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Contrasting non-breeding ecology of Swainson's Thrush (Catharus ustulatus) in Andean forest and shade-grown coffee plantations

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Abstract

Shade-grown coffee plantations provide Neotropical migratory birds an alternative to primary growth forest which is disappearing throughout their non-breeding range. However, it remains unclear whether plantations can provide enough structure to maintain viable non-breeding populations of many species. I studied Swainson's Thrush (*Catharus ustulatus*) in the Colombian Andes in a mixture of montane forest and shade-grown coffee plantation. In comparing the two habitats I looked at factors indicative of habitat quality, such as age/sex hierarchies, area of concentrated use, density, diet, and migration timing. My research aimed to determine whether Neotropical migrants benefit from this agroecosystem, and to find possible ways of improving shade-grown coffee practices in the future. My results indicated forest is more suitable non-breeding habitat for Swainson's Thrushes, and although a forested habitat is more suitable, shade-grown coffee provides an acceptable supplemental habitat in a region where increased agricultural use continues to reduce forest availability.

Keywords: Avian, Swainson's Thrush, Neotropical Migrant, Shade-grown Coffee, Andean Forest, Nonbreeding Habitat, Habitat Selection, Migration, Motus, Radio Telemetry, Deforestation, Stable Isotopes, Colombia

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Co-Authorship Statement

This thesis was developed by Sean J. McElaney under the supervision of Keith A.

Hobson at the University of Western Ontario. All work was done in collaboration with

Keith A. Hobson and Ana M. Gonzalez-Prieto. Data collection was primarily completed

by Sean J. McElaney and Ana M. Gonzalez-Prieto and analysis was completed by Sean J.

McElaney. This thesis has been written by Sean J. McElaney and any resulting

publications will be published with Keith A. Hobson and Ana M. Diaz-Prieto.

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List of Abbreviations

AICc - Akaike information criterion, small sample size corrected

AHY – After hatch year

ANOVA – Analysis of Variance

ASY – After second year

^{o}C – Degrees Celsius

^{13}C – Carbon-13

δ^{13}C – Stable-carbon isotopes

CO_2 – Carbon dioxide gas

dbh – Diameter at breast height

DNA – Deoxyribonucleic acid

EDTA – Ethylenediaminetetraacetic acid

g, mg – grams, milligrams

ha – hectares

µL, mL – microliters, milliliters

$MgCl_2$ – Magnesium chloride

min – minutes

mm, m, km – millimeters, meters, kilometers

mM, M – millimolar, molar

N_2 – Nitrogen gas

$\delta^{15}N$ – Stable-nitrogen isotopes

NaCl – Sodium Chloride

PCR - Polymerase chain reaction

s – seconds

SD – Standard deviation

SE – Standard error

SIBER – Stable Isotope Bayesian Ellipses in R

SWTH – Swainson's Thrush

SY – Second year

VHF – Very High Frequency

Introduction

Within recent decades, numerous migratory bird species breeding in North America have experienced significant population declines (Downes et al. 2011; Sauer et al. 2013; Sauer et al. 2017) with Neotropical migrants experiencing higher rates of decline compared with temperate migrants, or residents (Sauer et al 2013; Sauer et al. 2017). Causes for these declines are poorly understood because factors operating on breeding, non-breeding, and migratory stopover sites can contribute (Rappole and Mcdonald 1994; Marra et al. 1998; Norris et al. 2004; Norris 2005). Neotropical migrants may spend up to 8 months on their non-breeding grounds, therefore events in Central and South America are of particular concern (Rappole and Mcdonald 1994). Apart from direct habitat loss and fragmentation (Bender et al. 1998; Villard et al. 1999; La Sorte et al. 2017), factors such as habitat quality, climate, and intraspecific competition on the non-breeding grounds have been shown to have carry-over effects influencing the migration and/or breeding success of these migrants (Marra et al. 1998; Norris et al. 2004; González-Prieto and Hobson 2013). It is well recognized then, that a more complete understanding of all aspects of a yearly migration cycle is key to understanding the overall cause of such declines (Greenberg and Marra 2005; Marra et al. 2015; Rushing et al. 2017). Unfortunately, following individual birds throughout their annual cycles is a daunting task (Webster et al. 2002). However, with the help of intrinsic markers such as naturally occurring stable isotopes and genetic markers, as well as a wide array of extrinsic markers such as light-sensitive geolocators and VHF radio transmitters small enough to be applied to songbirds, the toolbox for investigating population

structure and connectivity has increased substantially (Hobson and Wassenaar 2008; Hobson and Norris 2008; Bridge et al. 2013; Taylor et al. 2017).

1.1 Non-breeding Habitat Quality

Fretwell and Lucas (1969) defined habitat for birds as "any portion of the surface of the earth where a species is able to colonize and live" and stated that distribution of birds among different habitats is caused by habitat selection, wherein birds choose a habitat that will optimize their fitness. This selection of habitat is dependent on habitat quality, the measure of the ability of the environment to provide opportunities to increase fitness (Hall et al. 1997). For Neotropical migratory passerines, some of the best measures of habitat quality during the non-breeding season are food availability and vegetation structure (Sherry et al. 2005; Brown and Sherry 2006; Ruiz-Sánchez et al. 2017). Another commonly used measure of habitat quality during the non-breeding season is survival estimates of birds using them, as it is the most highly correlated with fitness. However, using survival to determine habitat quality may be impractical, since many of the effects caused by poor habitat quality do not manifest until birds have already departed non-breeding sites (Johnson et al. 2006). Thus, non-breeding habitat quality can produce "carry-over" effects to other parts of the annual cycle, such as migration and breeding, which can affect year-round fitness (Marra et al. 1998; Sillet and Holmes 2002; Norris et al. 2004; Norris 2005).

Other studies have focused on density of birds and territory sizes to quantify non-breeding habitat quality in Neotropical migrants (Marra et. Al 1998; Ruiz-Sánchez et al. 2017). Ruiz-Sánchez et al. (2017), studied Wilson's Warbler (*Cardellina pusilla*) in cloud

forests in central Mexico during the non-breeding season. That study was conducted on

three sites of various disturbance levels, one site with mature primary growth forest (low

disturbance), a second site with mixed primary and secondary growth forest (medium

disturbance), and a third site with highly fragmented cloud forest mixed with agricultural

land (high disturbance). Birds occupying the low disturbance site were found to have

better body condition, higher abundance, and occupied smaller territory size compared to

the other two sites.

It has been suggested that to better understand the effects of non-breeding habitat

quality on fitness, it is important to focus specifically on individual- and population-level

effects on one species. It is also important to develop a variety of measurements of

habitat quality instead of focusing on one well-known metric such as density, or territory

size (Van Horne 1983; Vickery et al. 1992).

1.2 Impacts of Non-breeding Habitat Selection

Perhaps the most influential studies on impacts of habitat quality on non-breeding

Neotropical migrants were conducted on American Redstarts (*Setophaga ruticilla*) in

Jamaica during the non-breeding season (Marra et al. 1998; Marra and Holberton 1998;

Strong and Sherry 2000; Norris et al. 2004; Studds and Marra 2005). This has become a

model study due to stark contrasts in habitat quality between moist black mangrove

forests, and adjacent xeric scrub habitats. Differences demonstrated in birds inhabiting

either scrub or mangrove habitats included differences in body condition, male/female

hierarchies, spring departure date, and arrival to the breeding grounds. Adult males were

shown to preferentially inhabit higher quality mangrove forests, whereas immature males

and females were more often found in scrub habitat (Marra et al. 1998). Food availability was found to be higher in mangrove forests, which in turn led to higher body condition and higher rates of survival (Marra and Holberton 1998; Strong and Sherry 2000). Migratory departure dates also differed between the two habitats, with birds occupying in black mangrove departing earlier than birds in scrub habitat (Marra et al. 1998). This difference in habitat quality was also shown to have carry-over effects into other stages of the migratory life cycle. Birds from higher quality mangrove habitat were found to arrive earlier on the breeding grounds, and to have higher reproductive success (Marra et al. 1998; Studds and Marra 2005; Norris et al. 2004).

Johnson et al. (2006) looked at shade-grown coffee in this same Jamaican-Redstart system during the non-breeding season and found that change in body mass and annual survival in shade-grown coffee were comparable to the best natural habitats in the area, mangrove forest. The authors suggested that further research be conducted to better understand how shade-grown coffee plantations compare as habitat to the forests from which they were created. Stating "although some agroecosystems may provide habitat for some species, they are not adequate replacements for natural forest and do not possess their complete suite of species or ecosystem functions."

1.3 Shade-grown Coffee

Habitat loss and degradation is the greatest threat to wild bird populations (Johnson 2007). Among common causes for habitat loss, agriculture is the most significant cause of songbird habitat loss in the Americas (Wilcove et al. 1998; La Sorte et al. 2017). Of great interest then, are ways in which agriculture in Latin America can be made more

compatible with the needs of resident and migratory wildlife. The coffee industry primarily uses "sun-grown" coffee wherein forest canopy is destroyed, and coffee plants (*Coffea arabica*) are grown in the open. However, shade-grown coffee plantations (hereafter shade coffee), which involve a canopy of trees to shade the plants, can be beneficial to migratory birds, especially when compared to sun-coffee plantations (Wunderle and Latta 1996; Perfecto et al. 1996; Colorado and Rodewald 2017). Shade coffee varies in structure, from "rustic" with a high variability in tree species and levels of shade, to "shaded monoculture" having a monoculture of shade trees, often as a secondary forestry crop, just to provide classification of shade coffee (Toledo and Moguel 1996). Shade coffee supports higher levels of biodiversity across many different taxa of flora and fauna when compared to sun grown (Perfecto et al. 1996). Shade coffee can provide habitat for pollinators (Klein et al. 2003) and other animals that control coffee pests (Karp et al. 2013), which in turn can reduce need for pesticides and fertilizers. However, other studies have shown the importance of maintaining adjacent intact native forests to maintain pollinator populations (Ricketts et al. 2004). With Andean forest estimated at less than 90% of their original extent (Henderson et al. 1991), shade-coffee plantations have become one of the few remaining suitable habitats for non-breeding Neotropical migrants in areas at mid-to-high elevation in Latin America (Perfecto et al. 2005). However, it is still unclear how birds use shade coffee habitat, and how beneficial shade coffee habitat is compared to native forests.

1.3.1 Coffee Production

Shade coffee also has benefits that reach beyond animals. When compared to sun coffee, shade coffee is better at reducing erosion (Rice 1990). Shade coffee requires less

large equipment and pesticides, making it easier and more cost effective to grow for small farms with limited resources (Perfecto et al. 1996). Sun-grown coffee plantations became popularized in the 1970's when coffee leaf rust (*Hemileia vastatrix*), a fungal infection found on coffee plants, made its way to Central and South America (Toledo and Moguel 2012). Shade coffee provided a moister environment for the fungus to survive and germinate (Lopez-Bravo and Virginio-Fillho 2012), leading farmers to change coffee practices to prevent the spread of the fungus. The fact remains that in large-scale coffee productions, such as large single owner plantations, sun coffee produces larger yields, which leads to higher profits (Perfecto et al. 2005). Therefore, it may be hard to convince large plantation owners to switch from current methods towards more sustainable and beneficial practices when profits may be reduced as a result, unless increased revenue from shade coffee as a preferred consumer product can compensate.

In 2016/2017 Colombia was the third largest producer of coffee in the world with over 250 million kilograms of coffee produced (ICO 2017). Over one million hectares are devoted to coffee production, almost all of which falls between 1,200 and 1,800 meters above sea level (Perfecto et al. 1996). The coffee industry in Colombia provides over 800,000 jobs and generates over two billion USD every year (ICO 2017). Coffee production in Colombia, as in many other countries in the tropics, shows no signs of slowing down. Therefore, it is important to focus research towards better understanding how to make coffee production more sustainable and beneficial to nature (Perfecto et al. 1996).

Despite the benefits of shade coffee, these traditional plantations are rapidly being converted to sun coffee. This is in part due to decreased yields and decreased profits in

comparison to sun coffee. Several organizations have created certifications for shade

coffee which in turn can make the beans more valuable (i.e. Smithsonian Migratory Bird

Center "Bird-friendly" Coffee, Specialty Coffee Association of America and Rainforest

Alliance Certification). These certifications incentivize coffee growers to maintain

biodiversity in exchange for higher sale prices. However, it is unclear whether the

increase in per unit value is enough for farmers to cover the money lost due to lower

yields in shade coffee (Perfecto et al. 2005), especially given the large differences in

requirements needed to meet these certifications (Mas and Dietsch 2004). Between 1970

and 1990, following the emergence of the coffee leaf rust disease in South America, at

least 60% of all coffee production in Colombia was converted from high diversity/high

shade systems to low diversity/low shade systems (Perfecto et al. 1996), with a newer

study finding an increase to 80% by 2013 (Escobar 2013). Overall abundance of high

quality shade-coffee plantations continues to decline worldwide (Jha et al. 2014).

1.3.2 Shade-grown Coffee as a Non-breeding Habitat

Shade coffee has many advantages. Compared to sun-coffee plantations, shade coffee has

been found to have higher species richness (Komar 2006). In fact, one study found avian

species richness in shade coffee to be similar to that of native forests (Tejada-Cruz and

Sutherland 2004). Other studies found birds in shade-coffee plantations to be as abundant

as in natural forest, or more so. This difference may be due in part to the difference in

detectability of birds between a dense forested habitat and a more open agricultural

habitat (Komar 2006, Bakermans et al. 2009, Gomez et al. 2013). However, abundance

does not always imply better habitat quality, and other more robust measurements should

be taken (Van Horne 1983). Additionally, this difference in abundance is extremely

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variable across species, especially birds that require a dense understory. Bayly et al. 2016 found Gray-cheeked Thrush (*Catharus minimus*) to almost exclusively use forest when compared to shade coffee. This study, however, was conducted during spring migration, and may hold different results than birds on the non-breeding grounds.

To date, most studies have focused exclusively on shade coffee (Wunderle and Latta 2000; Johnson et al. 2006; Colorado and Rodewald 2017), yet to better understand the quality of shade coffee habitat it is important to include a comparison to a natural forest habitat (Van Horne 1983; Johnson et al. 2006). Wunderle and Latta (2000) evaluated the importance of shade coffee as non-breeding habitat for three different migratory warbler species in the Dominican Republic. By comparing age and sex ratios, differences in body condition, and levels of site fidelity the authors found shade coffee to be a suitable habitat for non-breeding Neotropical migrants, with site fidelity and return rates between years in shade coffee to be at similar levels to that of nearby native forests.

A study by Bayly et al. (2016) drew comparisons in shade-coffee plantations and forest in the Sierra Nevada of northern Colombia. The study focused on Tennessee Warbler (*Oreothlypis peregrina*), and Gray-cheeked Thrush occupying shade coffee and forest as migratory stopover sites during spring migration. The authors found forest to sustain higher number of individuals of both species. Foraging rate, or the rate of pecking behaviors observed on fruit or insects, was higher in forest than in shade coffee. Body mass, and rates of mass increase over time for birds in forest was higher when compared to birds in shade coffee.

1.4 Studying Diet with Stable Isotopes

In addition to foraging rate, avian diet can be further studied with the use of stable isotopes ^{13}C and ^{15}N, when comparing individuals feeding on isotopically different food sources (Hobson and Clark 1992a, Hobson and Clark 1992b). Stable isotopes are useful when studying ecosystems due to their predictable changes during biological processes (Peterson and Fry 1987). Both ^{13}C and ^{15}N isotopes offer different insights into dietary composition. ^{15}N proportion, for example, can increase between three to four parts per million when increasing a single trophic level (DeNiro and Epstein 1981; Peterson and Fry 1987). ^{13}C proportion can change with different environmental conditions, including moisture and humidity, and microclimates caused by differential habitat structure (Broadmeadow et al. 1992; Broadmeadow and Griffiths 1993). Marra et al. (1998) used stable carbon isotopes to link habitat quality during the non-breeding season to migration timing in American Redstarts in Jamaica. Birds occupying lower quality xeric scrub habitats were found to have higher ^{13}C enrichment than birds occupying moist mangrove habitats.

Sampling different tissue types can impact the isotopic concentrations in the consumer when compared to the food source, in a process called isotopic fractionation. Both carbon and nitrogen discrimination factors are heavily influenced by tissue type sampled for isotope analysis (Hobson and Clark 1992a). Additionally, tissue type has been shown to vary greatly in turnover rate for isotopes (Hobson and Clark 1992b). Most tissue types such as muscle, liver, and blood have a turnover rate of weeks, whereas other tissues such as feathers or hair are inert and lock in an isotope concentration as they are produced (Hobson and Clark 1992b). These inert tissues can be useful to infer diet or

habitat quality for migratory animals during stages of the life cycle that cannot be observed directly (Marra et al. 1998), in addition to tracking large scale migrations of individuals (Hobson 1999). However, depending on the need of the study, there are different methods to obtain a sample that is more representative of the current state of an animal. For example, blood plasma has a turnover rate of only a few days (Hobson and Clark 1993), and breath sampling of CO_2 can be used in stable carbon analysis for its high turnover rate, with turnover beginning after only a few hours of a dietary shift (Ayliffe 2004).

1.5 Migration

Migration is often regarded as the costliest part of the yearly cycle of a Neotropical migratory bird (Sillett and Holmes 2002; Klaassen et al. 2014). Due to this period of increased risk, birds are assumed to minimize the amount of time and energy spent on migration (Alerstam and Lindström 1990; Alerstam 2011). In small birds, this generally entails long nocturnal flights (Lank 1989; Alerstam 2009) and minimized stopover time with maximized fat accumulation (Hedenström and Alerstam 1997). Early migratory departure and high migration speeds are associated with benefits in fitness gained from arriving earlier on the breeding grounds (Alerstam 2011, Nilsson et al. 2013) With maximized fat accumulation being important for long-distance flights, birds undergo a dietary shift shortly before migrating, wherein they increase their overall rate of consumption, and shift to a carbohydrate heavy diet (Bairlein and Simons 1995), however resource availability directly influences the ability for birds to put on fat. Birds living in lower quality habitat have fewer available resources which can affect migratory departure date (Marra et al. 1998). When comparing shade-coffee plantations and native forest

Bayly et al. (2016) found lower foraging success in shade coffee, which could in turn lead to later migratory departure. However, early migratory departure does not always imply improved fitness. Birds that migrate too early are often met with harsh weather conditions upon arriving in North America. These harsh conditions can cause a decrease in body condition (Robson and Barriocanal 2008), or an increase in mortality (Whitmore et al. 1977, Møller 1994).

For many migratory passerine species, different sex and age classes have different migratory strategies (Francis and Cooke 1986). One example of such a difference is protandry, wherein males arrive at breeding sites earlier than females. Protandry has been reported in many migratory bird species (Morbey and Ydenberg 2001; Morbey et al. 2012). Morbey et al. (2012) found evidence of protandry in 71 species of migratory birds, with males arriving 5.2 days earlier on average than females across species. Possible mechanisms underlying protandry include different migratory departure dates, differences in migration speed, and differences in non-breeding range (Coppack and Pulido 2009).

