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Key Factors Influencing Breeding Seasons of Insectivorous African Passerines in a Guinea Savanna Habitat, Central Nigeria

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Abstract

Food and weather variables are known to be important factors influencing life history activities such as breeding in organisms. Studies that highlight these interactions are particularly needed in rapidly changing ecosystems due to anthropogenic activities. Our study determined breeding seasons of insectivorous African passerines in relation to insect prey abundance and diversity, temperature, rainfall and relative humidity in Pandam Game Reserve (PGR), (08°40'N 09°03'E) central Nigeria. Breeding seasons of insectivorous African passerines were determined by observing for brood patches in birds from five constant effort bird trapping sites and breeding behaviours on five line transects of 1000 m. Aerial insects were collected from 50 points at 100 m sections on the five line transects using sweep net of 35 cm diameter and pore size of $1mm^2$. Monthly records of temperature, rainfall and relative humidity were also collected. Mean number of breeding insectivorous African passerines per month were compared using one sample T-test. Effects of insect abundance and diversity, temperature, rainfall and relative humidity on breeding insectivorous African passerines were tested using Generalised Linear Model (GLM). Results showed significant difference in mean number of breeding insectivorous African passerines per month. Highest breeding activities were observed between June and October with peak in October; this mirrored the trend of insect abundance across months. Temperature and humidity had significant effects on insect abundance and diversity respectively, highest insect diversity index (H) was recorded in January. The study concludes that insectivorous African passerines probably breed all year round in PGR, however, breeding of many of the species peak in the wet season between June and October. This is likely influenced by high insect prey abundance in wet season indirectly affected by temperature and humidity two important factors determining habitat productivity.

Keywords: Breeding season, Insectivorous African Passerine, Breeding behavior, Pandam Game Reserve

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1. Introduction

The interlocking effects of biotic and abiotic environmental factors affects the breeding ecology of organisms in many ways. These interactions play key roles in the breeding success of organisms (Roff, 1992; Krebs & Davies, 1993) also to the extent of affecting entire annual cycles (Coppack & Both, 2002; Carey, 2009). In birds, life-history traits may be genetically linked in a way that selection for one trait will also affect one or more other aspects of annual cycles (Carey, 2009), therefore, different organisms elicit arrays of signs indicating annual cycles such as breeding seasons. For example, possession of brood patch is a reliable cue to identifying time and stage of breeding in birds (Cox *et al*. 2013). Other behavioural cues that reveal breeding periods in birds include carrying nesting materials or food by parent birds as well as increased presence of newly fledged young within an area; these are identified by gapes around the bill (Wittenberger, 1982).

Additionally, food is known to be a critical resource in the physiological processes and reproductive success of birds (Dawkins, 1997; Jawor & Breitwisch, 2006; Turshak & Mwansat, 2011). Therefore, the "food availability-breeding time" hypothesis suggests that most birds breed at the time when food is available for nestlings, thereby enhancing their reproductive success (Sodhi, 1993; Abdul, 2003). However, many exceptions show that some birds make trade-offs to balance pressures from factors such as predation, harsh weather regimes and competition for nesting sites (Martin, 1988; Cresswell, 1998; Cresswell *et al*., 2009; Chaskda & Mwansat, 2014). All birds require a good proportion of animal protein in the diet of their young for healthy growth. Animal protein diet of many birds particularly insectivorous species is known to be chiefly from insect sources (David *et al*., 2004; Moreby, 2004; Kopij 2005; Turshak & Mwansat, 2011).

Furthermore, weather variables such as temperature and rainfall are known to directly or indirectly affect breeding in organisms (Stenseth & Mysterud, 2005; Cornelissen, 2011). A study by Gyurácz et. al., (2016), showed that high temperatures in April and May were favourable for breeding in *Turdus merula* a partial migrant and *Sylvia atricapilla* a short-distance migrant. However, temperature in July was found to be most important for breeding success of *Fycedula hypoleuca*, a long-distance migrant. Furthermore, studies by Lloyd (1999) showed that rainfall stimulates the initiation of breeding in arid-zone birds in southern African. Breeding activities of nine out of 11 species studied increased noticeably after considerable rainfall. Although some resident insectivores breed in the absence of rainfall, some laid eggs within one week of small rain showers, however, granivores breed with more substantial rainfall which stimulated a synchronized population-wide breeding response. The study observed that timing and length of breeding season of studied bird species was dependent on the integrated effect that rainfall and temperature had on the growing season of vegetation.

