# MORPHOLOGICAL PREDICTORS OF FLIGHT DISTANCES BY SAVANNAH BIRDS IN AN AGRICULTURAL MOSAIC

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## INTRODUCTION

It is widely known that the world's biodiversity and wild lands are being threatened and altered by anthropogenic landscape change. Many of these ongoing changes are extensive and causing irreversible losses of biological diversity (Vitousek et al. 1997). One of these changes is the expansion of agriculture. Nearly 40% of Earth's terrestrial lands have been converted to agricultural lands (Foley et al. 2005). There are many different types of agriculture, with each form having varying effects on biodiversity. Traditional farming systems may support heterogeneous landscapes containing several production cover types including diverse field crops, grazing lands, or orchards. These production cover types are usually distributed in complex patterns and intermixed with other, more 'natural', cover types such as woodlands, wetlands, grasslands and habitat edges. More intensive or modern agriculture systems typically contain only a few crop species encompassing large homogeneous tracts (Fahrig et al. 2011). This difference in micro and macro structure of these agricultural types can have large implications for wildlife biodiversity. The habitat heterogeneity hypothesis states that an increase in habitat heterogeneity leads to an increase in species diversity (Benton et al. 2003). Landscape heterogeneity can directly impact biodiversity in many ways, one of those is through changes in movement of wildlife.

Wildlife move for many reasons: to acquire resources; to avoid predators and risks of mortality; to avoid competition; and to be near conspecifics for mating and other social interactions (Fahrig 2007). Landscape heterogeneity, like that caused by traditional agriculture, can influence the movement patterns of organisms, and thus affect dispersal rates and foraging behaviors (Johnson et al. 1992). For example, models suggest that animals moving through a habitat with low resource availability may have straighter and quicker movements, as the animal searches for higher-quality habitats (Fahrig 2007). The changes made to a landscape by agriculture, as well as other anthropogenic changes, will have an effect on landscape connectivity and in turn, the movement of animals within it (Taylor et al. 1993). It is important to study these patterns to understand specific species ecology as well as to prepare for conservation of biodiversity in ever-changing heterogeneous landscapes.

Characterizing the movement of species in differing landscapes can provide important information about that species' response to changes in the landscape (Allen 2014). Predicting how animal movements vary with landscape structure has been widely recognized as one of conservation biology's major challenges (Fahrig and Merriam 1994, Wiens 1994, Ims 1995, Beier and Noss 1998, Turchin 1998). Birds are often chosen as biological indicators of land use change because their ecology is well known and studied, they are easy to observe and identify, and they respond quickly to changes in habitat and plant community structure (Anderson et al. 2017; Evans et al. 2009; Morrison 1986; Vandewalle et al. 2010). Birds can make an excellent study taxon to look at the effects that agriculture and other landscape changes have on the movement of animals within those changes. The effects of landscape heterogeneity on bird populations have been largely studied, but typically fail to specifically address bird movements. Yet, movements are an inherent component of most ecological processes and, logically, must be essential for the persistence of populations and the (re)colonization of suitable habitats (Bélisle et al. 2001). Experimental manipulations, such as translocations are thought to provide meaningful measures of functional connectivity, such as the rates and paths of animal return to territorial patches providing measures of landscape resistance (Bélisle 2005).

I will examine the effects of anthropogenic landscape change from agriculture on the movement of bird species in the heterogeneous Lowveld of Swaziland. It will look into two basic components of movement by avian species: how they are moving and in what land types they are moving. The many unique species of the Lowveld will allow us to look at the effects of morphometric parameters, diet types and migration patterns on movement. The many landscape types, namely the savannah, community lands and sugar cane production fields, will allow us to look at heterogeneous landscape and patch effects on avian movement. We will look into each vegetative community type will affect the movement of avian species. Investigation of avian, and other taxon's, movement in Swaziland's rapidly changing landscape could be paramount to the conservation of Swaziland's biodiversity and ecosystem services.

