

## VARIATION IN ANIMAL BODY CONDITION BETWEEN TWO ALTITUDES IN A SMALL PASSERINE: NORTHERN RED BISHOP

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### ABSTRACT

This study examines how altitude and sex influence body condition in the Northern Red Bishop (*Euplectes franciscanus*) during the breeding season. We compared individuals from two distinct sites in Plateau State, Nigeria: the high-altitude Amurum Forest Reserve (1280 m) and the low-altitude Pandam Wildlife Park (175–315 m). Using residuals from a regression of body mass against wing length as a body condition index (BCI), we analyzed morphometric data from 102 birds. Generalized linear models revealed no significant differences in BCI between sites ( $p = 0.533$ ) or between sexes ( $p = 0.294$ ). These findings suggest that Northern Red Bishops maintain consistent body condition across altitude gradients, indicating ecological flexibility. This resilience may reflect similar habitat quality or adaptive traits. Further studies are needed to explore additional factors influencing body condition and the species' long-term responses to environmental change.

**Keywords:** Body condition index, passerine, *Euplectes franciscanus*, altitude, ecological resilience.

### INTRODUCTION

Forecasting the impacts of climate change on wildlife remains one of the most pressing challenges in modern ecology (Walther et al., 2002; Moritz & Agudo, 2013). The accelerating pace of global warming is already disrupting climate and weather patterns, leading to more frequent and intense heatwaves, droughts, increased precipitation over land, and shifts in storm tracks (Leggs, IPCC, 2021). These changes have profound implications for biodiversity, particularly for species that are sensitive to environmental variability. Birds, due to their ecological roles and high visibility, are often used as indicators of ecosystem health and are central to understanding the broader impacts of climate change on biodiversity (Sekercioglu, 2006; Bregman et al., 2016). Their extensive community science datasets (Neate-Clegg et al., 2020; Binley et al., 2021) and their role in driving conservation initiatives (Myers et al., 2000; Larsen et al., 2012) further underscore their importance in ecological research.

The Northern Red Bishop (*Euplectes franciscanus*), a small passerine bird in the Ploceidae family, is widely distributed across sub-Saharan Africa (Ahmed, 2014). This species is characterized by striking sexual dimorphism, with males displaying vibrant breeding plumage, and is known to thrive in diverse habitats, including grasslands, savannas, and agricultural areas (Prager & Andersson, 2010). Despite its broad distribution and ecological adaptability, there is limited research on how environmental factors, such as altitude, influence the body condition and physiological health of this species (Wilson et al., 2010; Gutiérrez-Pinto et al., 2014). Understanding these factors is critical for assessing the species' resilience to environmental changes, particularly in the context of climate change and habitat alteration. Body condition, a key indicator of an individual's health and fitness, is often quantified through metrics such as body mass, fat reserves, and muscle mass (Labocha & Hayes, 2012). Although definitions of body condition vary across studies, it is widely recognized as a proxy for overall avian health (Stevenson & Woods, 2006; Peig & Green, 2010; English et al., 2018). Body condition can reflect an individual's ability to cope with environmental stressors, resource availability, and habitat quality, and is influenced by the balance between energy intake and expenditure (McLean et al., 2018, 2020). It also serves as an indicator of phenotypic responses to climatic and environmental variables (McLean et al., 2018, 2020; Kouba et al., 2021). For example, studies have shown that warmer temperatures are associated with reduced body condition in several songbird species (van Buskirk et al., 2010; Gardner et al., 2016), a

trend that is likely exacerbated by climate change (van Buskirk et al., 2010). Furthermore, body condition can reflect early-life stress exposure (Grace et al., 2017) and influence survival rates and population dynamics (McLean et al., 2016). Thus, assessing body condition provides valuable insights into the health and adaptability of species under changing environmental conditions.

Altitude is a critical ecological variable that influences a range of environmental parameters, including temperature, oxygen availability, and the distribution of food resources (Hodkinson, 2005; Laiolo & Obeso, 2017). These factors can impose significant physiological and energetic demands on birds (Swanson & Liknes, 2006; Olson et al., 2009), potentially affecting their body condition, reproductive success, and overall fitness. For instance, higher altitudes are typically associated with lower temperatures and reduced oxygen levels, which may increase metabolic demands and challenge birds' ability to maintain optimal body condition. Comparative studies of body condition across altitudinal gradients can therefore provide critical insights into how species like the Northern Red Bishop cope with varying environmental conditions and highlight potential vulnerabilities to habitat changes.