1.6 Study Species

Swainson's Thrush (*Catharus ustulatus*), a long-distance Neotropical migrant, breeds throughout Canada and parts of the United States (Figure 1). Their population can be broken down into two groups: the "Russet-backed" group and the "Olive-backed" group. These two groups differ genetically, and in breeding and non-breeding ranges (Mack and Yong, 2000). The group I will focus on is the "Olive-backed" group. Their breeding habitat includes mostly fir-spruce forests and other coniferous and deciduous forests with

a dense understory, ranging from northeastern United States and Canada, westward

through the Rocky Mountains and into Alaska. During the non-breeding season,

Swainson's Thrush can be found in the Andes Mountains of South America, mostly in

closed-canopy forest but also in shade-coffee plantations. During the non-breeding

season, Swainson's Thrushes have a diet abundant in fruit, however will also eat insects

such as caterpillars, beetles, and ants (Mack and Yong, 2000; Jones et al. 2002).

Swainson's Thrushes, like many other Neotropical migrants, spend around half of the

year on their non-breeding grounds, three or four months on their breeding grounds, and

around two months on migration (Mack and Yong, 2000). Although there have been

several studies of this species on the breeding grounds and on migration (Child 1969;

Johnson and Geupel 1996; Ruegg and Smith 2002; Sandberg et al. 2002), there is a lack

of knowledge of their basic ecology during non-breeding season (Mack and Yong, 2000).

On my field sites, Swainson's Thrush is the most common Neotropical migratory bird in

both shade coffee and forest habitats. This, combined with their size, made them a

suitable candidate for a radio telemetry study.

1.7 Objectives and predictions

On the non-breeding grounds, there is a lack of information on how migratory birds are

using the habitats available to them (Rappole and Mcdonald 1994). There is a suggestion

that non-breeding Neotropical migrants are habitat generalists and occupy a wider range

of habitat types than on the breeding grounds (Wunderle and Waide 1993, Sherry and

Holmes 1995). However, in certain systems, adult males control higher quality habitat

over females and subadults (Marra et al. 1993; Marra 2000), and territory size is affected

by habitat quality (Ruiz-Sánchez et al. 2017). Since habitat quality during this period is

clearly linked with overall survival (Sherry and Holmes 1996; Norris et al. 2004), and because this is the most poorly understood component of the full life cycle of Neotropical migrants, my thesis is focused specifically on the non-breeding period.

The objective of my research was to better understand the importance of shade-grown coffee plantations as a non-breeding habitat for Neotropical migratory birds in comparison to native forest. Due to high rates of deforestation in the Andes, it is important to develop a better understanding of how migratory birds fare in agricultural environments such as shade coffee. I used a series of field techniques to assess the differences in habitat quality between Andean forest and shade-coffee plantations at the individual and population level in Swainson's Thrushes.

Habitat structure has an impact on habitat quality in non-breeding migratory birds (Ruiz- Sánchez et al. 2017). To compare structure between shade coffee and forest I used six metrics of habitat structure to quantify structural differences, including canopy height, % cover, understory density, average dbh, dbh of largest tree, and tree density.

Birds are typically found at higher densities in higher quality habitat and occupy smaller spaces due to an increased abundance of food (Marra et al. 1998; Ruiz- Sánchez et al. 2017). I used line transects to determine density differences between shade coffee and forest. I predicted that density of Swainson's Thrush would be higher in forest than in coffee.

Little is known on Swainson's Thrush on their non-breeding grounds (Mack and Yong, 2000), and through personal observation it was not clear whether they demonstrate true aggressive territorial behavior. Therefore, to assess area used between two habitats, I

focused on their core area, or area of concentrated use (Clutton-Brock et al. 1982; Samuel et al. 1985). I used handheld radio telemetry to determine the effect of habitat quality on area of concentrated use in Swainson's Thrush. I predicted that birds living in forest would occupy smaller areas due to higher food availability and increased foraging success. I used the Motus Wildlife Tracking System to determine migratory departure dates. The study by Marra et al. (1998), found redstarts in higher quality habitat departed earlier for migration. I predicted that thrushes occupying a forest habitat would depart earlier for migration, as higher food availability will allow for them to generate fat deposits more quickly than those living in shade coffee habitat.

I used age and sex ratios to determine if there was a hierarchical habitat preference between shade coffee and forest. I predicted more adult males would occupy forest and more young males and females would occupy shade coffee. Such hierarchical habitat segregations are indicative of difference in habitat quality (Marra et al. 1998). I used transects to determine density differences between shade coffee and forest. I predicted density of Swainson's Thrushes would be higher in forest than in shade coffee due to a more diverse habitat structure allowing for higher abundance of birds.

I used focal bird sampling (Rodewald and Brittingham 2007; Bayly et al. 2016) to compare foraging rates and stable δ^{15}N, and δ^{13}C isotopes to compare diet composition between both habitats. I predicted higher foraging rates in forest than in shade coffee due to increased food availability. I predicted forest to have higher fruit abundance which would result in a lower trophic level relative to birds in coffee, and in turn lead to lower blood δ^{15}N values. I also predicted that birds occupying forest will have a more diverse diet which will lead to a broader range of blood δ^{13}C values.

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Figure 1. Range map of Swainson's Thrush (*Catharus ustulatus*) © 2015 Boreal Songbird
Initiative

Methods

2.1 Study Sites

Research was conducted from the beginning of January to the end of March, 2017 and 2018, in the Eastern Andean Cordillera of Colombia (Figure 2.A). Data was collected on a pair of study sites (La Fragua (Figure 2.B), and Los Vientos (Figure 2.C)), separated by approximately 5 km near the town of Nilo, Cundinamarca, Colombia (4.306N, 74.620W). Sites are a mix of primary/secondary growth Andean forest and shade-grown coffee plantation at an altitude ranging from 1300-1700 m above sea level for forest, and 1300-1500 m for coffee. La Fragua is a large (~350 ha), single-owner plantation with a diverse canopy of shade trees, several small patches of forest, and a series of livestock pastures surrounding most of the forest and coffee. Los Vientos is a small town comprised of several small individually owned patches of shade-grown coffee. The diversity of shade trees present in shade coffee is lower at Los Vientos than that of La Fragua, however the forest is a much denser primary growth. Both sites are Rainforest Alliance Certified coffee producers (Sustainable Agriculture Network 2017), and both sites have an established banding, and avian blood isotope dataset developed over the past 4 years by colleagues. Swainson's Thrush is the most abundant Neotropical migrant on both study sites, and in both habitats.

2.2 Forest Structure

Since the composition of both habitats varied between sites, I took measurements of vegetation structure at different points (2017; n=98, 2018; n=45 in Los Vientos, and 2017; n=88, 2018; n=57 in La Fragua) for comparison. Points were chosen by creating a

50m by 50m grid plotted on a GPS, that covered our sites. At each point I visually

estimated canopy height (m), and % canopy cover. Understory density was rated on a

scale of 0-5. 0; bare ground (0% ground cover), 1; low density (20% ground cover), 2;

medium density (40% ground cover), 3; dense (60% ground cover), 4; very dense (80%

ground cover), 5; impassable, understory cannot be seen through (100% ground cover).

To determine tree size, dbh of the largest tree was measured, as well as dbh of 5

randomly selected trees. To determine density of trees (trees/m^2), one tree was selected at

random and then the distance to the five closest trees was recorded.

2.3 Banding and Transmitters

Passive mist netting with a series of 20, 36 mm mesh mist nets with differing lengths

(6m, 9m, 12m) per habitat was used to sample individuals daily. Netting occurred in the

morning from 06:00 to 11:00 h and again in the afternoon from 15:00 to 17:30 h. All

captured Swainson's Thrushes received a US Fish and Wildlife Service aluminum band,

and a subset received one of two models of radio transmitter, a Lotek NTQB-2 weighing

0.35 grams or a Lotek NTQB-3-2 (Figure 3) weighing 0.67 grams (Lotek, Newmarket,

Ontario). The two models of transmitter have pulse rates of 6.1 s and 10 s, respectively.

Radio transmitters were attached using the two-loop leg harness method demonstrated in

Rappole and Tipton (1991). Birds receiving a radio transmitter also received a colored leg

band on their left leg for easier confirmation during telemetry tracking. Birds were aged

according to feather characteristics described in Pyle (1997), as either, after hatch year

(unknown age), second year (immature), or after second year (adult). Birds receiving a

transmitter were also sampled for whole blood (brachial puncture, Owen 2011) to

determine sex. All other neotropical migrants captured in mist-nets were banded with US

Fish and Wildlife Service aluminum bands. Other common species included Gray-cheeked Thrush (*Catharus minimus*), Canada Warbler (*Cardellina canadensis*), and Mourning Warbler (*Geothlypis philadelphia*). For all birds, mass (g), and wing chord (mm) were measured, and visible subcutaneous fat was assessed following the 0-5 scale developed by Helms and Drury (1960).

2.4 Radio Telemetry and Motus

Following processing of an individual, a minimum of three hours was allowed before recording any telemetry locations. In my first season of field work (January-April 2017), I placed 65 radio transmitters on Swainson's Thrushes (La Fragua: 13 in forest and 7 in shade coffee; Los Vientos: 29 in forest and 16 in shade coffee). In the second season (January-March 2018) 83 radio transmitters were placed on Swainson's Thrushes (La Fragua: 20 in forest and 23 in shade coffee; Los Vientos: 26 in forest and 14 in shade coffee).

I operated three Motus towers (Motus; http://motus.org), two at the Los Vientos locality and one at La Fragua. Each tower consisted of 2-3, 9-element Yagi antennas attached to a SensorGnome receiver (www.sensorgnome.org) and was placed strategically to give as complete a coverage as possible of our montane field sites. Towers collected data 24 h/d and each individual detection gave identity of the bird, signal strength, and time. The data provided from towers allowed us to pinpoint the exact time a bird had departed from our sites.

For handheld radio telemetry, I used a Lotek SRX-600 telemetry receiver (Lotek, Newmarket, Ontario) attached to a five element Yagi antenna. Birds were followed daily,

with at least one detection taken per bird/d. Telemetry occurred from 06:00 -11:00 h and again from 15:00 – 18:00 h. Twice per week evening telemetry sessions were conducted which began 30 min after sunset. For each detection, date, time, habitat, tag ID, GPS location, bearing, and estimated distance to bird was recorded. If a bird was seen actively foraging, data recording began for focal bird sampling (see below).

Birds rarely strayed from the habitat in which they were initially banded. On only one occasion between the two years was a bird banded in forest and then found to occupy shade coffee habitat. This individual was removed as an outlier from our area of concentrated use analysis.

2.4.1 Night Telemetry and Temperature Sensors

Telemetry observations were collected at night to determine roosting locations. For nighttime observations, date, time, habitat, tag ID, GPS location, and bearing to triangulate the position of the bird were recorded with the assumption that the bird was not moving. To analyze triangulation of given points I used the R package "triangulation" (Milfeldt 2016). Due to time constraints these data were only collected for one site each year (Los Vientos: 2017, La Fragua: 2018). For each individual distance between mean daytime location and mean nighttime location was calculated to determine mean distance traveled between area of concentrated use and nighttime roost.

In 2018, I placed external temperature data loggers (HOBO© Pro v2 2x External Temperature Data Logger, Onset Computer Corporation, Bourne, Massachusetts) to record ambient temperature in forest and coffee at night. Over the course of the field season I distributed the five temperature loggers across forest and coffee at both sites.

GPS location, date, habitat, and site were recorded for each night the logger was placed. Each logger had two temperature probes; one was placed at a height of 2 m, and the other at ground level. I recorded nighttime temperature between 18:00 to 6:00h for each logger each night and used these data to compare differences between habitats.

2.5 Focal Bird Sampling

To quantify foraging behavior, I recorded attack rates (i.e. rate of pecking behaviors; Rodewald and Brittingham 2007, Bayly et al. 2016) for randomly encountered birds and tagged birds detected during radio telemetry during the 2018 season. For each foraging sequence, tag ID, date, time, habitat, duration of sequence until a bird was lost from view (s), the number of attacks on either insects or fruit, and substrate were recorded. An "attack" was considered a foraging event.

2.6 Density

Variable-width line transects (Bibby et al. 2000, Buckland et al. 2001, Diefenbach et al. 2003) were used to determine Swainson's Thrush density. Counts were conducted between 16:30-18:00h on 500 m transects for 20-30 min. Counts were alternated between habitats with at least two transects conducted in each habitat each week. Each individual Swainson's Thrush seen or heard was recorded at an estimated distance perpendicular to the transect rounded to the nearest 5 m. For each transect, I recorded time of day, duration of transect, and transect observer. Transects were completed by three individuals across the two years.

2.7 Stable Isotope Analysis

Due to delays in exportation of blood samples, samples for stable isotope analysis were collected during the 2014 and 2015 seasons by colleagues. Whole blood samples were collected (brachial puncture, Owen 2011) for use in isotope analyses randomly throughout the entire season. Blood samples (up to 70 µL) were collected using heparinized capillary tubes, then transferred and stored in microcentrifuge tubes with 95% ethanol to preserve the blood while in the field. Upon arriving in Canada, samples were processed for $\delta^{13}C$ and $\delta^{15}N$ at the Stable Isotope Laboratory of Environment and Climate Change Canada (Saskatoon, Saskatchewan, Canada) following methods outlined in Reed et al. (2018). Blood samples were removed from ethanol solution, freeze dried and powdered, then weighed (0.5 or 1.0 mg) into tin capsules. Samples were combusted and CO_2 and N_2 separated online using a Eurovector 3000 elemental analyzer (Eurovector, Milan, Italy) interfaced with a Nu Horizon (Nu Instruments, Wrexham, UK) triple collector isotope-ratio mass spectrometer via an open split and compared with a pure CO_2 or N_2 reference gas. Stable nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$) isotope ratios were expressed in delta (δ) notation as parts per mil (‰) deviation from the primary standards of atmospheric nitrogen and Vienna Pee Dee Belemnite carbonate standards, respectively. Using previously calibrated internal laboratory C and N standards (powdered keratin and gelatin), within runs, precision for $\delta^{13}C$ and $\delta^{15}N$ was better than 1‰.

2.8 DNA extraction/ Sex Determination

Swainson's Thrushes are not sexually dimorphic and using measurements such as wing chord and tarsus to determine sex can be inaccurate (Pyle 1997). To improve determination of sex, blood was collected on a subset of banded birds and placed directly on filter paper to later be processed for DNA sex determination. In birds, males are the homogametic sex with two Z chromosomes, whereas females have a Z and W chromosome. To determine sex, our samples were sent to the Berg lab at The University of Lethbridge. DNA was extracted from dried blood stored on filter paper, a 6mm circle of blood (~ 10 µL) was cut from the paper and extracted using a modified Chelex protocol (Walsh et al. 1991; Burg and Croxall 2001). Samples were placed in a 1.5 mL centrifuge tube with 300 µL of extraction buffer (0.1 M Tris pH 8; 0.05 M EDTA; 0.2 M NaCl; 1% SDS) with 5% Chelex w/v, 2.5 µL RNase (10 mg/ml) and 3.0 µL Proteinase K (20 mg/ml), and incubated for 12 hours at 50°C. From this, 200 µL of solution was transferred to a new 1.5 ml centrifuge tube with 300 µL 1x low TE (10 mM Tris pH 8; 0.1 mM EDTA) with 5% Chelex w/v. Sex was then determined by using PCR and the P8/P2 primer set to amplify the chromo helicase DNA-binding genes of the Z and W sex chromosomes (Griffiths et al. 1998). For Swainson's Thrush, this reaction produces a 355 base-pair product from the Z chromosome and a 390 base-pair product from the W chromosome. DNA extractions were diluted 1:20 for PCR amplification. PCR conditions (per 10 µL reaction) were 2.0 uL ClearFlexi Buffer 5x (Promega), 2.0 mM $MgCl_2$, 200 uM dNTP, 1.0 µM each primer, 0.5 units GoTaq (Promega) and 1 µL 1:20 dilution DNA template. The cycling conditions were as follows: 1 min 30 s at 94°C, 35 cycles of 30 s at 94°C, 45 s at 26 48°C, 45 s at 72°C and a final extension of 5 min at 72°C followed by 5

s at 4°C. PCR products were then run on a 3% agarose gel with a negative control and sex was manually scored by an observer based on the presence or absence of the W chromosome.

2.9 Statistical Analysis

All statistical analyses were performed using RStudio Version 1.1.453 and R version 3.5.0 statistical software (RStudio Team 2018; R Core Team 2018). For all models, I used Akaike's information criterion corrected for small sample sizes (AICc) to determine the best fit model. (Burnham and Anderson 2002). The best model was determined as the model with the lowest AICc value, except when there was more than one competitive model (ΔAICc < 2) in which the simpler model was selected.

2.9.1 Departure Date

I analyzed all Motus tower data using R 3.5.0 (R Core Team 2018) to determine the exact date of departure. Date of departure was defined as the last day the bird was detected by an on-site Motus tower. I looked at the hour of departure as well as departure signal to determine whether the bird had truly migrated or simply abandoned the site. Swainson's Thrush are a nocturnal migrating species (Mack and Yong, 2000), therefore a final detection between 18:00 and 24:00 h was used as the definition of a migratory departure. Only birds that have shown a true night migration departure were included for further analysis of migration timing. Birds that were tagged later than 15 March were excluded from this analysis as this was the date of first migratory departure during both years. I then compared mean departure date using a linear model with age, sex, area of

concentrated use, habitat, site, year, and a habitat by site interaction as explanatory variables.

2.9.2 Density

Transect data was processed using the R package "mrds" (Laake et al. 2014). I removed the outer 5% of all detections, or the detections furthest from the transect line (Thomas et al. 2010). I used AICc to evaluate the best fit detection function (where the detection function is the probability of detecting a bird at a given distance, Marques et al. 2007). I evaluated half normal and hazard rate key function models and adjusted these key functions by adding a cosine (half-normal) or polynomial (hazard rate) series adjustment. I then used this detection function to evaluate distance sampling models with year, observer, habitat, time of day, duration of transect, and site as covariates. I used AIC_c, visual inspection of quantile-quantile plots, and Kolmogorov-Smirnov and Cramer-von Mises goodness-of-fit tests, to select my final model (Buckland et al. 2001, 2004).

