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that will synergistically influence how populations can cope with climate change. We investigated relationships between distance to the forest edge, forest structure, microclimate, and terrestrial mammal detections in a selectively logged forest at the boundary of the Gunung Leuser National Park in Sumatra, Indonesia. We collected mammal detection data from motion-activated camera traps, microclimate data from automated climate data loggers, and forest structure data from vegetation plots. Daily mean and maximum temperatures significantly decreased with distance from the forest edge, whilst tree height and minimum temperatures increased. Mammal diversity was lower at the forest edge compared to the interior. Mammals were detected less frequently at the forest edge, although this relationship differed between mammal Orders. Mammal detections were best explained by temperature, tree height and tree diameter at breast height. These results demonstrate that abiotic changes in forests brought on by edge effects have negative impacts on mammals, but their impacts vary between mammal taxa, due to differing sensitivities to human disturbance. These data highlight the importance of considering local scale environmental drivers in determining species-environment relationships to identify key habitat features, such as microclimate refuges, that should be prioritised in ecosystem management.

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Living on the edge: Forest edge effects on microclimate and terrestrial mammal occurrence in disturbed lowland forest in Sumatra, Indonesia.

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25 Abstract

Species-environment relationships are often studied at large spatial scales, but effective conservation requires an understanding of local-scale environmental drivers and pressures. Widespread degradation and fragmentation of forests has greatly increased the proportion of tropical mammals' habitat that is impacted by edge effects. Edge effects include greater exposure to anthropogenic disturbance as well as abiotic changes that will synergistically influence how populations can cope with climate change. We investigated relationships between distance to the forest edge, forest structure, microclimate, and terrestrial mammal detections in a selectively logged forest at the boundary of the Gunung Leuser National Park in Sumatra, Indonesia. We collected mammal detection data from motion-activated camera traps, microclimate data from automated climate data loggers, and forest structure data from vegetation plots. Daily mean and maximum temperatures significantly decreased with distance from the forest edge, whilst tree height and minimum temperatures increased. Mammal diversity was lower at the forest edge compared to the interior. Mammals were detected less frequently at the forest edge, although this relationship differed between mammal Orders. Mammal detections were best explained by temperature, tree height and tree diameter at breast height. These results demonstrate that abiotic changes in forests brought on by edge effects have negative impacts on mammals, but their impacts vary between mammal taxa, due to differing sensitivities to human disturbance. These data highlight the importance of considering local scale environmental drivers in determining species-environment relationships to identify key habitat features, such as microclimate refuges, that should be prioritised in ecosystem management.

Keywords Fragmentation, habitat use, camera trap, remote monitoring, Indonesia.

Introduction

- 50 Addressing key drivers of biodiversity loss, such as habitat loss, fragmentation, and climate change are essential to prevent mammal extinctions and ensure healthy, resilient populations globally. Quality species distribution and habitat data are needed to do this effectively, but these are lacking for many species (Burivalova et al., 2019). Species' distributions and habitat suitability are often inferred from old survey data or educated guesses using expert knowledge
- 55 (IUCN, 2021a). Research activities often focus on charismatic, threatened species, but effective conservation requires information on whole communities, including common and invasive species. Up-to-date species data, quality environmental data, and ongoing monitoring are necessary to understand the status of biodiversity and to determine the outcome of conservation actions and allow for adaptive management.
- 60 Accurate predictions of species responses to environmental change are essential for effective long-term conservation. Most studies of species-environment relationships use species distribution models, SDMs, at large spatial and temporal scales. Environmental predictors used in SDMs are commonly derived from remote sensing data with coarse spatial and temporal resolutions (e.g., annual climate data from Worldclim; Hijmans et al 2015).
- 65 Conservationists often do not use these for local-scale planning and practice due to their high uncertainty and inability to account for local population stresses, such as edge effects or exploitation (Tulloch et al 2016). A modelling framework to determine species-environment relationships at local scales will provide information on local drivers of population declines and biodiversity loss and improve their uptake in long-term conservation planning. Developing
- 70 such a framework requires more empirical information on fine-scale species-environment relationships.

Tropical forests are heterogenous environments with significant variation at finer temporal and spatial resolutions (Marsh et al 2022). Landscape-scale models often do not include fine-scale variation in topography, logging intensity, forest structure, and microclimate because they

75 use categorical land units (e.g., primary forest, logged forest, agricultural land; Wearn et al., 2017). Microclimate variations (i.e., sub-annual variations with spatial scales <1km²) are important drivers of mammal distributions, behaviour, and phenology (McCain and King 2014; Buckley et al 2018; Tamian et al 2022). The inclusion of microclimate variables in SDMs has improved their performance for several mammal species (e.g., McCain and King 2014; Varner

80 and Dearing 2014; Mathewson et al 2020; Tamian et al 2022) but the influence of microclimate on mammal habitat choice in tropical forest has not been tested yet.

Microclimate variations are likely to be more extreme in fragmented forests and near forest edges. Edge effects have been observed up to 1km into forest patches (Laurance, 2004; Pohlman et al., 2007). Approximately 70% of forested areas are within 1km of a forest edge
85 (Haddad et al., 2015), and therefore a large proportion of forest habitats are likely to be subject to edge effects. Proximity to forest edges also leads to increased human disturbance from hunting and extraction of other resources. These changes are widely assumed to negatively impact mammals, with some studies reporting lower abundance of certain species at forest edges (e.g., Kinnaird et al., 2003). Species will respond differently to these changes, and the
90 most effective conservation strategies will depend on the target species. Few studies to date have directly investigated how edge-related abiotic changes relate to mammal distribution and habitat use.

In this study, we measure edge effects on forest structure and microclimate and identify their impact on forest mammals in a region of recovering secondary tropical forest near the
95 edge of a protected area in Sumatra, Indonesia. This will determine fine-scale environmental associations and provide urgently needed species data for mammals in the region. We hypothesise that edge effects create an environment less favourable for terrestrial forest mammals, resulting in them spending less time near forest edges. We predict that trees will be smaller and less well connected closer to the edge, and that this will result in increased light
100 penetration through the canopy and hotter temperatures. Finally, we predict that mammals will spend less time near forest edges, and that mammal detections will be negatively associated with temperature and light intensity, and positively associated with distance from the forest edge, larger trees, and increased canopy connectivity.

Study area

105 We collected data from Aras Napal in the Sikundur region on the boundary of the Gunung Leuser National Park in the North Sumatra province in Sumatra, Indonesia (Figure 1). Sikundur comprises secondary lowland forest that was selectively logged before the establishment of the Gunung Leuser National Park in 2004 (YOSL-OIC, 2009). Despite its protected status, illegal logging and hunting still occur in the area (Roth et al., 2020), although there are no available
110 data on the frequency and impacts of these activities. Aras Napal, which consists of around 150

households, is adjacent to the Sikundur forest. Subsistence and smallholder agriculture are the predominant land uses outside of the protected forest in Aras Napal, while the area to the North of the village comprises larger commercial rubber and oil palm plantations. Except for a handful of primate studies (Roth et al 2020; Harrison et al 2020; Hankinson et al 2021; 115 Hankinson et al 2022), there are no published data for mammals in Sikundur.

Methods

We investigated fine-scale species-environment interactions and determined abiotic edge effects on terrestrial mammals by measuring forest structure, microclimate, and mammal detections at 0.5km intervals along four transects (Figure 1). We liaised with landowners in 120 Aras Napal to identify starting locations in orange plantations adjacent to the forest edge and National Park boundary. We generated 2km Transects with survey points at 0.5km intervals from these starting locations using ArcGIS Pro (ESRI, 2010). Where possible, we set up monitoring locations within 50m of these points. In some cases, points had to be moved further due to landscape features that could not be crossed on foot. We conducted camera trap and 125 climate monitoring in all locations concurrently over 60 days from August – October 2019. To minimise disturbance-related changes in animal behaviour, we collected vegetation data only after the remote monitoring period was completed.

Forest Structure

We measured forest structure from 25x25m plots at all monitoring locations. Within each 130 plot, we recorded the total number of trees with a circumference at breast height of more than 31.4cm for each tree we recorded: Circumference at breast height, cm; total height, m; bole height, m; North-South crown width, m; East-West crown width, m; and crown connectivity with neighbouring crowns, %. We used the tree circumference to calculate the diameter at breast height (DBH), cm, and estimated crown area, m², from the crown widths and crown 135 depth.

Microclimate

At each monitoring location, we recorded below-canopy hourly ambient temperature (°C) and light intensity (lux) using Onset HOBO UA-002-08 8K Pendant Waterproof Temperature & Light Intensity Loggers (Onset n.d.). Due to a software issue, we were only able to collect

140 microclimate data for 49 out of the 60 days. We placed the loggers in a shaded location to minimise the risk of greenhouse effects within the sensor casing from direct sunlight, however, there were still some occasions of elevated temperature and light intensity. To minimise the effect of these records in the final dataset, we removed instances where the recorded light intensity exceeded 32,000 lux (level of direct sunlight, Hiscocks 2011 in Marsh et al. 2022), or
145 where temperature increased by more than 5°C between consecutive hourly recordings, along with the two data points immediately following them (ensuring loggers had ample time to return to ambient temperatures), resulting in the removal of 223 data points. Finally, we summarised climate data for the whole sampling period (including both night and daytime temperatures), and for each 24-hour period.

150 **Mammal occurrence**

We used mammal detections as a proxy to measure the occurrence of any detectable terrestrial mammal species at each sampling location. At each location we used one SpyPoint Force Dark remote trail camera (Spy Point n.d.), resulting in 20 cameras in total. These cameras feature 42 No-Glow LEDs and take infrared images at night, and therefore do not disturb
155 wildlife with camera flashes. We secured camera at a height of approximately 0.5m, facing towards animal signs or likely trails, and removed any vegetation directly in front of the camera. Camera locations were not baited to avoid influencing animal movement. Cameras were set to take one image followed by 30 seconds of video when triggered by movement.

At the end of the monitoring period, we collected the cameras and identified captured
160 species in individual images using their standardised common names from the Integrated Taxonomic Information System database (ITIS, n.d.). We attached a metadata tag with identified species names to each image. We extracted image metadata and tabulated all mammal detection events with the ‘camtrapR’ package in R version 4.0.0 (Niedballa et al., 2016; R Core Team, 2020). We applied a minimum delta time (i.e., the time difference between
165 two subsequent detection events of the same species at the same location) of 1 hour to prevent instances of the same individual being detected multiple times at one location. For each location, we counted the total number of mammal detections and the number of detections disaggregated by mammal Order. We calculated the naïve occupancy (i.e., the proportion of sites at which a species was detected) of each detected mammal species/Family. We checked
170 that the sampling effort was sufficient to capture all detectable Families with a species-

accumulation curve plotted with the ‘vegan’ R-package (Oksanen et al., 2019). We did this at the Family level since some small mammals could not be identified to species level.

Data analysis

We pooled data from all locations and grouped them by distance from the forest edge (i.e., 175 0km, 0.5km, 1km, 1.5km and 2km). We estimated mammal species richness at each distance by calculating the mean number of detected species from all locations at each distance from the edge. We determined the relationship between distance from the forest edge, environmental conditions, and detections using Generalised Linear Mixed Models (GLMMs), fitted with the R-package ‘glmmTMB’ (Brooks et al., 2017). Since our data collection followed a nested 180 sampling design, we included Location and Transect ID as random intercepts in all models to account for non-independence between samples.

We summarised environmental predictors for each location. We calculated mean temperature and light intensity for the whole sampling period (including night and daytime temperatures). We also calculated the mean, maximum, and minimum of each day for 185 temperature and light intensity at each sampling location. We summarised forest structure for each plot into the following variables: mean tree height, mean bole height, mean DBH, mean crown area, mean connectivity, and number of trees per plot. Environmental variables used in the models are provided in Supplementary Table 1.

We first tested for the effect of distance from the edge on microclimate and forest structure. 190 GLMMs for microclimate variables also included the day of year and hour as random intercepts. We next tested for significant associations between detection events and distance from the forest edge using Pearson’s chi-squared test. We then tested the effect of microclimate and forest structure variables on overall mammal detections using a Poisson generalized linear model with a Log:Link function fitted with the R-package ‘MASS’ (Venables & Ripley, 2002). 195 We used a correlation matrix to check for co-linearity among predictor variables. For those with a correlation coefficient above 0.7, we selected only one to be included in the model. We determined which combination of variables produced the best model performance based on their AIC criterion using an automated model selection with the R-package ‘MuMIn’ (Barton, 2020).

200 Finally, we tested for the effects of microclimate and forest structure variables on the occurrence of each mammal Order by fitting a negative binomial generalized linear mixed model with ‘glmmTMB’. Order was included as a random intercept. As in the GLM, we first selected independent variables using a correlation matrix and used automated model selection with ‘MuMin’ to select the best combination of variables based on the model AIC criterion.

205 **Results**

Edge effects on forest structure and microclimate

Forest Structure

210 There was a significant increase in tree height with increased distance from the forest edge ($P<0.05$, Table 1, Figure 2a), bole height ($P<0.01$, Table 1, Figure 2b) and height:DBH ratio ($P<0.05$, Table 1, Figure 2c). DBH, basal area, crown area and canopy connectivity did not change with distance from the edge (Table 1). Forest structure data are summarised in Supplementary Table 2 and Supplementary Fig. 1.

Microclimate

215 There was a significant negative effect ($P<0.01$) of distance from the forest edge on both temperature and light intensity, with both variables decreasing further into the forest (Table 2). Daily mean and maximum temperatures and light intensities all significantly decreased with increasing distance from the edge ($P<0.01$; Table 3). Effect sizes were larger for daily maximums compared with daily means for both temperature and light intensity (Table 3 & Figure 2d – h). These relationships were non-linear, with the gradient being much steeper closer 220 to the edge and flattening off around 1km from the forest edge (Figure 2d – h). The daily minimum temperature increased with distance from the edge ($P<0.01$; Table 3 & Figure 2f). Microclimate data are summarised in Supplementary Table 3 and Supplementary Fig. 2.

Mammal occurrence across a disturbance gradient

One location was removed due to a camera malfunction; the remaining 19 cameras yielded 225 1079 sampling days (after accounting for days lost due to camera malfunctions), 1384 images,

and 300 mammal detection events. We identified 16 mammal species across 14 families and six orders (Table 4). It was not possible to identify animals in the families Muridae (mice and rats) and Sciuridae (squirrels) to species level. The mean number of detected species was lowest at the forest edge ($\mu = 3.00 \pm 1.00$), and highest at 1km from the edge ($\mu = 7.00 \pm 3.56$). Three families had fewer than five detections, while five had more than 20. The species accumulation curve (Figure 3) shows that by around 200 total sampling days, 12 out of 14 families had been detected, indicating that the sampling effort was adequate to capture all present and detectable families.

The number of detection events of each mammal Order differed between distances ($\chi^2 = 235\ 75.324$, $df = 20$, $p < 0.01$; Figure 4). Primate detections were higher towards the National Park boundary, and elephants were detected only within 1km from the edge and not further into the forest. Moonrats were only detected at distances greater than 1km and carnivores were not detected at the boundary. Ungulates and rodents were detected at all distances but had a much higher detection rate at 1km than any other distance (Figure 4).

240 **Environmental predictors of mammal abundance**

All temperature and light intensity variables except for T_{min} were very highly correlated ($r > 0.7$), accordingly, only T_{max} and T_{min} were used in the models. We selected T_{max} since it was the most variable between locations and is likely to be a more important constraint to diurnal terrestrial mammals than mean temperature. Total height and bole height were also 245 strongly correlated ($r > 0.7$); consequently, we included total height only in the analysis.

Overall mammal detections

The best model performance was obtained with the variables T_{max} , T_{min} , tree height and DBH (Table 5). The deviance explained by this model was 27.72%. The number of detections decreased with increasing minimum and maximum temperatures, and tree height (Table 5, 250 Figure 5a – c), and increased with increasing in diameter at breast height (Table 5, Figure 5d).

Number of detections by mammal Order

The mixed model with the best performance included T_{max} , tree height, and DBH (Table 6; Figure 6). For all mammal Orders, T_{max} and tree height were negatively correlated with the

number of detections, with an increase in temperature and height leading to fewer detections
255 (Table 6; Figure 6a & b). DBH was positively correlated; increased DBH resulted in an increased number of detections (Table 6; Figure 6c).

Discussion

Edge effects on abiotic forest conditions

Mean and maximum temperatures and solar radiation were higher at the forest edge, while
260 minimum temperatures increased towards the interior. Elevated temperatures occur up to 500m – 1km into the forest (Figure 2d & e). Smaller forest fragments will be subject to more extreme diurnal variations than larger fragments. Open access climate datasets are usually only available at scales much larger than an animal's body size or even average home range. Many climate envelope models only incorporate annual means and do not account for fine-scale
265 temporal variations, such as daily maximums which can be much higher (Bennie et al., 2014). We recorded daily maximum temperatures up to 37.49°C, much higher than the overall mean of 25.54°C. The frequency and duration of these higher temperatures is likely an important constraint on survival. These effects are overlooked in models using annual means of coarse-scale data that could be underestimating local extinction risks.

270 Mammal-environment interactions

We found that mammals favour locations with wider trees, lower mean and maximum temperatures and higher minimum temperatures. These conditions are usually associated with less disturbed forests. Reduced detections rates in more disturbed and warmer regions in the forest, indicates that mammals are spending less time in these areas. This is likely to reduce
275 energy costs associated with elevated temperatures (Korstjens and Hillyer 2016). Total tree height was negatively associated with mammal detections, most likely due to the removal of tall emergent trees during historical selective logging. Most plots have a small DBH relative to the average height suggesting a higher proportion of young trees. This suggests that mammals prefer areas with more mature trees. A camera trap study in Tanzania reported similar findings,
280 with mammal abundance being negatively associated with stem density of small trees (DBH 5-10cm) and positively associated with larger trees (DBH >10cm; Martin et al. 2015). The

relationship between mammals and canopy height is likely more complex in secondary forest that differs markedly in vegetation structure from primary forests.

The number of detected individuals varied among Orders with distance from the National Park edge. This is unsurprising, given that some species are better able to cope with forest edge conditions, and are known to utilise the adjacent human-dominated landscape (Segan et al., 2016). For many species, forest edges have a notable negative impact. The number of species detected was lower at the forest edge, with only five compared with 8-13 elsewhere. Elephants, terrestrial primates and pigs were the most commonly detected at the edge and reportedly utilise agricultural lands, (Love et al., 2017; Castillo-Contreras et al., 2018; Ruppert et al., 2018). Deer, moonrats, and carnivores were only detected in the interior and are known to avoid human-dominated land (Brodie et al., 2015; Farris et al., 2017; Wynn-Grant et al., 2018; Brozovic et al., 2018). The results highlight the significant impacts of human disturbance on mammal species richness, abundance, and community composition.

Crop foraging events by Pig-tailed macaques and pigs in smallholder farms adjacent to the forest are reported daily; these species had the highest naïve occupancy (Slater 2019). Elephants were only detected within 1km of the forest edge and these events were associated with reports of them entering commercial plantations (Slater 2019). There is no evidence of elephants foraging or damaging smallholder plantations, and so Aras Napal residents have a generally favourable attitude towards them. We found no evidence of large carnivores utilising edge forest, and there are no reports of them entering agricultural areas. Although reported human-wildlife interactions are relatively infrequent and local tolerance of wildlife remains high (Slater 2019), the situation warrants monitoring to ensure human-wildlife conflict remains low.

While clear relationships between temperature, tree height and tree diameter and mammal detections were found, there are other factors that are likely important drivers of mammal occurrence. Higher human foot traffic and hunting risk will leads to more vigilant behaviours or avoidance of areas with high human footprint (e.g., wolverines, Stewart et al 2016). Differences in species composition and food availability at the edge will also influence the distribution of species, and the effects of abiotic changes at the forest edge could therefore be indirect. Deer, for example, are preferred prey for tigers (Allen, Sibarani and Krofel 2020) and were detected less at locations near the forest edge.

Unfortunately, due to our relatively small study area and low population density of certain mammal species, the sample numbers are too low to perform more detailed analyses. Future work that samples a larger area and includes different land use types at the boundary (e.g., oil palm plantations, roads etc) would yield higher sample numbers and enable more sophisticated analyses and a comparison of edge effects between differing land uses. Inferential approaches, such as occupancy modelling, would allow for interspecies comparisons by accounting for imperfect detection (Martin et al., 2015). This would give more detailed insights into how each species is impacted by environmental disturbance and how disturbance will influence the community structure and functional diversity of forests. These analyses are not appropriate with our current sampling design, since our intention was to monitor species preferences within their ranges, and not test for differences in occupancy between sites. This study does provide a useful baseline for which species are using the forest and those which appear to be more affected by environmental changes brought on by edge effects at the park boundary.

Conservation Implications

Sikundur represents key habitat for Indonesian mammals. Seven out of 17 detected species are threatened with extinction, while a further three are Near Threatened (IUCN, 2021b). Apart from three species with unknown population trends, all identified species have a decreasing population trend globally (IUCN, 2021b). Several species are endemic to Sumatra with very limited geographic ranges and low population sizes. The populations in Sikundur must be maintained to prevent mammal extinctions. Data on these populations will be critical to tracking national progress towards biodiversity targets and informing adaptive conservation management for several species of national and global conservation importance in Indonesia (Steenweg et al., 2017).

Conservation in secondary and fragmented forests requires an understanding of edge effects on target conservation species. Reserves and corridors will need to provide a buffer of at least 1km to protect threatened species (particularly large carnivores, deer, and primate species with a low tolerance for human disturbance) from harmful edge effects. Many reserves in agricultural landscapes are not large enough to provide this and will be unsuitable for these species in the long term without further action (Scriven et al., 2019). This work highlights the essential role of secondary, as well as primary, forests in preventing extinctions (Dent & Wright, 2009). Other secondary forest sites can support similar numbers of species to primary forests within 20 years of recovery following abandonment (Dunn, 2004). Protecting primary

345 forest should remain a priority, but secondary forest cover now exceeds primary forest in over 42 tropical countries (Dent & Wright, 2009). Conservation actions in human-modified forests will be key to prevent extinctions in the tropics and ensure healthy, resilient mammal populations.

Author contributions

350 Study conceptualisation & design: HS, AK, PG, S, AA; Field data collection: HS, S, VP, BE, SF; Data analysis: HS; Manuscript preparation: HS; editing & revision of manuscript HS, AK, PG.

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Conflicts of interest

365 There are no known conflicts of interest in relation to this work.

Ethical standards

All field research in Indonesia adhered to all legal requirements for foreign researchers in Indonesia, with the required research visa (Permit no: 70/SIP/FRP/E5/Dit.KI/III/2018 & 370 6/E5/E5 4/SIP EXT/2019), and a SIMAKSI entry permit for the National Park being obtained prior to the start of the work. We obtained permission to place cameras from landowners and Aras Napal residents. This study was approved by Bournemouth University's Research Ethics

committee prior to commencement and adhered to *Oryx* guidelines for ethical standards. This research was carried out in collaboration with researchers and conservationists from Syiah Kuala University in Banda Aceh, the Sumatran Orangutan Conservation Programme, and the 375 Aras Napal Community Group. This study used non-intrusive observatory methods only, and great care was taken to prevent any potential disturbances to the forest and wildlife.

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Tables

TABLE 1: Coefficient estimates with standard errors in parentheses for the GLMM with gaussian distribution testing the effects of distance from the forest edge on forest structure variables at Aras Napal (σ^2 = Residual variance; τ_{00} = Random intercept variance).