This study aims to investigate the variation of the body condition of the Northern Red Bishop by comparing individuals from two distinct altitudinal zones in Plateau State, Nigeria: a lowland area and a highland plateau. By examining differences in residuals of body mass and wing length as a measure of body condition index, we seek to determine whether altitude significantly influences the body condition of this species. The findings of this research will contribute to a broader understanding of how altitude influences avian physiology and ecology, particularly in understudied regions like sub-Saharan Africa. Furthermore, this study will provide valuable baseline data for future conservation efforts aimed at protecting the Northern Red Bishop and other avian species in the face of ongoing environmental changes. By clarifying the relationship between altitude and body condition, we can better predict how species may respond to shifting habitats and climatic conditions, ultimately informing more effective conservation strategies.

## MATERIALS AND METHOD

### Study Species

The Northern Red Bishop (*Euplectes franciscanus*), also referred to as the Orange Bishop, is a small passerine bird belonging to the family Ploceidae. It is a member of the largest genus within this family, which comprises over 60 species (Arkhipov et al., 2010). The breeding male is particularly striking, adorned with vibrant reddish-orange plumage contrasted by bold black markings. In contrast, females and non-breeding males exhibit a more subdued appearance, characterized by a pale brown and white feather pattern.

This species is widely distributed across Sub-Saharan Africa and has also been introduced to parts of the Western Hemisphere. Northern Red Bishops are relatively small, measuring approximately 11 cm in length and weighing between 12 and 22 grams. They typically inhabit tall grasslands, cultivated areas, and marshes, often near water sources. Their range extends from lowland regions to elevations of up to 1000 meters (Garrett, 1998).



**Figure 1: Northern Red Bishop. photocredit@ LostInCR(Photo 415569760)**

### Study Area

This study was conducted in Amurum Forest Reserve and Pandam Wildlife Park. Amurum Forest Reserve ( $9^{\circ}53'N$ ,  $8^{\circ}59'E$ ) is a 100-hectare rocky outcrop in dry scrub savannah with gallery forests and grasslands, located 15 km northeast of Jos, Plateau State, Nigeria. It lies at 1280m above sea level, with an annual rainfall of 1375-1750 mm and temperatures of 10-13°C. Meanwhile, Pandam Wildlife Park ( $08^{\circ}40'N$   $09^{\circ}03'E$ ) is a 22,400-hectare protected area managed by the Plateau State Tourism Cooperation. Located near the Benue River, it sits at 175-315m above sea level, with a wet season from April to October and an annual rainfall of 1000-1500mm. Both sites are designated Important Bird Areas. These sites provide distinct ecological conditions for comparative study.



**Figure 2: Map of study Area. The dots represent the position of Amurum and Pandam Data collection**

Bird sampling in the two-study area was carried out between 0600hr -1000hr and between 1600hr - 1800hr daily when bird activity is at its peak. Birds were trapped in mist nets, banded and data on morphometric (body mass, wing length), pectoral muscle score and moult score was also taken. Sampling was carried out between 5th October and 6th December 2019. We sampled during the breeding season to enable us sex adults based on breeding plumage. We classified the sex of adults as either male or female and that of juveniles as unknown since they lack breeding plumage. This study was carried out during the breeding season to correct for the breeding, therefore, sexing of adult birds based on plumage was quite straightforward. However, the juvenile and the immature birds are difficult to sex as they are yet to develop their adult features that will distinguish them as either breeding males or breeding females. Therefore, these were classified as “unknown sex” and will also be referred to as “juvenile/immature”.

Body Condition Index (BCI) was determined by plotting a regression of body mass over structural size (wing length), the residuals were used as a measure of body condition index for the analysis (Green, 2001; Labocha and Hayes, 2011).

### DATA ANALYSIS

Data were analyzed using R statistical software (version 4.0.1). To assess the assumptions of normality and homogeneity of variances, we performed the Shapiro–Wilk test and Levene’s test, respectively. Given that body mass and wing length may vary by sex (Dias et al., 2025), we employed a linear model to examine the effects of site (as a proxy for altitude) and sex on the body condition index (BCI) of the Northern red bishop. All sub-adult or juvenile sampled during this study were excluded from this analysis to control for extreme values or unknown sex. For data visualization, the ggplot2 package in R was utilized to create graphical representations of the results.

