BODY SIZE DIFFERENTIATIONS IN MALE COMMON STONECHAT (*Saxicola torquata axillaris*) SUB-POPULATIONS IN DIFFERENT OPEN HABITATS IN KENYA.

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DECLARATIONS

This thesis is my original work and has not been presented for the award of a degree in any other university.

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DEDICATION

This thesis is dedicated to God, my mother, Mrs. J.M. Madindou and brother, S.T. Madindou.

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ABSTRACT

Studies on how body size and shape of animals are influenced by selective pressures such as habitats, mates, foraging and migration, are of key importance in understanding the ultimate causes promoting biometric and morphological diversification. In ornithology, body size is a fundamental measure used to understand many ecological and behavioral issues including foraging, sexual selection, dominance relationships between and within species, and evolutionary processes.

The goal of this study was to assess body size differences of sedentary Common Stonechat (*Saxicola torquata axillaris*) populations that occupied different habitats in Kenya. The final aim was to identify the best linear predictor of body size for this species. Specific objectives included determining if body size differences of subpopulations of the species could be recorded in different habitats occupied the species, and which linear predictor can be used to predict the species' body size.

Studies were carried out in four habitats: forest glades and edges of a tropical rainforest (Isecheno, Kakamega); farmlands interspersed with fallow lands (Kinangop and Ol Kalou); pure croplands without fallow lands (Timau in Buuri and Mataara in Aberdares); and the forest edges of a coastal montane forest (Taita Hills). One hundred and thirty nine male Common Stonechats were captured using decoy traps in their territories. Their early morning songs (dawn choruses were recorded as well). Each individual had four biometrics taken which included body mass, wing, head and tarsus lengths. A strong correlation is assumed between body mass and some linear dimension, such as wing or tarsus length, with the presupposition that the linear dimension reflects the size component of mass. Body mass was used as a measure of size since it has vital importance with respect to forte of supporting structures (skeletons), the demands on the muscular system in locomotion and, the need for food.

One-way analyses of variance showed significant differences of Common Stonechat biometrics between the habitats (wing length, $F_{(3,135)} = 105.69$, $p < 0.05$, head length, $F_{(3,135)} = 4.87$, $p < 0.05$, tarsi length, $F_{(3,135)} = 5.01$ $p < 0.05$, and body mass, $F_{(3,135)} = 4.74$, $p < 0.05$). Such biometric differences could be related to habitat adaptations and, ultimately, to survival. Linear regressions of the wing, head and tarsus with body mass showed the head length to be the best linear predictor for body size. The largest birds were found in the farmlands interspersed with fallow land in Kinangop and Ol Kalou (16.28±0.02grams) and the smallest birds were found in the forest edges of the Taita Hills montane forests (16.13±0.02grams) and in the forest glades and forest edges of the tropical rainforest in Kakamega (16.14±0.02grams).

This study found that the choice of linear measurement that best expresses body size in different passerine species can differ from the conventional wing or tarsus lengths depending on the species in question. These results also suggest that habitat type has an influence on the body size of the Common Stonechat. (Competition for territories and predation could be some of the ecological factors leading to differences in body size). Further research on microhabitat features are now needed to understand the morphological differences recorded here.

CHAPTER ONE: INTRODUCTION

1.0 Background

1.1 Body Size of Birds

Body size is stated as one of the most significant traits of an organism's biology since it plays a huge role in development, reproduction, evolution, physiology and ecology (Hone *et al*. 2008). It also informs about the dimensions of the skeletal frame upon which soft tissues are supported. When body size is measured, it provides basic succinct information that summarizes huge amounts of biological information rooted in an ecological network (Guy *et al.,* 2005).

Body size disparity in an intra-species scenario is of ecological significance. In vertebrates, a larger body size provides individuals with greater feeding adeptness, and can enhance variability in food intake between larger and smaller individuals (Grant and Grant, 2008) within one species.

Variation in body size is often sustained within species. Environmental conditions can influence differences in habitat in an extensive landscape. Intraspecific competition could force small individuals into marginal areas with suboptimal habitats, while the larger individuals exploit good quality patches (Barbraud, 1999). Although larger-sized individuals of a species enjoy certain advantages when they occupy quality habitat patches, they may face greater risks of going extinct than smaller sized individuals. Further, analyses of extinction threat levels show that the smallest and largest vertebrates are at the highest risk. These include mammals, reptiles, amphibians, birds and marine creatures as well. Current reviews of drivers of extinction risk reveal that the weightiest vertebrates are at maximum threat through direct killing by humans. In contrast, the lightest vertebrates are most threatened by habitat loss and modification stemming especially from intense cultivation, pollution and logging (Ripple *et al*., 2017). Range size has

been found as a reliable predictor of extinction risk. Geographic range size was found to be a major predictor for extinction risk in birds and has been linked with body size and implicated as an important driver of species extinction risk. Vertebrates with the largest range sizes were generally less threatened than those with smaller range sizes (Bohm *et al*., 2016). Losses of small vertebrates were shown to have detrimental consequences due to unique and important ecological functions facilitated by their small body size, for example pollination services provided by bats and hummingbirds. Also, some of the world's smallest vertebrates, like marine forage fish, are critically important nutrient sources in food systems and can be centerpieces in harvesting economics (Cardillo *et al*., 2004).

Brown *et al*. (1993) developed an energetic depiction of fitness and modeled the connection between body size and fitness. Fitness defined as reproductive power, is the rate of conversion of energy into offspring. The metabolic theory postulates that, by setting the rates of resource uptake from the environment and resource allocation to survival, growth, and reproduction, metabolic rate controls ecological processes at all levels of organization from individuals to the biosphere (Brown *et al*., 2004). In reproduction, this is assumed to be a two-step process. Reproductive power entails energy acquisition from the environment which scales allometrically with body mass elevated to circa the 0.75 power. Rate of conversion of energy into offspring then scales as mass to circa the -0.25 power. This model showed that smaller individuals have superior capacity to transform resources into procreative work-they are only limited by rate of resource acquisition. Small individuals expend majority of their time foraging to meet a high mass-specific maintenance metabolism. Though larger individuals possess greater capability to secure resources, they are inhibited by the faster conversion rate into viable offspring that

smaller individuals are better able to do. Trade-offs between these two limiting processes results into an ideal size (Yom-Tov 2001).

Other studies devoted to understanding the ecological factors that determine intraspecific body size variation in passerines has captivated the interest of ecologists for a very long time. Studies by Olson *et al.* (2009) found that resource availability and increasing species richness also strongly correlate with body size. Rosenzweig (1968) contended that body size increases with growing resource availability, than with declining temperatures. He further argued that low food yields sets limits to the achievable body sizes in animals. Further research by Olson *et al.* (2009) showed that increased seasonality and low predictability of ecological settings do select for large body size. This showed that Bergmann's rule had limitations regarding ecological study area, the taxa being studied, explanatory variables, spatial patterns considered, and statistical methods used. Thus species richness could present trade-offs between body size and abundance. This means, if resources are limiting-given that abundance decreases with increasing size-an area could either sustain numerous small-sized species or few large rare species.

Jakober and Stauber (2000) in their research suggested that global warming through environmental variability is the main factor that influences body size variation in bird species. Cruz and Cruz (1992) state that weather variation is known to influence growth rates in a number of bird species. Poor weather may reduce energy available for growth by increasing the energy expenditure of hatchlings attempting to maintain body heat. It may also cause increased brooding by the parents, which may significantly reduce foraging time and food intake. In their 5-year study on chick growth rate of the Dark-rumped Petrel (*Pterodroma phaeopygia*) in the Galapagos Islands during and after the El Nino-southern Oscillation (ENSO) of 1982-83, Cruz and Cruz (1992) found that it took chicks longer during the ENSO to attain maturation levels

crucial to successful fledging in the food stress period. It was proposed that this could have ensued from constrictions on tissue maturation owing to a drop in ingested energy. Perhaps the parents could not locate food-upwelling currents, and phytoplankton-rich waters were displaced for extended periods. Cooch *et al*. (1991) agree that there is a significant environmental component to body size variation in birds. In their research on the Lesser Snow Geese (*Chen caerulescens caerulescens*), they found that late hatching goslings (young geese) with slower growth rates showed significantly reduced adult size. Further investigation showed that intra-seasonal differences in foraging behavior and food plant quality and quantity were the proximate mechanisms for this reduced growth rate of the late hatching goslings. Mendes *et al.* (2011) in their studies on the Blackbird (*Turdus merula*) found that body size variation was influenced mostly by feeding behaviour not by climatic factors.

Factors like predation, have been reported to impact body size whereby weighty prey individuals can be less swift than their lighter counterparts, and be exposed to higher predation rates. For instance, mean body weight of Great Tits (*Parus major*) in England increased subsequent to the disappearing of a prominent predator, the Sparrowhawk (*Accipiter nisus*). Great Tit numbers declined resulting from the return of the Sparrowhawk to the woods (Lemel, 1989).This shows that for any species, ecological factors and abiotic features can be positively linked to an extinction risk. Body size in a species could also be positively connected with extinction risk incurred through persecution, predators or habitat loss (Owens and Bennett, 2000).

Changes in morphological traits, such as body size and body condition, are significant indicators of transformations in the life history or habitat quality of a species. This can impact the performance of individuals and therefore the persistence of a species under environmental change (Steinicke *et al*., 2015). The effects thereof can only be observed in morphological

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changes as the species adapts to changes in its habitat. Common bird species like the Common Stonechat that are widespread are good model species for testing such hypotheses.

1.2 Problem statement

There remains knowledge gaps in determining whether differences in habitat could influence the body size of sedentary Common Stonechat populations. In addition to this, no studies have hitherto explored which linear dimension could be the best predictor for body size in the African Common Stonechats within and among subspecies. This is primarily because long-term data are lacking for any specific region in Africa. There is also considerable variation in measures of habitat condition as far as preferred quality by the Stonechats is concerned.

1.3 Justification

This study was carried out to assess if different habitats can influence body size in the Common Stonechat, a sedentary grassland bird species inhabiting a wide geographical area in Eastern Africa. Studies on body size in bird species have used altitudinal gradients as the main factor in body size differentiation within a species (Badyaev, 1997; Liao and Lu, 2011). However, studies on whether differences in habitats can influence body size in the Stonechat, an open habitat bird species have not been adequately conducted. This study can increase knowledge on how populations of one species adapt to different habitats in an extensive landscape. To aid in assessing body size for the passerine species in this study, it was also imperative to find out the best linear predictor of body size. This study will shed light on how the species is likely to adapt to effects of climate change in human modified landscapes.

1.4 Objectives

1.4.1. Main objective:

To assess the effect of habitat on the body size of sedentary Common Stonechat subpopulations in Kenya.

1.4.2 Specific objectives:

1. To determine if habitat differences influence body size of the Common Stonechat subpopulations in Kenya.

2. None of the conventional biometric variables can predict body size in Common Stonechats.

1.5 Hypotheses:

H_o: Habitat differences have no influence on the body size of Common Stonechat populations.

H_o: Wing length is the best linear predictor of body size in Common Stonechats.

