version 6.1.

The elevational m point was calculated as the elevation~~,~~ where the species had the highest abundances. It was calculated ~~a~~ the mean elevational abundances at all sites between lower and upper elevational limit of a species. Based on the ~~distribut~~ ~~l mean~~-point, we divided the species into three groups ~~based on the position of their elevational mean-point~~ as follows: (a) “lowland” group - species with their elevational ~~mean~~-point in the lower part of the elevatio gradient (up to 800 m a.s.l.), (b) “middle” group - species with ~~mean~~-point between 800 and 16 m a.s.l., and (c) “montane” grou pecies with their ~~mean~~-point in the upper third of the gradient (above 1,600 m a.s.l.). Note that ngle species (Great cuckoo-dove - *Reinwardtoena reinwardti*) occurring from nearly along the complete gradient (200-3,200 m) thus fall into the group of montane species.

All recorded bird species were parti d into five trophic guilds: insectivores, frugivores, frugivores-insectivores, insectivores-nectarivores and nectarivores based on dietary information in standard references (Hoyo et al. 1992-2011; Pratt & Beehler 2015) and our data (Sam et al. 2019; Sam et al. 2017). Abundances of passerines and non-passerines and individual feeding guilds were compared by non-parametric Kruskal-Wallis tests. We report mean ± SE and abundances per 12.56 ha recorded in 15-minute-long census unless we state otherwise. Geographical range sizes of all birds were obtained from Bird-Life International data zone web pages accessed in July 2016. Bodyweight (mean for males) of the birds were obtained from Hoyo et al. (1992-2011). Bird metabolism was calculated from bodyweight according to available equations (McNab 2009).

We conducted the field work under the Institutional Animal Care and Use Committee approval permit No. 118 000 561 19 and 999 020 778 29 awarded by PNG National Research Institute permit. Research was further permitted also by Australian Bird and Bat Banding permit No. 3173.

Results

In total, we recorded 25,715 birds belonging to 249 (Table S1 ecies during the point-counts along the elevational gradient of Mt. Wilhelm during this project epresents 87% of bird species recorded along the gradient so far (Marki et al. 2016; Sam & Koane 2014; Sam et al. 2019). Total bird species richness seemed to show a plateau at lower elevations (up to 1700 m a.s.l.) and decreased with increasing elevation afterward (Figure 2a). In contrast, *total abundance* of birds showed a humped shaped pattern, peaking between 1,700 and 2,700 m a.s.l. with ca. 420-450 individuals of all birds per 16 sampling points (i.e., 12.86 ha) (Figure 2c).

Passerines and non-passerines

Passerines were overall more species rich along the elevational gradient, represented by 161 species in comparison to non-passerines represented by 88 species (Figure 2b). We observed a linearly decreasing pattern in species richness of non-passerine birds ($N = 8$, $y = -5.9167x + 60.056$, $R^2 = 0.96$) along the elevational gradient and a hump-shaped pattern ($N = 8$, $y = -2.1012x^2 + 18.982x + 27.315$, $R^2 = 0.92$) in species richness of passerine birds (Figure 2b). The species richness of passerines ($r = 0.52$, $P = 0.19$, $N = 8$) and non-passerines ($r = 0.91$, $P = 0.001$, $N = 8$) correlated with their *total abundances* (Figure 2b, c).

Mean elevational abundances of passerine birds were overall significantly higher (mean ± SD = 3.90 ± 4.8) than *mean elevational abundances* of non-passerines (mean ± SD = 2.46 ± 3.1; $W = 21438$; $P < 0.001$). Total elevational abu ces showed similar results (passerines: 44.5 ± 65.3, non-passerines: 26.7 ± 43.1, W = 22636; 0.001). The *mean elevational abundances* (i.e. mean number of individuals per bird species) increased with increasing elevation of the assemblage, with approximately 2.5 times as many individuals per non-passerine species and nearly twice as many individuals per passerine species at the highest elevation than in the lowlands (Figure 3). The pattern was similar in wet as well as in dry season (Figure S4).

Passerine birds with the elevational mean-point in the montane forest (above 1600 m a.sl.) had higher *mean abundances* than birds with mid- and lowland mean point of distribution (Figure 4a, Table S1). However, with their increasing elevational mean point, the geographical ranges of the species decreased (Figure 4b). We found no significant change in *mean elevational abundances* of non-passerine birds with elevational mean-point (Figure 4c) but similarly to passerines, non-passerines with higher elevational mean-points had smaller ranges (Figure 4c). The abundance range-size relationships for all bird species of the complete forested gradient of Mt. Wilhelm showed a significantly negative relationship ($F_{1,248}$ = 8.22, P = 0.004, Figure S5). The trends remained negative, albeit nonsignificant, for passerines ($F_{1,159}$ = 1.17, P = 0.28) and non-passerines ($F_{1,86}$ = 2.6, P = 0.10) separately (Figure S5). However, the relationship of the three bird groups with different elevational midpoints showed a variable pattern, as the trend changed from a positive relationshp in the lowland group, to no trend for middle species, and negative trend for montane species (Figure S6). The r remained similar, when we split the data into abundances in wet and dry season (Figure S7). Finally, more abundant passerine montane birds had not only larger geographical ranges, but also longer elevational ranges (Figure S8).

Feeding guilds

Without respect to which feeding guild they belong, species occurring at low elevations had usually lower *mean elevational abundances* than species occurring at high elevations (Figure 4a) i.e., their *mean elevational abundance* increased with increasing elevation. Nectarivorous and insectivore-nectarivorous species had the highest *mean elevational abundances* which increased towards higher elevations (Figure 5a). Within insectivores, the pattern was driven purely by presence of flocks of nectar-feedings lorikeets at high elevations (i.e. the pat isappeared when we removed lorikeets from the dataset).

Total abundances of birds belonging to different feeding guilds however showed different patterns (Figure 5b). While *total abundances* of insectivo mid-elevational peak (Figure 5b), *total abundances* of other feeding guilds showed no trend (Figure 5b).

Within passerine birds, the *mean elevational abundances* of birds belonging to different feeding guilds (except frugivores) increased with their elevational mean-point (Figure 5c). In contrast, the *mean elevational abundances* of non-passerines birds belonging to various feeding guilds showed various patterns (Figure 5d).

Mean biomass of bird communities (Figure 6) recorded at each elevational study site decreased with increasing elevati showing different pattern from *mean elevational abundances* and *total abundances*. At the upper most two elevations (3,200 and 3,700 m) mean biomass of passerines was relatively larger than biomass of non-passerines. The pattern of decreasing biomass was observed both with passerines and n-passerines (Figure 6a), as well as in all feeding guilds (Figure 6b). Because large species ~~s ld~~ have ~~a priory~~ la ranges, we tested how strong was the relationship between body size and geographical range. We found only weakly positive correlation between body size and range size in non-passerine birds, and no correlation in passerines (Figure S9).

Discussion

In this study, we focused on the relationships between abundances~~,~~ and range sizes in passerine and non-passerine assemblages along a tropical elevational gradient, while we investigated also ~~their~~ species richne[illegible]pecies richness declines monotonically with increasing elevation on Mt. Wilhelm (Sam et al. 2019). Monotonic decline in species richness is reported to be a typical pattern for mountains with wet-base (McCain 2009). However, *total abundances* of bird assemblages at the individual elevations show a different, a hump-shaped pattern. This is an interesting observation, as previous studies show[illegible]hat unimodal or linearly decreasing patterns on density paralleled the patterns of total species richness along the same gradients (e.g., Pr[illegible]t al. 2014; Romdal 2001; Terborgh 1977). Our findings are similar to patterns in abundances of birds observed along elevational gradient in Cameroon (Ferenc et al. 2016), where a decline in species richness ~~and~~ uniform *t[illegible] abundance* ~~(i[illegible] increase in number of individuals per species)~~ of birds were observed with increasing elevatio[illegible]

The overall pattern in *total abundance* of bird assemblages we observed can be partitioned into a hump-shaped pattern for passerine birds and a decreasing trend for non-passerine birds. Such partitioned patterns correspond better with respective species richness patterns than overall species richness with overall *total abundance*. To our knowledge, there is not a single study focusing separately on abundance pattern in passerine and non-passerine birds along an elevational gradient. Our data further show that species richness and abundance of passerines increase relative to non-passerines with increasing elevation. This might be in concordance with previous suggestions that phylogenetically younger passerines should be relatively more abundant in less favorable and stable environments. Klopfer & MacArthur (1960) showed that the proportions of non-passerines towards passerines change from north to south. A study focusing on a similar pattern along an elevational gradient in Himalaya indicated that ratio between abundances of passerines/non-passerines increases only very slowly between 160 and 2,600 m a.s.l., and then increased abruptly between ca. 3,000 – 4,000 n[illegible]l. (Price et al. 2014). Unfort[illegible]ly, this study did not survey all non-passerines (Price et al. 2[illegible]).

The widespread pattern that abundance is positively correlated with geographic range size (Gaston & Blackburn 2000) does not seem to apply to New Guinean birds distributed along elevational gradients. Contrary to this widely accepted pattern, we described a negative correlation between the local abundance of birds and the complete range size of the given species. The deviation from a positive abundance-area relationship is caused by the combination of a decreasing range sizes and increasing abundances of birds towards high elevations. This observation is also consistent with the idea of taxon cycles whereby endemic species are confined to mountain tops. This observation also further fits to predictions of the densit[illegible]mpensation hypothesis. Individual species may increase their abundances to fill the available ec[illegible]ical space (MacArthur et al. 1972) in species-poor assemblages according to the density compensation hypothesis. The hypothesis thus assumes that small-range species that have insufficiently sparse local populations become extinct.

We showed that New Guinean bird species with small ranges are associated with high local abundances, as has been suggested for marsupials in Australia (Johnson 1998), birds of the Australian wet tropics (Williams et al. 2009) or Afromontane birds (Ferenc et al. 2016). There are only few previous examples of datasets that report either nonsignificant or negative abundance–range-size relationships from the temperate zone birds (Gaston 1996; Päivinen et al. 2005), but several studies have reported nonsignificant or negative abundance–range-size relationships from the tropics, both in birds (Ferenc et al. 2016; Nana et al. 2014; Reeve et al. 2016; Reif et al. 2006). However, studies reporting a positive trend (Theuerkauf et al. 2017) or no trend (Freeman 2018) in the tropics also exist.

Avian species richness declines monotonically with increasing elevation of Mt Wilhelm (Sam et al. 2019), which is a typical pattern for mountains with humid base (McCain 2009). However, we reported here the number of individuals per bird species to be increasing with increasing elevation and decreasing area. Further investigations of our data and its partitioning into feeding guilds showed that patterns of abundances for passerine birds are driven by insectivorous birds, while frugivores drive the decreasing pattern in non-passerines. This seems to be given solely by species richness of the feeding guild within the two groups of birds. While high proportion of the non-passerine birds of Mt. Wilhelm is identified as frugivorous (44%), followed by insectivorous (29%), most of the passerines (59%) are insectivorous.

The contrasting pattern for *total abundance* of passerine and non-passerine bird assemblages is an interesting observation considering the decreasing trend in overall environmental productivity (McCain 2009) and food availability (estimated by abundance of insects or fruits) along the elevational gradient (e.g., Janzen et al. 1976; Loiselle & Blake 1991), especially along wet mountains like Mt. Wilhelm (McCain 2009). On the other hand, observed patterns in abundances of both groups of birds are parallel to the species richness of these groups along our gradient which corresponds with previously reported results on relationship on abundance and species richness along elevational gradients (Terborgh 1977).

Mean biomass of bird communities recorded at each elevational study site decreased quite steeply with increasing elevation, showing ~~the~~ different pattern than *total abundances* of birds at given sites. At the upper most two elevations (3,200 and 3,700 m) mean biomass of passerines was relatively larger than biomass of non-passerines which corresponds partly also with their *mean elevational abundances* at these elevations. The decrease in biomass suggest decrease in energy flux into the birds at given elevation, very likely because of reduction of primary productivity (Dolton & de L. Brooke 1999).

Conclusions

In direct contrast to abundance-geographical range size relationship hypothesis investigated here, we found that montane species which associated with small geographical ranges have locally higher abundances than lowland species which are associated with large geographical ranges. The *mean abundances* of passerine and non-passerine birds follow a similar trend (significant for passerines, but nonsignificant for non-passerines), with montane birds having higher abundances then lowland birds. Abundances of passerines seem to be driven by insectivores, while non-passerines seem to be driven by frugivores. Our data further show that passerines and non-passerines have different patterns of species richness and *total abundance* along the same elevational gradient.

Acknowledgments

We wish to thank numerous field assistants from Kausi, Numba, Bundi, Bruno Sawmill, Sinopass, and Kegesugl for help in the field and hospitality.

References

Banks-Leite C, Pardini R, Boscolo D, Cassano CR, Püttker T, Barros CS, and Barlow J. 2014. Assessing the utility of statistical adjustments for imperfect detection in tropical conservation science. *Journal of Applied Ecology* 51:849-859.

Blackburn TM, Cassey P, and Gaston KJ. 2006. Variations on a theme: sources of heterogeneity in the form of the interspecific relationship between abundance and distribution. *Journal of Animal Ecology* 75:1426-1439.

Borregaard MK, and Rahbek C. 2010. Causality of the relationship between geographic distribution and species abundance. *The quarterly review of biology* 85:3-25.

Brown JH. 1984. On the relationship between abundance and distribution of species. *The American Naturalist* 124:255-279.

Buckland S, Anderson D, Burnham K, Laake J, Borchers D, and Thomas L. 2001. Introduction to distance sampling: Oxford University Press. *Oxford Considerations and Management Recommendations: Wildlife Society Bulletin* 34:1393-1395.

Ding TS, Yuan HW, Geng S, Lin YS, and Lee PF. 2005. Energy flux, body size and density in relation to bird species richness along an elevational gradient in Taiwan. *Global Ecology and Biogeography* 14:299-306.

Ferenc M, Fjeldså J, Sedláček O, Motombi FN, Nana ED, Mudrová K, and Hořák D. 2016. Abundance-area relationships in bird assemblages along an Afrotropical elevational gradient: space limitation in montane forest selects for higher population densities. *Oecologia* 181:225-233.