Similarly, most west African savannah bird species are known to breed seasonally with time of breeding depending on feeding guilds (Cox *et al*. 2011) which may be a strategy evolved to achieve optimality in leaving the most viable offspring(s) in a lifetime (Chapman & Reiss, 1992). Afrotropical insectivorous passerines have been opined to show a direct correlation between habitat resource availability and utilization (Turshak & Mwansat, 2021). The implications for bird species annual breeding cycles are far reaching (Lloyd, 1999) especially in the face of present anthropogenically driven modification of habitats (Mwansat & Da'an, 2017). Our study determined breeding seasons of insectivorous African passerines in relation to insect-prey abundance and diversity, temperature, rainfall and relative humidity in Pandam Game Reserve (PGR) central Nigeria.

2. Materials and method

2.1. *Study site*

PGR (08°48'N 09°09'E) is located in Plateau State, central Nigeria (Figure 1), covering an area of 22,400 ha. and lies on an altitude of between 175 to 315 m above sea level. Wet season lasts from April to October with annual rainfall between 1000-1500 mm. The land slopes gradually southwards and forms the Pandam Lake which is a wetland complex of approximately 2 km^2; Rivers Dep and Li and other seasonal rivers drain the park and join before emptying into River Benue (Ezealor, 2002).

Vegetation of the park is Guinea Savanna with gallery forest in riparian areas. Trees in the savanna include *Burkea africana* woodlands in the south, *Detarium microcarpum* woodlands in the central area and *Isoberlinia doka* woodlands to the north (Ezealor, 2002; Akosim *et al.* 2007)

Over 217 bird species have been recorded in PGR including a few observations of *Falco naumani, Ceratogymna elata*, *Scotopolia peli* and *Vanellus crassirostris* (Dami & Manu, 2008). Large flocks of *Dendrocygna viduata* spends dry seasons on the lakes in PGR especially on the Pandam Lake (Borrow & Demey, 2014). Mammals of global conservation concern that occur or used to do so include: *Choeropsis liberiensis heslopi*, *Syncerus caffer, Hippotragus equines* and *Trichechus senegalensis* (Ezealor, 2002).

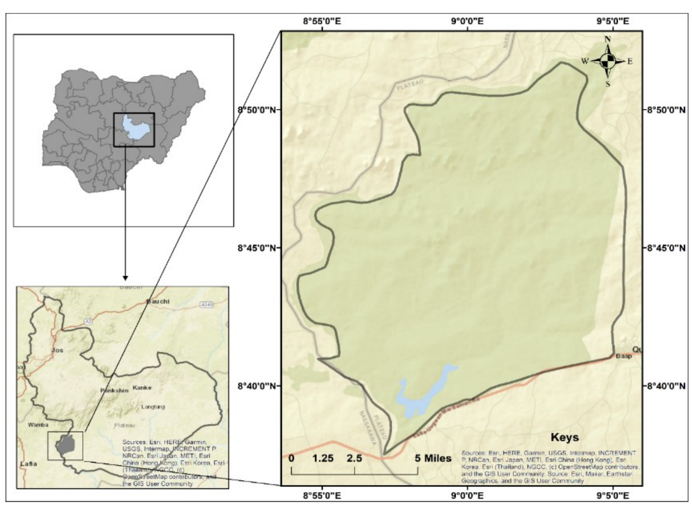

Figure 1: Map of the study site

2.2 *Data collection to determine breeding seasons of insectivorous African passerines*

Breeding seasons of insectivorous African passerines was determined by observing brood patches on trapped birds (Keyes & Grue, 1981; Bub, 1991; Chris, 2008; Kay, 2013) and by using the Long standing technique to observe breeding behaviours of the birds (Martin & Guepel, 1993; Bibby *et al.* 2000).

Three mist nets of lengths 6, 9 and 10 m were positioned across gallery forest and Guinea savanna vegetation types in PGR. Nets were mounted between 0530 – 1000 hours and 1600 – 1800 hours. These were checked after every 15 minutes for bird catch. Trapped birds were extracted, identified (Borrow & Demey, 2014) and observed for the presence of brood patch after which trapped individuals were released. Each trapping period lasted one week per month and was repeated monthly for twelve months.