	Dependent variables:						
	Tree height, m	Bole height, m	Diameter at breast height, cm	Tree basal area, cm ²	Height:DBH ratio	Crown area, m ²	Canopy connectivity, %
Distance from edge, m	0.002** (0.00)	0.002*** (0.00)	-0.001 (0.00)	0 (0.00)	0.006*** (0.00)	-0.0005 (0.00)	0.001 (0.00)
(Intercept)	17.72*** (1.05)	8.45*** (0.68)	33.25*** (1.50)	0.10*** (0.01)	55.53 *** (1.83)	45.289*** (4.12)	43.409*** (3.03)
Random effects							
σ^2	65.93	33.38	184.94	0.01	267.97	1356.24	538.29
$\tau_{00}^{\text{Transect}}$	1.13	0.20	0.00	0.00	0.00	0.00	9.87
N ^{Transect}	4	4	4	4	4	4	4
N	217	217	217	217	217	217	217
Akaike Inf. Crit.	1,544.51	1,397.02	1,764.32	-382.04	1,844.04	2,192.69	1,996.05

*p<0.1; **p<0.05; ***p<0.01

525 TABLE 2: Coefficient estimates with standard errors in parentheses for GLMM with gaussian distribution testing the effects of distance from the forest edge on hourly temperature and light intensity recorded over the whole sampling period at Aras Napal (σ^2 = Residual variance; τ_{00} = Random intercept variance)

<i>Dependent variable:</i>		
	Temperature, °C	Light intensity, lux
Distance from forest edge, m	-0.0002*** (0.00001)	-0.91*** (0.02)
(Intercept)	25.80*** (0.41)	2,025.94*** (392.20)
Random Effects		
σ^2	1.23	5881034.02
τ_{00}	0.36 Day of year	22637.55 Day of year
	3.58 hour	2015972.65 hour
	0.04 Transect	273899.88 Transect
N	4 Transect	4 Transect
	49 DOY	49 DOY
	24 hour	24 hour
N	21,071	21,071
Akaike Inf. Crit.	64,557.59	388,437.70

*p<0.1; **p<0.05; ***p<0.01

530 TABLE 3: Coefficient estimates with standard errors in parentheses for the GLMM with gaussian distribution testing the effects of distance from the forest edge on daily values of forest microclimate at Aras Napal (σ^2 = Residual variance; τ_{00} = Random intercept variance)

	Dependent variables:				
	Daily mean temp, °C	Daily max temp, °C	Daily min temp, °C	Daily mean light intensity, lux	Daily max light intensity, lux
Distance from forest edge, m	-0.0002*** (0.00)	-0.001*** (0.00)	0.0001*** (0.00)	-0.876*** (0.05)	-4.434*** (0.26)
(Intercept)	25.71*** (0.13)	30.18*** (0.39)	23.11*** (0.11)	1,982.21*** (264.35)	10,031.03*** (1205.12)
Random Effects					
σ^2	0.2	2.11	0.1	1258641.48	29722948.87
τ_{00}	0.47 DOY	1.26 DOY	0.47 DOY	0.00 DOY	0.00 DOY
	0.03 Transect	0.48 Transect	0.01 Transect	262871.95 Transect	5415830.38 Transect
N	4 Transect	4 Transect	4 Transect	4 Transect	4 Transect
	49 Day of year	49 Day of year	49 Day of year	49 Day of year	49 Day of year
N	908	908	908	908	908
Akaike Inf. Crit.	1,335.38	3,412.66	734.99	15,344.76	18,209.03

*p<0.1; **p<0.05; ***p<0.01



TABLE 4: Checklist of mammals detected at Aras Napal with the total number of detections and naïve occupancy (the proportion of sampling locations at which family/species was detected).

Order	Family	Species	Scientific name	IUCN status	Population trend	Detection events	Naïve occupancy
Erinaceomorpha	Erinaceidae	Moonrat	<i>Echinosorex gymnura</i>	LC	unknown	16	0.21
Primates	Cercopithecidae	Long-tailed macaque	<i>Macaca fascicularis</i>	LC	decreasing	1	0.05
	Cercopithecidae	Pig-tailed macaque	<i>Macaca nemestrina</i>	VU	decreasing	83	0.79
	Cercopithecidae	Thomas's langur	<i>Presbytis thomasi</i>	VU	decreasing	2	0.05
Carnivora	Ursidae	Sun bear	<i>Helarctos malayanus</i>	VU	decreasing	2	0.11
	Mustelidae	Oriental short-clawed otter	<i>Amblyonyx cinereus</i>	VU	decreasing	1	0.05
	Herpestidae	Collared mongoose	<i>Herpestes semitorquatus</i>	NT	decreasing	1	0.05
	Herpestidae	Short-tailed mongoose	<i>Herpestes brachyurus</i>	NT	decreasing	5	0.11
	Prionodontidae	Banded linsang	<i>Prionodon linsang</i>	LC	decreasing	5	0.16
	Felidae	Sumatran tiger	<i>Panthera tigris ssp. sumatrae</i>	CR	decreasing	1	0.05
Proboscidea	Elephantidae	Sumatran elephant	<i>Elephas maximus ssp. sumatrana</i>	CR	decreasing	11	0.21
Artiodactyla	Suidae	Wild boar	<i>Sus scrofa</i>	LC	Unknown	23	0.53
	Tragulidae	Lesser oriental chevrotain	<i>Tragulus kanchil</i>	LC	unknown	48	0.47
	Cervidae	Sambar	<i>Rusa unicolor</i>	VU	decreasing	3	0.16
	Cervidae	Southern red muntjac	<i>Muntiacus muntjak</i>	LC	decreasing	37	0.26
Rodentia	Muridae	Rat	--	--	--	9	0.26
	Muridae	Mouse	--	--	--	44	0.16
	Hystricidae	Malayan porcupine	<i>Hystrix brachyura</i>	LC	decreasing	16	0.37
	Sciuridae	Squirrel	--	--	--	17	0.37

535 **TABLE 5:** Coefficient estimates with standard errors in parentheses for the GLM with Poisson distribution testing the effects of environmental variables on the number of overall mammal detection events at Aras Napal. Significant effects ($\alpha = 0.05$) are highlighted in bold.

Model 1	
(Intercept)	27.47 * (10.72)
Maximum temperature, °C	-0.13 *** (0.03)
Minimum temperature, °C	-1.14 * (0.49)
Tree height, m	-0.11 *** (0.02)
Diameter at breast height, cm	0.19 *** (0.03)
N	19
Akaike Inf. Crit.	171.89

*** p < 0.001; ** p < 0.01; * p < 0.05.

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TABLE 6: Generalised linear mixed model (negative binomial) fit by the Laplace approximation of total detection events of different mammal Orders according to environmental variables. Significant P-values ($\alpha = 0.05$) are highlighted in bold. (σ^2 = Residual variance; τ_{00} = Random intercept variance; ICC = Intraclass correlation coefficient).

<i>Dependent variable:</i>	
Number of detections	
(Intercept)	-0.70 (0.05)
Tree height, m	-0.18*** (0.06)
Diameter at breast height, cm	0.29*** (0.07)
Random Effects	
σ^2	1.13
τ_{00} order	0.93
N _{order}	6
N	114
Akaike Inf. Crit.	429.44

Note:

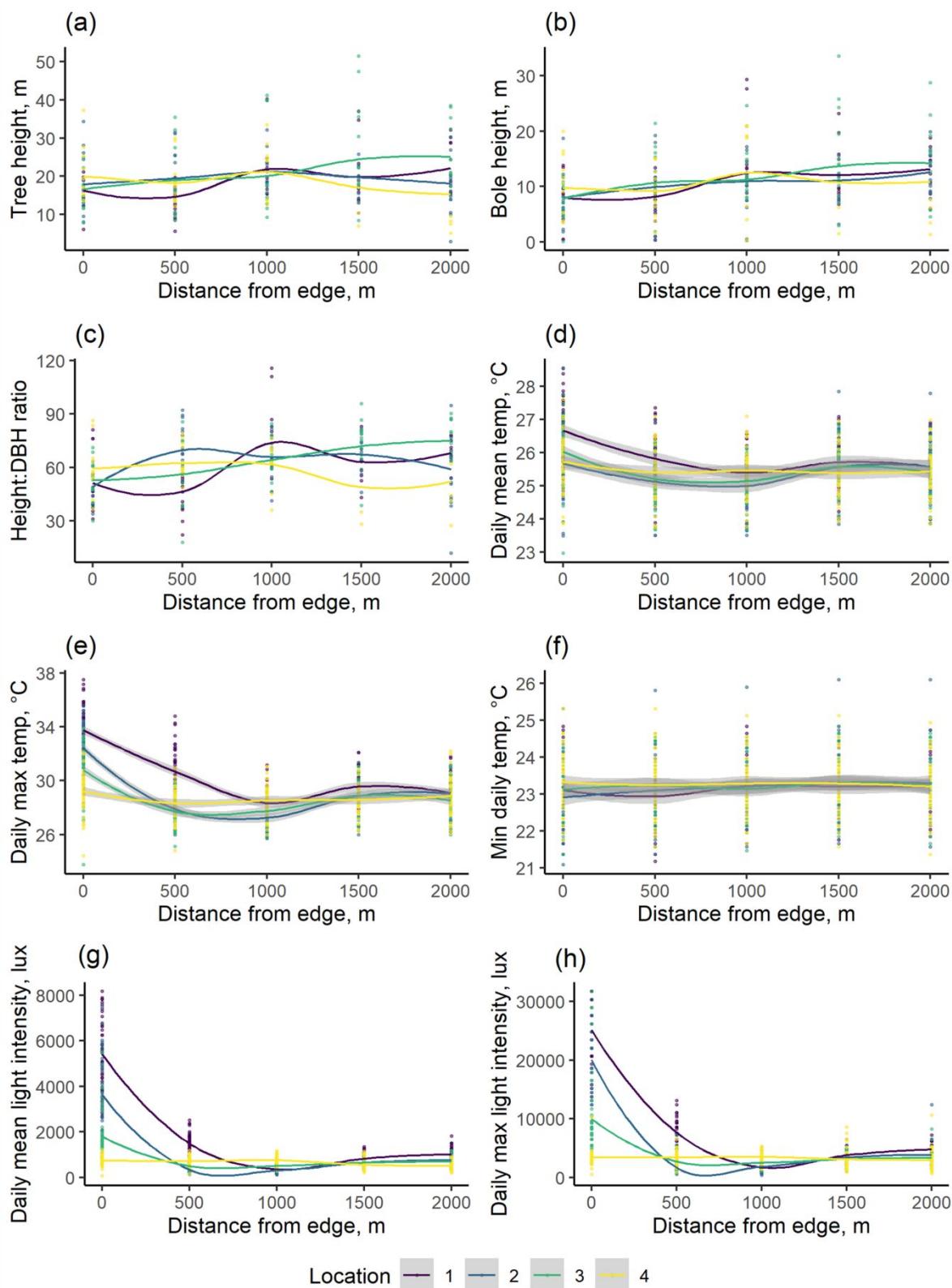
*p<0.1; **p<0.05; ***p<0.01

Figures



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FIG. 1: Monitoring locations in Sikundur and Aras Napal (right) and the Sikundur region within the Leuser ecosystem (left) in Sumatra, Indonesia.



550 **FIG. 2:** GLMM predictions (lines), with 95% confidence intervals (grey shading), and observed microclimate and forest structure with distance from the forest edge along transects at Aras Napal: (a) Mean light intensity of each day, lux; (b) Maximum light intensity of each day, lux; (c) Mean temperature of each day, °C; (d) Maximum temperature of each day, °C; (e) Minimum temperature of each day, °C; (f) Tree height, m; (g) Bole height, m; and (h) height:DBH ratio.

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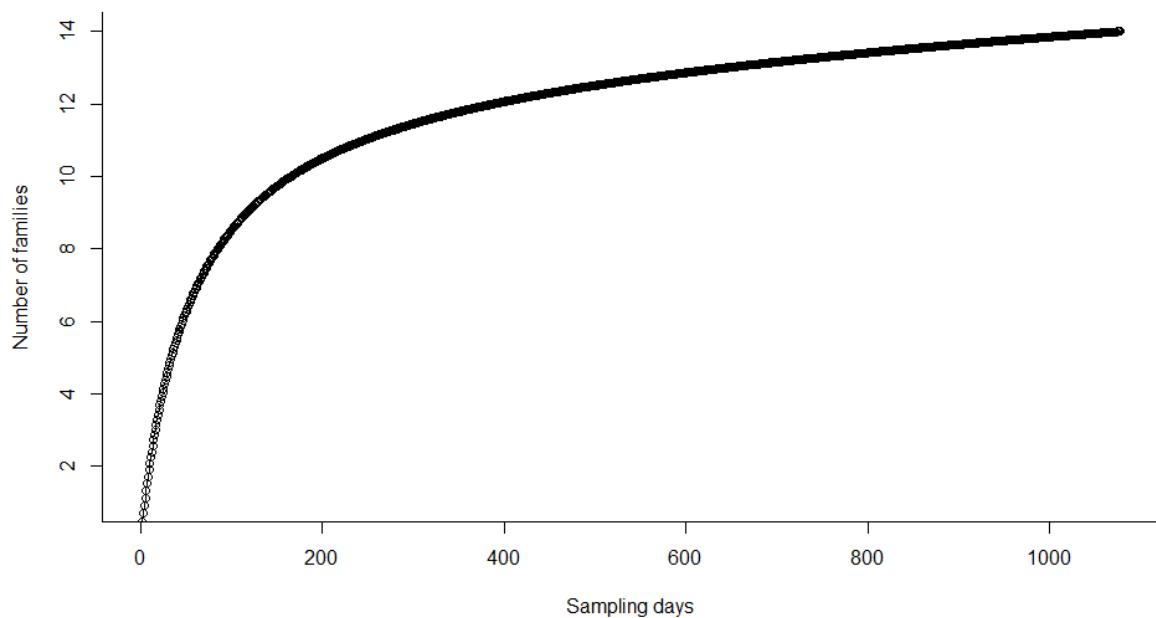


FIG. 3: Species accumulation curve showing number of mammal families detected with sampling effort in Aras Napal.

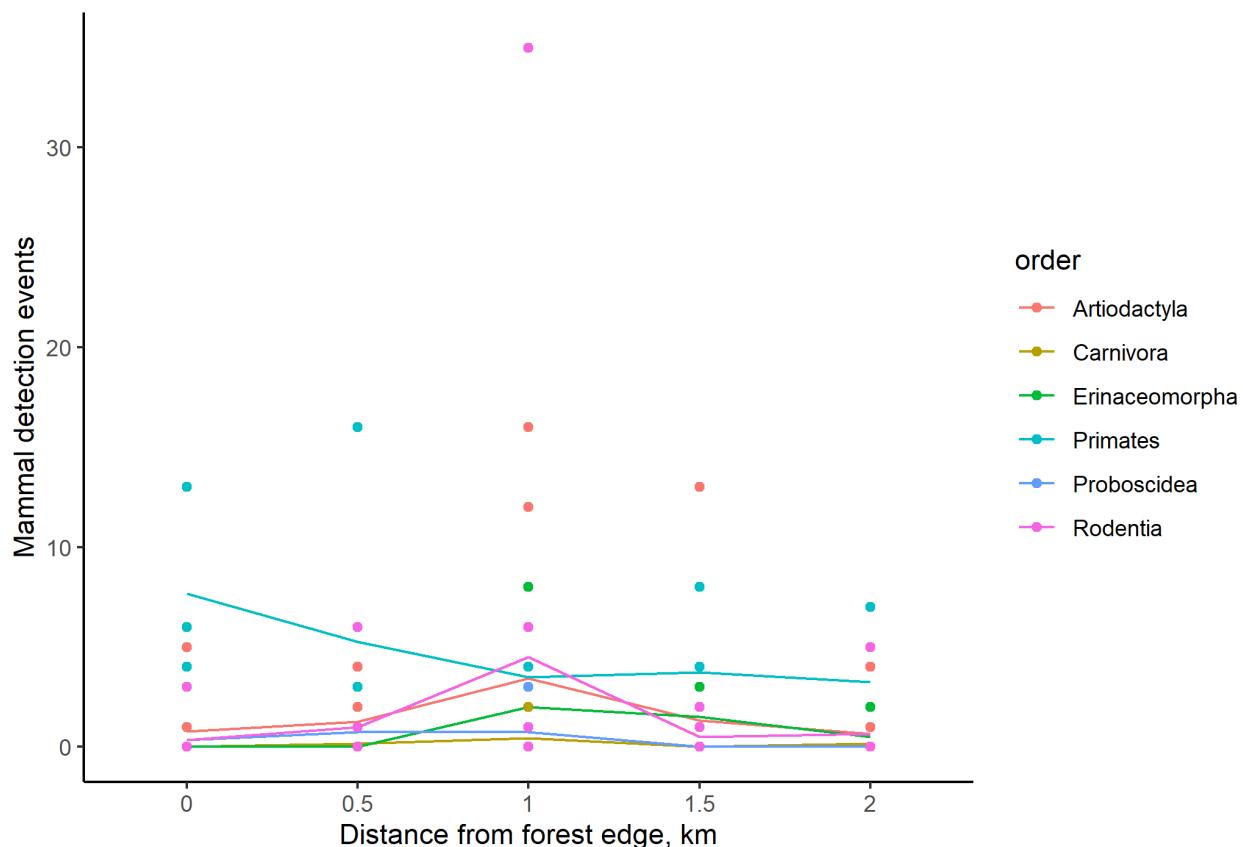


FIG. 4: Total number of detection events for each mammal Order detected at different distances

560 from the forest edge at Aras Napal.

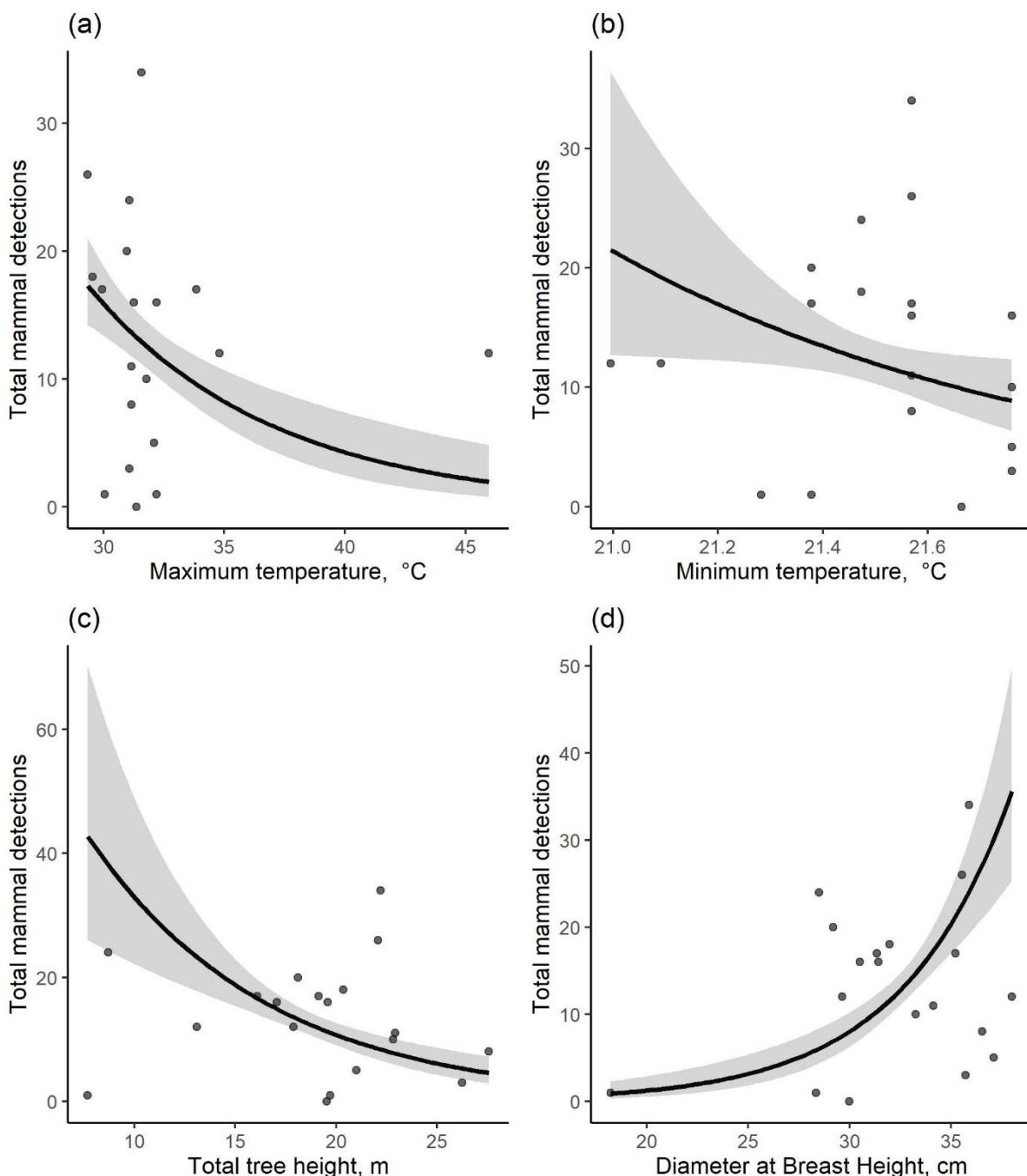


FIG. 5: GLM predictions (lines), with 95% confidence intervals (grey shading), and observed number of mammal detections against (a) maximum temperature, °C; (b) minimum temperature, °C; (c) tree height, m; and (d) DBH, cm on the total number of mammal detection events at Aras Napal.

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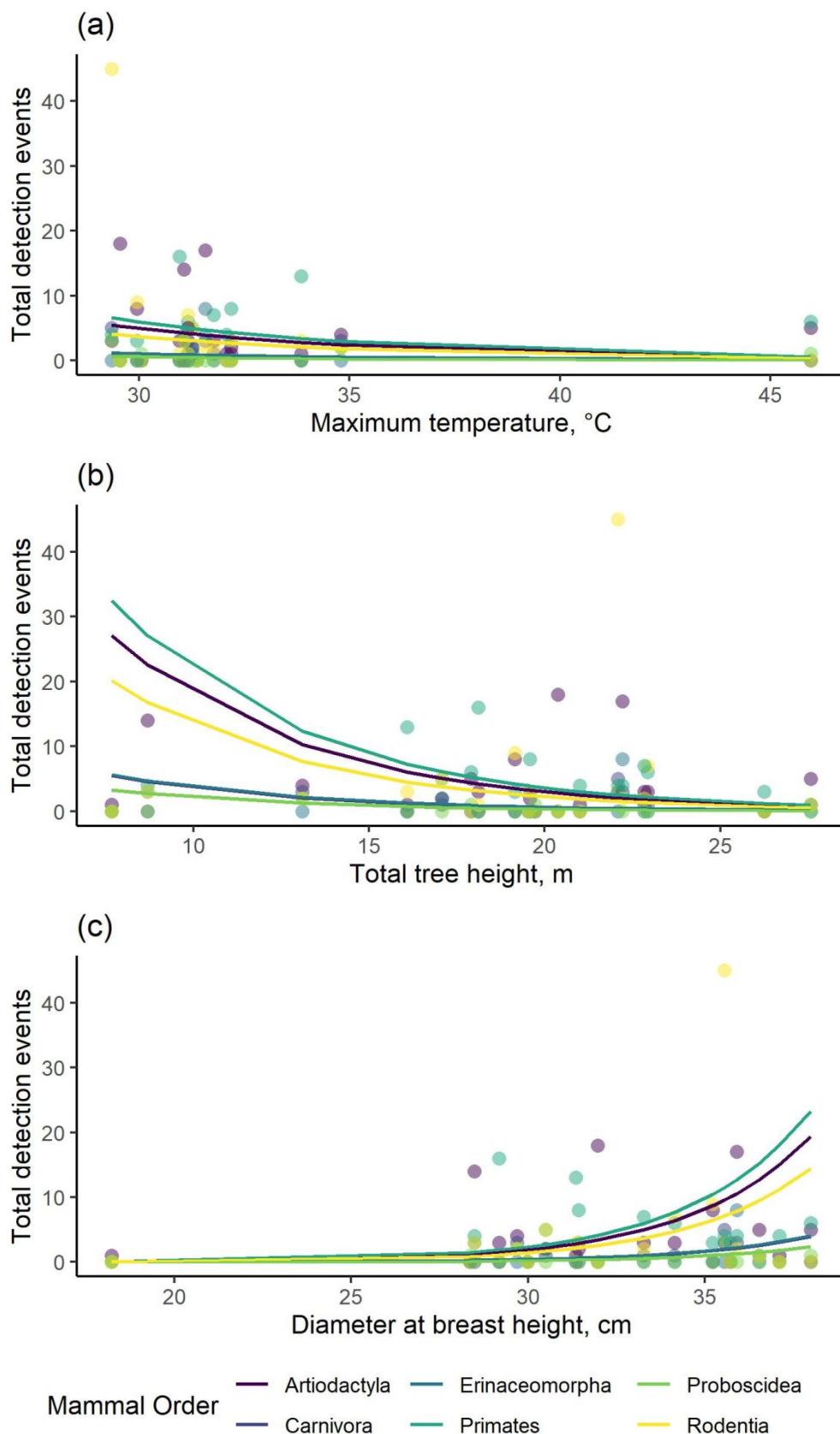


FIG. 6: GLMM predictions (lines) and observed values (points) of detection rates by mammal Order against (a) Maximum temperature, °C; (b) Tree height, m; and (c) Diameter at breast height, cm.

Living on the edge: Forest edge effects on microclimate and terrestrial mammal activity in disturbed lowland forest in Sumatra, Indonesia.