Fjeldså J, Bowie RC, and Rahbek C. 2012. The role of mountain ranges in the diversification of birds. *Annual Review of Ecology, Evolution, and Systematics* 43:249-265.

Freeman BG. 2018. No evidence for a positive correlation between abundance and range size in birds along a New Guinean elevational gradient. *Emu-Austral Ornithology*:1-9.

Gaston KJ. 1996. The multiple forms of the interspecific abundance-distribution relationship. *Oikos*:211-220.

Gaston KJ, and Blackburn TM. 2000. *Pattern and process in macroecology*. Oxford: Blackwell Publishing.

Gaston KJ, Blackburn TM, Greenwood JJ, Gregory RD, Quinn RM, and Lawton JH. 2000. Abundance–occupancy relationships. *Journal of Applied Ecology* 37:39-59.

Ghosh-Harihar MJ. 2013. Distribution and abundance of foliage-arthropods across elevational gradients in the east and west Himalayas. *Journal of animal ecology* 28:125-130.

Hoyo dJ, Elliott J, Sargatal J, and Christie DA. 1992-2011. Handbook of the Birds of the World (vol. 1-16). Barcelona, Spain: Lynx Editions.

Janzen DH, Ataroff M, Fariñas M, Reyes S, Rincon N, Soler A, Soriano P, and Vera M. 1976. Changes in the arthropod community along an elevational transect in the Venezuelan Andes. *Biotropica* 8:193-203.

Johnson C. 1998. Species extinction and the relationship between distribution and abundance. *Nature* 394:272-274.

Klopfer PH, and MacArthur RH. 1960. Niche size and faunal diversity. *American Naturalist* :293-300.

Loiselle BA, and Blake JG. 1991. Temporal variation in birds and fruits along an elevational gradient in Costa Rica. *Ecology* :180-193.

MacArthur RH. 1972. *Geographical ecology: patterns in the distribution of species*: Princeton University Press.

MacArthur RH, Diamond JM, and Karr JR. 1972. Density compensation in island faunas. *Ecology* 53:330-342.

Marki PZ, Sam K, Koane B, Kristensen JB, Kennedy JD, and Jønsson KA. 2016. New and noteworthy bird records from the Mt. Wilhelm elevational gradient, Papua New Guinea. *Bulletin of Brittish Ornithology Club* 137:263-271.

McAlpine JR, Keig R, and Falls R. 1983. Climate of Papua New Guinea. *CSIRO and Australian National University Press, Canberra*.

McCain CM. 2009. Global analysis of bird elevational diversity. *Global Ecology and Biogeography* 18:346-360.

Nana ED, Sedláček O, Bayly N, Ferenc M, Albrecht T, Reif J, Motombi FN, and Hořák D. 2014. Comparison of avian assemblage structures in two upper montane forests of the Cameroon volcanic line: lessons for bird conservation. *Biodiversity and Conservation* 23:1469-1484.

Paijmans K. 1976. New Guinea Vegetation. In: Paijmans K, editor. Canberra: National University Press. p 212 pp.

Päivinen J, Grapputo A, Kaitala V, Komonen A, Kotiaho JS, Saarinen K, and Wahlberg N. 2005. Negative density-distribution relationship in butterflies. *Bmc Biology* 3:5.

Pratt TK, and Beehler BM. 2015. *Birds of New Guinea*: Princeton University Press.

Price TD, Hooper DM, Buchanan CD, Johansson US, Tietze DT, Alström P, Olsson U, Ghosh-Harihar M, Ishtiaq F, and Gupta SK. 2014. Niche filling slows the diversification of Himalayan songbirds. *Nature* 509:222-225.

Rahbek C. 1995. The elevational gradient of species richness: a uniform pattern? *Ecography* 18:200-205.

Reeve AH, Borregaard MK, and Fjeldså J. 2016. Negative range size–abundance relationships in Indo-Pacific bird communities. *Ecography* 39:990-997.

Reif J, Hořák D, Sedláček O, Riegert J, Pešata M, Hrázský Z, Janeček Š, and Storch D. 2006. Unusual abundance–range size relationship in an Afromontane bird community: the effect of geographical isolation? *Journal of Biogeography* 33:1959-1968.

Romdal TS. 2001. Altitudinal distribution and abundance patterns of bird species in the Eastern Arc Mountains, Tanzania. *Scopus* 21:35-54.

Sam K, and Koane B. 2014. New avian records along the elevational gradient of Mt. Wilhelm, Papua New Guinea. *Bulletin of the British Ornithologists' Club* 134:116-133.

Sam K, Koane B, Bardos DC, 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. *Journal of Biogeography* 46:279-290.

Sam K, Koane B, Jeppy S, Sykorova J, and Novotny V. 2017. Diet of land birds along an elevational gradient in Papua New Guinea. *Scientific Reports* 7:44018.

Sekercioglu CH. 2006. Increasing awareness of avian ecological function. *Trends in Ecology & Evolution* 21:464-471.

Terborgh J. 1977. Bird species diversity on an Andean elevational gradient. *Ecology* 58:1007-1019.

Theuerkauf J, Chartendrault V, Desmoulins F, Barré N, and Gula R. 2017. Positive range–abundance relationships in Indo-Pacific bird communities. *Journal of Biogeography* 44:2161-2163.

Williams S, Williams YM, VanDerWal J, Isaac JL, Shoo LP, and Johnson CN. 2009. Ecological specialization and population size in a biodiversity hotspot: how rare species avoid extinction. *Proceedings of the National Academy of Sciences* 106:19737-19741.

Figure 1. Location of the elevational gradient of Mt. Wilhelm in Papua New Guinea (a) and the study sites along the gradient (b).

Figure 2. Species richness (fitted with exponential function: $y = -2.4107x^2 + 11.756x + 93.946$, $R^2 = 0.95$) of all birds recorded during point-counts from along the elevational gradient of Mt. Wilhelm (a); species richness of passerine and non-passerine birds separately (b). Total (i.e. summed) abundances of passerine (grey) and non-passerine (black) birds at respective elevational sites (c).

Figure 3. *Mean elevational abundance* of a passerine and non-passerine bird species (±SE) (i.e. mean number of individuals of a given species at a given elevation) occurring in the particular assemblage along the elevational gradient of Mt Wilhelm (fitted with loess smooth function).

Figure 4. Passerine (a ,b) and non-passerine (c, d) birds divided into three groups based on the position of their mean-point of elevational distribution on Mt. Wilhelm, and their *mean abundances* (a, c) and geographical range sizes in km^2 (b, d). Kruskal-Wallis - passerines (a) $\chi^2 = 16.3$, df = 2, N = 161, $P < 0.001$; (b) $\chi^2 = 67.3$, df = 2, N = 161, $P < 0.001$; non-passerines (c) $\chi^2 = 1.2$, df = 2, N = 88, P = 0.549; (d) $\chi^2 = 19.5$, df = 2, N = 88, $P < 0.001$. Lowland group = elevational mean-point up to 800m a.s.l., mid group = elevational mean-point between 801 and 1600m a.s.l., and montane group = elevational mean-point above 1600 m a.s.l.

Figure 5. *Mean elevational abundances* of birds partitioned into feeding guilds (a) and *total abundance* of bird assemblages partitioned into feeding guilds (b). *Mean abundances* of birds partitioned into feeding guilds and into passerines (c) and non-passerines (d). *Mean elevational abundance* refers to mean number of individuals of a given species at a given elevation. Subsequently, *mean abundance* refers to averaged *mean elevational abundances* of a species across all elevations where it was present. *Total abundance* refers to aggregated abundances of bird assemblage at a given elevations. Ne – Nectarivores, In – Insectivores, In-Ne – Insectivore-nectarivores, Fr – Frugivores, Fr-In – Frugivore-insectivores. Standard errors of the mean are not shown for the clarity of the graph. Lowland group = elevational mid-point up to 800m a.s.l., mid group = elevational mid-point between 801 and 1600m a.s.l., and montane group = elevational mid-point above 1600 m a.s.l.

Figure 6. Mean biomass (across the re-surveys of all point-counts) of passerine and non-passerine birds (a) and birds partitioned into feeding guilds (b) of Mt. Wilhelm (total biomass in kg/12.86 ha).

Figure 1.

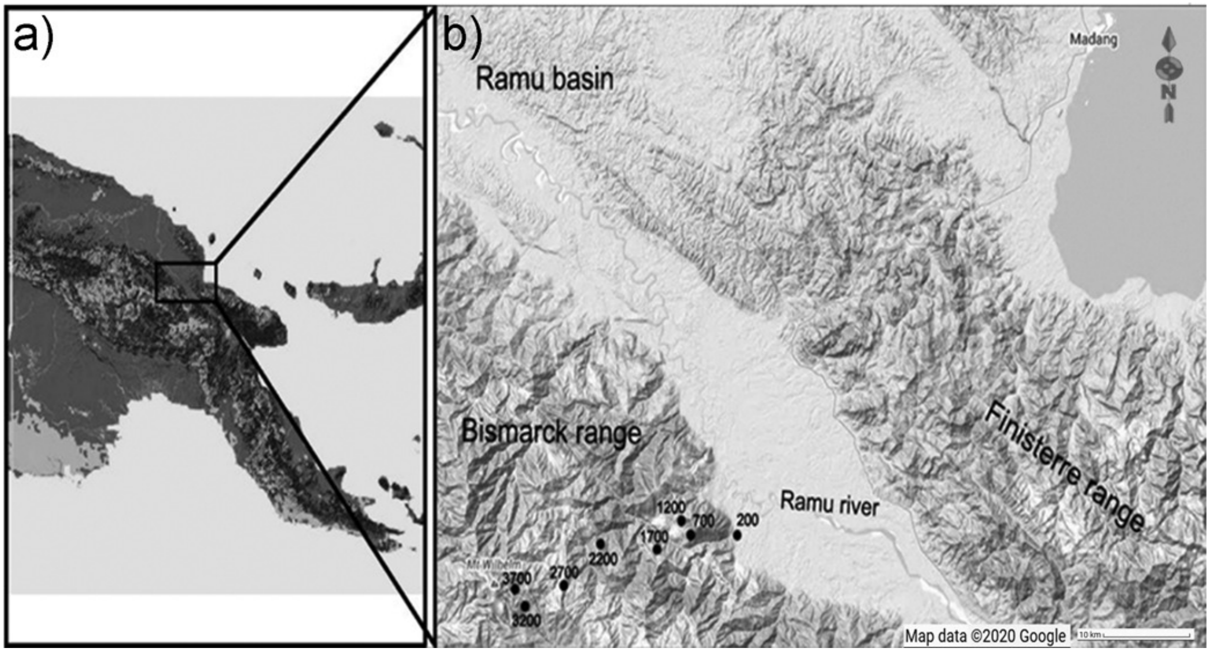
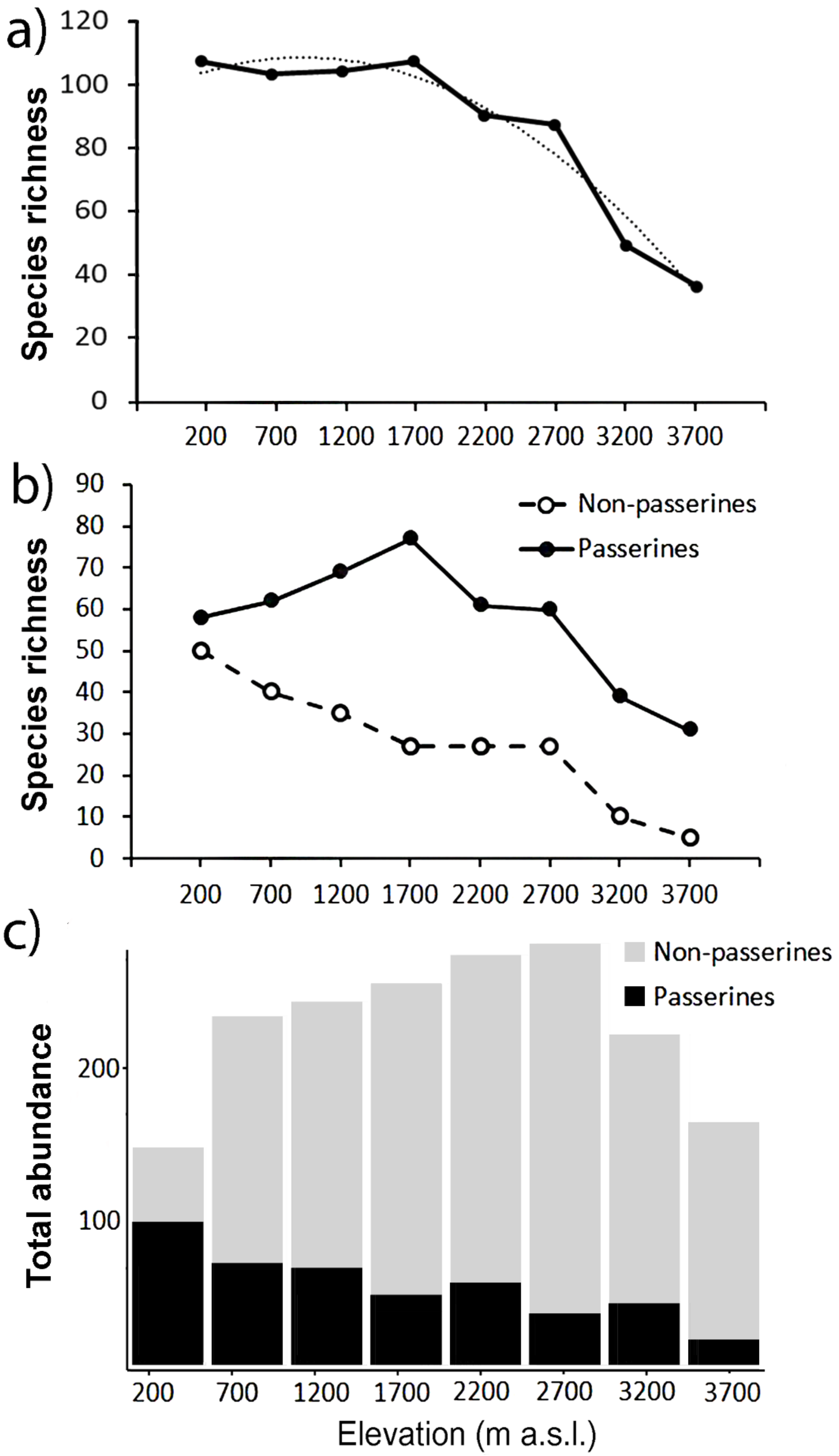

a)
b)
Ramu basin
Madang
N
Bismarck range
Finisterre range
Ramu river
1200
700
200
1700
2200
2700
Mt Wilhelm
3700
3200
Map data ©2020 Google
10 km

Figure 2.


a)
Species richness
120
100
80
60
40
20
0
200
700
1200
1700
2200
2700
3200
3700
b)
Species richness
90
80
70
60
50
40
30
20
10
0
Non-passerines
Passerines
200
700
1200
1700
2200
2700
3200
3700
c)
Total abundance
200
100
Non-passerines
Passerines
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)

487

488

Figure 3.