The Long standing technique involves observing birds exhibiting breeding behaviours, primarily carrying nest material or food, display in breeding plumage and mating. These behaviours were observed across five 1000 m transects systematically positioned in the study site. Each transect survey lasted five days per month and was repeated monthly for twelve months.

Categorisation of bird feeding guild was according to: Brown *et al*., (1982), Keith *et al*., (1992), Urban *et al*., (1997) and Fry *et al*., (2004).

2.3 Data collection to determine relationship between breeding seasons and Insect diversity and abundance

Insects were collected from 50 points along five 1000 m transects systematically positioned in the study site. Ten points 100 m apart were placed along each transect to achieve dispersion of sample points (*c.f.* Bibby *et al.* 2000). Points were recorded to a Global Positioning System (GPS, Garmin eTrex® 10) to aid re-location in subsequent surveys. Surveys were carried out between 0800-1100 hours and between 1500-1800 hours. At each point, 20 sweeps were made using sweep net of 35 cm diameter and pore size of $1mm^2$ to sample aerial insects within a 20 x 20 m quadrate. Insects collected were sorted and transferred into sample bottles containing 70 % alcohol; these were taken to the laboratory for identification and enumeration (Castner, 2000; Shattuck & Barnett, 2001).

2.3 Data collection to determine the relationship between breeding seasons and temperature, rainfall and relative humidity

Average monthly temperature, rainfall and relative humidity for the study area during the research (August 2013 to July 2014) were obtained from the Nigerian Metrological Development Agency (NiMet).

2.4 Statistical analyses

Monthly insect abundance was obtained by adding total number of insects collected at each point per month. Insect species diversity was calculated using Shannon-Wiener diversity index (H):

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

Where: H is the diversity index, P_i is the proportion of individual species, S is the total number of species in the community and i is the proportion of S species (Begon *et al.* 2003).
Data were statistically explored for normality of distribution of variables using 1-Sample Kolmogorov Smirnov test (Calvin, 2003). Pearson product-moment correlation was used to test relationships between variables. One sample T-test was used to compare mean number of insectivorous African passerines seen with brood patch per month, also those seen with breeding behaviours per month. Generalised Linear Model (GLM) was used to test effect of insect abundance and diversity, temperature, rainfall and relative humidity on insectivorous African passerines with brood patch and breeding behaviours per month. Insectivorous African passerines with brood patch per month and insectivorous African passerines with breeding behaviours were taken as dependent variables. Insect abundance and diversity, monthly temperature, rainfall and relative humidity were taken as covariates. Backward elimination method was used to obtain the best fit model, which was the model with the highest R squared value and the highest level of significance. Statistical Package for Social Sciences Version 20 (IBM SPSS, 2011) was used for data analysis.

3. Results

3.1 Determination of breeding seasons of insectivorous African passerines

3.1.1 Observed monthly occurrence of brood patch in insectivorous African passerines

A total of 262 birds were mist-netted out of which 92 (35.1 %) had brood patches. Fifty three (57.6%) of the birds with brood patches were insectivorous African passerines (Table 1). The month of October had highest record of insectivorous African passerines with brood patch followed by July. Mean number of insectivorous African passerines with brood patch differed significantly across months (One sample T-test: t=3.083, df = 11, P = 0.010). There was a positive but not significant correlation between possession of brood patch and breeding behaviours by insectivorous African passerines, (r_s = 0.513, P = 0.088), (Figure 2).

Table 1: List of mist netted insectivorous African passerines that had brood patch

