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Responses of the Ocellated Turkey (Meleagris ocellata) to Human Disturbance

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RESPONSES OF THE OCELLATED TURKEY (*MELEAGRIS OCELLATA*) TO HUMAN
DISTURBANCE

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ABSTRACT

Habitat loss and habitat degradation are major drivers of the current biodiversity crisis.

Nowhere else are these threats more severe than in the tropics. Because the tropics are

estimated to contain as much as 60% of all the species on Earth, they are critically important for

the conservation of biodiversity. To conserve species we need to understand both the factors

that lead to extinction and how the taxa that persist are able to adapt to the rapid

anthropogenic change of their environment. The Ocellated Turkey (*Meleagris ocellata*) is a

Neotropical galliform bird of conservation concern because it faces a rapidly changing

environment.

The goal of this thesis is two fold: 1) to expand our understanding of the natural history

of the Ocellated Turkey (*Meleagris ocellata*), and 2) to document the behavioral responses of

this species to different levels of anthropogenic habitat modification. Chapter One describes a

radiotelemetry study of adult males. This investigation is the first published record of the home

range use and movement patterns of adult males of this species during the breeding season.

These birds showed home ranges that were highly variable in size and composition (MCP $\bar{x}$=

969 ± 922 ha, 95%FK $\bar{x}$= 692 ± 819 ha, 50%FK $\bar{x}$= 90 ± 138 ha). In comparison to other similarly

sized Galliformes, the Ocellated Turkey home range is quite large. The average movement rate

also varied greatly between individuals ($\bar{x}$= 437 ± 264 m/h). A few individuals restricted their

movements to intact forest only, while others spent all day in open pasture. The majority of

radiotagged males (7 of 12) spent 50% or more of their time in areas without closed canopy cover. Chapter Two describes the association of habitat disturbance with male movement patterns and select indicators of health. There were no significant differences in home range size, blood and fecal parasites, feather barring regularity, male fleshy ornaments, and H:L ratios among the disturbance types. Additionally, most of the feather reflectance data did not differ between disturbance levels (low, intermediate, and high), but I did find differences in the blue ocelli of the secondary tail coverts among disturbance levels. The dominant ultraviolet spectrum hue of the ocelli were negatively correlated with coccidian parasite load but the dominant red spectrum hue was positively correlated with this parasite. Chapter Three presents various results from the field study that further our knowledge of the natural history of this species, including an analysis of flocking behavior, fecal parasite distribution at the landscape level, and notes on predator inspection behavior, the submission display of non-breeding males and their early attempts at courtship. Flocks were larger and showed less vigilance in open habitat but did not have a different foraging there compared to flocks in the forest. Mapping of the number of parasites found in feces identified "hot spots" with high concentrations of parasites, which surprisingly included a shade coffee grove. Young males used the double wing turn behavior to deflect aggression from alpha males. Incomplete action patterns for gobbling and strutting were observed in young male flocks. The results of this study suggest that a matrix of rainforest and cattle pasture is not harmful to Ocellated Turkey health,

although further studies that include measures of survivorship and fecundity are needed to

model accurately this species' population viability in an anthropogenic environment.

DEDICATION

I dedicate this research first and foremost to my wife who has always been there for me, even in a

shack in the jungle; my family for they too made a pilgrimage to the jungle; Dr. Richard Buchholz,

the man with the plan; and most importantly, the Ocellated Turkey because what would life be

without obscenely obstinate colorful turkeys.

ACKNOWLEDGEMENTS

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Chapter One

CHAPTER ONE

Home Range Movements and Population Densities of a Threatened Yucatan Endemic, the Ocellated Turkey (*Meleagris ocellata*).

Introduction

Species in the Order Galliformes are twice as likely to be threatened with extinction than birds in general (McGowan et al. 2012). The Galliformes suffer disproportionately from overharvest because large birds are preferentially targeted by hunters (Sreekar et al. 2015). Unsustainable exploitation and habitat degradation by logging, agriculture, and livestock production, are the major threats to the Galliformes, as they are for other vertebrate populations (WWF 2014). Ground-dwelling species such as most Galliformes species are at greater risk of direct disturbance by humans (Sodhi et al. 2004). The conservation of large tropical Galliformes is critically important because their large size may enable them to disproportionately shape their ecological communities through the seed dispersal (or seed predation) of plants with large fruits (Steiner 1995, Pérez-Méndez et al. 2015). Galliformes are also an important resource for predators by diversifying the prey base of many carnivorous birds and mammals (Redford 1992). Knowledge of species-specific natural history and

quantitative ecology are needed to manage populations of large game birds effectively. For example, the Wild Turkey (*Meleagris gallopavo*), the largest terrestrial bird in North America, was extirpated from, or rare in, much of its wide geographic range by the mid twentieth century, but with scientific management the population of this iconic species has now recovered (Hatfield and Vance 2009).

The current decline of the Ocellated Turkey (*Meleagris ocellata*), the only other species in the subfamily Meleagridinae, parallels the historical decline of its North American congener. Like the pattern seen during the early phase of the historical decline of the Wild Turkey, the Ocellated Turkey has been already extirpated from parts of its range, and is rarely seen outside of remote areas or actively protected parks and reserves. If current declines continue as they have from 1980, Ocellated Turkey populations will continue to decrease and form more fragmented populations that will further degrade due to reduction in gene flow, genetic drift, and inbreeding (Kampichler et al. 2010) leading to what Gilpin and Soule (1986) coined as an extinction vortex. The high visibility of this large bird at some sites often visited by tourists (e.g. Maya archaeological sites) may have misled monitoring agencies to list the species as Near Threatened rather than Vulnerable (IUCN 2014).

The Ocellated Turkey has a small geographic range, restricted to lowland scrub, dry forests and rainforests of NE Guatemala, NW Belize and southern Mexico in the Yucatan peninsula, increasing its extinction risk (Bennett and Owens 1997; Owens and Bennett 2000). Its narrow latitudinal range, primarily on a peninsula, no doubt puts the Ocellated Turkey at higher risk of extirpation than the widespread Wild Turkey, which did not suffer the same constraints. With rapid human population growth, deforestation is accelerating in Central

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America, and even internationally monitored protected areas, such as the Maya Biosphere Reserve, are suffering widespread habitat loss (Carr 2005). Thus, protection and active management of Ocellated Turkey populations in private and public habitat reserves surrounded by agricultural and urban areas is the most viable future for this species.

Few previous studies have focused on the Ocellated Turkey (Table 1). Studies monitoring the population dynamics of this species are sorely needed (McRoberts et al. 2012). Detailed species information is provided by Williams et al. (2010) in their privately published book and DVD, respectively, but their methodology and sample sizes are largely undocumented. There are several unpublished student research studies that employed quantitative methods that provide information useful for conservation planning of Ocellated Turkey populations, including descriptions of their diet (Baur 2008), reproductive behavior (Hanlon 2013) and translocation success (McRoberts 2014). Only two studies have measured Ocellated Turkey home ranges (Gonzalez et al. 1998 and McRoberts 2014).

Behavioral differences between Wild and Ocellated Turkeys, particularly during the breeding season, suggest that population surveys of the latter should not simply assume that Ocellated Turkeys are a tropical equivalent of the Wild Turkey species. The Wild Turkey mating system has been variably described as 'resource defense', 'female defense' (Williams and Austin 1988) or even lek-like polygyny (Watts and Stoke 1971), occasionally with male siblings partaking in kin-selected display coalitions (Watts 1968, Krakauer 2008). Williams et al. (2010) proposed that there are 'breeding' and 'non-breeding' adult males in Ocellated Turkey populations, with the non-breeders characterized by a lack of display (at least not in the presence of breeding adults; Williams et al. 2010, Hanlon 2013). The breeding Ocellated Turkey

males, called alphas by Hanlon (2013), defend display territories, which are visited by both females and non-breeding males (betas). Betas are tolerated on display territories by alphas as long as they do not display (Hanlon 2013), but it is not known if they achieve reproductive success surreptitiously elsewhere. In densely forested habitat, display areas are natural forest openings, such as seasonally dry 'bajos' (low areas) (Baur 2008). Pasture, shade-coffee groves, roads, and cleared archeology sites in contrast are common display sites in anthropogenically disturbed areas (personal observation). I investigated male home range movements and densities of Ocellated Turkeys during the breeding season in a protected population living in NW Belize, and compare them to their North American congener and other large Galliformes.

The three most popular methods used to estimate home range are minimum convex polygons (MCP), 95% fixed kernel analysis (95%FK), and 50% fixed kernel analysis (50%FK). The MCP is the oldest and simplest method for estimating home range. MCPs are constructed by simply connecting the outermost location points to create a polygon and the area within the polygon is an animal's home range. The 95%FK and 50%FK ranges are created by layering locality data onto an x-y plane to create a utilization distribution. Locality data are converted into a "kernel" which is hill shaped and the utility distribution is determined by the mean point for all the kernels present (Powell 2000). The advantage of calculating home ranges with multiple estimators is twofold: 1) MCP estimates, while sensitive to outliers, are easy to compare across studies, and 2) 95% and 50% fixed kernel estimates are truer to an animal's ranging patterns but due to unstandardized variables (number of locations used, time between locations, whether subsampling occurred) may be harder to compare across studies. Currently there are only two other radio telemetry studies of the Ocellated Turkey. Gonzalez et al. (1998)

documented female home ranges during the nesting and poult-rearing season. Similarly

McRoberts (2014) estimated the home range of several females during the breeding season, as

well as that of one juvenile male. Because neither previous study addresses the breeding

season home range of adult males that are typically targeted by hunters (Baur et al. 2012), I

investigated the movements of this subset of the population.

Methods

Study Sites

  Ocellated Turkeys were observed at two study sites: the Gallon Jug Estate and the La

Milpa Field Station area of Rio Bravo Conservation and Management Area (Figure 1 Appendix

ii). Gallon Jug Estate (17 33.634°N, 89 02.801° W) is a privately-owned ranch in NW Belize with

a central cleared core (1214 ha) used for cattle grazing surrounded by selectively logged forest

(40469 ha). Gallon Jug has a small shade grown coffee plantation, a paved airplane runway,

and an area of undisturbed forest (12141 ha) surrounding Chan Chich ecotourism lodge. Within

the central pasture are two small cattle feed lots that provide Ocellated Turkey with *ad libitum*

access to brewer's grain. The forests in Gallon Jug are tropical evergreen broadleaf lowland

forest over calcareous soils and are classified in the Holdridge classification as 'subtropical

moist forest' (Meerman 2000, Kelly and Rowe 2014). Contiguous with the Gallon Jug Estate is

the Maya Biosphere Reserve of Guatemala (2160309 ha) and the Rio Bravo Conservation

Management Area (RBCMA; 105218 ha). The latter is managed by Programme For Belize,

primarily for ecotourism and selective logging of tropical hardwoods. The second field site was

the La Milpa field station (17 50.487° N, 89 01.106° W) near the northern end of the RBCMA.

The forest is similar to that at Gallon Jug, but lacks large clearings. Both sites contain karst hills

and low, seasonally wet bajos. To the north of La Milpa the Mennonite community of Blue

Creek directly abuts the RBCMA forest with extensive and completely deforested agricultural

and grazing lands. Although Ocellated Turkeys are a protected species in Belize, and hunting is

not permitted in Gallon Jug and RBCMA, illegal poaching does occur, especially along the

northern perimeter.

Radio Telemetry

Radio backpacks consisting of 74g VHF radio transmitters (Model A1540B, Advanced

Telemetry Systems [ATS], Isanti, MN, USA) were fitted to males estimated to be at least 3 years

old (based on the body and spur sizes reported in known age captive males by Williams et al.

2010). The transmitter straps were 1/8” shock cord with the cord end knots glued with Gorilla

Glue (Cincinnati, Ohio, USA) to prevent the knot from slipping. The transmitters were

monitored with VHF R410 (ATS) and Model R1000 receivers (Communications Specialists Inc.,

Orange, California, USA) and a 3-element Yagi antenna (ATS 13869) while wearing full cup

headphones.

The locations of radio-tagged Ocellated Turkeys at the Gallon Jug study site were

monitored by radio telemetry three days per week from February 10, 2014 to June 10, 2014, 2

days per week from January 10, 2015 to May 1, 2015, and daily from May 2, 2015 to June 1,

2015, obtaining at least 30 locality data to make home range estimates ($\bar{x}=50\pm21$) (Seaman et al. 1999). During the 2014 field season the birds' locations were determined continuously from dawn to dusk, at 2 hr intervals. In 2015 telemetry data were collected once in the morning (0600-1200) and once again in the afternoon (1300 – 1800). Telemetry data collection was changed between the first and second field season to accommodate other data collecting activities that varied between the seasons. At Gallon Jug telemetry was conducted from four hilltop locations, providing signal collection angles that differed by 30°-180° (Figure 2 Appendix ii), such that 4 signal directions were collected quickly ($\bar{x}=80\pm19$ min) for all the radio-tagged subjects. The location of the sole radio-tagged male at the La Milpa study site was determined every two hours, over 5 sequential days every 3 weeks in the 2014 field season and until he was poached early in the 2015 field season after 11 days of tracking. At La Milpa water towers, Mayan pyramid sites, and other elevated locations served as standard telemetry signal collection points (Figure 3 Appendix ii). At both study sites, individual radio signals sometimes could not be detected from the standard collection points (n=80). In those cases I attempted to locate the missing bird by sampling every 500m on trails or roads starting nearest the bird's last known location in the time remaining until the next scheduled data collection from the highpoints.

I used Location Of A Signal (LOAS Ecological Software Solutions LLC) software to estimate bird locations from telemetry observations. BIOTAS (Ecological Software Solutions LLC) software allowed me to calculate minimum convex polygons (MCP), 95%, and 50% fixed kernel density estimates, respectively. MCPs and fixed kernel home ranges were based on at least 30 locality data points ($\bar{x}=50\pm21$) per bird collected over 1-11 months depending on initial

trap date and the survival of individual birds. Smoothing of fixed kernels was achieved using the least squares cross validation technique. I attributed any location triangulated to more than 8km from survey points ($\bar{x}$= 8 $\pm$12) to user error and thus eliminated them from analysis since my receivers would not be able to detect radio signals from more than 8km based off technical specifications from the manufacturer. Data were not subsampled because autocorrelation has only minor effects on kernel analyses (Solla et al. 1999). QGIS (http://www.qgis.org) was used to create shape files to overlay on maps of the study sites. Shape files used in QGIS were taken from Jan Meerman's website (http://biological-diversity.info/GIS.htm) and satellite imagery layers were sourced from Google Maps.

I calculated individual movement rates (m/hr) by dividing the sum of the total straight-line distances between sequential locations by the duration of daily telemetry on days ($\bar{x}$=11$\pm$7days) that had 3 or more locations. I measured straight-line distances using the drawing tool in QGIS. Home range overlap between individuals was measured as the percentage of area overlap of 50% FK home ranges, measured using the area tool in QGIS (Perez-Garcia et al. 2013). Because distantly separated individuals would never have had the opportunity to interact, I only calculated overlap percentage for males whose home range mid-point was within 8,914 m of the core perimeter of other males. This distance represents the diameter of the largest 95% FK home range found in our study subjects at Gallon Jug.

Block Count Survey

To investigate variation in the total number of birds present at the Gallon Jug study site over the two field seasons, each week I rapidly counted and classified the age (adult or juvenile), sex and flock size for all individuals in the pastures that were visible from a standardized route from 0600-0800. A single observer drove the route at a speed of 24-32 km/hr, and used binoculars (Nikon Monarch 10x42, Nikon Inc., Tokyo, Japan) to inspect birds initially detected by unaided eyesight. Maximum line of sight along the route was 400 m.