CHAPTER TWO: LITERATURE REVIEW

2.1 Biometric variation in birds

Morphological traits are traditionally used to determine the size of birds in scientific studies (Gosler *et al*., 1998; Salewski *et al*., 2014). Length measurements of specific parts and the weight vary between bird species (Ashton, 2002), populations within species (Alonso and Arizaga, 2006) and between the sexes (Lovich and Gibbons, 1992). When combined with other information such as better resistance against predation, ability to exploit diverse food sources and better survival in times of environmental stress (Hone and Benton, 2008; Churchill *et al.,* 2014), biometrics can be used to test evolutionary concepts like Cope's rule (*which stipulates that population pedigrees are disposed towards increase in body size over evolutionary time*) and to expound social interfaces like dominance and aggression (Goodenough *et al.,* 2010). Oftentimes, though it is not clear which measurements to take. There are conventional dimensions often taken in the field in studies of living birds. Only some of these dimensions are relevant to museum or laboratory specimen (Eck *et al.,* 2011). Studies on how selective pressures like habitats (Border *et al.* 2016), mates (Harri *et al.,* 1996; Nagel and Schluter,1998), foraging (Blanckenhorn, 2000) and migration (Olson *et al.,* 2009) affect body size, significantly aid the comprehension of decisive causes supporting biometric and morphological diversification of populations, which can possibly lead to speciation (Arizaga *et al.,* 2009).

Slotow and Goodfriend (1996) and Hernandez *et al.* (2011) assert that populations within a single species can vary in body size, throughout their geographical distribution. In birds and other vertebrates, body size is a pertinent characteristic in population undercurrents and life histories for the role it plays in reproduction and survivorship (Barr, 2012). Time-based and geographic differences in adult body size is associated with numerous influences, comprising

climate, inter and intraspecific competition and predation (Yom-tov *et al.,* 2006). In passerine intraspecific body size studies, a correlation is assumed between body weight and a linear aspect like the wing, tarsus, head or tail lengths. This is because weight incorporates variation in both size and condition (Sutherland *et al.,* 2004), of which condition, is due to fat and muscle measures (Gosler *et al.,* 1998). The choice of linear measure depends on the category of birds because all the measurements reflect the size component of mass (Hernandez *et al*., 2011). For most passerines, wing length (distance from carpal joint to tip of the closed wing) has long been acclaimed as a universal measure of body size (Sutherland *et al*., 2004). This is despite the fact that: a) the wing shape varies independently of size, b) feathers wear with time, c) wing length depends on age, and d) wing length may vary between years (Hogstad, 2011). Senar and Pascual (1997) in their study explored the efficiency of other linear measures like tarsus and keel as suitable predictors of body size. Results from their study supported the opinion that peripheral measures centered on feather lengths of wing or tail were poor interpreters of overall size than exterior skeletal measurements like tarsus. It emerged that since keel and tarsus length measure bones, they are assumed to provide a better estimate of overall body size. Culmen and wing length which measure the horny component (ramphotheca and feathers respectively), were disregarded since they reflect intrinsic variation due to wear and tear, that may lead to erroneous readings and assumption of body size estimation.

Bird biometric studies look into aspects like: sex and age determination, size differences among populations, wing morphology and, body mass - body size correlations (Hernandez *et al.,*2011) and migration behavior (Vögeli *et al.,* 2007; Baldwin *et al.,* 2010) among others. Animal biometrics are developed, calculated methods that signify and identify the phenotypic exterior of species, individuals, behaviors, and morphological qualities (Kuhl and Burghardt, 2013).

Biometric studies add value to an array of disciplines, like biogeography, population ecology, and behavioral research. Biometrics function as the node between pattern recognition, ecology, and information sciences, to produce structures for phenotypic measurements and interpretation. Phenotype is the conventional set of evident features of an individual resultant from the interaction of its genotype with its surroundings. Gender determination uses biometrics to assess sex-specific behavioral patterns like foraging strategies or life-history traits like survival and dispersal (Xirouchakis and Poulakakis, 2008; Gunnarsson *et al*., 2010). Biometrics have also been used to assess geographic intraspecific variation in birds and describe sub-specific differences (Sand *et al.,* 1995) and to estimate body size (Twedt and Linz, 2002). Linear measures of definite parts and body masses of birds vary among species, populations within species and between sexes (Badyaev, 2002)-depending on age and condition (Hernandez *et al.,* 2011). This variation has helped in taxonomic studies where subspecies differentiation in Europe was apparent in the Bluethroat species (*Luscinia svecica*). The Bluethroat is found in North America only on the tundra of Alaska and the Yukon Territory. It is common, however, across Europe and Asia where it is not restricted to tundra habitat. The subspecies found in France (*Luscinia svecica namnetum*) was the smallest in size compared to two other subspecies (*L. s. cyanella* and *L. s. azuricollis*) whose populations are geographically adjacent (Eybert *et al.,* 1999).

Body size can be measured through either skeletal measures or external measures (Senar and Pascual, 1997). The search for the best measure of body size in birds continues to challenge ornithologists. Rising and Somers (1989) propose this is so because, though the best measure of overall body size has been reported to be weight, consistent information on weight is challenging to acquire in intraspecific studies since it reflects condition (i.e. weight changes during the day) and as such cannot be used alone to study intraspecific variation. Hernandez *et al.* (2011) concur

with Rising and Somers (1989) that though body weight was initially used in previous studies to ascertain presence of seasonal disparities connected to definite periods like breeding and migration, there was need for a linear measure like the wing, tarsus, tail, or bill to be used with weight to determine body size in passerines. Gosler *et al.* (1998), state that a relationship is anticipated between body mass and a linear measurement, like the wing or tarsus length, since the latter reveals the size element of mass. Studies in other taxa like insects also uphold this notion that body mass and a linear measurement like head length should be considered as measures of body size (Chown and Gaston, 2009).

This presupposes then, that the choice of linear measurement that best expresses body size in different passerine species cannot be overlooked or assumed to be one general one. Conventional measures like wing length have long been used as measures of body size for most passerine species (Svensson, 1992). Reliability of wing length measurements has reduced considerably, since wing feathers are subject to wear, and individual wing length fluctuates yearly (Rising and Somers, 1989). Studies by Senar and Pascual (1997) proposed using keel length (which is the length of the sternum from the tracheal pit to the hind margin of the sternum), as the best estimator of body size instead of wing length. However, such a measurement sacrifices the individual being studied, which contradicts the upholding of the birds' welfare in research (Fair *et al*., 2010).

Suitable non-intrusive linear measurements in species' body size estimations should be researched in consecutive years. Linear measures that are commonly used include the wing, tarsus, and head lengths, depending on the category of bird species concerned. In most passerines, wing length has been a general measure of body size (Svennson, 1992), but current studies have shown that no single dimension can adequately reflect body size and the search is

on to define if tarsus length or wing length can be the paramount predictor for any passerine species being studied (Gosler *et al*., 2011). Studies on body size can be used as a surrogate to show how a species adapts to local conditions; a premise that would enhance understanding of sedentary common bird species in light of habitats that are being modified by humans or changing climates (Barr, 2012).

2.2 Body size and habitat

Winkler and Leisler (1985) postulate that body size is one important feature that certainly determines habitat selection. Size differences may influence dominance relationships, which in turn may determine the quality of the habitat occupied. Toyama (2017) reports on extensive research on the *Tropidurinae* iguanid lizards, whose diversification has allowed them to occupy different habitats and environments. The lizards occupy from tropical rain forests to deserts and dry forests; and this diversity of habitats has promoted the evolution of different strategies in terms of morphology and behavior, consequently triggering a high diversity in forms and performance. It is postulated that this diversity offers an opportunity to evaluate how morphological evolution occurs in the context of the occupation of several different types of habitat. Swain and Melville (2000) also found in their research that of seven lizard species, that larger sized species with longer appendages and higher sprinting ability inhabited open microhabitats, while smaller closely related species in closed microhabitats exhibited shorter appendages and slower maximum sprint speeds. This hypothesis was tested to assess links between ecological structures like habitat features and animals morphology to highlight the close relationship between phenotype and environment.

Habitat is the environment suitable for a particular species for shelter, protection, food, and suitable reproductive mates (Lindenmayer and Fischer, 2006). Physical factors like soil,

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moisture, range of temperature, and light intensity contribute to the makeup of a habitat and accentuated by biotic factors like, accessibility to food and interactions with predators (Vickery *et al.,* 1992). Any particular species can thrive in a habitat well, however, a species' presence/absence at any actual locality hinges to a large degree on coincidence, antagonist or mutualist ecological interactions, and dispersal abilities (Gehring and Swihart, 2003).

Habitats can change over time due to events like bush fires or floods. They can also be altered through direct human actions: deforestation, tilling of grasslands, river damming and diversions, and draining of swamps to name a few. Generalist species among plants and animals can still have their habitat requirements fulfilled in a landscape having a variety of habitats despite changes the habitats are subjected to.

Lindmayer and Fischer (2006) state that landscapes transformed by humans where there is extensive vegetation loss might experience little loss of suitable habitat for particular species. A species may actually thrive in this scenario. They further state that scenarios involving habitat fragmentation may benefit species that are effectual colonizers. Studies on whether generalist bird species can thrive with habitat modification (Liker *et al.,* 2008), habitat loss, or fragmentation have proved this (Vickery *et al.,* 1992). Mennechez and Clergeau (2006) state that different species respond to landscape modifications in different ways due to degree of specialization and life history traits. They further state that habitat generalists regulate their movement and resource use to the configuration of the landscape. Generalists, thus competently source for resources like food and shelter, making use of unique artificial patches. Habitat specialists often decline or disappear due to their inflexibility and reluctance to cross the milieu adjacent to their habitation. A study on the European Starling (*Sturnus vulgaris*) by Mennechez and Clergeau (2006) showed the flexibility of the species' tolerance for huge landscape changes

due to urbanization and if it could still reproduce in large numbers. It was found that the starlings had low numbers of fledglings than their counterparts in the rural habitats. The body sizes were drastically different too with the individuals in the rural habitats exhibiting the biggest body sizes. The conclusion of the study was that this species was not an effective colonizer.

Habitat and body size have been shown to influence life histories of songbirds. Mason and Burns (2015) found in their research on Tanagers (Family *Thraupidae*) that larger individuals produced slower-paced, lower pitched vocal displays in contracted bandwidths than smaller tanagers. Their findings further showed that out of ten songs, nine song characters were influenced by body mass, and 30% of the song characters were correlated with habitat and gave insights into the progression of learned singing presentations in tanagers.

Results from another research by Liker *et al.* (2008) on effects of urbanized and rural habitats on body size of house sparrows, showed that mass, body condition and tarsus length differed amongst study sites. House sparrows (*Passer domesticus*) in increasingly urbanized habitats were significantly smaller in body size and in inferior condition than birds in increasingly rural habitats.

Urquhart (2002) reported that the Common Stonechat is an effectual colonizer, having a wide geographic range covering a variety of habitats. It is a generalist and its habitat includes farmlands, forest edges and open grasslands with small bushes among others. No research as yet has been carried out to ascertain if their body size differs between populations inhabiting different habitats in Kenya. This study sought to fill that knowledge gap.