S/NO	Common name	Latin name	Individual Total (IT)	Percentage (%) of IT
1	Snowy-crown Robin Chat	*Cossypha niveicapilla*	3	5.66
2	Red-shoulder Cuckoo-shrike	*Campephaga phoenicea*	1	1.89
3	Common Bulbul	*Pycnonotus barbatus*	2	3.77
4	African Thrush	*Turdus pelios*	8	15.09
5	Grey-backed Camaroptera	*Camaroptera brachyura*	4	7.55
6	Twany-flanked Prinia	*Prinia subflava*	1	1.89
7	Yellow-crowned Gonolek	*Laniarius barbarus*	4	7.55
8	Red-wing Warbler	*Heliolais erythropterus*	2	3.77
9	White-crowned Robin Chat	*Cossypha albicapilla*	6	11.32
10	Brown Barbler	*Turdoides plebejus*	2	3.77
11	Black-cap Barbler	*Turdoides reinwardtii*	4	7.55
12	Common Wattle Eye	*Platysteira cyanea*	1	1.89
13	White-browed forest flycatcher	*Fraseria cinerascens*	1	1.89
14	Tropical Boubou	*Laniarius aethiopicus*	1	1.89
15	Senegal Eremomola	*Eremomola pusilla*	1	1.89
16	Yellow-billed Shrike	*Corvinella corvine*	1	1.89
17	Grey-headed Shrike	*Malaconotus gladiator*	1	1.89
18	African Paradise flycatcher	*Terpsiphone viridis*	5	9.43
19	Little Greenbul	*Andropadus virens*	4	7.55
20	Senegal Batis	*Batis senegalensis*	1	1.89
	TOTAL		53	100

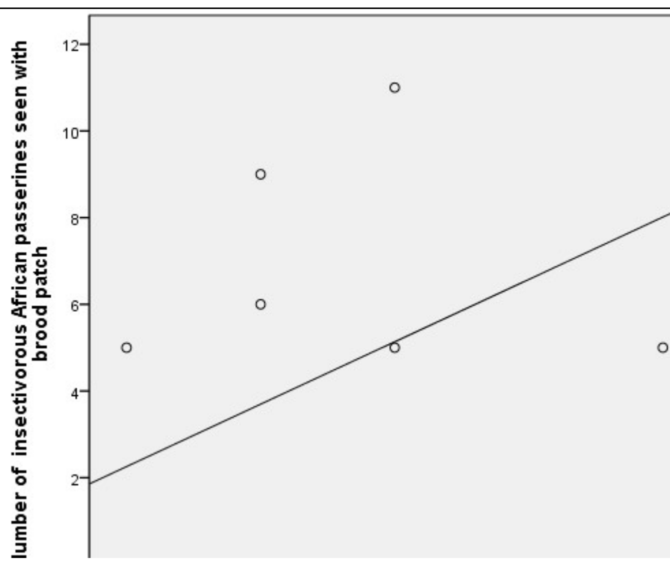

Figure 2: Relationship between possession of brood patch and display of other breeding behaviours by insectivorous African passerines.

3.1.2 Observed monthly display of breeding behaviours of insectivorous African passerines

A total of one thousand seven hundred and thirty (1,730) individual birds consisting 94 species spread across 54 families were recorded on five 1000 m transects in the study. Six hundred and seventy six (39.1%) of the total were insectivorous African Passerines, 2.7 % displayed breeding behaviours (Figure 3). *Terpsiphone viridis* had the highest frequency of display of breeding behaviours (Figure 4). Highest exhibition of breeding behaviours observed per month was in October. Breeding behaviours were concentrated in the wet season between July and October. No breeding behaviours were observed in January, March, May, June and November and there was significant difference in mean number of insectivorous African passerines with breeding behaviours across months (One sample T-test: t=3.000, df = 11, P = 0.012).