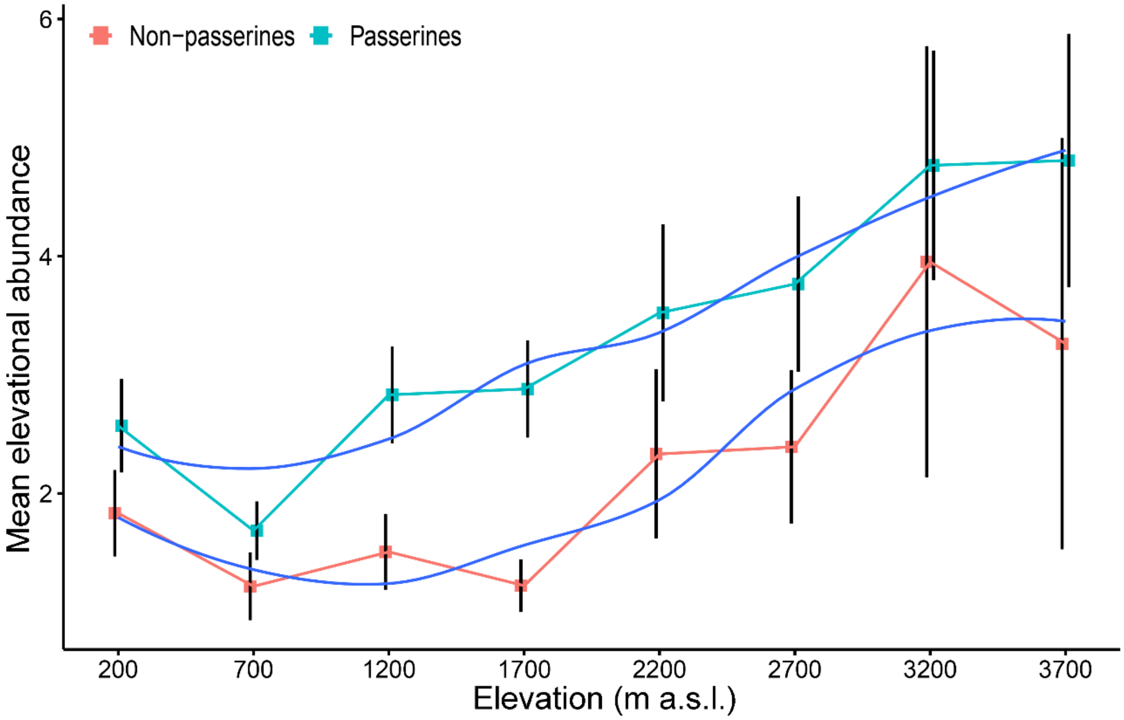

Non−passerines
Passerines
Mean elevational abundance
2
4
6
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)

Figure 4.

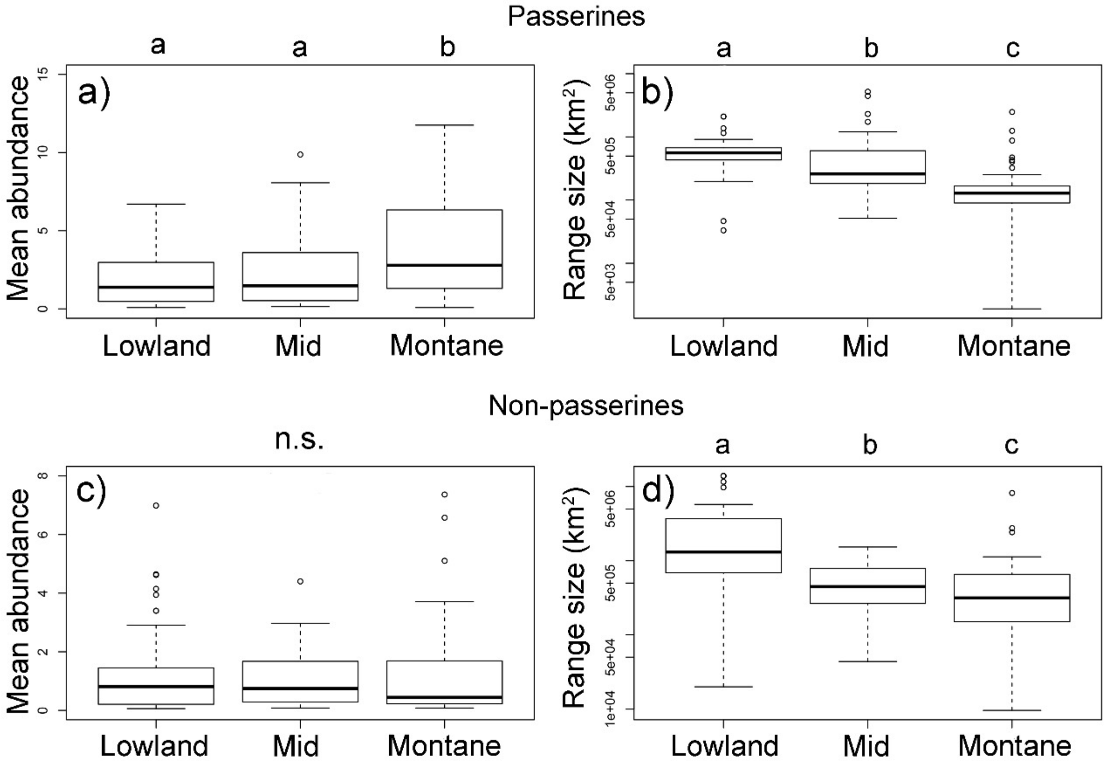

Passerines
a
a
b
a)
Mean abundance
0
5
10
15
Lowland
Mid
Montane
a
b
c
b)
Range size (km^2)
5e+03
5e+04
5e+05
5e+06
Lowland
Mid
Montane
Non-passerines
n.s.
c)
Mean abundance
0
2
4
6
8
Lowland
Mid
Montane
a
b
c
d)
Range size (km^2)
1e+04
5e+04
5e+05
5e+06
Lowland
Mid
Montane

Figure 5.

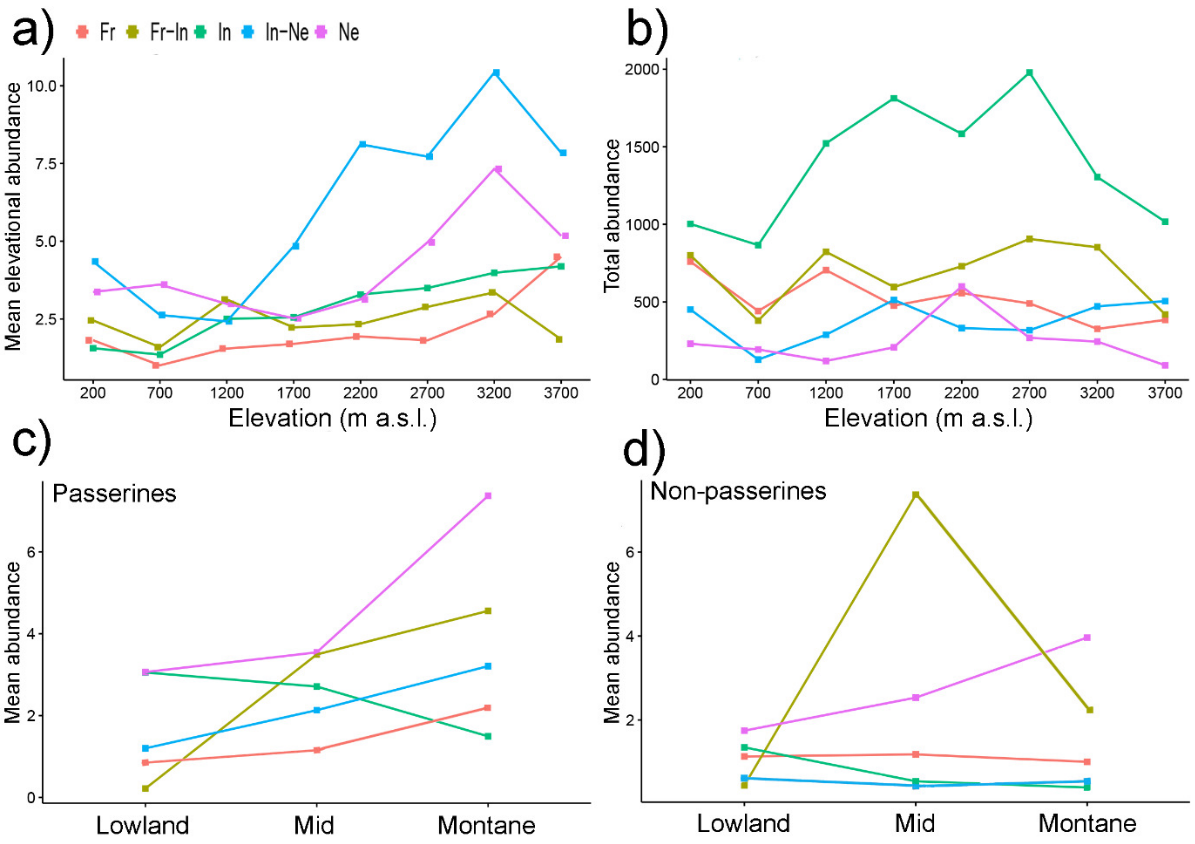

a)
Fr
Fr-In
In
In-Ne
Ne
Mean elevational abundance
10.0
7.5
5.0
2.5
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)
b)
Total abundance
2000
1500
1000
500
0
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)
c)
Passerines
Mean abundance
6
4
2
0
Lowland
Mid
Montane
d)
Non-passerines
Mean abundance
6
4
2
Lowland
Mid
Montane

Figure 6.

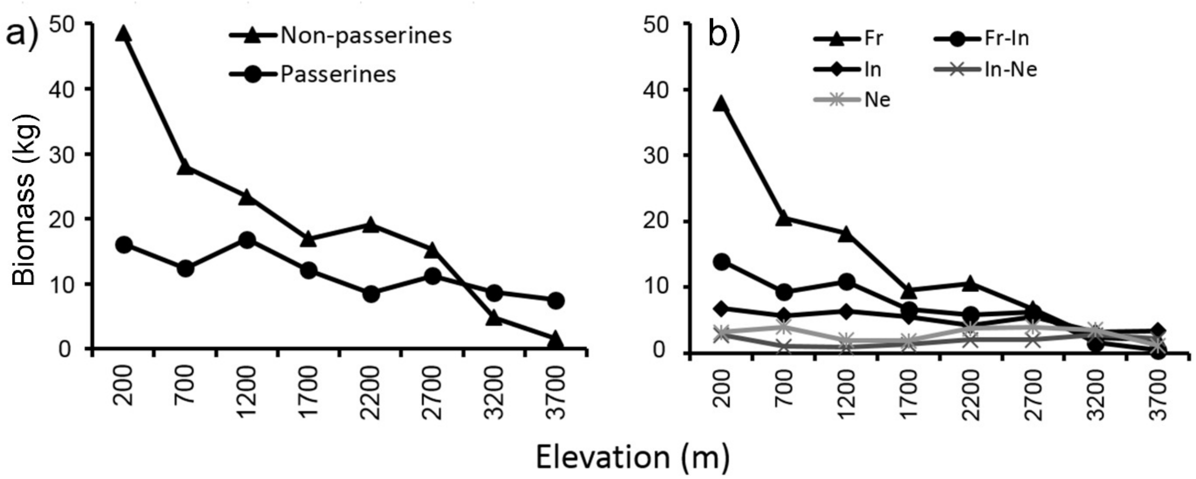

a)
b)
Biomass (kg)
0
10
20
30
40
50
Non-passerines
Passerines
Fr
Fr-In
In
In-Ne
Ne
200
700
1200
1700
2200
2700
3200
3700
Elevation (m)

Figure 1

Location of the elevational gradient of Mt. Wilhelm in Papua New Guinea and the study sites along the gradient.

Location of the elevational gradient of Mt. Wilhelm in Papua New Guinea (a) and the study sites along the gradient (b).