The Objective of this study is gain a better understanding of the morphological components of birds that explain their ability to move across large gaps between patches of habitat. Like those created by intensive agriculture. If agriculture growth sustains and continues to convert earth's more natural lands into large tracts of homogeneous croplands, it is important to understand how birds will cross these ever-growing gaps between quality habitat and what birds will even be capable of crossing these gaps. Furthermore, knowing which birds will be least capable to cross gaps will allow peoples interested in the conservation of birds to place special concern on the sensitive species as agricultural expansion increases. Investigation of avian, and other taxon's, movement in Swaziland's rapidly changing landscape could be paramount to the conservation of Swaziland's biodiversity and ecosystem services as a whole.

## HYPOTHESIS

We hypothesize that wing loading and aspect ratio will be the strongest predictors of flight distances by the savannah birds across open agriculture.

## METHODS

*Study area*

Our study will take place in the Northeast corner of Swaziland, stationed at the Savannah Research Center located in Mbuluzi Game Reserve 26.1564° S, 31.9824° E. Our field work will be conducted between June-July 2017 in the lowveld region, a tropical savanna that is recognized for its high biodiversity. This is especially apparent in avifaunal communities; over 500 species of birds and over 50 bird species endemic to Southern Africa have been recorded in Swaziland. The lowveld of Swaziland is separated from the Mozambique coastal plains by the

Lubombo mountain range on its eastern border. Altitude in the lowveld ranges from 150–400m above sea level. Mean monthly temperature in January is 26°C and in July it is 18°C, while mean annual rainfall ranges between 550 and 725mm (Goudie & Price Williams, 1983). The vegetation can be classified as lowveld savanna (Acocks 1988). It is dominated by Acacia nigrescens–Sclerocarya birrea savanna with patches of riverine forest along rivers (Sweet & Khumalo, 1994). Widespread shrub encroachment has occurred under a wide range of management and environmental conditions throughout the area within the past 30 years (Sirami & Monadjem 2012).

The study area is also significant because in the next 40 years the population of sub-Saharan Africa will double due to high fertility in the region. This upsurge will account for nearly half of the global increase of 2.4 billion over the same 40-year period (Cleland 2013). This puts sub-Saharan Africa, including Swaziland, in an explosive human population growth that will affect its social structure, landscape structure and biodiversity.

During any portion of the below described methods, if any bird showed signs of stress it was returned to its capture location and released. . Only healthy adult birds and developed juveniles were used, none with visible signs of injury, low weight, or unhealthy amounts of ticks

*Capture Methods*

Study birds were captured using mist nets. Net site locations were chosen based observation of bird movements in the area a day previous to setting the nets up. Nets were placed on habitat edges, in riparian zones and in natural movement bottlenecks created by landscape features. Nets were placed indiscriminately with the simple goal of catching as many birds as possible. No species were targeted. Some nets were set in fields that were constantly frequented by birds and then the fields were flushed. This consisted of several researchers walking through the fields, moving vegetation and flushing birds into the opposing mist nets. The birds were then safely and quickly rem oved from the mist nets, placed in cloth bags and transferred to a central processing station.

*Processing Methods*

Birds then had their metamorphic features measured and recorded. Birds were identified, then given an individual ID. After this their mass (g) , wing chord (mm), wing length (mm), wing depth (mm), tarsus (mm), eyelid size (mm), and head size (mm) was recorded. Then one of the birds' wings was opened fully and placed against graph paper and a photo of it wing was taken. The wing measurements were used to calculate aspect ratio. The mass and wing photo were used to calculate wing loading for each bird. Area of each wing was later calculated using an image processing software, ImageJ, with the graph paper placed behind the wings used as a constant scale. Tarsus, eyelid and head measurements were exploratory measurements taken that may be later analyzed to look at bird's ability for spatial recognition. They were then marked with model paint on their tail feathers to identify birds that had been captured. We did not use any recaptured birds in our study.

*Wing loading*

The ratio of a bird's weight to the area of both wings, expressed as g/cm2. The calculations of wing loading in this study did not include the area of the root box.

*Aspect Ratio*

Aspect ratio was calculated 3 different ways in this study to find if any particular method of calculating aspect ratio was more explanatory for our bird's flight distances.