2.3 The Common Stonechat habitat

Stonechats are insectivorous birds occupying a wide range of habitats (Versteegh, 2012; BirdLife, 2017). The African Common Stonechat (*Saxicola torquata axillaris*) in Kenya occupy a variety of habitats including grasslands, cultivated farmlands, a combination of grasslands and cultivated farmlands, and forest edges (pers.obs.). In Bamenda Highlands, Cameroon, the Stonechats were observed in dense scrubland with grassland patches in a disturbed montane forest where they were found to be good colonizers of the mosaic habitat created by the ongoing forest fragmentation of the highlands (Reif *et al.,* 2007). In their study in Switzerland, Arlettaz *et al*. (2008) observed Stonechats in cultivated farmlands, with patches of permanent extensive grassland habitat. But they were recorded as completely absent in consistent, intensive farmlands with no recurrent greensward patches. In the United Kingdom, it occurs in open scrubby habitats, on structures such as fences and telephone wires. It has been sighted in the alpine moorland, heathland, dry plains, scattered bushland and grasslands, forest edges, forest clearings, field hedges and fallows, wide-ranging shrubby riverbeds, swamp fringes, roadsides and railway borders (BirdLife, 2017).

2.4 Common Stonechat research

The Common Stonechat has a range of diverse life history parameters across subspecies and populations with disjunct distributions. Common Stonechats have been extensively used as models for testing hypotheses linking migration, physiology and breeding behavior, to photoperiodic responsiveness and migratory restlessness (Scheuerlein *et al.,* 2001; Baldwin *et al.,* 2010; Apfelbeck *et al*., 2017a, b). Common Stonechats were studied by Gwinner *et al.,* (2003) to find out how they regulate their metabolic activity to the prevailing conditions in Kenya, Austria and Kazakhstan, where they lived at different latitudes and different

environments. Their results found that metabolic throughput, was higher in north-temperate migratory individuals than in sedentary tropical individuals of the same species. To validate this, Tieleman (2007) carried out a study on Common Stonechats from Kazakhstan and Kenya to assess if the physiological response to variation in temperature can provide insights into how they adapt to different environments. The results showed that Kenyan birds were better sequestered to compensate for their limited capacity to elevate metabolic rate, hence having a slower pace of life than their Kazakhstan counterparts. Stonechats from Kenya were also found to have higher body mass, and lower mass-specific BMR compared with the Kazakhstan stonechats. Basal metabolic rate (BMR) represents a significant component of animal energy budgets and is correlated with a range of ecological, physiological and life-history variables, as well as phylogeny. It is the minimum energy expended by a post-absorptive animal measured during the rest phase (Versteegh *et al*, 2012). A possible plausible adaptive explanation postulates that variation in BMR derives from the observation that species from tropical environments have lower BMRs than species from temperate environments. This is hypothesized to result from the need to reduce (i) the rates of endogenous heat production in hot environments where evaporative water loss is restricted by water scarcity and (ii) the food requirements and energy expenditure in environments where resources are sparse and widely distributed the high BMRs of species from temperate and polar latitudes are associated with high maximal rates of thermogenesis and increased cold tolerance (White *et al*., 2006). With these findings it could be hypothesized that, intraspecific body size in a sedentary species like the Common Stonechat inhabiting a heterogeneous landscape, may possibly be expected to differ in body size due to the adaptations the species has to make to regulate energy expenditure and thrive to give rise to the next generation as well.

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In another research, Versteegh (2012) studied four geographically distinct stonechat subspecies: Kazakh/Siberian Stonechats (*Saxicola torquata maura*), European Stonechats (*S.t. rubicola*), Irish Stonechats (*S.t. hibernans*) and Kenyan Stonechats (*S.t.axillaris)* in captivity to examine how constitutive immunity is adapted to environmental seasonality, and if this can result in diverse genetically programmed annual cycles in different environments. This could possibly mean that in differing environments, having varied habitats, the immunity of a sedentary bird species has to acquire certain adaptations to deal with pathogen pressure that could be caused by environment-specific seasonal variation in ecological factors.

In all these studies body size differences were not factored in the research. Body size could enrich physiological studies since standard measures of metabolism are expressed as a function of body size. Such information could enhance knowledge in how sedentary Common Stonechats populations adapt to live in diverse environments.

2.5 The stonechat (Genus Saxicola): a study model species

The stonechats (*Genus Saxicola*) are small passerines (< 20 g) that inhabit open habitats over a wide range of latitudes in Eurasia and Africa. There are 12 recognized species and 45 described subspecies (Illera *et al*., 2008). From these, the stonechat complex (*Saxicola torquata*) has undergone huge radiation with more than 20 subspecies described. Stonechats breed from the Southern tip of South Africa (35ºS) to Siberia (70ºN) and, therefore, they are exposed to a wide range of photoperiodic conditions. Habitats on their breeding grounds range from highly episodic permafrost areas to mild temperate zones and the tropics. To match this, Stonechats have developed a suite of traits among passerine birds as having the widest north-south breeding range. Traits include, strong latitudinal cline in metabolic rate, with innate, complex metabolic rates in higher-latitude populations. Such traits aid their adaptation to the temporality or

seasonality of their particular breeding sites. They are monogamous, breed seasonally, and defend their breeding territory irrespective of latitude (Apfelbeck *et al*., 2017a). Some subpopulations are resident, whilst others are long-distance migrants; yet some populations are partial migrants (Urquhart, 2002).

Figure 1 The Common Stonechat (*Saxicola torquata axillaris*).

The subspecies *Saxicola torquata axillaris* (Figure 1) is concentrated in central and western Kenya uplands west of 38ºE. It occupies areas receiving over 500 mm of rainfall and its distribution marks the eastern margins of its distribution (BirdLife, 2017). The habitat that is preferred includes a range of open and semi-open environments, from farmlands, extensive grasslands with isolated bushes, small trees and hedges which are used for perching (Scheuerlein and Gwinner, 2002).

The Common Stonechats are small to medium-sized compact birds. They weigh 14–18 g as adults. Their bills are short, strong, and rather broad at the base. They have well-developed rectal and nasal bristles. Their legs are relatively long and rather slender. The wing tips are rounded or sometimes bluntly pointed. The tail is short and square. The male is mostly black and white and has a deep chestnut on the breast with white on the sides. The female is streaked brown above and brown or buff below. They are largely monogamous with few occasional exceptions (Urquhart, 2002). The Common Stonechats breed during short rainy seasons, with the precise timing depending on the rains. Breeding lasts from four to six months; they lay one clutch with comprising an average of three eggs per year (Scheuerlein and Gwinner, 2002). Their food consists of insects, spiders and other small invertebrates (Urquhart, 2002). Stonechats make a good study species and are renowned for their longevity, physiology, ecology, abundance, habitat and accessibility. They are also widespread (Apfelbeck *et al*. 2017*b*). The 'pace of life' studies are well identified with the Stonechat species as study models. In these studies, comparative research has been paralleled with metabolic turnover rates of sedentary stonechat populations from different latitudes like Kenya, Kazhakstan and Austria under lab conditions to assess annual reproduction, life span and metabolic rates of the Stonechat genus in many environments over a wide range of latitudes (Versteegh, 2012).

In their research, Revaz *et al.* (2008) used the Stonechat as a bio-indicator passerine to investigate if newly engineered agro-ecosystems (with extra land beside it) could avail appropriate reproductive environments for wildlife. Stonechat populations in modern revitalized agro-ecosystems were used to assess whether they could be suitable breeding habitats for the Stonechat. Their results showed that zones in revitalized, thoroughly cultivated farmlands could sustain Stonechat populations comparable to similar Stonechat populations in past, widespread

rural environments. None of these studies however, compared whether different habitats could affect the body sizes of individual populations. This necessitates the need to identify a suitable linear predictor of intraspecific variation in body size for this passerine species without assuming the use of the conventional wing length. Alonso and Arizaga (2006) in their study on the biometrics of the Citril Finch (*Serinus citrinella*) found that wing length was the best estimator of body size for their study species. They however proposed that skeletal measures such as keel or tarsus could be better linear measures since wing length can be badly affected by abrasion over time and halting in moulting seasons which may give false body size measures. With the huge number of subspecies and populations within the Stonechat taxa (Urquhart, 2002), it would be worthwhile to explore if differences in habitat contribute to morphometric variations.

CHAPTER 3: STUDY SITES, MATERIALS AND METHODS

3. 1 Introduction

This chapter showcases the different sites wherein 20-29 male individuals of the study species were identified, observed and captured. Characteristics of the sites (Table 1) and a map (Figure.2) are given that show the diversity of habitats that the Common Stonechats were found.

3.2 Study sites

The study comprised of six sites distributed in four different habitat types: Forest glades and forest edges in tropical rainforest (Kakamega forest) were typified as 'Habitat I', Farmlands interspersed with fallow land (Murungaru,Kinangop and Muumbi,Ol Kalou) as 'Habitat II', Croplands (Mataara and Timau) as 'Habitat III', and Forest edges of a coastal montane forest (Taita Hills) as 'Habitat IV'

These sites were: 1) the forest glades and edges in Isecheno, Kakamega tropical rainforest, Kakamega County 2) Timau wheat farms on the northeastern slopes of Mt. Kenya, Buuri subcounty, Meru County; 3) Mataara tea, coffee and tomato farms on the edge of Aberdare ranges in Gatundu North subcounty, Kiambu County; 4) and farmlands interspersed with fallow land in Murungaru, Kinangop Plateau in North Kinangop sub-county; 5) Muumbi in Ol Kalou sub-county (both of Nyandarua County) and, 6) forest edges of a coastal montane forest in Taita Hills in Taita sub-county, Taita Taveta county.