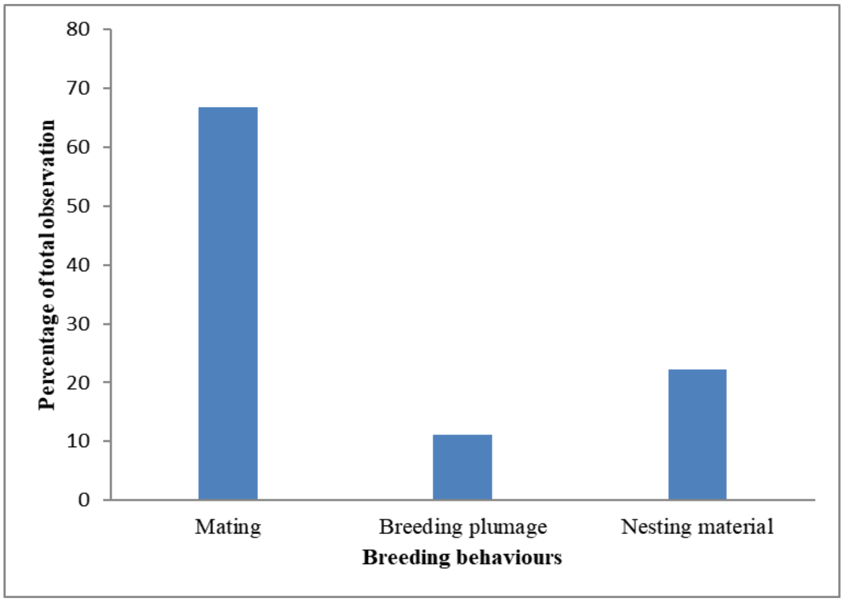

Figure 3: Breeding behaviours exhibited by insectivorous African passerines

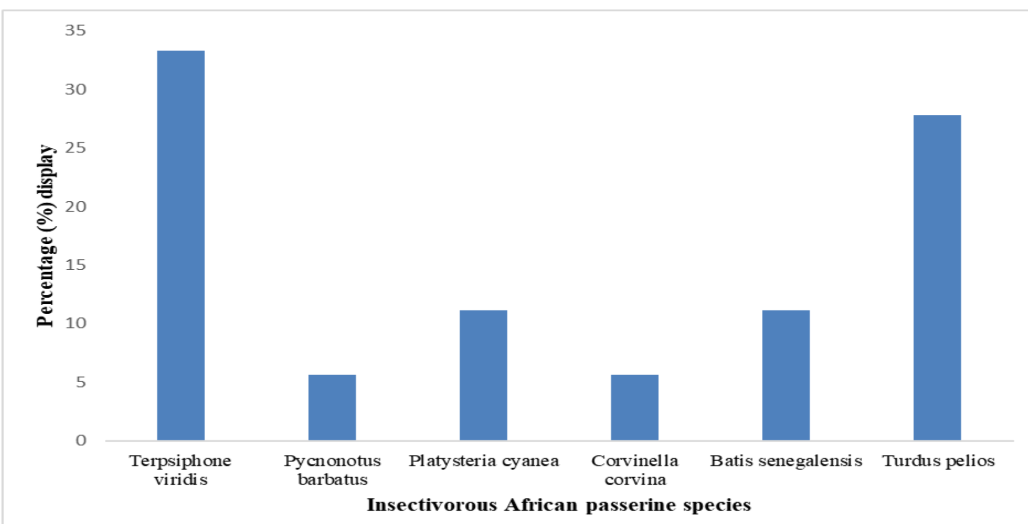

Figure 4: Percentage display of breeding behaviours by Insectivorous African passerines.

3.2 Effect of Insect abundance and diversity on breeding season of Insectivorous African passerines

A total of 2018 insects distributed in 16 orders and 58 families were collected from 50 points on five 1000 m transects in the study. The order Orthoptera had highest abundance (57.88%) while Blatteria and Dermaptera had least abundance (0.17% each). Also, the order Orthoptera had highest diversity index (H = 0.7791) while Dermaptera had least diversity index (H = 0.0081). The month of August had highest insect abundance while March had least abundance; also, diversity was highest in January and least in May (Table 2).

There was negative and no significant correlation between insectivorous African passerines with brood patch and insect abundance (r_s =-0.035, P= 0.915). There was also negative and no significant correlation between insectivorous African passerines with brood patch and insect diversity per month (r_s = -0.067, P = 0.835). However, there was positive but no significant correlation between insectivorous African passerines exhibiting nesting behaviour and insect abundance (r_s = 0.389, P = 0.211). Correlation between insectivorous African passerines exhibiting breeding behaviour and insect diversity per month was not significant and negative (r_s = -0.082, P = 0.799). There was no significant effect of insect abundance (ANOVA: F=0.032, df=1, P=0.862) and diversity (ANOVA: F=0.062, df=1, P=0.808) on insectivorous African passerines with brood patch. There was also no significant effect of insect abundance (ANOVA: F=1.559, df=1, P=0.243) and diversity (ANOVA: F=0.021, df=1, P=0.889) on insectivorous African passerines with breeding behaviours.

Table 2: Abundance and diversity of insects recorded per month in PGR between August 2013 and July 2014.