1: Square of the wing span divided by the wing area mm2/cm2 (Norberg 1987).
2: Wing span divided by average wing depth mm/mm (root box not included).
3: Wing span divided by wing depth mm/mm (root box not included).

*Translocation and Release Methods*

Birds were then quickly but carefully taken in their cloths bags to the release site. The release sites were open sugar cane fields consisting of bare ground and sparse low 0.3-0.5m) sugar cane shoots. The sites were usually surrounded by tall sugar cane (3-3.5m) but always had one side that was adjoined to savannah. The birds were placed in the release box. They were then allowed to settle down and view their surroundings from the release box for 30 seconds. The box was then opened to release the bird. Birds were given 4 minutes to leave the box on their own then the box was approached from behind to coax the birds out of the box. We recorded the time the box was opened, the time the bird left the box and the time the bird landed. We also recorded the flight distance, the flight direction relative to the savannah edge and the flight pattern of the bird. The flight patterns were either direct or indirect.

The release box was a 40x40x25cm box that placed up a camera tripod that stood 1 m tall. The bottom and sides of the box was made of bent 2mm gauge wire fencing with 1x2cm spacing between wires. The top of the box was the opening mechanism of the box, it was made of 4mm thick corrugated plastic (yard sign material). The box was opened by pulling the lid open with cordage. We opened the box crouching 20m behind the box.

*ImageJ*

The wing photos were analyzed using the image processing software ImageJ-win64. The scale for each wing photo was set against the grids of the graph paper behind each wing. The wings were then traced and measured. The output measurements were area, standard deviation of area and the perimeter of the wing.

*Data Analysis*

The data was run through fixed linear mixed effect models for the r package lmer 4 in R statistical software V 3.2.5 (R Core team 2016). We ran a series of 16 candidate models comparing difference morphometric traits and controlling for flight pattern and the random effect of release site. We compared the AICc between the candidate models to find the strongest explaining model. It was only considered to be more explanatory than the null hypothesis if it was more than 2 AICc units above the null hypothesis. We also ran glmer models to see if there was a correlation between wind speed and direction and the bird's flight distances. There was none. We did this with flight distance and velocity as a dependent variable.

We then made a prediction line of our best models. Comparing the morphometric variable to the dependent variable which was flight distance. We then plotted this line and our data points to compare their relationship.

## RESULTS

*Summary statistics*

In total 150 individuals were used in this study, representing 38 genera and 49 species. 42 of these individuals were not used in our data analysis models because only 1-2 individuals of its species were captured. We did not feel these would be a fair representation of their species. 108 individuals were used in r analysis representing 20 species. These were used because we had at least 3 replicates of each of these species.

Table 1. Table one list the 20 species used in the core statistical analysis, the number of replicates for each species and their morphometric measurements. Mass and Wing length are listed with their respective standard deviation.