Line Transect Surveys

I used line transects consisting of existing vehicle roads, logging roads, trails, and horse paths at Gallon Jug in areas not covered by the block count survey (Figure 4a, 4b Appendix ii). Each section was characterized for mean visibility over 10 points located every 10-50m (depending on heterogeneity) by using a Bushnell Tour V rangefinder (Bushnell, Overland Park, KS, USA) to find the distance of the nearest obscuring vegetation that would completely block observation of an Ocellated Turkey, in each of four compass directions. I recorded the time spent in each section, walking speed or speed of the vehicle, and turkey sightings. When a sighting occurred, time of day, initial observation distance, perpendicular distance to the transect, as well as the number of individuals, sex and behavioral reactions of the birds were determined using the range finder, binoculars, and handheld GPS unit, respectively, as

described previously. Transects were traveled by vehicle, when possible, at least ten times a week and on foot at least twice a month.

Density estimates

The turkey sightings data from the road and trail transects were analyzed with the classic distance sampling (CDS) engine of the software program DISTANCE 6.2 (Thomas et al. 2010). This approach assumes that: a) transects are placed at random, b) individuals on the transect itself have 100% probability of detection, c) sighted animals have not changed their distance from the transect in response to the surveyor, and d) animal groups of different sizes have an equal likelihood of being detected. My study violated assumptions a and probably d. My transects were existing roads, paths and trails that were not randomly distributed across the study site but based on similar studies of the Wild Turkey (Butler et al. 2005) we have no *a priori* reason to suspect that Ocellated Turkeys prefer or avoid habitat near a road. It seems logical to expect that small flocks will be harder to detect, especially at great distances. As a precaution I truncated the data set to remove the most distant 5% of turkey sightings. Abundance is estimated using the Horvitz-Thompson criterion which interprets the number of spotted groups based on a detection probability form. The program assumes that the probability of detection decreases with distance from the transect. The best probability function to use for abundance estimation was chosen from a set of model forms (half-normal, hazard-rate, and uniform key functions with Hermite and simple polynomial series adjustment terms) using Akaike's Information Criterion (AIC) and goodness-of-fit statistics. Finally the HT

estimate of group abundance was multiplied by the mean group size to estimate population size in the survey area.

Statistical Analysis

The three estimates of home ranges (MCPs 95%FK and 50%FK), were compiled and averaged to create mean values. Birds that survived two field seasons had two home range estimates created (one for each field season) and the home range with the largest number of locality points was used for statistical comparison. The 5 birds that had two home range estimates over two field seasons were analyzed for significant home range differences across seasons using a paired t-test. The paired t-test had a sample size of 5 and 4 degrees of freedom. A simple correlation was used to test whether home range size was dependent on the number of locations triangulated for each bird (n = 12).

RESULTS

Male Home Range and Movement Patterns

A total of twenty-four males were captured by drop netting (n= 7), baiting with alpha-chloralose-laced cracked corn (n= 14), foot snare (n= 1), and net gunning (n= 2), depending on the local vegetation structure and degree of habituation of individual birds. In 2014, between January 1st and March 12th, I banded and/or radio-tagged 13 male Ocellated Turkeys captured with a total of 130 trap-hours of effort. Ten of those birds were still alive at the end of the first

field season. At the start of the second field season, nine of the birds tagged in the first field

season were still alive. In the second field season, between January 1st and May 7th, I banded

and/or radio-tagged an additional 11 male Ocellated Turkeys captured with 210 trap-hours of

effort. Seven of the first field season birds that survived to January 2015 were still alive at the

end of our second field season in June, and 7 of the birds newly marked in the second field

season survived to study end as well. Over the course of the two field seasons, 5 of our radio-

tagged birds appeared to have been killed by predators. Individuals who were radio-tagged that

were killed by predators survived on average 105 days (SD ± 155 days) while individuals that did

not suffer predation had on average survived 313 days (SD ± 207 days). Home range estimates

and statistical comparisons were made using the twelve birds that survived long enough to

provide 30 or more radiotelemtry locations (home range maps can be found in Appendix i).

I recorded 30-98 locations per bird (Table 2). The total (MCP) home range size varied

widely from 68ha-2244ha ($\bar{x}$= 969ha SD ± 922ha; Table 2 Appendix i), and was not associated

with the number of locations MCP (r(df=10) = 0.36, p = 0.24). The mean 95% and 50% fixed

kernel estimates of home range were 692ha SE ± 819ha and 90ha SD ± 138ha, respectively, and

individual home ranges were independent of the number of triangulated locations used to

produce them 95%FK (r(df=10) = -0.12, p = 0.70), and 50%FK (r(10) = -0.21, p = 0.50). The

breeding home ranges of individuals did not differ significantly in size between years (MCP

(t(df=4) = 1.41 p = 0.22), 95%FK (t(df=4) = 0.33 p = 0.875), and 50%FK home ranges (t(df=4) = -

0.01 p = 0.99). Mean overlap of the core home ranges of neighboring males was 29% ± SD 37%

(range 0.5-100%). Four males in 2014 and 3 males in 2015 had core home ranges (50% FK) with

multiple centers of activity. Daily summed movements for males that were tracked throughout

the day ranged from 354-6515m ($\bar{x}$=2942 SD ±1900) (Table 3). The mean rate of movement

(m/hr) was similar across study years (2014, 492 SE ±285; 2015, 334 SE ±218).

Habitat Characteristics and Use of Habitat Type

The visibility, and hence vegetation density, was found to vary across transects. The

average visibility for each section of each transect was calculated (Table 4b). Areas with less

visibility have higher vegetation densities.

The MCP ranges of all birds included both open pasture and closed forest locations. The

mean percent of each male's total radiolocations in open areas (x=46%) was similar to

occurrences in forest (x=54%). The 50% FK home ranges, however, showed that individual

males had heavy utilization of one or the other habitat types (Table 2) at the core of their

individual ranges.

Abundance and Distribution

During both field seasons birds were most numerous in the fields before the breeding

season began (January to mid February) and hit their lowest numbers in June (first field season)

and March (second field season) (Figures 5 and 6). The highest count was on the 9th of January

in the first field season (107) and on the 20th of February in the second field season (104). The

lowest count was on June 10th in the first field season (39) and on April 26th in the second field

season (31).

There were 566 sightings of Ocellated Turkeys along the 31 line transect survey routes over the study period. The maximum distances from the transects at which turkeys were detected were 368m, 103m, and 25m, for pasture, mixed and forest transects, respectively (excluding two observations of an individual at 209m in an atypical unvegetated strip within the forest). Mean flock size was 2±2.23 with variation across habitat types (Table 5). Sightings were least common in the forest transects (Table 5), where visibility was poor due to thick vegetation. Encounter rates were highest along transects with high heterogeneity of vegetation structure (i.e. "mixed"). Despite the high visibility in pasture habitat, encounter rates were only half those in mixed habitat. Encounter rates in forest were approximately 20% of those in pasture and approximately 10% of those in mixed habitat. More than half of the encounters in the forest were of turkeys seen directly on the transect route. To estimate overall population density across habitat types in the Gallon Jug region, the half-normal key with cosine adjustment provided the best model of detection probability (AIC= 5447.96) with significant goodness of fit (Kolmogorov-Smirnov test, D=0.2455, p<0.0001). Effective survey width (i.e. reliable detectability) occurred to 59.41m on either side of the transects. Based on the detection function generated by this analysis, the greater Gallon Jug landscape has an Ocellated Turkey encounter density estimated at $0.070/Km^2$ (with 95% confidence intervals of 0.038-0.130). Given that mean flock size was 2 birds, this model suggests that my study area has a density of only 0.14 individuals per Km^2.

Discussion

Despite its phylogenetic uniqueness, small geographic range, and declining populations, there have been no comprehensive conservation efforts to understand the ecological requirements of the Ocellated Turkey. Trophy hunting of breeding males holds promise for providing financial incentives to local citizens to protect this species (Baur et al. 2012), but there is insufficient quantitative knowledge of its biology to allow for sustainable management. Nevertheless it is assumed that the species will fare well in disturbed habitat in coexistence with livestock and agriculture (Lechuga 2001). Small studies by Gonzalez et al. (1998) and McRoberts (2014) laid the groundwork for understanding how Ocellated Turkeys make use of their home ranges with a focus on females. The unique reproductive strategies of male Ocellated Turkeys (Williams et al. 2010, Hanlon 2013), however, suggest that this species may have management requirements different from its congener the Wild Turkey. I found that adult male Ocellated Turkeys had a mean 95%FK during the breeding season in Belize that was 29% smaller than the mean annual home range found by McRoberts (2014) for a subadult male and several females in Mexico. He also found evidence of long distance (19.8 km) seasonal movements of hens from their winter range to their nesting areas, which may explain why the mean annual home range was so much larger than the nesting/chick-rearing home range (28 ha) of hens in Guatemala reported by Gonzalez et al. (1998). My radiotelemetry data set is the largest and most comprehensive study of the Ocellated Turkey to date, and the first that investigates adult males during the breeding season.

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My estimates of the male Ocellated Turkey home range during the breeding season are much larger than those reported for other large, ground dwelling Galliformes (Table 6). The Ocellated Turkey home range movements covered areas 189-375% larger than equivalent measurements of the Wild Turkey. Probably the larger mean home range can be attributed to the fact that some males have multiple centers of activity that can be separated by relatively large distances (5km or more), as shown for the only male monitored at the La Milpa study site (Figure 7). Differences in other factors that could influence home range size, that were not measured in this study, include intra-sexual aggression (Sinervo and Lively 1996), food abundance (Mills and Knowlton 1991), and risk of predation (Anderson et al. 2005). It is not clear whether differences in these variables contribute to the interspecific variation in home range size among these and other Galliformes species. The breeding home range of the Ocellated Turkey is much larger than the other similarly sized Galliformes, the Great Argus pheasant (*Argusianus argus*), Capercailie (*Tetrao urogallus*), and Yellow-knobbed Curassow (*Crax daubentoni*), can be explained by the idiosyncracies of their breeding behavior. The tropical male Argus pheasant moves little during the breeding season because it occupies and maintains its small courtship site in an exploded lek (Davidson 1981b), a mating system shared by the temperate Capercaillie (Segelbacher et al. 2007). The tropical monogamous male Yellow-knobbed Curassow, on the other hand, has a more restricted home range than the Ocellated Turkey probably because, unlike the turkey species, it participates in nesting and chick-rearing (Bertsch and Barreto 2008).

The differences in home range between temperate and tropical turkey species are also reflected in their rates of movement. Juhan (2003) found that male Wild Turkeys moved 241

m/hr in hunting preserves in southern Georgia, which is almost half the rate, traveled by

Ocellated Turkeys in my study. Godwin et al. (1994) observed adult male Wild Turkey moving

between 2907m and 4904m per day. I observed Ocellated Turkey moving on average 2888m (±

1872m) per day. While Ocellated Turkey may move shorter distances than Wild Turkey they

could perhaps be moving in straighter lines than Wild Turkey increasing their home range sizes.

Ocellated Turkey habitat preference (open vs. closed canopy) and daily path length was

examined as well. There was no correlation between home range size and percent of time

spent in open or closed habitat.   When looking at habitat use, based on 95% FK analyses, most

males were more likely to occur in one habitat type (open or closed), but several birds spent

time in both open and closed habitat. Individual males' occurrence only in open or only in

closed habitat intensifies when I look at an individual's 50% FK core home range. I found that

10 of our 12 males showed a strong preference for either open or closed habitat. Wild Turkey

males in contrast utilized wooded closed areas much more heavily (71.9%) than they did open

clearings (15.6%) (Lambert et al. 1990). Additionally, Morgan et al. (2006) found that adult

males tended to avoid open fields when suitable closed cover pine stands where available.

They believed that food and protection provided from predators influenced these male's

decision.

The decline in Ocellated Turkey numbers in the open fields of Gallon Jug over the course

of the breeding season suggests that individuals are using different habitats during different

parts of the year. A possible explanation for the drop in numbers could be that later in the

breeding season (April and May) females are incubating eggs and no longer visit fields.

Additionally at the end of May and beginning of June the rainy season begins which may result

in more and different forage opportunities elsewhere. Continuing block counts in the non-breeding season should show when Ocellated Turkey numbers again increase in the fields which may indicate another shift of food resources.

Ocellated Turkeys are easily seen in large, protected areas where they are not hunted and have habituated to human presence. At sites like Gallon Jug and various archaeological parks in Belize, where there are extensive areas that have been cleared of trees, flocks of turkeys can be seen from great distances, possibly leading to the misconception that this species remains widespread throughout its range with stable population numbers. I have shown that flocks are larger in open, disturbed habitat, and that in the forest this species seems to prefer open paths and roads. Both of these findings should raise concern about prior interpretation of the species status (IUCN 2014) because these behaviors will make the species appear more abundant than it really is in those habitats. My results also suggest that proper estimates of forest-dwelling Ocellated Turkey numbers will require random placement of transects because in that habitat this species seems to prefer roads in a way not seen in its temperate congener. This effect may occur only during the breeding season when males seek display areas in forest openings. Further population surveys are needed in other seasons to understand the best survey techniques for this species at those times of the year.

Ocellated Turkeys densities (0.14 birds/ Km^2) seem quite low relative to studies of other large Galliformes species. Based on a combination of calling data and direct observation on a transect grid, Winarni et al (2009) reported total density estimates for the Great Argus pheasant ranging from 0.86-3.72 birds/Km^2 across study years. Likewise the mean encounter rates of Ocellated Turkeys across the Gallon Jug area when converted to equivalent units (0.3

flocks/100 Km) was in the low range of similar measures of Wild Turkey flocks found during road-based surveys in Texas (0.1-2.2 flocks/100 Km) (Erxleben et al. 2010). By comparison encounter rates for other Neotropical Galliformes (e.g. walking trail-based surveys of curassows in Venezuela were 3-127/100 Km (Strahl and Silva 1997) are equivalent or much higher.

My study adds an important piece to our understanding of the natural history of the Ocellated Turkey. By pairing this study with the results of Gonzalez (1998) and McRoberts (2014) we begin to get a more complete view of the movement patterns of Ocellated Turkey. One of the limitations of this study is the inability to identify all the variables that dictate home range size in male Ocellated Turkey during the breeding season. Ocellated Turkey males have large home ranges during the breeding season, which makes study and conservation difficult. Differences from Wild Turkey, larger home ranges, faster movement rates, less utilization of wooded areas (in some instances), and low densities, will require a different set of guidelines for the conservation of Ocellated Turkey compared to Wild Turkey. Furthermore, the different mating system used by Ocellated Turkey, resource defense polygyny, will provide unique challenges compared to the Wild Turkey as suitable habitat for male display courts will have to be identified and included in any conservation planning. Continuing research needs to emphasize how different levels of human disturbance affect home range size and breeding success in both male and female Ocellated Turkey.

Table 1: Key themes of the scientific literature on the biology of the Ocellated Turkey.