HELEN D. SLATER, PHILLIPA K. GILLINGHAM, VICTORIA PRATT, BEN EATON, SIMON FLETCHER, ABDULLAH ABDULLAH, SUPRIADI, and AMANDA H. KORSTJENS

SUPPLEMENTARY TABLE 1: *Environmental variables collected from all monitoring locations at Sikundur.*

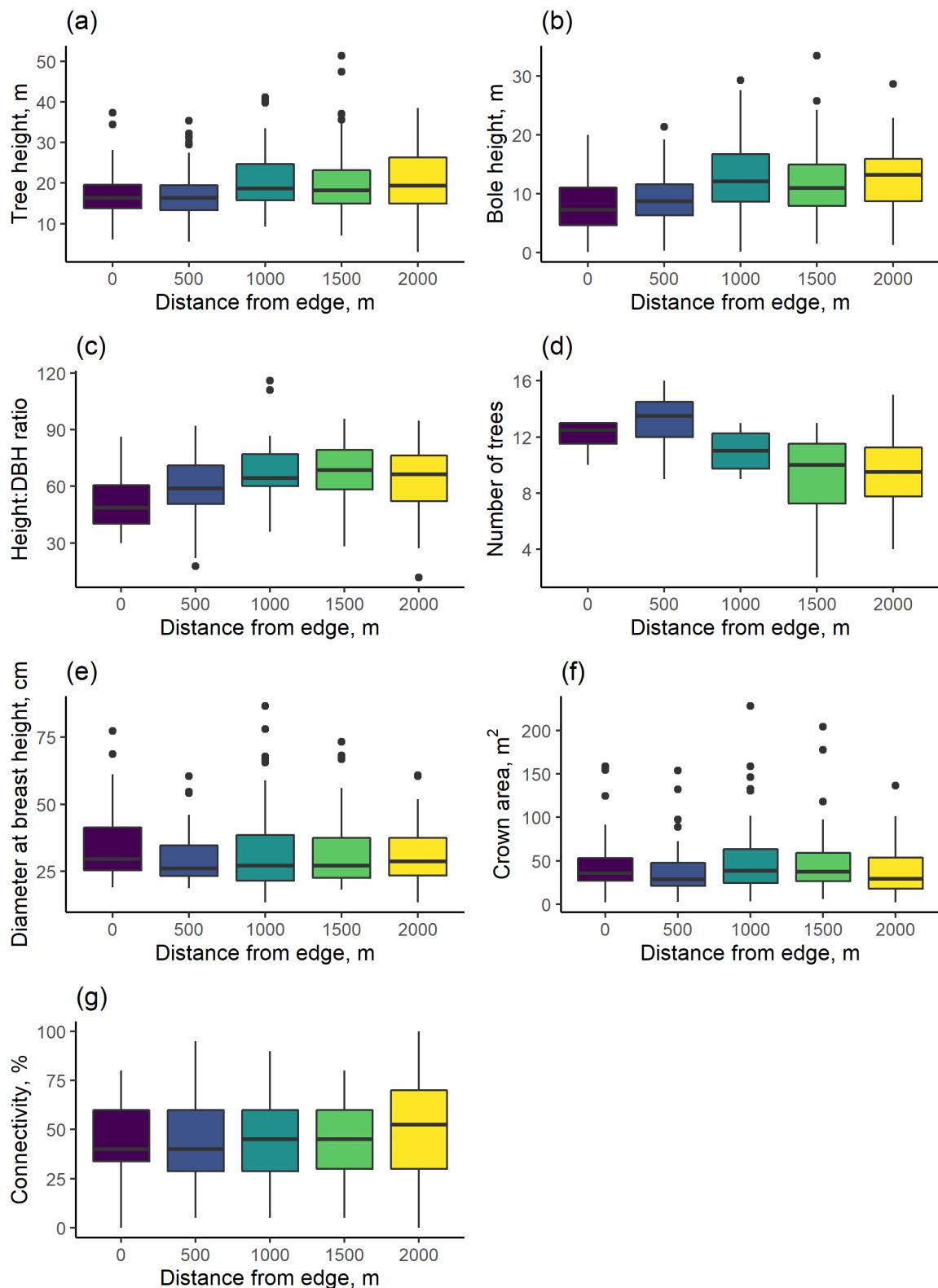
Variable	Description(units)
T _{hour}	Hourly temperature (°C)
T _{day}	Mean temperature of each 24-hour period (°C)
T _{max}	Maximum temperature of each 24-hour period (°C)
T _{min}	Minimum temperature of each 24-hour period (°C)
Li _{hour}	Hourly light intensity (lux)
Li _{day}	Mean light intensity recorded of each 24-hour period (lux)
Li _{max}	Maximum light intensity recorded of each 24-hour period (lux)
Total height	Total tree height for each tree (m)
Bole height	Height to the first major branch for each tree (m)
Number of trees	Total number of trees DBH>10cm per plot
DBH	Diameter at breast height for each tree (cm)
HDR	Height to DBH ratio for each tree
Crown area	Estimated crown area for each tree (m ²)
Connectivity	Estimated connectivity with neighbouring crowns for each tree (%)

SUPPLEMENTARY TABLE 2: *Descriptive statistics of forest structure variables collected from plots at different distances from the forest edge at Aras Napal (μ = mean, SD = standard deviation).*

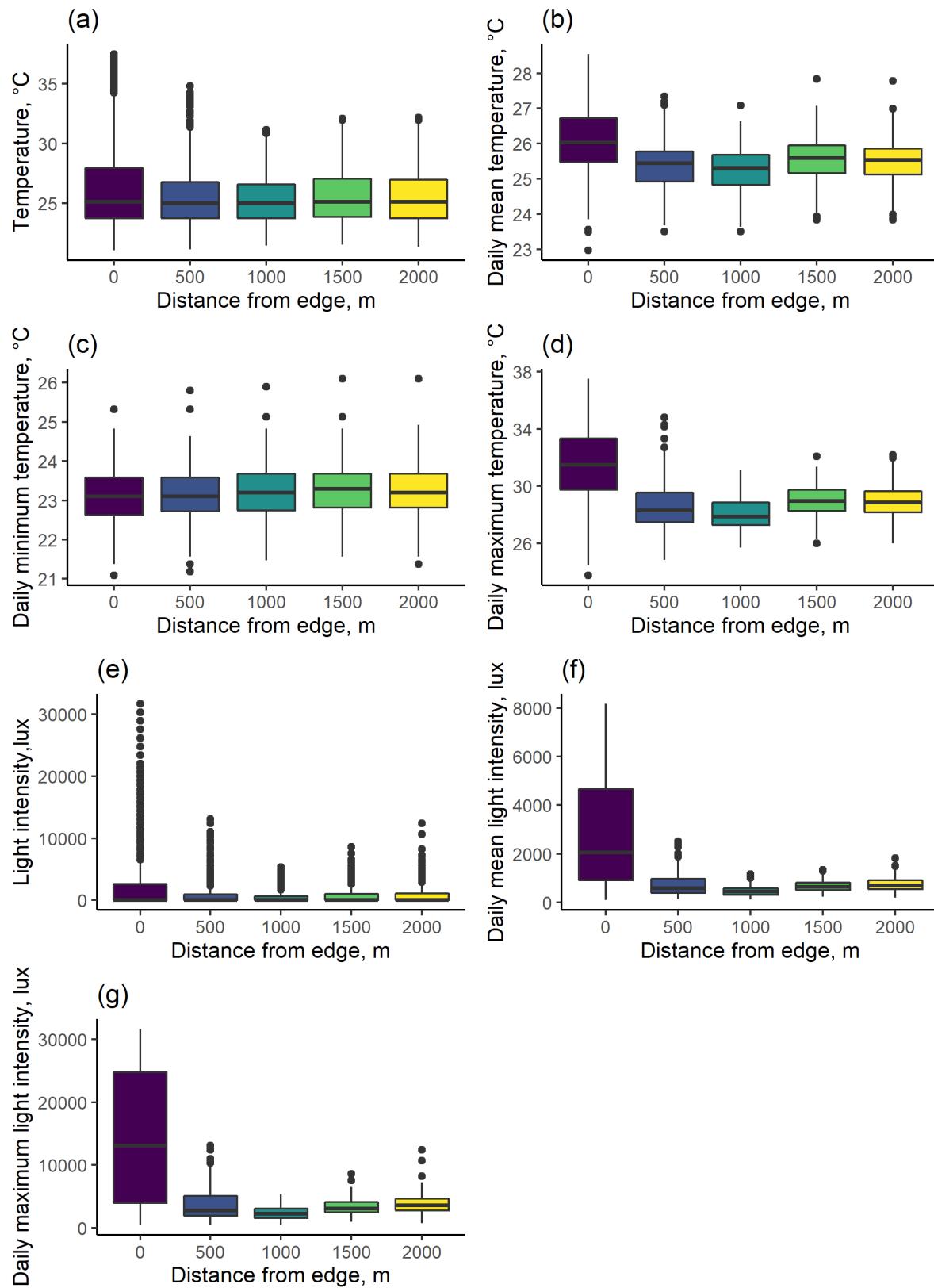
		All locations	0km	0.5km	1km	1.5km	2km
Number of trees per plot	N	20	4	4	4	4	4
	μ	10.85	12.13	13.50	11.23	10.71	11.11
	SD	3.41	1.18	2.38	1.58	2.70	3.61
Tree height, m	N	217	48	52	44	35	38
	μ	19.45	17.48	17.44	21.83	21.43	20.08
	SD	8.27	6.34	6.79	8.51	10.37	8.93
Bole height, m	N	217	48	52	44	35	38
	μ	10.71	8.06	9.13	12.68	12.24	12.51
	SD	6.08	4.61	4.90	6.85	6.84	5.67
Diameter at breast height, cm	N	217	48	52	44	35	38
	μ	33.45	34.62	30.11	33.68	32.49	31.36
	SD	13.58	13.26	9.98	17.96	14.55	11.40
Height:DBH ratio	N	217	48	52	44	35	38
	μ	61.39	52.15	59.23	67.89	66.46	63.80
	SD	16.94	13.97	16.78	15.70	15.42	18.32
Crown area, m ²	N	217	48	52	44	35	38
	μ	44.86	45.73	38.09	53.76	50.76	37.31
	SD	36.74	33.98	29.37	45.83	42.74	29.26
Canopy connectivity, %	N	217	48	52	44	35	38
	μ	45.00	44.27	44.23	44.43	43.86	48.68
	SD	25.33	20.68	24.22	23.33	20.37	28.18

SUPPLEMENTARY TABLE 3: *Descriptive statistics of hourly and daily microclimate recorded at different distances from the forest edge at Aras Napal (μ = mean, SD = standard deviation).*

		All locations	0km	0.5km	1km	1.5km	2km
Hourly temperature, °C	<i>N</i>	21071	4005	4266	4270	4274	4256
	μ	25.54	26.06	25.38	25.24	25.55	25.49
	<i>SD</i>	2.25	3.00	2.09	1.79	2.09	2.07
Hourly light intensity, lux	<i>N</i>	21071	4005	4266	4270	4274	4256
	μ	1075.59	2866.37	751.40	474.54	663.04	732.70
	<i>SD</i>	2890.35	5847.67	1462.34	812.08	1068.53	1209.76
Daily mean temperature, °C	<i>N</i>	244	49	49	49	49	48
	μ	25.55	26.05	25.38	25.23	25.56	25.51
	<i>SD</i>	0.75	0.83	0.72	0.61	0.68	0.66
Daily maximum temperature, °C	<i>N</i>	244	49	49	49	49	48
	μ	30.33	33.75	30.44	28.58	29.50	29.36
	<i>SD</i>	2.45	2.32	1.98	1.15	1.24	1.21
Daily minimum temperature, °C	<i>N</i>	244	49	49	49	49	48
	μ	22.99	22.81	22.87	23.07	23.12	23.06
	<i>SD</i>	0.72	0.76	0.76	0.70	0.68	0.68
Daily mean light intensity, lux	<i>N</i>	244	49	49	49	49	48
	μ	1106.08	2842.93	771.93	474.78	674.50	759.19
	<i>SD</i>	1004.60	994.20	324.12	122.65	181.85	240.73
Daily maximum light intensity, lux	<i>N</i>	244	49	49	49	49	48
	μ	9074.33	24899.23	7293.13	3523.55	4388.18	5188.22
	<i>SD</i>	8733.83	6720.61	2593.22	1006.51	1427.45	1854.69



SUPPLEMENTARY FIG. 1: Forest structure variables recorded from plots at different distances from the forest edge at Aras Napal: (a) Tree top height, m; (b) height to first major branch, m; (c) height:DBH ratio; (d) number of trees per plot; (e) Diameter at breast height, cm; (f) crown area, m²; and (g) Crown connectivity, %.



SUPPLEMENTARY FIG. 2: Microclimate conditions recorded from locations at different distances from the forest edge at Aras Napal. (a) Hourly temperature; (b) mean temperature of each day; (c) minimum temperature of each day; (d) maximum temperature of each day; (e) hourly light intensity; (f) mean light intensity of each day; and (g) maximum light intensity of each day.

SUPPLEMENTARY MATERIAL 1

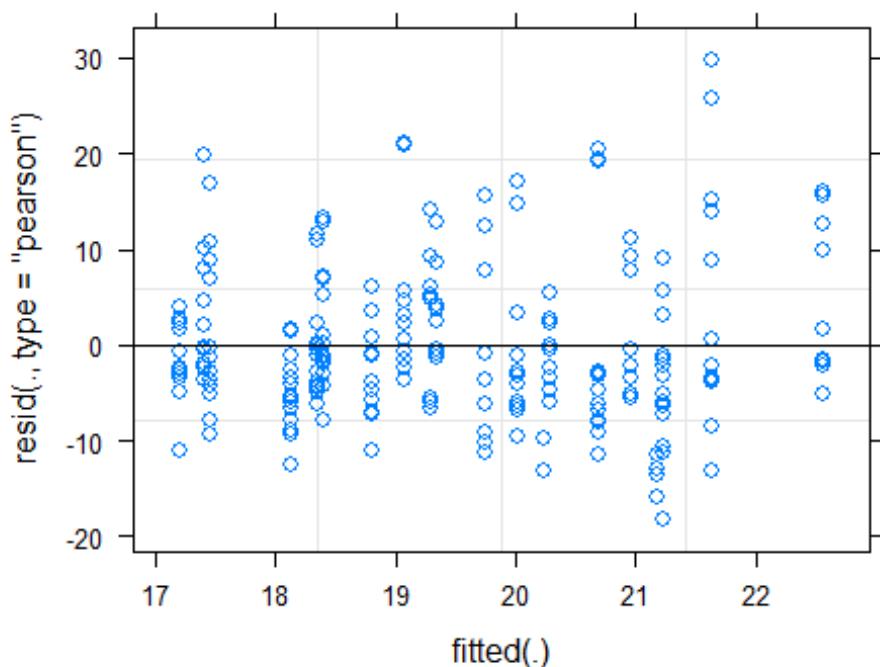
The below text presents R code used to fit Generalised Linear Models and Generalised Linear Mixed Models to determine the effects of distance to the forest edge on forest conditions, and the relationship between microclimate and forest conditions on mammal detections in Sikundur, North Sumatra, Indonesia.

1) Edge effects on forest & microclimate

1a) Generalized Linear Mixed Models of the effects of distance from forest edge on Forest structure

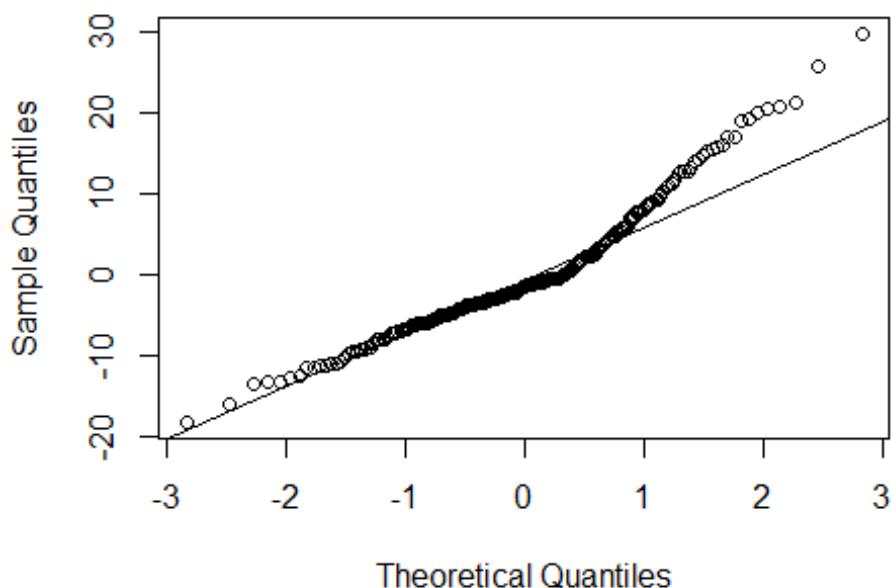
```
# Load raw datafile
rawveg <- read.csv("trees.csv")
# Format vegetation data:
# Calculate basal area for all indvl trees
basal.area.fn <- function(x){ (pi*(x)^2)/40000 } # calculate basal
area in m^2
rawveg["ba"] = basal.area.fn(rawveg$dbh)
# Calculate Lorey's mean height for each plot (mean tree height
weighted by basal area)
Loreys <-
Lorey.height(rawveg$ba, rawveg$Theight, group.id=rawveg$camID)
Loreys <- rename(Loreys, "camID" = group.id, "Lorey" = Lorey.height)
# Count number of trees per plot
n <- rawveg %>% count(camID)
# Calculate mean, max and min for tree variables
veg <- rawveg %>%
  group_by(camID) %>%
  summarise(dbh = mean(dbh), height = mean(Theight), bole =
mean(Bheight), crown=mean(crown), conn=mean(conn))
# Combine data into one data frame
veg <- merge(veg, n)
veg <- merge(veg, Loreys)
veg <- veg %>% rename(LocID=camID)
rawveg <- rawveg %>% rename(Transect=transect)
rawveg <- rawveg %>% rename(LocID=camID)
rawveg$Transect <- factor(rawveg$Transect)
# Run the models:

# Tree height
treeheight.glmm <- lmer(Theight ~ dist + (1|Transect), data = rawveg)
# check model fit
plot(treeheight.glmm)
```



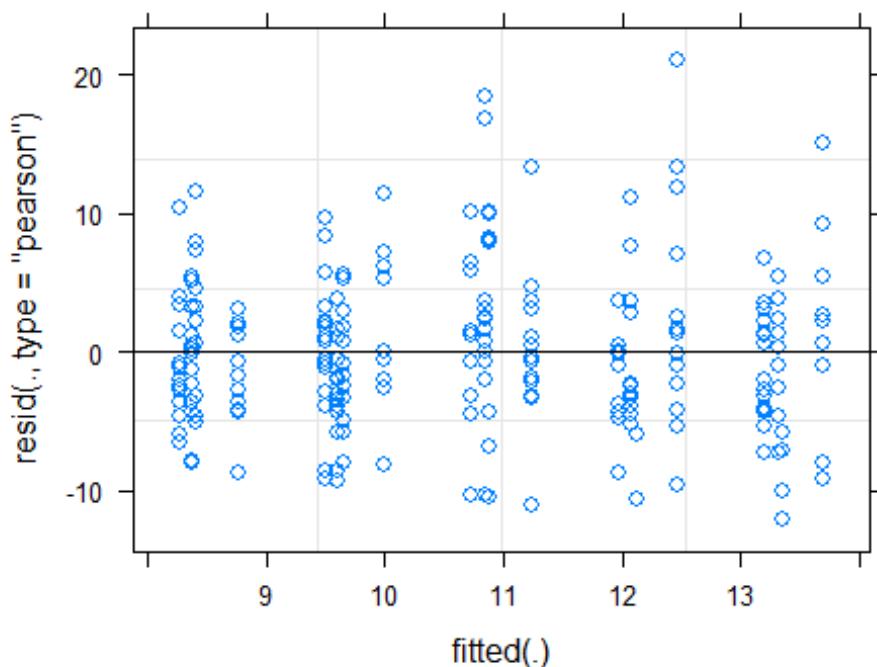
```
qqnorm(resid(treeheight.glmm))  
qqline(resid(treeheight.glmm))
```

Normal Q-Q Plot



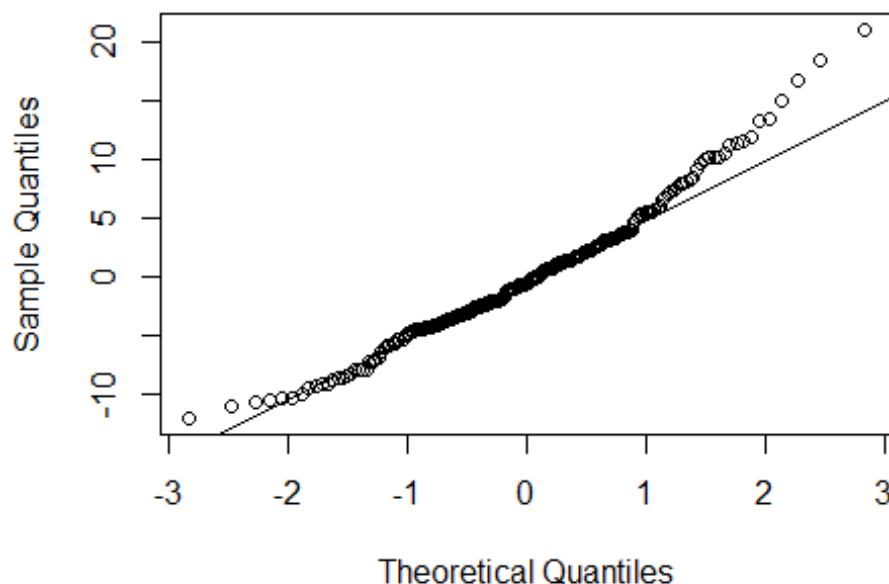
```
# Summary tables  
summary(treeheight.glmm)
```

```
## Linear mixed model fit by REML [ 'lmerMod' ]
## Formula: Theight ~ dist + (1 / Transect)
##   Data: rawveg
##
## REML criterion at convergence: 1536.5
##
## Scaled residuals:
##    Min      1Q  Median      3Q     Max
## -2.2447 -0.6230 -0.1940  0.4627  3.6666
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept) 1.133   1.065
##   Residual           65.934   8.120
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 1.771e+01 1.052e+00 16.83
## dist       1.884e-03 7.917e-04  2.38
##
## Correlation of Fixed Effects:
##   (Intr)
## dist -0.682
#
# Bole height
bole.glmm <- lmer(Bheight ~ dist + (1/Transect), data = rawveg)
# check model fit
plot(bole.glmm)
```



```
qqnorm(resid(bole.gLmm))  
qqline(resid(bole.gLmm))
```

Normal Q-Q Plot

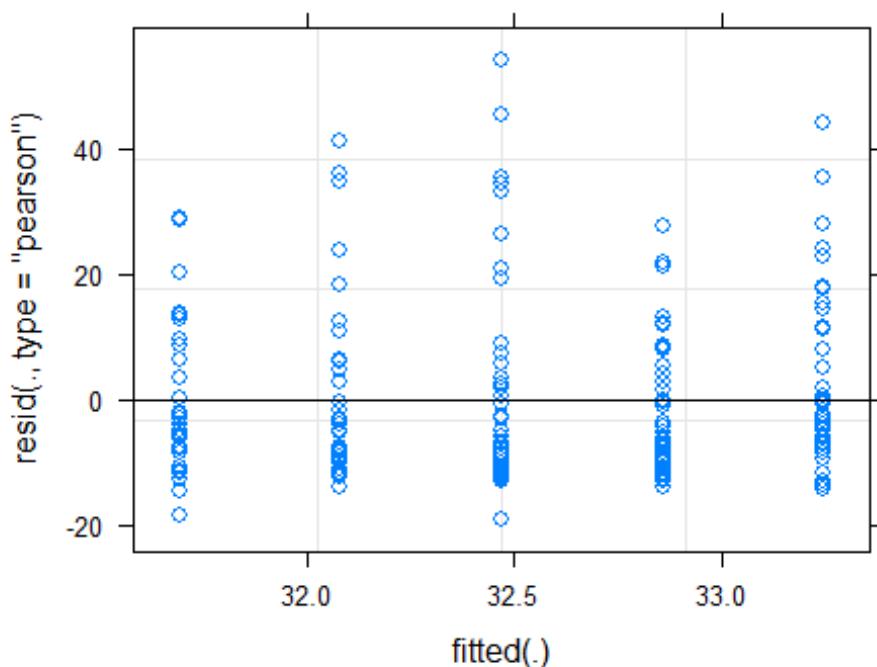


```
# Summary tables  
summary(bole.gLmm)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: Bheight ~ dist + (1 / Transect)
##   Data: rawveg
##
## REML criterion at convergence: 1389
##
## Scaled residuals:
##     Min      1Q Median      3Q     Max
## -2.0864 -0.6522 -0.1049  0.5360  3.6406
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept) 0.1961  0.4428
##   Residual           33.3777  5.7773
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 8.4514056  0.6826742 12.380
## dist        0.0024707  0.0005619  4.397
##
## Correlation of Fixed Effects:
##   (Intr) 
## dist -0.750
#
# Diameter at breast height
dbh.glmm <- lmer(dbh ~ dist + (1/Transect), data = rawveg)

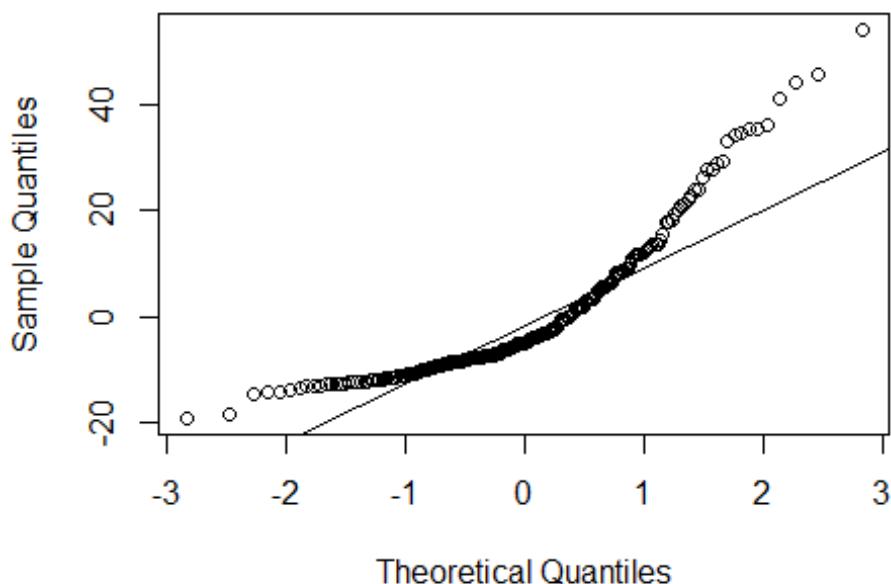
## boundary (singular) fit: see help('isSingular')

# check model fit
plot(dbh.glmm)
```



```
qqnorm(resid(dbh.gLmm))  
qqline(resid(dbh.gLmm))
```