Table 1 Study site characteristics

Site	Altitude (m)	Annual Rainfall (mm)	Temperature(^{o}C)	Habitat	Land use
Kakamega	1550-1650	2000	15°C-29°C	Forest glades and forest edges of a tropical rainforest	Grazing/grass harvesting/charcoal burning
Kinangop (Murungaru)	2400-2700	750-1000	14.2^{o}C-25°C	Farmland interspersed with tussock grasslands	Pasture land/Farming
Ol Kalou (Mumbi)	2400-2700	750-1000	14.2^{o}C-25°C	Farmland interspersed with tussock grasslands	Pasture land/Farming
Mataara, Aberdares	2066	962-1000	18°C-25.7^{o}C	Croplands	Tea,coffee,maize plantations
Timau, Mt.Kenya (Timau)	1500-2900	1170-2500	19°C	Croplands	Wheat Farming
Taita hills	2149-2228	1332-1910	23°C-18.2^{o}C	Forest edges of a coastal montane forest	Small scale farming/logging
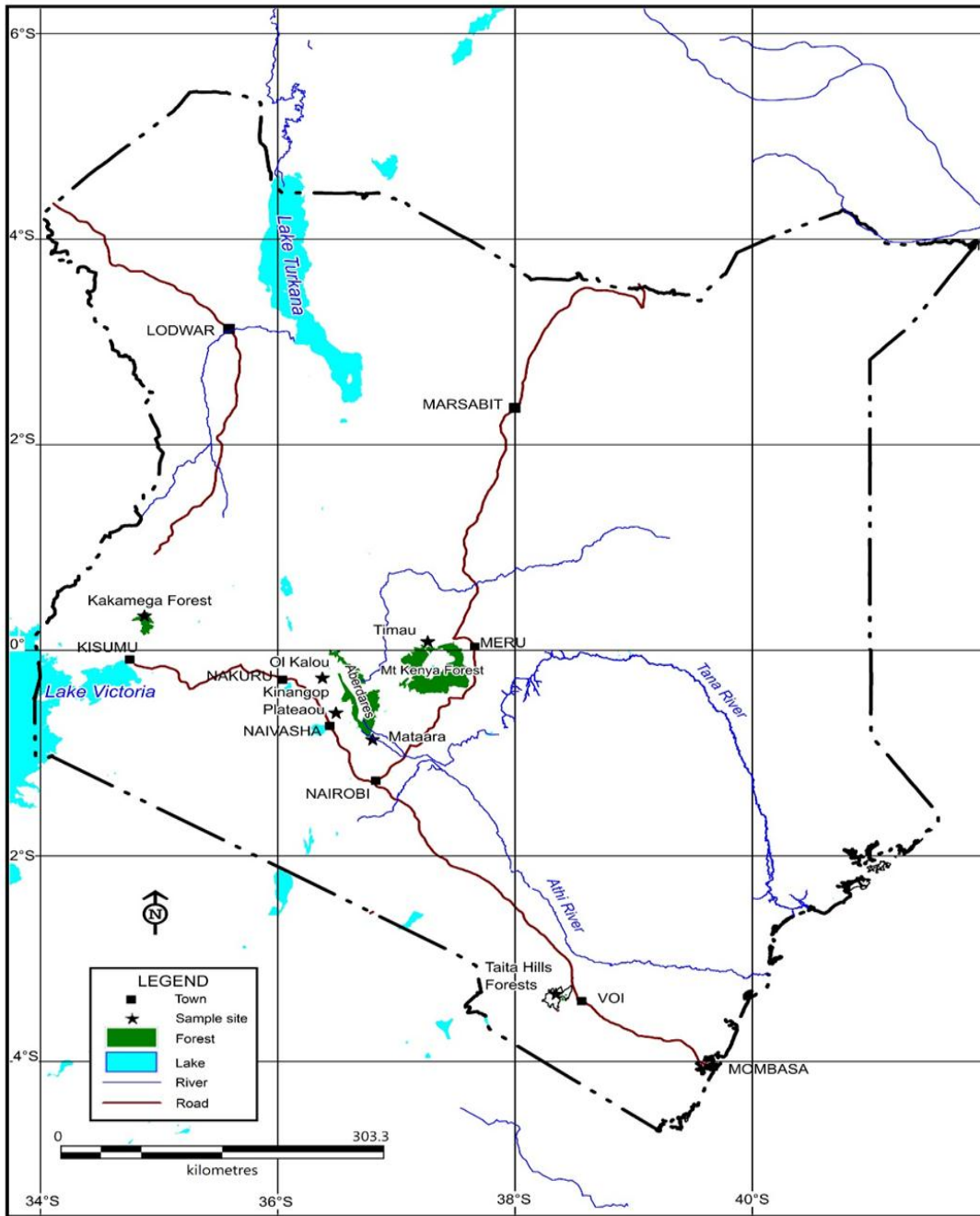
Figure 2 Study sites of the Common Stonechats in central, western and south-east Kenya.

3.2.1 Site descriptions

<u>Isecheno, Kakamega Forest</u>

Location and elevation:

Kakamega forest glades and forest edges are found between 00°14′19″North and 34°57′13″East at an altitude of 1550-1650 m a.s.l. It is found in Kakamega County. This is a mid-altitude tropical rainforest, the easternmost outlier of the Congo Basin rainforests. Kakamega forest approximately measures 19,649 hectares. Dense indigenous forest is estimated at 11,345 ha, while semi-dense indigenous forest covers 2,705 ha. Forest plantations are estimated to cover 832 ha, scattered trees and glades at 1,557 ha, and cleared or cultivated area cover 2,002 ha (BirdLife 2017).

Climate

Rainfall is circa 2,000 mm/year. The yearly mean maximum ambient temperature is 27°C, and mean minimum temperature is 15°C. The soils of Kakamega forest are well-drained, deep red to yellowish red, friable sandy clay to sandy loam texture. They are developed from undifferentiated basement system rocks and are classified as Ferralo-Chromic Acrisols.

Natural vegetation

The study area consisted of grassy bushed glades and the forest edges bordering a tea plantation, in the Isecheno fragment managed by the Kenya Forest Service. Small trees and shrubs recorded in the glades included: *Combretum molle, Psidium guajava, Maesa lanceolata, Harungana madagascariensis and Chaetacme aristata*. Forest edges are lined by dense thickets of *Acanthus pubescensi* (BirdLife 2017).

Socio-economic activities

Illegal tree-felling and charcoal burning are rampant. Forest and glade grazing of livestock prevents tree regeneration and causes policing problems. Hunting for bush-meat, debarking of certain trees for traditional medicine, and firewood collection (estimated at 100,000 m^3/year) are also serious problems (Bennun and Njoroge, 1999).

Mataara, Aberdare Mountain ranges

Location and land elevation

Mataara is found in Gatundu North constituency in Kiambu County. It is found between 36° 40.98' East and 0° 26.16' South at an altitude of about 2066 metres a.s.l. It is a settlement that lies on the eastern slopes of the Aberdare ranges, and borders Kieni forest.

Climate

The annual temperature here averages between 18°C and 25.7°C. In a year, the average rainfall ranges between 962-1000 mm. Long rains fall between mid-March to May, with a cold season following this during June to August. Short rains occur between mid-October to November. The soils are volcanic in origin and very fertile.

Socio-economic activities

Expansive and small subsistence croplands are abundant where tea, coffee, vegetables, maize, beans, peas and potatoes are grown. Common Stonechats were observed foraging and nesting on these farms.

Location and land elevation

These two sites are located in Nyandarua County, in North Kinangop and Ol Kalou subcounties respectively. Murungaru in North Kinangop, Kinangop Plateau is found between 36º 33.78' East and 0º 39.18' South at an average altitude of 2431 m a.s.l. Muumbi in Ol Kalou/Ol'joro Orok Plateau is found between 36°22'39.05"East and 0°16'21.72"South at an average altitude of 2360.9 metres a.s.l. These plateaus have slopes that are interrupted by low undulating hills. The gentle slopes flatten to plain like features encouraging formation of marshlands and swamps. They contain wide stretches of montane grasslands bounded by the forests of the Aberdare Mountains (IBA KE001) and Kikuyu Escarpment (KE004) to the east and south, and by a steep scarp dropping to the Rift Valley floor on the west.

Climate

The average annual temperature is 14.2°C-24ºC with precipitation averaging circa. 1,000 mm/year. The soils are volcanic in origin and vary in both fertility and distribution. Shallow soils are found in hilly areas while deep well drained soils are found on the slopes and plateaus. The predominant soils are nitosols, andosols, leptosols, luvisols, phaezems and planosols.

Natural vegetation

The plateaus are covered with almost treeless, tussocky grassland, together with tussock bogs in the marshy valleys. The tussock grasses include *Andropogon amethystinus*, *Cymbopogon nardus*, *Digitaria diagonalis*, *Eleusine jaegeri*, *Eragrostis botruodes*, *Hyparrhenia hirta*, *H. tamba* and *Pennisetum hohenackeri*.

Socio-economic activities

Cultivation takes place on large areas of land planted with maize, wheat, cabbages and potatoes; and interspersed with tracts of pasture fields. Other crops that flourish here include carrots, kales, tomatoes and peas. Dairy, sheep and poultry farming is also practiced. Common Stonechats were common in these farmlands interspersed with tussocky fallow land (Bennun and Njoroge 1999).

<u>Timau in Mount Kenya area</u>

Location and land elevation

Timau is located in the upper highlands of the pyrethrum-wheat zone in Buuri Sub-county of Meru County between 0005'31.53'' N and 37014'51.64'' E at an altitude ranging from 1500-2900mm. It is on the northeastern side of Mt. Kenya.

Climate

Annual rainfall ranges from 1170 mm to 2,500 mm/year with temperatures that range from $7.5^{\circ}C$ to $18.36^{\circ}C$. Soils are chromic and ferric luvisols and lithosols. The dominant soil type is the deep red loam soils, which are well drained and fairly fertile. The topography of the district was largely influenced by the volcanic activity of Mount Kenya (Gakuubi and Wanzala, 2012).

Natural vegetation

Much of Buuri sub-county is dominated by scattered trees, stretches of dry grass and shrubs as the main vegetation types with a number of forests in the neighbourhood, the largest being Mount Kenya forest. These vegetation types are the main sources of ethnobotanical products traditionally used in healthcare systems for both humans and animals.

Socio-economic activities

Timau and Kisima are the most favorable sites in Kenya for wheat farming in small or large scale. A number of grassland bird species nest in the grasses, shrubs and trees that border and forage in the expansive wheat farms (Bennun and Njoroge, 1999).

Taita Hills

Location and land elevation

Taita Hills is found between 38°20.70' East and 3°22.56' South, at an altitude of 2149 to 2228 m in Taita sub-county, Taita-Taveta County. Dawida is the main body of the Taita hills mist forests. These forests are part of the Eastern Arc Mountain Biodiversity Hotspot (Bennun and Njoroge, 1999).

Climate

Average annual rainfall is between 1332-1910 mm per year with the long rainy season occurring from March to May and the shorter rainy season from November to December. The immediate vast surrounding lowlands are very dry with a minimum yearly rainfall as low as 250 mm. Temperatures range between 23ºC and 18.2ºC. The soils are acidic and. They are well-drained dusky-red to dark brown sandy clay loam and in some areas rocky and stony. Soil fertility is very low. Aluminium levels are very high in these soils with low calcium and no potassium.

Natural vegetation

Scattered forest fragments of different sizes, ranging from 200 ha to 1 ha form Taita Hills mist forests. Total area of natural forest in Taita Hills is approximately six km². Area of closed forest with generally high intact and contiguous canopy is two km². Area of open forest-forest with broken and non-contiguous canopy is four km.² Flanks of the hills are covered by dry bush-land (Pellika *et al*. 2004).

Socio-economic activities

Near the hilltops consists of smallholder cultivation and remnant patches of moist forest. The agriculture in the hills is characterized by intensive small-scale subsistence farming. Maize, beans, peas, potatoes, cabbages, tomatoes, cassava and banana are the typical crops grown on the farmlands. In the slopes and lower parts of the hills, maize, sorghum, millet and onions are cultivated where average annual rainfall is ranges from 600 and 900 mm. Soil is used to make bricks and is a major income earner for the locals. Forest edge has been increasing due to pressure from expanding cultivation and logging (Wagura, 2014). Generalist bird species and grassland species utilize these edges for foraging and nesting resources.

3.3. Preliminary record searches and reconnaissance surveys

A physical search of ringing (bird-banding) files and database accounts was done at the Ornithology Section, Zoology Department of the National Museums of Kenya. Through this, 12 sites were identified, from where the study species had recorded the most capture-recapture numbers of more than 30 individuals between the 1970s and 1990s. These sites were found to be: Nandi Hills, Ahero, Mount Elgon, Menengai Crater, Kinangop grasslands, Ol Kalou, Ngong Hills, Kakamega Forest, Mataara in Aberdares, Dawida in Taita Hills, Lower Kabete and Timau.