### RESULT

A total of 102 Northern Red Bishops were sampled<sup>n</sup>49 from Amurum Forest Reserve (30 females, 17 males, 2 unknown) and 53 from Pandam Wildlife Park (38 females, 15 males). After excluding juvenile/immature individuals with unknown sex, 100 adult birds were included in the body condition analysis (Table 1).

**Table 1: Summary of the number of norther red bishop sampled at Amurum forest reserve and Pandam wildlife park.**

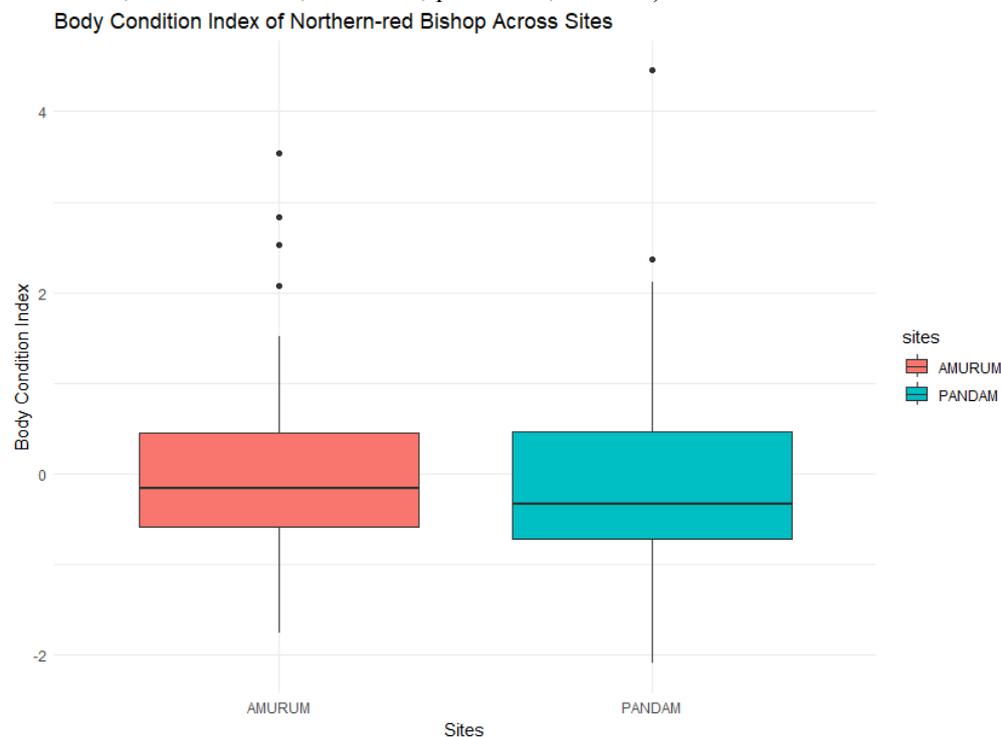
Sites	Male	Male (%)	Female	Female (%)	Total	Total (%)
Amurum Forest Reserve (High altitude)	17	36.2%	30	63.8%	47	46.1%
Pandam wildlife Park (Low Altitude)	15	28.3%	38	71.7%	53	53.9
Total	32	32.0%	68	68.0%	100	100%

**Table 2: Generalized linear model output on the difference in body condition index between Northern red bishops in Amurum Forest Reserve and Pandam Wildlife Park, while controlling for sex**