Normal Q-Q Plot



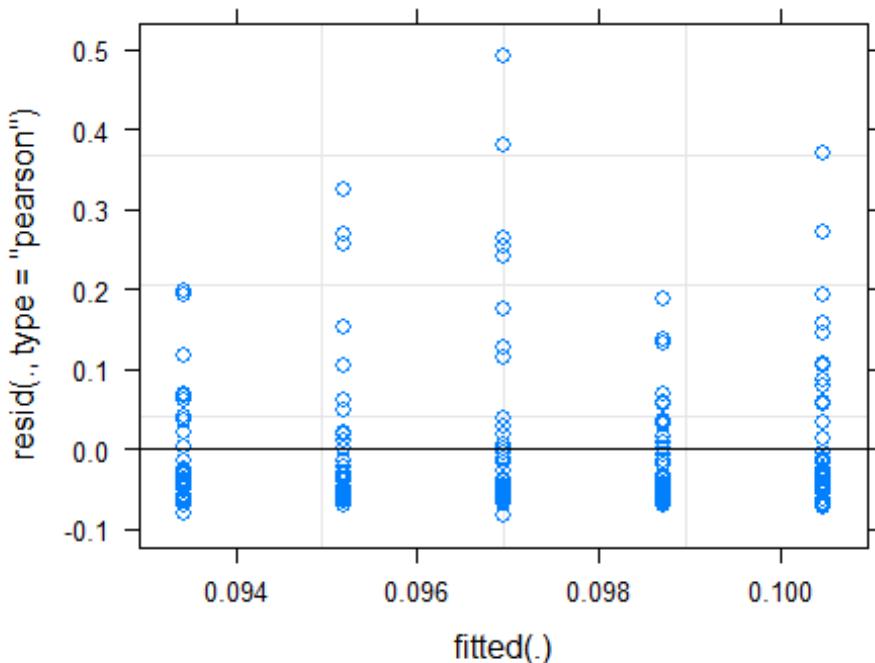
```
# Summary tables  
summary(dbh.gLmm)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: dbh ~ dist + (1 | Transect)
##   Data: rawveg
##
## REML criterion at convergence: 1751.7
##
## Scaled residuals:
##     Min      1Q Median      3Q     Max
## -1.4197 -0.6681 -0.3681  0.4259  4.0220
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept)    0        0.00
##   Residual             181       13.45
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##                   Estimate Std. Error t value
## (Intercept) 33.2475793 1.5035111 22.113
## dist        -0.0007778 0.0013057 -0.596
##
## Correlation of Fixed Effects:
##   (Intr) dist
## dist -0.794
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# Basal area
ba.glmm <- lmer(ba ~ dist + (1|Transect), data = rawveg)

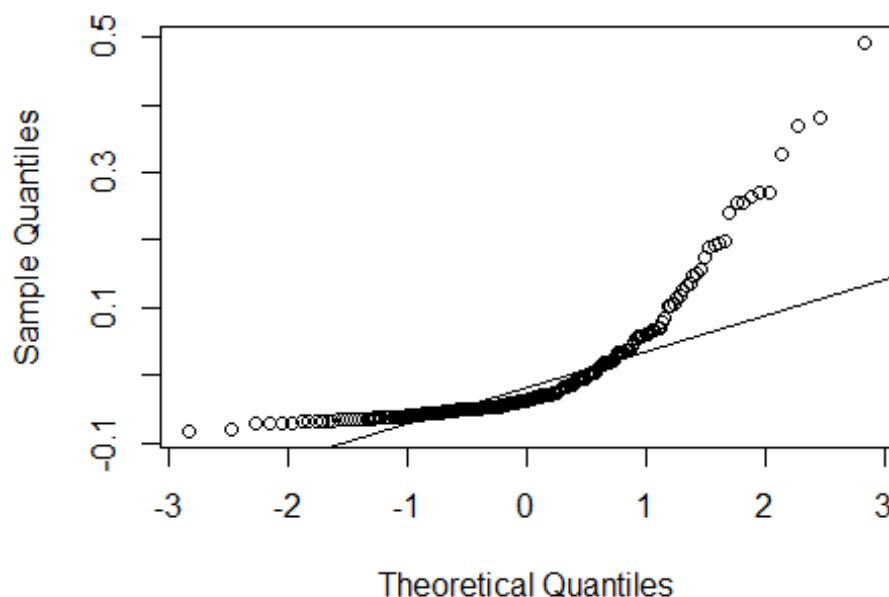
## boundary (singular) fit: see help('isSingular')

# check model fit
plot(ba.glmm)
```



```
qqnorm(resid(ba.gLmm))  
qqline(resid(ba.gLmm))
```

Normal Q-Q Plot



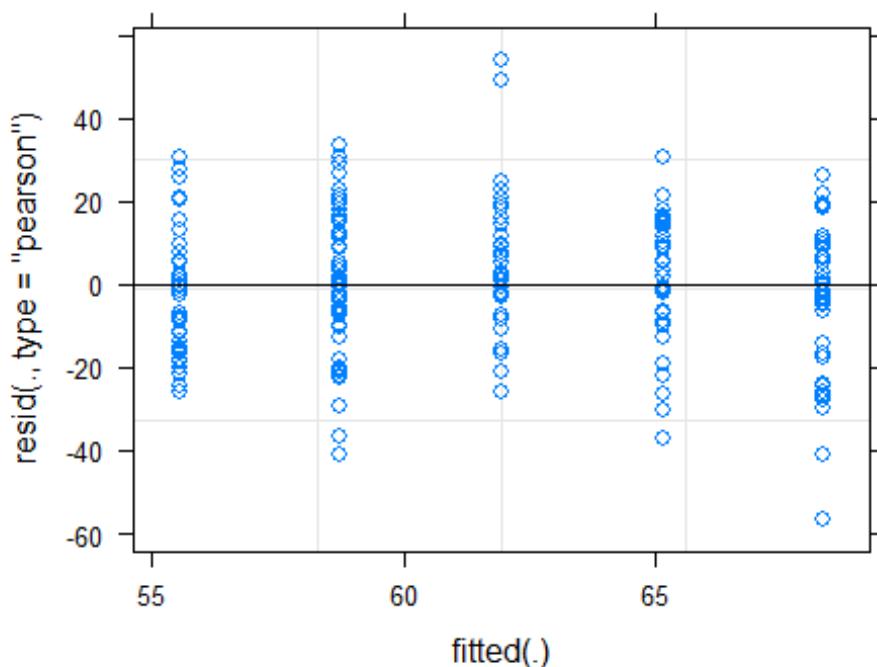
```
# Summary tables  
summary(ba.gLmm)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: ba ~ dist + (1 | Transect)
##   Data: rawveg
##
## REML criterion at convergence: -390.8
##
## Scaled residuals:
##     Min      1Q Median      3Q     Max
## -0.8989 -0.5850 -0.4041  0.1914  5.3317
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept) 0.000000 0.00000
##   Residual           0.008508 0.09224
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##                   Estimate Std. Error t value
## (Intercept)  1.005e-01  1.031e-02  9.746
## dist       -3.515e-06  8.952e-06 -0.393
##
## Correlation of Fixed Effects:
##   (Intr) dist
## dist -0.794
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# Height:DBH ratio
hdr.glmm <- lmer(HDR ~ dist + (1|Transect), data = rawveg)

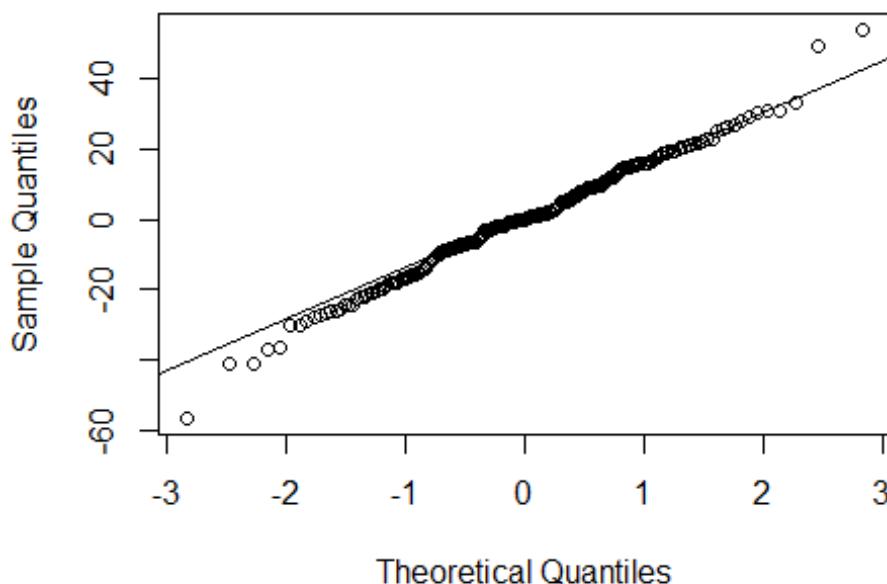
## boundary (singular) fit: see help('isSingular')

# check model fit
plot(hdr.glmm)
```



```
qqnorm(resid(hdr.gLmm))  
qqline(resid(hdr.gLmm))
```

Normal Q-Q Plot



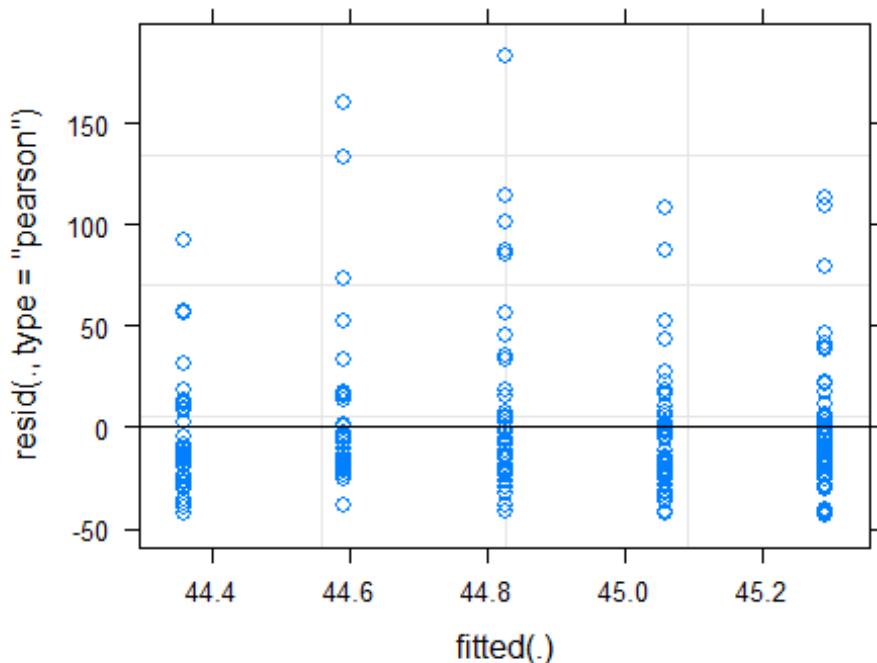
```
# Summary tables  
summary(hdr.gLmm)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: HDR ~ dist + (1 | Transect)
##   Data: rawveg
##
## REML criterion at convergence: 1836
##
## Scaled residuals:
##     Min      1Q Median      3Q     Max
## -3.4548 -0.5482  0.0045  0.6647  3.2986
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept)    0        0.00
##   Residual             268      16.37
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##           Estimate Std. Error t value
## (Intercept) 55.528937  1.829414 30.353
## dist        0.006404  0.001589  4.031
##
## Correlation of Fixed Effects:
##   (Intr)
## dist -0.794
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# Crown area
ca.glmm <- lmer(crown ~ dist + (1|Transect), data = rawveg)

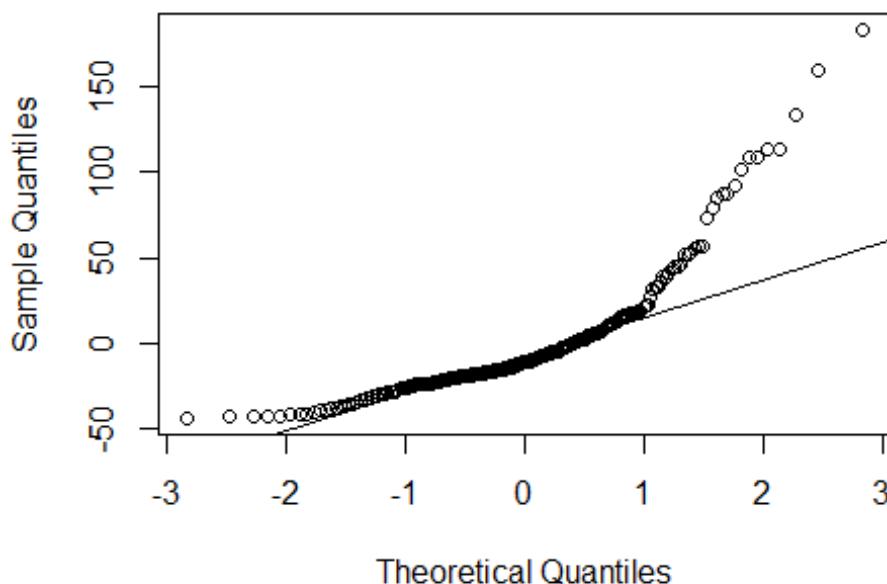
## boundary (singular) fit: see help('isSingular')

# check model fit
plot(ca.glmm)
```



```
qqnorm(resid(ca.gLmm))  
qqline(resid(ca.gLmm))
```

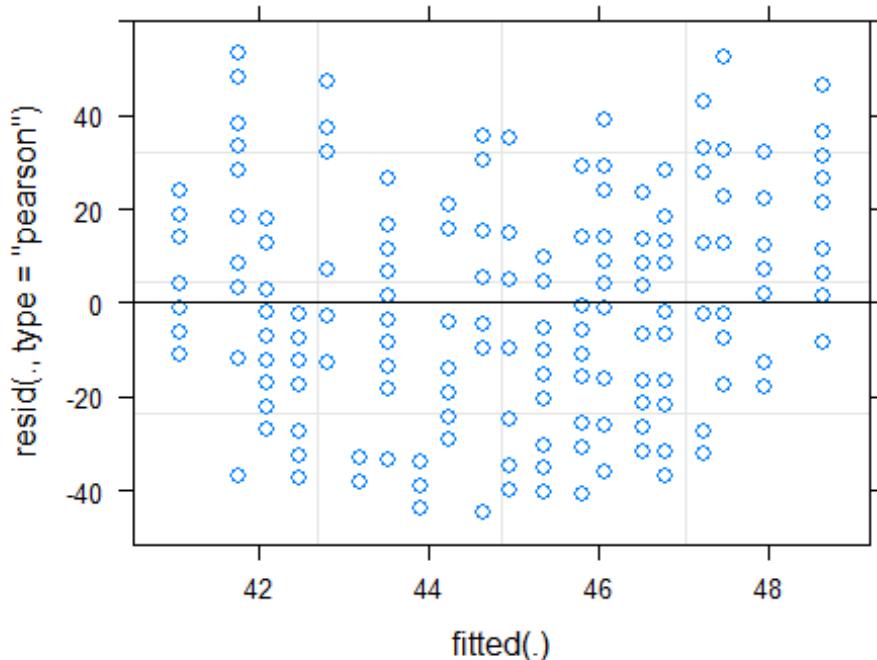
Normal Q-Q Plot



```
# Summary tables  
summary(ca.gLmm)
```

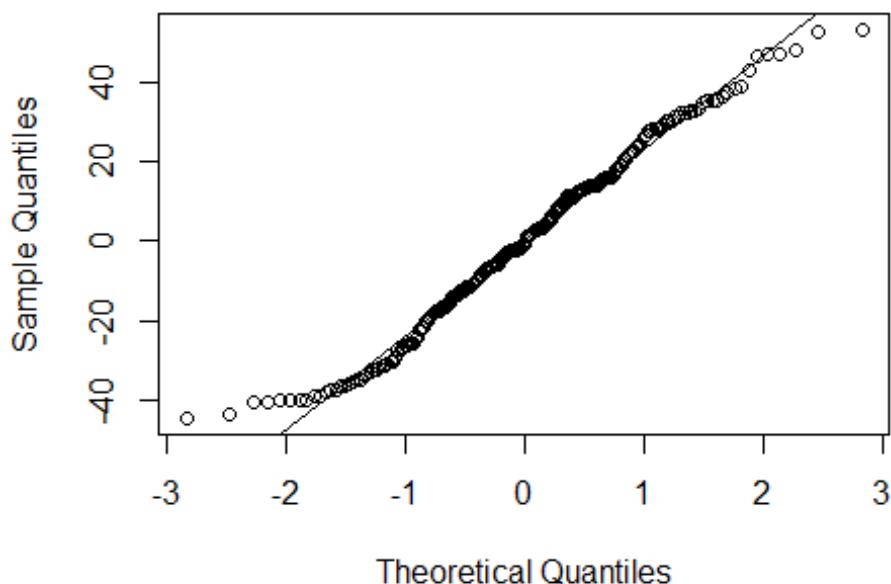
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: crown ~ dist + (1 | Transect)
##   Data: rawveg
##
## REML criterion at convergence: 2184.7
##
## Scaled residuals:
##     Min      1Q Median      3Q     Max
## -1.1793 -0.5830 -0.2925  0.2188  4.9736
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept)    0       0.00
##   Residual             1356     36.83
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##           Estimate Std. Error t value
## (Intercept) 45.288582  4.115664 11.00
## dist        -0.000464  0.003574 -0.13
##
## Correlation of Fixed Effects:
##   (Intr) dist
## dist -0.794
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# Canopy connectivity
conn.glmm <- lmer(conn ~ dist + (1|Transect), data = rawveg)
# check model fit
plot(conn.glmm)
```



```
qqnorm(resid(conn.gLmm))  
qqline(resid(conn.gLmm))
```

Normal Q-Q Plot



```
# Summary tables  
summary(conn.gLmm)
```

```

## Linear mixed model fit by REML ['lmerMod']
## Formula: conn ~ dist + (1 | Transect)
##   Data: rawveg
##
## REML criterion at convergence: 1988
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.92434 -0.71227 -0.04584  0.66175  2.29420
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   Transect (Intercept) 9.866    3.141
##   Residual           538.291  23.201
## Number of obs: 217, groups: Transect, 4
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 43.408706  3.032277 14.316
## dist        0.001417  0.002262  0.626
##
## Correlation of Fixed Effects:
##      (Intr)
## dist -0.676

```

1b) Generalized Linear Mixed Models of the effects of distance from forest edge on microclimate

```

# Read in raw data
clim <- read.csv("clim_hourly.csv")
# Clean climate data to remove instance where lux >32,000 or
difference between consecutive temps is >5.
clim <- filter(clim,keep!="FALSE")

# Tidy dataframe
clim <- clim %>% dplyr::select(LocID,Transect,dist,DOY,hour,temp,LI)
# remove unnecessary columns
clim$Transect <- as.factor(clim$Transect) # Set TransectID column as
a factor, not a number

# Summarise data by monitoring location
clim.sum <- clim %>%
  group_by(LocID) %>%
  summarise(Tmean=mean(temp),LImean=mean(LI))

# Create daily summaries of climate data for each monitoring
location
dailyclim <- clim %>%
  group_by(Transect,LocID,dist,DOY) %>%

```

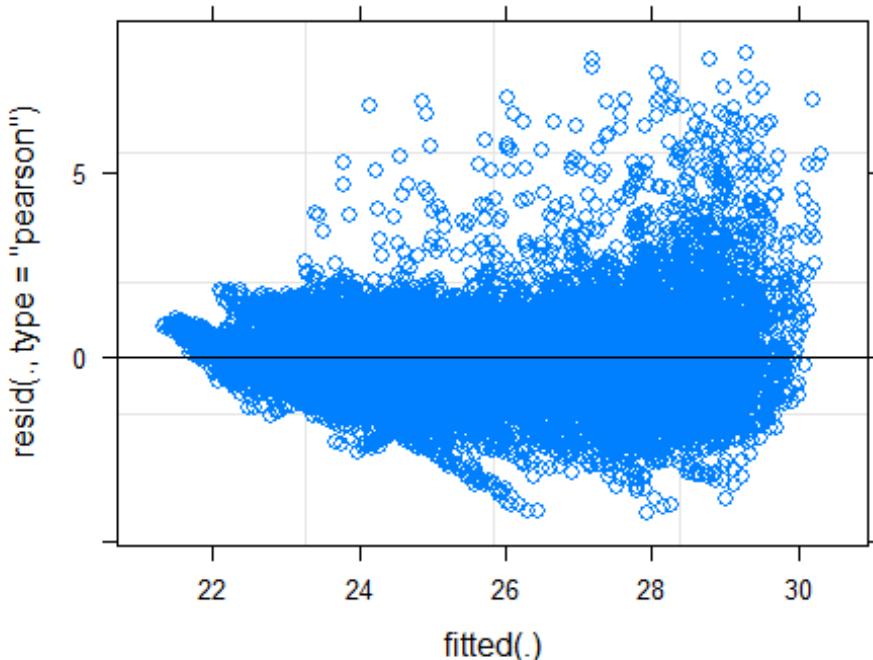
```
summarise(Tmean=mean(temp), Tmax=max(temp), Tmin=min(temp),
          LImean=mean(LI), LImax=max(LI))

## `summarise()` has grouped output by 'Transect', 'LocID', 'dist'.
# You can
## override using the `.groups` argument.

# 1) All data, with location, day of year and hour included as
# random intercepts.

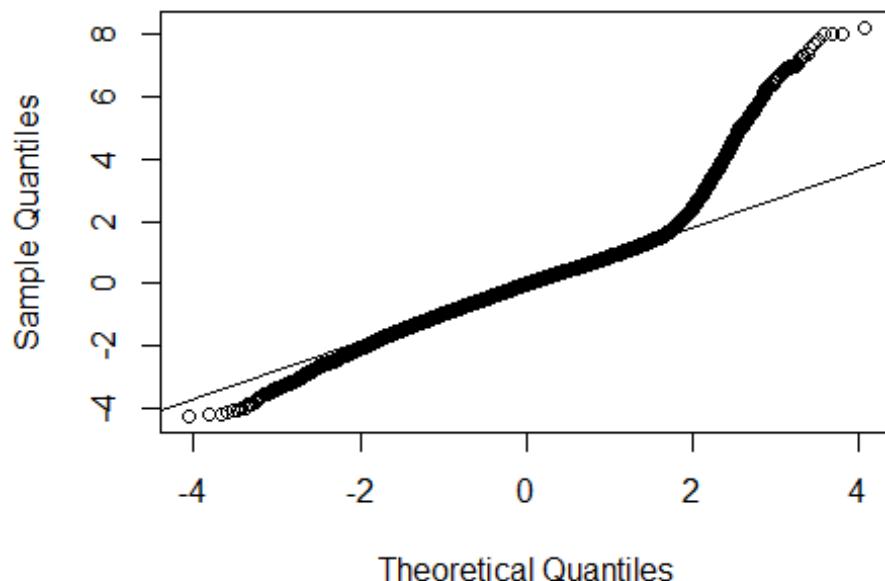
# Temperatures
Tall <- lmer(temp ~ dist + (1/Transect) + (1/DOY) + (1/hour), data =
clim)