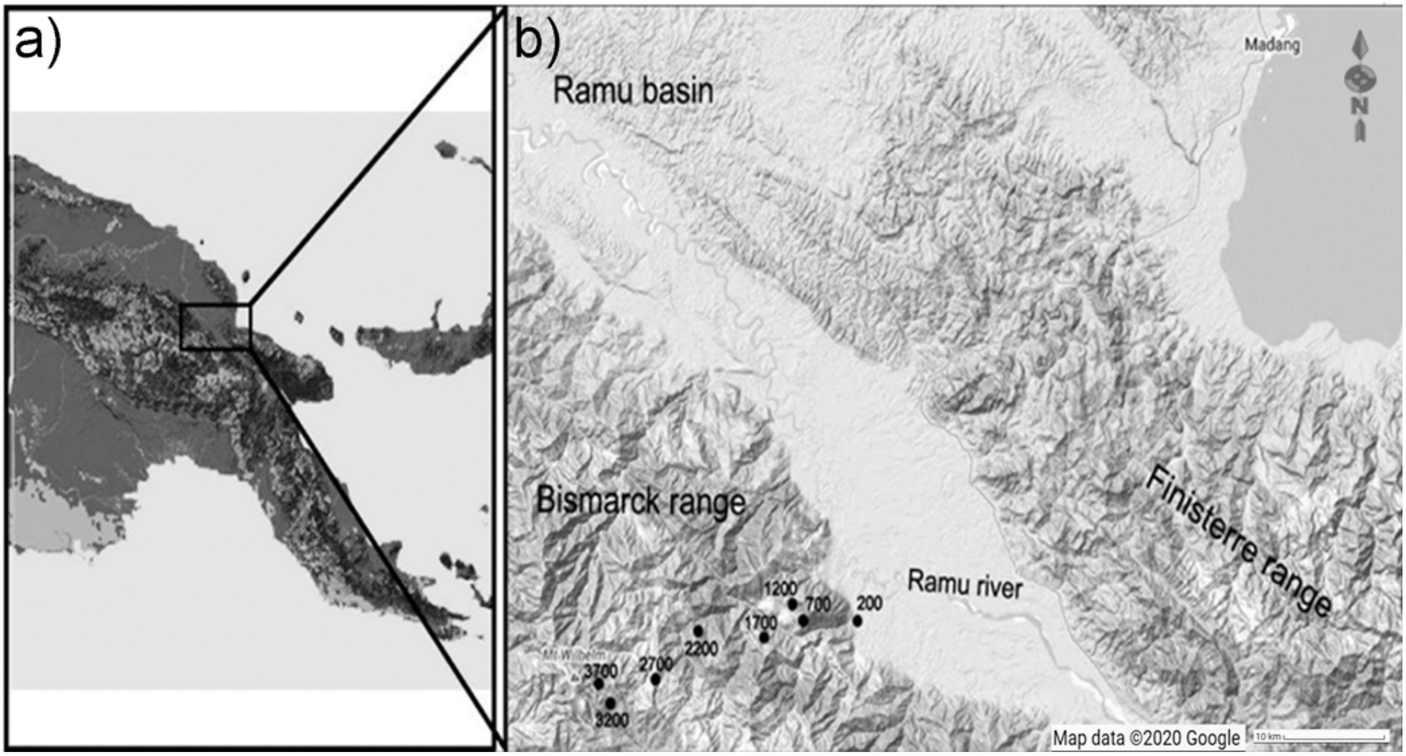


Figure 2

Patterns of species richness and total abundance of all birds along the elevational gradient of Mt. Wilhel.

Species richness (fitted with exponential function: $y = -2.4107x^2 + 11.756x + 93.946$, $R^2 = 0.95$) of all birds recorded during point-counts from along the elevational gradient of Mt. Wilhelm (a); species richness of passerine and non-passerine birds separately (b). Total (i.e. summed) abundances of passerine (grey) and non-passerine (black) birds at respective elevational sites (c).

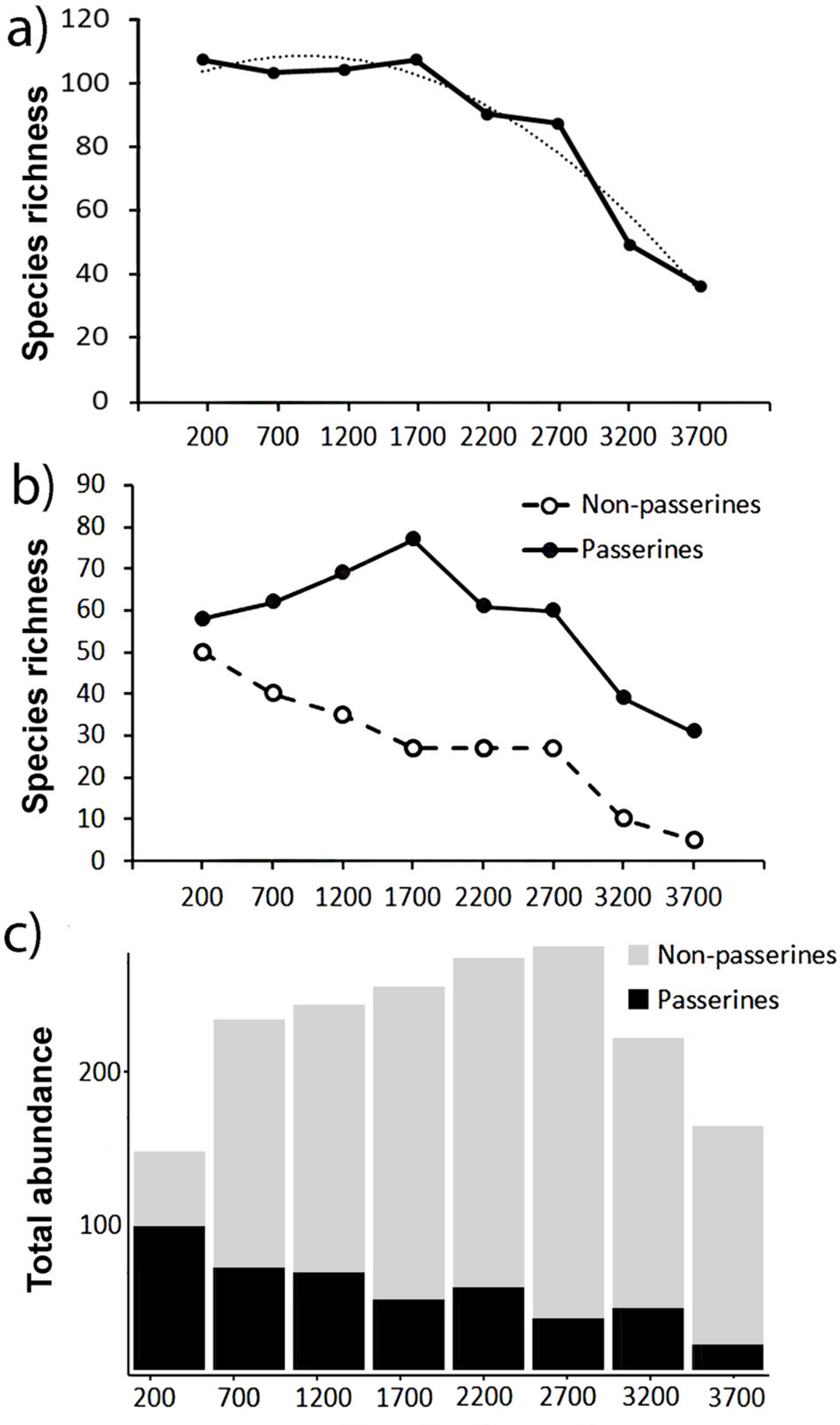

a)
Species richness
120
100
80
60
40
20
0
200
700
1200
1700
2200
2700
3200
3700
b)
Species richness
90
80
70
60
50
40
30
20
10
0
Non-passerines
Passerines
200
700
1200
1700
2200
2700
3200
3700
c)
Total abundance
200
100
Non-passerines
Passerines
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)

Figure 3

Mean elevational abundance of a passerine and non-passerine bird species along the elevational gradient of Mt Wilhel.

Mean elevational abundance of a passerine and non-passerine bird species (±SE) (i.e. mean number of individuals of a given species at a given elevation) occurring in the particular assemblage along the elevational gradient of Mt Wilhelm (fitted with loess smooth function).

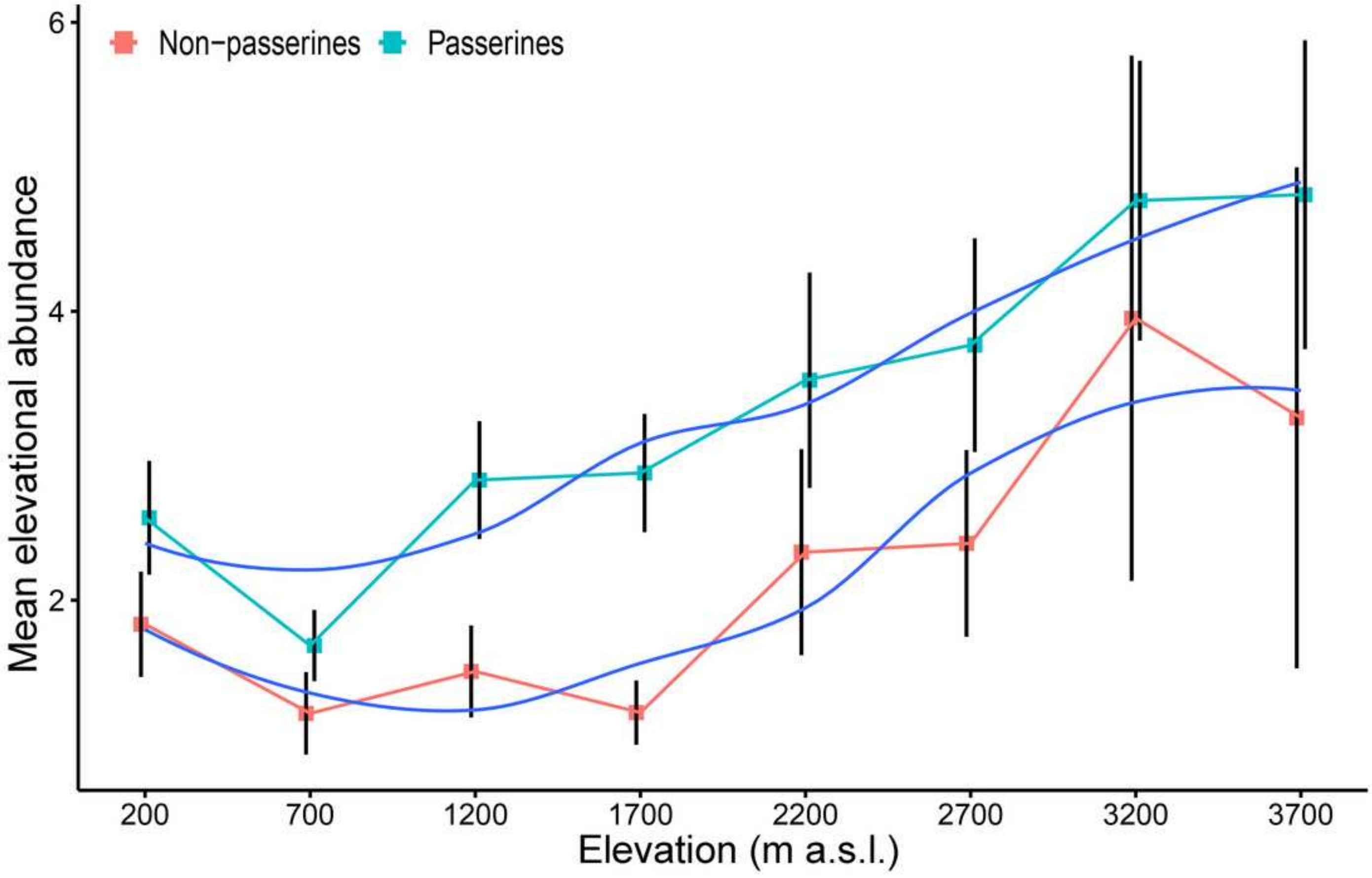


Figure 4

Passerine and non-passerine birds divided into three groups based on the position of their mean-point of elevational distribution on Mt. Wilhelm, and their *mean abundances* and geographical range sizes in km^2

Passerine (a ,b) and non-passerine (c, d) birds divided into three groups based on the position of their mean-point of elevational distribution on Mt. Wilhelm, and their *mean abundances* (a, c) and geographical range sizes in km^2 (b, d). Kruskal-Wallis - passerines (a) $\chi^2 = 16.3$, df = 2, N = 161, P < 0.001; (b) $\chi^2 = 67.3$, df = 2, N = 161, P < 0.001; non-passerines (c) $\chi^2 = 1.2$, df = 2, N = 88, P = 0.549; (d) $\chi^2 = 19.5$, df = 2, N = 88, P < 0.001. Lowland group = elevational mean-point up to 800m a.s.l., mid group = elevational mean-point between 801 and 1600m a.s.l., and montane group = elevational mean-point above 1600 m a.s.l.

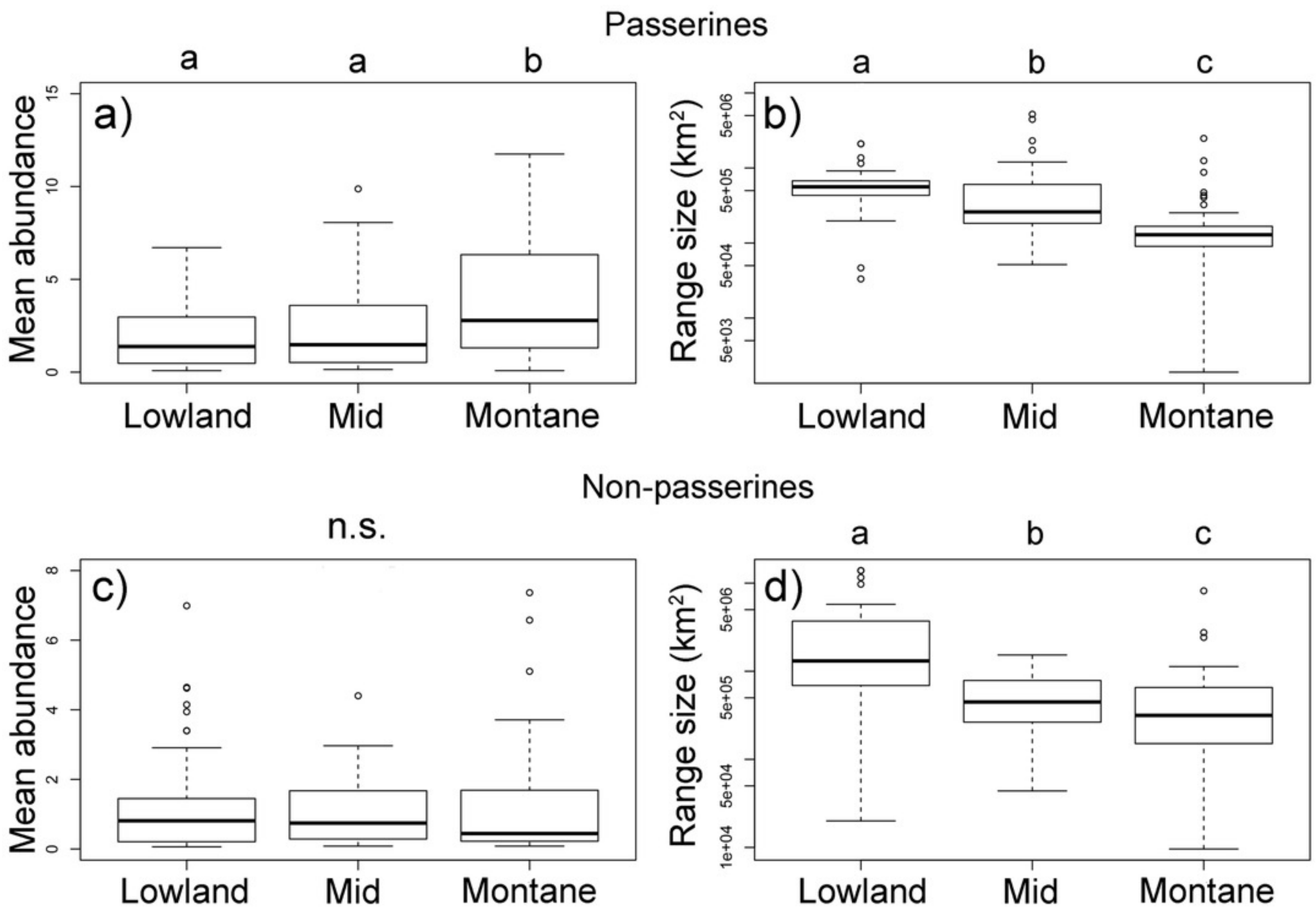

Passerines
a
a
b
a)
Mean abundance
0
5
10
15
Lowland
Mid
Montane
a
b
c
b)
Range size (km^2)
5e+03
5e+04
5e+05
5e+06
Lowland
Mid
Montane
Non-passerines
n.s.
c)
Mean abundance
0
2
4
6
8
Lowland
Mid
Montane
a
b
c
d)
Range size (km^2)
1e+04
5e+04
5e+05
5e+06
Lowland
Mid
Montane

Figure 5

Mean elevational abundances of birds partitioned into feeding guilds and *total abundance* of bird assemblages partitioned into feeding guild.