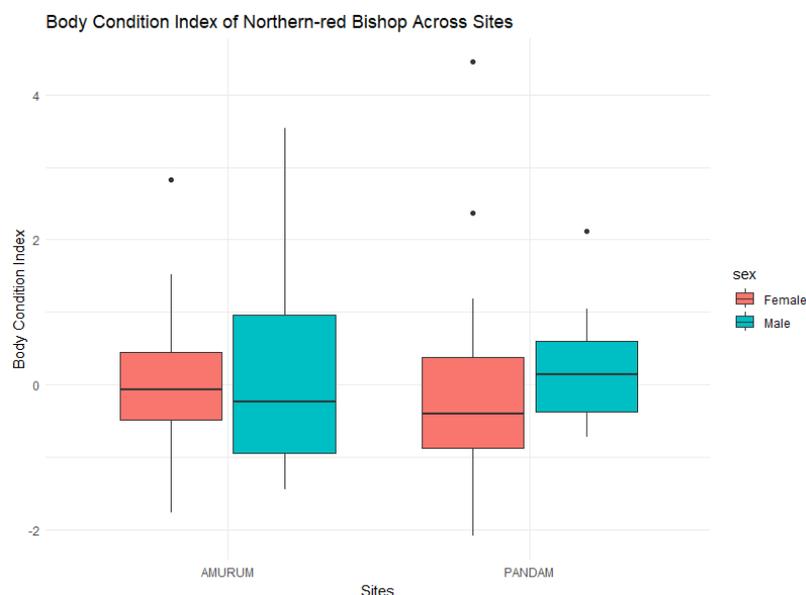
Variables	Estimates	Std. Error	t value	P value
Intercept	0.007	0.186	0.036	0.972
Sites: Pandam	-0.142	0.227	-0.626	0.533
Sex: Male	0.256	0.243	1.054	0.294

AIC: 312.72,  $F=1.057_{3,96}$ , p-value: 0.3713

The body condition index at the Pandam wildlife park was not significantly different from Amurum Forest Reserve (Estimate = -0.141916, SE = 0.22669,  $t = -0.626$ ,  $p = 0.533$ ; Table 2). Also, Male individuals did not show a significantly different body condition index compared to females (Estimate = 0.25569, SE = 0.24254,  $t = 1.054$ ,  $p = 0.294$ ; Table 2).



**Figure 3:** Difference in body condition index (BCI) between northern red bishop sampled in Amurum forest reserve and Pandam wildlife park.



**Figure 4:** Difference in body condition index (BCI) between sexes of Northern Red Bishop in Amurum Forest Reserve and Pandam Wildlife Park.

## DISCUSSION

The results of this study indicate that the body condition index (BCI) of the Northern Red Bishop (*Euplectes franciscanus*) does not vary significantly between the high-altitude Amurum Forest Reserve and the low-altitude Pandam Wildlife Park, nor between sexes. This suggests a remarkable adaptability

of the species to varying environmental conditions, which may reflect comparable resource availability or habitat suitability across the altitudinal gradient.

Despite the pronounced differences in altitude (1280 m vs. 175–315 m), temperature, and associated ecological conditions between the two sites, the Northern Red Bishop exhibited no significant variation in BCI. Interestingly, individuals at the high-altitude site (Amurum) were slightly heavier, a trend consistent with patterns observed in other bird species, such as snowfinches (*Montifringilla* spp.) and the Eurasian Tree Sparrow (*Passer montanus*), which display larger body sizes at higher elevations (Qu et al., 2021; Schumm et al., 2020; Ding et al., 2021). This could be attributed to thermoregulatory adaptations, where increased body mass helps mitigate heat loss in colder high-altitude environments (Gardner et al., 2011; Teplitsky & Millien, 2014). Alternatively, the absence of BCI differences may indicate that the species' broad distribution across Nigeria reflects a high degree of ecological plasticity, enabling it to thrive in diverse habitats without compromising physiological condition.

The lack of significant differences in BCI between males and females contrasts with findings in many sexually dimorphic birds, where reproductive roles often impose divergent energetic demands (Kappeler et al., 2023; Valdebenito et al., 2021). For instance, male Northern Red Bishops invest heavily in breeding plumage and courtship displays, while females bear the costs of egg production and incubation (Ishong & Omotoriogun, 2022; Yang & Nakagawa, n.d.). The absence of sex-based BCI variation in this study suggests compensatory mechanisms, such as differential foraging strategies or metabolic adjustments, may balance these energetic trade-offs. Alternatively, the timing of sampling during the breeding season could have captured both sexes at peak condition, masking potential disparities that might emerge during other life stages.

While this study provides valuable insights into the adaptability of Northern Red Bishops, the low explanatory power of the model (Table 2) highlights the potential influence of unmeasured variables. Factors such as food availability, predation pressure, or microclimatic conditions could further elucidate BCI dynamics. Future research should incorporate longitudinal data, broader geographic sampling, and direct measures of environmental stressors (e.g., temperature fluctuations, resource abundance) to refine our understanding of the species' resilience to climate change and habitat alteration.