# check model fit
plot(Tall)
```



```
qqnorm(resid(Tall))
qqline(resid(Tall))
```

Normal Q-Q Plot

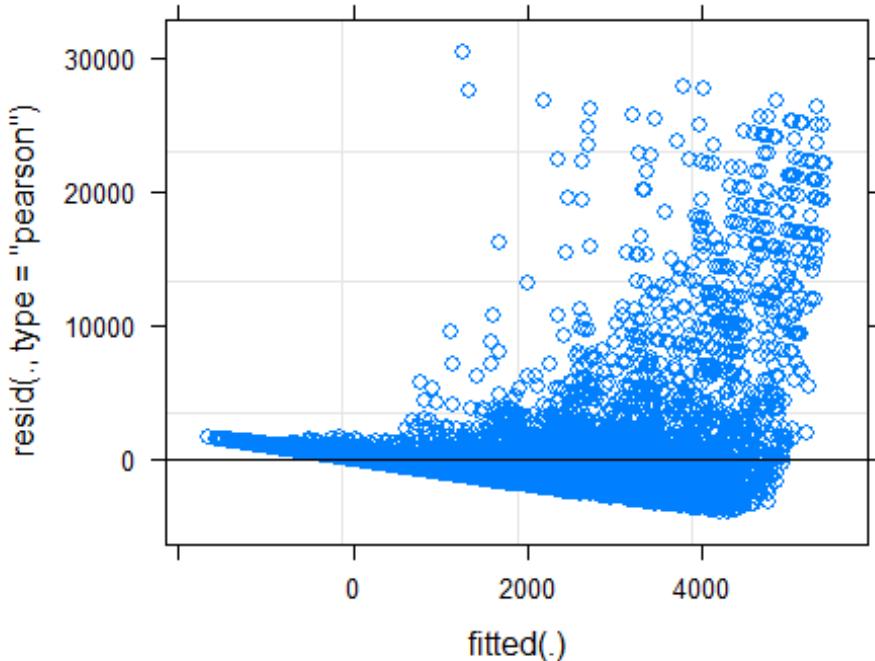


```
# Summary tables
summary(Tall)

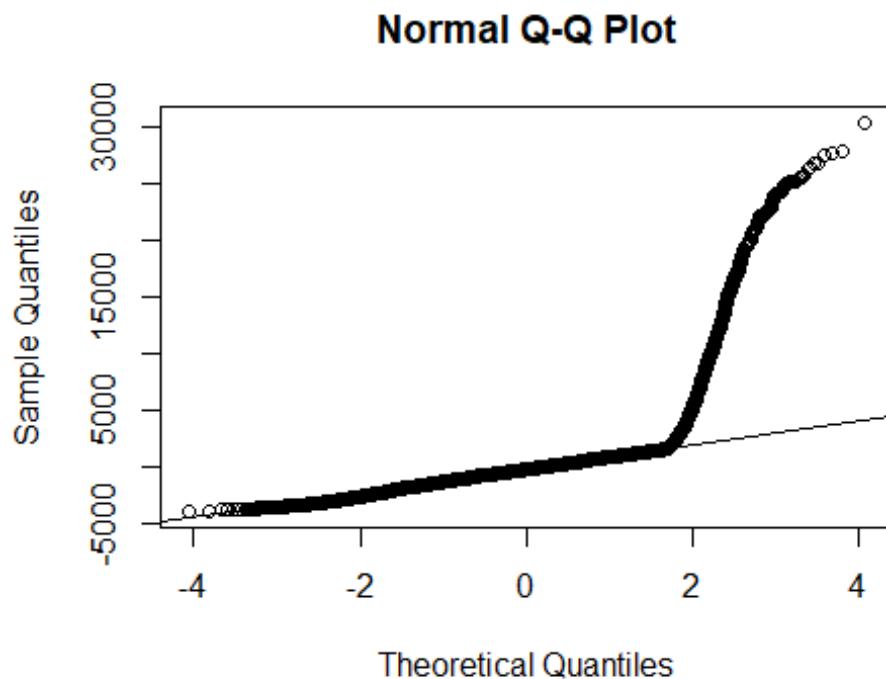
## Linear mixed model fit by REML ['LmerMod']
## Formula: temp ~ dist + (1 | Transect) + (1 | DOY) + (1 | hour)
##   Data: clim
##
## REML criterion at convergence: 64545.6
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max 
## -3.8343 -0.5908 -0.0089  0.5183  7.4188 
##
## Random effects:
## Groups   Name        Variance Std.Dev.
## DOY      (Intercept) 0.3624   0.6020 
## hour     (Intercept) 3.5780   1.8916 
## Transect (Intercept) 0.0358   0.1892 
## Residual           1.2262   1.1073 
## Number of obs: 21071, groups: DOY, 49; hour, 24; Transect, 4
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 2.580e+01 4.070e-01  63.40 
## dist        -2.371e-04 1.087e-05 -21.81 
##
## Correlation of Fixed Effects:
```

```
##      (Intr)
## dist -0.027

# Light intensity
LIall <- lmer(LI ~ dist + (1/Transect) + (1/DOY) + (1/hour), data =
clim)
# check model fit
plot(LIall)
```



```
qqnorm(resid(LIall))
qqline(resid(LIall))
```



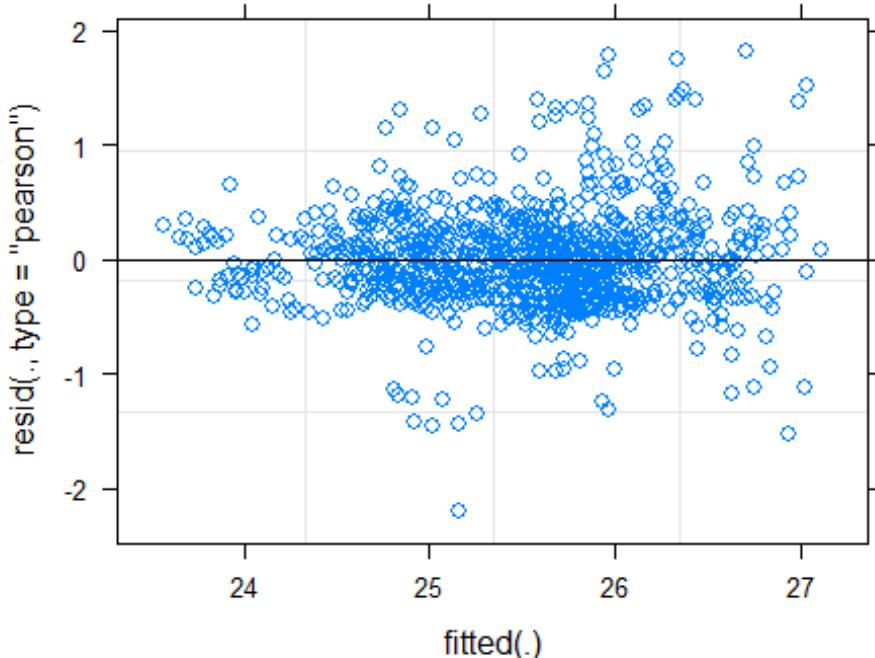
```
# Summary tables
summary(LIall)

## Linear mixed model fit by REML ['LmerMod']
## Formula: LI ~ dist + (1 | Transect) + (1 | DOY) + (1 | hour)
##   Data: clim
##
## REML criterion at convergence: 388425.7
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max 
## -1.6275 -0.3987 -0.1026  0.1898 12.5453 
##
## Random effects:
## Groups   Name        Variance Std.Dev.
## DOY      (Intercept) 22638    150.5 
## hour     (Intercept) 2015973  1419.8 
## Transect (Intercept) 273900   523.4 
## Residual           5881034  2425.1 
## Number of obs: 21071, groups: DOY, 49; hour, 24; Transect, 4
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 2025.9375  392.1956  5.166 
## dist        -0.9056    0.0238 -38.043
##
## Correlation of Fixed Effects:
```

```
##      (Intr)
## dist -0.061

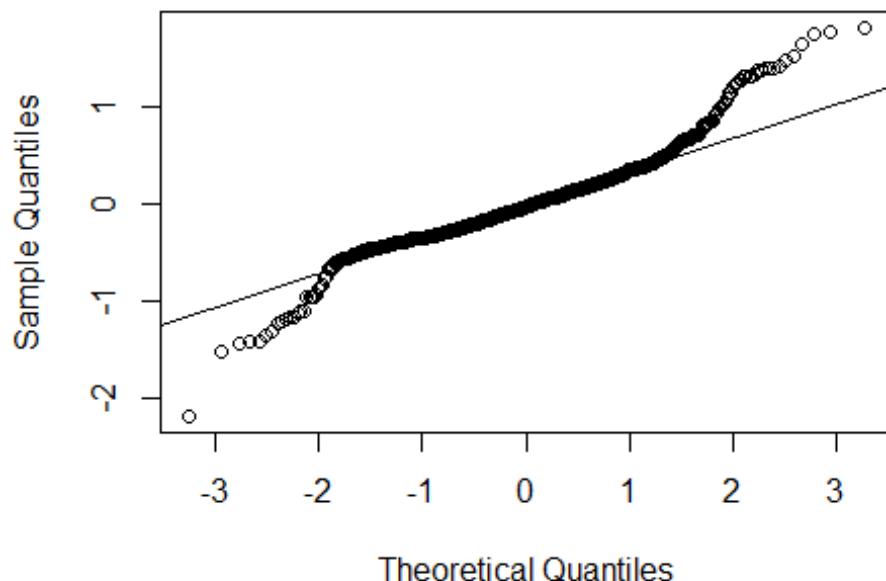
# 2) Maximum, minimum & mean daily temperature and maximum & mean
# daily light intensity, with location and day of year as random
# intercepts.

# Mean daily temp
Tmean <- lmer(Tmean ~ dist + (1/Transect) + (1/DOY), data =
dailyclim)
# check model fit
plot(Tmean)
```



```
qqnorm(resid(Tmean))
qqline(resid(Tmean))
```

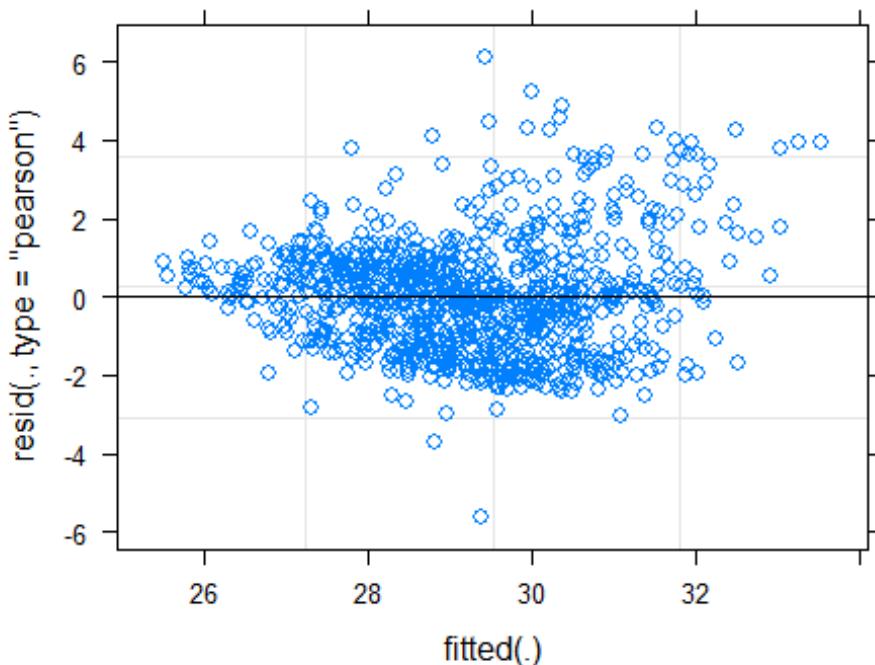
Normal Q-Q Plot



```
# Summary tables
summary(Tmean)

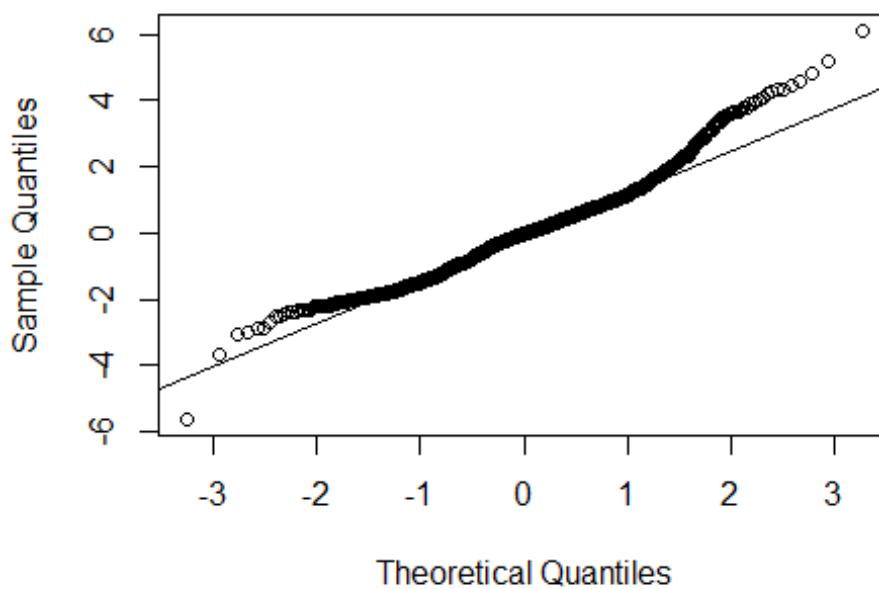
## Linear mixed model fit by REML ['LmerMod']
## Formula: Tmean ~ dist + (1 | Transect) + (1 | DOY)
##   Data: dailyclim
##
## REML criterion at convergence: 1325.4
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max 
## -4.9232 -0.5966 -0.0694  0.4634  4.0830 
##
## Random effects:
## Groups   Name        Variance Std.Dev.
## DOY      (Intercept) 0.46896  0.6848 
## Transect (Intercept) 0.02968  0.1723 
## Residual            0.19880  0.4459 
## Number of obs: 908, groups: DOY, 49; Transect, 4
##
## Fixed effects:
##                  Estimate Std. Error t value
## (Intercept)  2.571e+01  1.329e-01 193.386
## dist       -1.789e-04  2.096e-05 -8.539
##
## Correlation of Fixed Effects:
##          (Intr)
## dist -0.157
```

```
# Max daily temp  
Tmax <- lmer(Tmax ~ dist + (1/Transect) + (1/DOY), data = dailyclim)  
# check model fit  
plot(Tmax)
```



```
qqnorm(resid(Tmax))  
qqline(resid(Tmax))
```

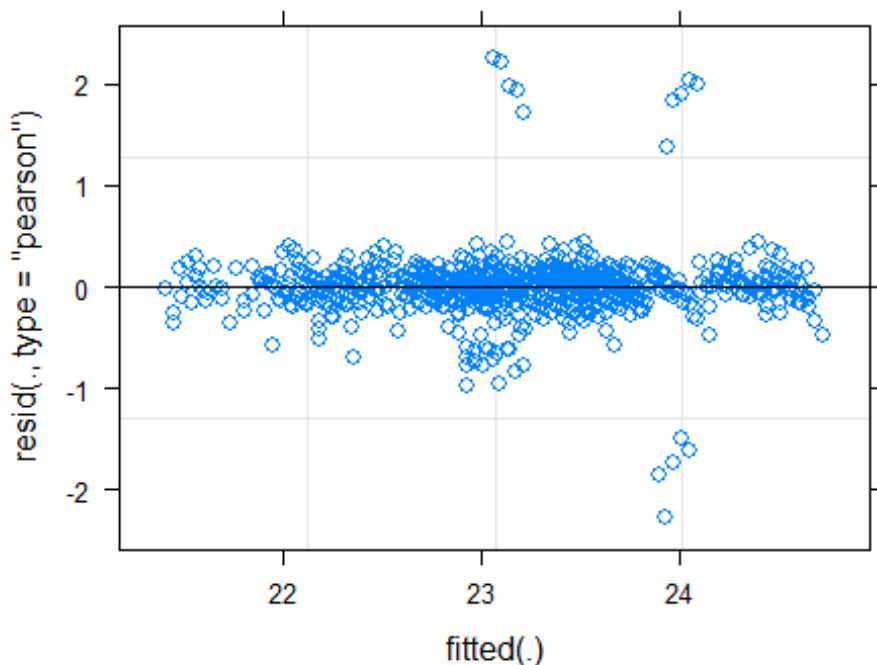
Normal Q-Q Plot



```
# Summary tables
summary(Tmax)

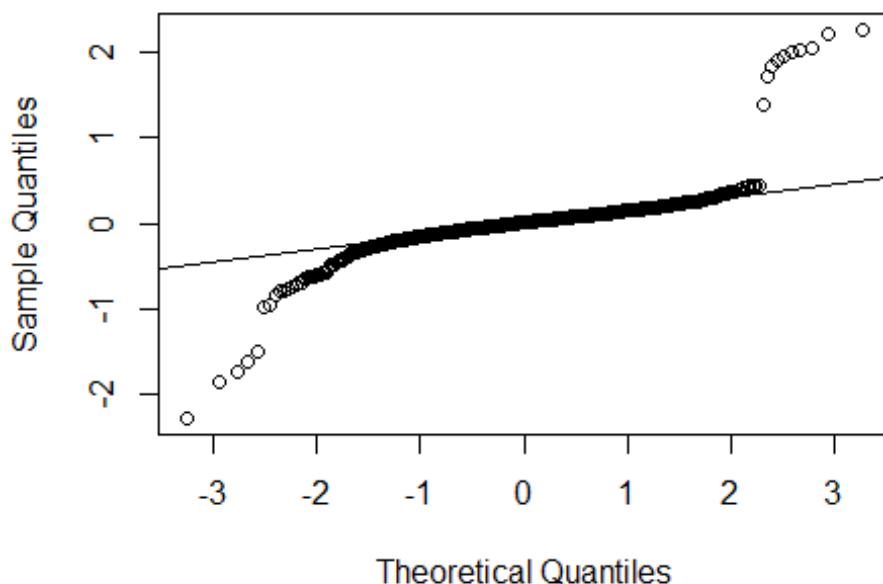
## Linear mixed model fit by REML ['LmerMod']
## Formula: Tmax ~ dist + (1 | Transect) + (1 | DOY)
##   Data: dailyclim
##
## REML criterion at convergence: 3402.7
##
## Scaled residuals:
##       Min      1Q Median      3Q      Max
## -3.8707 -0.6835 -0.0205  0.5247  4.2119
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   DOY     (Intercept) 1.2600   1.1225
##   Transect (Intercept) 0.4835   0.6954
##   Residual           2.1063   1.4513
## Number of obs: 908, groups: DOY, 49; Transect, 4
##
## Fixed effects:
##                   Estimate Std. Error t value
## (Intercept)  3.018e+01  3.922e-01   76.96
## dist        -1.002e-03  6.821e-05  -14.68
##
## Correlation of Fixed Effects:
##   (Intr) 
## dist -0.174

# Min daily temp
Tmin <- lmer(Tmin ~ dist + (1/Transect) + (1/DOY), data = dailyclim)
# check model fit
plot(Tmin)
```



```
qqnorm(resid(Tmin))  
qqline(resid(Tmin))
```

Normal Q-Q Plot

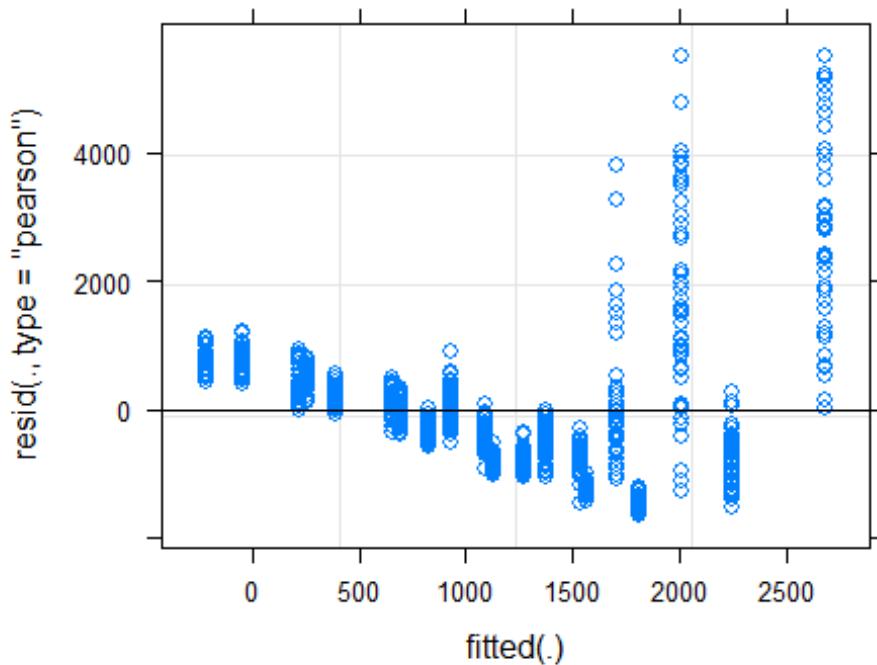


```
# Summary tables  
summary(Tmin)
```

```
## Linear mixed model fit by REML [ 'lmerMod' ]
## Formula: Tmin ~ dist + (1 | Transect) + (1 | DOY)
##   Data: dailyclim
##
## REML criterion at convergence: 725
##
## Scaled residuals:
##       Min      1Q Median      3Q     Max
## -7.2158 -0.3042  0.0361  0.3302  7.1668
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   DOY      (Intercept) 0.471665 0.68678
##   Transect (Intercept) 0.006919 0.08318
##   Residual            0.099035 0.31470
## Number of obs: 908, groups: DOY, 49; Transect, 4
##
## Fixed effects:
##           Estimate Std. Error t value
## (Intercept) 2.311e+01 1.081e-01 213.679
## dist        7.711e-05 1.479e-05   5.213
##
## Correlation of Fixed Effects:
##   (Intr) 
## dist -0.136
# Mean daily light intensity
LImean <- lmer(LImean ~ dist + (1/Transect) + (1/DOY), data =
dailyclim)

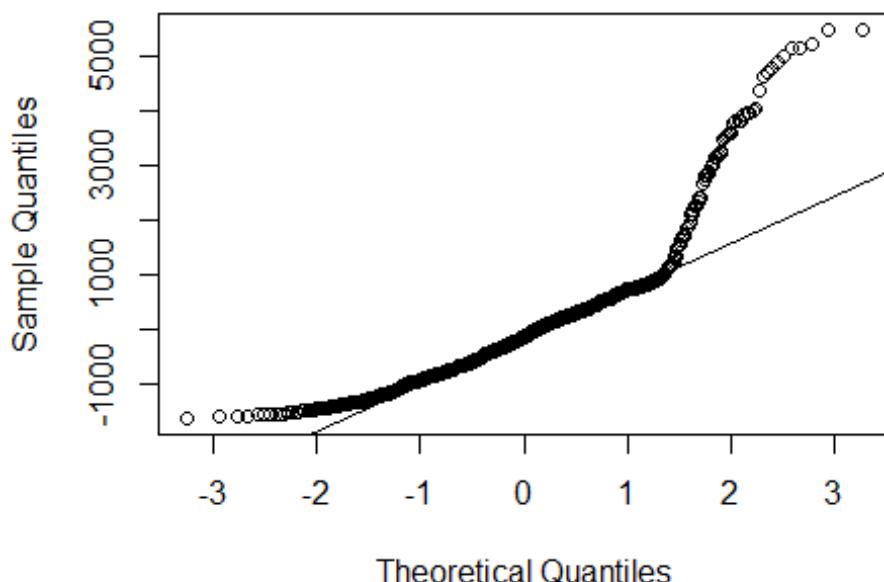
## boundary (singular) fit: see help('isSingular')