Author and Year	Title	Key Themes
Shufeldt 1913	Unusual Plumages of the Ocellated Turkey	Description of Atypical Plumage
Leopold 1948	The Wild Turkeys of Mexico	Home Range Natural History
Steadman et al. 1979	Natural History of the Ocellated Turkey	Comprehensive Natural History
Sugihara and Heston 1981	Field Notes on Winter Flocks of the Ocellated Turkey	Flock Composition Feeding Habits
Gonzalez et al. 1998	Habitat use and Reproductive Ecology of the Ocellated Turkey in Tikal National Park Guatemala	Habitat Use Female and Poult Survival Home Range
Baur 2008	Structure of a Lowland Neotropical Galliform Bird Guild	Diet Habitat Use Nest Data Hunting Rates
Williams et al. 2010	The Ocellated Turkey in the Land of the Maya	Natural History Alternate Mating Strategies Hunting
Kampichler et al. 2010	Indication of a Species in an Extinction Vortex: The Ocellated Turkey on the Yucatan Peninsula, Mexico	Habitats of Importance Effects and Patterns of Human Predation Extinction Risk
Hanlon 2013	Male Reproductive Strategies and Mating Displays in the Ocellated Turkey (Meleagris ocellata)	Ethograms of OT Male Reproductive Strategies
McRoberts 2014	Investigations into the Ecology and Management of Ocellated Turkeys in Campeche, Mexico	Ecology and Natural History Diet and Feeding Ecology Home Range and Movement

Table 2: Male's behavior state, number of locations and resulting home range estimates, and core habitat percent open utilization distribution based off of locality data

Bird ID	Alpha or beta	Number of locality data	MCP (ha)	95%FK (ha)	50%Fk (ha)	Core range percent open utilization
10	Alpha	70	362	90	17	100
40	Beta	45	68	38	1	62
30	Alpha	58	2244	1189	126	100
28	Beta	60	1705	2630	445	75
45	Alpha	57	95	36	2	0
34	Beta	60	181	230	21	91
36	Beta	32	809	190	9	58
38	Alpha	37	1873	1078	90	100
48	Beta	42	540	304	16	0
49	Beta	39	973	1760	289	0
43-2	Alpha	36	115	202	24	0
31	Alpha	97	2663	564	47	0

Table 3: Mean meters per hour moved and daily summed movement of radio-tagged males

Bird	Mean meters/hour	Daily summed movement
10	174 (±102)	1305 (±934)
28	541 (±285)	3983 (±2652)
30	165 (±81)	1265 (±715)
34	404 (±281)	3286 (±2372)
40	826 (±441)	5767 (±3446)
45	718 (±667)	3490 (±3324)
36	857 (±507)	6515 (±4518)
38	256 (±189)	1787 (±870)
49	411 (±269)	2132 (±810)
31	557 (±469)	3352 (±2476)
43-2	90 (±96)	520 (±365)
48	245 (±230)	1258 (±940)

Table 4a: Line transect sections detailing lengths (m) and portions of line transects that were in differing levels of habitat disturbance (low and intermediate disturbance have canopy cover high disturbance does not).

Route	Low	Intermediate	High	Total
A	7988	--	--	7988
B	--	2049	1463, 790	4302
C	3400	--	--	3400
D	1112	--	--	1112
E	2867	--	--	2867
F	2121	8352	--	10473
G	--	--	1034, 2856	3890
H	--	693, 403, 325, 451	--	1872
I	3932	1317	668	5917
J	2125	641	622, 690	4078
K	3680, 441	156	--	4277
L	--	--	2494, 1250	3744

Table 4b: Line transect routes with visibility for each section. Each section is subdivided into as many as 4 subsections A – D. The direction indicated before each distance (m) indicates which direction the transect the measurement was taken from and the final value is the visibility looking strait down the transect route.

Route	Section A	Section B	Section C	Section D
A	SW: 26 NW:4 S: 4	--	--	--
B	W: 38 E: 26 N: 203	W: 198 E: 230 N 128	W: 81 E: 26 N: 179	--
C	NE: 5 SW: 5 E: 110	--	--	--
D	E: 3 W: 2 N: 24	--	--	--
E	N: 4 S: 5 E: 111	--	--	--
F	W: 18 E: 17 N: 414	S: 14 N: 13 W: 136	SE: 4 NW: 4 S: 34	--
G	W: 191 E: 340 S: 184	W: 28 E: 230 S: 140	--	--
H	S: 14 N:14 W: 269	S: 23 N: 27 W: 289	S: 8 N: 14 W 69	S: 6 N: 8 W: 66
I	S: 11 N: 312 W: 298	S: 26 N:37 W: 237	SW: 13 NE: 12 NW: 179	--
J	N: 144 S: 75 E: 57	NE: 10 SW: 11 SE: 232	E: 113 W: 37 S: 414	E: 126 W: 25 S: 206
K	N: 5 S:5 NE: 110	--	--	--
L	E: 30 W: 354 S: 344	S: 114 N: 287 W: 278	--	--

Table 5. Summary of line transect results.

Habitat (Number of Routes)	Total Route Surveys	Total Transect Length (m)	Number of Sightings	Sightings on Roads	Mean Flock Size ± SD	Ocellated Turkeys per Km
Pasture (9)	344	7,598,074	333	8%	2.20 ± 2.57	0.096
Mixed (12)	153	1,271,890	122	33%	1.89 ± 1.71	0.182
Forest (10)	163	8,532,650	111	53%	1.42 ± 1.16	0.019

Table 6: Comparison of male Ocellated Turkey home range estimates to equivalent estimates in other large ground-, and forest-dwelling male Galliformes observed during their breeding seasons.

Author	Species	Home Range Type	Average HR (ha)
This Study	*M. ocellata*	MCP	979
Smith et al. 1988	*M. gallopavo*		261
Winarni et al. 2009	*Argusianus argus*		15
This Study	*M. ocellata*	95% FK	692
Juhan 2003	*M. gallopavo*		366
Bertsch and Barreto 2008	*Crax daubentoni*		197
This Study	*M. ocellata*	50% FK	90
Wegge and Larsen 1987	*Tetrao urogallus*	Modified Minimum Area	26
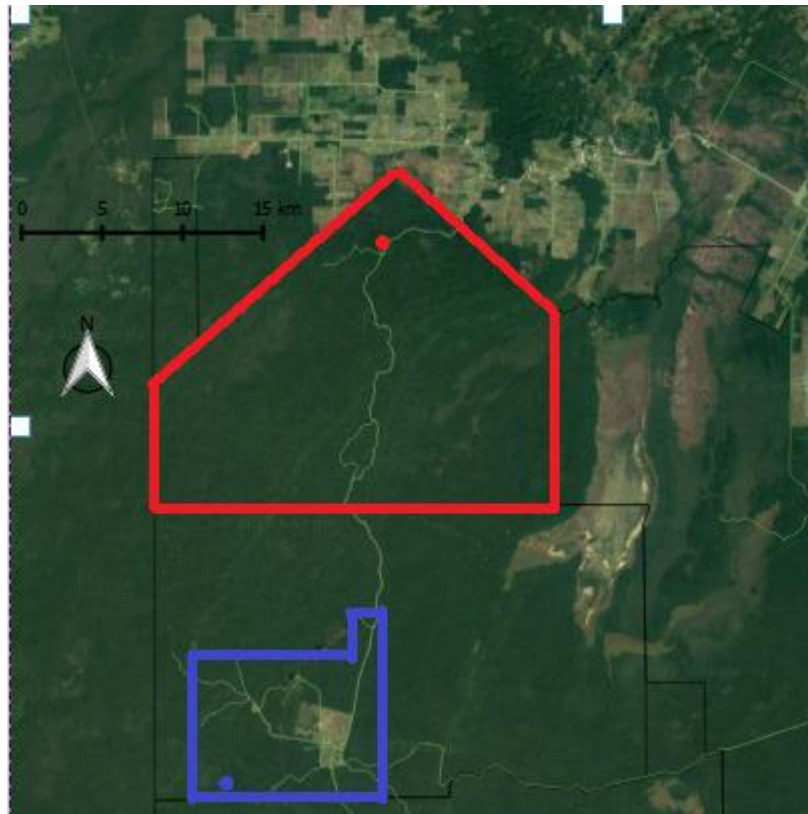
Figure 1: An aerial view of the Gallon Jug Estate (blue) with Chanchich eco lodge as a blue dot and the Rio Bravo Conservation and Management Area (red) with La Milpa field station as a red dot.
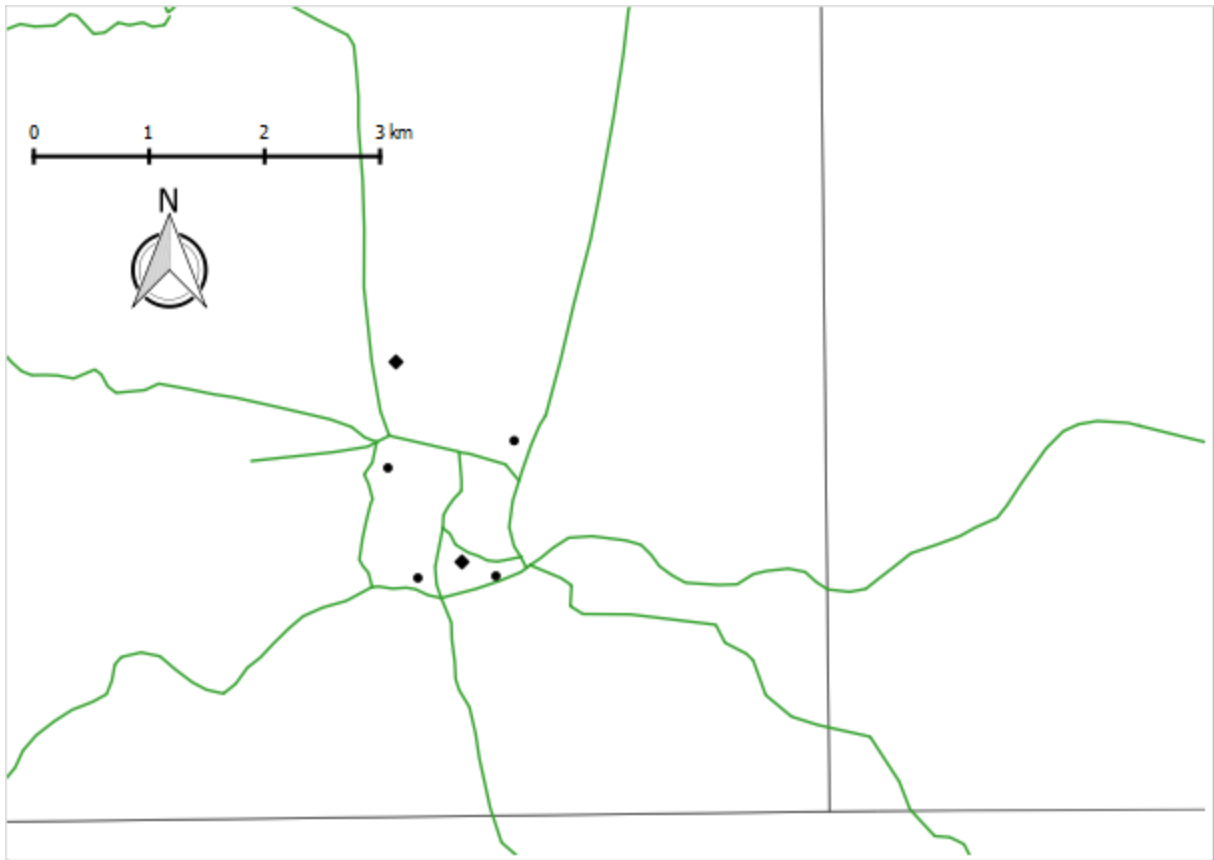
Figure 2: A roadmap (green lines) of the central area of the Gallon Jug study site. Black circles show the locations of hilltops where scheduled radio-telemetry was conducted while diamonds represent areas where spent brewers grain (supplemental feed) is available ad libitum. Solid black lines indicate Gallon Jug's southeast border.
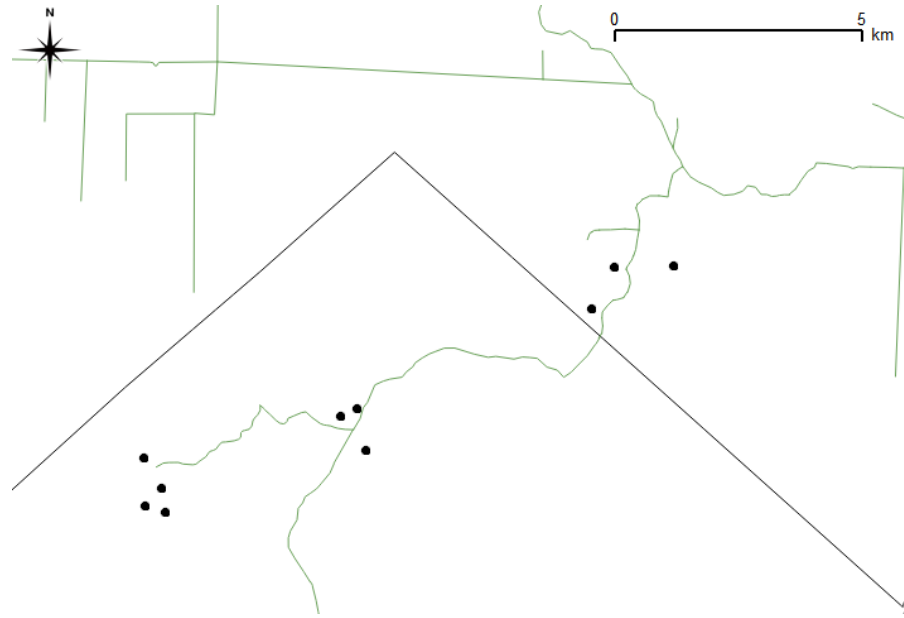
Figure 3: Roadmap (green lines) of the La Milpa study site. Black points indicate the location of highpoints (Mayan pyramids, field station structures, and hilltops in pastures, respectively clustered from south to north) used as radiotelemetry locations. The black line is the northern border of the Rio Bravo Conservation and Management Area
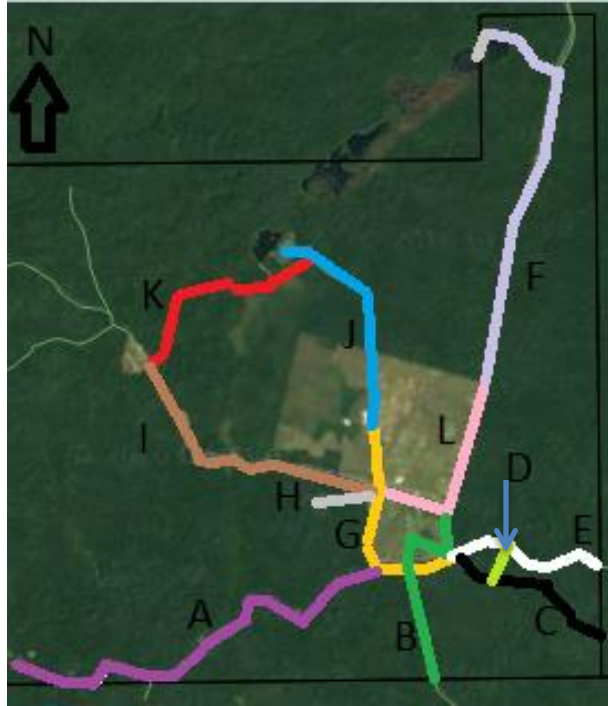
Figure 4: Survey routes used for block counts and distance sampling at the Gallon Jug study site.
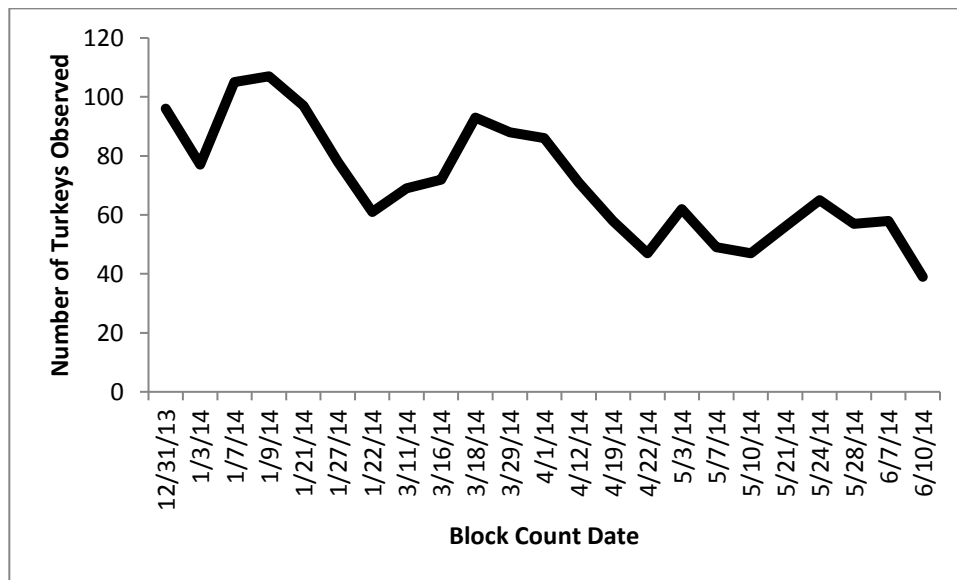
Figure 5: Total number of Ocellated Turkeys (males, females, sub-adult males) counted in the open fields of Gallon Jug during the first field season.
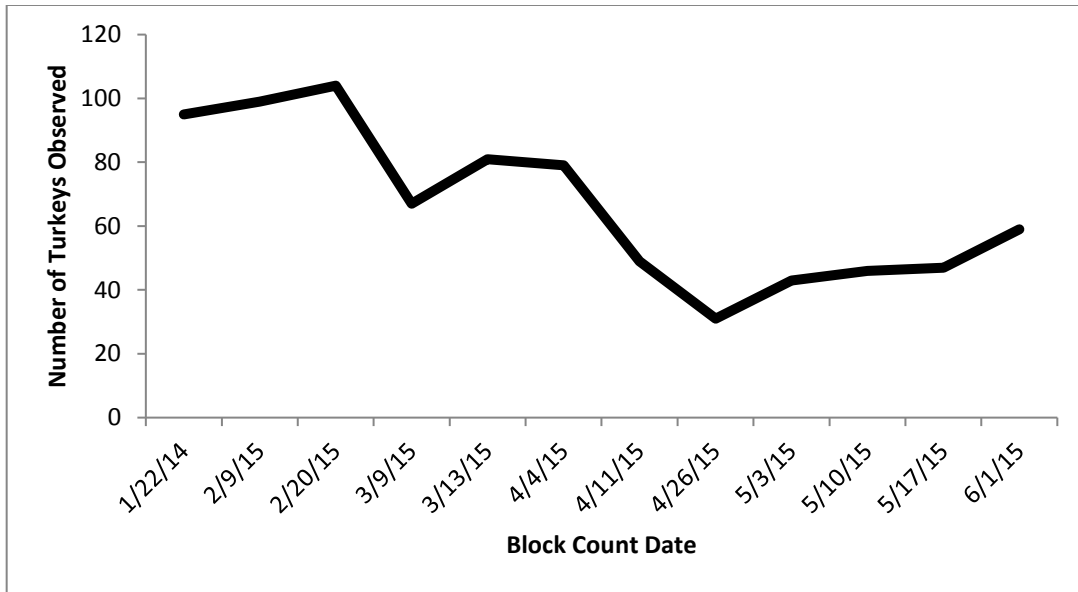
Figure 6: Total number of Ocellated Turkeys (males, females, sub-adult males) counted in the open fields of Gallon Jug during the second field season.