2.9.3 Area of Concentrated Use

To calculate area of concentrated use, I used the minimum convex polygon method of home range analysis using the R package "adehabitatHR" (Calenge 2006) in which a polygon is created using the outermost observations, and the area inside is considered the home range (Mohr, 1947). However, this calculation is highly influenced by points taken on the periphery of the home range (Harris et al. 1990). To mitigate this problem other studies have reduced the number of observations to include between 60-95 percent of all observations (Mohr and Stumph, 1966; Clutton-Brock et al. 1982). Since I was interested in an area of concentrated use and not a large home range value, I used a polygon

containing 65 % of total observations after visually inspecting the data. I then used a general linear model to compare area of concentrated use with habitat, age, sex, year, site and a habitat by site interaction.

2.9.4 Stable Isotopes

For analysis of stable isotope diet data, I depicted blood sample isotope data in biplots and examined age/sex/habitat groups using the Bayesian ellipse approach using the R package SIBER (Jackson et al. 2011). Biplots consisted of $\delta^{13}C$ on the x-axis, and $\delta^{15}N$ on the y-axis and allow for the comparison of isotopic niche space between the two habitats. I also used linear models comparing $\delta^{13}C$ and $\delta^{15}N$ stable isotope values with date, habitat, site, sex, age, and a site by habitat interaction.

2.9.5 Age/Sex Ratios

To determine differences in age and sex ratios between habitats I used chi-square tests. Tests were completed for age and sex separately, with one test being completed for each year separately and both years combined. I kept age and sex tests separate since there was such a large disparity between number of birds of known age (n = 446) and birds of known sex (n=188). Expected values were calculated by multiplying the total number of captures in forest by the corresponding fraction for each age and sex in shade coffee and vice-versa.

2.9.6 Focal Bird Sampling

Foraging rate (number of attacks per minute) was not normally distributed due to many observations having zero attacks recorded. I assessed Poisson distribution, zero inflation,

and negative binomial linear models to determine best fit using AICc. I found the

negative binomial model to be the best fit and I used this to compare foraging rate with

age, sex, habitat, time of day, and date.

2.9.7 Night Telemetry

To view differences in distribution between daytime and nighttime habitat use, I used

kernel density estimators (Silverman 1986; Sheather and Jones 1991), using the kernel

density function in ArcMap 10.5 (ESRI 2017). Kernel estimators were created by

combining all daytime observations of all birds into one model and all nighttime

observations of all birds into another model. Kernel models were used to visually

demonstrate the difference in habitat occupancy between day and night. To supplement

the information from this model, I used a linear model to compare mean distance

travelled between daytime area of concentrated use and nighttime roost with habitat, site,

age, sex, and a habitat by site interaction.

2.9.8 Temperature

Ambient temperature data using the Hobo recorders was determined on a per night basis,

wherein I averaged temperature between both probes on a single logger for each night

between 18:00-6:00 h. I compared mean nightly temperature with date, habitat, site, and a

site by habitat interaction using a linear model.

2.9.9 Forest Structure

Metrics of forest structure included percent canopy cover (%), canopy height (m),

understory density (0-5), dbh of largest tree (cm), mean dbh of 5 trees (cm), and density

of trees (trees/m^2). These six metrics were first assessed for normality of data using Shapiro–Wilk test. I then compared differences between habitats and sites using one-way ANOVA, and Tukey post-hoc tests. All metrics were normally distributed (Shapiro-Wilk test of normality $p<0.05$).
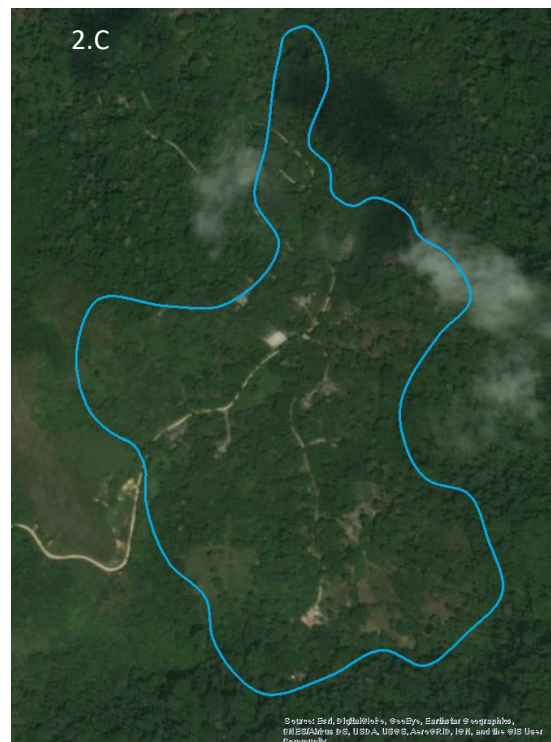
Figure 2. Maps of study sites. 2.A approximate location of sites in Colombia. 2.B La Fragua, area outlined in blue is shade coffee, and area outlined in green is forest. 2.C Los Vientos, area outlined in blue is shade coffee. Maps provided by ESRI (2017).

Figure 3. Lotek NTQB-3-2 radio transmitter tag affixed to the back of a Swainson's

Thrush (*Catharus ustulatus*) using a two leg-loop harness.

Results

A total of 446 Swainson's Thrushes were banded during the two years of field work, 188 of which were processed for DNA sex determination. VHF transmitters were placed on 185 Swainson's Thrushes and, of those, 136 were determined to have a migratory departure, and 86 birds were tracked long enough to analyze area of concentrated use. 315 individuals (from previous sampling by colleagues in 2014-2015) had blood samples processed for stable isotope analysis.

3.1 Departure Date

For both years combined, migratory departure was determined for 136 birds. The model containing habitat, age, sex, site, and habitat by site interaction was found to be significant (Table 1, $F_{5,129} = 8.91$, $R^2 = 0.3072$, $p < 0.001$). For both years, birds from shade coffee departed earlier by an average of 5 days (Figure 4, $p = 0.031$). Males departed on average 12 days earlier than females (Figure 5, $p < 0.001$).

Table 1. Results of linear model for migratory departure date (n=136) of Swainson's Thrush (*Catharus ustulatus*) departing from shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	Migration Departure Date			
	Coefficient	SE	t value	p-value
Intercept	107.155	2.733	39.197	< 2e-16 ***
Sex (Male)	-12.467	2.263	-5.507	2.74e-07 ***
Age (ASY)	3.682	2.264	1.626	0.107
Year	-	-	-	-
Habitat (Forest)	5.013	2.106	3.255	0.031*
Site	0.251	2.353	0.107	0.915
Habitat * Site	-	-	-	-
Age*Sex	-	-	-	-
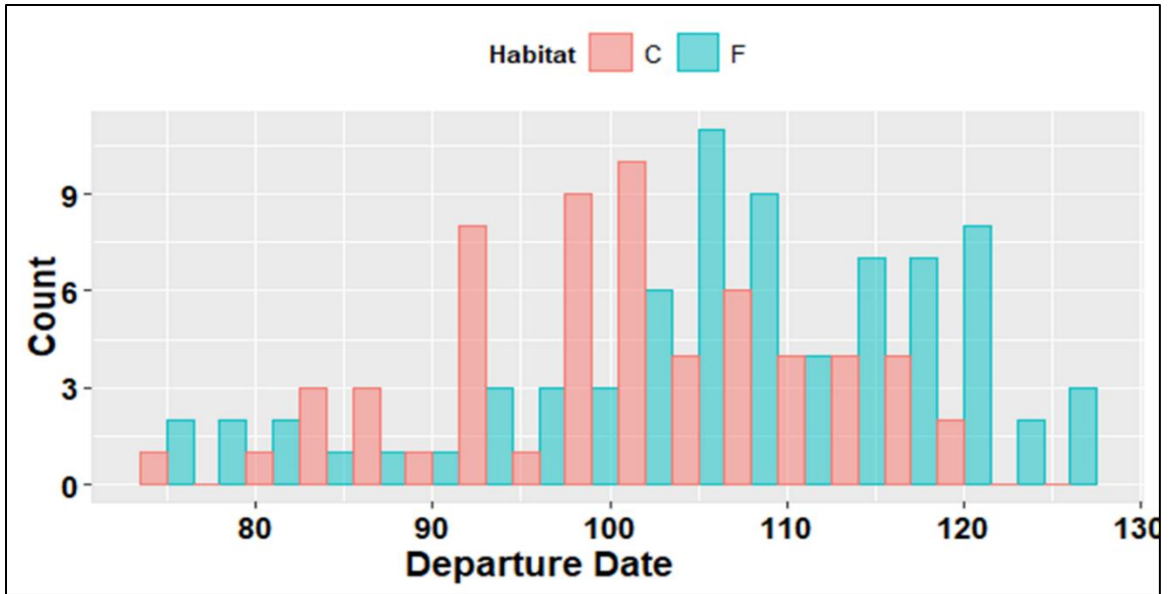
Figure 4. Distribution of migratory departure date of Swainson's Thrush (*Catharus ustulatus*) departing from two sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Results are separated by habitat type of shade coffee (red) and forest (blue). Birds living in shade coffee departed on average 5 days earlier than birds in forest (p = 0.031).
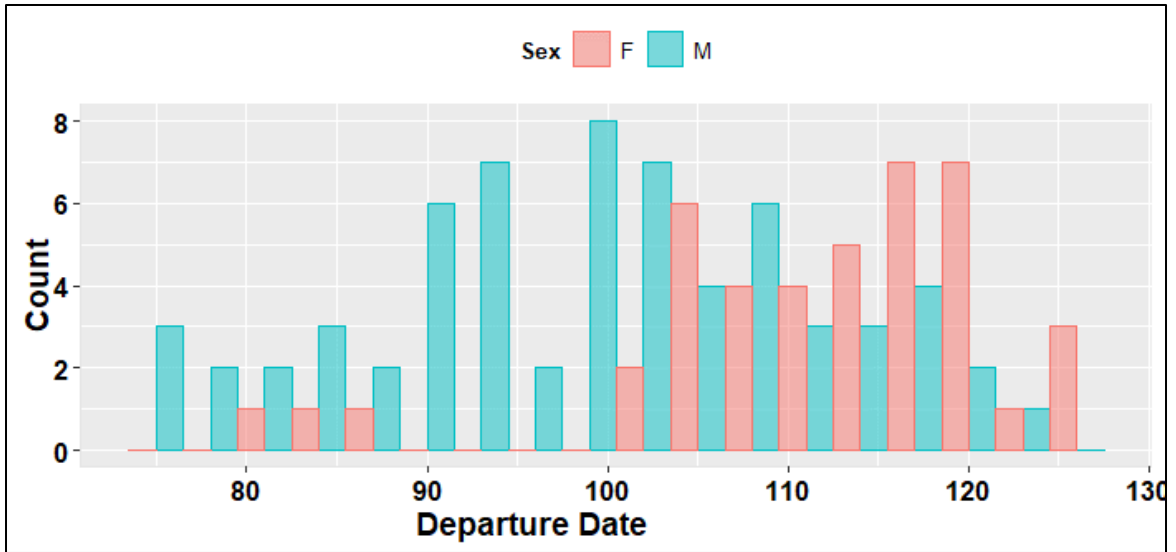
Figure 5. Distribution of migratory departure date of Swainson's Thrush (*Catharus ustulatus*) departing from two sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Results are separated by sex, male (blue, n=65) and female (red, n=42). Males departed on average 12 days earlier than females ($p < 0.001$).

3.2 Foraging Rate

Foraging observations were made on 89 occasions for a total of 41 minutes and 2 seconds. I excluded randomly encountered untagged birds since the number of observations was low (n=9 out of 98 total observations). I focused then only on tagged birds to account for differences in foraging rate between individuals. The negative binomial regression with habitat, time of day, and food type (insect, or fruit) controlling for duration of observation received the most support (Table 2, AICc = 281.57, w_i = 0.68). Birds in forest had a higher foraging rate than birds in shade coffee, 6.42 strikes per minute for forest and 3.15 strikes per minute for shade coffee (Figure 6). Food type was also found to impact foraging rate which reflects the observation that when birds foraged on fruit several strikes were often made on a clump of fruit where food was more concentrated, whereas attacks on insects were less concentrated. However, a model including a food type by habitat interaction was not supported (AICc = 293.12, w_i = 0.06), suggesting that diet composition did not vary much between habitats.

Table 2. Results of negative binomial model for foraging rate (n=89) of Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2018. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	Foraging Rate			
	Coefficient	SE	z value	p-value
Intercept	5.787	0.739	7.830	1.25e-11 ***
Habitat (Forest)	3.109	0.403	7.710	2.14e-11 ***
Time of day	-3.309	1.392	-2.377	0.019 *
Tag ID	-	-	-	-
Food Type (Insect)	-2.548	0.408	-6.240	1.65e-8 ***
Substrate	-	-	-	-
Date	-	-	-	-
Food Type * Habitat	-	-	-	-
Habitat * Site	-	-	-	-
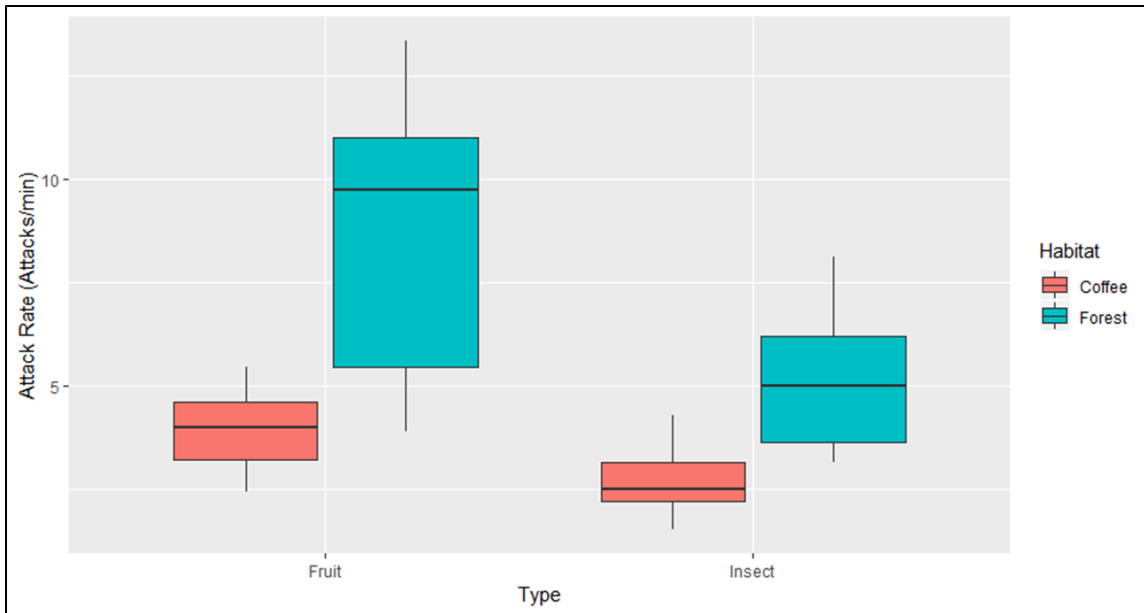
Figure 6. Comparison of foraging rates (attacks/minute) of Swainson's Thrush (*Catharus ustulatus*) inhabiting two sites (La Fragua and Los Vientos) in the Colombian Andes in 2018. Comparisons were drawn between two habitats, forest (blue) and shade coffee (red) differentiating between food items (fruit vs. insects). Rectangles represent the interquartile range, the dividing line is the median, while whiskers represent maximum or minimum values.

3.3 Age/Sex Ratios

Combining data from both years, both sites and both habitats, the sex ratio differed from 1:1. I found an approximately 2:1 ratio of males to females with 122 males and 66 females recorded on our sites. Our age ratio was close to 1:1 with 233 adults to 213 immatures. There was no difference in sex ratio between habitats either year (2017: $x^2 = 2.012$, $p = 0.16$, 2018: $x^2 = 0.562$, $p = 0.45$). When combining years, I still found no difference in sex ratio ($x^2 = 2.471$, $p = 0.11$). Similarly, there was no difference in age ratio between habitats either year (2017: $x^2 = 0.705$, $p = 0.55$, 2018: $x^2 = 0.013$, $p = 0.90$). When combining years, I found no difference in age ratio ($x^2 = 0.235$, $p = 0.63$).

3.4 Density

Over both years, on 65 transects, a total of 1183 Swainson's Thrushes were detected. To estimate density, I used half-normal detection function with cosine adjustment (AICc = 561.24, $w_i = 0.96$). Density estimates varied greatly with date, as migratory Swainson's Thrushes from other locations began moving through our sites around 10 March both years. However, forest had a consistently higher density than shade coffee on average (Figure 7, Forest = 68.47 birds/km^2, Coffee = 42.96 birds/km^2). I found the model comparing density estimates with date, and habitat to be highly significant (Table 3, $F_{2,62} = 64.11$, $R^2 = 0.6636$, $p < 0.001$).

Table 3. Results of linear model for density (birds/m^2) of Swainson's Thrush (*Catharus ustulatus*) based on line transects (n=65) taken in shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	Density			
	Coefficient	SE	t value	p-value
Intercept	-23.014	7.510	-3.064	0.00323 **
Habitat (Forest)	25.903	4.316	9.660	5.59e-14 ***
Date	1.110	0.115	6.002	1.11e-7 ***
Year	-	-	-	-
Site	-	-	-	-
Habitat * Site	-	-	-	-
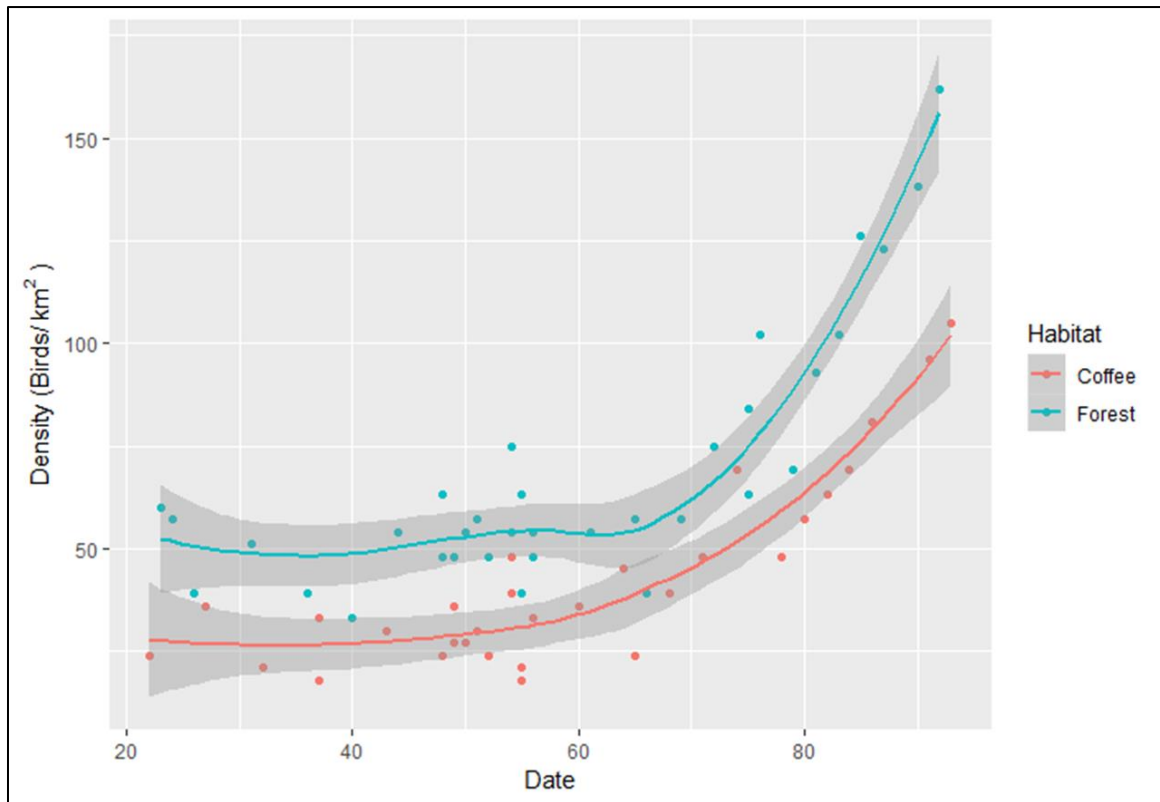
Figure 7. The density (individuals/km²) of Swainson's Thrush of Swainson's Thrush

(*Catharus ustulatus*) encountered in shade-grown coffee plantations, and forest on two

sites (La Fragua and Los Vientos) in the Colombian Andes in 2018. Density was higher

in forest (blue) than in shade-coffee plantations (red). Gray shading represents 95%

confidence interval. Density in both habitats increased over time. Estimates were

corrected for detectability using r package "mrds". Density was plotted over date of

survey to demonstrate seasonal variability during migration.