| Species | Scientific name | N | Mass ± SD (g) | Wing Length ± SD (mm) | Wing Depth (mm) | Wing Chord (mm) | Taursus (mm) | Head (mm) | Eyelid (mm) | Wing Area ($cm^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| African Firefinch | *Lagonosticta rubricata* | 4 | 10.0 ± 1.4 | 67.5 ± 1.3 | 45.0 | 47.0 | 14.2 | 15.8 | 4.1 | 21.0 |
| Black backed Puffback | *Dryoscopus cubla* | 4 | 26.6 ± 1.5 | 108.5 ± 7.3 | 69.8 | 76.1 | 25.4 | 24.8 | 6.5 | 57.4 |
| Bronze Mannikin | *Spermestes cucullatus* | 8 | 9.9 ± 2.2 | 67.3 ± 3.6 | 38.5 | 46.9 | 16.2 | 14.5 | 3.7 | 19.1 |
| Cape White eye | *Zosterops capensis* | 4 | 11.3 ± 0.1 | 79.3 ± 2.9 | 47.3 | 59.5 | 16.3 | 19.1 | 4.2 | 29.4 |
| Common Waxbill | *Estrilda astrild* | 23 | 7.8 ± 0.1 | 66.6 ± 3.4 | 40.3 | 45.8 | 17.0 | 15.9 | 3.9 | 21.5 |
| Green backed Camaroptera | *Camaroptera brachyura* | 5 | 11.4 ± 1.1 | 71.8 ± 7.4 | 47.2 | 49.6 | 20.1 | 19.3 | 5.1 | 26.4 |
| Little Bee eater | *Merops pusillus* | 3 | 16 ± 1.0 | 119.3 ± 2.1 | 58.3 | 82.0 | 8.0 | 20.1 | 5.1 | 54.7 |
| Long billed Crombec | *Sylvietta rufescens* | 4 | 12.0 ± 0.8 | 75.5 ± 2.6 | 54.0 | 59.8 | 21.5 | 19.6 | 4.6 | 34.0 |
| Orange breasted Waxbill | *Sporaeginthus subflavus* | 6 | 6.9 ± 0.5 | 62.3 ± 1.6 | 39.0 | 43.6 | 12.6 | 14.5 | 3.6 | 17.4 |
| Rattling Cisticola | *Cisticola chiniana* | 3 | 15.0 ± 7.9 | 75.3 ± 7.2 | 47.3 | 51.0 | 22.2 | 18.8 | 4.6 | 28.9 |
| Red collared Widowbird | *Euplectes ardens* | 4 | 19.0 ± 3.2 | 94.8 ± 10.3 | 57.6 | 66.6 | 23.1 | 19.5 | 5.3 | 38.4 |
| Red faced Cisticola | *Cisticola erythrops* | 4 | 13.8 ± 2.9 | 79.3 ± 13.4 | 52.3 | 54.5 | 23.3 | 20.9 | 4.8 | 33.6 |
| Red faced Mousebird | *Urocolius indicus* | 4 | 51.8 ± 3.4 | 127.0 ± 2.6 | 67.0 | 79.0 | 22.7 | 23.8 | 6.1 | 66.5 |
| Sombre Greenbul | *Andropadus importunus* | 3 | 30.0± 2.7 | 119.0 ± 4.4 | 86.3 | 84.3 | 25.2 | 25.1 | 5.8 | 74.8 |
| Spectacled Weaver | *Ploceus ocularis* | 5 | 24.3 ± 3.3 | 97.4 ± 7.6 | 62.0 | 71.2 | 21.8 | 20.0 | 5.8 | 47.2 |
| White browed Robin chat | *Cossypha heuglini* | 4 | 36.3 ± 3.9 | 127.8 ± 5.5 | 81.8 | 91.8 | 34.4 | 28.3 | 7.2 | 82.5 |
| White browed Scrub Robin | *Cercotrichas leucophrys* | 4 | 17.9 ± 0.2 | 84.5 ± 6.2 | 59.0 | 63.6 | 26.4 | 23.0 | 5.8 | 43.8 |
| White throated Robin Chat | *Cossypha humeralis* | 3 | 23.5 ± 3.9 | 98.3 ± 10.7 | 65.7 | 75.0 | 26.4 | 22.4 | 6.1 | 46.2 |
| Yellow Breasted Apalis | *Apalis flavida* | 5 | 8.1 ± 0.2 | 68.8 ± 2.8 | 44.2 | 48.9 | 19.2 | 17.8 | 4.4 | 20.9 |
| Yellow fronted Canary | *Crithagra mozambicus* | 8 | 12.8 ± 1.23 | 91.9 ± 2.2 | 52.1 | 65.0 | 18.5 | 17.8 | 3.8 | 39.7 |

*Findings*

We found that Wing length alone was the strongest predictor of flight distance. The second strongest predictor was mass. Both had significant and positive relationships with flight distance. Wing loading nor any of the aspect ratios were strong predictors of flight distance. We were unable to find any significant predictors of velocity.