Mean elevational abundances of birds partitioned into feeding guilds (a) and *total abundance* of bird assemblages partitioned into feeding guilds (b). *Mean abundances* of birds partitioned into feeding guilds and into passerines (c) and non-passerines (d). *Mean elevational abundance* refers to mean number of individuals of a given species at a given elevation. Subsequently, *mean abundance* refers to averaged *mean elevational abundances* of a species across all elevations where it was present. *Total abundance* refers to aggregated abundances of bird assemblage at a given elevations. Ne – Nectarivores, In – Insectivores, In-Ne – Insectivore-nectarivores, Fr – Frugivores, Fr-In – Frugivore-insectivores. Standard errors of the mean are not shown for the clarity of the graph. Lowland group = elevational mid-point up to 800m a.s.l., mid group = elevational mid-point between 801 and 1600m a.s.l., and montane group = elevational mid-point above 1600 m a.s.l.

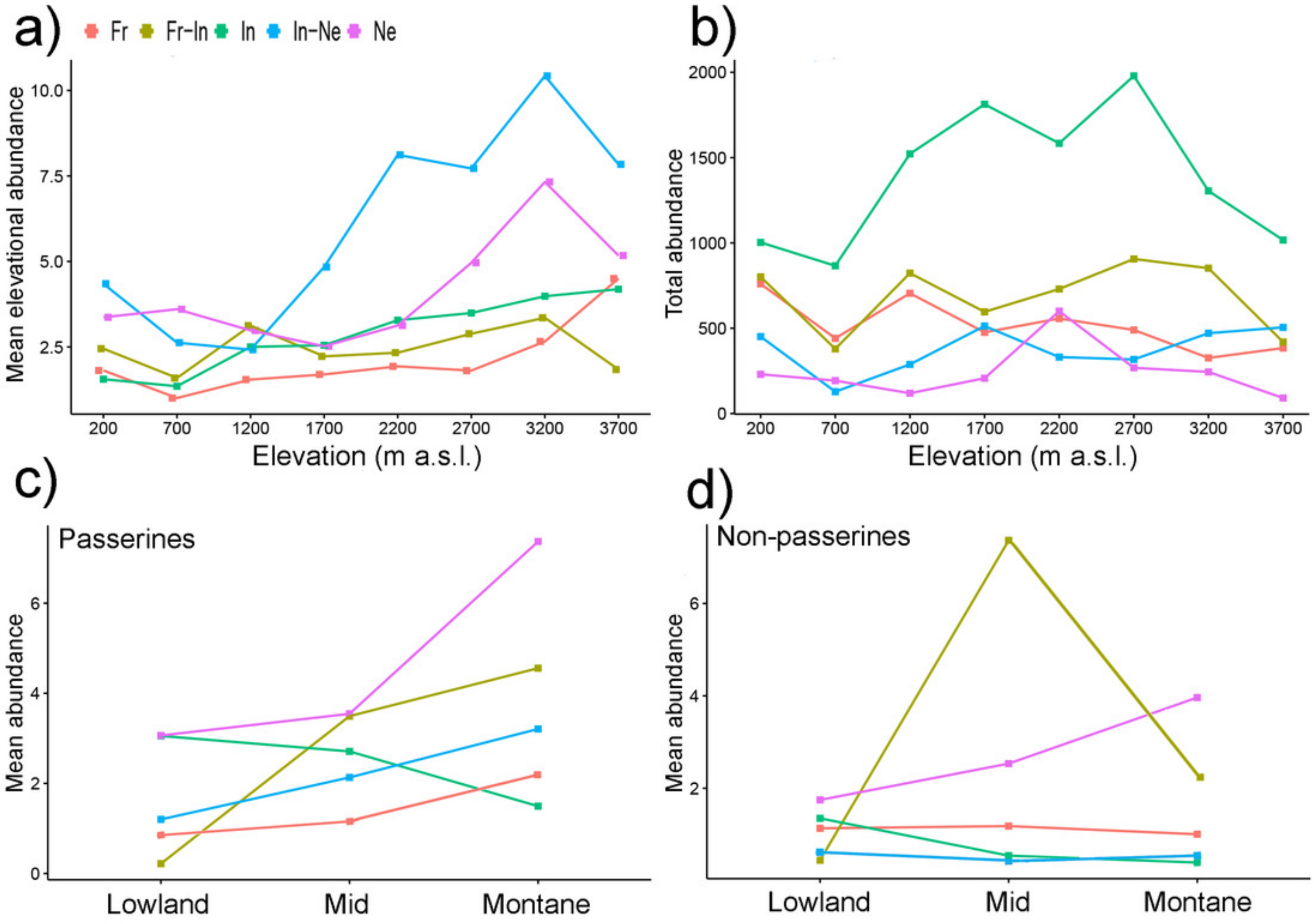

a)
Fr
Fr-In
In
In-Ne
Ne
Mean elevational abundance
10.0
7.5
5.0
2.5
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)
b)
Total abundance
2000
1500
1000
500
0
200
700
1200
1700
2200
2700
3200
3700
Elevation (m a.s.l.)
c)
Passerines
Mean abundance
6
4
2
0
Lowland
Mid
Montane
d)
Non-passerines
Mean abundance
6
4
2
Lowland
Mid
Montane

Figure 6

Mean biomass of passerine and non-passerine birds and birds partitioned into feeding guilds of Mt. Wilhelm.

Mean biomass (across the re-surveys of all point-counts) of passerine and non-passerine birds (a) and birds partitioned into feeding guilds (b) of Mt. Wilhelm (total biomass in kg/12.86 ha).

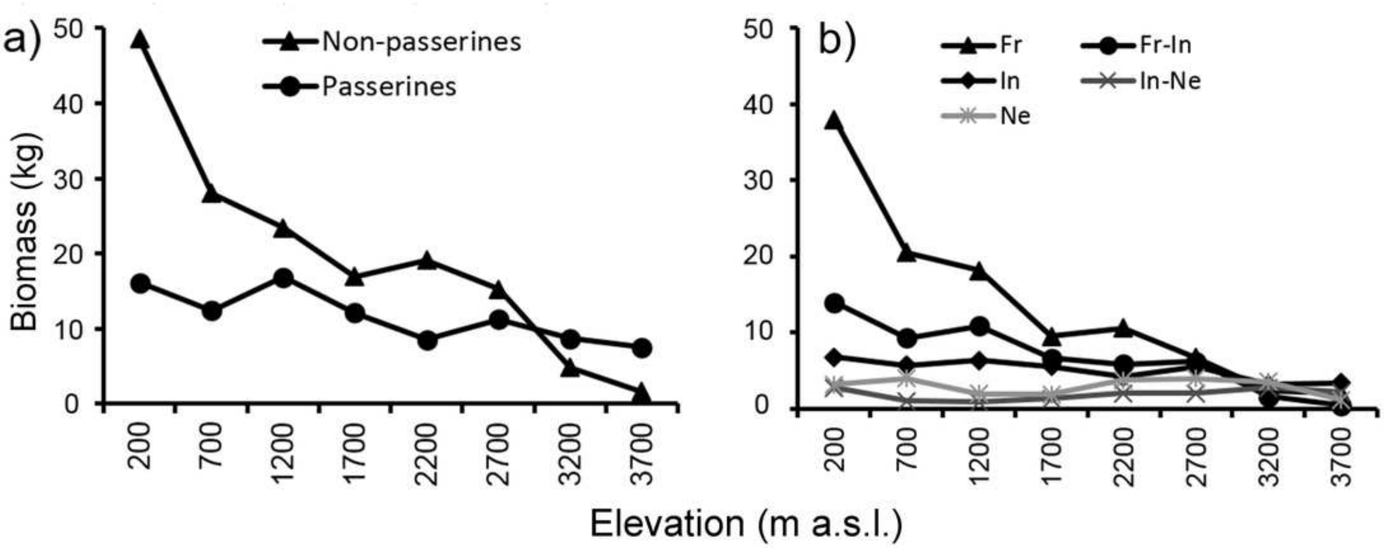


Figure S1. Correlation between mean abundances of all bird species recorded during point-counts (PC) and during mist-netting (MN, data from (Sam et al. 2019)). The correlation between the data was rather close, with some birds being recorded only during point-counts but not during mist-netting. Typically, these were canopy species like pigeons and doves. A species which was often recorded during point-counts but only rarely in nets was a canopy occupying honeyeater *Melidectes belfordi* (abundances 19.8 in PC vs. 2 in MN).

Deleted: Spearman c

Deleted: to

Commented [MOU1]: give number of species

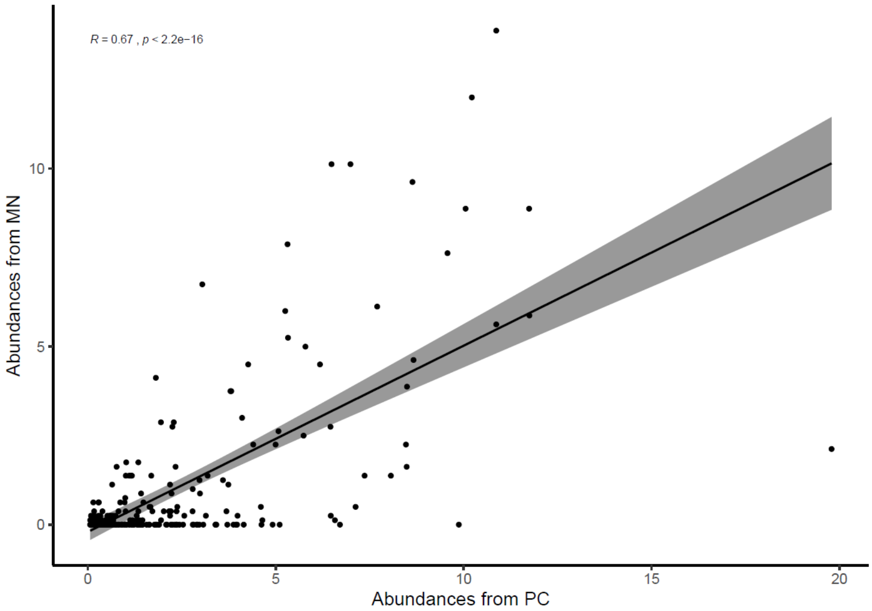


Figure S2. Non-passerine and passerine birds divided into three groups based on the position of their mean-point of elevational distribution on Mt. Wilhelm and their mean abundance obtained from mist-netting data (data from Sam et al. 2019) of individual species across elevations (a) and their range sizes in km^2 (b). Significant differences between the groups of birds are denoted by different letters above the box-plots. Note log scale used on y-axis and different scale of y-axes in part a and b. Lowland group = elevational mid-point up to 800m a.s.l., mid group = elevational mid-point between 801 and 1600m a.s.l., and montane group = elevational mid-point above 1600 m a.s.l. : Kruskal-Wallis test for Passerines (N = 161) (a) $\chi^2 = 22.4$, df = 2, N = 161, P < 0.001, (b) $\chi^2 = 67.3$, df = 2, N = 161, P < 0.001. Non-passerines (N = 88) (c) $\chi^2 = 1.89$, df = 2, N = 88, P =0.388 (d) $\chi^2 = 19.546$, df = 2, N = 88, P < 0.001.

Commented [MOU2]: again it isn't clear to me that mean abundance (the average of all sites where at least one bird was caught?) makes sense.

Deleted: m

Deleted: (

Commented [MOU3]: it might be simpler to list the elevations (200, 700); (1200); (1700, 2200, 2700, 3200, 3700). is there any reason to split them in this particular way

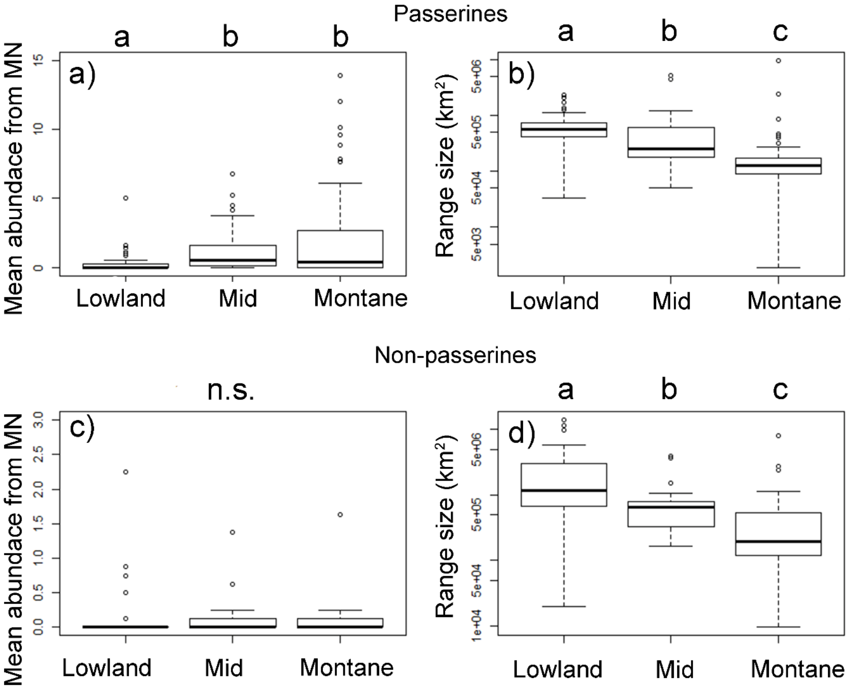


Figure S3. Correlation between mean elevational abundances of all bird species recorded during point-counts (249 species * 8 elevations = > N = 1992). Intercept shows data for passerines only (N = 1288).