# check model fit
plot(LImean)
```



```
qqnorm(resid(LImean))  
qqline(resid(LImean))
```

Normal Q-Q Plot



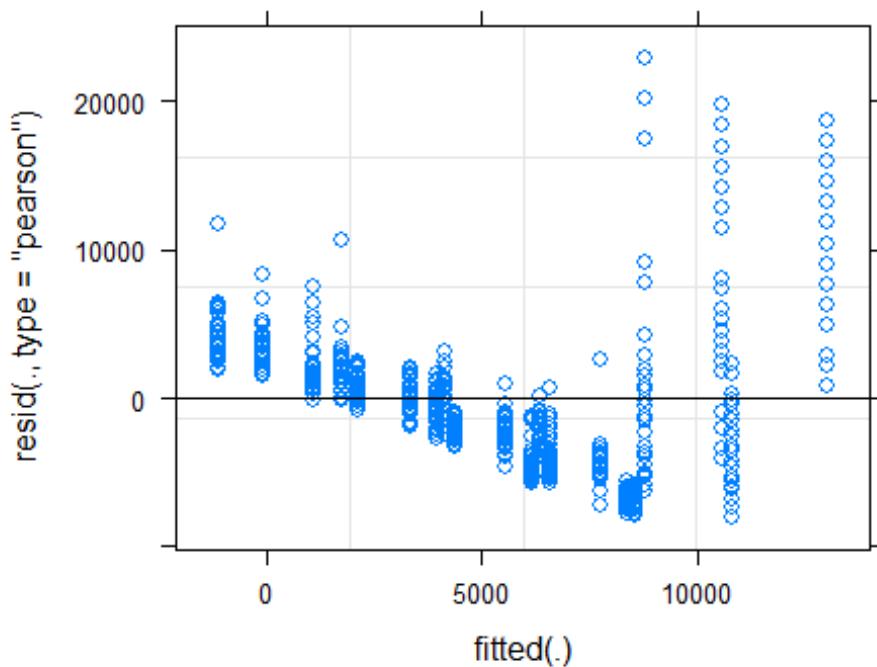
```
# Summary tables  
summary(LImean)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: LImean ~ dist + (1 | Transect) + (1 | DOY)
##   Data: dailyclim
##
## REML criterion at convergence: 15334.8
##
## Scaled residuals:
##     Min      1Q Median      3Q     Max
## -1.4660 -0.6591 -0.1311  0.3839  4.8957
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   DOY      (Intercept) 5.545e-11 7.446e-06
##   Transect (Intercept) 2.629e+05 5.127e+02
##   Residual            1.259e+06 1.122e+03
## Number of obs: 908, groups: DOY, 49; Transect, 4
##
## Fixed effects:
##                   Estimate Std. Error t value
## (Intercept) 1982.21074  264.35350  7.498
## dist        -0.87646    0.05271 -16.627
##
## Correlation of Fixed Effects:
##   (Intr)
## dist -0.199
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# Max daily light intensity
LImax <- lmer(LImax ~ dist + (1|Transect) + (1|DOY), data =
dailyclim)

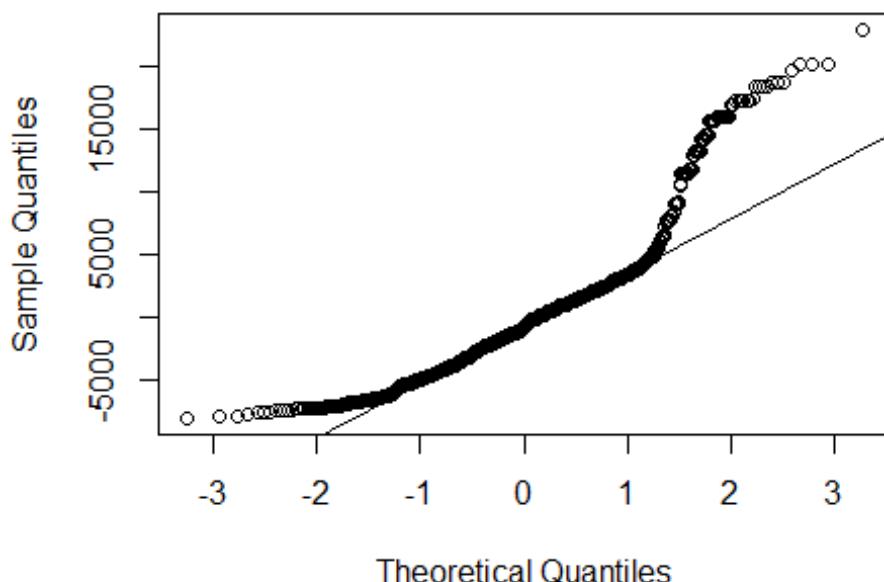
## boundary (singular) fit: see help('isSingular')

# check model fit
plot(LImax)
```



```
qqnorm(resid(LImax))  
qqline(resid(LImax))
```

Normal Q-Q Plot



```
# Summary tables  
summary(LImax)
```

```

## Linear mixed model fit by REML ['lmerMod']
## Formula: LImax ~ dist + (1 | Transect) + (1 | DOY)
##   Data: dailyclim
##
## REML criterion at convergence: 18199
##
## Scaled residuals:
##       Min      1Q Median      3Q     Max
## -1.4726 -0.6995 -0.1533  0.3803  4.2006
##
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   DOY      (Intercept) 1.346e-07 3.668e-04
##   Transect (Intercept) 5.416e+06 2.327e+03
##   Residual            2.972e+07 5.452e+03
## Number of obs: 908, groups: DOY, 49; Transect, 4
##
## Fixed effects:
##           Estimate Std. Error t value
## (Intercept) 10031.0313 1205.1180 8.324
## dist        -4.4339    0.2562 -17.309
##
## Correlation of Fixed Effects:
##   (Intr)
## dist -0.213
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

```

2) Relationships between mammal activity, forest structure & microclimate

2a) Generalized Linear Model of effects of structure & microclimate on mammal activity (ALL MAMMALS)

```

# Read raw data
transect <- read.csv("transects.csv")

# check for colinerarity between predictor variables with a
correlation matrix
vars <- dplyr::select(transect, -Camera, -dist, -detections_total)
cor <- rcorr(as.matrix(vars))
round(cor$P, 2)

##          Tmean Tmax Tmin Trange LImean LImax Theightmean
BheightMean
## Tmean          NA 0.00 0.05   0.00   0.00   0.00      0.58
0.27
## Tmax          0.00   NA 0.00   0.00   0.00   0.00      0.45
0.17
## Tmin          0.05 0.00   NA   0.01   0.01   0.01      0.03
0.01

```

## Trange	0.00	0.00	0.01	NA	0.00	0.00	0.42
0.15							
## LImean	0.00	0.00	0.01	0.00	NA	0.00	0.69
0.26							
## LImax	0.00	0.00	0.01	0.00	0.00	NA	0.27
0.06							
## Theightmean	0.58	0.45	0.03	0.42	0.69	0.27	NA
0.00							
## BheightMean	0.27	0.17	0.01	0.15	0.26	0.06	0.00
NA							
## no_trees	0.45	0.53	0.34	0.40	0.41	0.62	0.08
0.15							
## tree_density	0.45	0.53	0.34	0.40	0.41	0.62	0.08
0.15							
## SBA	0.17	0.18	0.85	0.17	0.09	0.47	0.00
0.01							
## DBH_mean	0.31	0.39	0.33	0.43	0.21	0.67	0.00
0.00							
## HDR	0.15	0.11	0.03	0.10	0.19	0.06	0.00
0.00							
## CA_mean	0.45	0.41	0.61	0.48	0.30	0.90	0.00
0.04							
## conn_mean	0.56	0.35	0.10	0.40	0.58	0.45	0.02
0.03							
## conn_mean	no_trees tree_density SBA DBH_mean HDR CA_mean						
## Tmean	0.45		0.45 0.17	0.31 0.15	0.45		
0.56							
## Tmax	0.53		0.53 0.18	0.39 0.11	0.41		
0.35							
## Tmin	0.34		0.34 0.85	0.33 0.03	0.61		
0.10							
## Trange	0.40		0.40 0.17	0.43 0.10	0.48		
0.40							
## LImean	0.41		0.41 0.09	0.21 0.19	0.30		
0.58							
## LImax	0.62		0.62 0.47	0.67 0.06	0.90		
0.45							
## Theightmean	0.08		0.08 0.00	0.00 0.00	0.00		
0.02							
## BheightMean	0.15		0.15 0.01	0.00 0.00	0.04		
0.03							
## no_trees	NA		0.00 0.00	0.22 0.06	0.21		
0.01							
## tree_density	0.00		NA 0.00	0.22 0.06	0.21		
0.01							
## SBA	0.00		0.00 NA	0.00 0.02	0.00		
0.02							
## DBH_mean	0.22		0.22 0.00	NA 0.07	0.00		

```

0.07
## HDR          0.06      0.06 0.02      0.07  NA   0.05
0.01
## CA_mean     0.21      0.21 0.00      0.00 0.05   NA
0.23
## conn_mean    0.01      0.01 0.02      0.07 0.01   0.23
NA

round(cor$r, 2)

##           Tmean   Tmax  Tmin Trange LImean LImax Theightmean
BheightMean
## Tmean        1.00  0.95 -0.45   0.97  0.91  0.84      -0.13
-0.27
## Tmax         0.95  1.00 -0.62   0.99  0.98  0.79      -0.18
-0.33
## Tmin        -0.45 -0.62  1.00  -0.61 -0.61 -0.55      0.49
0.61
## Trange       0.97  0.99 -0.61   1.00  0.97  0.83      -0.20
-0.35
## LImean       0.91  0.98 -0.61   0.97  1.00  0.79      -0.10
-0.27
## LImax        0.84  0.79 -0.55   0.83  0.79  1.00      -0.27
-0.43
## Theightmean -0.13 -0.18  0.49  -0.20 -0.10 -0.27      1.00
0.92
## BheightMean -0.27 -0.33  0.61  -0.35 -0.27 -0.43      0.92
1.00
## no_trees      0.18  0.15 -0.23   0.20  0.20  0.12      0.41
0.34
## tree_density  0.18  0.15 -0.23   0.20  0.20  0.12      0.41
0.34
## SBA           0.33  0.32 -0.05   0.33  0.40  0.18      0.67
0.55
## DBH_mean      0.25  0.21  0.23   0.19  0.30  0.10      0.75
0.63
## HDR           -0.35 -0.38  0.50  -0.39 -0.32 -0.43      0.90
0.85
## CA_mean       0.18  0.20  0.12   0.17  0.25 -0.03      0.63
0.48
## conn_mean     -0.14 -0.22  0.39  -0.20 -0.14 -0.18      0.54
0.51
## conn_mean
no_trees  tree_density   SBA DBH_mean   HDR CA_mean
## conn_mean
## Tmean        0.18      0.18 0.33      0.25 -0.35   0.18
-0.14
## Tmax         0.15      0.15 0.32      0.21 -0.38   0.20
-0.22
## Tmin        -0.23     -0.23 -0.05      0.23  0.50   0.12
0.39

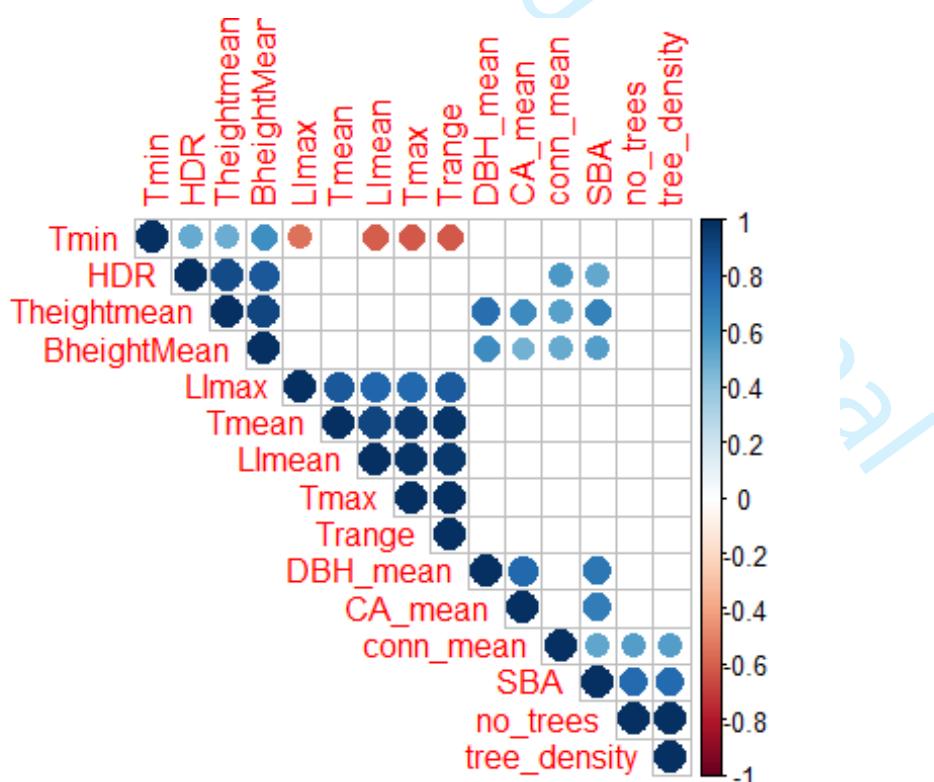
```

```

## Trange      0.20      0.20  0.33  0.19 -0.39  0.17
-0.20
## LImean     0.20      0.20  0.40  0.30 -0.32  0.25
-0.14
## LImax      0.12      0.12  0.18  0.10 -0.43 -0.03
-0.18
## Theightmean 0.41      0.41  0.67  0.75  0.90  0.63
0.54
## BheightMean 0.34      0.34  0.55  0.63  0.85  0.48
0.51
## no_trees    1.00      1.00  0.77  0.29  0.45  0.30
0.56
## tree_density 1.00      1.00  0.77  0.29  0.45  0.30
0.56
## SBA         0.77      0.77  1.00  0.73  0.52  0.70
0.53
## DBH_mean    0.29      0.29  0.73  1.00  0.42  0.78
0.43
## HDR         0.45      0.45  0.52  0.42  1.00  0.45
0.57
## CA_mean     0.30      0.30  0.70  0.78  0.45  1.00
0.29
## conn_mean   0.56      0.56  0.53  0.43  0.57  0.29
1.00

diag(cor$P) <- 0
corrplot(cor$r, type="upper", order="hclust",
          p.mat = cor$P, sig.Level = 0.05, insig = "blank")

```



```

poisson <- glm(data = transect,
                 detections_total ~ dist + Tmax + Tmin +
                 Theightmean + no_trees + CA_mean + DBH_mean +
                 conn_mean,
                 family = "poisson", na.action=na.fail)
dredge(poisson)

## Fixed term is "(Intercept)"

## Global model call: glm(formula = detections_total ~ dist + Tmax +
## Tmin + Theightmean +
##     no_trees + CA_mean + DBH_mean + conn_mean, family =
## "poisson",
##     data = transect, na.action = na.fail)
## ---

## Model selection table
##          (Int)      CA_mean    cnn_mean DBH_mean      dst      no_trs
Thg
## 229 27.760000               0.18620
-0.112200
## 237 36.060000               0.21770  0.2425000
-0.123600
## 101 2.133000                0.16700
-0.118900
## 231 27.720000               -3.514e-03 0.18760
-0.106700
## 230 27.710000      5.706e-03 0.17960
-0.115000
## 245 27.620000               0.18650      0.0006855
-0.112700
## 117 2.149000                0.18110      0.0259100
-0.136800
## 109 1.661000                0.17880  0.0973000
-0.125100
## 103 2.218000               -3.784e-03 0.16830
-0.112400
## 253 32.790000               0.23620  0.2909000  0.0247200
-0.144400
## 102 2.255000      6.169e-03 0.15910
-0.121400
## 119 2.405000               -1.048e-02 0.20350      0.0582100
-0.142000
## 238 35.680000      3.237e-03 0.21260  0.2340000
-0.124400
## 239 35.820000               -6.045e-04 0.21720  0.2367000
-0.122300
## 125 1.207000                0.21450  0.1928000  0.0435300
-0.161300
## 127 1.349000               -1.134e-02 0.24420  0.2215000  0.0831900
-0.171500

```

## 118	2.294000	7.423e-03	0.17410	0.0290500
-0.142600				
## 247	22.110000		-6.614e-03	0.20030
-0.121700				
## 232	27.710000	4.633e-03	-2.928e-03	0.18190
-0.109700				
## 110	1.818000	5.347e-03	0.17040	0.0866300
-0.126300				
## 111	1.824000		-2.909e-03	0.17720
-0.118700				
## 246	26.930000	5.872e-03	0.18110	0.0037390
-0.118000				
## 104	2.299000	4.929e-03	-3.127e-03	0.16160
-0.115300				
## 255	27.160000		-6.190e-03	0.24940
-0.153400				
## 120	2.475000	4.770e-03	-9.848e-03	0.19760
-0.145100				
## 254	32.060000	4.119e-03	0.23130	0.2843000
-0.147300				
## 126	1.360000	6.678e-03	0.20730	0.1873000
-0.165600				
## 240	35.590000	3.156e-03	-2.617e-04	0.21250
-0.123900				
## 112	1.926000	4.515e-03	-2.361e-03	0.17030
-0.120800				
## 128	1.418000	3.496e-03	-1.086e-02	0.23910
-0.173100				
## 248	22.150000	4.665e-03	-6.018e-03	0.19480
-0.124900				
## 213	46.400000		0.09829	-0.0680100
## 37	0.609200		0.10220	
-0.071380				
## 45	-0.129600		0.12910	0.1859000
-0.088560				
## 256	27.030000	2.960e-03	-5.830e-03	0.24510
-0.154800				
## 165	-9.037000		0.11320	
-0.087480				
## 53	0.736900		0.10190	-0.0244600
-0.063880				
## 221	45.050000		0.09610	-0.0417300
## 38	0.594900	-7.338e-04	0.10370	-0.0696100
-0.071330				
## 39	0.612500		-2.776e-04	0.10220
-0.070820				
## 215	47.120000		1.015e-03	0.09760
## 214	46.400000	-3.884e-04	0.09899	-0.0679300
## 173	-6.040000		0.13090	0.1476000