3.5 Area of Concentrated Use

Over both years, 86 birds were recorded with enough detections to calculate area of concentrated use. I found the model comparing area of concentrated use with age, sex, habitat, and site to be highly significant (Table 4, $F_{4,81} = 54.57$, $R^2 = 0.716$, $p < 0.001$). Birds in coffee occupied larger areas than birds in forest on average (Figure 8, Coffee = 1.268 ha, Forest = 0.328 ha). Females had slightly larger areas of concentrated use than males on average (Female = 0.798 ha, Male = 0.592 ha). No difference in area of concentrated use was found between our two sites.

Table 4. Results of linear model for area of concentrated use (n=86) of Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	Area of Concentrated Use			
	Coefficient	SE	t value	p-value
Intercept	1.353	0.084	16.046	< 2e-16 ***
Sex (Male)	-0.212	0.067	-3.190	0.0020 **
Age (ASY)	0.189	0.065	2.867	0.0053 **
Year	-	-	-	-
Site	-0.100	0.068	-14.012	0.143
Habitat (Forest)	-0.943	0.067	-1.48	< 2e-16 ***
Habitat * Site	-	-	-	-
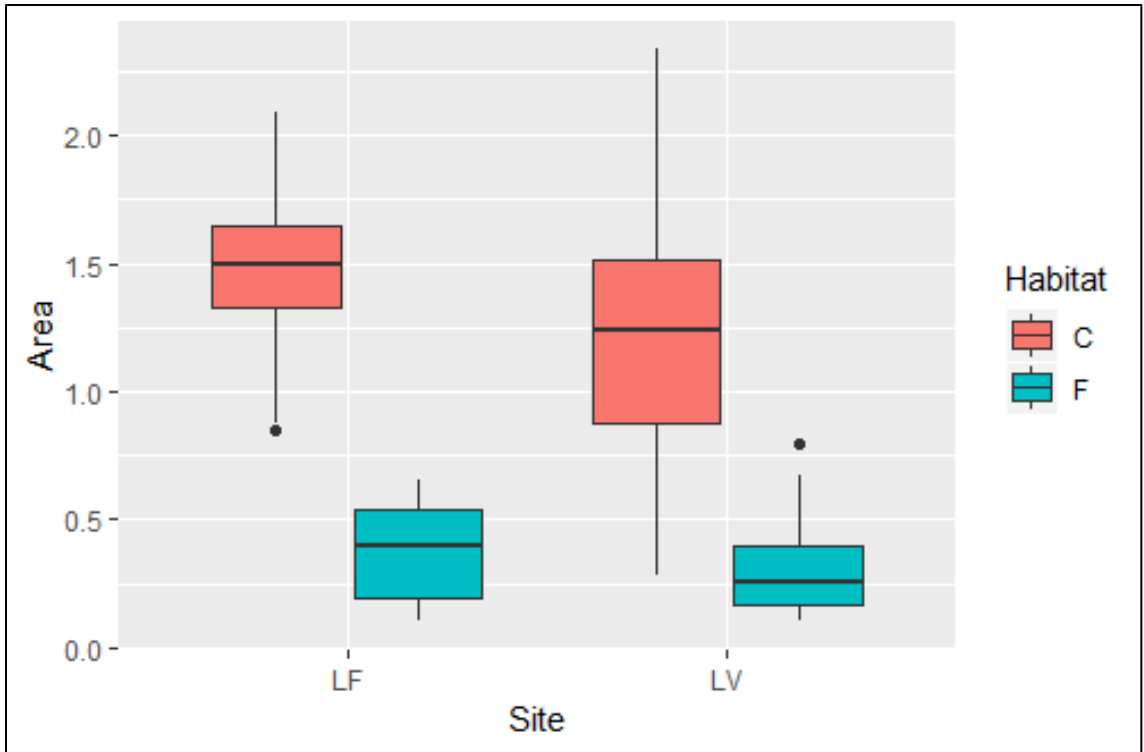
Figure 8. 65% Area of concentrated use (hectares) of Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and forest at two different field sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Area of concentrated use was lower in forest (blue) than in shade-coffee plantation (red). Boxplots are further separated by site. Rectangles represent the interquartile range, the dividing line is the median, while whiskers represent maximum or minimum values, and dots represent outliers beyond 1.5 times the interquartile range.

3.6 Stable Isotopes

Stable isotope samples for 315 Swainson's Thrushes were obtained in 2014 and 2015. Blood $\delta^{13}C$ values ranged from -29.6 to -20.90 ‰, while blood $\delta^{15}N$ values ranged from 1.5 to 13.8 ‰. For $\delta^{13}C$ values, the model containing site, habitat, and date was highly significant (Table 5, $F_{3,311} = 37.18$, $R^2 = 0.257$, $p < 0.001$). For $\delta^{15}N$ values, the model containing site, habitat, and habitat by site interaction was highly significant (Table 6, $F_{3,311} = 22.94$, $R^2 = 0.173$, $p < 0.001$). Values of $\delta^{15}N$ were higher in shade coffee than in forest, which is consistent with lower fruit abundance in shade coffee. When comparing values in isotopic space, large amounts of overlap between both habitats were found when controlling for site (Figures 9, 10). However, when comparing between the two sites, birds in La Fragua had a larger dietary breadth (Figure 11).

Table 5. Results of linear model for δ^{13}C values (n=315) found in blood samples taken from Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2014 and 2015. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	δ^{13}C Values			
	Coefficient	SE	t value	p-value
Intercept	-26.356	0.142	-185.235	< 2e-16 ***
Date	1.190	0.154	7.716	0.0011 **
Site	0.008	0.002	3.287	1.64e-13 ***
Habitat (Forest)	-0.623	0.151	-4.134	4.58e-05 ***
Habitat * Site	-	-	-	-

Table 6. Results of linear model for $\delta^{15}N$ values found in blood samples taken from Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2014 and 2015. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	$\delta^{15}N$ Values			
	Coefficient	SE	t value	p-value
Intercept	5.785	0.1942	29.788	< 2e-16 ***
Date	-	-	-	-
Site	0.182	0.2758	-0.658	0.143
Habitat (Forest)	-1.404	0.2484	-5.656	3.51e-08 ***
Habitat * Site	1.399	0.3514	3.982	8.53e-05 ***
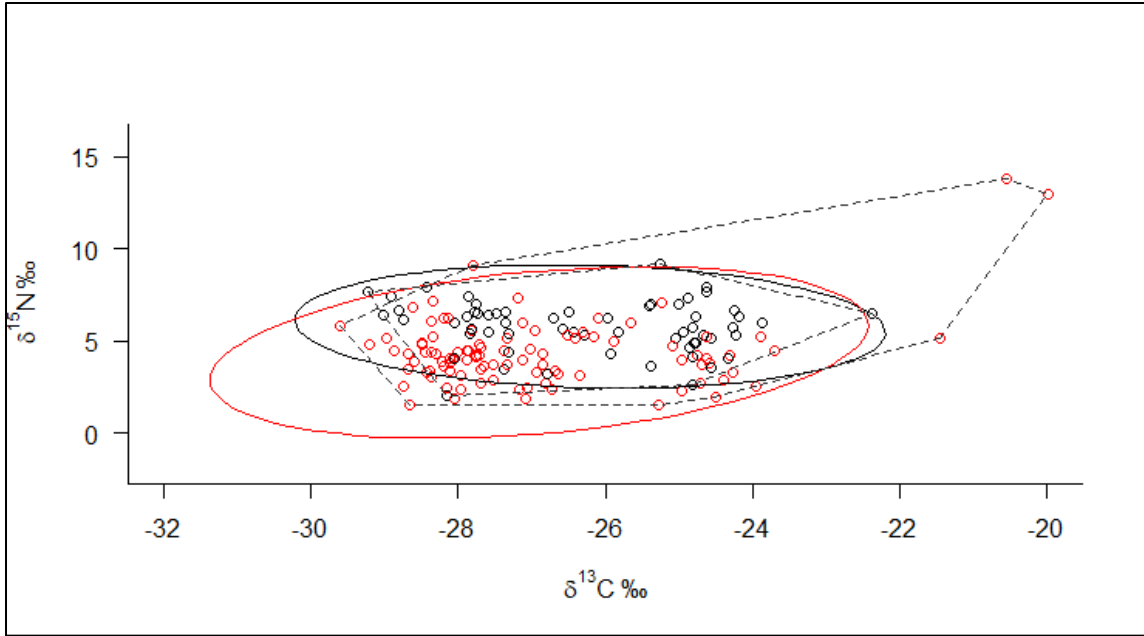
Figure 9. Siber ellipses of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable-isotope values from blood samples taken from Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on one site (La Fragua) in the Colombian Andes in 2014 and 2015. Points are separated by habitat type, forest (shown as black points) and coffee (shown as red points). Ellipses show normal distributions.
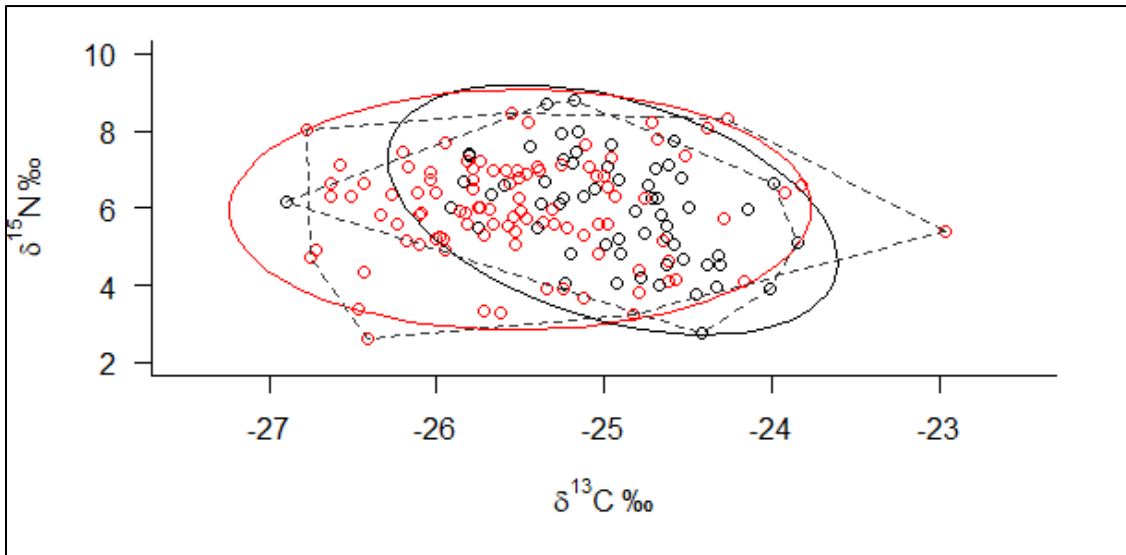
Figure 10. Siber ellipses of carbon (δ^{13}C) and nitrogen (δ^{15}N) stable-isotope values from blood samples taken from Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on one site (Los Vientos) in the Colombian Andes in 2014 and 2015. Points are separated by habitat type, forest (shown as black points) and coffee (shown as red points). Ellipses show normal distributions.
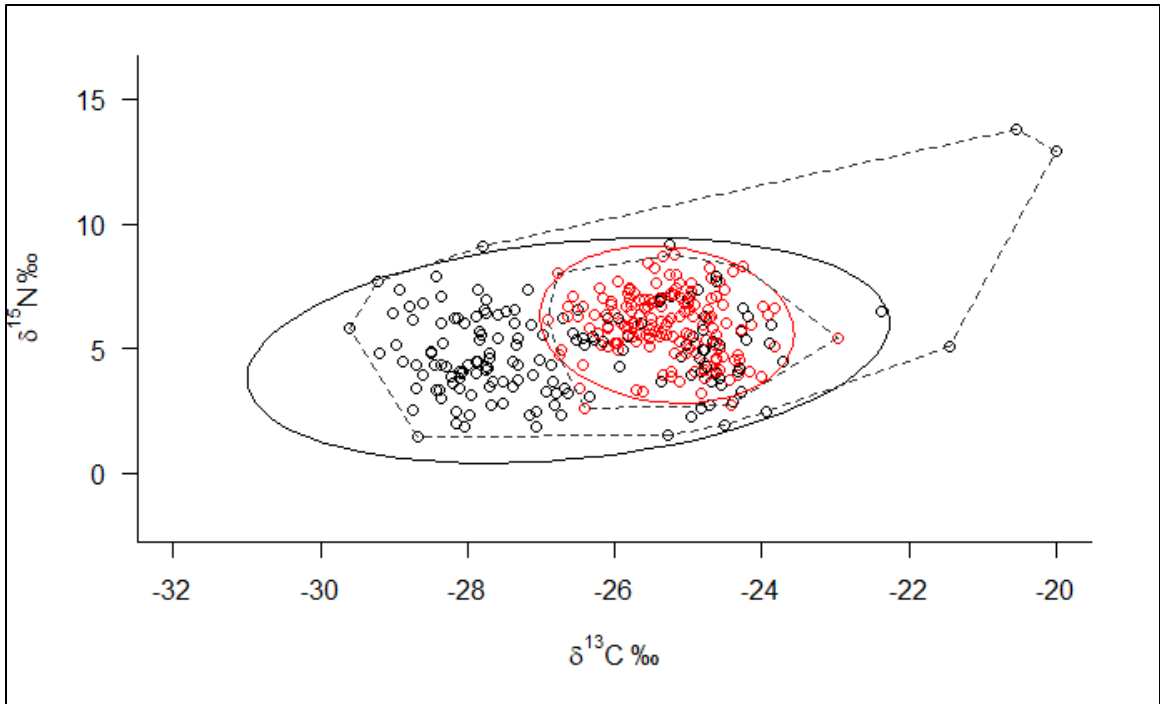
Figure 11. Siber ellipses of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable-isotope values values from blood samples taken from Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest on two sites in the Colombian Andes in 2014 and 2015. Points are separated by site, La Fragua (shown as black points) and Los Vientos (shown as red points). Ellipses show normal distributions.

3.7 Night Roosting

Roosting sites for 73 individuals were determined over both years, and distance from roosting site to center of core area calculated. The model comparing distance between daytime and nighttime habitat occupancy with age, sex, and habitat was highly significant (Table 7, $F_{3,69} = 51.13$, $R^2 = 0.6389$, $p < 0.001$). Birds living in shade coffee traveled further at night to roost than birds in forest, and typically moved from coffee to forest to roost: birds from shade coffee traveled 335.6 m on average and birds in forest traveled 99.1 m on average (Figure 12). Adults traveled on average 73.3 m further to roost than immature birds. No difference was detected between sexes. To illustrate differences in habitat occupancy between day and night I created kernel density estimators which plot the abundance of Swainson's Thrush detections (Figure 13,14).

