Effects of moult and breeding on the body condition of some forest birds in southwest Nigeria

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Summary

By using body mass and tarsus length as a proxy for body condition, the effects of moult (actively moulting, new feathers or old feathers) and breeding (breeding or non-breeding) on the Grey-headed Bristlebill *Bleda canicapillus*, White-throated Greenbul *Phyllastrephus albigularis*, Little Greenbul *Eurillas virens* and Yellow-whiskered Greenbul *Eurillas latirostris*, were investigated in two rainforest patches in southwest Nigeria, 2017–2019. The relative frequency of the studied species across the study sites and the numbers of moulting and breeding individuals are presented. Despite breeding and moulting birds being recorded over much of the year in all four species, only six birds (2 %) of three species were moulting while breeding, suggesting a trade-off. Moult did not significantly influence the body condition of any bird species, but the body condition of breeding Grey-headed Bristlebill, Little Greenbul and White-throated Greenbul was significantly lower than that of non-breeding birds. This was not the case for the Yellow-whiskered Greenbul, which may be able to synchronise moult and breeding with peak food availability.

Résumé

Effets de la mue et de la reproduction sur l'état corporel de quelques oiseaux forestiers du sud-ouest du Nigeria. En considérant la masse corporelle et la longueur du tarse comme significatives de l'état corporel, les effets de la mue (mue en cours, plumes nouvelles ou vieilles plumes) et de la reproduction (période de reproduction en cours ou non) ont été examinés sur le Bulbul fourmilier *Bleda canicapillus*, Bulbul à gorge blanche *Phyllastrephus albigularis*, Bulbul verdâtre *Eurillas virens* et Bulbul à moustaches jaunes *Eurillas latirostris* dans deux forêts humides du sud-ouest du Nigeria, 2017–2019. La fréquence relative des espèces étudiées dans les différents sites de l'étude et le nombre des individus en train de muer ou en période de reproduction sont présentés. Bien que des oiseaux aient été observés en période de reproduction ou de mue pendant la majeure partie de l’année pour les quatre espèces, seuls six oiseaux (2 %) de trois espèces étaient en train de muer tout en étant en période de reproduction, ce qui suggère un compromis entre les deux processus. La mue n’a pas eu d’influence significative sur l’état corporel de ces espèces mais, pour le Bulbul fourmilier, le Bulbul verdâtre et le Bulbul à gorge blanche, l’état corporel des individus en période de reproduction était significativement moins bon que celui des oiseaux non reproducteurs. Ce n’était pas le cas du Bulbul à moustaches jaunes, qui pourrait être en mesure de synchroniser la mue et la reproduction avec la disponibilité alimentaire maximum.

Introduction

In view of energetic costs and the optimization of productivity, moulting and breeding birds exploit resource-rich habitats or synchronize these demanding activities with the peak of food availability (*e.g*. Aidley & Wilkinson 1987, Sherry & Holmes 1996, Cox *et al.* 2013). Moulting and breeding have contrasting effects on body condition (Gosler 1994), which can be regarded as the organism's physiological state (estimated from the levels of nutrients stored) that influences its performance (Brown 1996). A non-invasive technique based on morphometric measurements (such as mass, fat, pectoral muscle, tarsus, head, bill and tail), is commonly used in estimating the body condition of birds (Gosler & Harper 2000, Moya-Laraño *et al*. 2008). Most such studies have been conducted in temperate areas, where birds have shorter life spans and greater clutch sizes compared to tropical birds (Ricklefs & Wikelski 2002). As these life history parameters influence the allocation of resources to physiological and phenological activities (Ricklefs & Wikelski 2002), baseline data are needed in the tropics, particularly Africa, for comparison. In Nigeria, morphometric measurements have been used to elucidate the phenology of moult (Aidley & Wilkinson 1987), body reserves (Nwaogu & Cresswell 2016) and breeding condition (Cox *et al*. 2013) of resident and migratory birds. However, how these variables influence the body condition of birds is still poorly known in the area. The present study therefore analysed three years of data (2017–19) of four forest bulbuls ringed in the framework of studies by the Ornithological Monitoring and Forest Restoration Project in southwest Nigeria. The aim was to determine the influence of moult and breeding on the body condition of birds.