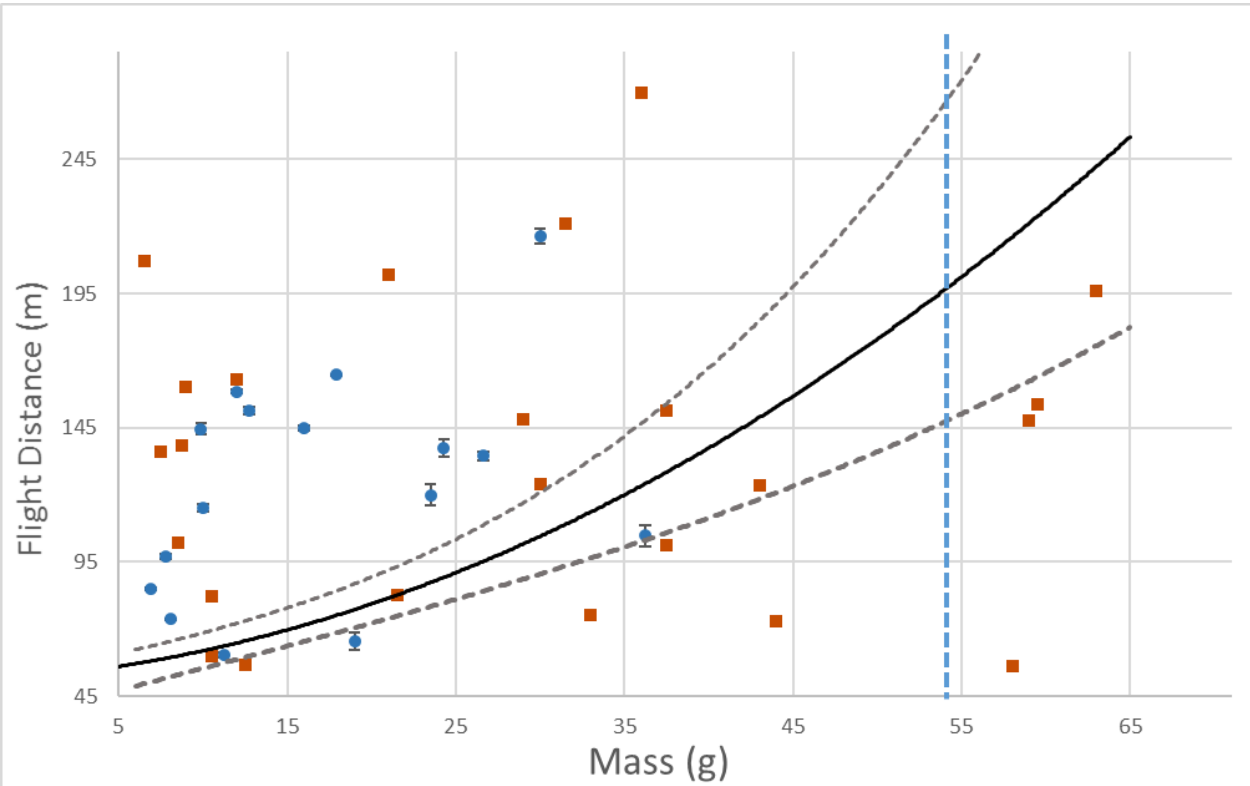


Figure 1. Figure one shows the relationship between flight distance and mass. The blue dots plotted are data points we used from species we had at least 3 replicates of. They have error lines showing the standard deviation of mass for each species. These points were used in our R analysis to create the predictive black line on the graph. The dotted black lines are the standard errors of the predictive line. The red blocks represent the data from the bird species we had low replicates of. They were used on the graph to see how well they fit with our prediction. The blue dotted line denotes the end of our R predicted line and shows where we have further extended it to reach the more outlying points