Year	Month	Insect abundance	Insect diversity index (H)
2014	January	162	**4.50146**
2014	February	113	3.73393
2014	March	85	2.61743
2014	April	115	2.80442
2014	May	103	1.3207
2014	June	176	1.88443
2014	July	164	1.67159
2013	August	**374**	1.5434
2013	September	211	2.67947
2013	October	220	2.24839
2013	November	155	4.20994
2013	December	140	3.9412
Total		2018	

3.3 *Effect of temperature, rainfall and relative humidity on breeding season of Insectivorous African passerines*

Highest mean temperature, relative humidity and rainfall were recorded in March, July and September respectively (Figure 5). There was no significant correlation between insectivorous African passerines with brood patch and temperature (r_s =0.125, P> 0.05), rainfall (r_s = -0.118, P> 0.05) and relative Humidity (r_s = -0.129, P > 0.05). There was negative and no significant correlation between insectivorous African passerines with breeding behaviours and temperature (r_s = - 0.509, P > 0.05), rainfall (r_s = 0.189, P >0.05) and relative humidity (r_s = 0.147, P > 0.05).

Furthermore, there was no significant effect of temperature (ANOVA: F=0.399, df =1, P>0.05), rainfall (ANOVA: F=0.019, df=1, P>0.05) and relative humidity (ANOVA: F=0.617, df=1, P>0.05) on insectivorous African passerines with brood patch. There was also no significant effect of temperature (ANOVA: F=1.717, df =1, P>0.05), rainfall (ANOVA: F=0.262, df=1, P>0.05) and relative humidity (ANOVA: F>0.05, df=1, P>0.05) on insectivorous African passerines with breeding behaviours.

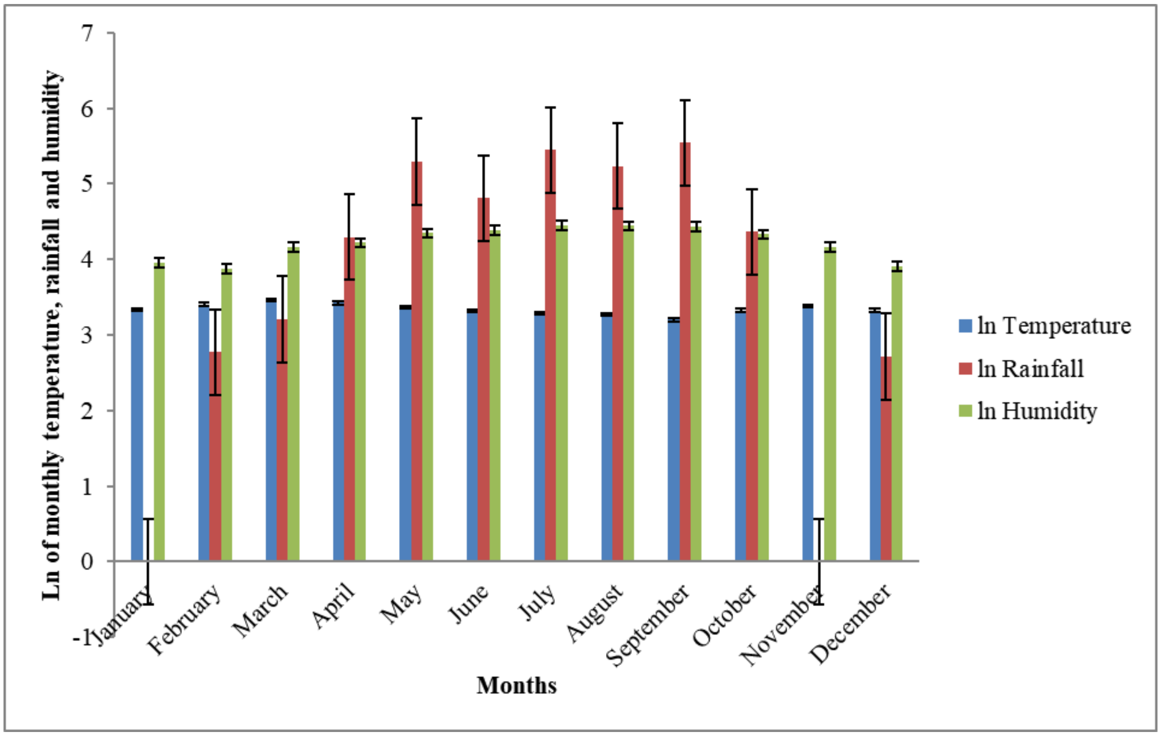

Figure 5: Mean monthly temperature, rainfall and relative humidity across months of the year