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A 14 day reconnaissance species-sighting expedition was organized to the 12 sites to ascertain whether the Common Stonechats would still be found and to estimate their abundances. Each site was assessed for two days. In each site, the study species were identified using their songs and plumage. Telescopes, binoculars and guide books were also used to make sure the right species was identified and their movements and behavior. Once their territorial behavior was established, recording of their songs was done. Songs from one individual in the species were processed and used to provoke a conspecific for purposes of stimulating aggression and defense from a territory owner and finally its capture. Three 18-metre mist nets and decoy traps were then set up to test which method would best capture them. Two decoy traps with stuffed study stand-alone skins of the species were placed in the center of each of the territories (each territory holder sung at perches on the perimeter of their territory, and flew inside the territory to forage or feed its nesting female partner). Recent bird and mammal studies have proved that male residents react more vigorously towards songs or calls of an intruder when they are played back in the centre of a territory rather than at the edges (Amrhein and Lerch, 2010).

Territorial sizes were not computed in this study because it takes at least 12 simulation trials to get correct estimations of the territorial size (Ringler *et al*., 2011). This was not possible within 14 days in which capture and recapture, and recording of bird songs had to be done for a minimum of 20 individuals in each of the six sites).

Mist nets were set up on the edges of the estimated territory perimeters where the particular territory holders were observed frequently foraging. The mist nets did not record any captures because the species utilizes perches heavily and instead of flying into the mist nets, they were perching on top of the nets and on the poles holding up the nets. The decoy traps with the playback of dawn choruses, proved to be the best option as they readily attracted the target

species and its competitors, other territorial species like the Common Fiscal, in all the sites. The GPS points of all captured Common Stonechats in their territories were recorded where the decoy traps stood. Results showed that only 6 out of the 12 sites had at least twenty identified active male Common Stonechats during the breeding season for good capture-recapture efforts. It was imperative to time the research during the breeding season since that is the time that the males are most vigorous at defending the territories, their mates and the resources therein.

3.4. Data collection methods

3.4.1 Bird trapping and biometric measurements

In each of the six sites, approximately 14-17 days were employed in the capture efforts of the species where a total of 139 males were captured. The numbers of the birds reflects the number of territories encountered in each site. Key features of what biometrics were taken are shown and the statistical analyses they were subjected to are documented.

In all the sub-populations, there was marked activity suggesting the start of the breeding season and was evidenced by males that were observed bringing food to their brooding mates frequently. The male Common Stonechats were captured as they were foraging and defending territories on farms, between the farms, on undisturbed grassland and the forest edges.

In each identified territory, two stuffed Common Stonechat decoys (Figure 3) were raised on one-meter poles Attached to the decoy trap were netted cloth traps underneath the platforms with a spring that would be triggered by the landing of the territorial male when it lands to attack the decoy. A playback with a recorded Common Stonechat male song was placed at the bottom of the pole. Variations in the play back song inform a territory holder of an intruder and the resident male will try to out sing the decoy to match up to its song (Milius 2004). Playbacks were

put together using Avisoft-SASLab Pro software, version 4.51Raimund Specht, Berlin, Germany. Each playback consisted of at least 20 songs recorded from one male singing around various points of its territory.

Figure 3 Decoy trap

Each targeted male Common Stonechat was captured in a netted trap mounted on the attached platform. The biometric measurements of the captured birds were recorded at each site of capture in a ringing notebook. The measurements included wing length (maximum chord), which was measured using a metal ruler with a zero-stop, and read to the nearest 0.5 mm. The bird was held in a ringer's grip, the carpal joint was pushed against the zero stop, and the primaries gently flattened against the ruler (using the thumb of the hand holding the bird). The index finger of the other hand then pressed laterally against the carpal joint to straighten the curvature of the wing

until it was parallel to the scale of the ruler (Figure 4). Tarsus length was measured from back of the tarsus to the front of the metatarsus joint (Figure 5).The head and tarsus measurements were taken using a digital Vernier caliper to the nearest 0.5 mm. Head length was measured from the hindmost point of the head to the tip of the bill (Figure 6). Body mass was measured using a spring balance with a maximum of 50 g to the nearest 0.1g. Birds were placed in cloth bags for weighing. The weight of the bag or container was measured aforehand. Using the spring scale, the bird was suspended from the scale to obtain the gross weight of the cloth plus the bag. After measuring each bird, the bird weight was obtained by subtracting the bag weight from the gross weight (gross weight – bag weight = bird weight). The gross weight, bag weight and bird weight were all recorded in the ringing notebook.

Figure 4 Measuring wing length (*Measuring birds*,Gesellschaft, 2005).
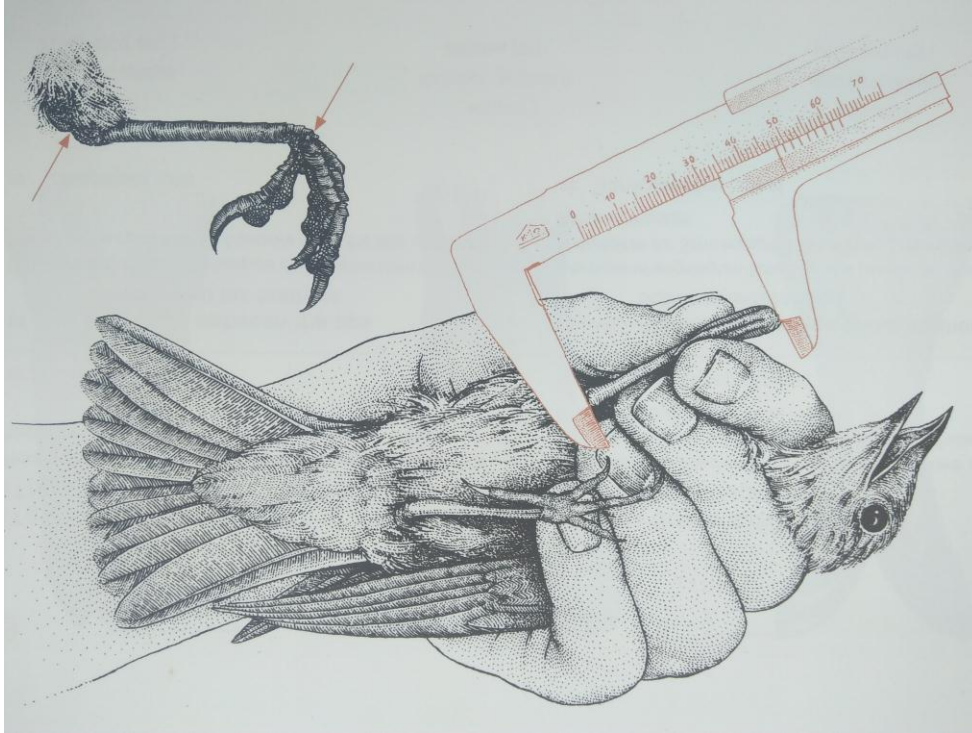
Figure 5 Measuring tarsus length (*Measuring birds*, Gesellschaft, 2005).
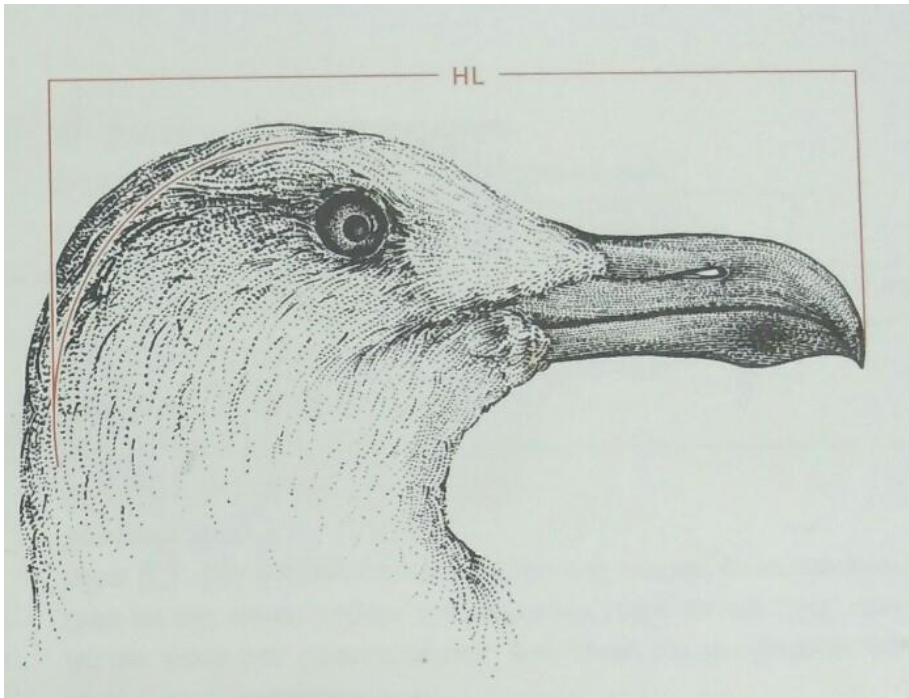
Figure 6 Head length measurement (*Measuring birds*, Gesellschaft, 2005).

3.5. Statistical Analyses

Statistical analyses were carried out using SPSS 21(IBM SPSS Statistics), except where otherwise stated. The four habitats were the dependent variables. Four body biometrics (wing, head tarsus and body mass) were considered the independent variables. One-way ANOVAs was carried out to find out differences in biometrics among the four habitats. Tukey post hoc tests were done to determine where the differences in the biometrics lay. To find the best linear predictor of body size, independent linear regressions were performed using wing, tarsus and head lengths with body to measure body sizes of individuals. The linear measure that showed the least variability with the body mass would be considered to be the best linear predictor of body size in the Common Stonechats.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter summarizes investigations of body size differentiation of Common Stonechats in varied habitats. Forest glades and forest edges in a tropical rainforest (Kakamega forest) were typified as 'Habitat I', Farmlands interspersed with fallow land (Murungaru,Kinangop and Muumbi,Ol Kalou) as 'Habitat II', Croplands (Mataara and Timau) as 'Habitat III', and Forest edges of a coastal montane forest(Taita Hills) as 'Habitat IV'. The highest numbers of individuals caught were recorded in the croplands of Timau and the forest edges of Taita Hills. The lowest captures were recorded in the forest glades and edges of Kakamega forest, the croplands of Mataara and in the farmlands interspersed with farmlands of Ol Kalou (Table 3).

Table 2 Summary of capture efforts at study sites

Site	Habitat type	Number of individuals captured	Period of Capture(days)
Kakamega forest	Forest glades and forest edges of a tropical rainforest	20	15
Mataara	Croplands	20	16
Murungaru-Kinangop	Farmland interspersed with tussock grasslands	23	17
Muumbi-Ol Kalou	Farmland interspersed with tussock grasslands	20	14
Timau	Croplands	27	14
Taita Hills	Forest edges of a coastal montane forest	29	16
Total		**139**	

4.2 Body biometrics among four habitats

One-Way ANOVAs were used to evaluate the null hypotheses that there are no differences in Common Stonechat biometrics across 4 habitats.