Table 7. Results of linear model for distance between night roost and daytime core area (m) of Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest at two different field sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	Distance between daytime and nighttime habitat occupancy (m)			
	Coefficient	SE	t value	p-value
Intercept	382.54	21.55	17.751	< 2e-16 ***
Sex (Male)	-29.28	19.09	-1.534	0.1288
Age (ASY)	-73.30	18.88	-3.883	0.0002 ***
Year	-	-	-	-
Site	-	-	-	-
Habitat (Forest)	-227.13	19.48	-11.659	< 2e-16 ***
Habitat * Site	-	-	-	-
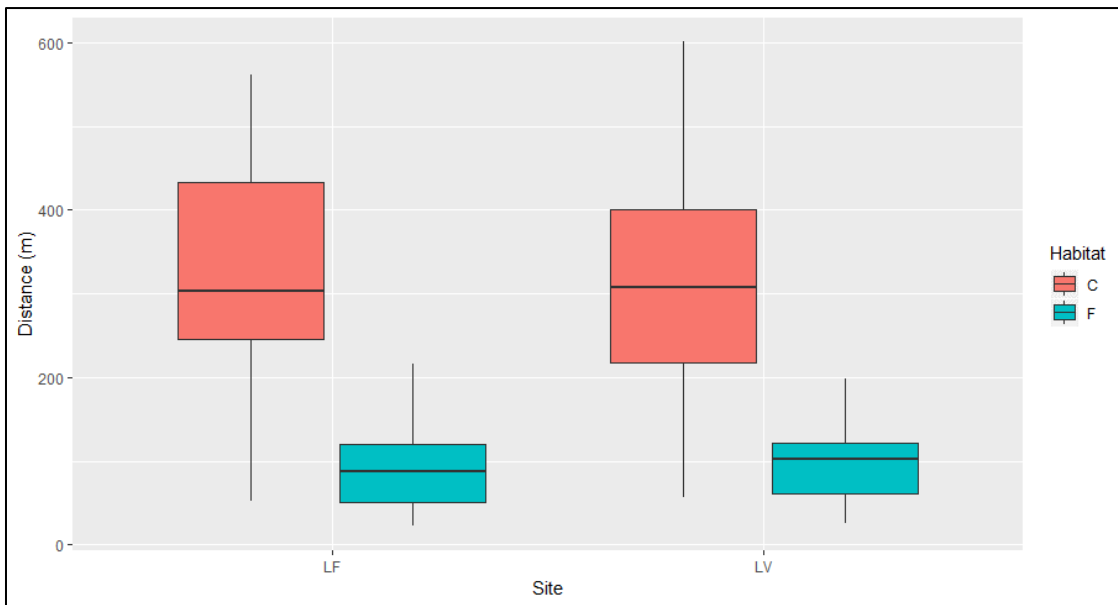
Figure 12. Distance between night roost and daytime core area (m) of Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest at two different field sites (La Fragua and Los Vientos) in the Colombian Andes in 2017 and 2018. Distance was lower in forest (blue) than in shade-coffee plantations (red). Boxplots are separated by site. Rectangles represent the interquartile range, the dividing line is the median, while whiskers represent maximum or minimum values.
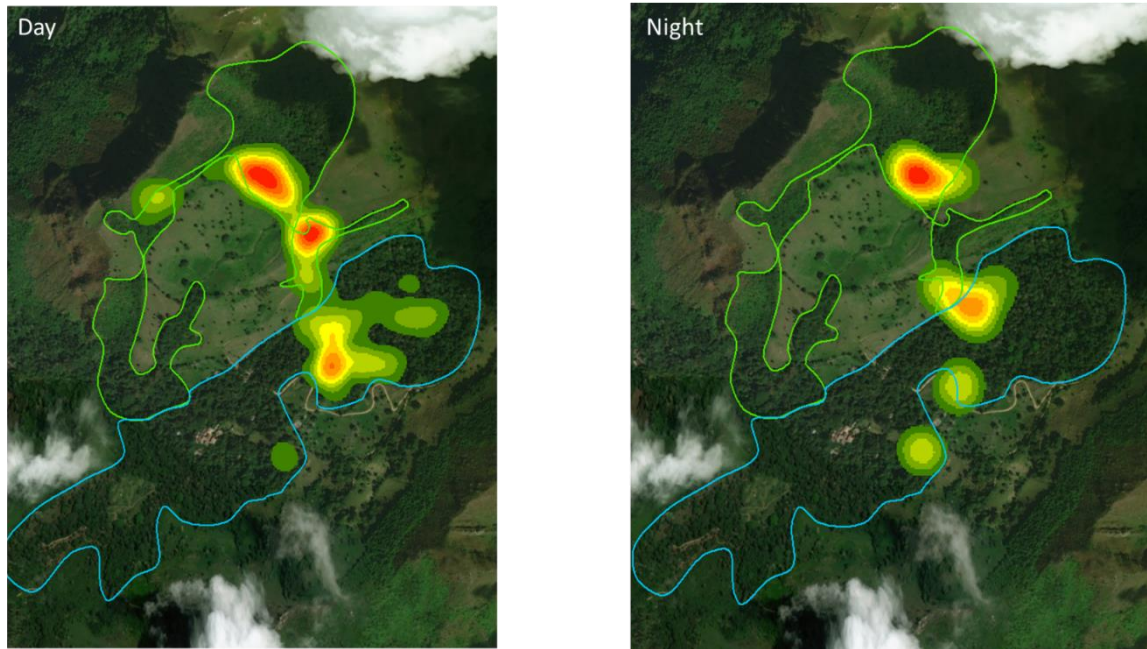
Figure 13. Kernel density estimator for daytime and nighttime habitat occupancy in Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest at a field site (La Fragua) in 2018. Daytime habitat occupancy on the left and nighttime roosting areas on the right. Red indicates high abundance of detections and green indicates low abundance of detections. The blue line outlines the shade-grown coffee plantation, and green outlines forest. Maps provided by ESRI (2017).
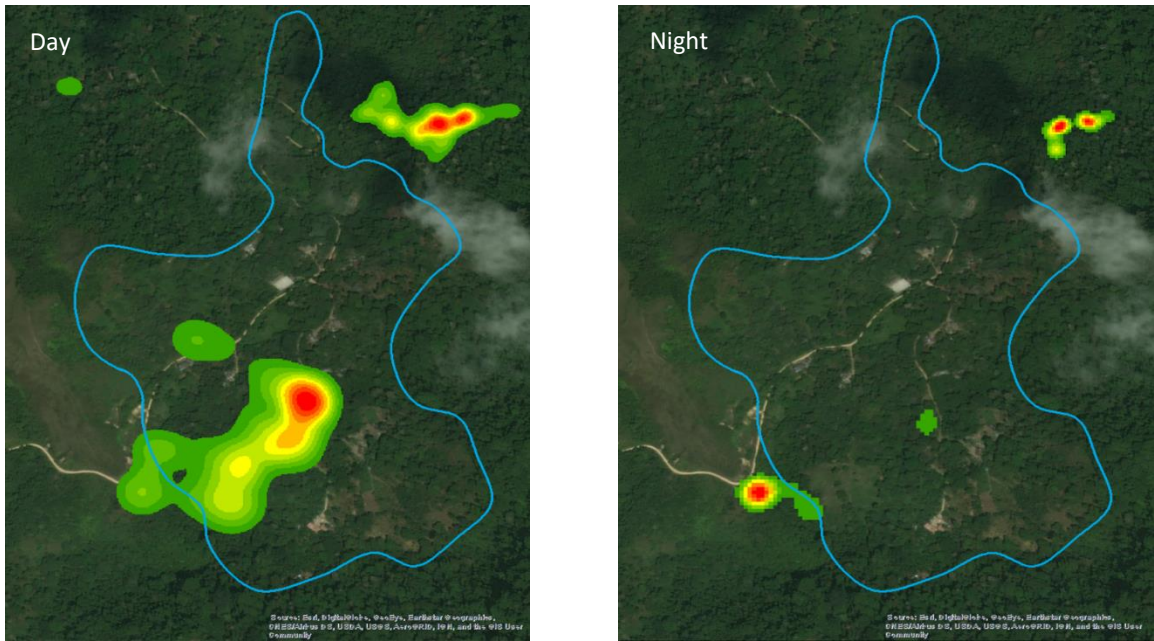
Figure 14. Kernel density estimator for daytime and nighttime habitat occupancy in Swainson's Thrush (*Catharus ustulatus*) inhabiting shade-grown coffee plantations and Andean forest at a field site (Los Vientos) in 2017. Daytime habitat occupancy on the left and nighttime roosting areas on the right. Red indicates high abundance of detections and green indicates low abundance of detections. The blue line outlines the shade grown coffee, everything outside the blue line is forest. Maps provided by ESRI (2017).

3.8 Temperature

Five temperature loggers were distributed on 66 different nights for a total of 330 overnight temperature recordings across shade coffee and forest. The model comparing temperature to habitat and date to be highly significant (Table 8, $F_{2,327} = 94.35$, $R^2 = 0.363$, $p < 0.001$). Forest was warmer than coffee at night by 0.8 ± 0.07 °C ($p < 0.001$).

Table 8. Results of linear model for mean overnight temperature (°C, n=330), recorded in shade-grown coffee plantations and Andean forest on two sites (La Fragua and Los Vientos) in the Colombian Andes in 2018. Dropped terms are noted by dashes (-), and significance is noted by asterisks (* < 0.05, ** < 0.01, *** < 0.001).

	Temperature			
	Coefficient	SE	t value	p-value
Intercept	18.99	0.102	185.328	< 2e-16 ***
Date	-0.016	0.002	-7.574	3.78e-13 ***
Habitat (Forest)	0.821	0.072	11.301	< 2e-16 ***
Site	-	-	-	-
Habitat * Site	-	-	-	-

3.9 Habitat Structure

288 points were surveyed for habitat structure over both years. All metrics were compared between sites and habitats using a one-way ANOVA. Differences were compared using Tukey's post-hoc test (Table 9). Percent canopy cover was higher in forest than coffee across both sites ($F_{3,383} = 139.30$, $p < 0.001$). Canopy height (m) was highest in shade coffee at La Fragua ($F_{3,383} = 8.49$, $p < 0.001$). Understory density was higher in forest than coffee across both sites, with Los Vientos forest having the highest understory density ($F_{3,383} = 149.38$, $p < 0.001$). Dbh of the largest tree (cm) was higher at La Fragua across both habitats ($F_{3,383} = 18.23$, $p < 0.001$). Average dbh (cm) was higher in forest than in coffee across both sites ($F_{3,383} = 72.30$, $p < 0.001$). Lastly, tree density (trees/m^2) was higher in forest than in shade coffee with Los Vientos forest having the highest tree density ($F_{3,383} = 59.08$, $p < 0.001$).

Table 9. Results of ANOVA and Tukey's post-hoc tests of mean percent canopy cover (±SE), canopy height (±SE), understory density score (0-5; ±SE), dbh of largest tree (±SE), mean dbh of 5 trees (±SE), and density of trees (±SE) recorded in shade-grown coffee plantations and Andean forest on two sites (La Fragua (n=145) and Los Vientos (n=142) in the Colombian Andes in 2017 and 2018.

	Habitat Structure					
	Canopy Cover (%)	Canopy Height (m)	Understory Density	Dbh of largest tree (cm)	Average Dbh (cm)	Tree Density (trees/m^2)
La Fragua Forest	81.72±9.86a	17.04±4.20b	2.64±0.95b	205.44±130.61a	38.54±31.95c	0.40±0.27a
Los Vientos Forest	80.70±15.90a	18.10±3.97b	3.59±0.89a	127.73±55.37b	23.68±7.97d	0.42±0.27a
La Fragua Coffee	44.59±21.86b	20.38±5.31a	1.40±.50c	245.08±130.14a	84.97±31.79a	0.03±0.05b
Los Vientos Coffee	36.72±19.58c	16.73±4.79b	1.20±.51c	164.12±65.39b	61.85±26.29b	0.05±0.09b

Note: Means in each column followed by the same letter are not significantly different (p<0.05) according to Tukey's HSD test.

Discussion

Shade coffee is commonly viewed as a suitable habitat for non-breeding Neotropical migrant birds (Wunderle and Latta 1996; Perfecto et al. 1996; Tejeda-Cruz and Sutherland 2004; Bakermans et al. 2012; Colorado and Rodewald 2017). However, there is still a lack of evidence that shade coffee is of equal quality to the forested habitat it has replaced (Komar 2006). In this thesis, I used a series of field techniques to assess the differences in habitat quality between Andean forest and shade-coffee plantations at the individual and population level in Swainson's Thrushes. Because bird density is typically higher in higher-quality habitats (Marra et al. 1998; Johnson et al. 2006; Ruiz- Sánchez et al. 2017), density of Swainson's Thrush was compared between the two habitats using line transects. Birds were found at higher densities in forest than in shade coffee. Age and sex classes in other non-breeding Neotropical migrants have been demonstrated to segregate between high- and low-quality habitat with adult males preferentially occupying high quality habitat (Marra et al. 1998). Age/sex classes are also known to depart for spring migration at different times (Francis and Cooke 1986). I compared age/sex ratios and spring departure dates between shade coffee and forest, finding no difference between habitats. Non-breeding Neotropical migrants use more space in lower quality habitats (Ruiz- Sánchez et al. 2017). I used minimum convex polygons to determine areas of concentrated use to compare habitat use between shade coffee and forest. Across both sites, Swainson's Thrush occupied larger areas in shade coffee than in forest, consistent with my predictions, suggesting forest provides better habitat than shade coffee for non-breeding Neotropical migratory birds.

4.1 Shade-grown Coffee as a Non-breeding Habitat

Although forest appears to provide superior habitat to non-breeding Swainson's Thrush in the Andes of Colombia, this does not imply that shade coffee does not successfully support populations of non-breeding Neotropical migrants. It is important, therefore, to compare differences in habitat quality with native forests before making any final conclusions on shade coffee as a method of conservation.

4.1.1 Density

Density of Swainson's Thrush was found to be almost twice as high in forest as in coffee. As the season progressed the density of Swainson's Thrush increased substantially, almost tripling across both habitats. Given that this increase began around 10 March in both years, the increase was likely caused by a migratory influx of Swainson's Thrush from more southern non-breeding sites. Interestingly, the ratio of thrush density between shade coffee and forest stayed close to the same during this migratory influx. This suggests that birds in both habitats are possibly interacting to reach an equilibrium.

The average density of birds in forest when exluding transects conducted after 10 March (n=22) was 51.45 birds per square kilometer. This value is similar to the findings of Sherry and Holmes (1988), where Swainson's Thrushes on the breeding ground in New Hampshire were found at a density of 56.1 birds per square kilometer in unfragmented forest. Suggesting that the density of Swainson's Thrush found in forest on our sites is comparable to denisities elsewhere in forested habitats, including on the breeding grounds.

4.1.2 Age/Sex Ratios

No differences were found in occupancy between age or sex classes. This is contrary to the findings of Marra et al. (1998), where more male American Redstarts were found in higher quality habitat. Although one possible explanation for this could be that shade coffee is of equal quality to forest, causing no need for habitat segregation, I suggest an alternative explanation. American Redstarts are sexually dimorphic with males being the larger sex, and males have been shown to be more territorial and aggressive than females (Marra 1998; Marra 2000). Swainson's Thrush on the other hand are not sexually dimorphic in size; only the extremes in size can be differentiated as males or females (Pyle 1997; Mack and Yong 2000), but there is a large amount of overlap. Additionally, Swainson's Thrush do not appear to demonstrate aggressive or territorial behavior on the non-breeding grounds (personal observation), which may account for a more equal distribution of males and females across habitats of varying quality.

4.1.3 Area of Concentrated Use

Area of concentrated use was lower in forest than in coffee. This result is consistent with the findings of Marra et al. (1998) and Ruiz- Sánchez et al. (2017), where Neotropical migrants occupied smaller areas in higher quality habitats. Females occupied larger areas than males on average across both habitats. Suggesting females are possibly settling for lower quality habitat than males within shade coffee and forest.

4.1.4 Diet

In comparing diet between both habitats, I used foraging rate and stable carbon and nitrogen istope measurments in blood to determine dietary differences. Foraging rate was

higher in forest than in shade coffee, which is consistent with previous research in shade

coffee systems (Bayly et al. 2016). Different isotopic values were detected between

habitats and between sites. Across both sites, birds in coffee showed higher blood $\delta^{15}N$

values, which is indicative of higher trophic level, or in the case of Swainson's Thrush,

higher rates of insect consumption compared to fruit (DeNiro and Epstein 1981; Peterson

and Fry 1987). This is likely a result of a reduced abundance of fruiting trees in shade

coffee. Across both sites, birds in coffee also showed higher blood $\delta^{13}C$ values, which is

consistent with previous results finding birds from drier, and lower quality non-breeding

habitat to have higher tissue $\delta^{13}C$ values (Marra et al. 1998; González-Prieto and Hobson

2013). This difference in ^{13}C proportion is brought on by different environmental

conditions, including moisture and humidity, and microclimates caused by differential

habitat structure (Broadmeadow et al. 1992; Broadmeadow and Griffiths 1993). The

denser canopy and overall habitat structure found in forest is likely the cause of this

difference.

4.1.5 Departure Date

Swainson's Thrushes occupying shade coffee departed earlier for migration by an

average of 5 days. This is contrary to my prediction that birds living in forest would

migrate earlier because higher food availability would allow for faster rates of fat

accumulation. Previous studies that have looked at the effect of habitat quality on

migration timing have found birds from lower quality habitat arrive later to breeding

grounds than birds from high quality habitat (Marra et al. 1998; González-Prieto and

Hobson 2013). However, these studies have not focused on departure date from non-

breeding sites, but instead at arrival on breeding sites. Other studies have focused on

departure date from non-breeding sites as a key driver of overall migration speed and arrival on breeding grounds, finding that birds departing earlier from non-breeding grounds arrive earlier on breeding grounds (McKinnon et al. 2014, McKinnon et al. 2016). However, with my results these two ideas appear to be contradictary. A possible explanation for this difference is that birds from shade coffee are departing earlier in search of sites with better opportunities for fat accumulation, and therefore take more time during stopover bouts which would lead to a longer migration.

Additionally, I found male Swainson's Thrushes departed our sites 12 days earlier on average than females. This is an example of protandrous behavior, which has been demonstrated in many migratory bird species (Morbey and Ydenberg 2001; Morbey et al. 2012). However, this is the first study to show differences in departure dates from non-breeding sites in Swainson's Thrushes.

4.1.6 Roosting Sites

Swainson's Thrushes spending the day in shade coffee traveled greater distances at night in search of roosting sites, travelling on average approximately three times the distance of birds in forest. Additionally, birds occupying shade coffee almost exclusively roosted in forest at night. Only 4 individuals, of a total 32 birds in shade coffee, did not move to forested habitat to roost. Of the remaining 28 birds that did roost in forest, roosting sites were typically on the periphery of the forest, or in small forest patches located within the confines of the shade coffee habitat. No birds using forest for diurnal habitat were found roosting in shade coffee at night. This result is consistent with the findings of Jirinec et al. (2011), where Black-throated Blue Warblers (*Dendroica caerulescens*) occupying coffee

farms in Jamaica were found to move out of coffee at night to roost in adjacent forest.

Smith et al. (2008) found a similar result with Northern Waterthrush (*Parkesia noveboracensis*) in Puerto Rico, where birds traveled up to two km each day to roost in high quality mangrove habitat.

This daily migration of birds between daytime and nighttime habitats is poorly understood and may be caused by multiple factors. One explanation is that birds are seeking an area with more forest structure to roost making them less susceptible to predators. Forest had higher understory density and higher tree density than shade coffee making the habitat more structurally diverse. Additionally, due to these structural differences, differences in average nighttime temperatures were detected on my sites with forest being around 0.8°C warmer than shade coffee. These warmer temperatures found in forest may make for more ideal roosting conditions. My results suggest that maintaining adjacent forests may help maintain viable non-breeding populations of Neotropical migrants by creating roosting sites that are beneficial to birds living in both shade coffee and forest. However, it is unclear whether birds would adjust to roosting within shade-coffee plantations in the absence of adjacent forests.

4.1.7 Habitat Structure

Habitat structure is an important indicator of habitat quality for non-breeding Neotropical migrants, with dense unfragmented forests being superior to habitats with low structural variation and high fragmentation (Ruiz- Sánchez et al. 2017). In surveying six metrics of habitat structure, I found forest to have higher density of trees, higher understory density, and more canopy cover. These metrics are more indicative of habitat structure, providing

different layers to the forest and higher biodiversity of plant species. Overall, forest is more structurally diverse than shade coffee.

Coffee and forest had similar canopy height and dbh of largest tree. This is due to the selection process of shade trees in shade-coffee plantations. When shade trees are selected as remnants of a native forest, they are often chosen based on their size and shade coverage (Perfecto et al. 2005), meaning the remaining trees are among the largest trees on the site and therefore are comparable to the largest trees in the forest. This is further exemplified when looking at average dbh of trees, the mean dbh of trees in coffee was more than double that of forest, due to the remnant tree population being chosen based on their size and shade capacity.