4. Discussion

4.1. Determination of breeding seasons of insectivorous African passerines

4.1.1 Observed monthly occurrence of brood patch in insectivorous African passerines

Possession of brood patch by birds is known to be a reliable cue to identifying time of breeding and stage of breeding in small savanna birds (Bub, 1991; Chris, 2008; Cox *et al.* 2013). Through observation of brood patches, insectivorous African passerines were seen to breed in the study area spanning the months of February to December with interruptions between May and June. However, about 70% bred between July and December suggesting this period as their main breeding period in PGR. It is also worthy of note that about 33% of all individuals with brood patches recorded during this study were seen in the month of October alone suggesting highest breeding activities during this month. Lack of seasonal specificity in breeding by insectivorous African passerines in the study may be attributed to species specific breeding requirements (Martin, 1988; Cresswell *et al.* 2009; Sillanpa *et al.* 2009). The ability of birds to recognise these requirements and adjust accordingly may influence parental reproductive performance such as nestling feeding and nestling survival as well as fledgling rates (Johnson & Sherry, 2001; Abdul, 2003).

4.1.2 Observed monthly display of breeding behaviours of insectivorous African passerines

It is known that display of behaviours such as breeding plumage, carrying nesting materials and food by parent birds and mating indicates their breeding seasons (Wittenberger, 1982). Three of these behaviours: carrying of nesting materials, breeding plumage and mating were exhibited by insectivorous African passerines in the study. These were observed across study period spanning the months of February to December with interruptions between May, June, July and November. About 90% of the activities were exhibited between August and December also suggesting this as a main breeding period for insectivorous African passerines in PGR. However, 28% of the breeding behaviours were observed in the month of October suggesting highest breeding activities in this month.

4.2 Effect of Insect abundance and diversity on breeding season of Insectivorous African passerines

Studies have shown that factors which alter the distribution, abundance and diversity of prey will have ripple effects on their predators (Chapman, 1995; Jonzén *et al.,* 2007). Similarly, factors which affects the dynamics of insect-prey of birds will also affect birds with more impacts on insectivorous species (Dawkins, 1997; Jawor & Breitwisch, 2006; Turshak & Mwansat, 2011). Insect order Orthoptera had highest abundance while the orders Blatteria and Dermaptera had least abundance. This may be a direct response to niche speciation which is characterised by resource availability. For example, Orthopterans are herbivores; hence, their high abundance may be as a result of available resource in the habitat all year round (Cornelissen, 2011). Similarly, Turshak and Mwansat (2011) have reported that Orthoptera, Hymenoptera, Coleoptera, and Diptera were the largest insect orders recorded during field sampling and examination of faecal droppings of insectivorous African passerines in central Nigeria.

Insect abundance and diversity were highest in August and January respectively. This may be due to the influence of complex interactions between factors like temperature, rainfall and humidity on resource availability (Telleria & Santos, 1993; Frampton *et al.,* 2000; Lindstrom et *al.,* 2005). This may be accounting for most savanna birds breeding seasonally (Cox *et al.* 2013) as well as synchronising with availability of food (Carey, 2009). It is opined that insect-prey choice for primarily insectivorous birds depends on the most abundant insect species (Mwansat *et al.* 2015). The peak periods of insect abundance which was between June and October coincided with periods of highest breeding activities of insectivorous African passerines which was between July and October. This suggests synchronisation of breeding periods by insectivorous African passerines with periods of high insect-prey abundance in PGR. This view agrees with the breeding time-food availability theory which posits that organsims breed in periods of food available (Sodhi, 1993; Abdul, 2003) to enhance survival and viability of offspring(s) (Chapman & Reiss, 1992; Krebs & Davies, 1993; Daguay *et al.* 2000). This view is corroborated by the study of Lindstrom *et al.* (2005) which showed that abundance of insect-prey was the single most important factor that explained yearly variation in the reproductive output of Brambling species.