Figure 7: Bird #45 at the La Milpa study site illustrates multiple centers of activity as indicated by the two different areas in his 50% FK home range and twelve areas in his 95% FK home range.

CHAPTER TWO

Variation in Behavior and Health Across a Human Disturbance Gradient of a Threatened

Yucatan Endemic

Introduction

Sixty percent of all known species reside in the tropics (Bradshaw et al. 2008), and thus

anthropogenic habitat destruction in the tropics has a disproportionate effect on global

biodiversity loss. Because less than 10% of tropical forest occurs in protected areas, Gardner et

al. (2009) call for conservation ecologists to develop a scientific framework for understanding

the persistence of forest species in human-modified habitat. All forest species are not equally

affected by anthropogenic disturbance and habitat change. Some species, such as the great

curassow (*Crax rubra*), a terrestrial frugivore that rarely leaves the protection of intact forest,

experiences population decline with even minor degrees of forest disturbance (Arriaga-Weiss et

al. 2008). Other forest bird species make temporary use of human modified landscapes for

select activities such as feeding, roosting, or courtship, such that the resources they find there

might allow their populations to persist despite a loss of forest cover (e.g. keel-billed toucans

(*Ramphastos sulfuratus*); Graham 2001). For forest species that are willing to make use of

human-modified habitats, a better understanding is needed of the impact of different types of

disturbance on their survival and reproductive success (Chazdon et al. 2009). Anthropogenic

disturbance of tropical forest ranges from the seemingly minor ecological impact of ecotourism,

to the intermediate structural alteration of forests by shaded coffee groves, 'milpa' agriculture,

and selective logging, and ending in the complete deforestation that occurs for commercial

agriculture and cattle ranching. Humans rapidly modify the environment and cues used by

animals to choose where to live may become maladaptive (Weldon and Haddad 2005; Sih et al.

2004). Consequently, disturbed areas may act as 'ecological traps' for some forest birds (Gates

and Gysel 1978), causing population decline. Thus, traditional indices used to assess

conservation status in a location, such as species abundance and documentation of

reproductive activity, are inadequate predictors of habitat quality and population viability

(Hansen 2011) in a human-modified landscape.

Anthropogenically disturbed areas can attract forest wildlife but have negative

consequences such as increased parasitism, poor nutrition, and physiological stress. Human-

modified habitats may offer point food sources (e.g. gardens, cattle troughs, bird feeders, trash

bins, etc.) where wildlife aggregate, possibly resulting in greater transmission of disease and

parasites (Rosatte et al. 2010). Parasite loads often increase in fragmented habitats (Arroyo-

Rodriguez and Dias 2010; Cottontail et al. 2009; Giraudeau et al. 2014). Many of these

processes are related to changes in the spatial use of the habitat. When an organism is forced

to reuse the same parts of its home range it can come into repeated contact with feces from

conspecifics, increasing the opportunities for parasitic infection, as demonstrated by a positive

association between home range utilization and parasite loads among some primate species

(Nunn and Dokey 2006). Logging activities and deforestation appear to increase parasite burden among red colobus monkeys (*Procolobus tephrosceles*) through increased fecal exposure in smaller home ranges and by forcing them to travel on the ground where they are exposed to additional disease vectors (Gillespie and Chapman 2006).

Abundant anthropogenic resources may allow animals to have smaller home ranges with lower maintenance costs, however smaller home ranges may have tradeoffs. Consequences may include chronic parasitism that reduces host survival (Hudson et al. 1992; Lafferty and Morris 1996), poor reproductive success (Marzal et al. 2005), impaired male courtship (Clayton 1990), increased female mate sampling costs (Buchholz 2004), increased thermoregulatory costs (Booth et al. 1993), and sub-optimal foraging (Lozano 1991). Additionally, parasitized animals may experience a downward health spiral when the energetic costs of parasitism reduce their ability to pursue alternative spatial movements that would allow them to escape reinfection. Similarly, the increased frequency of behavioral interaction with conspecifics, predators or humans that can occur in human-modified environments may induce a glucocorticoid stress response that can suppress immunity as reflected in changes in leukocyte ratios (Davis et al. 2008), and resulting in greater disease susceptibility (Acevedo-Whitehouse and Duffus 2009).

Disturbance, poor nutrition and parasitism can interact in complex ways. Food sources in disturbed areas may be nutritionally inferior to natural foods despite their abundance and ease of access. Animals in poor nutritional health may have reduced body size, decreased birth rates, increased infant mortality, and changes in behavior such as lengthier or more frequent foraging bouts (Trites and Donnelly 2003). Low protein diets affect not just host immunity, but

also how pathogens interact to harm the host during co-infection (Budischak et al. 2015). Black

howler monkeys (*Alouatta pigra*) must eat poorer quality foliage after forest damage, which in

turn increases their ingestion of the intermediate host of trematode parasites, resulting in more

infections (Behie et al. 2014).

Alternatively, one could argue that the greater caloric abundance available from

disturbed sites can strengthen immune protection against disease (e.g. by 'feeding a fever';

Becker et al. 2015) or compensate for the host's resource loss to parasites, as occurs with cyclic

fluctuations of natural foods (Appleby et al. 1999). In addition, such a diet can easily be

nutritionally supplemented with specific food items available in the forest, and thus could be

adaptive despite the costs. Empirical studies support both arguments (Becker et al. 2015);

anthropogenic provisioning can either increase pathogens in wildlife or decrease them. Species

such as elk (*Cervus elaphus*) (Hines et al. 2007), European greenfinch (*Chloris chloris*) (Lawson et

al. 2012), and Indian flying fox (*Pteropus giganteus*) (Field et al. 2001) have all shown increased

parasitism where anthropogenic food sources occur. Parasite burden increases because of

increased contact among individuals that aggregate at food sources (Cross et al. 2007; Lawson

et al. 2012) including exposure to novel parasite species if aggregations are multi-species (Field

et al. 2001). In contrast anthropogenic food sources may positively impacts populations, as

illustrated by Lace monitors (*Varanus varius*) (Jessop et al. 2012), Long-tailed macaque (*Macaca

fascicularis*) (Lane et al. 2011), and Red fox (*Vulpes vulpes*) (Hegglin et al. 2007), by improving

nutrition and body condition, lowering parasite intensities, and decreasing consumption of

natural foods that act as intermediate hosts for parasites.

The responses of animals to environmental change are complex (Acevedo-Whitehouse and Duffus 2009) and determining the likely outcomes requires an integrative approach (Warne et al. 2015). Collecting detailed demographic information for population viability analysis (Beissinger 2002) may not be feasible, thus a research approach that integrates the behavior and physiological health of individuals of a species (Cooke et al. 2014) may be required. Apart from typical measures of animal health, such as parasite burden, immune status, and body weight, bioindicators of environmental quality can be used. Behavioral variables, such as optimal home range use (Mitchell and Powell 2012) and courtship rate (Laiolo et al. 2011), in addition to morphological variables, such as condition-dependent plumage or fleshy ornamentation can provide a more holistic picture of the conservation needs of a species.

Observations of an animal's behavior can reveal information about its perception of the environment. Foraging rates, vigilance rates, and flight initiation distance have all been used to assess how animals perceive risks when interacting with humans (Gill 2007). Flight initiation, or the distance at which an animal flees, is an indicator of an animal's perceived risk of predation. When in a riskier situation animals are more likely to flee sooner than animals that feel safer (Lima 1998). For example, woodchucks (*Marmota monax*), increase their flight initiation distance when further away from a refuge burrow (Kramer and Bonenfant 1997). By factoring in flight initiation distance as a measure of disturbance along with bioindicators I may be able to create a more holistic picture the Ocellated Turkey's response to disturbance.

Hill (1994) was the first to propose that the sexual ornaments assessed by birds during mate choice could serve as indicators of environmental quality. Birds in poor nutritional state

or that are heavily parasitized can suffer impaired feather growth (Grubb 2006) and have

reduced quality of sexual ornaments such as reduced feather reflectance and smaller fleshy

ornaments (Hill and Montgomerie 1994; Ohlsson et al. 2002). These traits, therefore, can be

used as biomarkers of forest fragmentation (Stratford and Stouffer 2001), nutritional state

(Ohlsson et al. 2002), and parasite loads (Buchholz 1995; Hill et al. 2004). Feathers that express

coloration via structural elements rely heavily on the precise alignment of elements to scatter

light. Food quality, quantity, and parasite loads have been shown to disrupt the alignment of

feather structural elements. Brown-headed cowbirds (*Molothrus ater*) that were placed under

fasting conditions during feather moults had structural colors that were duller than cowbirds

that did not fast (McGraw et al. 2002). Hill et al. (2004) also experimentally illustrated that

coccidian burden can also decrease feather reflectance in Wild Turkey (*Meleagris gallopavo*)

especially across the UV spectrum.

I explore the costs and benefits that Ocellated Turkey (*Meleagris ocellata*) experience

when utilizing anthropomorphically altered habitats by measuring home range size, biomarkers

of animal health (feather reflectance, fleshy ornaments, and feather barring regularity),

parasite burdens, and behavioral cues such as foraging rates, vigilance rates, and flight initiation

distances. Ocellated Turkeys are poorly understood Yucatan forest endemics that use human-

disturbed areas near intact forest (Hanlon 2013). I studied a protected population in NW Belize

where areas of varying degrees of disturbance (cattle pasture, shade coffee groves, and

ecotourism lodges) occur alongside large tracts of virtually undisturbed forest. Some individuals

seem to restrict themselves to the forest, while others venture out into disturbed areas

regularly, or spend most of the day in human-modified habitat (Chapter 1). The presence of

differing habitat disturbance provides an opportunity to contrast the difference in health and behavior of Ocellated Turkey in different levels of anthropomorphized habitats.

My objectives are two-fold: a) to identify possible bioindicators that could be used for population health assessment of Ocellated Turkeys, and b) to identify features of existing human-modified habitats that should be managed to improve the long-term viability of this species. My hypothesis is that disturbance is bad for the Ocellated Turkey. Birds in the most highly disturbed areas should suffer the most negative consequences followed by birds that inhabit intermediate areas and finally birds in lightly disturbed areas should suffer the fewest negative health consequences. I predict bioindicators such as sexual ornaments will indicate parasite burden and body condition, as they do in the sexually selected frontal process, and feather iridescence, of the congeneric Wild Turkey (*Meleagris gallopavo*) (Buchholz 1995, Hill et al. 2005). Additionally, I hypothesize that Ocellated Turkey home range movements respond to anthropogenic resources in accordance with optimality theory (Schradin and Pillay 2006), which predicts that supplemental food decreases home range size (Taitt and Krebs 1981). Cattle pasture, feedlots and roadsides likely provide concentrated food resources for this species, such that home ranges shrink and are more stable in disturbed areas because individuals no longer need to bear the costs of searching widely to meet their energetic or other needs (Quinn and Whisson 2005; Lurz et al. 2000; Prange et al. 2004). However, I predict that as a consequence of small, overlapping home ranges, where social stress and parasitism are relatively high for a species that normally occurs at low densities in undisturbed forest, individuals in human-modified habitat will be in poorer health than forest-dwelling turkeys.

Methods

Study Species and Study Site

Ocellated Turkeys are endemic to the rainforests of northern Belize, northern

Guatemala and southern Mexico (Steadman et al. 1979). Although populations in protected

areas appear to be healthy, they are declining rapidly elsewhere (Kampichler 2010). Few

quantitative studies of their ecology exist (Chapter 1), and yet it is generally assumed, without

supporting evidence, that they should be managed like their well-studied temperate congener,

the North American Wild Turkey (*Meleagris gallopavo*). The Ocellated Turkey is smaller, less

sexually dimorphic, and differs in male breeding behavior from Wild Turkeys (Williams et al.

2010, Hanlon 2013). Wild Turkeys are omnivorous with their diet varying seasonally and greatly

across their broad latitudinal range (Hurst 1992). The diet of the Ocellated Turkey, in contrast,

consists primarily of seeds (77%), fruit pulp (11%) and leaf matter (10%), and very little animal

matter (1%) (Baur 2008). While foraging in grassy areas along roadsides, forest paths and

clearings and on cattle pastures, both sexes of Ocellated Turkey walk slowly as they strip the

seeds from grass (personal observation). At the Gallon Jug study site (Chapter 1) some

individual turkey feed primarily on the brewer's grain store piles at two cattle feedlots, but

forest dwelling turkeys elsewhere ignore corn and millet offered to them.

Gallon Jug Estate (17 33.634°N, 89 02.801° W) is a privately-owned ranch in NW Belize

with a cleared central core (1214 ha) used for cattle grazing surrounded by selectively logged

forest (40469 ha). In addition there is a small shade grown coffee plantation, a paved airplane

runway, sawmill, lawns around homes and buildings, and an area of undisturbed forest (12141

ha) surrounding the Chan Chich ecotourism lodge. Within the central pasture are two small

cattle feedlots where brewer's grain is provided *ad libitum*. The forests in Gallon Jug are

tropical evergreen broadleaf lowland forest, growing on calcareous soils, and are classified as

the Holdridge life zone 'subtropical moist forest' (Meerman 2000, Kelly and Rowe 2014).