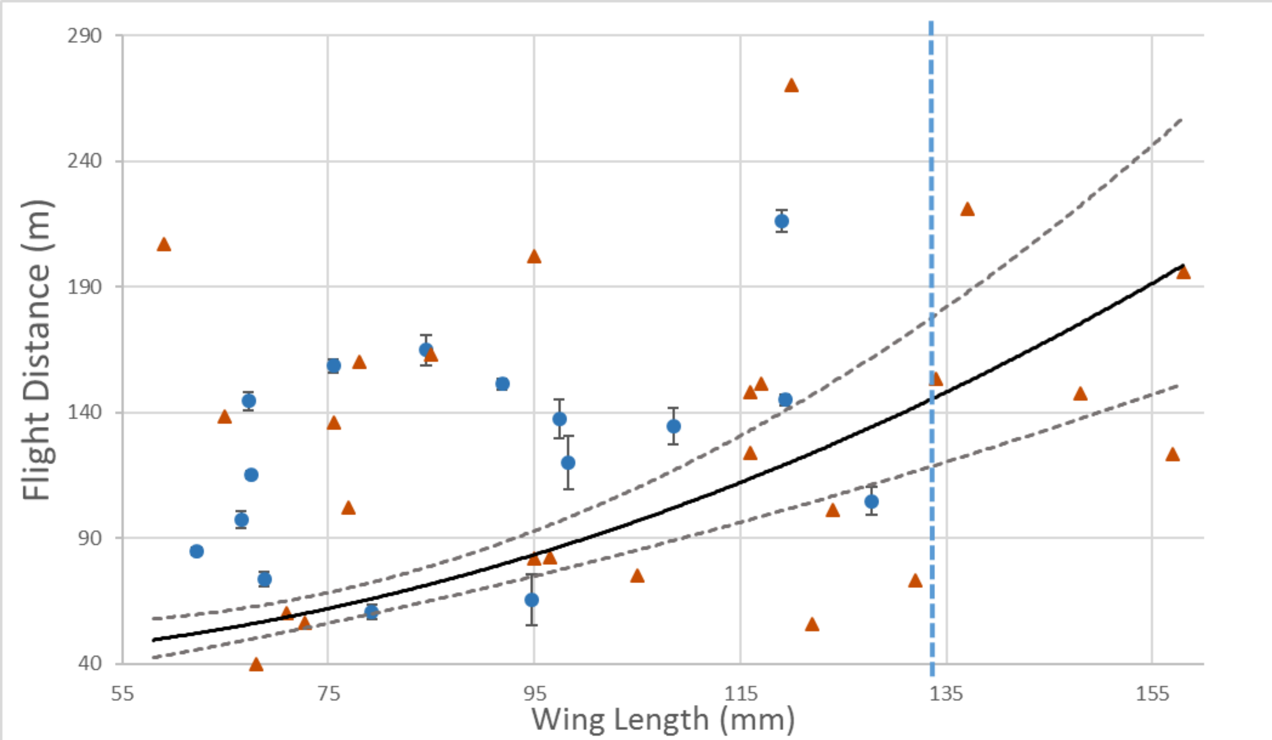


Figure 2. Figure two shows the relationship between flight distance and wing length. The blue dots plotted are data points we used from species we had at least 3 replicates of. They have error lines showing the standard deviation of wing length for each species. These points were used in our R analysis to create the predictive black line on the graph. The dotted black lines are the standard errors of the predictive line. The red triangles represent the data from the bird species we had low replicates of. They were placed on the graph to see how well they fit with our prediction. The blue dotted line denotes the end of our R predicted line and shows where we have further extended it to reach the more outlying points

## Discussion

Our results gave us predictors of flight distances by savannah birds in an agricultural mosaic, however they did not agree with our original hypothesis. We predicted that wing loading and aspect ratio would be the best predictors of flight distance. We believed that these would be very telling predictors of flight distance as they accounted for mass and wing morphology. Our strongest predictors were wing length and mass. These results are important but are one dimensional. They tell us that larger birds or birds with longer wings are more likely to fly further.

The implications of this is that larger birds or birds with longer wings will be more able to cross large gaps of open agriculture. This is important when considering how far savannah patches can be separated from each other by agriculture such as sugarcane. Further studies could use this information and information like it to create rules or regulations on how large agriculture gaps could become before significantly cutting off avian species. It could also be used to highlight species of specific concern, like the smallest birds or the birds with the shortest wings. Further studies should explore more bird species and attempt to gain more data points on the existing species in this study. Having data on more bird species will allow us to have a better idea on morphological predictors of the whole range of savannah birds in Swaziland.  Further studies should also look at bird's natural motivation to cross these gaps, as they could fly very differently in their natural state than they did when translocated and released. Ultimately these studies will allow us to understand avian movement across an agriculture mosaic and hopefully help us to understand how to conserve and protect them.

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