Study sites

All birds were trapped and ringed in two regenerating secondary rainforest patches, located *c.* 25 km apart in southwest Nigeria (Fig. 1): the International Institute of

Tropical Agriculture (IITA) Forest Reserve (IFR) and Emerald Forest Reserve (EFR). Both are private forests dedicated to biodiversity conservation, research and recreation, and enjoy a relatively high degree of protection.

The IFR (7°30′N, 3°55′E; 243 m a.s.l.; 360 ha) is located within the expanding city of Ibadan, which experiences tropical dry and wet conditions, with an annual rainfall of 1500–2000 mm (Ezealor 2001) and a daytime temperature of 26–38°C (Neuenschwander *et al.* 2015). The IFR supports important species of native trees such as *Albizia zygia, Ceiba pentandra*, *Cola gigantia, Milicia excelsa* and *Terminalia superba* (Manu *et al*. 2005, Neuenschwander *et al.* 2015). Although protected, with a perimeter fence and patrol against illegal logging and poaching, urbanization has isolated the IFR from surrounding forest patches (Awoyemi & Bown 2019). Despite this, the IFR supports *c.* 270 bird species (Adeyanju *et al.* 2014), including 67 species that are restricted to the Guinea-Congo Forests Biome (Ezealor 2001), qualifying it as an Important Bird and Biodiversity Area (IBA).

Due to their proximity, the EFR (7°18′N, 4°8′E; 130 m a.s.l.; 120 ha) and IFR experience a similar climate. The EFR is dissected by two seasonal streams, the Aworin and Akinrin, which flow into the River Osun (Awoyemi *et al.* 2020), which provides water to communities in the surrounding areas (Olajire & Imeokpartia 2000). The streams and river support luxuriant vegetation forming gallery forest, an important habitat corridor in the area. *Antiaris toxicaria, Brachystegia eurycoma, Cynometra megalophylla* and *Triplochiton scleroxylon* are some of the native tree species that dominate the EFR, which supports a high diversity of Guineo-Congolian bird species that qualify the reserve as an IBA (Awoyemi *et al*. 2020).

Figure 1. Southwest Nigeria, showing the location of the Forest Reserves where birds were mist-netted (map by IITA GIS Unit).

Methods

Birds were mist-netted at both forest patches during quarterly Constant Effort Surveys (Mar–Apr, Jun–Jul, Sep, Nov–Dec), from 2017 to 2019. In each forest patch and during each survey, birds were trapped at three sites for three days, using the same mist-nets (120 m long, 2.5 m high, five shelves and 32 mm mesh). For the measurements, pliers, vernier calipers, metre rules and an electronic balance were used. Nets were opened at 6h00, closed at 11h00 and checked at 30-min. intervals. Birds were identified using Borrow & Demey (2014). Where possible, photographs were taken to confirm identification while all ringing data (SAFRING) were submitted to the A.P. Leventis Ornithological Research Institute (APLORI), Jos, Nigeria. I participated in all surveys and ringed 231 (61 %) of the 376 birds of the four species (Grey-headed Bristlebill *Bleda canicapillus*, Little Greenbul *Eurillas virens*, White-throated Greenbul *Phyllastrephus albigularis* and Yellow-whiskered Greenbul *Eurillas latirostris*) considered for this study. These species were chosen for being the most commonly netted bulbuls within the framework of the project. The remaining birds were ringed by other visiting ornithologists.

Given the focus of this study, all newly captured and re-trapped (*i.e* birds that had been captured during previous surveys) adults, were included in the analysis. Measurements taken included tarsus and mass, while breeding evidence was estimated from brood patches, following the established scoring system (0–5), where 0 = no brood patch, 1 = patch forming, de-feathering process has begun, 2 = breast and belly fully de-feathered, some wrinkling of skin evident and signs of oedema, 3 = skin of belly opaque and engorged, broad swollen wrinkles, 4 = skin shows thin wrinkles, no longer engorged, and 5 = re-feathering (Beer *et al.* 2001). All individuals scoring 0 were classified as non-breeding while those with 1–5 represented breeding individuals (Beer *et al.* 2001). Further, the ten primary feathers of each bird were classified as actively moulting when having a score of 1–4 (where 1 = feather missing or new feather in pin, 2 = feather emerging from sheath up to ⅓ grown, 3 = new feather between ⅓ and ⅔ grown and 4 = new feather from ⅔ to fully grown but with remains of waxy sheath persisting), new when scoring 5 (new feather fully developed with no trace of sheath remaining at base) or old when scoring 0 (old feather remaining), following Beer *et al.* (2001). The relative frequencies of birds classified as moulting or breeding (Aidley & Wilkinson 1987) were expressed here as the numbers of individuals that were actively moulting or breeding respectively during the study period (only one record of breeding or moulting used per individual, irrespective of whether this was at its first capture or as a retrap), relative to the total number of captured individuals of that species.