## Conclusion

Biologically, the results suggest that Northern Red Bishops are highly adaptable and capable of maintaining similar body conditions across different sites, sexes. However, the low explanatory power of the model indicates that other factors not included in the analysis may play a more significant role in determining body condition. Further research is needed to identify these factors and better understand the species' ecology and physiology.

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## REFERENCES

1. Ahmed, N. B. E. (2014). *Breeding habits and nesting success of the village* (Doctoral dissertation, University of Khartoum).
2. Arkhipov, Vladimir Yu, Leon A Bennun, David Brewer et al. (2010). Handbook of Birds of the World. Lynx Edicions. (15): 74-78.
3. Binley, A. D., Bennett, J. R., Schuster, R., Rodewald, A. D., La Sorte, F. A., Fink, D., ... & Wilson, S. (2023). Species traits drive responses of forest birds to agriculturally-modified habitats throughout the annual cycle. *Ecography*, 2023(9), e06457.

4. Bregman, T. P., Lees, A. C., MacGregor, H. E., Darski, B., de Moura, N. G., Aleixo, A., ... & Tobias, J. A. (2016). Using avian functional traits to assess the impact of land-cover change on ecosystem processes linked to resilience in tropical forests. *Proceedings of the Royal Society B: Biological Sciences*, 283(1844), 20161289.
5. Bulgarella, M., Wilson, R. E., Kopuchian, C., Valqui, T., & McCracken, K. G. (2007). Elevational variation in body size of crested ducks (*Lophonetta specularioides*) from the central high Andes, Mendoza, and Patagonia.
6. Chang, A. M. (2017). *Habitat use, movement patterns, and body condition of male and female Snowy Owls (*Bubo scandiacus*) in winter* (Doctoral dissertation, University of Saskatchewan).
7. Dias, T., Lemoine, N. P., Yanco, S. W., Zimova, M., Bay, R. A., & Weeks, B. C. (2025). Long-term increases in wing length occur independently of changes in climate and climate-driven shifts in body size. *Proceedings B*, 292(2039), 20242556.
8. English, P. B., Richardson, M. J., & Garzón-Galvis, C. (2018). From crowdsourcing to extreme citizen science: participatory research for environmental health. *Annual review of public health*, 39(1), 335-350.
9. Gardner, J. L., Amano, T., Sutherland, W. J., Clayton, M., & Peters, A. (2016). Individual and demographic consequences of reduced body condition following repeated exposure to high temperatures. *Ecology*, 97(3), 786-795.
10. Gardner, J. L., Peters, A., Kearney, M. R., Joseph, L., & Heinsohn, R. (2011). Declining body size: a third universal response to warming?. *Trends in ecology & evolution*, 26(6), 285-291.
11. Garrett, K. L. (1998). Population trends and ecological attributes of introduced parrots, doves and finches in California. In *Proceedings of the Vertebrate Pest Conference* (Vol. 18, No. 18).
12. Gutiérrez-Pinto, N., McCracken, K. G., Alza, L., Tubaro, P., Kopuchian, C., Astie, A., & Cadena, C. D. (2014). The validity of ecogeographical rules is context-dependent: testing for Bergmann's and Allen's rules by latitude and elevation in a widespread Andean duck. *Biological Journal of the Linnean Society*, 111(4), 850-862.
13. Hodkinson, I. D. (2005). Terrestrial insects along elevation gradients: species and community responses to altitude. *Biological reviews*, 80(3), 489-513.
14. Ishong, A. J., & Omotoriogun, T. C. (2022). Intra-and inter-annual variation in body mass of two species of weavers in an Afrotropical environment. *Bird Study*, 69(3-4), 83-89.
15. Kappeler, P. M., Benhaiem, S., Fichtel, C., Fromhage, L., Höner, O. P., Jennions, M. D., & Goymann, W. (2023). Sex roles and sex ratios in animals. *Biological Reviews*, 98(2), 462-480.
16. Kausar, R., Anwar, Z., Bashir, R., Rehan, S., Murtaza, G., & Usman, M. (2025). Seasonal Variations in Hematology of Birds. In *Ecology of Avian Zoonotic Diseases-New Challenges*. IntechOpen.
17. Kouba, M., Bartoš, L., Bartošová, J., Hongisto, K., & Korpimäki, E. (2021). Long-term trends in the body condition of parents and offspring of Tengmalm's owls under fluctuating food conditions and climate change. *Scientific reports*, 11(1), 18893.
18. Labocha, M. K., & Hayes, J. P. (2012). Morphometric indices of body condition in birds: a review. *Journal of Ornithology*, 153, 1-22.
19. Laiolo, P., & Obeso, J. R. (2017). Life-history responses to the altitudinal gradient. *High mountain conservation in a changing world*, 253-283.
20. Legg, S. (2021). IPCC, 2021: Climate change 2021-the physical science basis. *Interaction*, 49(4), 44-45.
21. McCloy, M. W., & Grace, J. K. (2023). Short-term weather patterns influence avian body condition during the breeding season. *Frontiers in Ecology and Evolution*, 11, 1154656.
22. McLean, N. M., van der Jeugd, H. P., Van Turnhout, C. A., Lefcheck, J. S., & Van de Pol, M. (2020). Reduced avian body condition due to global warming has little reproductive or population consequences. *Oikos*, 129(5), 714-730.
23. McLean, N., Lawson, C. R., Leech, D. I., & van de Pol, M. (2016). Predicting when climate-driven phenotypic change affects population dynamics. *Ecology letters*, 19(6), 595-608.
24. McLean, N., Van Der Jeugd, H. P., & van de Pol, M. (2018). High intra-specific variation in avian body condition responses to climate limits generalisation across species. *PLoS One*, 13(2), e0192401.