Contiguous with the Gallon Jug Estate is the Maya Biosphere Reserve of Guatemala and the Rio

Bravo Conservation Management Area (RBCMA; 105,218 ha), the latter of which is managed for

sustainable conservation use by the Programme For Belize, primarily through selective logging

of tropical hardwoods and ecotourism. Within the RBCMA is my second field site, the La Milpa

field station (17 50.487° N, 89 01.106° W), with the same forest type as Gallon Jug, but lacking

any large clearings. Both sites contain karst hills and low, seasonally wet bajos. To the north of

La Milpa the Mennonite community of Blue Creek directly abuts La Milpa's forest with

extensive, and completely deforested, agricultural and grazing lands. Although the Ocellated

Turkey is a protected species in Belize, and hunting is not permitted in Gallon Jug and RBCMA,

although illegal poaching sometimes occurs, along the northern perimeter of the protected

area.

Capture and Processing

Ocellated Turkey were trapped using a variety of methods as described in Chapter 1.

Measurements recorded from captured turkeys included: weight, spur length, snood length

(un-stretched and stretched, after Buchholz 1995), the length, width and height of the crown,

tarsus length, and the number and location of caruncles. Two feathers were collected from

each of the following three locations: the center of the chest at wing level, right wing secondary

wing coverts number 5 and 6, and right-side secondary tail retrices numbers 4 and 5. Blood

samples were collected for making blood smears and for preservation of DNA. A fecal sample

was collected if available, and stored in 2.5% potassium dichromate solution. This research was

conducted with the approval of the University of Mississippi IACUC (Protocol no. 11-005) and

the Belize Department of Forestry.

Radio Telemetry and Home Range Estimation

A more detailed methodology for telemetry is provided in Chapter 1. Radio backpacks

74g VHF radio transmitter A1540B (Advanced Telemetry Systems [ATS], Isanti, MN, USA) were

fitted to males 3+ years or older (*n*=17). The locations of radio-tagged Ocellated Turkeys were

monitored by radio telemetry 3 days per week from February 10, 2014 to June 10, and 2 days

per week from January 10, 2015 to May 1, 2015 and daily from May 2, 2015 June 1, 2015 at the

Gallon Jug study site. During the 2014 field season the bird locations were determined

continuously from dawn to dusk, at 2 hr intervals. In 2015 telemetry locations were

determined once in the morning (0600-1200) and again in the afternoon (1300 – 1800). The

only radio-tagged male at the La Milpa study site was tracked for 5 sequential days every 3

weeks in the 2014 field season and until he was poached early in the 2015 field season after 11

days of tracking. At least 30 locality data points ($\bar{x}$=50$\pm$21) per bird were used to create

minimum convex polygons (MCPs) and fixed kernels (FK) home ranges. Location Of A Signal

(Ecological Software Solutions LLC) software was used to estimate bird locations from telemetry

observations and BIOTAS (Ecological Software Solutions LLC) software was used to calculate MCPs, 95%, and 50% FK density estimates.

Fecal Parasites

Fresh fecal samples were collected during handling or when defecation of marked birds was observed. Fecal samples were air dried and then mixed with 30 ml of water and potassium dichromate concentrate. After collection, 30ml potassium dichromate-fecal mixtures were aerated by stirring repeatedly over 3 days to allow sporulation of oocysts. Thereafter they were sealed in plastic tubes and stored at ambient temperature until they were brought back to the University of Mississippi for processing. In the lab, 1mL of re-suspended fecal matter was centrifuged in a 15-ml conical centrifuge tube filled to rim with sugar solution (1.28g/mL of a 56% sucrose solution) and capped with a cover glass. Centrifugation in the swing arm IEC HN-SII Centrifuge (International Equipment Company, Needham Heights, MA, USA) was for 6 minutes at 1,000 rpm (85Gs). The coverslip with parasite eggs, oocysts and larvae in the adhering top layer were examined at 100x magnification using an Olympus BX40 compound light microscope (Olympus Corporation, Tokyo, Japan). For objects that required fine scale identification 400x magnification was used. Parasite counts were standardized by dry fecal weight of each individual sample, determined by drying 1mL of fecal suspension in a Model 6M oven (GCA/Precision Scientific Chennai, India) overnight at 36°C. For analysis, I used coccidian oocysts as the measure of parasitism because they were the most common and abundant parasite across all samples.

Blood Parasites and White Blood Cell Counts

A small blood sample was collected by syringe from the brachial vein. Thin blood smears were air dried and then placed in a slide box for transport back to the University of Mississippi. The smears were then fixed in 100% methanol and stained in Wright's stain (Polysciences, Inc., Warrington, PA) for 27 minutes, and diluted Wrights (50% Wrights and 50% PBS) for 15 minutes, followed by a wash with distilled water and air-drying. Two slides per bird were examined for both blood parasites and white blood cell counts. Blood parasites were quantified by examining 10,000 erythrocytes under the oil immersion objective (1000x) for the presence of hematozoa. Once hematozoa were quantified all hematozoa were combined for a total hematozoa burden which was used in statistical tests. The heterophil:lymphocyte ratio (H:L) was determined from the first 100 leukocytes of those types encountered in the optical field. The H:L ratio was used as an indicator of stress (Davis et al. 2008). The average of the two slides per bird was used in the statistical analyses of blood parasite numbers and H:L.

Feather Barring Regularity Measurements

The secondary tail retrices were scanned on a flatbed scanner (Canon MX850) at 600 dpi and saved as .tif files. The feather was placed face down on the scanner bed oriented so that the rachis was perpendicular to the scanning bar. The regularity of feather barring was measured using a code developed by Gluckman and Cardoso (2009) for Matlab (R2009a, The MathWorks, Natick, Massachusetts, U.S.A.). The regularity score was based on two components the barring of the center of the inner vane and the center of the outer vane

barring excluding the rachis. The downy lower barbs and the colored upper barbs were not included in feather regularity measures as there is no barring present in those sections. Barring on the inner and out vane of the feather was measured separately and then averaged to give a regularity score for each feather. Regularity scores lay between 0.0 and 1.0, representing a spectrum from irregular to regular barring, respectively.

Feather Color Spectra Collection

The reflectance spectra of breast feathers, secondary tail retrices, and secondary wing coverts were measured using an Ocean Optics (Dunedin, FL) USB2000 fiber optic spectrometer with a PX-2 xenon light source. Large feathers, secondary wing coverts and secondary rectrices, were measured singularly and breast feathers were overlapped to create an area of measurement equivalent to that on the larger feathers. The light source was placed so that it shone on the feather from above at a 90° angle to the rachis. The light collecting probe was positioned at the angle that reflected the most light (brightness) from the 300-700nm range. Feathers were placed on the reflectance stage so that the feather was positioned flat on the stage with the light probe at a 90° angle to the feather. The collimating lens on the light collecting probe was focused so that a 2mm diameter spot measured on each feather. The angles that provided the highest reflection for each feather type were: 90° for the breast feather colored edge, 70° for the blue ocelli of the secondary tail retrices, and 40° for the copper secondary wing covert (for a schematic of how feathers were measured see Appendices ii). Breast feathers were measured at the proximal end where the colored edges of two feathers were overlapped to create a 2mm patch. The blue ocelli at the distal end of the

secondary tail retrices were measured. Finally the copper center of the inner vane (the colored

side that is not overlapped by other feathers) of the secondary wing covert was measured.

Three replicate measurements were collected of each area on each of the two feathers of each

type (breast, secondary wing covert, secondary tail rectrices) per bird. Tristimulus values

(brightness B1, chroma S1 values, and hue H1) were calculated by the software program CLR

(Montgomerie 2008) for wavelength subsets (300-450nm, 450-500nm, 500-550nm, and 550-

700nm) relevant to wild and domestic turkeys vision (Hill et al. 2005).

Disturbance Tolerance Measure

Marked males were observed in three times in total, no more than once in a day chosen

opportunistically such that all subjects had to be observed once (or twice) before any could be

viewed for the second (or third) observation bout. When a marked bird was spotted, its

location was recorded relative to the observer's position as determined with a GPS unit

(Garmin, Canton of Schaffhausen, Switzerland). Focal animal sampling of behavior occurred for

three 5 min observation periods each separated by 5 min without behavior recording. During

each 5-minute observation period, behaviors were noted every 5 seconds. After observations

were completed I would slowly but steadily approach the bird until it fled. Observations began

as soon as I spotted and identified a bird, which was always before it became concerned with

my proximity as assessed by the lack of attention to me. If the subject went out of sight during

the 5-minute observation window I waited up to 15 minutes for it to return. Observations of

less than 15 min of behavior per day in total were excluded from analysis. During observation,

the following variables where recorded: the distance of the bird from forest, the distance of the

observer to the bird, distance until the bird became vigilant due to observer approach, the

distance from observer when flight initiation occurred, the percentage of time the bird was

vigilant, and the percentage of time the bird foraged. These variables were scored according to

the criteria in Table 1. The scores were added together for each variable and then summed to

generate a disturbance score for each individual. Each bird had three disturbance scores, which

equates to three 15-minute observation windows totaling 45 minutes, which were averaged to

create an overall disturbance score. High scores were indicative of disturbed birds (usually

found in highly disturbed areas) and low scores were indicative of undisturbed birds (usually

found in lowly disturbed areas).

Statistical Analyses

Data were tested for normality with the Shapiro-Wilk test, and, where appropriate, a

Levene's test for homogeneity of variance. Non-normally distributed data were transformed as

appropriate when necessary (see results). One-way analysis of variance (ANOVA) was used to

test for differences in disturbance score between the disturbance categories (high,

intermediate, low) with n = 4 for each group. When significant results were found from

ANOVAs they were further analyzed using Tukey post-hoc tests. Capture location was used to

assign birds to a disturbance type: birds captured in fields were considered to inhabit highly

disturbed habitat, birds captured in coffee plantations and grassy strips around roads were

considered to inhabit intermediately disturbed habitat, and birds captured in the jungle were

considered to live in lowly disturbed areas. Because capture location may not reflect the

disturbance level of the habitat type where a subject spends most of its time, an alternative

approach to analysis was to use the percentage of time spent in areas without canopy cover as

the independent variable in regressions and correlations. Individuals that spent more time in

open areas were assumed to experience greater disturbance than individuals that spent less

time in open areas. Details for statistical tests such as sample size, degrees of freedom,

predictor variables, and effector variables can be found in Tables 2, 3a, and 3b. Means are

reported with standard deviation (± SD). All analyses were conducted with SPSS (SPSS v22,

IBM, Armonk NY, USA).

Results

Capture Success

Of the twenty four males captured seventeen were fitted with radios, twelve of which

were successfully monitored long enough to calculate home range estimates. Males had to be

monitored for at least a month to gather 30 or more locations. Of the five that died 2 were

depredated in low disturbed habitat, two were depredated in moderately disturbed habitat,

and one was depredated in highly disturbed habitat.

Parasite Burden

There was no significant association of fecal parasite load with disturbance habitat type.

Coccidia burden (Log oocysts/g) was not dependent on the level of disturbance (F(df = 2, 9) =

0.12, *p* = 0.88). The mean coccidian burden was not associated with disturbance levels, but was lowest in the field-living individuals (Table 4; Figure 1). Similarly hematozoa burden did not differ between levels of disturbance (F(df = 2, 9) = 4.87, *p* = 0.08) (*Haemproteus* (F(df = 2,9) = 2.73, p = 0.16), *Plasmodium* (F(df = 2, 9) = 2.21, p = 0.16); however, the lowest intensity of infection was among forest birds (Figure 2). The percent of time spent in open areas was not associated with fecal parasite burden (t(df = 1, 10) = 1.95, p = 0.08) with an adjusted R^2 = 0.20 with an equation of y = 1.09 + 0.1x. The percent of time spent in open areas was not associated with hematozoa burden (t(df = 1, 10) = 0.95, p = 0.36) with an adjusted R^2 = 0.08 with an equation of y = 5.64 + 0.04x.

Home Range

Home range did not vary significantly between the three disturbance groups in any of the home range size estimates F(df = 2, 9) = 1.86, p = 0.21) (MCP, 95%FK, and 50%FK) (Table 5 + 6). The percent of time spent in open habitat was not correlated with home range size for MCP (r(df= 10) = 0.36, p = 0.24), 95%FK (r(df= 10) = -0.12, p = 0.70), and 50%FK (r(df= 10) = -0.21, p = 0.50).

Disturbance Tolerance Measure

The mean disturbance score differed significantly across birds captured in different disturbance habitats (*F*(2, 9) = 15.27 p < 0.001, ω^2 = 0.70). Birds in the highest disturbed habitats had the highest mean disturbance score (18.75 ±1.65). Birds in habitats that lived in

intermediate disturbance habitats had a lower mean disturbance score (14.56 ±1.37), and birds

in lightly disturbed habitats had the lowest mean disturbance score (13.07 ±1.47). The mean

disturbance increased significantly (p = 0.009) by 4.18 (95% CI (1.21 to 7.16)) score units from

intermediate to high disturbance capture habitats, and by 5.67 (95% CI (2.70 to 8.64)) score

units from low to high disturbance (p = 0.001). Disturbance score was significantly associated

with an individual's use of open habitat types (F(1, 10) = 5.92, p = 0.03) with an R^2 of 0.37 and

an equation of y = 13.05 + 0.05x.

Initial distance from the observer was the only variable that significantly predicted flight

initiation distance (Multiple regression, slope=0.87, F(2, 9) = 8.56, p < 0.005, adj. R^2 = 0.67).

Bird's flight initiation distance equation is = -14.09 + 0.87(distance from observer to bird).

Fleshy Ornaments

Fleshy head ornamentation was not correlated with parasite burdens (Table 7). Neither

did snood length (F(df= 2, 9) = 0.12, p = 0.88), crown volume (F(df= 2, 9) = 2.28, p = 0.15), and

caruncle number (F(df= 2, 9) = 2.13, p = 0.17), did not vary significantly between disturbance

types (Table 8). Variation in snood length (t(df= 10) = -1.39, p = 0.19) with an adjusted R^2 = 0.07

and an equation of y = 75.57 + -10.16x, caruncle number (t(df= 10) = 0.77, p = 0.45) with an

adjusted R^2 = -0.37 and an equation of y = 15.09 + 0.56x, and crown volume (t(df= 10) = -1.16, p

= 0.27) with an adjusted R^2 = 0.03 and an equation of y = 58.97 + -7.34x was not associated with

the percent use of open habitats.

H:L Ratio

H:L ratio did not differ significantly between levels of disturbance ($F_{(df= 2, 9)}$ = 0.65, p = 0.54). The highest H:L ratios were found in the intermediate group (Figure 3). No significant correlation was found between H:L ratio and the percent of time spent in open habitat ($r_{(df= 10)}$ = -0.09, p = 0.38).

Feather Reflectance Traits

No significant differences were found between any feather reflectance values (B1, H1, and S1 values) of any of feather types (breast, secondary tail retrices, and secondary wing covert) between males in the three disturbance habitats (Tables 9-11). Additionally, I found no correlation between feather reflectance variables of any feather type with the percent of time spent in open habitat (Table 12).

Variation in feather reflectance values of secondary tail retrices was generally not associated with coccidian burden (Table 13), except for a strong negative correlation of ultraviolet hue ($r_{(df= 10)}$ = -0.67, p = 0.01), and a strong positive correlation of red hue ($r_{(df= 10)}$ = 0.68, p = 0.01), with oocyst concentration. Variation in hematozoa burden was unrelated to hue in secondary tail retrices (Table 13). Hematozoa burden did show a positive relationship with all brightness values, a negative relationship with saturation in ultraviolet, violet and red wavelengths, and a positive correlation with blue wavelengths (Table 13 Appendix i). Breast feathers showed no correlation between fecal or hematozoa parasite burden and feather reflectance values (Table 14). Secondary wing coverts only showed a positive correlation

between hematozoa burden and saturation in the red wavelength (r(df= 10) = 0.62, p = 0.03) and no correlations (positive or negative) with fecal parasite burden (Table 15).