```

-0.095050
## 61  0.024910          0.12510  0.1592000 -0.0094920
-0.083140
## 47  -0.162600         1.077e-03 0.13020  0.1905000
-0.091210
## 46  -0.161100 -1.420e-03        0.13200  0.1868000
-0.088650
## 181 -6.506000          0.11010          -0.0117700
-0.079550
## 167 -9.380000         -1.399e-03 0.11320
-0.085120
## 166 -9.220000  1.380e-03        0.11080
-0.087920
## 55   0.736400          2.340e-03 0.10240 -0.0287500
-0.067330
## 197 34.070000          0.08297
## 54   0.733500 -1.738e-04        0.10220 -0.0244400
-0.063880
## 199 32.480000         -8.751e-03 0.09280
## 40   0.596400 -8.910e-04 -3.900e-04 0.10380
-0.070520
## 175 -5.980000          1.489e-04 0.13110  0.1486000
-0.095360
## 189 -5.923000          0.13060  0.1465000 -0.0006553
-0.094560
## 174 -6.030000 -6.188e-05        0.13110  0.1477000
-0.095040
## 63   0.029920          2.220e-03 0.12540  0.1569000 -0.0140700
-0.086090
## 223 45.510000          5.310e-04 0.09588 -0.0388800 -0.0711400
## 222 45.040000  1.396e-04          0.09582 -0.0421400 -0.0696500
## 216 47.100000 -1.635e-04        9.946e-04 0.09791          -0.0710600
## 62   -0.005726 -1.187e-03        0.12770  0.1608000 -0.0092470
-0.083370
## 48   -0.181000 -1.018e-03        9.450e-04 0.13210  0.1905000
-0.090950
## 198 34.210000 -3.178e-03          0.08908
## 205 35.350000          0.08482  0.0301100
## 182 -6.703000  1.062e-03          0.10830          -0.0115000
-0.080050
## 183 -6.508000          -2.118e-06 0.11010 -0.0117700
-0.079550
## 168 -9.468000  8.881e-04 -1.292e-03 0.11170
-0.085570
## 21   1.359000          0.05306          -0.0477000
## 56   0.753900  9.107e-04  2.496e-03 0.10070 -0.0291500
-0.067570
## 149 12.770000          0.05945          -0.0583200
## 200 32.590000 -3.901e-03 -8.824e-03 0.10030

```

## 207	30.950000		-9.183e-03	0.09118	-0.0366400	
## 71	2.256000		-1.021e-02	0.06577		
## 29	1.759000			0.04753	-0.1326000	-0.0556200
## 85	1.953000			0.05651		-0.0437200
## 79	3.031000		-1.167e-02	0.06306	-0.1734000	
## 93	2.817000			0.05034	-0.1946000	-0.0530500
## 5	1.128000			0.04466		
## 7	1.153000		-6.934e-03	0.05267		
## 69	1.859000			0.05088		
## 23	1.325000		-2.747e-03	0.05541		-0.0409600
## 22	1.344000	-7.133e-04		0.05443		-0.0475000
## 98	3.817000	2.509e-02				
		-0.048350				
## 151	15.740000		3.491e-03	0.05799		-0.0695000
## 191	-5.514000		3.864e-04	0.13030	0.1469000	-0.0020640
	-0.094280					
## 176	-5.979000	-1.150e-05	1.476e-04	0.13110	0.1487000	
	-0.095350					
## 190	-5.909000	-7.216e-05		0.13080	0.1466000	-0.0006665
	-0.094540					
## 157	11.010000			0.05603	-0.0599400	-0.0603200
## 87	2.179000		-7.118e-03	0.06470		-0.0240900
## 206	35.790000	-3.519e-03		0.09202	0.0367700	
## 150	12.890000	-2.011e-03		0.06342		-0.0579800
## 64	0.025730	-1.625e-04	2.191e-03	0.12580	0.1571000	-0.0139800
	-0.086080					
## 133	6.987000			0.04700		
## 77	2.396000			0.04697	-0.1295000	
## 72	2.186000	-3.075e-03	-1.029e-02	0.07177		
## 95	3.078000		-7.623e-03	0.06001	-0.2027000	-0.0332900
## 184	-6.534000	1.110e-03	1.725e-04	0.10810		-0.0121200
	-0.079940					
## 13	1.276000			0.04190	-0.0570500	
## 224	45.510000	2.303e-04	5.524e-04	0.09542	-0.0394500	-0.0712800
## 106	4.357000	2.366e-02			-0.1508000	
	-0.047730					
## 31	1.716000		-1.793e-03	0.04944	-0.1267000	-0.0510400
## 6	1.061000	-3.165e-03		0.05101		
## 210	27.810000	1.991e-02				-0.0494300
## 30	1.767000	3.391e-04		0.04687	-0.1330000	-0.0557400
## 34	2.396000	1.908e-02				
	-0.034710					
## 208	31.360000	-3.634e-03	-9.165e-03	0.09848	-0.0293500	
## 86	1.955000	8.872e-05		0.05634		-0.0437400
## 26	2.803000	1.225e-02			-0.1886000	-0.0539700
## 15	1.289000		-6.906e-03	0.05008	-0.0523600	
## 8	1.058000	-4.550e-03	-7.131e-03	0.06203		
## 18	2.408000	1.366e-02				-0.0407800
## 135	3.809000		-6.284e-03	0.05289		

## 70	1.812000	-1.952e-03		0.05465	
## 90	3.963000	1.351e-02		-0.2588000	-0.0534400
## 226	12.990000	2.523e-02			
	-0.042210				
## 80	2.982000	-1.730e-03	-1.168e-02	0.06641	-0.1708000
## 94	2.893000	2.258e-03		0.04603	-0.1999000
## 218	23.660000	1.829e-02		-0.2077000	-0.0605200
## 24	1.287000	-1.676e-03	-2.925e-03	0.05879	-0.0400900
## 50	2.516000	1.905e-02			-0.0279800
	-0.025400				
## 114	3.732000	2.427e-02			-0.0133500
	-0.041980				
## 25	3.262000			-0.2176000	-0.0433300
## 100	3.826000	2.505e-02	-4.667e-04		
	-0.047350				
## 2	2.118000	1.046e-02			
## 134	7.261000	-4.150e-03		0.05550	
## 146	10.140000	1.470e-02			-0.0464700
## 141	6.757000			0.04659	-0.0066640
## 122	4.376000	2.117e-02		-0.2109000	-0.0309400
	-0.032780				
## 159	13.910000		3.015e-03	0.05539	-0.0483500
## 194	20.500000	1.538e-02			-0.0695300
## 82	2.977000	1.445e-02			-0.0380400
## 89	4.310000			-0.2737000	-0.0425900
## 152	15.680000	-1.166e-03	3.336e-03	0.06035	-0.0688000
## 158	11.180000	-1.362e-03		0.05889	-0.0567000
## 162	-2.529000	2.038e-02			-0.0599600
	-0.041270				
## 88	2.143000	-1.708e-03	-7.285e-03	0.06808	-0.0232100
## 14	1.210000	-2.989e-03		0.04795	-0.0556800
## 78	2.366000	-1.033e-03		0.04898	-0.1282000
## 42	2.463000	1.791e-02			-0.0491400
	-0.032880				
## 1	2.581000				
## 66	2.832000	1.185e-02			
## 212	33.560000	1.937e-02	6.409e-03		-0.0708100
## 36	2.391000	1.920e-02	7.672e-04		
	-0.036410				
## 58	2.792000	1.567e-02		-0.1505000	-0.0435400
	-0.015290				
## 9	2.717000			-0.1327000	
## 242	21.690000	2.334e-02			-0.0342600
	-0.020610				
## 17	2.855000				-0.0259100
## 74	3.443000	1.076e-02		-0.1715000	
## 10	2.274000	9.234e-03		-0.0997300	
## 20	2.405000	1.355e-02	6.501e-04		-0.0425500
## 4	2.222000	1.189e-02	-4.055e-03		

## 73	3.796000				-0.1929000
## 16	1.193000	-4.374e-03	-7.100e-03	0.05918	-0.0503900
## 154	5.618000	1.277e-02			-0.1699000 -0.0549200
## 28	2.801000	1.193e-02	1.745e-03		-0.1927000 -0.0588300
## 136	4.048000	-4.907e-03	-6.419e-03	0.06304	
## 108	4.458000	2.328e-02	-2.473e-03		-0.1655000
	-0.042350				
## 234	8.821000	2.393e-02			-0.1327000
	-0.044710				
## 143	2.056000		-6.716e-03	0.05050	-0.0453700
## 76	4.108000	1.393e-02	-7.989e-03		-0.2122000
## 32	1.707000	-3.247e-04	-1.833e-03	0.05012	-0.1261000 -0.0508200
## 68	3.222000	1.448e-02	-6.078e-03		
## 52	2.528000	1.972e-02	4.484e-03		-0.0366000
	-0.032460				
## 130	5.708000	1.073e-02			
## 27	3.235000		3.201e-03		-0.2227000 -0.0527500
## 96	3.095000	5.560e-04	-7.570e-03	0.05889	-0.2039000 -0.0336400
## 57	3.184000				-0.2337000 -0.0512100
	0.009370				
## 192	-5.515000	3.943e-05	3.925e-04	0.13020	0.1468000 -0.0020800
	-0.094290				
## 65	3.141000				
## 148	16.190000	1.431e-02	6.797e-03		-0.0694300
## 153	2.128000				-0.2240000 -0.0431200
## 92	4.117000	1.416e-02	-2.489e-03		-0.2638000 -0.0467400
## 178	3.998000	1.869e-02			-0.0304400
	-0.022730				
## 33	2.714000				
	-0.007020				
## 196	18.770000	1.697e-02	-4.515e-03		
## 228	12.970000	2.520e-02	-2.892e-04		
	-0.041620				
## 202	16.940000	1.396e-02			-0.1124000
## 3	2.648000		-1.624e-03		
## 129	4.999000				
## 170	-6.191000	1.890e-02			-0.1079000
	-0.042750				
## 217	11.770000				-0.2565000 -0.0440100
## 116	3.684000	2.422e-02	1.425e-03		-0.0166700
	-0.043480				
## 75	4.260000		-4.661e-03		-0.2215000
## 12	2.390000	1.061e-02	-4.227e-03		-0.1027000
## 142	7.265000	-4.151e-03		0.05551	0.0001218
## 81	3.279000				-0.0239300
## 145	7.514000				-0.0283900
## 11	2.817000		-2.296e-03		-0.1385000
## 220	27.640000	1.810e-02	4.117e-03		-0.1878000 -0.0730300
## 41	2.838000				-0.1305000

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-0.006506
## 250 19.540000 2.072e-02           -0.1948000 -0.0486400
-0.014730
## 19   2.833000                  2.282e-03           -0.0326800
## 137  0.226800                  -0.1499000
## 193  13.250000
## 84   3.070000  1.487e-02 -1.757e-03           -0.0328700
## 121  4.224000                  -0.2782000 -0.0461500
0.004292
## 91   4.278000                  4.468e-04           -0.2727000 -0.0438800
## 49   2.840000                  -0.0268700
0.001348
## 105  4.119000                  -0.1959000
-0.010980
## 164  -2.465000  2.043e-02  3.922e-04
-0.042070
## 44   2.459000  1.800e-02  3.456e-04           -0.0478300
-0.033690
## 201  8.901000                  -0.1742000
## 138  2.435000  9.261e-03           -0.0984300
## 132  3.710000  1.187e-02 -3.694e-03
## 97   3.408000
-0.009406
## 60   2.792000  1.648e-02  4.288e-03           -0.1456000 -0.0507600
-0.022700
## 67   3.335000                  -2.492e-03
## 209  15.740000
## 156  10.660000  1.274e-02  5.091e-03           -0.1491000 -0.0709400
## 244  27.490000  2.265e-02  6.264e-03           -0.0557200
-0.019910
## 147  14.650000                  7.487e-03           -0.0544700
## 124  4.363000  2.117e-02  3.035e-04           -0.2100000 -0.0315100
-0.033160
## 160  13.920000 -7.346e-04  2.930e-03  0.05696 -0.0468900 -0.0690800
## 186  1.160000  1.598e-02           -0.1551000 -0.0411500
-0.018020
## 204  12.920000  1.558e-02 -6.681e-03           -0.1678000
## 155  7.175000                  4.899e-03           -0.2036000 -0.0585500
## 35   2.717000                  -6.395e-04
-0.005809
## 161  3.599000
-0.006162
## 59   3.191000                  2.371e-03           -0.2312000 -0.0552800
0.005990
## 131  4.233000                  -1.257e-03
## 185  6.270000                  -0.2238000 -0.0553900
0.013570
## 144  2.561000 -4.589e-03 -6.771e-03  0.06037 -0.0379100
## 180  10.080000  1.820e-02  6.737e-03           -0.0534300

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-0.022440			
## 177 11.770000			-0.0405400
0.013680			
## 139 -3.114000	-3.972e-03	-0.1838000	
## 169 -3.071000		-0.1695000	
-0.012440			
## 249 20.330000		-0.2625000	-0.0645100
0.022270			
## 236 8.265000	2.357e-02	-2.193e-03	-0.1485000
-0.040430			
## 83 3.206000	1.222e-03		-0.0278300
## 113 3.315000			-0.0227800
-0.001511			
## 43 2.852000	-1.747e-03	-0.1360000	
-0.003180			
## 140 -1.595000	1.026e-02	-5.304e-03	-0.1363000
## 51 2.852000	2.548e-03		-0.0321200
-0.001912			
## 211 23.220000	7.512e-03		-0.0533900
## 195 12.520000	-1.156e-03		
## 225 12.400000			
-0.002895			
## 107 4.307000	-4.005e-03	-0.2186000	
-0.003766			
## 219 16.240000	4.359e-03	-0.2359000	-0.0575100
## 203 5.423000	-4.431e-03	-0.2159000	
## 241 23.650000			-0.0449900
0.020050			
## 172 -6.548000	1.868e-02	-9.796e-04	-0.1142000
-0.040810			
## 233 5.950000		-0.1888000	
-0.009507			
## 99 3.443000	-1.335e-03		
-0.006944			
## 123 4.230000	-1.357e-04	-0.2786000	-0.0459000
0.004457			
## 179 18.810000	7.429e-03		-0.0664100
0.013800			
## 163 3.460000	-5.652e-04		
-0.005232			
## 252 23.480000	2.059e-02	4.257e-03	-0.1751000
-0.015280			-0.0612700
## 187 11.100000	4.785e-03		-0.2029000
0.013290			-0.0700600
## 188 6.172000	1.605e-02	5.300e-03	-0.1346000
-0.018820			-0.0573800
## 171 -4.424000	-2.950e-03		-0.1880000
-0.008100			
## 243 31.280000	7.498e-03		-0.0713400

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0.020580
## 115 3.258000          1.605e-03           -0.0266300
-0.003173
## 227 12.260000         -9.938e-04
-0.001228
## 251 24.460000         4.137e-03           -0.2410000 -0.0767700
0.021940
## 235 4.669000          -3.972e-03           -0.2170000
-0.003539
##          Tmx      Tmn df LogLik AICc delta weight
## 229 -0.13110 -1.158000 5 -80.943 176.5 0.00 0.305
## 237 -0.13880 -1.582000 6 -79.089 177.2 0.68 0.217
## 101 -0.08511          4 -83.789 178.4 1.93 0.116
## 231 -0.13390 -1.153000 6 -80.647 180.3 3.79 0.046
## 230 -0.13380 -1.151000 6 -80.674 180.3 3.85 0.045
## 245 -0.13120 -1.152000 6 -80.943 180.9 4.38 0.034
## 117 -0.09788          5 -83.201 181.0 4.52 0.032
## 109 -0.08176          5 -83.429 181.5 4.97 0.025
## 103 -0.08804          5 -83.444 181.5 5.00 0.025
## 253 -0.14430 -1.446000 7 -78.681 181.5 5.04 0.024
## 102 -0.08799          5 -83.481 181.6 5.08 0.024
## 119 -0.12280          6 -81.522 182.0 5.54 0.019
## 238 -0.13980 -1.561000 7 -79.006 182.2 5.69 0.018
## 239 -0.13900 -1.570000 7 -79.080 182.3 5.84 0.016
## 125 -0.09999          6 -82.035 183.1 6.57 0.011
## 127 -0.12800          7 -80.070 184.3 7.82 0.006
## 118 -0.10320          6 -82.767 184.5 8.03 0.005
## 247 -0.13990 -0.896000 7 -80.375 184.9 8.43 0.005
## 232 -0.13560 -1.149000 7 -80.481 185.1 8.64 0.004
## 110 -0.08452          6 -83.204 185.4 8.91 0.004
## 111 -0.08462          6 -83.236 185.5 8.97 0.003
## 246 -0.13440 -1.116000 7 -80.665 185.5 9.01 0.003
## 104 -0.08972          6 -83.262 185.5 9.02 0.003
## 255 -0.15210 -1.185000 8 -78.192 186.8 10.28 0.002
## 120 -0.12460          7 -81.359 186.9 10.40 0.002
## 254 -0.14610 -1.409000 8 -78.550 187.5 11.00 0.001
## 126 -0.10480          7 -81.691 187.6 11.06 0.001
## 240 -0.13980 -1.556000 8 -79.004 188.4 11.91 0.001
## 112 -0.08637          7 -83.084 190.4 13.85 0.000
## 128 -0.12920          8 -79.986 190.4 13.87 0.000
## 248 -0.14170 -0.894700 8 -80.211 190.8 14.32 0.000
## 213 -0.10180 -2.001000 5 -88.944 192.5 16.00 0.000
## 37                      3 -92.965 193.5 17.03 0.000
## 45                      4 -91.624 194.1 17.60 0.000
## 256 -0.15300 -1.176000 9 -78.129 194.3 17.76 0.000
## 165 0.446200           4 -92.041 194.9 18.44 0.000
## 53                      4 -92.257 195.4 18.87 0.000
## 221 -0.10150 -1.933000 6 -88.885 196.8 20.27 0.000
## 38                      4 -92.961 196.8 20.28 0.000

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## 39		4	-92.963	196.8	20.28	0.000	
## 215	-0.10120	-2.035000	6	-88.929	196.9	20.36	0.000
## 214	-0.10170	-2.002000	6	-88.943	196.9	20.38	0.000
## 173		5	-91.325	197.3	20.76	0.000	
## 61		5	-91.542	197.7	21.20	0.000	
## 47		5	-91.597	197.8	21.31	0.000	
## 46		5	-91.610	197.8	21.33	0.000	
## 181	0.332000	5	-91.939	198.5	21.99	0.000	
## 167	0.462800	5	-91.997	198.6	22.11	0.000	
## 166	0.455900	5	-92.027	198.7	22.17	0.000	
## 55		5	-92.150	198.9	22.41	0.000	
## 197	-0.08976	-1.456000	4	-94.133	199.1	22.62	0.000
## 54		5	-92.257	199.1	22.63	0.000	
## 199	-0.09842	-1.367000	5	-92.297	199.2	22.71	0.000
## 40		5	-92.957	200.5	24.03	0.000	
## 175	0.276600	6	-91.325	201.6	25.15	0.000	
## 189	0.274600	6	-91.325	201.7	25.15	0.000	
## 174	0.279100	6	-91.325	201.7	25.15	0.000	
## 63		6	-91.445	201.9	25.39	0.000	
## 223	-0.10120	-1.955000	7	-88.881	201.9	25.44	0.000
## 222	-0.10150	-1.932000	7	-88.884	202.0	25.45	0.000
## 216	-0.10120	-2.035000	7	-88.929	202.0	25.54	0.000
## 62		6	-91.532	202.1	25.56	0.000	
## 48		6	-91.590	202.2	25.68	0.000	
## 198	-0.08951	-1.466000	5	-94.055	202.7	26.22	0.000
## 205	-0.09031	-1.519000	5	-94.101	202.8	26.32	0.000
## 182	0.342000	6	-91.931	202.9	26.36	0.000	
## 183	0.332100	6	-91.939	202.9	26.38	0.000	
## 168	0.467600	6	-91.992	203.0	26.48	0.000	
## 21		3	-97.765	203.1	26.63	0.000	
## 56		6	-92.144	203.3	26.79	0.000	
## 149	-0.535100	4	-96.249	203.4	26.85	0.000	
## 200	-0.09814	-1.376000	6	-92.187	203.4	26.87	0.000
## 207	-0.09842	-1.291000	6	-92.253	203.5	27.00	0.000
## 71	-0.04346		4	-96.607	204.1	27.57	0.000
## 29		4	-96.912	204.7	28.18	0.000	
## 85	-0.02329		4	-97.002	204.9	28.36	0.000
## 79	-0.05752		5	-95.269	205.2	28.65	0.000
## 93	-0.03469		5	-95.352	205.3	28.82	0.000
## 5		2	-100.454	205.7	29.16	0.000	
## 7		3	-99.141	205.9	29.38	0.000	
## 69	-0.02911		3	-99.212	206.0	29.52	0.000
## 23		4	-97.603	206.1	29.56	0.000	
## 22		4	-97.762	206.4	29.88	0.000	
## 98	-0.04453		4	-97.828	206.5	30.01	0.000
## 151	-0.672200		5	-96.080	206.8	30.27	0.000
## 191	0.255800		7	-91.323	206.8	30.33	0.000
## 176	0.276500		7	-91.325	206.8	30.33	0.000
## 190	0.273900		7	-91.325	206.8	30.33	0.000

## 157	-0.444400	5	-96.122	206.9	30.36	0.000
## 87	-0.03600	5	-96.147	206.9	30.41	0.000
## 206	-0.09018	6	-94.008	207.0	30.51	0.000
## 150	-0.542500	5	-96.220	207.1	30.55	0.000
## 64		7	-91.445	207.1	30.57	0.000
## 133	-0.276100	3	-99.995	207.6	31.09	0.000
## 77	-0.03778	4	-98.416	207.7	31.19	0.000
## 72	-0.04304	5	-96.541	207.7	31.20	0.000
## 95	-0.04915	6	-94.398	207.8	31.29	0.000
## 184	0.334300	7	-91.931	208.0	31.54	0.000
## 13		3	-100.275	208.2	31.65	0.000
## 224	-0.10120	8	-88.880	208.2	31.66	0.000
## 106	-0.05496	5	-96.827	208.3	31.77	0.000
## 31		5	-96.844	208.3	31.80	0.000
## 6		3	-100.381	208.4	31.86	0.000
## 210	-0.06104	5	-96.879	208.4	31.87	0.000
## 30		5	-96.911	208.4	31.94	0.000
## 34		3	-100.425	208.4	31.95	0.000
## 208	-0.09814	7	-92.158	208.5	32.00	0.000
## 86	-0.02331	5	-97.002	208.6	32.12	0.000
## 26		4	-98.947	208.8	32.25	0.000
## 15		4	-98.990	208.8	32.34	0.000
## 8		4	-99.001	208.9	32.36	0.000
## 18		3	-100.641	208.9	32.38	0.000
## 135	-0.125100	4	-99.057	209.0	32.47	0.000
## 70	-0.02876	4	-99.184	209.2	32.72	0.000
## 90	-0.03584	5	-97.320	209.3	32.75	0.000
## 226	-0.05822	5	-97.387	209.4	32.89	0.000
## 80	-0.05706	6	-95.248	209.5	32.99	0.000
## 94	-0.03536	6	-95.313	209.6	33.13	0.000
## 218	-0.06550	6	-95.374	209.7	33.25	0.000
## 24		5	-97.583	209.8	33.28	0.000
## 50		4	-99.485	209.8	33.33	0.000
## 114	-0.04011	5	-97.636	209.9	33.38	0.000
## 25		3	-101.291	210.2	33.68	0.000
## 100	-0.04474	5	-97.823	210.3	33.76	0.000
## 2		2	-102.802	210.4	33.85	0.000
## 134	-0.293100	4	-99.874	210.6	34.10	0.000
## 146	-0.358900	4	-99.958	210.8	34.27	0.000
## 141	-0.264400	4	-99.993	210.8	34.34	0.000
## 122	-0.04883	6	-95.989	211.0	34.48	0.000
## 159	-0.579900	6	-96.000	211.0	34.50	0.000
## 194	-0.05479	4	-100.086	211.0	34.53	0.000
## 82	-0.01971	4	-100.106	211.1	34.57	0.000
## 89	-0.03112	4	-100.121	211.1	34.60	0.000
## 152	-0.670500	6	-96.070	211.1	34.64	0.000
## 158	-0.454100	6	-96.109	211.2	34.72	0.000
## 162	0.232200	4	-100.190	211.2	34.73	0.000
## 88	-0.03604	6	-96.126	211.3	34.75	0.000

## 14		4	-100.210	211.3	34.78	0.000	
## 78	-0.03750	5	-98.408	211.4	34.93	0.000	
## 42		4	-100.302	211.5	34.96	0.000	
## 1		1	-104.643	211.5	35.02	0.000	
## 66	-0.02417	3	-101.970	211.5	35.04	0.000	
## 212	-0.06008	-1.368000	6	-96.314	211.6	35.13	0.000
## 36		4	-100.412	211.7	35.18	0.000	
## 58		5	-98.605	211.8	35.32	0.000	
## 9		2	-103.600	211.9	35.45	0.000	
## 242	-0.06035	-0.811600	6	-96.475	212.0	35.45	0.000
## 17		2	-103.632	212.0	35.51	0.000	
## 74	-0.03625		4	-100.589	212.0	35.53	0.000
## 10		3	-102.253	212.1	35.60	0.000	
## 20		4	-100.632	212.1	35.62	0.000	
## 4		3	-102.313	212.2	35.72	0.000	
## 73	-0.03172		3	-102.366	212.3	35.83	0.000
## 16		5	-98.861	212.3	35.83	0.000	
## 154		5	-98.870	212.4	35.85	0.000	
## 28		5	-98.879	212.4	35.87	0.000	
## 136		5	-98.896	212.4	35.91	0.000	
## 108	-0.05712		6	-96.710	212.4	35.92	0.000
## 234	-0.06043	-0.203500	6	-96.732	212.5	35.96	0.000
## 143		5	-98.986	212.6	36.09	0.000	
## 76	-0.04982		5	-98.994	212.6	36.10	0.000
## 32		6	-96.843	212.7	36.19	0.000	
## 68	-0.03217		4	-100.947	212.8	36.25	0.000
## 52		5	-99.126	212.9	36.37	0.000	
## 130		3	-102.637	212.9	36.37	0.000	
## 27		4	-101.047	213.0	36.45	0.000	
## 96	-0.04922		7	-94.396	213.0	36.47	0.000
## 57		4	-101.089	213.0	36.53	0.000	
## 192	0.255900		8	-91.323	213.0	36.54	0.000
## 65	-0.01745		2	-104.232	213.2	36.71	0.000
## 148		5	-99.335	213.3	36.78	0.000	
## 153	0.052930		4	-101.279	213.4	36.91	0.000
## 92	-0.04040		6	-97.208	213.4	36.91	0.000
## 178		5	-99.472	213.6	37.06	0.000	
## 33		2	-104.488	213.7	37.23	0.000	
## 196	-0.05731	-0.693800	5	-99.557	213.7	37.23	0.000
## 228	-0.05832	-0.410900	6	-97.385	213.8	37.27	0.000
## 202	-0.05579	-0.607800	5	-99.608	213.8	37.33	0.000
## 3		2	-104.552	213.9	37.35	0.000	
## 129		2	-104.572	213.9	37.39	0.000	
## 170	0.411900		5	-99.730	214.1	37.57	0.000
## 217	-0.04176	-0.331100	5	-99.780	214.2	37.67	0.000
## 116	-0.03836		6	-97.603	214.2	37.70	0.000
## 75	-0.03931		4	-101.732	214.3	37.82	0.000
## 12		4	-101.735	214.3	37.83	0.000	
## 142		5	-99.874	214.4	37.86	0.000	

## 81	-0.01386		3	-103.386	214.4	37.87	0.000
## 145		-0.215400	3	-103.390	214.4	37.88	0.000
## 11			3	-103.430	214.5	37.96	0.000
## 220	-0.06419	-1.070000	7	-95.153	214.5	37.99	0.000
## 41			3	-103.477	214.6	38.05	0.000
## 250	-0.06476	-0.688300	7	-95.188	214.6	38.06	0.000
## 19			3	-103.509	214.6	38.12	0.000
## 137		0.116600	3	-103.538	214.7	38.17	0.000
## 193	-0.03391	-0.445700	3	-103.548	214.7	38.20	0.000
## 84	-0.02264		5	-100.050	214.7	38.21	0.000
## 121	-0.02967		5	-100.081	214.8	38.28	0.000
## 91	-0.03032		5	-100.117	214.8	38.35	0.000
## 49			3	-103.627	214.9	38.35	0.000
## 105	-0.03522		4	-102.033	214.9	38.42	0.000
## 164		0.229000	5	-100.186	215.0	38.49	0.000
## 44			5	-100.299	215.2	38.71	0.000
## 201	-0.03867	-0.228000	4	-102.201	215.3	38.76	0.000
## 138		-0.007612	4	-102.253	215.4	38.86	0.000
## 132		-0.069870	4	-102.288	215.4	38.93	0.000
## 97	-0.02022		3	-103.961	215.5	39.02	0.000
## 60			6	-98.278	215.6	39.05	0.000
## 67	-0.02032		3	-104.025	215.6	39.15	0.000
## 209	-0.03365	-0.548400	4	-102.412	215.7	39.18	0.000
## 156		-0.369700	6	-98.534	216.1	39.57	0.000
## 244	-0.05931	-1.083000	7	-95.949	216.1	39.58	0.000
## 147		-0.548800	4	-102.618	216.1	39.59	0.000
## 124	-0.04843		7	-95.987	216.2	39.65	0.000
## 160		-0.581500	7	-95.996	216.2	39.67	0.000
## 186		0.076730	6	-98.590	216.2	39.68	0.000
## 204	-0.06062	-0.401700	6	-98.605	216.2	39.71	0.000
## 155		-0.184600	5	-100.962	216.5	40.04	0.000
## 35			3	-104.479	216.6	40.06	0.000
## 161		-0.041890	3	-104.481	216.6	40.06	0.000
## 59			5	-100.982	216.6	40.08	0.000
## 131		-0.074410	3	-104.525	216.7	40.15	0.000
## 185		-0.145700	5	-101.033	216.7	40.18	0.000
## 144		-0.066240	6	-98.846	216.7	40.19	0.000
## 180		-0.353000	6	-98.875	216.7	40.25	0.000
## 177		-0.419700	4	-103.112	217.1	40.58	0.000
## 139		0.281200	4	-103.157	217.2	40.67	0.000
## 169		0.281900	4	-103.217	217.3	40.79	0.000
## 249	-0.04715	-0.730700	6	-99.166	217.3	40.83	0.000
## 236	-0.06158	-0.174100	7	-96.641	217.5	40.96	0.000
## 83	-0.01185		4	-103.356	217.6	41.07	0.000
## 113	-0.01447		4	-103.381	217.6	41.12	0.000
## 43			4	-103.410	217.7	41.17	0.000
## 140		0.189700	5	-101.610	217.8	41.33	0.000
## 51			4	-103.501	217.9	41.36	0.000
## 211	-0.03361	-0.897800	5	-101.624	217.9	41.36	0.000

```

## 195 -0.03393 -0.409500 4 -103.508 217.9 41.37 0.000
## 225 -0.03326 -0.404500 4 -103.529 217.9 41.41 0.000
## 107 -0.03948 5 -101.704 218.0 41.52 0.000
## 219 -0.04066 -0.543700 6 -99.527 218.1 41.55 0.000
## 203 -0.04057 -0.052930 5 -101.725 218.1 41.56 0.000
## 241 -0.03869 -0.917500 5 -101.843 218.3 41.80 0.000
## 172 0.429400 6 -99.711 218.4 41.92 0.000
## 233 -0.03732 -0.083660 5 -102.016 218.6 42.15 0.000
## 99 -0.02105 4 -103.919 218.7 42.19 0.000
## 123 -0.02986 6 -100.081 219.2 42.66 0.000
## 179 -0.748500 5 -102.342 219.3 42.80 0.000
## 163 -0.035200 4 -104.473 219.8 43.30 0.000
## 252 -0.06337 -0.875900 8 -94.954 220.3 43.81 0.000
## 187 -0.372900 6 -100.729 220.5 43.96 0.000
## 188 -0.158900 7 -98.232 220.6 44.14 0.000
## 171 0.347500 5 -103.042 220.7 44.20 0.000
## 243 -0.03890 -1.274000 6 -101.042 221.1 44.58 0.000
## 115 -0.01249 5 -103.335 221.3 44.78 0.000
## 227 -0.03365 -0.396900 5 -103.505 221.6 45.12 0.000
## 251 -0.04605 -0.926800 7 -98.935 222.1 45.55 0.000
## 235 -0.03986 -0.016630 6 -101.703 222.4 45.91 0.000
## Models ranked by AICc(x)