However, these results may not be generalizable to all shade-coffee plantations due to differences in shade quality across shade coffee systems and within a single plantation. Based on the criteria presented in Miguel and Toledo (1999) and Perfecto et al. (2003), shade coffee can be defined as one of four different classifications, which are defined by percent canopy cover and species richness of canopy trees. The classifications being: Rustic (71-100% canopy cover), Traditional Polyculture (41-70% canopy cover), Commercial Polyculture (31-40% canopy cover), and Shaded Monoculture (10-30% canopy cover). Given these criteria, my sites La Fragua and Los Vientos are classified as Traditional Polyculture and Commercial Polyculture, respectively. Shaded Monoculture differs drastically from the other classifications as it refers to a monoculture of trees, often non-native, chosen for their rate of growth and shade capabilities. (Toledo and Moguel 1996; Perfecto et al. 2005). These trees may be planted just to attain certifications associated with shade coffee production, or to create a secondary crop of

forestry trees to be used for lumber (Mas and Dietsch 2004). With such large variation in shade type, understanding the impacts of these differences on non-breeding Neotropical migratory songbirds is key.

4.2 Study Limitations and Assumptions

Within the time constraints of two years, I assessed the differences in habitat quality between two habitats across two sites. With that time constraint came a few assumptions and study limitations. Firstly, in my research I assumed that the population of Swainson's Thrush sampled was a representative sample of Swainson's Thrushes living in shade coffee and forest throughout the Andes. Due to mountainous terrain, mist netting was constrained to small portions of my sites, and therefore I did not have a homogenous sample of birds in each habitat. Due to the remoteness of our field sites, I carried a limited number of VHF transmitters to our banding stations every day. These transmitters were placed on the first available Swainson's Thrushes, sometimes leaving out birds caught later in the day. I do not believe this created any sampling bias within my data. Although birds may have been biased to sampling earlier in the day, birds were still sampled at random.

Both of our sites Los Vientos, and La Fragua, were sprayed with fungicides, and La Fragua was also sprayed with insecticides, a few times over the course of the field season. I did not collect any data on the type of insecticide or fungicide used or the frequency of which they were applied. I did not consider what effect these sprayings had on the birds. I believe that these sprayings are typical of any shade-grown coffee

plantation within the Colombian Andes and therefore would not have influenced the outcome of my study.

One important limitation to note is that a malfunction in the Motus tower placed near the forest of Los Vientos in May of 2017 might have caused the loss of some departure dates (n=6 out of 45 total birds tagged in forest), but I do not believe this would have changed my results. The information that was lost from this tower, if any, was late season departure dates from forest. My data already showed birds from forest to depart for migration later than from coffee so having these data could only strengthen this result. Additionally, for my departure dates, I assumed that the tower was able to pick up all departures, and that all true migratory departures took place between 18:00-24:00h. To determine nighttime roost data, I assumed that birds were not moving past sunset to be able to triangulate their position without visual confirmation. I waited thirty minutes after sunset to make sure birds had stopped moving and were settled into roosting sites. I do not think this assumption impacted my results.

By completing two years of data analysis I was able to make my results more generalizable. The two years had variation in weather patterns (personal observation): 2017 was drier in general, and 2018 was wetter, and I assumed that these two years were representative of a typical climate for this season in Colombia. Although shade-coffee plantations can be highly variable (Toledo and Moguel 1996; Perfecto et al. 2005), I assumed that my two field sites (La Fragua and Los Vientos) were representative of shade-coffee plantations and Andean forests in general.

4.3 Conservation Implications

In a region where deforestation rates are high (Wilcove et al. 1998; La Sorte et al. 2017), the purpose or goal of maintaining shade-coffee plantations should be to maintain a balance between agricultural practices and availability of suitable habitat for migrant and resident bird species. With Andean forests estimated at less than 90% of their original extent (Henderson et al. 1991), shade-coffee plantations play an important role as a supplementary habitat for non-breeding Neotropical migrants in areas at mid-to-high elevation in Latin America (Perfecto et al. 2005). Shade coffee provides higher quality non-breeding habitat for Neotropical migratory birds when compared to sun coffee, or other forms of agriculture which result in low habitat diversity (Wunderle and Latta 1996; Perfecto et al. 1996; Tejeda-Cruz and Sutherland 2004; Bakermans et al. 2012; Colorado and Rodewald 2017). Therefore, the relative importance of shade coffee as songbird habitat should not be undermined by the superior quality of a natural forested habitat. Instead, a more suitable conservation plan may be to combine the two habitats to create a mosaic of shade coffee mixed with remnant forest patches (Wegner and Merriam 1979). My results suggest that maintaining adjacent forests may help maintain viable non-breeding populations of Neotropical migrants with birds preferentially roosting in forest regardless of diurnal habitat.

Maintaining shade-coffee plantations and converting sun coffee to shade coffee could have major benefits to humans, to the environment, and to Neotropical migratory birds. I suggest greater efforts be focused on educating the public, by informing coffee farmers of the benefits of shade coffee, including increased per unit value, and possible increase in profit for small plantation owners (Perfecto et al. 2005). Then, possibly more

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importantly, increasing demand of shade coffee through increased awareness of the availability of certified sustainably grown coffee, and informing the general public of the importance of sustainability in coffee consumption. Lobbying for big name brands such as Starbucks to carry and promote shade-grown coffee in their stores could completely change the coffee industry.

4.4 Future Work

The results of this research suggest that native Andean forests provide superior non-breeding habitat for Swainson's Thrushes. However, there are many avenues for further exploration. Not all shade coffee is comparable (Toledo and Moguel 1996), so further research could be done to compare different levels or qualities of shade. Comparing forest to "rustic" shade-coffee plantations with minimal disturbance would likely provide different results than comparing forest to a shaded monoculture.

Although Swainson's Thrush can successfully utilize shade coffee as an non-breeding habitat, this does not imply all species of Neotropical migrants can survive in this agroecosystem. Similar to the results of Bayly et al. (2106), I found that Gray-cheeked Thrush, a close relative of the Swainson's Thrush, are rarely found in shade coffee. Of 72 Gray-cheeked Thrushes banded between both years, only 7 were banded in shade coffee. Further research is needed to understand which species can benefit from shade coffee, and which species still rely on native forests to thrive.

Shade coffee has the potential to be part of a sustainable conservation plan for many Neotropical migratory birds. However, more research is needed to better understand how to maximize the quality of this agro-habitat. My research showed a

possible need for Swainson's Thrushes to have forest corridors connecting shade coffee patches for use as overnight roosting sites. Maintaining intact forests adjacent to shade-coffee plantations has been shown to be beneficial to other organisms and beneficial to overall quality of coffee production (Ricketts et al. 2004; Jirinec et al. 2011).

4.5 Conclusions

Habitat quality during the non-breeding season has lasting impacts throughout the full migratory life cycle of Neotropical migratory birds (Marra et al. 1998; Norris et al. 2004; González-Prieto and Hobson 2013). With many Neotropical migrants experiencing steep population declines (Sauer et al. 2017), continued research is needed to develop understanding on ways to improve habitat quality across all stages of the annual cycle. My research found that shade-grown coffee plantations do not provide the same quality of habitat as native forests. However, this does not mean that shade coffee is not a beneficial ecosystem. Shade coffee offers a supplemental habitat to native Andean forest that is rapidly disappearing. Shade coffee has been shown to support higher species richness than the more widely used sun-coffee method (Wunderle and Latta 1996; Perfecto et al. 1996; Colorado and Rodewald 2017). Shade coffee can also provide habitat for pollinators (Klein et al. 2003) and other animals that control coffee pests (Karp et al. 2013), which in turn can reduce need for pesticides and fertilizers. However, other studies have shown the importance of maintaining adjacent intact native forests (Ricketts et al. 2004; Jirinec et al. 2011).

Ultimately the aim of my research was to better understand a complex ecosystem that has many positive conservation implications. Continued deforestation in the Andes

has led to population declines in many bird species, migratory and resident. Shade coffee

will never replace the forested habitat from which it was created, but coming up with a

plan to mitigate the effects of deforestation can only have a positive impact.

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Appendices

Appendix A. Banding data for Swainson's Thrush

Site	Station	Year	Band Code	Species	Age	Sex	Fat	Muscle	Wing Chord	Weight
Los Vientos	Coffee	2017	1461-65744	SWTH	ASY	F	0	3	92	27.3
Los Vientos	Coffee	2017	1461-65736	SWTH	SY	M	0	2	97	28
Los Vientos	Coffee	2017	1461-65739	SWTH	SY	M	1	2	96	30.4
Los Vientos	Coffee	2017	1461-65740	SWTH	SY	M	1	2	96	31.1
Los Vientos	Coffee	2017	1461-65741	SWTH	SY	M	1	2	100	29.8
Los Vientos	Coffee	2017	1461-65742	SWTH	SY	M	3	2	94	30.7
Los Vientos	Coffee	2017	1461-65743	SWTH	SY	M	0	3	101	30.2
Los Vientos	Coffee	2017	1461-65745	SWTH	ASY	M	0	2	98	29.8
Los Vientos	Coffee	2017	1461-65746	SWTH	ASY	M	1	3	98	30.8
Los Vientos	Coffee	2017	1461-65747	SWTH	ASY	M	1	2	95	29.3
Los Vientos	Coffee	2017	1461-65748	SWTH	ASY	M	1	2	101	29.4
Los Vientos	Coffee	2017	1461-65749	SWTH	SY	M	0	2	97	28.2
Los Vientos	Coffee	2017	1461-65750	SWTH	SY	M	1	2	99	31.4
La Fragua	Coffee	2017	1461-65792	SWTH	SY	M	1	3	95	
Los Vientos	Coffee	2017	1451-53685	SWTH	ASY	M	1	2	97	29.7
La Fragua	Coffee	2017	1461-65590	SWTH	ASY	M	3	3	99	34.1
Los Vientos	Coffee	2017	2741-83178	SWTH	SY	U	0	2	99	27.6
Los Vientos	Coffee	2017	2741-83180	SWTH	SY	U	1	1	97	30
Los Vientos	Coffee	2017	2741-83182	SWTH	ASY	U	0	2	95	28.5

Los Vientos	Coffee	2017	2741-83183	SWTH	SY	U	0	1	95	26.7
Los Vientos	Coffee	2017	2741-83184	SWTH	ASY	U	0	1	93	24.7
Los Vientos	Coffee	2017	2741-83185	SWTH	SY	U	0	1	94	26.3
La Vuelta	Coffee	2017	2741-83010	SWTH	SY	U	1	2	100	31.6
La Vuelta	Coffee	2017	2741-83011	SWTH	SY	U	1	1	95	27.8
Los Vientos	Coffee	2017	1461-65751	SWTH	ASY	U	1	3	96	29.4
La Fragua	Coffee	2017	1461-65793	SWTH	SY	U	1	3	92	27.3
Los Vientos	Coffee	2016	1451-53665	SWTH	ASY	U	1	1	99	27.3
Los Vientos	Coffee	2016	1451-53895	SWTH	ASY	U	1	1	99.5	28.4
La Fragua	Coffee	2017	2741-83012	SWTH	SY	F	1	1	94	30.1
La Fragua	Coffee	2017	1461-65721	SWTH	ASY	F	0	2	96	28.6
La Fragua	Coffee	2017	1461-65723	SWTH	ASY	F	0	2	95	26.5
La Fragua	Coffee	2017	2741-83018	SWTH	SY	F	1	3	89	28.5
La Fragua	Coffee	2017	2741-83023	SWTH	ASY	F	1	3	96	27.7
La Fragua	Coffee	2017	2741-83025	SWTH	SY	F	1	3	95	29.6
La Fragua	Coffee	2017	2741-83040	SWTH	SY	F	1	3	94	29.7
La Fragua	Coffee	2017	2741-83041	SWTH	ASY	F	1	3	90	28.1
La Fragua	Coffee	2017	2741-83056	SWTH	SY	F	1	3	95	27.8
La Fragua	Coffee	2017	2741-83059	SWTH	ASY	F	1	3	89	29.8
La Fragua	Coffee	2017	2741-83062	SWTH	ASY	F	2	3	99	29.2
La Fragua	Coffee	2017	2741-83063	SWTH	ASY	F	1	3	89	28.9
La Fragua	Coffee	2017	2741-83064	SWTH	SY	F	4	3	94	35
La Fragua	Coffee	2017	2741-83065	SWTH	ASY	F	1	3	100	30.1

La Fragua	Coffee	2017	2741-83066	SWTH	SY	F	1	3	96	30.2
La Fragua	Coffee	2017	2741-83069	SWTH	SY	F	1	3	93	31
La Fragua	Coffee	2017	2741-83071	SWTH	SY	F	1	3	93	26.3
La Fragua	Coffee	2017	2741-83080	SWTH	SY	F	1	2	93	29.5
La Fragua	Coffee	2017	1451-53161	SWTH	ASY	F	1	1	97	30.3
La Fragua	Coffee	2017	2741-83013	SWTH	SY	M	0	1	99	28.3
La Fragua	Coffee	2017	2741-83014	SWTH	SY	M	1	2	99	31
La Fragua	Coffee	2017	2741-83015	SWTH	SY	M	1	1	102	28.8
La Fragua	Coffee	2017	2741-83016	SWTH	ASY	M	1	1	95	25.5
La Fragua	Coffee	2017	2741-83017	SWTH	ASY	M	1	1	99	30.6
La Fragua	Coffee	2017	2741-83019	SWTH	ASY	M	2	2	100	31
La Fragua	Coffee	2017	2741-83020	SWTH	SY	M	1	3	96	27.2
La Fragua	Coffee	2017	2741-83021	SWTH	SY	M	1	2	97	32.7
La Fragua	Coffee	2017	2741-83022	SWTH	ASY	M	1	2	98	30.8
La Fragua	Coffee	2017	2741-83024	SWTH	ASY	M	2	2	103	30.4
La Fragua	Coffee	2017	2741-83026	SWTH	ASY	M	1	3	102	30.3
La Fragua	Coffee	2017	2741-83027	SWTH	SY	M	1	2	95	30
La Fragua	Coffee	2017	2741-83028	SWTH	SY	M	4	3	100	37.7
La Fragua	Coffee	2017	2741-83029	SWTH	SY	M	1	2	97	32.2
La Fragua	Coffee	2017	2741-83030	SWTH	ASY	M	1	3	96	30.7
La Fragua	Coffee	2017	2741-83031	SWTH	SY	M	1	3	96	30.5
La Fragua	Coffee	2017	2741-83032	SWTH	SY	M	1	3	96	30.9
La Fragua	Coffee	2017	2741-83035	SWTH	ASY	M	0	3	98	30.5

La Fragua	Coffee	2017	2741-83036	SWTH	SY	M	0	3	100	28.5
La Fragua	Coffee	2017	2741-83037	SWTH	ASY	M	1	2	99	26.1
La Fragua	Coffee	2017	2741-83038	SWTH	ASY	M	0	3	96	30
La Fragua	Coffee	2017	2741-83039	SWTH	ASY	M	1	3	99	29.7
La Fragua	Coffee	2017	2741-83042	SWTH	SY	M	1	2	96	26.5
La Fragua	Coffee	2017	2741-83043	SWTH	ASY	M	5	3	97	37.8
La Fragua	Coffee	2017	2741-83045	SWTH	SY	M	1	3	97	30.6
La Fragua	Coffee	2017	2741-83047	SWTH	SY	M	1	3	97	32.2
La Fragua	Coffee	2017	2741-83048	SWTH	ASY	M	1	3	100	30.4
La Fragua	Coffee	2017	2741-83050	SWTH	ASY	M	3	3	93	34.2
La Fragua	Coffee	2017	2741-83051	SWTH	SY	M	1	3	97	31.2
La Fragua	Coffee	2017	2741-83053	SWTH	SY	M	1	3	95	30.4
La Fragua	Coffee	2017	2741-83054	SWTH	SY	M	1	3	96	29.6
La Fragua	Coffee	2017	2741-83057	SWTH	SY	M	1	3	97	30.5
La Fragua	Coffee	2017	2741-83060	SWTH	SY	M	5	3	95	36.5
La Fragua	Coffee	2017	2741-83061	SWTH	SY	M	1	2	91	28.5
La Fragua	Coffee	2017	2741-83067	SWTH	SY	M	2	3	92	31.3
La Fragua	Coffee	2017	2741-83068	SWTH	ASY	M	0	2	97	32.3
La Fragua	Coffee	2017	2741-83072	SWTH	ASY	M	1	3	99	
La Fragua	Coffee	2017	2741-83073	SWTH	SY	M	5	2	94	37.6
La Fragua	Coffee	2017	2741-83074	SWTH	ASY	M	3	3	97	35.1
La Fragua	Coffee	2017	2741-83075	SWTH	SY	M	1	3	98	31.6
La Fragua	Coffee	2017	2741-83076	SWTH	ASY	M	2	3	97	32.8

La Fragua	Coffee	2017	2741-83077	SWTH	SY	M	0	2	98	30.1
La Fragua	Coffee	2017	2741-83078	SWTH	SY	M	4	2	97	37
La Fragua	Coffee	2017	2741-83079	SWTH	ASY	M	3	2	98	33.6
La Fragua	Coffee	2017	1461-64780	SWTH	ASY	M	1	2	102	30.7
La Fragua	Coffee	2017	1461-65722	SWTH	SY	U	1	2	91	27.3
La Fragua	Coffee	2017	2741-83033	SWTH	SY	U	2	2	101	31.5
La Fragua	Coffee	2017	2741-83034	SWTH	SY	U	1	3	95	28.3
La Fragua	Coffee	2017	2741-83044	SWTH	ASY	U	3	2	95	30
La Fragua	Coffee	2017	2741-83046	SWTH	ASY	U	1	2	101	28.4
La Fragua	Coffee	2017	2741-83049	SWTH	SY	U	1	3	97	26.4
La Fragua	Coffee	2017	2741-83055	SWTH	ASY	U	1	3	99	30.8
La Fragua	Coffee	2017	1451-76104	SWTH	ASY	U	1	3	95	30.8
La Fragua	Coffee	2017	1461-65948	SWTH	ASY	U	0	3	95	29.6
Los Vientos	Coffee	2017	1461-65706	SWTH	ASY	U	1	2	95	26.2
Los Vientos	Coffee	2017	1451-53871	SWTH	ASY	U	0	1	92	25.4
Los Vientos	Forest	2017	1461-65724	SWTH	SY	F	1	2	93	25.6
Los Vientos	Forest	2017	1461-65726	SWTH	ASY	F	1	3	90	28.9
Los Vientos	Forest	2017	1461-65727	SWTH	ASY	F	1	2	98	30.7
Los Vientos	Forest	2017	1461-65731	SWTH	SY	F	1	2	90	26.2
Los Vientos	Forest	2017	1461-65752	SWTH	SY	F	1	2	99	29.3
Los Vientos	Forest	2017	1461-65756	SWTH	SY	F	0	3	94	28
Los Vientos	Forest	2017	1461-65795	SWTH	SY	F	4	2	95	37.3
Los Vientos	Forest	2017	1461-65796	SWTH	ASY	F	5	3	95	38.4