Feather Barring Regularity

Feather barring regularity did not vary between levels of disturbance (F(df= 2, 9) = 0.34, p = 0.72). The mean feather barring was most regular in the field (high disturbance) habitats and the least regular in jungle (low disturbance) habitats (Table 16). There was no correlation between feather barring regularity and the percentage of time spent in open areas (r(df= 10) = 0.57, p = 0.051).

Discussion

The goal of this study was to try and identify bioindicators in a population of Ocellated Turkey that inhabit an ecosystem with varying degrees of human disturbance. Bioindicators such as fleshy ornament size, feather barring regularity, and feather spectra reflection, may be used to assess the health of Ocellated Turkey over a disturbance gradient. Other variables such as parasite burdens, home range size, white blood cell counts, and behavioral disturbance scores were used to help identify existing features of human modified habitat that should be managed to improve long-term viability of Ocellated Turkey.

I found that disturbance scores significantly varied between different habitat disturbances. Birds in highly disturbed habitats had the highest disturbance scores followed by birds in intermediately disturbed habitats and birds in the lowly disturbed habitats had the

lowest disturbance scores. Birds in the jungle were more sensitive to human proximity than were birds in the intermediate or field areas and they also fled at a higher rate than either of these other two groups. Birds often perceive humans as predators (Weston et al. 2012; Carney and Sydeman 1999) and as a result flee from humans. My study compliments other literature on flight initiation illustrating that birds in less disturbed areas more readily flee than birds in more disturbed areas (Carrete and Tella 2010). However, flight initiation and disturbance scores may not reflect an environments disturbance on an animal but an animal's personality and its tolerance of risks (Smith and Blumstein 2008, Carrete and Tella 2011). Other more physiologically based variables may enhance our understanding of the effects of anthropogenically disturbed habitats on Ocellated Turkey health.

Sexually selected male ornaments are often condition-dependent, they may serve as indicators of environmental quality (Hill and Montgomerie 1994). The length of the sexually selected frontal process, or snood, of the wild turkey, for example, is negatively associated with infection by coccidia, an intestinal parasitic protozoan (Buchholz 1995). Among Ocellated Turkeys, snood length was not associated with parasite load, but the birds in the intermediately disturbed areas had the smallest snood length. The other fleshy ornaments, crown volume and caruncle number did not show the same association with habitat disturbance as snood length. The crown was smallest in highly disturbed areas, moderate in modestly disturbed areas, and largest in lightly disturbed areas. Caruncle numbers were not significantly different between disturbance types.

As with other sexual ornaments, feathers may serve as bioindicators. McGraw et al. (2002) experimentally demonstrated that brown-headed cowbirds (*Molothrus ater*) suffered

decreased hue, saturation, and brightness in their structural feathers as a result of fasting. Hill

et al. (2005) found that by experimentally manipulating coccidian parasite load captive raised

male Wild Turkeys (*Meleagris gallapavo*) had wing covert feathers with decreased UV

reflectance and duller breast feathers. Ocellated Turkeys exhibited a negative correlation

between coccidian infection and peak hue in the ultraviolet spectrum of the structurally based

coloration in the blue ocelli in secondary retrices.   There was no difference between secondary

wing coverts and breast feathers in my males unlike Hill et al. (2005) findings for those feathers

in Wild Turkeys. The difference between the two species may have arisen from the high oocyst

numbers (10,000) used to experimentally inoculate the captive wild turkeys studied by Hill et al.

(2005).

Feather barring regularity, another bioindicator, is indicative of habitat quality as the

feather is growing more regular barring indicates an environment with better food resources

than an environment in which feather barring is more irregular (Gluckman and Cardoso 2010).

Feather barring was most regular in highly disturbed habitats and least regular in lowly

disturbed habitats. One possible explanation for more regular feather barring in the high

disturbance compared to low disturbance could be due to a more dependable steady source of

food in the fields compared to the patchy food resources available in the jungle. Bioindicators

are not the only way to assess the impact of an environment on an animal.

Internal parasite burdens are another way to quantify the impact of habitat disturbance.

I expected the aggregations of males found around grain piles in the cattle feed lots to increase

transmission of directly transmitted parasites such as coccidians (Ilomnen et al. 1999; Wiehn et

al. 1999). However the abundant calories that are easily obtained from these grain piles may

allow the birds in highly disturbed areas to afford the energetic costs of parasite suppression, and remain in good body condition despite parasite exposure. The highest mean coccidian burden found in birds occupying areas of intermediate disturbance might result from exposure to the high transmission rates of disturbed areas without constant access to the abundant food resources in the feedlots. Infection levels of *Haemoproteus* were also highest in birds occupying areas of intermediate disturbance. Blood parasites, which require transmission by a blood-feeding insect vector, are most likely to be transmitted at night when the birds are roosting in the canopy of tall trees (Forrester 1990). If birds in intermediate disturbance habitats roost closely together, it might facilitate feeding by insects and thus disease transmission. Furthermore, the spatial distribution and use of habitat may influence parasite burden.

Animals strive to optimize their home ranges (Mitchell and Powell 2004). Many variables such as food resources, availability of mates, predation pressure, and risk of disease and parasites dictate an animal's home range. Surprisingly the largest home ranges (MCP, 95%FK, and 50%FK) were home ranges of birds in highly disturbed areas that had access to supplemental feed. Birds in intermediate habitat had the second largest home ranges (MCP, 95%FK, 50%FK) and the smallest mean home range size was found in birds that occupied areas of intermediate disturbance. I expected the high levels of supplemental food to significantly reduce the home range of birds in highly disturbed areas. Intermediate birds may have had smallest home ranges due to their high parasite burdens, which decrease available energy. Main and Bull (2000) found that bobtail lizards (*Tiliqua rugosa*) with high tick loads must save energy by moving less, and basking more, leading to even smaller home ranges. Birds in highly

disturbed areas may be able to afford the extra energetic costs of larger home ranges because of the abundance of food available to them.

Investigating the circulating white blood cell counts we may be able to further deduce if high parasite burdens are precipitating a stress response. If the birds in areas of intermediate disturbance are in the poorest condition, their physiological stress should be revealed by high Heterolymph Lymphocyte (H:L) ratios (Davis et al. 2008). While I found no significant differences of mean H:L ratios between disturbance levels I did find that H:L ratios were highest for birds living in intermediately disturbed areas. There is different way of looking at the lack of significant difference of H:L ratio between habitats. Most studies assume that increased glucocorticoid levels in disturbed areas are indicative of poor health and negative fitness consequences (Creel et al. 2002; Wasser et al. 1997). Bonier et al. (2009) argue that increased environmental challenges can cause increases in glucocorticoid levels, which reallocate resources in an adaptive manner. Therefore, in some instances increased glucocorticoids, or their proxy in my study, increased H:L ratios, can be indicative of an adaptive response and not an indicator of poor health due to disturbance.

My results do not support the hypothesis that Ocellated Turkeys in anthropogenically disturbed habitats will suffer poorer health than birds in less disturbed habitats. Instead the birds in moderately disturbed habitats showed the poorest health as indicated by the highest fecal parasite load, the highest blood parasite load, the highest H:L ratio, the smallest snood length, and the smallest home ranges (MCP, 95%FK, and 50%FK). In conclusion, despite a lack of statistically significant differences in the health indicators of Ocellated Turkeys, there is a consistent trend among several variables that suggest that birds living in areas of intermediate

disturbance may be negatively impacted by human disturbance. I attribute the lack of

significance of the difference between disturbance types to the small sample size (N=4 per

habitat) in the face of high within group variation. Some of the study subjects did not restrict

their movements to the disturbance type in which they were initially trapped, and thus varied

in their exposure to disturbance beyond the way in which I classified them. Also my study was

not informed by the disturbance conditions of these males outside of the breeding season.

Static traits, like feathers, may be more representative of the habitat males occupied before

they dispersed for the breeding season. Ocellated Turkeys molt before the breeding season

begins and as a result feather qualities may reflect the habitat during the molt, which may be

different than their breeding home range. I strongly believe that males do not occupy the same

habit during the breeding season as they do during the non-breeding season.

I believe this research will be important in guiding future research and conservation

efforts, and is an important first step to understanding how differing levels of habitat

disturbance affect the population viability of Ocellated Turkeys. Further studies need to be

carried out to assess how Ocellated Turkey survival and reproductive success are impacted by

disturbance type, experimental manipulation of food resources to measure the effect on home

range size, further investigation into parasites especially on how parasites affect secondary

male characteristics and female choice, and more precise measures of glucocorticoid levels.

Continuing long-term study of this Ocellated Turkey population could provide information

crucial to preventing their extinction.

Table 1: Rubric for determining the disturbance score value for the levels of each variable. These variable disturbance values were then summed to determine an overall disturbance score for each marked subject.

Variable Disturbance score	Distance from forest	Distance until vigilant or Fleeing	% of time vigilant	% of time foraging	Response to humans/non-natural noises if present
1 Low	0-50m	91+	76-100%	0-25%	Flees upon initial site (100m+ at initial site)
2	51-100m	61-90	51-75%	26-50%	Leaves then returns
3	101-150m	31-60	26-50%	51-75%	Becomes Vigilant (100m)
4 High	151m+	0-30	0-25%	76-100%	No response

Table 2: Parameters of One-way ANOVA tests used to investigate the effect of disturbance on male health and condition.

	Statistical Test	Degrees of Freedom	Sample Size	Independent Variable	Dependent Variable
Fecal Parasite	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Parasite burden
Blood Parasite	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Parasite burden
Home Range (MCP, 95FK, 50FK)	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Home range size (MCP, 95FK, 50FK)
Disturbance Tolerance	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Disturbance Tolerance
Fleshy Ornaments (snood, crown volume, carruncle number)	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Fleshy ornament (snood, crown volume, carruncle number)
H:L Ratio	One-way ANOVA	2 Between 9 Within	12	Disturbance category	H:L ratio
Feather Barring Regularity	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Feather barring regularity
Feather reflectance (breast, tail retrices, wing coverts)	One-way ANOVA	2 Between 9 Within	12	Disturbance category	Feather reflectance (breast, tail retrices, wing coverts)

Table 3a: Detailed components of multiple regression and correlations used in Chapter 2

	Statistical Test	Degrees of Freedom	Sample Size	Independent Variable	Dependent Variable
Fecal Parasite	Regression	10	12	Time in open	Parasite burden
Blood Parasite	Regression	10	12	Time in open	Parasite burden
Home Range (MCP, 95FK, 50FK)	Correlation	9	12	Time in open	Home range size (MCP, 95FK, 50FK)
Disturbance Tolerance	Multiple Regression	8	12	Flight initiation	Distance to observer, distance to jungle, group size, flight speed
Disturbance Tolerance	Regression	10	12	Time in open	Disturbance score
H:L Ratio	Correlation	10	12	Time in open	H:L ratio
Feather Barring Regularity	Correlation	10	12	Time in open	Feather barring regularity

Table 3b: Detailed components of correlations for sexual ornaments in Chapter 2

	Statistical Test	Degrees of Freedom	Sample Size	Independent Variable	Dependent Variable
Fleshy Ornaments (snood, crown volume, carrunlce number)	Regression	10	12	Time in open	Snood length, crown volume, carruncle number
Feather reflectance and fecal parasites (breast, tail retrices, wing coverts)	Regression	10	12	Fecal parasite burden	Feather reflectance
Feather reflectance and blood parasites (breast, tail retrices, wing coverts)	Correlation	10	12	Blood parasite burden	Feather reflectance
Feather reflectance and time spent in open habitat (breast, tail retrices, wing coverts)	Correlation	10	12	Time in open	All feather values B, H, S (breast, tail retrices, wing coverts)

Table 4: Fecal (coccidian oocysts/g) and hematozoa (number infected per 10,000 erythrocytes) burdens of males captured in the three disturbance habitat types

Variable	High	Intermediate	Low
Fecal Burden	0.45 ±0.13	0.53 ±0.27	0.49 ±0.12
Hematozoa Burden	9.12 ± 5.29	11.37 ± 5.85	3.12 ± 1.65

Table 5: Average home ranges (ha) of birds captured in the three disturbance types.

Home Range Type	High	Intermediate	Low
MCP	1094 (± 1046)	739 (±819)	1072 (±1116)
95%FK	986 (±1217)	383 (±470)	707 (±718)
50%FK	147 (±206)	30 (±40)	94 (±130)

Table 6: Home range size estimates did not differ significantly between disturbance types.

Dependent Variable	Statistic	Partial Eta Squared
MCP	$F(2, 9) = 0.15, p > 0.85$	0.03
95% FK	$F(2, 9) = 0.34, p > 0.71$	0.07
50% FK	$F(2, 9) = 0.48 \; p > 0.63$	0.09

Table 7: Correlation r values showing that fleshy ornament quality was not correlated with parasite burdens (p values are in parentheses).

Fleshy ornament	Fecal burden	Hematozoan burden
		r (p)
	r (p)	
Snood	0.10 (0.75)	0.09 (0.77)
Caruncle Number	0.25 (0.41)	0.54 (0.68)
Crown Volume	0.27 (0.39)	-0.03 (0.92)

Table 8: Mean (+/- SD) of male fleshy ornaments in different disturbance types

Variable	High	Intermediate	Low
Snood (cm)	2.97 ± 0.92	2.75 ± 1.99	3.25 ± 1.06
Caruncle Number	58 ± 9	59 ± 17	42 ± 8
Crown Volume (cm^3)	0.78 ± 0.40	1.99 ± 1.41	2.86 ± 1.88

Table 9: Statistical parameters of One-way ANOVA tests of the reflectance variables of the secondary tail retrices from males captured in three disturbance habitat types.

Test	DF	F	Significance
B1 300nm-450nm	2, 9	1.61	0.25
B1 450nm-500nm	2, 9	1.52	0.26
B1 500nm-550nm	2, 9	1.26	0.32
B1 550nm-700nm	2, 9	1.87	0.20
H1 300nm-450nm	2, 9	0.55	0.59
H1 450nm-500nm	--	--	--
H1 500nm-550nm	--	--	--
H1550nm-700nm	2, 9	0.39	0.68
S1 Red	2, 9	0.67	0.53
S1 Green	2, 9	0.13	0.87
S1 Blue	2, 9	1.08	0.38
S1 Ultra Violet	2, 9	1.00	0.40
S1 Yellow	2, 9	0.06	0.93
S1 Violet	2, 9	1.18	0.34

Note: -- indicates that ANOVA tests were not conducted because these variables showed no variation.

Table 10: One-way ANOVA values of breast feather colored edges

Test	DF	F	Significance
B1 300nm-450nm	2, 9	1.67	0.24
B1 450nm-500nm	2, 9	0.69	0.52
B1 500nm-550nm	2, 9	0.25	0.78
B1 550nm-700nm	2, 9	0.27	0.76
H1 300nm-450nm	--	--	--
H1 450nm-500nm	--	--	--
H1 500nm-550nm	--	--	--
H1550nm-700nm	2, 9	1.10	0.37
S1 Red	2, 9	0.46	0.64
S1 Green	2, 9	1.92	0.20
S1 Blue	2, 9	1.73	0.23
S1 Ultra Violet	2, 9	1.45	0.28
S1 Yellow	2, 9	1.35	0.30
S1 Violet	2, 9	1.35	0.30

Note: -- indicates that ANOVA tests were not conducted because these variables showed no variation.

Table 11: One-way ANOVA values of wing coverts.