In estimating body condition, the body mass of an individual bird was divided by its tarsus length (a proxy for body size) to control for variations that might arise as larger individuals tend to weigh more (see Battley *et al.* 2004, Moya-Laraño *et al.* 2008), independently of moult stage and breeding status. Other estimates of body size, including head, bill and tail, were not measured during the present data collection. Although wings were measured, they do not give useful data in birds that are moulting. While the condition of the fat layer or the pectoral muscles are valuable characters for the study of migrants (Battley *et al.* 2004, Nwaogu & Cresswell 2016), body mass was used as an estimate of body condition of the resident birds on which this study focused.

Graphical exploration and Shapiro-Wilk Tests ($P > 0.05$) were conducted to determine normality of the dataset before fitting General Linear Models using R Statistical Software (R Development Core Team 2013), to test if the body condition (body mass / tarsus length) of birds was dependent on moult stage (actively moulting, new feathers or old feathers), breeding status (breeding or non-breeding), site (IFR or EFR) and species. In addition, two-way interactions across moult stage, breeding status, site and species were included in the models. Using stepwise backward elimination (Crawley 2013), variables with the highest P values were removed and the procedure repeated until the best model was attained. The surviving models were compared using Akaike's Information Criterion (AIC: Burnham & Anderson 2002) and the best model was selected as the one with the lowest AIC value. Statistical significance was considered at $P < 0.05$.

Results

The relative abundance of the four species across the study sites, and the numbers of individuals that were moulting and breeding, are presented in Table 1. Although evidence of breeding and moulting was recorded in most months of the year (Table 1), only six different birds (2 %) of three species (two Little Greenbuls, one White-throated Greenbuls and three Yellow-whiskered Greenbuls) were actively moulting while breeding. The fitted General Linear Models revealed that the body condition of breeding Grey-headed Bristlebills, Little Greenbuls and White-throated Greenbuls was significantly lower than that of non-breeding birds (Table 2, Fig. 2).

Table 1. Bird species mist-netted, showing relative abundance between study sites (IFR and EFR), number and % of individuals that bred (as indicated by brood patch) or moulted during the study, and the months when breeding and moult were recorded (similar in both sites), 2017–19.

	IFR	EFR	Total	N (%) bred	N (%) moult	Breed months	Moult months
Grey-headed Bristlebill	86	14	100	21 (21)	17 (17)	3,5,6,10	5–7,9–11
Yellow-whiskered Greenbul	92	48	140	29 (21)	25 (18)	3,5–7,9,10,12	3,6,10,12
Little Greenbul	71	0	71	11 (15)	16 (23)	2,3,5,6,12	3,6,9,10,12
White-throated Greenbul	41	24	65	10 (15)	11 (17)	6,9	6,9–12
Total	**290**	**86**	**376**	**71 (19)**	**69 (18)**		

Table 2. Summary statistics of variables retained in the final General Linear Model (breeding status, species, and breeding status x species) predicting the body condition of 376 birds by species and breeding status in southwest Nigeria, 2017–19. Significant *P* values are indicated in bold.

Variable	Estimate	SE	*t*	*P*
Intercept (Breeding and Grey-headed Bristlebill)	1.205	0.041	29.405	**<0.001**
Non-breeding	0.145	0.046	3.143	**<0.001**
Little Greenbul	–0.292	0.07	–4.184	**<0.001**
White-throated Greenbul	–0.305	0.072	–4.224	**<0.001**
Yellow-whiskered Greenbul	–0.076	0.054	–1.406	0.161
Non-breeding x Little Greenbul	0.026	0.077	0.331	0.741
Non-breeding x White-throated Greenbul	–0.051	0.079	–0.639	0.523
Non-breeding x Yellow-whiskered Greenbul	–0.126	0.061	–2.083	**0.04**

Adjusted $r^2 = 0.306$, AIC = –181.033.