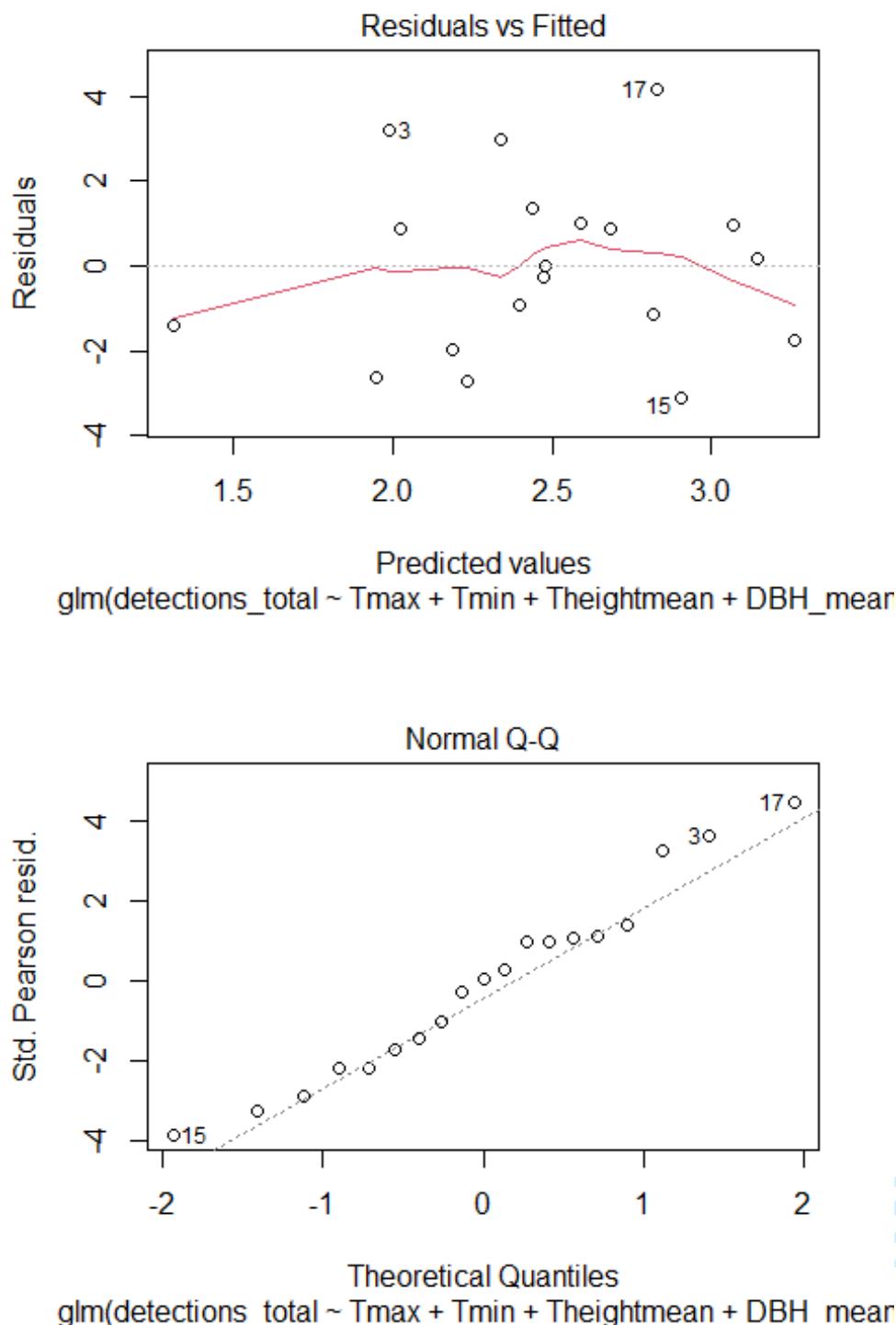
poisson2 <- glm(data = transect,
                  detections_total ~ Tmax + Tmin +
                  Theightmean + DBH_mean,
                  family = "poisson", na.action=na.fail)
summary(poisson2)

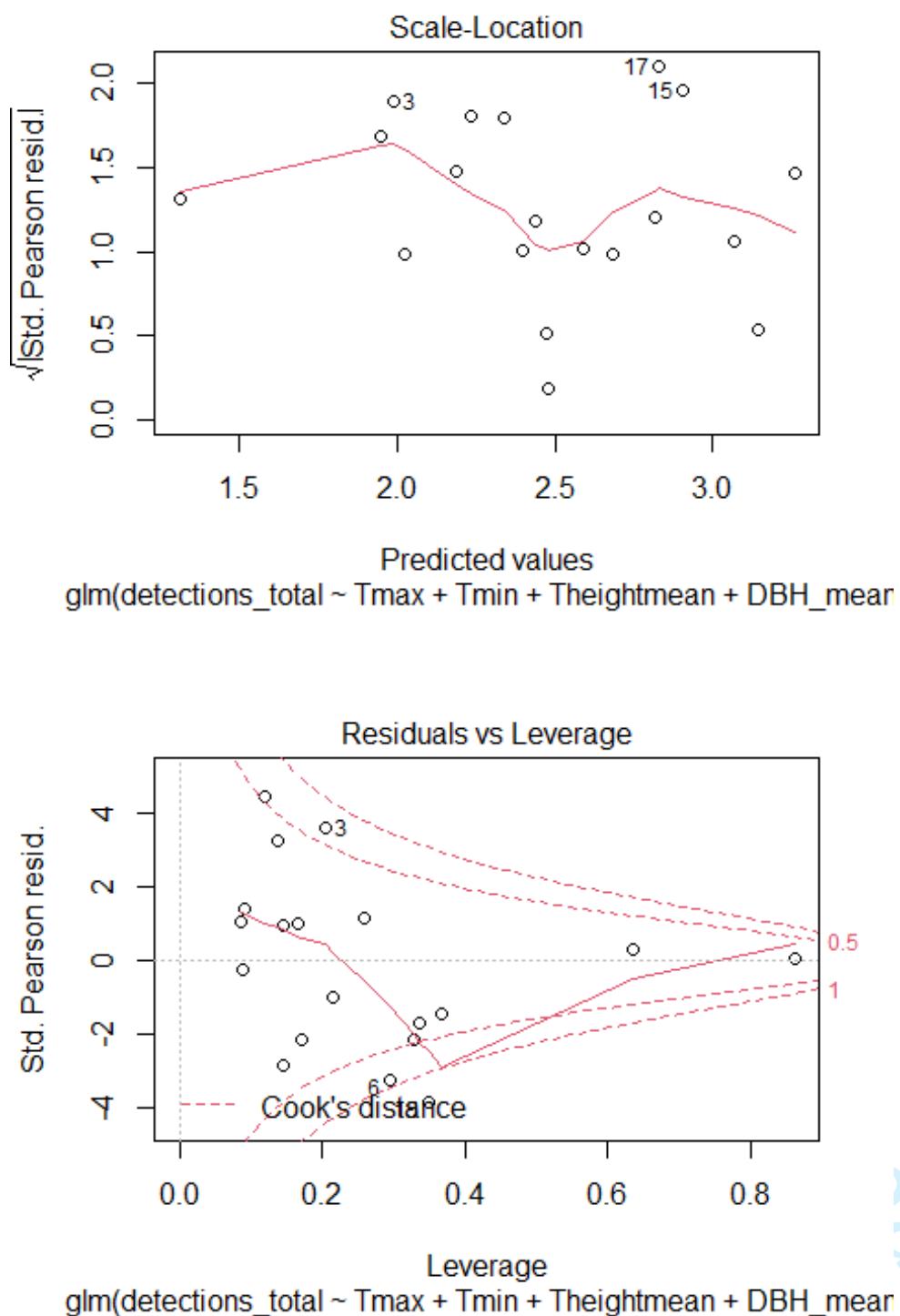
##
## Call:
## glm(formula = detections_total ~ Tmax + Tmin + Theightmean +
##      DBH_mean, family = "poisson", data = transect, na.action =
## na.fail)
##
## Deviance Residuals:
##      Min        1Q     Median        3Q       Max
## -3.7420   -1.7817    0.0123    0.9462    3.6463
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) 27.75857  10.83941  2.561  0.0104 *
## Tmax        -0.13112  0.02885 -4.545 5.49e-06 ***
## Tmin        -1.15827  0.48958 -2.366  0.0180 *
## Theightmean -0.11216  0.02131 -5.264 1.41e-07 ***
## DBH_mean     0.18618  0.02961  6.288 3.23e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)

```

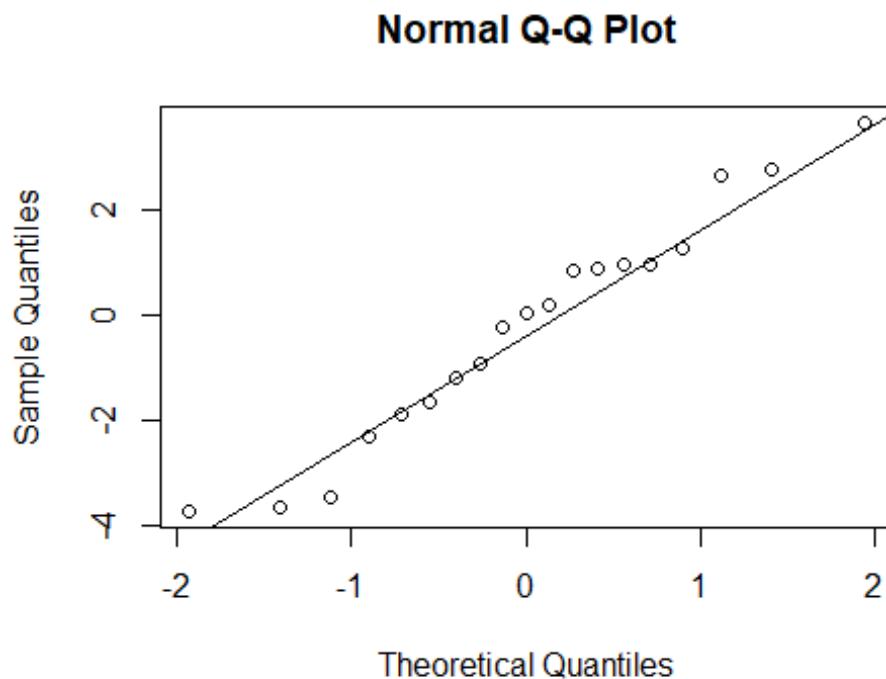
```
##  
##      Null deviance: 134.116  on 18  degrees of freedom  
## Residual deviance:  86.717  on 14  degrees of freedom  
## AIC: 171.89  
##  
## Number of Fisher Scoring iterations: 5  
  
plot(poission2)
```

DRAFT submitted to journal





```
qqnorm(resid(poisson2))
qqline(resid(poisson2))
```



2b) GLMM of structure & microclimate effects on mammal activity, with Order included as a random factor

```

camtraps <- read.csv("transects_order.csv")
mem <- glmmTMB(detections ~
  Tmax+height+dbh+crown+conn+n+
  (1/order),
  data = camtraps,family=nbinom2,na.action="na.fail")
summary(mem)

## Family: nbinom2 ( Log )
## Formula:
## detections ~ Tmax + height + dbh + crown + conn + n + (1 / order)
## Data: camtraps
##
##      AIC      BIC   LogLik deviance df.resid
##     433.6    458.3   -207.8     415.6      105
##
## Random effects:
## 
## Conditional model:
## Groups Name        Variance Std.Dev.
## order  (Intercept) 0.9653   0.9825
## Number of obs: 114, groups: order, 6
##
## Dispersion parameter for nbinom2 family (): 0.684
## 
## Conditional model:
##             Estimate Std. Error z value Pr(>|z|)

```

```

## (Intercept) -0.346849  1.894620 -0.183 0.854743
## Tmax        -0.183244  0.062560 -2.929 0.003400 **
## height      -0.213762  0.065111 -3.283 0.001027 **
## dbh          0.291361  0.086560  3.366 0.000763 ***
## crown        0.016992  0.019021  0.893 0.371688
## conn         -0.003055  0.012974 -0.236 0.813818
## n            0.064078  0.068790  0.932 0.351593
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

dredge(mem)

## Fixed terms are "cond((Int))" and "disp((Int))"

## Global model call: gLmmTMB(formula = detections ~ Tmax + height +
## dbh + crown +
##     conn + n + (1 | order), data = camtraps, family = nbinom2,
##     na.action = "na.fail", ziformula = ~0, dispformula = ~1)
## ---
## Model selection table
##   cnd((Int)) dsp((Int))   cnd(cnn) cnd(crw) cnd(dbh) cnd(hgh)
cnd(n)
## 45   -0.6757      +           0.29070 -0.179400
## 61   -0.8524      +           0.31860 -0.208600
0.053840
## 47   -0.2439      +           0.017090 0.26040 -0.186100
## 46   -0.8474      + 0.0036600 0.29270 -0.185700
## 63   -0.4525      +           0.017300 0.28760 -0.214000
0.054560
## 62   -0.7157      + -0.0037830 0.32240 -0.208100
0.065560
## 48   -0.4363      + 0.0040680 0.017500 0.26150 -0.192600
## 64   -0.3468      + -0.0030550 0.016990 0.29140 -0.213800
0.064080
## 13   -4.0570      +           0.20240 -0.103400
## 15   -3.8020      +           0.014840 0.17680 -0.108400
## 14   -4.2770      + 0.0074200 0.20950 -0.120400
## 5    -2.6280      +           0.09819
## 29   -3.9280      +           0.19900 -0.099200 -
0.009502
## 37   -0.9018      +           0.10660
## 21   -2.3670      +           0.10490 -
0.045520
## 16   -4.0190      + 0.0080620 0.016220 0.18180 -0.126600
## 3    -0.6786      +           0.027840
## 30   -3.8960      + 0.0112700 0.20060 -0.113000 -
0.036940
## 7    -2.4210      +           0.010670 0.07698
## 38   -0.6109      + -0.0083500 0.12150
## 53   -0.8823      +           0.11150 -

```

<i>0.036280</i>						
## 31	-3.6940	+		0.014710	0.17430	-0.105100
<i>0.007819</i>						-
## 6	-2.6650	+	-0.0032630		0.10350	
## 39	-0.6804	+		0.010560	0.08527	
## 35	0.9719	+		0.029900		
## 1	0.5937	+				
## 19	-0.3056	+		0.028620		-
<i>0.038570</i>						
## 23	-2.1610	+		0.009937	0.08454	-
<i>0.044850</i>						
## 43	2.0040	+		0.042110		-0.050070
## 11	-0.4341	+		0.034400		-0.028300
## 22	-2.2770	+	0.0038040		0.10080	-
<i>0.056170</i>						
## 32	-3.6220	+	0.0118000	0.016240	0.17250	-0.119400
<i>0.036820</i>						
## 4	-0.7198	+	0.0012530	0.027600		
## 40	-0.4289	+	-0.0078820	0.009029	0.10220	
## 55	-0.6659	+		0.009895	0.09096	-
<i>0.035470</i>						
## 8	-2.4610	+	-0.0028350	0.010150	0.08253	
## 54	-0.6992	+	-0.0053900		0.11870	-
<i>0.019360</i>						
## 51	1.0760	+		0.030330		-
<i>0.028670</i>						
## 33	1.8650	+				
## 36	1.1180	+	-0.0019450	0.030380		
## 17	0.9352	+				-
<i>0.032240</i>						
## 20	-0.3558	+	0.0080960	0.027590		-
<i>0.061350</i>						
## 9	0.3095	+			0.014800	
## 2	0.4423	+	0.0036400			
## 27	-0.1981	+		0.033140		-0.020250
<i>0.031440</i>						
## 12	-0.5313	+	0.0060950	0.036280		-0.040950
## 24	-2.0520	+	0.0041610	0.010410	0.07901	-
<i>0.056440</i>						
## 44	1.8530	+	0.0037480	0.042920		-0.056640
## 59	1.9850	+		0.041640		-0.047660
<i>0.008013</i>						
## 18	0.8073	+	0.0104100			-
<i>0.061130</i>						
## 56	-0.5149	+	-0.0047740	0.009286	0.09860	-
<i>0.020520</i>						
## 49	1.9650	+				-
<i>0.023490</i>						
## 28	-0.1881	+	0.0119600	0.035740		-0.037770

```

0.058920
## 52      0.8756      +  0.0031340 0.029720      -
0.038790
## 25      0.5611      +
0.043320
## 41      1.6160      +
## 34      1.7430      +  0.0015380
## 10      0.2965      +  0.0020660      0.011000
## 60      1.6670      +  0.0067310 0.041950      -0.053570 -
0.027010
## 50      1.4420      +  0.0078910      -
0.049040
## 26      0.6126      +  0.0085900      0.014910 -
0.062640
## 57      1.4960      +
0.033380
## 42      1.6030      +  0.0003773      0.008559
## 58      1.1990      +  0.0066050      0.012910 -
0.051790
##      cnd(Tmx) df  LogLik  AICc delta weight
## 45 -0.15100  6 -208.721 430.2  0.00  0.293
## 61 -0.17460  7 -208.249 431.6  1.33  0.151
## 47 -0.15390  7 -208.326 431.7  1.48  0.140
## 46 -0.14870  7 -208.662 432.4  2.15  0.100
## 63 -0.17720  8 -207.840 433.1  2.82  0.071
## 62 -0.18200  8 -208.208 433.8  3.56  0.049
## 48 -0.15100  8 -208.251 433.9  3.65  0.047
## 64 -0.18320  9 -207.812 435.4  5.13  0.023
## 13           5 -212.474 435.5  5.28  0.021
## 15           6 -212.182 437.1  6.92  0.009
## 14           6 -212.236 437.3  7.03  0.009
## 5            4 -214.507 437.4  7.15  0.008
## 29           6 -212.458 437.7  7.47  0.007
## 37 -0.06271  5 -213.606 437.8  7.54  0.007
## 21           5 -214.012 438.6  8.35  0.004
## 16           7 -211.894 438.8  8.62  0.004
## 3            4 -215.274 438.9  8.69  0.004
## 30           7 -212.047 439.1  8.92  0.003
## 7            5 -214.356 439.3  9.04  0.003
## 38 -0.07619  6 -213.265 439.3  9.09  0.003
## 53 -0.05628  6 -213.293 439.4  9.14  0.003
## 31           7 -212.171 439.4  9.17  0.003
## 6            5 -214.449 439.5  9.23  0.003
## 39 -0.06289  6 -213.459 439.7  9.48  0.003
## 35 -0.05461  5 -214.582 439.7  9.49  0.003
## 1            3 -217.079 440.4 10.15  0.002
## 19           5 -214.954 440.5 10.24  0.002
## 23           6 -213.880 440.5 10.32  0.002
## 43 -0.07420  6 -213.909 440.6 10.38  0.002

```

```

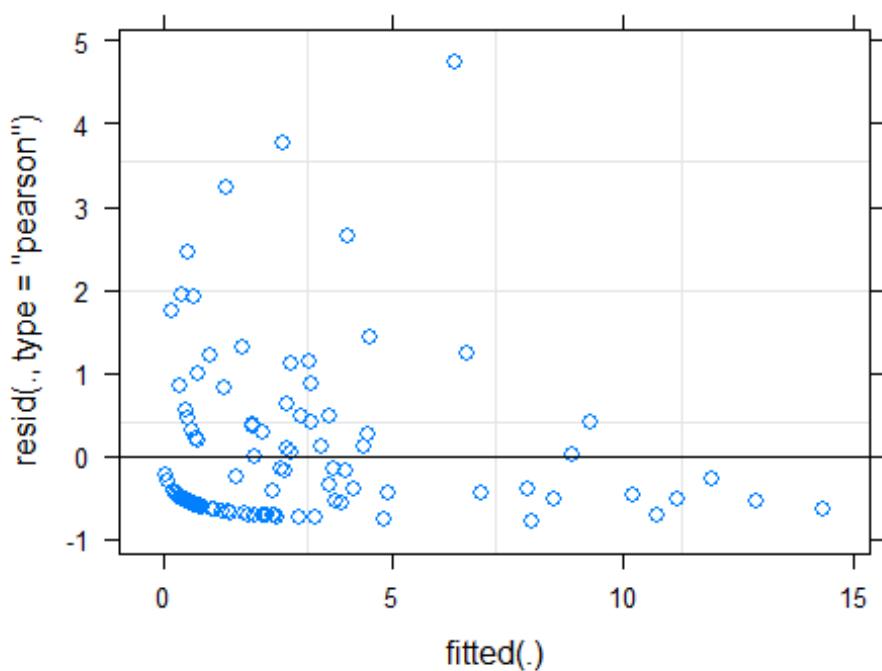
## 11      5 -215.029 440.6 10.39  0.002
## 22      6 -213.961 440.7 10.48  0.002
## 32      8 -211.706 440.8 10.56  0.001
## 4       5 -215.265 441.1 10.86  0.001
## 40     -0.07560 7 -213.156 441.4 11.14  0.001
## 55     -0.05647 7 -213.163 441.4 11.15  0.001
## 8       6 -214.312 441.4 11.18  0.001
## 54     -0.06798 7 -213.219 441.5 11.27  0.001
## 51     -0.04897 6 -214.409 441.6 11.37  0.001
## 33     -0.03981 4 -216.676 441.7 11.49  0.001
## 36     -0.05732 6 -214.562 441.9 11.68  0.001
## 17      4 -216.874 442.1 11.89  0.001
## 20      6 -214.696 442.2 11.95  0.001
## 9       4 -216.985 442.3 12.11  0.001
## 2      4 -217.007 442.4 12.15  0.001
## 27      6 -214.845 442.5 12.25  0.001
## 12      6 -214.867 442.5 12.29  0.001
## 24      7 -213.818 442.7 12.47  0.001
## 44     -0.07160 7 -213.848 442.8 12.53  0.001
## 59     -0.07174 7 -213.898 442.9 12.63  0.001
## 18      5 -216.473 443.5 13.27  0.000
## 56     -0.06688 8 -213.104 443.6 13.35  0.000
## 49     -0.03514 5 -216.571 443.7 13.47  0.000
## 28      7 -214.361 443.8 13.55  0.000
## 52     -0.04259 7 -214.379 443.8 13.59  0.000
## 25      5 -216.634 443.8 13.60  0.000
## 41     -0.03753 5 -216.641 443.8 13.61  0.000
## 34     -0.03800 5 -216.664 443.9 13.66  0.000
## 10      5 -216.967 444.5 14.26  0.000
## 60     -0.06115 8 -213.763 444.9 14.67  0.000
## 50     -0.02058 6 -216.392 445.6 15.34  0.000
## 26      6 -216.400 445.6 15.36  0.000
## 57     -0.02839 6 -216.453 445.7 15.46  0.000
## 42     -0.03724 6 -216.640 446.1 15.84  0.000
## 58     -0.01817 7 -216.339 447.7 17.51  0.000
## Models ranked by AICc(x)
## Random terms (all models):
## 'cond(1 | order)'

mem2 <- glmer.nb(detections ~
  Tmax+height+dbh+
  (1|order),
  data = camtraps,na.action="na.fail")
summary (mem2)

## Generalized Linear mixed model fit by maximum Likelihood (Laplace
## Approximation) [glmerMod]
## Family: Negative Binomial(0.6652)  ( Log )
## Formula: detections ~ Tmax + height + dbh + (1 | order)
## Data: camtraps

```

```
##  
##      AIC      BIC LogLik deviance df.resid  
##    429.4    445.9   -208.7     417.4      108  
##  
## Scaled residuals:  
##      Min      1Q Median      3Q      Max  
## -0.7837 -0.5935 -0.4605  0.2735  4.7401  
##  
## Random effects:  
## Groups Name      Variance Std.Dev.  
## order  (Intercept) 0.93      0.9644  
## Number of obs: 114, groups: order, 6  
##  
## Fixed effects:  
##             Estimate Std. Error z value Pr(>|z|)  
## (Intercept) -0.70293   1.75282 -0.401  0.68840  
## Tmax        -0.14962   0.05146 -2.907  0.00365 **  
## height       -0.17802   0.05862 -3.037  0.00239 **  
## dbh          0.28827   0.07256  3.973 7.11e-05 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Correlation of Fixed Effects:  
##          (Intr) Tmax  height  
## Tmax  -0.534  
## height -0.081  0.580  
## dbh    -0.284 -0.577 -0.819  
  
plot(mem2)
```



```
qqnorm(resid(mem2))  
qqline(resid(mem2))
```

Normal Q-Q Plot