Test	DF	F	Significance
B1 300nm-450nm	2, 9	1.60	0.25
B1 450nm-500nm	2, 9	0.85	0.45
B1 500nm-550nm	2, 9	0.35	0.71
B1 550nm-700nm	2, 9	0.79	0.47
H1 300nm-450nm	--	--	--
H1 450nm-500nm	--	--	--
H1 500nm-550nm	--	--	--
H1550nm-700nm	--	--	--
S1 Red	2, 9	1.54	0.26
S1 Green	2, 9	0.93	0.42
S1 Blue	2, 9	0.97	0.41
S1 Ultra Violet	2, 9	0.82	0.46
S1 Yellow	2, 9	0	1.00
S1 Violet	2, 9	0.72	0.51

Note: -- indicates that ANOVA tests were not conducted because these variables showed no variation.

Table 12: r values for investigating the correlation of the percent of time in open areas and feather reflectance values

Reflectance Variable	r	P
Tail Retrix b1 300-450	1.89	0.41
Tail Retrix b1 450-500	1.00	0.57
Tail Retrix b1 500-550	-0.76	0.63
Tail Retrix b1 550-700	-1.65	0.38
Tail Retrix h1 300-450	-0.60	0.58
Tail Retrix h1 550-700	0.07	0.94
Tail Retrix S1R	-0.51	0.86
Tail Retrix S1G	-0.84	0.45
Tail Retrix S1B	-0.24	0.92
Tail Retrix S1U	3.30	0.49
Tail Retrix S1Y	-0.68	0.31
Tail Retrix S1V	-3.42	0.41
Breast b1 300-450	1.91	0.29
Breast b1 450-500	-2.69	0.48
Breast b1 500-550	1.57	0.61
Breast b1 550-700	-0.86	0.35
Breast h1 550-700	-.27	0.39
Breast S1R	0.05	0.90
Breast S1G	-0.64	0.21
Breast S1B	-0.66	0.86
Breast S1 U	-1.86	0.64
Breast S1V	1.23	0.58
Wing Covert b1 300-450	0.49	0.62
Wing Covert b1 450-500	-1.01	0.57
Wing Covert b1 500-550	-0.93	0.43
Wing Covert b1 550-700	1.58	0.29
Wing Covert S1R	0.59	0.23
Wing Covert S1G	-0.21	0.55
Wing Covert S1B	-0.07	0.99
Wing Covert S1U	2.90	0.67
Wing Covert S1 V	-3.02	0.32

Table 13: Correlation of parasite burdens with reflectance components of the secondary tail retrices.

Reflectance Variable	Fecal Burden r (p)	Hematozoan Burden r (p)
B1 300-450	0.14 (0.65)	0.67* (0.01)
B1 450-500	0.16 (0.61)	0.66* (0.02)
B1 500-550	0.11 (0.72)	0.66* (0.02)
B1 550-700	0.11 (0.72)	0.68* (0.01)
H1 300-450	-0.67* (0.01)	-0.32 (0.31)
H1 450-500	No variation	No variation
H1 500-550	No variation	No variation
H1 550-700	0.68* (0.01)	0.20 (0.52)
S1 R	-0.04 (0.89)	-0.62* (0.03)
S1 G	-0.23 (0.47)	0.43 (0.16)
S1 B	-0.09 (0.71)	0.59* (0.04)
S1 U	-0.08 (0.80)	-0.67* (0.02)
S1 Y	-0.21 (0.51)	-0.28 (0.37)
S1 V	-0.06 (0.83)	-0.68* (0.01)

*Correlation is significant at the 0.05 level (2-tailed)
p-values are in parenthesis

Table 14: Correlatoin of parasite burdens with reflectance from the breast feather's colored edge.

Reflectance Variable	Fecal Burden r (p)	Hematozoan Burden r (p)
B1 300-450	0.17 (0.58)	0.19 (0.55)
B1 450-500	0.06 (0.86)	0.01 (0.96)
B1 500-550	-0.01 (0.98)	0.01 (0.98)
B1 550-700	0.11 (0.73)	0.23 (0.46)
H1 300-450	No variation	No variation
H1 450-500	No variation	No variation
H1 500-550	No variation	No variation
H1 550-700	-0.09 (0.75)	0.13 (0.67)
S1 R	0.31 (0.32)	0.39 (0.20)
S1 G	-0.23 (0.46)	-0.11 (0.73)
S1 B	0.14 (0.66)	0.17 (0.59)
S1 U	-0.18 (0.56)	-0.19 (0.54)
S1 Y	-0.11 (0.71)	-0.08 (0.78)
S1 V	-0.11 (0.71)	-0.08 (0.78)

*Correlation is significant at the 0.05 level (2-tailed)
p-values are in parenthesis

Table 15: Correlation of blood parasites, fecal parasites, and color components of the wing coverts.

Reflectance Variable	Fecal Burden r (p)	Hematozoan Burden r (p)
B1 300-450	0.05 (0.87)	0.45 (0.14)
B1 450-500	0.16 (0.61)	0.32 (0.29)
B1 500-550	0.16 (0.62)	0.16 (0.62)
B1 550-700	0.30 (0.33)	0.39 (0.21)
H1 300-450	No variation	No variation
H1 450-500	No variation	No variation
H1 500-550	No variation	No variation
H1 550-700	No variation	No variation
S1 R	0.28 (0.37)	0.62* (0.03)
S1 G	-0.07 (0.82)	-0.24 (0.46)
S1 B	0.27 (0.38)	0.24 (0.45)
S1 U	-0.28 (0.37)	-0.20 (0.53)
S1 Y	No variation	No variation
S1 V	-0.30 (0.34)	-0.15 (0.63)

*Correlation is significant at the 0.05 level (2-tailed).
p-values are in parenthesis

Table 16: ANOVA group means for feather barring regularity in disturbance types

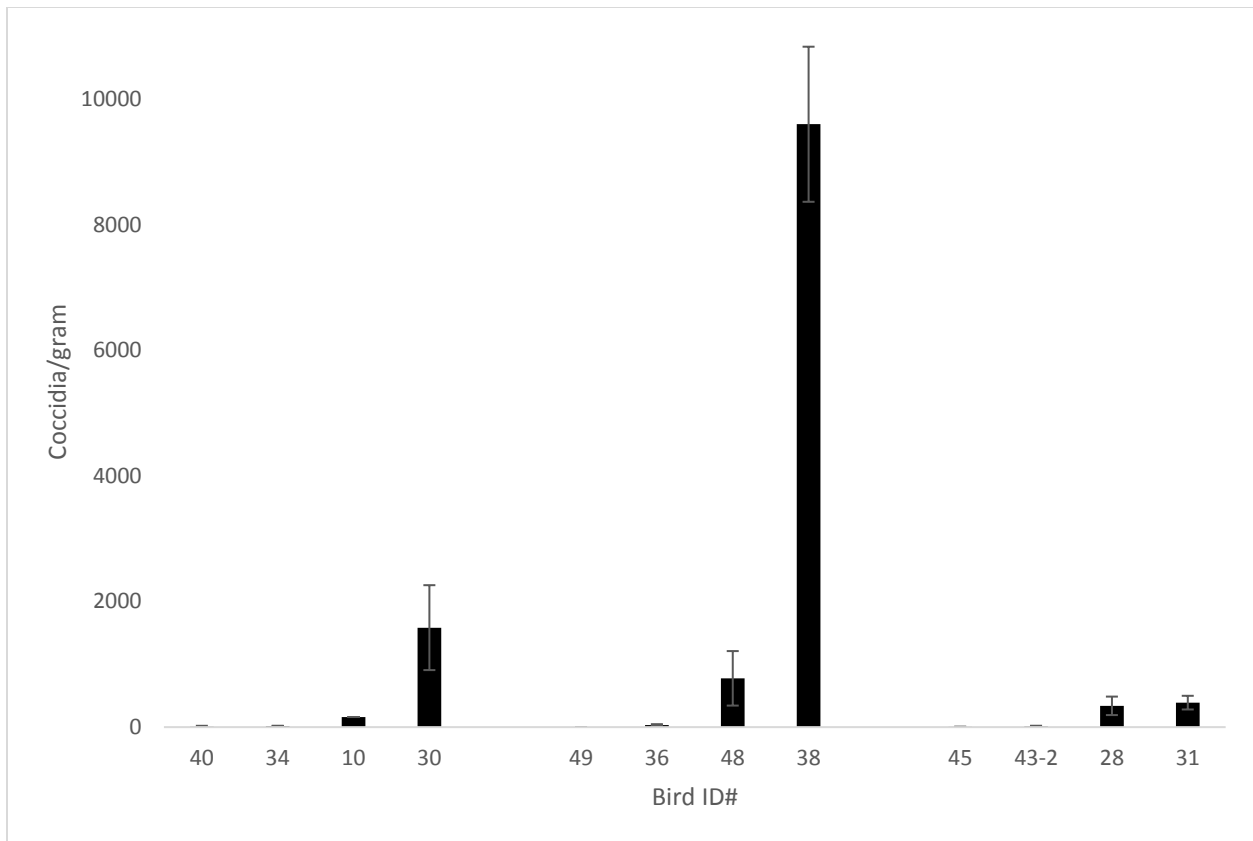| Test	High	Intermediate	Low
Feather Regularity	-0.36 ± 0.18	-0.40 ± 0.12	-0.44 ± 0.04

Figure 1: The number of coccidian oocysts in a fecal sample collected from each of twelve male Ocellated Turkeys with known home range sizes, grouped by habitat type of capture location. The group on the left are individuals in highly disturbed areas, the group in the center are individuals in intermediately disturbed areas, and the group on the right are individuals in lightly disturbed areas.
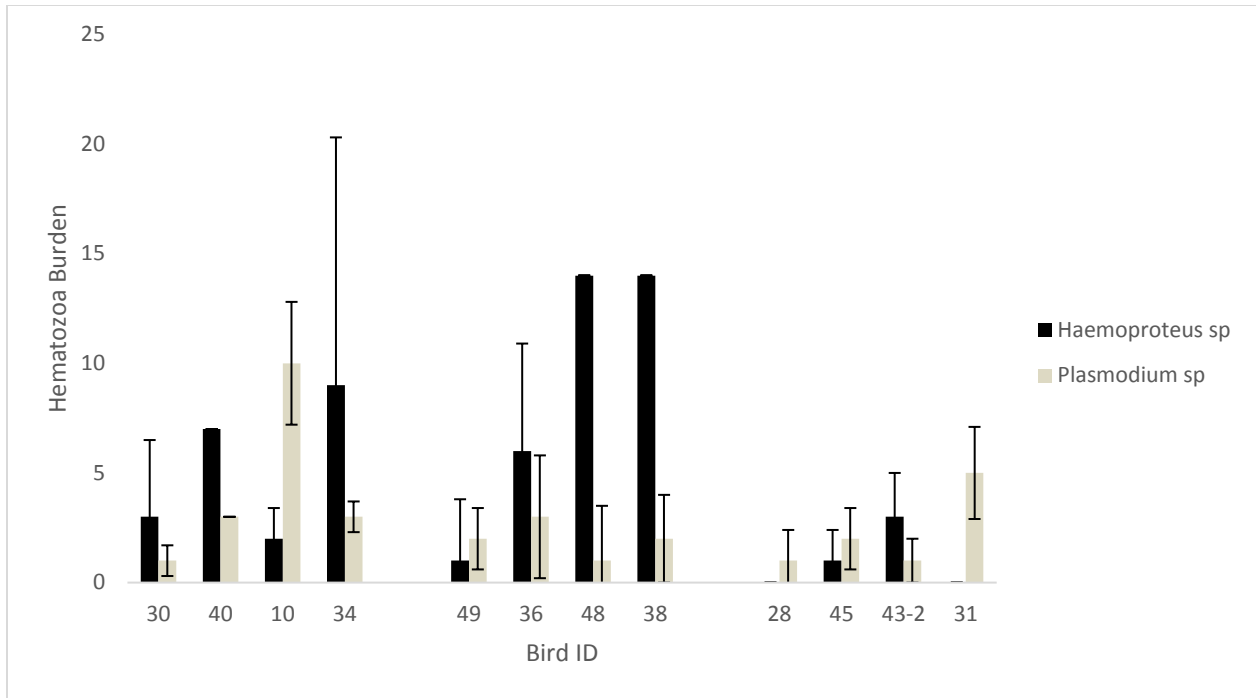
Figure 2: Number of erythrocytes infected with *Haemoproteus* and *Plasmodium* (per 10,000 erythrocytes inspected) in each of 12 male Ocellated Turkeys with known home range sizes. The group on the left are individuals in highly disturbed areas, the group in the center are individuals in intermediately disturbed areas, and the group on the right are individuals in lightly disturbed areas.
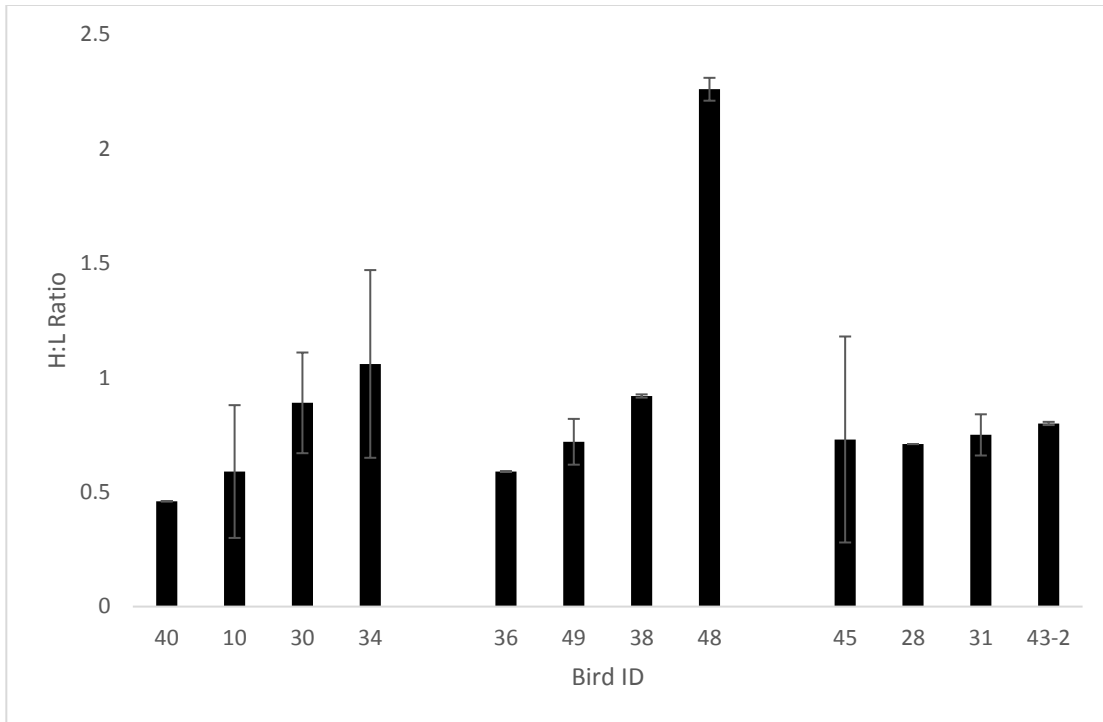
Figure 3: Individual H:L ratio values of 12 birds grouped by disturbance habitat type of capture location. The group on the left are individuals in highly disturbed areas, the group in the center are individuals in intermediately disturbed areas, and the group on the right are individuals in lightly disturbed areas.

CHAPTER THREE

Flocks, Parasites, and Natural History Observations of the Ocellated Turkey

Introduction

Studies of natural history are becoming rarer in the scientific literature but provide

information critical addressing environmental issues (Bury 2006). Without a detailed

understanding of an organism's natural history conservation plans to restore threatened and

endangered animals to viable populations may be doomed to failure. Populations of the near

threatened Ocellated Turkey are predicted to continue to decline in coming years, thus

increasing the need to more fully understand the behavior and ecology of this unique

species(Kampichler et al. 2010). In this chapter I report observations on a variety of aspects of

the natural history of the Ocellated Turkey that did not fit well into the other chapters. First I

describe how habitat structure (open and closed canopy) affects aspects of the flocking

behavior of unmarked individuals. Second I provide additional observations on the description

and context of a submissive action pattern characteristic of sub-adult males. Finally I describe

the landscape distribution of coccidian oocysts across the Gallon Jug study site.