Los Vientos	Forest	2017	1461-65798	SWTH	SY	F	1	3	95	30.2
Los Vientos	Forest	2017	1461-65800	SWTH	SY	F	1	3	91	31.1
Los Vientos	Forest	2017	2741-83201	SWTH	ASY	F	1	2	95	25.7
Los Vientos	Forest	2017	2741-83202	SWTH	SY	F	3	3	93	32
Los Vientos	Forest	2017	2741-83203	SWTH	ASY	F	2	2	95	29.7
Los Vientos	Forest	2017	2741-83207	SWTH	SY	F	0	2	92	26.1
Los Vientos	Forest	2017	2741-83209	SWTH	SY	F	3	2	97	30.5
Los Vientos	Forest	2017	2741-83213	SWTH	SY	F	1	3	94	27.2
Los Vientos	Forest	2017	2741-83215	SWTH	ASY	F	1	2	92	28.6
Los Vientos	Forest	2017	2741-83216	SWTH	SY	F	4	3	89	31.8
Los Vientos	Forest	2017	1461-53770	SWTH	ASY	F	1	3	94	29.3
Los Vientos	Forest	2017	1461-65733	SWTH	ASY	M	1	3	98	28.2
Los Vientos	Forest	2017	1461-65734	SWTH	SY	M	0	1	96	27.2
Los Vientos	Forest	2017	1461-65735	SWTH	AHY	M	1	2	100	32.6
Los Vientos	Forest	2017	1461-65754	SWTH	ASY	M	2	3	98	31.1
Los Vientos	Forest	2017	1461-65755	SWTH	SY	M	1	3	101	30.9
Los Vientos	Forest	2017	1461-65757	SWTH	SY	M	1	2	96	27.1
Los Vientos	Forest	2017	1461-65758	SWTH	SY	M	1	3	91	28.6
Los Vientos	Forest	2017	1461-65759	SWTH	SY	M	1	2	92	32.2
Los Vientos	Forest	2017	1461-65763	SWTH	SY	M	0	2	96	26.7
Los Vientos	Forest	2017	1461-65764	SWTH	SY	M	0	2	100	28.3
Los Vientos	Forest	2017	1461-65765	SWTH	SY	M	0	2	99	31
Los Vientos	Forest	2017	1461-65766	SWTH	SY	M	0	2	95	27.9

Los Vientos	Forest	2017	1461-65768	SWTH	SY	M	0	2	96	29.5
Los Vientos	Forest	2017	1461-65769	SWTH	SY	M	0	2	94	28.6
Los Vientos	Forest	2017	1461-65771	SWTH	SY	M	0	3	103	31.4
Los Vientos	Forest	2017	1461-65797	SWTH	ASY	M	5	3	105	38.8
Los Vientos	Forest	2017	2741-83208	SWTH	ASY	M	4	2	99	39.2
Los Vientos	Forest	2017	2741-83210	SWTH	SY	M	1	1	96	28.5
Los Vientos	Forest	2017	2741-83214	SWTH	ASY	M	2	3	104	32.9
Los Vientos	Forest	2017	1451-53416	SWTH	ASY	M	1	3	102	31.9
Los Vientos	Forest	2017	1451-53637	SWTH	ASY	M	1	2	100	29.7
Los Vientos	Forest	2017	2741-83161	SWTH	ASY	U	1	1	96	29.1
Los Vientos	Forest	2017	2741-83162	SWTH	SY	U	1	1	95	27
Los Vientos	Forest	2017	2741-83163	SWTH	ASY	U	0	1	93	25.5
Los Vientos	Forest	2017	2741-83165	SWTH	SY	U	1	1	98	
Los Vientos	Forest	2017	2741-83167	SWTH	SY	U	0	2	99	26.7
Los Vientos	Forest	2017	2741-83168	SWTH	ASY	U	1	1	101	29
Los Vientos	Forest	2017	2741-83177	SWTH	ASY	U	1	2	95	28.6
Los Vientos	Forest	2017	1461-65701	SWTH	SY	U	1	1	94	27.6
Los Vientos	Forest	2017	1461-65702	SWTH	ASY	U	1	1	96	24.8
Los Vientos	Forest	2017	1461-65703	SWTH	ASY	U	1	2	100	29.8
Los Vientos	Forest	2017	1461-65704	SWTH	ASY	U	1	2	98	29.8
La Vuelta	Forest	2017	2741-83001	SWTH	ASY	U	1	2	96	29.7
La Vuelta	Forest	2017	2741-83002	SWTH	ASY	U	1	2	94	31.3
La Vuelta	Forest	2017	2741-83003	SWTH	SY	U	2	2	99	31.3

La Vuelta	Forest	2017	2741-83004	SWTH	ASY	U	1	2	93	28.7
La Vuelta	Forest	2017	2741-83005	SWTH	SY	U	1	2	96	28.7
La Vuelta	Forest	2017	2741-83006	SWTH	ASY	U	1	2	94	28.5
La Vuelta	Forest	2017	2741-83007	SWTH	ASY	U	0	2	97	29.5
La Vuelta	Forest	2017	2741-83008	SWTH	SY	U	1	1	101	32.9
La Vuelta	Forest	2017	2741-83009	SWTH	SY	U	1	2	94	29.2
Los Vientos	Forest	2017	1461-65730	SWTH	SY	U	0	2	97	30.9
Los Vientos	Forest	2017	1461-65760	SWTH	SY	U	1	2	94	28.7
Los Vientos	Forest	2017	1461-65761	SWTH	ASY	U	1	2	102	27
Los Vientos	Forest	2017	1461-65772	SWTH	SY	U	0	3	93	25
Los Vientos	Forest	2017	1461-65773	SWTH	AHY	U	1	2	102	33
Los Vientos	Forest	2017	1461-65774	SWTH	SY	U	3	2	101	33.1
Los Vientos	Forest	2017	1461-65776	SWTH	ASY	U	4	3	101	33.5
Los Vientos	Forest	2017	1461-65777	SWTH	ASY	U	4	3	99	39.2
Los Vientos	Forest	2017	1461-65778	SWTH	SY	U	1	3	97	30.6
Los Vientos	Forest	2017	1461-65779	SWTH	SY	U	1	2	94	26.3
Los Vientos	Forest	2017	1461-65780	SWTH	SY	U	1	3	95	30
Los Vientos	Forest	2017	1461-65781	SWTH	ASY	U	2	3	100	
Los Vientos	Forest	2017	1461-65782	SWTH	SY	U	1	2	98	27.9
Los Vientos	Forest	2017	1461-65783	SWTH	SY	U	1	2	100	30.5
Los Vientos	Forest	2017	1461-65784	SWTH	SY	U	0	2	94	30.7
Los Vientos	Forest	2017	1461-65785	SWTH	AHY	U	1	3	96	29.8
Los Vientos	Forest	2017	1461-65786	SWTH	SY	U	0	3	99	30.4

Los Vientos	Forest	2017	1461-65787	SWTH	AHY	U	1	3	99	27.5
La Fragua	Forest	2017	1461-65788	SWTH		U				
La Fragua	Forest	2017	1461-65789	SWTH	SY	U	1	2	99	28.1
La Fragua	Forest	2017	1461-65790	SWTH	AHY	U	1	3	102	30.9
La Fragua	Forest	2017	1461-65791	SWTH	AHY	U	1	2	98	32.2
Los Vientos	Forest	2017	2741-83204	SWTH	SY	U	4	2	93	35.3
Los Vientos	Forest	2017	2741-83205	SWTH	SY	U	3	3	89	33
La Vuelta	Forest	2016	1451-53265	SWTH	ASY	U	1	1	103.5	29.1
La Vuelta	Forest	2016	1451-76856	SWTH	ASY	U	3	2	95.5	31.3
La Vuelta	Forest	2016	1451-53907	SWTH	ASY	U	2	1	96.5	30.7
La Vuelta	Forest	2016	1451-76862	SWTH	ASY	U	1	2	100	32.1
La Vuelta	Forest	2016	1461-65606	SWTH	ASY	U	2	3	95	28.9
Los Vientos	Forest	2017	1451-53814	SWTH	ASY	U	0	1	97	28.3
Los Vientos	Forest	2017	1451-53606	SWTH	ASY	U	0	1	94	28.1
Los Vientos	Forest	2017	1451-52637	SWTH	ASY	U	1	1	100	28.9
La Fragua	Forest	2017	1461-65712	SWTH	ASY	F	1	2	95	28.7
La Fragua	Forest	2017	1461-65713	SWTH	ASY	F	1	2	98	29
La Fragua	Forest	2017	1461-65717	SWTH	SY	F	0	2	94	27.8
La Fragua	Forest	2017	1461-65718	SWTH	AHY	F	1	2	94	28.2
La Fragua	Forest	2017	1451-53104	SWTH	ASY	F	1	2	99	30.6
La Fragua	Forest	2017	1461-65707	SWTH	ASY	M	1	2	99	29.1
La Fragua	Forest	2017	1461-65708	SWTH	SY	M	1	2	97	30
La Fragua	Forest	2017	1461-65719	SWTH	SY	M	1	2	99	29.8

La Fragua	Forest	2017	1451-76157	SWTH	ASY	M	1	2	99	30.9
La Fragua	Forest	2017	1451-90369	SWTH	ASY	M	1	2	101	28.8
La Fragua	Forest	2017	1451-76124	SWTH	ASY	M	1	2	101	31.1
La Fragua	Forest	2018	2741-83415	SWTH	SY	M	1	2	96	28.5
La Fragua	Forest	2018	2741-83416	SWTH	SY	U	0	2	92	26
La Fragua	Forest	2018	2741-83417	SWTH	SY	M	0	1	95	28.3
La Fragua	Forest	2018	2741-83418	SWTH	SY	M	1	2	97	29.8
La Fragua	Forest	2018	2741-83419	SWTH	SY	M	1	2	95	31.6
La Fragua	Forest	2018	2741-83095	SWTH	SY	U	1	2	95	28.8
La Fragua	Forest	2018	2741-83096	SWTH	ASY	U	1	2	99	29.1
La Fragua	Forest	2018	2741-83099	SWTH	SY	F	1	2	93	27.6
La Fragua	Forest	2018	2741-83098	SWTH	ASY	M	1	2	102	30.4
La Fragua	Forest	2018	2741-83308	SWTH	SY	U	1	2	99	30.6
La Fragua	Forest	2018	2741-83309	SWTH	SY	U	0	1	102	31.7
La Fragua	Forest	2018	2741-83310	SWTH	AHY	U	1	2	94	28.4
La Fragua	Forest	2018	2741-83311	SWTH	SY	U	1	2	98	31.2
La Fragua	Forest	2018	2741-83312	SWTH	SY	U	1	2	90	26
La Fragua	Forest	2018	2741-83313	SWTH	ASY	U	0	2	100	30.5
La Fragua	Forest	2018	2741-83314	SWTH	SY	U	1	2	97	29.8
La Fragua	Forest	2018	1451-90238	SWTH	ASY	U	1	2	102	32.4
Los Vientos	Forest	2018	2741-83081	SWTH	ASY	U	0	2	101	28.2
Los Vientos	Forest	2018	2741-83082	SWTH	SY	U	0	2	97	26.8
Los Vientos	Forest	2018	2741-83083	SWTH	ASY	M	0	2	103	30.8

Los Vientos	Forest	2018	1451-53770	SWTH	ASY	U	1	2	94	
Los Vientos	Forest	2018	2741-83084	SWTH	SY	M	0	2	96	28.5
Los Vientos	Forest	2018	1451-53343	SWTH	ASY	U	1	2	96	30.6
Los Vientos	Forest	2018	1451-53547	SWTH	ASY	U	1	2	93	29.8
Los Vientos	Forest	2018	2741-83405	SWTH	SY	F	0	1	94	25.6
Los Vientos	Forest	2018	2741-83406	SWTH	SY	F	0	2	94	29.5
Los Vientos	Forest	2018	2741-83407	SWTH	SY	F	1	2	92	31
Los Vientos	Forest	2018	2741-83408	SWTH	SY	F	1	2	98	30.5
Los Vientos	Forest	2018	2741-83221	SWTH	SY	F	1	2	89	29.4
Los Vientos	Forest	2018	2741-83222	SWTH	SY	M	1	2	97	28.6
Los Vientos	Forest	2018	2741-83223	SWTH	SY	M	1	2	97	30
Los Vientos	Forest	2018	2741-83224	SWTH	SY	F	1	2	93	28.4
Los Vientos	Forest	2018	2741-83225	SWTH	ASY	U	1	2	99	29.2
Los Vientos	Forest	2018	2741-83226	SWTH	ASY	U	1		100	29.6
Los Vientos	Forest	2018	2741-83227	SWTH	SY	M	0	2	97	30.1
Los Vientos	Forest	2018	2741-83229	SWTH	ASY	M	1	2	100	28.2
Los Vientos	Forest	2018	2741-83230	SWTH	ASY	U	1	2	96	27.5
Los Vientos	Forest	2018	2741-83231	SWTH	ASY	U	1	2	97	31.3
Los Vientos	Forest	2018	2741-83232	SWTH	ASY	U	2	2	91	29.9
Los Vientos	Forest	2018	2741-83233	SWTH	SY	U	1	2	98	31.4
Los Vientos	Forest	2018	2741-83234	SWTH	SY	U	1	2	94	30
Los Vientos	Forest	2018	2741-83235	SWTH	AHY	U	1	2	98	32.1
Los Vientos	Forest	2018	2741-83237	SWTH	SY	U	1	2	98	30.5

Los Vientos	Forest	2018	2741-83238	SWTH	SY	U	1	2	101	30.8
Los Vientos	Forest	2018	2741-83239	SWTH	ASY	U	0	2	100	29.8
Los Vientos	Forest	2018	2741-83240	SWTH	ASY	U	0	2	102	27.1
Los Vientos	Forest	2018	2741-83241	SWTH	ASY	U	0	2	96	29.5
Los Vientos	Forest	2018	2741-83242	SWTH	ASY	U	0	2	101	28.8
Los Vientos	Forest	2018	2741-83243	SWTH	ASY	U	0	2	95	30.7
Los Vientos	Forest	2018	2741-83244	SWTH	SY	U	1	2	95	32.1
Los Vientos	Forest	2018	1451-53450	SWTH	ASY	U	1	2	98	27.6
Los Vientos	Forest	2018	2741-83245	SWTH	SY	U	0	1	98	21.1
Los Vientos	Forest	2018	1451-53070	SWTH	ASY	U	1	2	99	34.9
Los Vientos	Forest	2018	2741-83246	SWTH	SY	U	1	2	92	31.9
Los Vientos	Forest	2018	2741-83247	SWTH	SY	U	1	2	98	27.5
Los Vientos	Forest	2018	2741-83248	SWTH	ASY	U	1	2	102	30
Los Vientos	Forest	2018	2741-83249	SWTH	ASY	U	0	2	102	29.1
Los Vientos	Forest	2018	2741-83250	SWTH	ASY	U	1	2	98	30.2
Los Vientos	Forest	2018	2741-83251	SWTH	ASY	U	0	2	100	29.3
Los Vientos	Forest	2018	2741-83252	SWTH	ASY	U	1	2	99	29.8
Los Vientos	Forest	2018	2741-83253	SWTH	SY	U	1	2	98	31
Los Vientos	Forest	2018	2741-83254	SWTH	SY	U	0	2	101	29.3
Los Vientos	Forest	2018	2741-83255	SWTH	ASY	U	0	2	105	31
Los Vientos	Forest	2018	2741-83256	SWTH	ASY	U	1	2	97	30.3
Los Vientos	Forest	2018	2741-83257	SWTH	SY	U	0	2	102	26.8
Los Vientos	Forest	2018	2741-83258	SWTH	ASY	U	0	2	102	27.1

Los Vientos	Forest	2018	2741-83259	SWTH	ASY	U	1	2	99	28.5
Los Vientos	Forest	2018	2741-83260	SWTH	ASY	U	0	2	100	31.8
Los Vientos	Forest	2018	2741-83261	SWTH	SY	U	1	2	99	30
Los Vientos	Forest	2018	2741-83262	SWTH	ASY	U	1	2	97	29.8
Los Vientos	Forest	2018	2741-83263	SWTH	ASY	U	1	2	103	30.2
Los Vientos	Forest	2018	2741-83264	SWTH	ASY	U	0	2	94	28.2
Los Vientos	Forest	2018	2741-83266	SWTH	ASY	U	1	2	99	29.8
Los Vientos	Forest	2018	2741-83267	SWTH	ASY	U	0	2	100	29.4
Los Vientos	Forest	2018	2741-83268	SWTH	ASY	U	0	2	98	27.4
Los Vientos	Forest	2018	2741-83269	SWTH	SY	U	1	2	94	27.7
Los Vientos	Forest	2018	2741-83270	SWTH	ASY	U	1	2	95	31.4
Los Vientos	Forest	2018	2741-83272	SWTH	ASY	U	1	2	100	31.6
Los Vientos	Forest	2018	2741-83274	SWTH	SY	U	1	2	93	27.4
Los Vientos	Forest	2018	2741-83281	SWTH	SY	U	1	2	99	29.7
Los Vientos	Forest	2018	2741-83282	SWTH	AHY	U	1	2	101	30.3
Los Vientos	Forest	2018	2741-83283	SWTH	ASY	U	1	2	95	28.8
Los Vientos	Forest	2018	2741-83285	SWTH	ASY	U	1	2	100	25.6
Los Vientos	Forest	2018	2741-83286	SWTH	SY	U	1	2	98	31.4
Los Vientos	Forest	2018	2741-83287	SWTH	ASY	U	1	2	102	31.1
Los Vientos	Forest	2018	1451-53724	SWTH	ASY	U	0	2	102	32.4
Los Vientos	Forest	2018	2741-83275	SWTH	SY	U	0	2	95	26
Los Vientos	Forest	2018	2741-83276	SWTH	ASY	U	1	2	98	31
Los Vientos	Forest	2018	2741-83277	SWTH	SY	U	0	2	97	28.9