25. Moritz, C., & Agudo, R. (2013). The future of species under climate change: resilience or decline?. *science*, 341(6145), 504-508.
26. Neate-Clegg, M. H., Horns, J. J., Adler, F. R., Aytakin, M. Ç. K., & Şekercioglu, Ç. H. (2020). Monitoring the world's bird populations with community science data. *Biological Conservation*, 248, 108653.
27. Olson, V. A., Davies, R. G., Orme, C. D. L., Thomas, G. H., Meiri, S., Blackburn, T. M., ... & Bennett, P. M. (2009). Global biogeography and ecology of body size in birds. *Ecology Letters*, 12(3), 249-259.
28. Peig, J., & Green, A. J. (2010). The paradigm of body condition: a critical reappraisal of current methods based on mass and length. *Functional Ecology*, 24(6), 1323-1332.
29. Prager, M., & Andersson, S. (2010). Convergent evolution of red carotenoid coloration in widowbirds and bishops (*Euplectes* spp.). *Evolution*, 64(12), 3609-3619.
30. Sekercioglu, C. H. (2006). Increasing awareness of avian ecological function. *Trends in ecology & evolution*, 21(8), 464-471.
31. Stevenson, R. D., & Woods Jr, W. A. (2006). Condition indices for conservation: new uses for evolving tools. *Integrative and comparative biology*, 46(6), 1169-1190.
32. Swanson, D. L., & Liknes, E. T. (2006). A comparative analysis of thermogenic capacity and cold tolerance in small birds. *Journal of Experimental Biology*, 209(3), 466-474.
33. Teplitsky, C., & Millien, V. (2014). Climate warming and Bergmann's rule through time: is there any evidence?. *Evolutionary applications*, 7(1), 156-168.
34. Valdebenito, J. O., Halimubieke, N., Lendvai, Á. Z., Figuerola, J., Eichhorn, G., & Székely, T. (2021). Seasonal variation in sex-specific immunity in wild birds. *Scientific reports*, 11(1), 1349.
35. Van Buskirk, J., Mulvihill, R. S., & Leberman, R. C. (2010). Declining body sizes in North American birds associated with climate change. *Oikos*, 119(6), 1047-1055.
36. Walther, G. R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J., ... & Bairlein, F. (2002). Ecological responses to recent climate change. *Nature*, 416(6879), 389-395.
37. Wilson, A. J., Réale, D., Clements, M. N., Morrissey, M. M., Postma, E., Walling, C. A., ... & Nussey, D. H. (2010). An ecologist's guide to the animal model. *Journal of animal ecology*, 79(1), 13-26.
38. Yang, Y., & Nakagawa, S. (n.d) Reliability of meta-analyses in ecology and evolution:(mostly) good news from a case study on sexual signals 2 Pietro Pollo1\*, Malgorzata Lagisz1, Renato Chaves Macedo-Rego2, Ayumi Mizuno1, 3, 3.