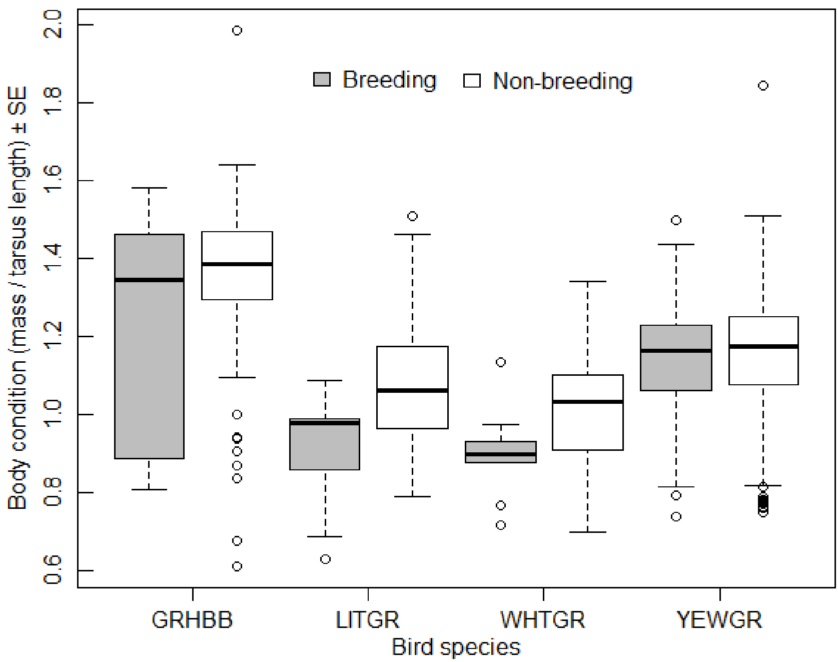

Figure 2. Body condition in breeding and non-breeding Grey-headed Bristlebill (GRHBB), Little Greenbul (LITGR), White-throated Greenbul (WHTGR), Yellow-whiskered Greenbul (YEWGR). The boxplots show median, first and third quartiles (box ends), 1.5 x interquartiles (whiskers), and outliers (points).

Discussion

The relative abundance of the mist-netted species between the study sites (Table 1) appears to be due to patch size rather than quality. The IFR is three times bigger than the EFR. Furthermore, since body condition, which is commonly used as a proxy to examine patch quality (Sherry & Holmes 1996, Johnson 2007) did not significantly vary between the two sites, there is no evidence that the two sites are not of similar quality, as might be expected considering their proximity and similarities in climate, altitude and vegetation. The similarities of moulting and breeding phenology between the sites (Table 1) further support this suggestion. While two individual Little Greenbuls, one White-throated Greenbul and three individual Yellow-whiskered Greenbuls were moulting while breeding, no Grey-headed Bristlebills were found undergoing both processes simultaneously, notwithstanding the trapping of 17 (17 %) moulting and 21 (21 %) breeding birds (Table 1). This suggests a strong trade-off, which is common in temperate birds (*e.g.* Siikamaki *et al.* 1994, Svensson & Nilsson, 1997). Although moult-breeding overlap is more common in tropical birds, it is usually associated with a prolonged breeding or moult period in relatively aseasonal areas (Foster 1974, Moreno 2004), whereas the climate of SW Nigeria is highly seasonal.

The lack of significant effects of moult on body condition suggests that only breeding was particularly energy-demanding relative to the resources available to the studied species. Excepting the Yellow-whiskered Greenbul, the body condition of all study species was significantly lower in breeding birds (Fig. 2, Table 2). Extra energetic costs on breeding individuals compared with non-breeding and moulting birds comprise nest-site selection, nest building, egg formation and fertilisation, incubation, food provisioning for dependent young and nest defence.

The phenological flexibility in assigning resources to either moult or breeding, independent of the season (Table 1), suggests an all-year round availability of food resources. Studies shedding more light on the phenology of insects and fruits are still needed in the area and would be helpful in unravelling synchronisation between food availability, moult and breeding. For instance, the lack of significant effects of moult and breeding on the body condition of the Yellow-whiskered Greenbul, which recorded the most netted adults (Table 1) and the most individuals with moult-breeding overlap (recorded in Mar and Oct), may be due to the ability of this species to synchronise moult and breeding with the peak in food availability, or to that peak being relatively extensive, thereby enhancing both survival and productivity.

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