The four biometrics: body weight, wing, head and tarsus lengths in habitats were measured in: (Forest glades and forest edges of Kakamega tropical rainforest): I, (Farmlands interspersed with fallow land Murungaru, Kinangop/Muumbi, Ol Kalou): II, (Croplands (Mataara and Timau):III, and (Forest edges of Taita Hills, a coastal montane forest):IV. The analyses showed that the species' biometrics were all statistically significant among the 4 habitats (Table 4). Habitat categories were assumed to be distinct, homogenous and with little overlaps.

Table 3 Summary results of Tukey post-hoc test

Variable	Mean ± SE	Differences	F test
Wing length	70.83 ±0.48	I and IV	$F_{3,135} = 105.69, p < 0.05$
	70.83±0.40	II and IV	
	70.83±0.40	III and IV	
Head length	33.39±0.29	II and IV	$F_{3,135} = 4.87, p < 0.05$
	33.39±0.26	II and III	
	33.39±0.33	II and I	
Tarsus length	23.16±0.26	II and III	$F_{3,135} = 5.01, p < 0.05$
	23.16±0.31	I and IV	
Body mass	16.19±0.30	I and III	$F_{3,135} = 4.74, p < 0.05$
	16.19±0.33	I and IV	

i) Mean wing lengths between forest glades and forest edges of Kakamega tropical rainforest and the forest edges of Taita Hills.

ii) Head lengths differed significantly between the farmlands interspersed with fallow land in Kinangop/Ol Kalou, and the forest edges of Taita Hills. Head lengths also differed between the farmlands interspersed with fallow land and the forest edges of Taita Hills, between the farmlands interspersed with fallow land in Kinangop/Ol Kalou and the pure farmlands; and between the farmlands interspersed with fallow land in Kinangop/Ol Kalou and the forest glades and forest edges of Kakamega tropical rainforest.

iii) Tarsi lengths differed significantly between the farmlands interspersed with fallow land in Kinangop/Ol Kalou and pure farmlands, and between the farmlands interspersed with fallow land in Kinangop/Ol Kalou and the forest edges of Taita Hills.

iv) Body weights differed significantly between forest glades and forest edges of Kakamega tropical rainforest and the pure farmlands, and between forest glades and forest edges of Kakamega tropical rainforest and the forest edges of Taita Hills.

Table 4 Means and standard errors of biometrics

Habitat: I= Forest glades and forest edges of a tropical rainforest, Habitat II=Farmlands interspersed with fallow land, Habitat III=Farmlands (pure croplands), Habitat IV=Forest edges of a montane forest. M= mean, SE= Standard error, F= Fishers' statistic.

Wing(mm)				Head(mm)				Tarsus(mm)				Weight(g)			
I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
69	73	70	66	34	34.6	33	32.1	23	23.8	23.2	20.4	18	16.5	15	15.5
74	71	71	68	32	32.9	31	34.5	23	23.1	21.5	23.2	15	16.5	15.5	17.5
71.5	71	73	67	33	33.5	32.4	32.4	24	23.1	23	22.3	15.5	15.5	17.5	17.5
71.5	71	72.5	69	33	34.3	33.8	32.8	24	23.5	23.8	21.8	15	16	17	17.5
72	74.5	72	66	34	32.9	34.1	33.1	23	22.2	24.	22.2	15.5	15.5	16.5	18
70	71	70	65	32	33.7	32.4	33.3	23	22.9	21.7	23.8	14	15	16	17
72	71	70	65	34	34.6	33.3	33.8	24	23.7	23.1	23.4	15	15.5	15.5	15.5
69	71.5	70.5	68	33	34.4	34.1	32.6	23	22.7	22.3	21.6	15	15.5	17	16.5
69.5	73	71	67	33	34.3	32	33.4	23	23.1	24.1	23.2	15	15	16.5	17
70	73	70	65.5	33	33.6	33.2	32.3	23	23.7	21.6	21.7	14.5	13	15.5	17.5
68.5	74.5	70	64	32	33.1	31.9	33.5	22	23	23.3	22.4	14	16.5	17	16.5
71	72	70	64	33	33.4	32.7	33.3	24	23.3	21.8	22.8	16	15.5	16	17
71.5	70	75	66	34	33.7	34	31.7	23	22.1	23.	22.1	15.5	14.5	16.5	15
69	73	70	68.5	32	32.6	32.5	32.3	23	23.6	23.7	22.9	15	14.5	16.5	16.5
70.5	74	73	66	33	33.2	32.4	32.3	23	23.1	22.6	22.8	15	14	16	17.5
68	73.5	69	67	32	34.7	32.2	34.9	22	22.9	22.6	23.2	14	17	17	16.5
71	75	72	64	32	34.3	33	32.4	23	24.7	23.4	22.3	15	14.5	15	15.5
71	73	70.5	66	34	33.7	32	34.1	23	24.9	22.3	23.3	17	14.5	16	14
69	74	71	67	34	33.2	32.3	33.2	22	23.4	22.2	23.5	20	15	18	17.5
71	74	71	65	33	33.9	33	32.3	23	23.1	22	23.4	15	15.5	15.5	16
	71	75	68		32.9	33.3	33.2		23	22.8	22.4		15.5	15.5	16.5
	74.5	71	65		34.7	32.7	32.2		23.5	22.4	22.7		16.5	20	15.5
	71	72	65		33	34.8	32.6		22.9	24.	23.1		15.5	15.5	16.5
	73	74	65.5		34.5	35	32.8		26	23.6	22		17	18.5	16
	73.5	76	67		33.3	33.4	33.4		23.2	22.4	22.7		16	16.5	18

Table 5 (continued)

Habitats	Wing(mm)				Head(mm)				Tarsus(mm)				Weight(g)			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
		71	75	65		33.5	34.3	32.08		24.1	23.8	22.9		16.5	16	16
		71	73	68		33.8	33.5	32.8		26.2	22.6	22		17.5	17	16
		72	72	66		33.7	32.7	33.2		24.3	23.5	23.1		17	16	16
		74.5	70	65		33.1	33.5	32.7		22.9	23.1	22.9		17	15	15.5
		72	74			34	35.8			25.6	23.6			14	17.5	
		69	72			32.6	32.9			21.9	22.9			15	16	
		71	75			34.6	34.2			25.9	23.3			16	16	
		73	74			31.7	34.2			20.2	23.7			17	16.5	
		73	74			33.4	32.8			22.6	23.6			17.5	16.5	
		71	74			33.4	34.6			26.6	23.4			17.5	17	
		72	74			33.2	33.6			22.2	22.6			18	17	
		73	75			33.7	34.3			23.5	22.9			17	17	
		71	71			34.3	33			23.2	23.8			18	18	
		75.5	74			41.8	33.9			31.1	23.3			16.5	16	
		73	72			40.8	32.9			31.5	23.5			18	16	
		74	72			32.3	33.9			21.8	22.91			17.5	17.5	
		74	74			34	34			22.6	22.9			17.5	16.5	
		69	73			33.1	33.3			21.2	23.0			16.5	15.5	
			71				33.2				23.				16.5	
			74				32.8				23.3				16.5	
			75				33.9				23.8				17	
			75				31.9				22.9				16	
n	20	43	47	29	20	43	47	29	20	43	47	29	20	43	47	29
Mean	**70.5**	**72.4**	**72.5**	**66.2**	**33.1**	**34**	**33.3**	**33.0**	**23**	**23.8**	**23**	**22.6**	**15.5**	**16.1**	**16.5**	**16.5**
Standard Error	0.33	0.24	0.28	0.26	0.2	0.27	0.14	0.13	0.1	0.32	0.1	0.13	0.32	0.19	0.14	0.18
F statistic	$F_{(3,135)}=105.69, p<.001$				$F_{(3,135)}=4.87, p<.005$				$F_{(3,135)}=5.01, p<.005$				$F_{(3,135)}=4.74, p<.005$			

4.3 Linear estimator for body size

Simple linear regressions were done to predict body mass, the surrogate of body size, based on wing, head and tarsus lengths (Figures 7, 8 and 9). When wing length was used as a linear predictor, a non-significant regression equation was found ($F_{(1,137)}$ = .000, p = 0.989), with an R^2 of 0.000. Using head length as a linear predictor, a significant regression equation was found ($F_{(1,137)}$ = 3.916, p =.05) with an R^2 of .028. Predicted body mass was equal to 11.044 + 0.154*(head length) grams when head length is measured in millimetres. Body mass increased by 0.154 for each millimetre of head length. Tarsus length as a linear predictor was found to have the following insignificant regression equation, ($F_{(1,137)}$ = .074, p =.786), with an R^2 of .001. Predicted body mass was equal to 15.733 + .020*(tarsus length) grams when tarsus length is measured in millimetres. Body mass increased by 0.020 for each millimetre of tarsus length.
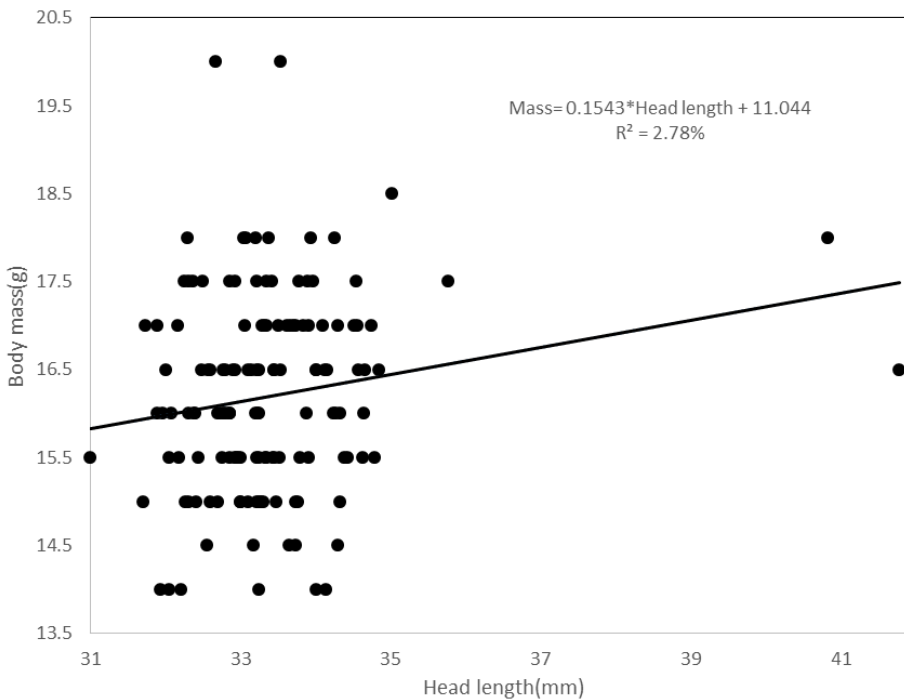