Los Vientos	Forest	2018	2741-83278	SWTH	SY	U	1	1	96	24.9
Los Vientos	Forest	2018	2741-83279	SWTH	SY	U	1	2	92	29.1
Los Vientos	Forest	2018	2741-83280	SWTH	ASY	U	1	2	101	31.2
Los Vientos	Forest	2018	2741-83217	SWTH	ASY	U	1	2	101	31.5
Los Vientos	Forest	2018	2741-83219	SWTH	AHY	M	0	2	102	29.6
Los Vientos	Forest	2018	1451-53356	SWTH	ASY	U	1	1	99	29.6
Los Vientos	Forest	2018	2741-83426	SWTH	SY	M	1	2	97	29.1
Los Vientos	Forest	2018	2741-83427	SWTH	ASY	F	0	2	94	27
Los Vientos	Forest	2018	2741-83429	SWTH	ASY	U	2	2	99	28.4
Los Vientos	Forest	2018	2741-83430	SWTH	SY	U	1	2	92	26.4
Los Vientos	Forest	2018	2741-83432	SWTH	SY	U	1	2	98	30.5
Los Vientos	Forest	2018	2741-83433	SWTH	SY	U	1	2	95	26.9
Los Vientos	Forest	2018	2741-83434	SWTH	ASY	U	1	2	100	29.7
Los Vientos	Forest	2018	2741-83435	SWTH	ASY	U	1	3	100	31.8
Los Vientos	Forest	2018	2741-83436	SWTH	ASY	U	0	2	100	31.2
Los Vientos	Forest	2018	2741-83437	SWTH	ASY	U	1	2	101	32
Los Vientos	Forest	2018	2741-83438	SWTH	ASY	U	1	2	97	31
Los Vientos	Forest	2018	2741-83439	SWTH	SY	U	0	2	96	28.6
Los Vientos	Forest	2018	2741-83440	SWTH	SY	U	0	2	95	27.5
Los Vientos	Forest	2018	2741-83441	SWTH	SY	U	0	2	95	30.3
Los Vientos	Forest	2018	2741-83442	SWTH	ASY	U	1	2	101	31.2
Los Vientos	Forest	2018	2741-83443	SWTH	SY	U	0	2	97	28.5
Los Vientos	Forest	2018	2741-83444	SWTH	SY	U	0	2	94	28.6

Los Vientos	Forest	2018	2741-83445	SWTH	ASY	U	1	2	99	27.7
Los Vientos	Forest	2018	2741-83446	SWTH	SY	U	0	2	92	24.6
Los Vientos	Forest	2018	2741-83447	SWTH	SY	U	1	2	99	29.2
Los Vientos	Forest	2018	2741-83448	SWTH	SY	U	0	2	93	26.2
Los Vientos	Forest	2018	2741-83449	SWTH	SY	U	1	2	95	31
Los Vientos	Forest	2018	2741-83450	SWTH	ASY	U	0	2	98	26.8
Los Vientos	Forest	2018	2741-83451	SWTH	SY	U	0	2	95	29
Los Vientos	Forest	2018	2741-83452	SWTH	SY	U	0	2	98	28.7
Los Vientos	Forest	2018	2741-83453	SWTH	SY	U	1	2	96	27.5
Los Vientos	Coffee	2018	2741-83410	SWTH	ASY	U	0	2	100	27.8
Los Vientos	Coffee	2018	2741-83411	SWTH	SY	M	1	2	95	28.9
Los Vientos	Coffee	2018	2741-83412	SWTH	SY	F	0	2	94	29.5
Los Vientos	Coffee	2018	2741-83414	SWTH	ASY	U	1	2	93	28.56
La Fragua	Coffee	2018	2741-83420	SWTH	SY	F	1	2	101	31.8
La Fragua	Coffee	2018	2741-83421	SWTH	SY	M	1	2	96	27.2
La Fragua	Coffee	2018	2741-83422	SWTH	SY	M	1	2	95	29.2
La Fragua	Coffee	2018	2741-83423	SWTH	SY	M	1	2	98	30
La Fragua	Coffee	2018	2741-83424	SWTH	AHY	F	1	2	95	28.5
La Fragua	Coffee	2018	2741-83425	SWTH	ASY	U	1	2	98	30.3
Los Vientos	Coffee	2018	2741-83087	SWTH	SY	M	0	2	97	28.8
Los Vientos	Coffee	2018	2741-83085	SWTH	SY	U	0	1	92	25.7
Los Vientos	Coffee	2018	2741-83089	SWTH	ASY	U	1	2	102	34.6
Los Vientos	Coffee	2018	2741-83092	SWTH	ASY	U	1	2	100	29.5

Los Vientos	Coffee	2018	2741-83091	SWTH	SY	F	0	2	92	27.5
La Fragua	Coffee	2018	2741-83401	SWTH	SY	F	1	2	94	28.6
La Fragua	Coffee	2018	2741-83402	SWTH	SY	M	1	2	99	29.6
La Fragua	Coffee	2018	2741-83403	SWTH	SY	F	1	2	92	26.9
La Fragua	Coffee	2018	1451-90361	SWTH	ASY	U	1	2	102	33.1
La Fragua	Coffee	2018	2741-83404	SWTH	SY	M	1	2	99	28.9
La Fragua	Coffee	2018	1451-90153	SWTH	ASY	U	0	2	101	29.6
Los Vientos	Coffee	2018	2741-83454	SWTH	SY	M	0	2	98	29.2
Los Vientos	Coffee	2018	2741-83455	SWTH	ASY	M	1	2	98	30.3
Los Vientos	Coffee	2018	2741-83456	SWTH	ASY	M	1	2	98	29.8
Los Vientos	Coffee	2018	2741-83457	SWTH	ASY	U	1	2	97	29.6
Los Vientos	Coffee	2018	2741-83459	SWTH	SY	U	1	2	94	28.8
Los Vientos	Coffee	2018	2741-83460	SWTH	SY	U	0	2	95	29.5
Los Vientos	Coffee	2018	2741-83461	SWTH	SY	U	1	2	98	31.6
Los Vientos	Coffee	2018	2741-83462	SWTH	ASY	U	1	2	95	32.9
Los Vientos	Coffee	2018	2741-83463	SWTH	SY	U	1	2	98	30.4
Los Vientos	Coffee	2018	2741-83464	SWTH	SY	U	0	2	94	30.8
Los Vientos	Coffee	2018	2741-83465	SWTH	SY	U	1	2	95	30.6
Los Vientos	Coffee	2018	2741-83466	SWTH	ASY	U	0	2	102	32.1
Los Vientos	Coffee	2018	2741-83467	SWTH	ASY	U	0	2	96	31
Los Vientos	Coffee	2018	2741-83469	SWTH	ASY	U	0	2	100	29.3
Los Vientos	Coffee	2018	2741-83470	SWTH	SY	U	0	2	90	27.9
Los Vientos	Coffee	2018	2741-83471	SWTH	SY	U	0	2	97	29

Los Vientos	Coffee	2018	2741-83472	SWTH	SY	U	1	2	94	32.2
Los Vientos	Coffee	2018	2741-83473	SWTH	SY	U	1	2	95	27.9
Los Vientos	Coffee	2018	2741-83474	SWTH	SY	U	0	2	98	28.8
Los Vientos	Coffee	2018	2741-83475	SWTH	SY	U	0	2	98	29
Los Vientos	Coffee	2018	2741-83476	SWTH	AHY	U	1	2	100	29.5
Los Vientos	Coffee	2018	2741-83477	SWTH	ASY	U	1	2	97	29.4
Los Vientos	Coffee	2018	2741-83478	SWTH	SY	U	0	2	95	29.5
Los Vientos	Coffee	2018	2741-83479	SWTH	SY	U	1	2	98	32.9
Los Vientos	Coffee	2018	2741-83480	SWTH	ASY	U	1	2	98	28.9
Los Vientos	Coffee	2018	2741-83481	SWTH	ASY	U	1	2	97	31.8
Los Vientos	Coffee	2018	2741-83482	SWTH	SY	U	1	2	96	31.3
Los Vientos	Coffee	2018	2741-83483	SWTH	ASY	U	1	2	105	29.7
Los Vientos	Coffee	2018	2741-83484	SWTH	ASY	U	1	2	96	27.3
Los Vientos	Coffee	2018	2741-83485	SWTH	SY	U	1	2	96	29.2
Los Vientos	Coffee	2018	2741-83486	SWTH	SY	U	1	2	96	30.4
Los Vientos	Coffee	2018	2741-83487	SWTH	ASY	U	0	2	97	28.6
Los Vientos	Coffee	2018	2741-83488	SWTH	AHY	U	0	1	100	28.1
Los Vientos	Coffee	2018	2741-83489	SWTH	ASY	U	0	2	100	28.9
Los Vientos	Coffee	2018	2741-83490	SWTH	SY	U	0	2	99	28.6
Los Vientos	Coffee	2018	2741-83491	SWTH	SY	U	0	2	100	29.5
Los Vientos	Coffee	2018	2741-83492	SWTH	AHY	U	0	2	95	29.5
Los Vientos	Coffee	2018	2741-83493	SWTH	ASY	U	0	2	99	27.7
Los Vientos	Coffee	2018	2741-83494	SWTH	ASY	U	1	2	103	31.7

Los Vientos	Coffee	2018	2741-83495	SWTH	SY	U	0	2	94	29.4
Los Vientos	Coffee	2018	2741-83496	SWTH	AHY	U	0	2	93	28.9
Los Vientos	Coffee	2018	2741-83497	SWTH	ASY	U	1	2	96	30.9
Los Vientos	Coffee	2018	2741-83498	SWTH	SY	U	0	2	98	30.3
Los Vientos	Coffee	2018	2741-83499	SWTH	ASY	U	1	2	100	31.4
Los Vientos	Coffee	2018	2741-83500	SWTH	ASY	U	1	2	94	31
Los Vientos	Coffee	2018	2741-83305	SWTH	SY	U	1	2	94	31.2
Los Vientos	Coffee	2018	2741-83306	SWTH	SY	U	0	2	96	32.9
Los Vientos	Coffee	2018	2741-83307	SWTH	ASY	U	0	2	100	29
La Fragua	Coffee	2018	2741-83315	SWTH	SY	U	0	2	93	27.7
La Fragua	Coffee	2018	2741-83316	SWTH	SY	U	0	2	96	30.1
La Fragua	Coffee	2018	2741-83317	SWTH	SY	U	1	2	95	30.9
La Fragua	Coffee	2018	2741-83318	SWTH	ASY	U	0	2	101	31.7
La Fragua	Coffee	2018	2741-83319	SWTH	SY	U	0	2	99	31.3
La Fragua	Coffee	2018	2741-83320	SWTH	SY	U	1	2	95	30.8
La Fragua	Coffee	2018	1451-53160	SWTH	ASY	U	1	2	99	29.4
Los Vientos	Forest	2017	1451-53542	SWTH	ASY	F	1	1	100	29.1
Los Vientos	Forest	2017	1451-53786	SWTH	ASY	U	1	1	98	32.3
La Fragua	Forest	2018	1451-76146	SWTH	ASY	U	1	2	99	29.3
La Fragua	Coffee	2017	1451-76973	SWTH	ASY	F	1	2	102	30.4
La Fragua	Coffee	2017	1451-90320	SWTH	ASY	U	1	3	97	30.6
La Fragua	Coffee	2017	1461-64709	SWTH	ASY	M	2	3	97	32.4
La Fragua	Forest	2017	1461-64763	SWTH	ASY	F	1	2	95	28.8

Los Vientos	Forest	2017	1461-65577	SWTH	ASY	U	0	2	101	30.6
La Fragua	Forest	2017	1461-65711	SWTH	AHY	M	0	1	99	29.9
La Fragua	Coffee	2017	1461-65720	SWTH	ASY	F	1	2	89	28.1
Los Vientos	Coffee	2017	1461-65738	SWTH	ASY	M	1	2	99	28.2
Los Vientos	Forest	2017	1461-65762	SWTH	SY	M	1	2	100	32
Los Vientos	Forest	2017	1461-65775	SWTH	SY	U	0	3	93	29.1
La Fragua	Coffee	2017	2741-83052	SWTH	ASY	M	1	3	100	31.3
La Fragua	Coffee	2017	2741-83070	SWTH	SY	F	1	3	95	30.4
Los Vientos	Coffee	2018	2741-83088	SWTH	SY	U	0	1	96	28.2
La Fragua	Forest	2018	2741-83094	SWTH	SY	M	1	2	97	30
Los Vientos	Forest	2017	2741-83160	SWTH	SY	U	1	2	93	30.3
Los Vientos	Forest	2017	2741-83172	SWTH	SY	F	1	1	94	29.1
Los Vientos	Forest	2018	2741-83218	SWTH	SY	M	0	2	99	27.8
Los Vientos	Forest	2018	2741-83220	SWTH	SY	F	0	2	94	28.6
Los Vientos	Forest	2018	2741-83236	SWTH	SY	U	1	2	95	31.6
Los Vientos	Forest	2018	2741-83273	SWTH	SY	U	1	2	95	30
Los Vientos	Forest	2018	2741-83428	SWTH	SY	U	1	3	92	27.6
Los Vientos	Forest	2018	2741-83431	SWTH	ASY	U	0	2	97	28.9
Los Vientos	Coffee	2018	2741-83458	SWTH	ASY	U	1	1	100	30.1
Los Vientos	Coffee	2018	2741-83468	SWTH	SY	U	0	2	96	28.6

Appendix B. Animal Use Protocol

Western

AUP Number: 2017-005
PI Name: Hobson, Keith
AUP Title: Ecology Of Migratory Songbirds In North America
**Approval Date:** 03/07/2017
Official Notice of Animal Use Subcommittee (AUS) Approval: Your new Animal Use Protocol (AUP) entitled "Ecology Of Migratory Songbirds In North America" has been APPROVED by the Animal Use Subcommittee of the University Council on Animal Care. This approval, although valid for four years, and is subject to annual Protocol Renewal.2017-005::1

1. This AUP number must be indicated when ordering animals for this project.
2. Animals for other projects may not be ordered under this AUP number.
3. Purchases of animals other than through this system must be cleared through the ACVS office. Health certificates will be required.

The holder of this Animal Use Protocol is responsible to ensure that all associated safety components (biosafety, radiation safety, general laboratory safety) comply with institutional safety standards and have received all necessary approvals. Please consult directly with your institutional safety officers.
Submitted by: Copeman, Laura
on behalf of the Animal Use Subcommittee
University Council on Animal Care

The University *of* Western Ontario
Animal Use Subcommittee / University Council on Animal Care
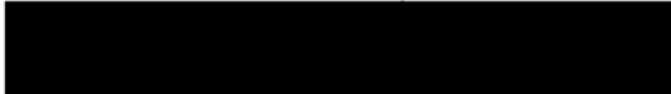
Appendix C. Colombia Export Permit

SELVA: Investigación para la Conservación en el Neotrópico
w w w . s e l v a . o r g . c o

Bogotá, 19 de Febrero del 2016

Señora
Claudia Victoria González Hernández
Subdirector de Instrumentos, Permisos y Trámites Ambientales
Autoridad Nacional de Licencias Ambientales – ANLA

REF: Solicitud para la expedición del permiso de exportación de especímenes no listados en los Apendices CITES con fines de investigación

Reciba un cordial saludo,

Por medio de esta carta, radicamos nuestra solicitud de emisión de un permiso de exportación para el proyecto titulado: **ESPECIES MIGRATORIAS - Orígenes y factores que determinan la condición física de aves migratorias Neotropicales durante el otoño en el Darién Colombiano.** Este proyecto está siendo desarrollado por la estudiante Laura Cardenas Ortiz de la Universidad de Saskatchewan con el apoyo de la Asociación SELVA, identificada con el NIT 900338513-3, bajo el área de investigación de Especies Migratorias con el permiso de investigación resolución No. 0819 del 2013 y No. 0597 del 2014.

Adjuntamos a esta carta los siguientes documentos:

1. Formato de solicitud para la exportación de especímenes no listados en CITES
2. Metodología y descripción del proyecto de investigación
3. Copia del Permiso de Investigación de SELVA: Resolución No. 0597
4. Solicitud de liquidación por servicio de evaluación de permisos
5. Certificado de la Cámara de Comercio de la Asociación SELVA.
6. Documento que certifica que la universidad receptora (Saskatchewan University) de las muestras avala la investigación.

Quedamos atentos a su respuesta y al procedimiento a seguir para adelantar el trámite del permiso.

Atentamente,

Nicholas J Bayly
Representante Legal (S)

Curriculum Vitae

Sean McElaney

Education:
University of Western Ontario,
Master of Science in Biology, to be completed 2019
Courses completed: Analytical Methods and Study Design (Statistics)
Topics in Biological Methods, Stable Isotopes

The University of Texas at Austin, 2013
Bachelor of Science in Ecology, Evolution, and Behavioral Biology

Skills:
Bird Banding, Identification Aging and Sexing Neotropical migratory birds,
Teaching, Curriculum Development, Public Outreach, Microsoft Excel,
PowerPoint, Publisher, and Word, Wilderness CPR/First-aid certified

Languages:
Fluent in English and Spanish

Awards:
Best Lightning Talk, Ecology and Evolution, Biology Graduate Research Forum,
2017 University of Western Ontario, London, ON

Conference Presentations:
Biology Graduate Research Forum   **London, ON, Canada**
Oct 2017 – Lightning Talk
Nocturnal roosting in shade coffee plantations: Neotropical migrants and the need for
safe havens

AOS, SCO Conference 2017   **Lansing, MI, USA**
Aug 2017 – Lightning Talk
Nocturnal roosting in shade coffee plantations: Neotropical migrants and the need for
safe havens

Work Experience:
The University of Western Ontario- London, ON   **2017 - Current**
Teaching Assistant
•   Teaching assistant for two undergraduate level biology courses and one field
      ecology course.

SELVA- Sierra Nevada/Los Vientos Colombia   **2016 - 2018**
Field technician/Banding course instructor
•   Assisted in instructing a Spanish course on mist netting and banding birds.
•   Conducted research to better understand how migratory birds function on wintering grounds.

Town of Kiawah Island Wildlife Department- Kiawah Island, SC   **2015**
Banding Assistant
•   Mist netted and banded migratory songbirds to better understand population declines in birds.

Southern Sierra Research Station- Blythe, CA   **2015**
Yellow-billed Cuckoo field technician
•   Set up canopy mist nets to catch Yellow-billed Cuckoos (*Coccyzus americanus*).
•   Conducted surveys, and radio telemetry on an endangered population of Yellow-billed Cuckoos.

Smithsonian Migratory Bird Center- Matagorda, TX   **2014 - 2015**
Bird Bander/ Education Outreach Coordinator
•   Organized and lead over 20 field trips (Ages 6-18) teaching about conservation of the gulf coast.
•   Mist netted and banded migratory passerines to further knowledge of bird migration.

Tulane Andean Hummingbird Research Station- Wayquecha, Peru   **2014**
Field Technician
•   Mist netted and processed multiple species of Andean hummingbirds.
•   Conducted radio telemetry on Shining Sunbeam (*Aglaeactis cupripennis*).

Lady Bird Johnson Wildflower Center- Austin, TX   **2012 - 2013**
Education Intern
•   Developed nature and wildlife curriculum for children grades 1-5 for weekly field trips.
•   Led public outreach events and coordinated volunteers.

Outreach and Service:
Society of Biology Graduate Students SOBGS – Seminar Committee, **2017 – 2018**
Lung Association of Ontario – Fundraising events, and outreach **2017 – 2018**
The Nature Conservancy – Education outreach, and CBC coordinator **2014 – 2018**