Commented [MOU4]: across seasons

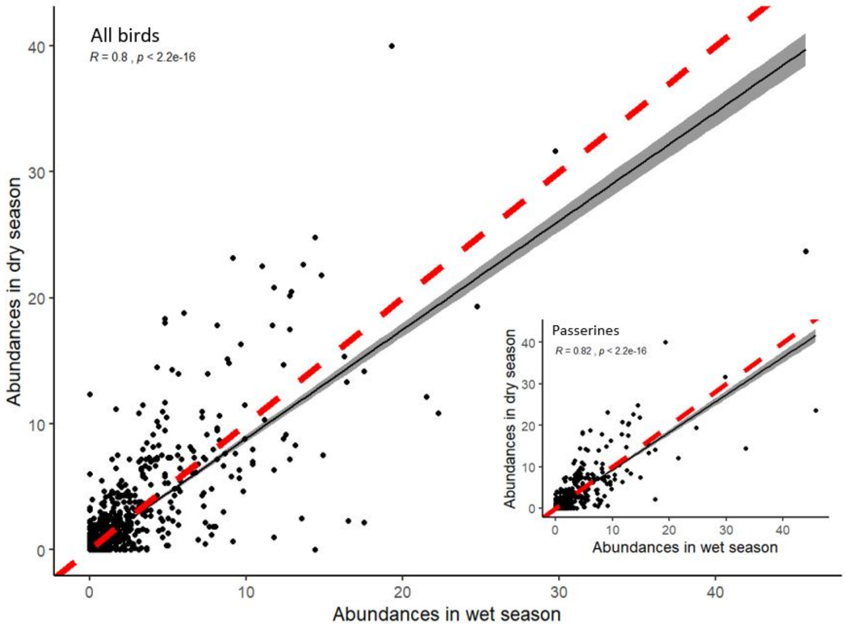


Figure S4. Mean (±SE) number of individuals per passerine and non-passerine bird species occurring in the particular assemblage along the elevational gradient of Mt Wilhelm.

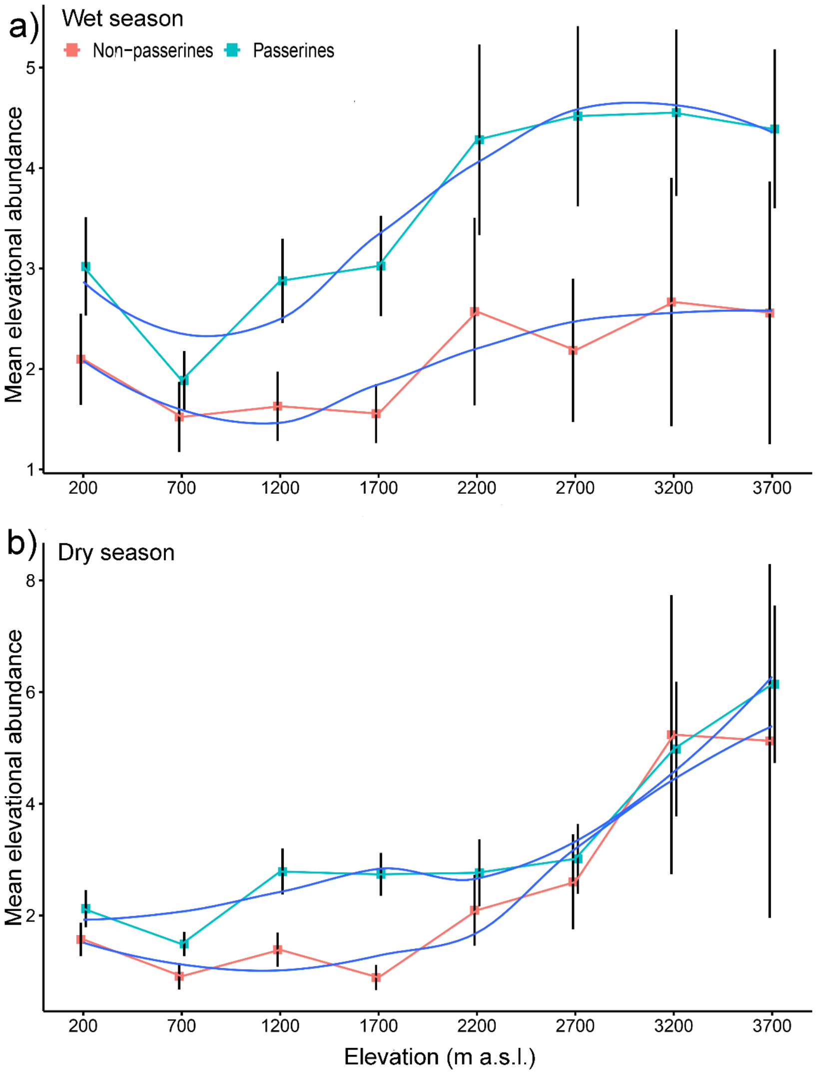


Figure S5. Relationship between mean abundance and geographical ranges (log transformed) of individual bird species. Only the relationship between mean abundances of all bird species and their ranges was significant (black line, $F_{1,248} = 8.22$, $P = 0.004$). After subsampling into passerine and non-passerine birds, the trends remained negative, albeit non-significant, for passerines ($F_{1,159} = 1.17$, $P = 0.28$) and non-passerines ($F_{1,86} = 2.6$, $P = 0.10$) separately.

Deleted: of

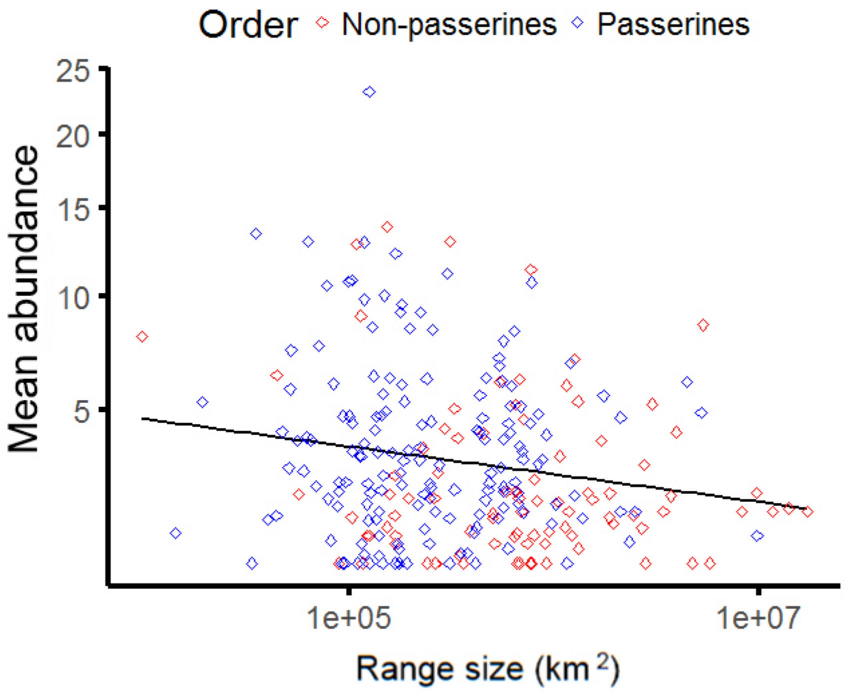


Figure S6. Abundance-range size relationship of three groups of passerines (black dashed lines) and non-passerine (red lines) bird species. (a) species with midpoints below 800 m a.s.l. (b) species with midpoints between 800 and 1600 m a.s.l. (c) species with mean-point above 1600 m a.s.l. Trends are depicted by regression lines fitted by the ordinary least squares method. Note log scale used on x-axes and square-root transformation on y-axes. The insets depict the patterns we expected for particular species groups based on range size limitations and increasing abundance towards higher elevations

Commented [MOU5]: this is basically just species recorded at 1200m?

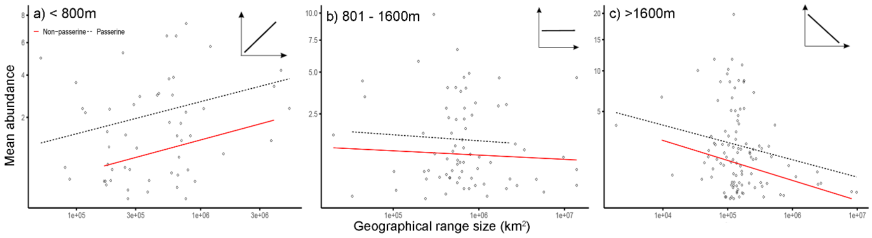


Figure S7. Passerine (a ,b) and non-passerine (c, d) birds divided into three groups based on the position of their mean-point of elevational distribution on Mt. Wilhelm, and their mean abundances in wet (a, c) and dry season (b, d). Kruskal-Wallis - passerines in dry season (a) $\chi^2 = 5.5$, df = 2, N = 161, $P < 0.05$; in wet season (b) $\chi^2 = 17.3$, df = 2, N = 161, $P < 0.001$; non-passerines in dry season (c) $\chi^2 = 1.9$, df = 2, N = 88, P = 0.377; in wet season (d) $\chi^2 = 0.5$, df = 2, N = 88, P =0.773. Significant differences between the groups of birds are denoted by different letters above the box-plots. Lowland group = elevational mean-point up to 800m a.s.l., mid group = elevational mean-point between 801 and 1600m a.s.l., and montane group = elevational mean-point above 1600 m a.s.l.

Commented [MOU6]: maximum

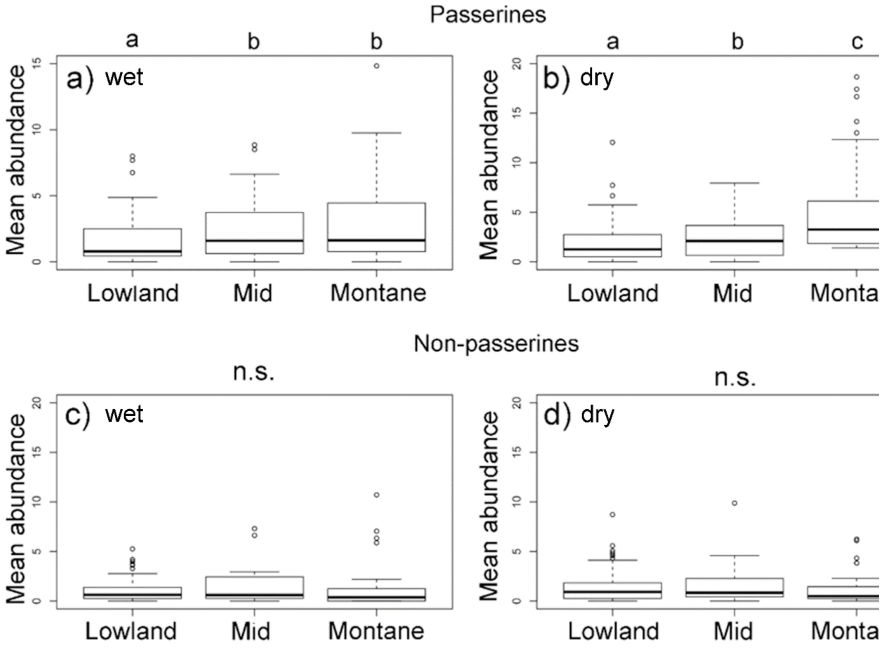


Figure S8. Passerine (a) and non-passerine (b) birds divided into three groups based on the position of their mean-point of elevational distribution on Mt. Wilhelm, and the length of their elevational ranges. Kruskal-Wallis passerines (a): $\chi^2 = 22.7$, df = 2, N = 161, $P < 0.001$; non-passerines (b) $\chi^2 = 10.8$, df = 2, N = 88, P = 0.004. Significant differences between the groups of birds are denoted by different letters above the box-plots. Lowland group = elevational mean-point up to 800m a.s.l., mid group = elevational mean-point between 801 and 1600m a.s.l., and montane group = elevational mean-point above 1600 m a.s.l.

Commented [MOU7]: max

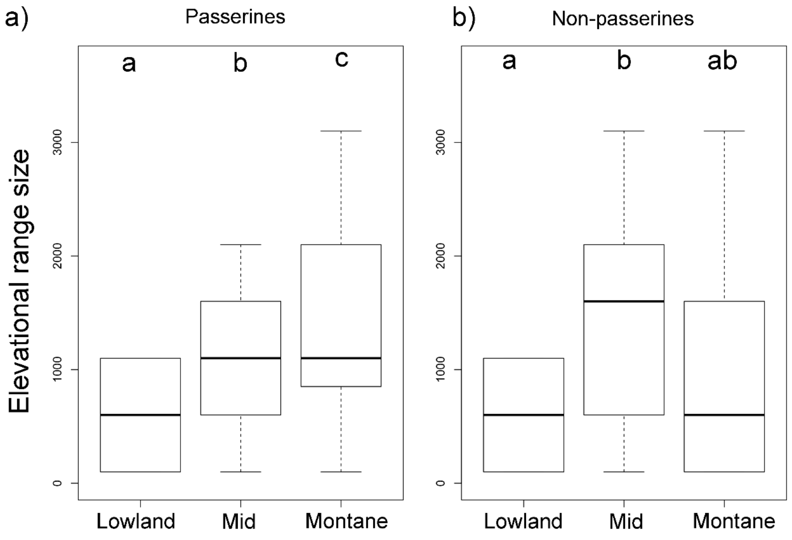


Figure S9. Body mass of passerine and non-passerine bird species and size of the geographical range they occupy. Passerines: $F_{1,159} = 0.105$, P=0.746; non-passerines: $F_{1,247} = 1.24$, P=0.268.