Figure 7 Regression of body mass against head length.
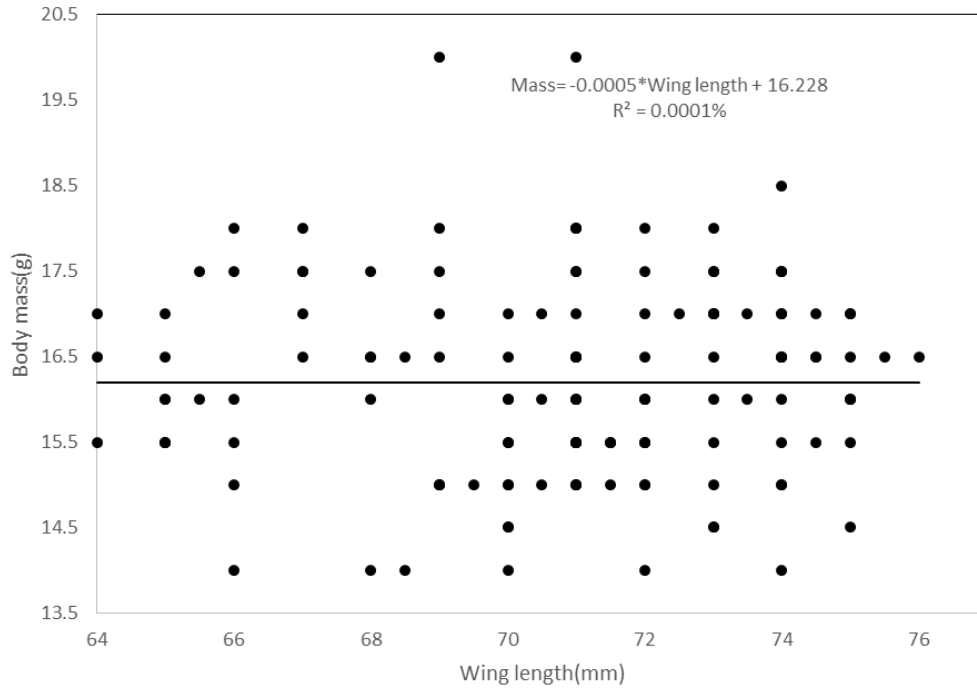
Figure 8 Regression of body mass against wing length

Figure 9 Regression of body mass against tarsus length.

Using head length as a linear predictor of body size, calculated body mass for the Common Stonechat in the four habitats showed (Table 6) that the population with the largest size were found in habitat II, Kinangop and Ol Kalou (Farmlands interspersed with fallow land) and the smallest sized chats were found in habitat IV, Taita Hills (Forest edges of a coastal montane forest).

Table 5 Using head length as the linear estimator of body mass

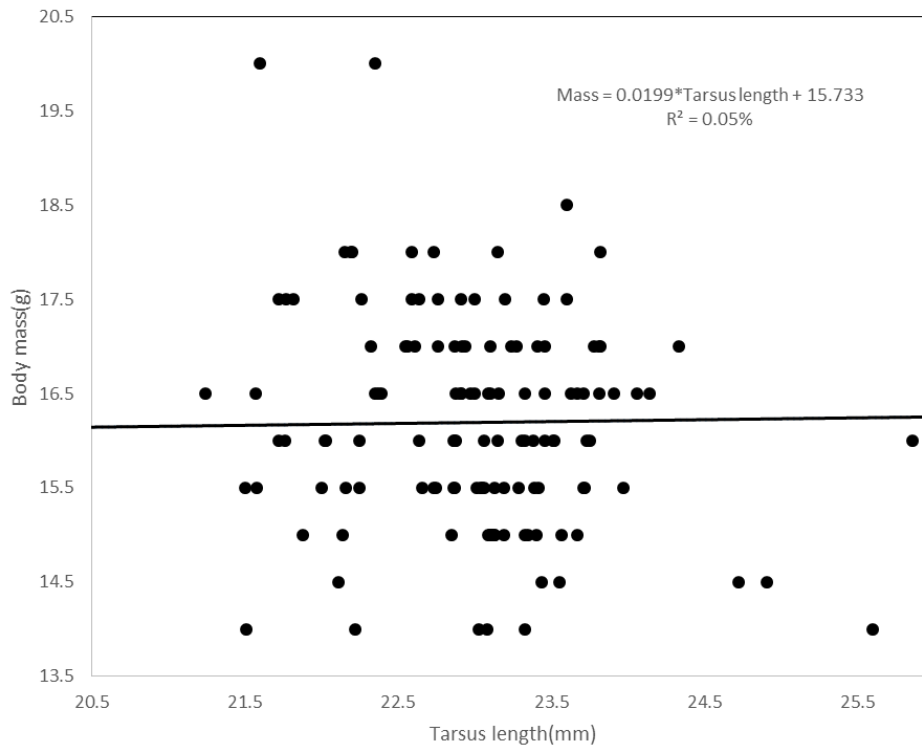| Forest edges and glades of tropical rainforest		Farmlands Grasslands		Pure croplands		Forest Edges Montane Forest	
Head Length	**Head Predicted Weight**	**Head Length**	**Head Predicted Weight**	**Head Length**	**Head Predicted Weight**	**Head Length**	**Head Predicted Weight**
33.4	16.3	34.6	16.4	33	16.1	32.1	16
32.3	16	32.9	16.1	31	15.8	34.5	16.4
32.5	16.1	33.5	16	32.4	16	32.5	16.1
33.1	16.2	34.3	16.3	33.8	16.3	32.9	16.1
34.4	16.4	32.4	16.1	34	16.3	33.1	16.2
31.9	16	33.7	16.3	32.4	16	33.3	16.2
33.7	16.3	34.6	16.4	33.3	16.2	33.9	16.3
33.3	16.2	34	16.4	34.1	16.3	32.6	16.1
32.7	16.1	34.3	16.3	32	16	33.4	16.2
33.2	16.2	33.6	16.2	33.2	16.2	32.3	16
32.1	16	33.1	16.2	31.9	16	33.5	16.2
33.2	16.2	33.4	16.2	32.7	16.1	33.3	16.2
33.5	16.2	33.7	16.3	34	16.3	31.7	15.9
32.4	16	32.6	16.1	32.5	16.1	33	16.1
33.3	16.2	33.2	16.2	32.4	16	33	16.1
32.2	16	34.7	16.4	32.2	16	34.9	16.4
32.3	16	34.4	16.3	33	16.1	32.4	16.1
33.7	16.3	33.7	16.2	32	16.9	34.1	16.3
33.5	16.2	33.2	16.2	32.3	16	33.2	16.2
33.3	16.2	33.9	16.3	33	16.1	32.3	16
		32.9	16.1	33.3	16.2	33.2	16.2
		34.7	16.4	32.7	16.1	32.2	16
		33	16.1	34.8	16.4	32.6	16.1
		34.5	16.4	35	16.5	32.8	16.1
		33.3	16.2	33.4	16.2	33.4	16.2
		33.5	16.2	34.3	16.3	32.1	16

Table 6 (continued)

Forest edges and glades of tropical rainforest		Farmlands Grasslands		Pure croplands		Forest Edges Montane Forest	
Head Length	**Head Predicted Weight**	**Head Length**	**Head Predicted Weight**	**Head Length**	**Head Predicted Weight**	**Head Length**	**Head Predicted Weight**
		33.8	16.3	33.5	16.2	32.8	16.1
		33.7	16.2	32.7	16.1	33.2	16.2
		33.1	16.1	33.5	16.2	32.8	16.1
		34	16.3	35.8	16.6		
		32.6	16.2	32.9	16.1		
		34.6	16.4	34.2	16.3		
		31.7	15.9	34.2	16.		
		33.4	16.2	32.8	16.1		
		33.4	16.2	34.6	16.4		
		33.2	16.2	33.6	16.2		
		33.7	16.2	34.3	16.3		
		34.3	16.3	33.0	16.1		
		41.8	17.5	33.9	16.3		
		40.8	17.3	32.9	16.1		
		32.3	16.0	33.9	16.3		
		34	16.3	34.0	16.3		
		33.1	16.2	33.3	16.2		
				33.2	16.2		
				32.8	16.1		
				33.9	16.3		
				31.9	16.		
Mean	**16.1**		**16.3**		**16.2**		**16.1**
SE	**0.02**		**0.04**		**0.02**		**0.02**

CHAPTER 5: DISCUSSION

5.1 Introduction

The Stonechat is a generalist species. A generalist species is able to thrive in a wide variety of habitats and can make use of a variety of different resources. Some species decline anthropogenic changes in landscape, whereas others thrive and even increase in altered habitats (Segura *et al.*, 2010). The Common Stonechat, a sub-species found in East Africa is regarded as benefitting from agriculture induced habitat fragmentation since it is able to exploit diverse habitats including edge habitat that has lots of grass and shrub cover (Ghering and Swihart, 2003). It does qualify to be a generalist species. This study sought to find out how the variety in habitats affects this species' body size in sedentary subpopulations in Kenya using external body measures and to find out the most probable linear predictor of body size.

5.2 Biometrics

Using body biometrics to assess the intraspecific body size differences in a species may give a clue to the survival strategies of sedentary populations in a wide ranging heterogeneous landscape. The present study showed that selective pressures within different habitats can influence a species' body biometrics in sedentary populations. Body biometrics of the Common Stonechat differed significantly between four habitats across Kenya. The shortest mean wing lengths were recorded in the Taita Hills and Kakamega forest. Short wing lengths exhibited by Common Stonechats in the Taita Hills habitat, may be proof of selective pressures and could tell us how the species responds to habitat edges. Winkler and Leisler (1992) have proposed that shorter wings may be most expedient in exploiting cluttered habitats. The Common Stonechat probably had to contend with other grassland species like the Common Fiscal and the Taita Fiscal for territories. Fighting for territory in a cluttered habitat where a species can be both

competitor and prey would entail smaller wings that enable an individual to quickly get away into a hedge or bush at the forest edge.

A species would need to be a great colonizer of areas that have ongoing habitat degradation, like the Taita Hills forests (Wagura, 2014) to exploit the benefits of food resources made available by the degradation, and to thrive where other species shy away from. In this forest edge habitat, the increased number of birds of prey like the Little Sparrowhawk, Common Fiscal and the Lanner Falcon that forage in and out of the fragmented forest may have the Common Stonechat on the prey list. Its exposure as it perches to sing in the open, in defence of its territory, may make it more vulnerable. Shorter wings enable individuals to perform fast vertical take-off and manoeuvrability into shrubs than if one had longer wings (Pennycuick *et al.*, 1994; Brown *et al.*, 2013). (The Common Stonechats would utilize this strategy for survival and quick manoeuvre in the forest edge of the coastal montane forest during escape or search for insects). Thus, the Common Stonechats in Taita Hills may be adapted to moving through environments with more dense features and may be exhibiting shorter wings to this effect. In reporting on their 30-year research on Cliff Swallows, Brown *et al.* (2013) found that environmental factors contributed to a short wing length. Their investigations showed that a cold May in 1996 killed half of the nesting population from starvation and caused a marked drop in wing length. Only the birds with short wings were able to catch insects on the wing. Environmental factors were not recorded in the stonechat sites, however, future studies should consider them as important factors influencing morphology and life history of stonechats living in different habitats.