4.3 Effect of temperature, rainfall and relative humidity on breeding season of Insectivorous African passerines

Mean monthly temperature was highest in March and least in September; mean monthly humidity was highest in July and least in February, while Rainfall was highest in September. Monthly rainfall and humidity had a similar pattern throughout the year as reported by Ezealor (2001) and Akisom *et al.* (2007). The period with highest record of humidity and rainfall was similar to the period when insectivorous African passerines were observed with the highest number of brood patches and breeding behaviours. This may be as a result of the advantage of rainfall that provides high net productivity of food for insect-prey of insectivorous African passerines (Telleria & Santos, 1993; Llyod, 1999; Carey, 2009). This probability was further demonstrated by the positive correlation between insect abundance and rainfall. Rainfall is therefore, potentially a strong driver of demographic qualities and the resulting population dynamics of bird species as suggested by Alterweg *et al.* (2014). Alterweg *et al.* (2014) opined that rainfall can be seen to place habitats into qualitative and poor ones; seasons into ones with rich food source and poor food source. However, humidity was found to account for variation in insect diversity per month in this study, hence, serving as a confounding factor. Negative effect of humidity on insect diversity may have selected for abundance of certain species while limiting the diversity of many. Monthly temperature was highest in March which may be why least abundance of insect species was also recorded in the month of March. Temperature may generally be affecting many of the insectivorous African passerines in the study site. This view is corroborated by Alterweg *et al.* (2014) who reported that extreme temperatures related negatively to survival of bird species. Temperature has been known to exert different effects on bird species, for example it has been known to influence bird nest design (Handsell, 2005) also, the breeding success of Pied flycatcher (Johnson & Sherry, 2001; Eeva *et al.* 2002). Generally, extreme weather is known to affect offspring quality independent of date of breeding and parental quality (Schmidt & Whelan, 2005)

5. Conclusion

Results of this study show that most of insectivorous African passerines breed in the wet season between July and October. Also, that while insect abundance, rainfall and relative humidity were highest between May and October, insect diversity was highest in January and temperature was highest in March. Showing that many Insectivorous African passerines in PGR synchronise their breeding periods with periods of high insect-prey abundance. This implies that high humidity and rainfall may be limiting factors to insect-prey diversity while high temperature may be a limiting factor to insect prey abundance. Species specific studies of these interactions alongside other breeding parameters relating to breeding success are therefore, recommended.

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Appendix A: Pearson's product - moment Correlations between variables

		Number of insectivorous African passerines with brood patch	Number of insectivorous African passerines with breeding behaviour	Monthly Temperature	Rainfall	Humidity	Insect abundance	Insect diversity
Number of insectivorous African passerines with brood patch	Pearson Correlation	1	.513	.125	-.118	-.129	-.035	-.067
	Sig. (2-tailed)		.088	.698	.714	.689	.915	.835
	N	12	12	12	12	12	12	12
Number of insectivorous African passerines with breeding behaviour	Pearson Correlation	.513	1	-.509	.187	.147	.389	-.082
	Sig. (2-tailed)	.088		.091	.560	.649	.211	.799
	N	12	12	12	12	12	12	12
Monthly Temperature	Pearson Correlation	.125	-.509	1	-.670*	-.549	-.679*	.259
	Sig. (2-tailed)	.698	.091		.017	.065	.015	.417
	N	12	12	12	12	12	12	12
Rainfall	Pearson Correlation	-.118	.187	-.670*	1	.875**	.413	-.784**
	Sig. (2-tailed)	.714	.560	.017		.000	.182	.003
	N	12	12	12	12	12	12	12
Humidity	Pearson Correlation	-.129	.147	-.549	.875**	1	.519	-.848**
	Sig. (2-tailed)	.689	.649	.065	.000		.084	.000
	N	12	12	12	12	12	12	12
Insect abundance	Pearson Correlation	-.035	.389	-.679*	.413	.519	1	-.319
	Sig. (2-tailed)	.915	.211	.015	.182	.084		.312
	N	12	12	12	12	12	12	12
Insect diversity	Pearson Correlation	-.067	-.082	.259	-.784**	-.848**	-.319	1
	Sig. (2-tailed)	.835	.799	.417	.003	.000	.312	
	N	12	12	12	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).