Deleted: geographicla

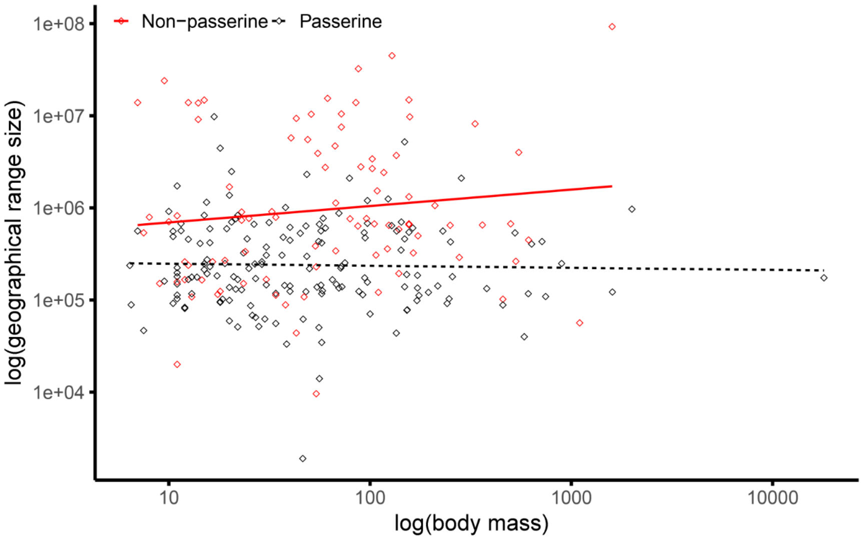


Table S1. List of bird species recorded during the point counts along Mt. Wilhelm elevational gradient in Papua New Guinea. Their *mean elevational abundances* at each elevation where they were recorded and *mean abundances* (i.e. across the range they occupied). Further, for each bird species it is specified to which order it belongs (PASS. for passerines and NON for non-passerines), where is its elevational mean-point and to which group of birds it was identified based on this mean-point (either lowland, mid-elevation or montane bird species). Finally, last two column show to which feeding guild the species belong and what is the size of its range (in km^2). Feeding specialization was obtained from Sam et al. 2019; Sam et al. 2017) and range are was obtained from Bird-Life International data zone.

Deleted: (

Scientific name	Mean elevational abundances per each elevation								Mean abundance	Order	Mean-point	Group	Guild	Area
	200	700	1200	1700	2200	2700	3200	3700						
Acanthiza cinerea				1.83	1.56	5.77	1.67		2.706	PASS.	2450	Mont.	In	122000
Acanthiza murina					7	3.6	3.14	10.29	6.007	PASS.	2950	Mont.	In	83100
Accipiter fasciatus					2				2	NON	2200	Mont.	Ca	8000000
Accipiter meyerianus					1				1	NON	2200	Mont.	Ca	263000
Aegotheles albertisi					1				1	NON	2200	Mont.	In	88500
Aegotheles insignis						1.33			1.333	NON	2700	Mont.	In	166000
Aepypodius arfakianus				2.33					2.333	NON	1700	Mid	Fr	194000
Aerodramus hirundinaceus				2.5					2.5	NON	1700	Mid	In	584000
Ailuroedus buccoides		1.5	1	1					1.167	PASS.	1200	Mid	Fr-In	375000
Ailuroedus melanotis					1				1	PASS.	2200	Mont.	Fr-In	167000
Aleadryas rufinucha				1.4	4.4	2.33	2.73	1.8	2.532	PASS.	2700	Mont.	In	142000

Alisterus chloropterus		1	1		8.22	10			5.056	NON	1700	Mid	Fr	324000
Alopecoenas beccarii			1.33	1.67					1.5	NON	1450	Mid	Fr	167000
Alopecoenas jobiensis			1		4				2.5	NON	1700	Mid	Fr	647000
Amalocichla incerta				1					1	PASS.	1700	Mont.	In	144000
Amblyornis macgregoriae				1		1	2.63		1.542	PASS.	2450	Mont.	Fr	14000
Anthus gutturalis							10.8	16.07	13.436	PASS.	3450	Mont.	In	34600
Aplonis cantoroides	4.86								4.857	PASS.	200	Low.	Fr-In	831000
Aplonis metallica	10.71								10.714	PASS.	200	Low.	Fr-In	770000
Arses insularis	1.71	2.25	3.43	3					2.598	PASS.	950	Mid	In	249000
Artamus maximus						6.83	2	5	4.611	PASS.	3200	Mont.	In	249000
Astrapia stephaniae					1	2.14	10.17	2.6	3.977	PASS.	2950	Mont.	Fr	55600
Cacatua galerita	9	4.9	2.09	1					4.248	NON	950	Mid	Fr	4000000
Cacomantis castaneiventris	1	1	2	1.88	2.14	1			1.503	NON	1450	Mid	In	791000
Cacomantis flabelliformis			3	1.43	1.57	1.75	1.88		1.925	NON	2200	Mont.	In	2000000
Cacomantis leucolophus	1.4	1.25	3.22						1.957	NON	700	Low.	In	497000
Cacomantis variolosus	3	3.6	1.67	1.25					2.379	NON	950	Mid	In	4000000
Caligavis obscura			1						1	PASS.	1200	Mid	Fr-In	174000
Caligavis subfrenata				1.5	1	6.57	7.91	4.63	4.321	PASS.	2700	Mont.	In-Ne	133000
Campochaera sloetii	1.5		3.33						2.417	PASS.	700	Low.	Fr-In	230000
Caprimulgus macrurus	1								1	NON	200	Low.	In	6000000
Carterornis chrysomela	2.64	1.8	3.8						2.745	PASS.	700	Low.	In	641000
Casuarius bennetti						1			1	NON	2700	Mont.	Fr	359000
Centropus phasianinus	2.29	1							1.643	NON	450	Low.	In	3000000
Ceyx azureus	3	1.67	1.33						2	NON	700	Low.	In	3000000
Ceyx lepidus	5.11	6.43	7.58						6.374	NON	700	Low.	In	43800
Ceyx pusillus	1								1	NON	200	Low.	In	910000
Chaetorhynchus papuensis	1	1	3.22	2.17					1.847	PASS.	950	Mid	In	306000
Chalcophaps indica	1	1							1	NON	450	Low.	Fr-In	5000000
Chalcophaps stephani		1.67	1						1.333	NON	950	Mid	Fr	902000
Charmosyna josefinae				9.5	25	7			13.833	NON	2200	Mont.	Ne	151000
Charmosyna papou				4.4	8.86	10.57	12.67	3.8	8.059	NON	2700	Mont.	Ne	9600
Charmosyna placentis	2	2.5							2.25	NON	450	Low.	Ne	821000
Charmosyna rubronotata	2.33								2.333	NON	200	Low.	Ne	259000
Charmosyna wilhelminae		4	6.57			2.5			4.357	NON	1700	Mid	Ne	290000
Chlamydera lauterbachi					1				1	PASS.	2200	Mont.	Fr-In	124000
Chrysococcyx minutillus	1								1	NON	200	Low.	In	3000000
Chrysococcyx ruficollis						1.67			1.667	NON	2700	Mont.	In	151000
Cicinnurus regius	3.18	2.25							2.716	PASS.	450	Low.	Fr-In	480000
Cinnyris jugularis	3	4	5.29	7.38					4.915	PASS.	950	Mid	In-Ne	5000000
Clytoceyx rex				1.25	1				1.125	NON	1950	Mont.	In	341000
Clytomyias insignis							1	2	1.5	PASS.	3450	Mont.	In	139000
Cnemophilus loriae				1	1	1	1.5		1.125	PASS.	2450	Mont.	Fr-In	138000
Cnemophilus macgregorii					1.4	1.88	3	1.4	1.919	PASS.	2950	Mont.	Fr	43700
Collocalia esculenta				7	1.67	1			3.222	NON	2200	Mont.	In	3000000
Colluricincla megarhyncha	3.58	4.5	11.92	11.71	2.5				6.844	PASS.	1200	Mid	In	1000000
Columba vitiensis					1	2.33			1.667	NON	2450	Mont.	Fr	1000000

Coracina boyeri	1	10	1.67						4.222	PASS.	700	Low.	Fr-In	604000
Coracina caeruleogrisea		1	2.25	1.33	2	1.2			1.557	PASS.	1700	Mont.	In	405000
Coracina incerta	1	1.33							1.167	PASS.	450	Low.	In	348000
Coracina longicauda				1		2.67			1.833	PASS.	2200	Mont.	In	135000
Coracina melas	1.25								1.25	PASS.	200	Low.	In	593000
Coracina montana		1	4.33	5.73	1.5	1			2.712	PASS.	1700	Mont.	Fr-In	247000
Coracina papuensis	7.27	3.67	10	3.4					6.085	PASS.	950	Mid	In	4000000
Coracina schisticeps					1				1	PASS.	2200	Mont.	Fr-In	166000
Coracina tenuirostris	1		1.75						1.375	PASS.	700	Low.	In	2000000
Corvus tristis	4.88	3.67	3	3					3.635	PASS.	950	Mid	Fr-In	693000
Cracticus cassicus	7.83								7.833	PASS.	200	Low.	Fr-In	561000
Cracticus quoyi	1								1	PASS.	200	Low.	In	1000000
Crateroscelis murina	1	8.7	8.79	6.38					6.218	PASS.	950	Mid	In	237000
Crateroscelis nigrorufa				1.33					1.333	PASS.	1700	Mont.	In	114000
Crateroscelis robusta		4		3.44	5.33	6	9.46	9.36	6.266	PASS.	2200	Mont.	In	156000
Cyclopsitta diophthalma	1.5	4	8.54	2.8					4.21	NON	950	Mid	Fr	448000
Cyclopsitta gulielmitertii	2.25		1.5						1.875	NON	700	Low.	Fr	102000
Dacelo gaudichaud	10.91	1.5							6.205	NON	450	Low.	In	671000
Daphoenositta miranda						2.5	1.71	1.25	1.821	PASS.	3200	Mont.	In	39900
Dicaeum geelvinkianum	3.2	7.1	6.93	12.31	5.85				7.076	PASS.	1200	Mid	Fr	535000
Dicrurus bracteatus	6.17	3.33							4.75	PASS.	450	Low.	In	2000000
Diphyllodes magnificus		3.8	4.43	2.33					3.521	PASS.	1200	Mid	Fr-In	112000
Ducula chalconota				1.33	3.43	1			1.921	NON	2200	Mont.	Fr	165000
Ducula pinon	1.43	1.5							1.464	NON	450	Low.	Fr	635000
Ducula rufigaster	1								1	NON	200	Low.	Fr	671000
Ducula zoeae	7	2.43	4.62						4.681	NON	700	Low.	Fr	707000
Eclectus roratus	7.08	3.78	1						3.954	NON	700	Low.	Fr	2000000
Epimachus fastosus			1	1.5	2.67	4.09			2.314	PASS.	1950	Mont.	Fr-In	78200
Epimachus meyeri				2	3.5	8.77	4.8		4.767	PASS.	2450	Mont.	Fr-In	135000
Erythropitta erythrogaster	1.6	3.2							2.4	PASS.	450	Low.	In	1000000
Erythrura trichroa				4	2.33	1.6	2	7	3.387	PASS.	2700	Mont.		875000
Eudynamys scolopaceus	2.4	2.5							2.45	NON	450	Low.	Fr-In	10000000
Eugerygone rubra				1	2.38	3.75	1.67	2.11	2.181	PASS.	2700	Mont.	In	121000
Eulacestoma nigropectus						2.75			2.75	PASS.	2700	Mont.	In	88700
Eurystomus orientalis	1.17	3							2.083	NON	450	Low.	In	10000000
Garritornis isidorei	2.5								2.5	PASS.	200	Low.	In	561000
Geoffroyus geoffroyi	2.8								2.8	NON	200	Low.	Fr	793000
Geoffroyus simplex	1								1	NON	200	Low.	Fr	238000
Gerygone chloronota	1.5	2.67	2.38						2.181	PASS.	700	Low.	In	1000000
Gerygone chrysogaster	2.5	3.78							3.139	PASS.	450	Low.	In	544000
Gerygone palpebrosa	1.67		1.8						1.733	PASS.	700	Low.	In	969000
Gerygone ruficollis				6.18	4.38	7.75	3.17	1.33	4.561	PASS.	2700	Mont.	In	103000
Grallina bruijnii			3	1					2	PASS.	1450	Mid	In	260000
Gymnophaps albertisii		4		3.78	14.67	11.15	1	2	6.1	NON	2200	Mont.	Fr	536000
Harpyopsis novaeguineae			1	2		1			1.333	NON	1950	Mont.	Ca	734000
Henicophaps albifrons	1	1	1						1	NON	700	Low.	Fr	769000