Common Stonechats in the forest edges of the coastal montane forest had the lowest mean head length, while their counterparts in the farmlands interspersed with fallow land had the highest mean head length. This could be an indicator on the habitat quality. As evidenced by Larsson

(1993) in his research on the heritability of body size in a natural population of the Great Tit (*Parus major*) and its relation to age and environmental conditions during growth; low quality habitats could influence growth conditions over breeding seasons. This could mean that lesser quality resources invested in fledging growth could lead to smaller adult individuals whilst, good quality habitats could ensure better investment of quality resources, hence bigger sized individuals, who would then have the advantage of breeding bigger sized offspring for more generations if the habitat they inhabit is not negatively modified and has little or no competition from other conspecifics or other species interested in utilizing the same habitat.

Head length has been associated with heritability studies as one of the ecologically important traits in natural populations along with tarsus length and body mass (Moller, 2010). Larsson *et al*. (1997) found that head lengths were shorter in offspring that were exposed to poor growth conditions than of the offspring that were exposed to good growth conditions. Mean head length of offspring that grew under good conditions did not differ from mean head lengths of their parents. This means that parents that grew under poor conditions, and reared offspring under the same conditions were likely to make up a population of small sized individuals than those parents that have grown and reared offspring in a good condition. This could one of many theories explaining for the differences in head length in the Common Stonechat study. However, habitat conditions as an objective was not assessed in this study. Common Stonechats from the farmlands interspersed with fallow land habitat and the forest edges of the coastal montane forest habitat had differences in head lengths and overall body size. This could be a reflection of differences in habitat quality, leading to different feeding and different growth patterns, which are ultimately reflected in the biometrics as posited by Esteban *et al*. (2000) in their Dipper (*Cinclus cinclus*) study where they also found that different sedentary subpopulations of the

species throughout Europe differed in body size. Future genetic studies could clarify how the biometric variation reported in Common Stonechats may be caused by genetic differentiation among the parental birds.

Results in this study also showed significant differences in tarsi lengths between habitats. Tarsi were longest in the farmlands interspersed with fallow land which can be attributed to the greater variety of perching and foraging opportunities available with reduced interspecific competition than in pure farmlands. Longer tarsi, bigger head size and heavy weight were significantly correlated. There could be a possible selection on tarsus length that can drive increase in head size which warrants further investigation. The population in the farmlands interspersed with fallow land strongly showed this, (although data on foraging strategies in all the habitats was not exquisitely collected) and could be an adaptation for maximizing available resources in this habitat.

Forest glades and forest edges may present a diverse number of predators and competitors than the grassland bird species normally contend with. Predators of forest bird species may be presented with an added prey to their diet which may be easier to hunt than the sulking forest species which hide or camouflage in normal closed forests (Marini *et al*., 1995; Heske *et al*., 1999). Blouin-Demers and Weatherhead (2001) affirm this in their research on the Black Rat Snake (*Elathe obsoleta obsoleta*) that utilized the forest edge mostly for thermoregulatory purposes and not for foraging. Their findings showed that fragmented forests fashioned an environment essentially akin to that ideal for rat snakes in their natural habitat. This increased interaction between the snakes and nesting birds, which the snakes exploited as easy prey.

The Common Stonechat, being a territorial species, is involved in territorial defense (singing and aerial displays) totally aware that it is exposing itself as easy prey to forest generalist predators like the Black Kite (Storch *et al*., 2005) and to territory competitors like the Common Fiscal. The forest edges and forest glades of Kakamega forest in Isecheno did not have enough perches for the stonechat and the fiscal. Both species heavily utilize perches in foraging, a major factor for the two species in defining their territory (Soobramoney *et al*., 2004). Low availability of foraging perches means having larger territories for this species (pers. obs.). Both the Northern Fiscal and the Common Stonechat move through their territories using successive perches, which is a cost-effective strategy in terms of energy invested (Andersson *et al.,* 2009). The glades did not seem to offer as many perches as were present in the pure croplands, and the stonechats showed competitive disadvantages in relation to the Northern Fiscal (*Lanius humeralis*), Fiscal Shrike (*Lanius collaris*), and the Ruppell's Robin Chats(*Cossypha semirufa*) which also utilized the grassy glades for foraging and singing (BirdLife, 2017). In addition, the Fiscal Shrike also preys on the Stonechats' fledglings (Scheuerlein and Gwinner, 2006) making the territory uninhabitable, and in need of better reproductive strategies. This could affect the adults' ability to produce and fledge offspring in good timing with the reproductive seasons. All the energy spent on defending the territory and the nest may not leave much time for a male Stonechat to invest in feeding, and could be a possible cause for low weights recorded in this habitat, an observation also reported by Marler *et al.* (1995) on the male mountain spiny lizards (*Sceloporus jarrovi*). Their research entailed manipulation of testosterone to intensify territorial defense. This is a sexually selected trait. Results showed that increased territorial defense showcased decrease in survival. They found the cause to be lower ratios of energy intake to energy expenditure, leading to lower body weights in the male mountain spiny lizards.

In competition with forest generalists for invertebrates exploiting the glades and forest edges in Kakamega forest, the Common Stonechat may also experience reduced uptake of what it needs for daily survival and for feeding its young. During breeding season then, it may forego feeding itself to feed the young and the incubating female. This phenomenon was observed differently in the pure croplands of Timau and Mataara which are expansive, with different crops grown that attract different species of invertebrates, thereby assuring open habitat species with greater food supply, even when the crops were harvested (Vickery *et al.,* 2002). Also, in the pure croplands, perches, and fences of various heights are enough for the open habitat species reducing the need to fight for larger territories, with the perch height varieties accommodating other grassland species' preference (Andersson and Bodin, 2009). Perches in the pure croplands are more visible than in the forest edges, enabling Common Stonechats to easily spot predators and flee from them. They may also be less predominant on a predators' prey list with bigger invertebrates and rodents that inhabit the pure croplands. It is thus expected that Common Stonechats in farmlands would have higher body weights with less predation pressure and in quality habitat than their counterparts on the forest edges and forest glades of Kakamega forest.

Burke *et al.* (2011), define an edge as the transition zone between two different habitats or land uses. Interaction between two different habitats results in an edge effect. The more habitats differ from each other in structure the greater the intensity of edge effect. Fonderflick *et al.* (2012) have stated that the response of a species to the edge of a habitat such as a forest or lake, may be negative, neutral or positive. Edges can negatively modify habitat for bird species when rates of nest predation or brood parasitism ('nest predation hypothesis) increase (Andren and Anglestam,1988; Soderstrom *et al.,* 1998), or shortages in food supply (reduced food supply hypothesis) (Burke and Nol,1998; Benton *et al.*, 2003). Negative behavioral responses to edges

describes why species avoid certain areas of habitat near edges. This prevents a species' full use of its main habitat in a landscape mosaic (edge-avoiding species). Species considered as having neutral response to edges will neither avoid nor get attracted to edges and, it is anticipated that they will unrestrainedly use the total amount of their principal habitat existent in the landscape mosaic. Reino *et al.,* (2009) found that Stonechats, Iberian Crested Larks (*Galerida cristata pallida*) and Corn Buntings (*Embereza calandra*) were among the open habitat species that showed positive response to forest edges in their study on how distance from plantation edges affect farmland birds in Portugal. These three species rely on invertebrates, whose abundance increases with fragmentation (van Halder *et al.,* 2010). The disturbed area and farmlands may have opened up vast food resources for a greater number of grassland species and provided forest generalists with expanded territories for foraging. This would lead to greater competition for these resources in all feeding guilds, especially for the insectivorous passerines, which all exploit the exposed invertebrates in the forest edges and farmlands (González-Gómez *et al,.* 2006).

In their research, Terraube *et al.* (2016) support this proposition through their research to show how forest edges are important habitats in evaluating avian abundance and richness, and in recording occurrence of sensitive species. They proposed the following mechanisms as the possible cause of this abundance and richness: (1) individuals mix as they disperse between adjacent habitat patches hence spill-over effects (2) resources present at the edge that are rare/ absent in nearby patches, and (3) increased access to complementary resources in two adjacent patches (van Halder *et al.,* 2010).

5.2 Body size

Body size estimation in birds is a challenge frequently faced by ornithologists. It is defined as the size of skeletal structure whereon soft tissues are supported. Body size is best measured as

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skeletal mass or lean dry mass. In real time, this is difficult to measure in live birds hence some surrogate variables are necessary. Past measures include wing, tarsus, or head lengths depending on the type of birds being examined.

In the study of a single species, using body mass singly as a measure of body size can give a poor estimate of size. A correlation is proposed between some linear dimension like wing, tarsus, head or tail length and body mass (Gosler *et al.,* 2010). Of the three linear measures selected to determine best predictor of body mass, hence size of Common Stonechats, the head length was found to give the highest correlation with body mass. Using this as a predictor of body size, the largest sized Common Stonechats were found in the farmlands interspersed with fallow land habitat, in Kinangop and Ol Kalou. Second largest birds were found in the pure croplands of Timau and Mataara. Third largest birds were found in the forest glades and forest edges of the tropical rainforest in Kakamega Forest and the smallest sized birds were found in the forest edges of a coastal montane forest habitat in the Taita Hills forests. Head length (bill and head) was endorsed as a suitable an index of body size by Monaghan *et al*. (1983) and Monaghan and Metcalfe (1986) for the following reasons: it correlates well with other body measurements, is reliable, replicable, is stable across age groups and does not vary seasonally like wing length. It is interesting that head length is the variable has emerged as the best estimator of body size away from the conventional wing length in the Common Stonechat.

Gosler *et al.* (2010), insist on a measure being found for passerine species when dealing with intraspecific body size differences and advise against the conventionally assumed wing length as estimator of body size for all passerines. It is worth noting that had body weight been used on its own without a linear dimension to estimate the body size, the largest sized birds would be found in the pure croplands of Timau and Mataara. However, the determination of the linear dimension

and the regression thereof, has showed that the largest sized birds were found in the farmlands interspersed with fallow land in Kinangop and Ol Kalou. This study shows that differences in habitat could have an influence on the body size of the Common Stonechat populations. The particular combinations of factors in these habitats that contribute to differences in size can be interesting subjects of future research.

5.3 Conclusion

The results of this study demonstrate the use of biometric data in finding intraspecific body size and the differences thereof in sedentary populations of a common passerine. The findings have also showed that differences in habitat can affect body size in common bird species.

5.4 Further research and recommendations

5.4.1 Further research

Further research could entail investigating specific factors in the habitats that influence the morphology of the Common Stonechat species as it adapts to each habitat in its wide geographical range in Kenya.

Further research could also utilize the dawn choruses that were collected to assess whether body size and habitat affect their vocal displays and song characters.

5.4.2 Conservation action

The presence of an open habitat bird species near forest edges should alarm conservationists that forests are being opened up and there is loss of canopy cover. This should prompt action towards restricting anthropogenic activities that can render forests vulnerable to deforestation activities. The Common Stonechat as mentioned earlier is a bio-indicator that there is increased open habitat and less forest cover especially near forests like Taita Hills forest and Kakamega tropical rainforest.

5.4.3 Management actions

Even though the Common Stonechat is a common bird species that can persist and thrive with modification of habitat, certain needs like quality breeding sites that are undisturbed would enable the species to thrive. There is need to educate more farmers to allow more strips of fallow land for this species and other grassland species that nest on the ground and need certain amounts of vegetation available.

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