Heteromyias albispecularis				3.43	1	1			1.81	PASS.	2200	Mont.	In	123000
Ifrita kowaldi				2	2	9.6	7.08	3.29	4.794	PASS.	2700	Mont.	In	91900
Lalage atrovirens	1								1	PASS.	200	Low.	Fr-In	306000
Leptocoma sericea	7.83	1.5	3.13						4.153	PASS.	700	Low.	In-Ne	915000
Loboparadisea sericea				1.5		1			1.25	PASS.	2200	Mont.	Fr	174000
Lonchura spectabilis				1	3.33				2.167	PASS.	1950	Mont.	Gr	214000
Lonchura tristissima	4								4	PASS.	200	Low.	Gr	560000
Lophorina superba				3.57					3.571	PASS.	1700	Mont.	Fr-In	160000
Loriculus aurantiifrons	2.22								2.222	NON	200	Low.	Ne	20000
Lorius lory	5.43	12.11	3.55						7.028	NON	700	Low.	Ne	10000000
Machaerirhynchus flaviventer	1.13	2	3.85	1					1.993	PASS.	950	Mid	In	702000
Machaerirhynchus nigripectus			6	4.5	2	3	1.33		3.367	PASS.	2200	Mont.	In	219000
Macropygia amboinensis	3.9	2	4	4.27	3.22				3.479	NON	1200	Mid	Fr	1000000
Macropygia nigrirostris		1		5	12	2.86			5.214	NON	1700	Mid	Fr	647000
Malurus alboscapulatus				2.5	6				4.25	PASS.	1950	Mont.	In	431000
Manucodia chalybatus			1.4						1.4	PASS.	1200	Mid	Fr	81000
Megalurus macrurus				2					2	PASS.	1700	Mont.	In	2000000
Megapodius decollatus	1	1.67							1.333	NON	450	Low.	Fr-In	10000000
Melampitta lugubris						3	2.14	4	3.048	PASS.	3200	Mont.	In	59300
Melanocharis longicauda				1		1			1	PASS.	2200	Mont.	Fr-In	94300
Melanocharis nigra	5.5	12.33	6.36	6	1				6.238	PASS.	1200	Mid	Fr-In	461000
Melanocharis striativentris				2.78		1.5			2.139	PASS.	2200	Mont.	Fr	86800
Melanocharis versteri				5	7.92	5.69	5.54	4	5.631	PASS.	2700	Mont.	Fr-In	145000
Melanorectes nigrescens				2.57	2.8	2			2.457	PASS.	2200	Mont.	In	126000
Melidectes belfordi				10	22.43	30.57	39.08	13.91	23.197	PASS.	2700	Mont.	In-Ne	124000
Melidectes fuscus					3.86	1.71	6.08	18.85	7.624	PASS.	2950	Mont.	In-Ne	70500
Melidectes princeps							1	9.64	5.318	PASS.	3450	Mont.	In-Ne	1900
Melidectes rufocrissalis				9.44	1	1.5			3.981	PASS.	2200	Mont.	Fr-In	64700
Melidectes torquatus			2.5	4.73	1				2.742	PASS.	1700	Mont.	Fr-In	95800
Melidora macrorrhina	1	2							1.5	NON	450	Low.	In	108000
Melilestes megarhynchus	3	4.1	2.83	2.13	1				2.612	PASS.	1200	Mid	In-Ne	562000
Meliphaga analoga	18.58	8.4	9.27	4.13	1				8.276	PASS.	1200	Mid	In-Ne	636000
Meliphaga aruensis	1.83	1.5	3.25						2.194	PASS.	700	Low.	Fr-In	664000
Meliphaga montana			3.88						3.875	PASS.	1200	Mid	Fr-In	118000
Meliphaga orientalis				8.5	1.25	1.25			3.667	PASS.	2200	Mont.	In-Ne	193000
Melipotes fumigatus			3.5	4.17	3.5	5.5	8.33	4.89	4.981	PASS.	2450	Mont.	Fr-In	149000
Merops ornatus	2								2	NON	200	Low.	In	13760000
Microdynamis parva	2								2	NON	200	Low.	Fr	9360000
Microeca flavovirescens	2.63	4.57	4.22						3.806	PASS.	700	Low.	In	675000
Microeca griseoceps			1						1	PASS.	1200	Mid	In	189000
Microeca papuana				2.23	6.7	5.54			4.823	PASS.	2200	Mont.	In	142000
Micropsitta bruijnii			3						3	NON	1200	Mid	In-Ne	269000
Micropsitta pusio	6.57	6.29	5						5.952	NON	700	Low.	In-Ne	9120000
Mino anais	1	1							1	PASS.	450	Low.	Fr	411000
Mino dumontii	4.43	2.38							3.402	PASS.	450	Low.	Fr-In	701000
Monachella muelleriana	1.67								1.667	PASS.	200	Low.	In	418000

Monarcha frater			2.67						2.667	PASS.	1200	Mid	In	179000
Monarcha rubiensis	1.33								1.333	PASS.	200	Low.	In	244000
Myiagra alecto	2.56	2	1						1.852	PASS.	700	Low.	In	1000000
Myzomela rosenbergii			1.5	11	28.14	4.64	5.62	4.3	9.199	PASS.	2450	Mont.	In-Ne	177000
Neopsittacus musschenbroekii			6.5	5.63	2.33	2.67	1.5		3.725	NON	2200	Mont.	Ne	229000
Neopsittacus pullicauda				6.13	5.2	10.56	11.18	12	9.012	NON	2700	Mont.	Ne	113000
Oedistoma iliolophus		6.67	9.23	2.44					6.114	PASS.	1200	Mid	In	557000
Oreocharis arfaki				2.91	3.25	5	2	2.5	3.132	PASS.	2700	Mont.	Fr	50200
Oreopsittacus arfaki					3.43	11.43	20.25	16.22	12.832	NON	2950	Mont.	Ne	108000
Oreostruthus fuliginosus								5.8	5.8	PASS.	3700	Mont.	Fr-In	51000
Oriolus szalayi	5.14								5.143	PASS.	200	Low.	Fr-In	680000
Ornorectes cristatus			2.5						2.5	PASS.	1200	Mid	In	88200
Otidiphaps nobilis			1						1	NON	1200	Mid	Fr	260000
Pachycare flavogriseum			1.33	1.33					1.333	PASS.	1450	Mid	In	171000
Pachycephala hyperythra	3	1.17	9.73	5.29					4.795	PASS.	950	Mid	In	99100
Pachycephala modesta						2.25	3		2.625	PASS.	2950	Mont.	In	68100
Pachycephala monacha		1							1	PASS.	700	Low.	In	33200
Pachycephala schlegelii				6.9	9.29	15.64	6.17	4.3	8.459	PASS.	2700	Mont.	In	129000
Pachycephala simplex		3	3.5						3.25	PASS.	950	Mid	In	829000
Pachycephala soror		3.5	7.2	4.27	2.22	1.5			3.739	PASS.	1700	Mont.	In	220000
Pachycephalopsis poliosoma			7.83	2.83					5.333	PASS.	1450	Mid	In	185000
Paradigalla brevicauda					1				1	PASS.	2200	Mont.	Fr-In	91700
Paradisaea minor	8.5	9.6	15.39						11.162	PASS.	700	Low.	Fr-In	298000
Paramythia montium						3.58	8.21	27.23	13.009	PASS.	3200	Mont.	Fr	62200
Peltops blainvillii	2.44	1.29							1.865	PASS.	450	Low.	In	530000
Peltops montanus		1.5		4	1	3.67			2.542	PASS.	1700	Mont.	In	324000
Peneothello bimaculata		6.83	6.86	8.56					7.415	PASS.	1200	Mid	In	51600
Peneothello cyanus				14.39	17.5	5			12.295	PASS.	2200	Mont.	In	167000
Peneothello sigillata						11.25	9.92	10.42	10.53	PASS.	3200	Mont.	In	77400
Philemon buceroides	9.82	1.33							5.576	PASS.	450	Low.	In-Ne	432000
Philemon meyeri	7.08	3.5	2.17						4.25	PASS.	700	Low.	In-Ne	46600
Phylloscopus maforensis			2.33	4.27	1				2.535	PASS.	1700	Mont.	In	473000
Pitohui dichrous		6.88	15.07	5.64					9.196	PASS.	1200	Mid	Fr-In	222000
Pitohui kirhocephalus	3.4	8.6	8.2						6.733	PASS.	700	Low.	In	538000
Pitta sordida	2	2							2	PASS.	450	Low.	In	2000000
Podargus ocellatus				1					1	NON	1700	Mid	In	761000
Poecilodryas albonotata					1.25	1	1.2		1.15	PASS.	2700	Mont.	In	117000
Poecilodryas hypoleuca	3.75	6	3.17						4.306	PASS.	700	Low.	In	417000
Probosciger aterrimus	3.36	2.38	1.6						2.446	NON	700	Low.	Fr	14880000
Pseudeos fuscata	3.11			5.75	20.27	16.43			11.391	NON	1450	Mid	Fr-In	766000
Pseudorectes ferrugineus	7.83		4						5.917	PASS.	700	Low.	Fr-In	615000
Psittacella brehmii					1	2			1.5	NON	2450	Mont.	Fr	124000
Psittacella picta						1.25	2	4	2.417	NON	3200	Mont.	Fr	56400
Psittaculirostris edwardsii	3	3	2.8						2.933	NON	700	Low.	Fr	1320000
Psitteuteles goldiei						13	13		13	NON	2950	Mont.	Ne	307000
Psittrichas fulgidus	2								2	NON	200	Low.	Fr	5512000

Pteridophora alberti						1			1	PASS.	2700	Mont.	Fr-In	109000
Ptilinopus coronulatus	1.5	1	2.25	4.6					2.338	NON	950	Mid	Fr	670000
Ptilinopus iozonus	5.33								5.333	NON	200	Low.	Fr	10400000
Ptilinopus magnificus	2.7		2.2						2.45	NON	700	Low.	Fr	32400000
Ptilinopus ornatus		2.5		1	1.25				1.583	NON	1450	Mid	Fr	385000
Ptilinopus perlatus	1	1.5							1.25	NON	450	Low.	Fr	10480000
Ptilinopus pulchellus	1.88	1.33	1.5						1.569	NON	700	Low.	Fr	7536000
Ptilinopus rivoli				4	4.75	3.75	3.75		4.063	NON	2450	Mont.	Fr	335000
Ptilinopus superbus	1.67	1.33	4.14		2				2.286	NON	1200	Mid	Fr	2000000
Ptiloprora guisei				3	6.5	5	1.8		4.075	PASS.	2450	Mont.	Fr-In	61900
Ptiloprora meekiana				2					2	PASS.	1700	Mont.	In	139000
Ptiloprora perstriata					3.5	18.86	14.79	6.2	10.836	PASS.	2950	Mont.	In	102000
Ptiloris magnificus		2	8.31						5.154	PASS.	950	Mid	Fr-In	605000
Ptilorrhoa caerulescens	2	1.83	2						1.944	PASS.	700	Low.	In	427000
Ptilorrhoa castanonota			2.33						2.333	PASS.	1200	Mid	In	246000
Ptilorrhoa leucosticta				1.4	1.5	2			1.633	PASS.	2200	Mont.	In	232000
Pycnopygius ixoides	1.33	1	4.5						2.278	PASS.	700	Low.	Fr	460000
Rallicula forbesi						1.5			1.5	NON	2700	Mont.	In	121000
Reinwardtoena reinwardti	1	1.5	2	1.33	1.63	1.8	1.5		1.537	NON	1700	Mid	Fr	656000
Rhagologus leucostigma				3.8	2.7	2.25			2.917	PASS.	2200	Mont.	Fr-In	146000
Rhipidura albolimbata				11.07	12.33	12.29	8.46	6	10.03	PASS.	2700	Mont.	In	148000
Rhipidura atra		1.5	3.43	10.79	7.29	6.9			5.98	PASS.	1700	Mont.	In	179000
Rhipidura brachyrhyncha					4.13	10.67	6.62	3.88	6.321	PASS.	2950	Mont.	In	131000
Rhipidura hyperythra		4							4	PASS.	700	Low.	In	456000
Rhipidura leucothorax	3.83	1.5	1						2.111	PASS.	700	Low.	In	565000
Rhipidura rufidorsa		3							3	PASS.	700	Low.	In	488000
Rhipidura rufiventris	3.67	3.88	9.08						5.54	PASS.	700	Low.	In	2000000
Rhipidura threnothorax	6.75	3.75	6.13		1.5				4.531	PASS.	1200	Mid	In	594000
Rhyticeros plicatus	7.58	3.67	4.45						5.235	NON	700	Low.	Fr	24000000
Saxicola caprata				2	1				1.5	PASS.	1950	Mont.	In	10000000
Scolopax rosenbergii						1			1	NON	2700	Mont.	In	115000
Scythrops novaehollandiae	2								2	NON	200	Low.	Fr-In	92800000
Sericornis arfakianus			3						3	PASS.	1200	Mid	In	177000
Sericornis nouhuysi				5.17	12.39	17.79	12	6.33	10.734	PASS.	2700	Mont.	In	98600
Sericornis papuensis				7.67	7	18.25	6.36		9.82	PASS.	2450	Mont.	In	117000
Sericornis perspicillatus				15.14	18.83	4.86			12.944	PASS.	2200	Mont.	In	117000
Sericornis spilodera		4.5	5.33	2		1			3.208	PASS.	1700	Mont.	In	274000
Syma megarhyncha			2.71	2.67	2.33	2			2.429	NON	1950	Mont.	In	157000
Syma torotoro	1	2.75							1.875	NON	450	Low.	In	14800000
Symposiachrus axillaris			3.8	5	2.08	3			3.471	PASS.	1950	Mont.	In	113000
Symposiachrus guttula	2.6	3.75	1						2.45	PASS.	700	Low.	In	664000
Symposiachrus manadensis	4.71								4.714	PASS.	200	Low.	In	445000
Talegalla jobiensis	2.78	1.6	1.17						1.848	NON	700	Low.	Fr-In	4000000
Tanysiptera galatea	2.09	1.4							1.745	NON	450	Low.	In	15440000
Timeliopsis fulvigula				3.6					3.6	PASS.	1700	Mont.	In	137000
Toxorhamphus novaeguineae	7.92	8	9.29						8.401	PASS.	700	Low.	In-Ne	197000

Toxorhamphus poliopterus			6	12.5	10.29				9.595	PASS.	1700	Mont.	In-Ne	179000
Tregellasia leucops		1.5	5.2						3.35	PASS.	950	Mid	In	183000
Trichoglossus haematodus	13.42	7.4	4.9						8.572	NON	700	Low.	Ne	44880000
Trugon terrestris				1	1				1	NON	1950	Mont.	Fr	652000
Turdus poliocephalus						1.5	7.67	15.86	8.341	PASS.	3200	Mont.	In	253000
Xanthotis flaviventer		5.86	3.2						4.529	PASS.	950	Mid	In	762000
Zosterops minor	2	7.2	4.33						4.511	PASS.	700	Low.	In	224000
Zosterops novaeguineae		2		3.92	5.64	3			3.64	PASS.	1700	Mont.	In	103000

Sam, K., B. Koane, D. C. Bardos, S. Jeppy, and V. Novotny. 2019. Species richness of birds along a complete rain forest elevational gradient in the tropics: Habitat complexity and food resources matter. Journal of Biogeography **46**:279-290.