Flocking

Birds flock for two main reasons: to more easily and efficiently find food, and to reduce predation risk through enhanced vigilance (Jullien and Clobert 2000). However, to date attempts to disentangle the two factors and the extent to which they promote flocking behavior have been limited. Even in the absence of predators on oceanic islands, birds stillflock, suggesting that predation avoidance alone does not explain flocking (Beauchamp 2004). Elgar (1987) surmises that the decreased individual average food intake rate associated with feeding in flocks is offset by the dilution effect on predation risk provided by feeding with multiple individuals. Flock size has been experimentally shown to increase in response to perceived predation risk (Caraco et al. 1980). Elgar (1987) found that house sparrows (*Passer domesticus*) form larger flocks as the size of experimental feeders is increased. However, he points out that "food intake rate alone was not an adequate measure of the costs and benefits of foraging in groups of different sizes". These studies illustrate how flocking behavior is determined by the combined benefits of improved food intake and predator avoidance.

At Gallon Jug as Ocellated Turkeys move through the open, disturbed pastures and closed, forest habitats they face changing resource distributions and altered predation risk. In pastures, anthropogenic food sources such as non-native pasture grasses and point food sources like grain piles are abundant, making them attractive for foraging birds. In one sense pasutres are also safer because the high visibility there may improve detection of predators. However, pastures provide no cover where Ocellated Turkeys can evade avian predators when they are attacked, such as by the Ornate hawk-eagle (*Spizaetus ornatus*). In contrast in the

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forest, food resources such as grasses and fruits, are probably patchily distributed and require

greater travel to obtain. Unlike the pastures though there is an abundance of refuges from

predators as well as a reduced number of attack angles. To assess how Ocellated Turkeys

tradeoff the predator avoidance benefits of group living with the increased competition for

food among flockmates that occurs in larger groups, I investigated the vigilance and feeding

rates of Ocellated Turkey in different sized flocks in pastures and forests. I predict that

abundant food resources in fields provide Ocellated Turkey with a greater food intake allowing

increased flock size and decreased vigilance rates despite increased predation risk, than birds in

the forest.

Parasites in the Landscape

Parasites are not evenly distributed across the landscape (Smith 2001). "Hot spots"

occur where hosts are more likely to become infected. The parasite *Toxoplasma gondii* has a

highly heterogenous distribution in urban areas with highly contaminated hot spots that

provide significant risks of infection to cats (*Felis catus*) and other animals (Afonso et al. 2008).

Similarly the oocysts of Soay sheep's (*Ovis aries*) intestinal parasites are more concentrated in

tall grass swards, causing the host to adjust their grazing patterns (Hutchings et al. 2002). By

better understanding the inoculum 'shadow' across the landscape, and how it varies with

human disturbance, we can more fully understand the costs and benefits of the different

ranging habits exhibited in Ocellated Turkeys. I predict that areas of high anthropogenic

disturbance, which include areas with concentrated food resources and open pasture, to be

"hot spots" of coccidian oocysts and have higher levels of oocysts than the less disturbed areas with natural food sources.

Behavior of sub-adult males

Most previous studies of the Ocellated Turkey (see Chapter One Table 1) have focused on mature males and females. Little is known about the natural history of young males between the time that they no longer associate in a flock with their mother and when they reach sexual maturity at 2 years of age. These males live in small flocks with other young males that may associate with females or older males for varying periods (personal observation). Although sub-adult males are not thought to engage in copulation, Williams et al. (2010) noted a hunter killed young male that showed evidence of feather wear on the primary flight feathers that suggested they had been used in the strutting behavior of courtship. They postulated that young males might display to females when adult males are not present. Steadman et al. (1979) described the 'double wing turn' behavior, which may be the way that young males demonstrate subordination to adult males. The double wing turn occurs when a young male approaches an adult male, stretches his wings twice, then turns 180° away from the dominant bird. Besides these two observations the literature on young male behavior is still very limited. This section will focus on the observations of young males made in the field opportunistically, including their flocking behavior, predator inspection, interaction with adult males, and the ontogeny of courtship actions.

Methodology

Study Sites

These natural history observations were recorded at the Gallon Jug Estate (17 33.634°N, 89 02.801° W), a privately-owned ranch in NW Belize that is described in more detail in the previous chapters.

Flocking Behavior

Observations of flock size were recorded during the block counts and the line transect surveys described in Chapter One. Flocks were defined as including at least two individuals. Most individuals were not uniquely marked but because flocks were assessed so rapidly across most of the study site during the once-weekly block counts, I assumed that each flock sighted during the two-hour survey period represented an independent observation. Observations during line transect surveys were opportunistic and thus it is more difficult know the independence of those data points. The problem of data non-independence in studies of unmarked individuals plagues ecology in general, but is not easily avoided in field studies of wild species that are difficult to capture (Lengyel et al. 2012). An ANOVA was used to compare the flock size observations in habitats with ('forest') and without ('open') canopy cover. The relationship between foraging and vigilance rates and flock size were studied in marked males only, as described in detail in Chapter Two. It was not known whether the flockmates of these birds were the same between different observations of the focal animal. The percentage of time that these birds engaged in foraging and vigilance was calculated by dividing the number

of scan samples positive for each behavior by the total time of observation. Each male

contributed three points to the data set used in the analysis. I used flock size as my

independent variable and my dependent variables were percent of time foraging and percent

of time vigilant in two simple regressions: 1) foraging percent and flock size (n = 36), and 2)

vigilance rate and flock size (n = 36). The standardized residuals from the regressions were

used to control for flock size, and were used in an ANOVA to compare the mean difference

between vigilance rates, and foraging rates, in open (n = 14) and closed (n = 22) habitats.

Spatial Distribution of Parasites

Fresh fecal samples were collected along survey routes throughout the entirety of the

Gallon Jug study site. If defecation was observed during behavioral recordings, the open

ground, grass and leaf litter in the bird's location was searched after the turkeys departed.

Fresh feces are quickly covered with flies whose larvae consume much of the feces in less than

4 hours, so it was relatively easy to distinguish fresh feces from old samples. When fecal

samples were collected the time of day (morning or evening), fecal composition, and GPS were

all recorded. After collection most samples were spread on aluminum foil indoors and allowed

to air dry for 48-72 hours. Dry samples were stored in 10 mL tubes containing 100 % white

vinegar to retard bacterial growth during storage. Oocysts were enumerated as described in

Chapter Two. The GPS coordinates of each fecal collected were used to create a heat map

overlay of oocyst density across the Gallon Jug study site.

Young Male Behavior

Young male natural history observations were collected opportunistically, mostly during.

block counts and line transect surveys. Occasionally when an interesting behavior was being

displayed extra time was set aside to record these observations and take pictures if possible.

Statistical Approach

Flock sizes, foraging rates and vigilance data were tested for normality with the Shapiro-

Wilk test, and where appropriate a Levene's test for homogeneity of variance. Non-normally

distributed data were transformed. One-way ANOVAs, independent t-tests, and regression

analysis were all used (Table 1). Means are reported with standard deviation (± SD). All

analyses were conducted with SPSS (SPSS v22, IBM, Armonk NY, USA). Pseudoreplication of

data points likely occurs in the flocking data set. As in other studies of flocking (e.g. South and

Pruett-Jones 2000; Pizo et al. 1995; Keys and Dugatkin 1990) I have assumed that the non-

independent nature of these data do not obviate my conclusions.

Results

Flocking Behavior

The mean flock size of birds in open habitats (2.59 ± 3.21) was significantly larger than in closed habitats (1.75 ± 1.54) (t(1, 717) = 17.60, p = 0.05). Foraging rate was not significantly correlated with flock size (t(df= 35) = 1.85, p = 0.07) with an adjusted R^2 of 0.06 and an equation of y = 32.25 + 1.66x. After controlling for flock size there was a significant difference between foraging rates in open and closed canopy habitats (F(1, 34) = 12.45, p = 0.05). Vigilance rate was significantly negatively correlated with flock size (t(df= 35) = -3.32, p = 0.02) with an adjusted R^2 of 0.22 and an equation of y = 28.97 + -2.00x. After controlling for flock size there was a difference of vigilance between open and closed habitats (F(df= 1, 34) = 5.81, p = 0.02).

Spatial Distribution of Parasites

Fecal samples were collected from sites of high disturbance (n=61), intermediate disturbance (n=62), and low disturbance (n=59). There was no significant difference of fecal parasite numbers between habitat types (F(df= 2, 179) = 0.61, p = 0.54). The heat map shows areas that should be considered "hot spots" (Figure 1).

Behavior of Young Males

Flocking

Juvenile males are smaller than subadult males and stay close to a female (172 observations). Generally, these young males are left alone when the female enters a dominant

male's territory and occasionally females have more than 1 young male accompanying them. Sub-adult males are found in bachelor flocks consisting of 4 to 9 young males (3 different flocks sighted 12 or more times each). These bachelor flocks generally haunt the same areas and are prone to curiosity. Observations of young bachelor flocks investigating cars, cows, and predation events were quite common.

Predator Inspection

One instance of predator inspection by a young male bachelor flock was observed. A common black hawk (*Buteogallus anthrocinus*) depredated a bare-throated tiger heron (*Tigrisoma mexicanum*) at 10:45 am on February 20th 2015. Six young males in a bachelor flock observed the black hawk eating the bare-throated tiger heron while it was in the open grass near the Gallon Jug runway. Young males approached as close as 2m with their necks stretched out as much as possible with their fan spread and tilted in the direction of the black hawk (Appendix iii). While observing the kill site they all made alarm vocalizations by 'putting' loudly (heard from 50m+ away). The black hawk lunged at the young males three times, causing them to retreat 3 or 4 meters before reapproaching to their original distance while continuing to observe and putt. Two of the young males emitted incomplete gobble calls when within 3m of the black hawk. After approximately 35 minutes the young males left the black hawk but maintained vigilant stances until 150m away.

Gobbling and Display Attempts

Young males were observed on 4 occasions trying to gobble and experimenting with displays. In all cases no adult males were in the general proximity and on only one occasion was a female nearby (4m away, foraging). Steadman et al. (1979) describes the adult male gobble as being composed of a drum and then a gobble or phonetically as "whump-whump-whump-pum-pum-pum-peedle-glunk". The young males all failed to properly gobble, lacking both the whump-whump-whump drum section and the peedle-glunk section at the end. Gobbles were distinctly lacking the drum and at the end of their gobble the noise they make can best be described as a deflating balloon noise with a honk at the end.

There were 2 occasions when young males were observed displaying to each other. Both display attempts were not fully developed and consisted mainly of parallel walking while flapping/dragging primary flight feathers across the dirt. In adult males only the wing opposite the female is flapped while the wing near the female is dragged, young males were seen to flap both wings simultaneously in an uncoordinated fashion. Young males were however able to spread their tail fan and properly angle it in the direction of their display mate. Another departure from typical male display behavior was the lack of a proper breast feather display. Displaying young males' breast feathers did not form an inverted V, causing the breast feathers to stand out at a roughly 90° angle from the breast of the bird.

Submission Displays

Young males in Gallon Jug were observed displaying the double wing turn on three different occasions. Young males performed the 'double wing turn' exclusively when in the

presence of large territorial adult males. When a territorial male approached a young male in

the 'full boxy' posture (Hanlon 2013) young males would respond by raising their wings above

their back without extending them fully, 'wing stretch' (Steadman 1979) twice and then turn

two full circles in front of the male. My description of the double wing turn is slightly different

than Steadman's, however. First, adult males were always the ones who approached young

males. A territorial male always immediately lost interest in the young male after the double

wing turn and would either walk off or return his attention to the female. Second, my

observations recorded young males doing two 360° turns to complete the double wing turn,

instead of the 180 turn described by Steadman (1979).

Discussion

Birds should optimize their food intake by minimizing predation risks. Williams et al.

(2003) demonstrated experimentally that northern bobwhite quail (*Colinus virginianus*)

decreased individual vigilance in open areas when in larger coveys and increased vigilance

when moved to smaller coveys. Flocks in my study were larger in open areas than they were in

closed areas but flock size did not significantly impact foraging rates. However, there was a

significant difference between vigilance rates among individuals in open habitats compared to

those in closed habitats. Individuals in closed habitats foraged less and were vigilant more than

their open habitat brethren. Although I cannot definitively say that predation risk is higher in

open habitat, I can conclude that Ocellated Turkeys seem to adjust their flocking to combat

predation risk. In open areas, flock size increases which decreases predation risk via the

dilution effect and the many eyes hypothesis (Roberts 1996). Smaller flock sizes in closed areas

can utilize more sources of cover (Devereux et al. 2006) but at the expense of increased

vigilance and decreased foraging rate. The negative correlation between flock size and

vigilance rate suggests that individuals in smaller flocks, such as the flocks in closed habitats,

are warier of attack. The results of my study suggest that Ocellated Turkey deal with predation

risks in different habitat types by adjusting flocking and vigilance behaviors.

I found no significant differences of oocyst numbers among three disturbance types.

However, the heat map (Figure 1) showed "hot spots" at both cattle feed lots where

concentrated food resources attract a high density of Ocellated Turkeys, a pattern similar to

that seen in other species (Hudson et al. 1992, Arneberg et al. 1998). Unexpectedly the highest

number of coccidian oocysts were found in the intermediately disturbed shaded coffee groves.

Several possible reasons may explain this: 1) if parasites are not distributed evenly throughout a

host population a highly infected individual may just happen to reside in the coffee plantation;

2) the shade canopy over the coffee plants may protect the oocysts from drying out or being

destroyed by UV light (Wainwright and Lagunas-Solar 2007), leading to higher survival of the

parasite there, and 3) individuals that feed in the tree-less feed lots during the day may roost in

the nearby coffee overstory at night when oocysts are more likely to be shed in feces (Brawner

and Hill 1999).

Fully understanding the natural history of a species is vital to its protection and

conservation (Bury 2006). Perhaps one of the most important aspects of the natural history of

young Ocellated Turkey males to be gleaned from my observation is their status as non-breeders. Young males showed no signs of attempting to breed with females across two field seasons and demonstrate behavioral submission to older adult males. I believe that it is highly unlikely that young males practice kleptogamy when adult males are not present. Kleptogamy has been observed in Wild Turkey (*Meleagris gallopavo*) young males as early as their first year in certain situations (Burget 1957). Young male Wild Turkey generally do not breed due to the inhibitory actions of mature males unless there are no mature males to adequately suppress a young male's courtly advances (Schorger 1966). Watts and Stokes (1971) observed young Wild Turkey males courting females late in the season but never copulated after the displays. Young male Ocellated Turkey may perhaps act like young Wild Turkey in the absence of adult males but in both of my study sites young males were always suppressed by adult males. Further natural history observations and studies should be conducted on young males specifically focusing on bachelor flocks as they integrate into the adult male population. An interesting question that remains is do young males from bachelor flocks go on to compete with local mature males for nuptial courts or do they disperse to new areas?

Table 1: Parameters of the statistical tests used in Chapter Three.

	Statistical Test	Degrees of Freedom	Sample Size	Independent Variable	Dependent Variable
Closed flock size vs. open flock size	Independent t-test	717	719	Open or closed habitat	Flock size
Foraging and flock size	Regression	35	36	Flock size	Foraging rate
Vigilance and flock size	Regression	35	36	Flock size	Vigilance rate
Parasite distribution	One-way ANOVA	2, 179	182	Disturbance category	Mean parasite number
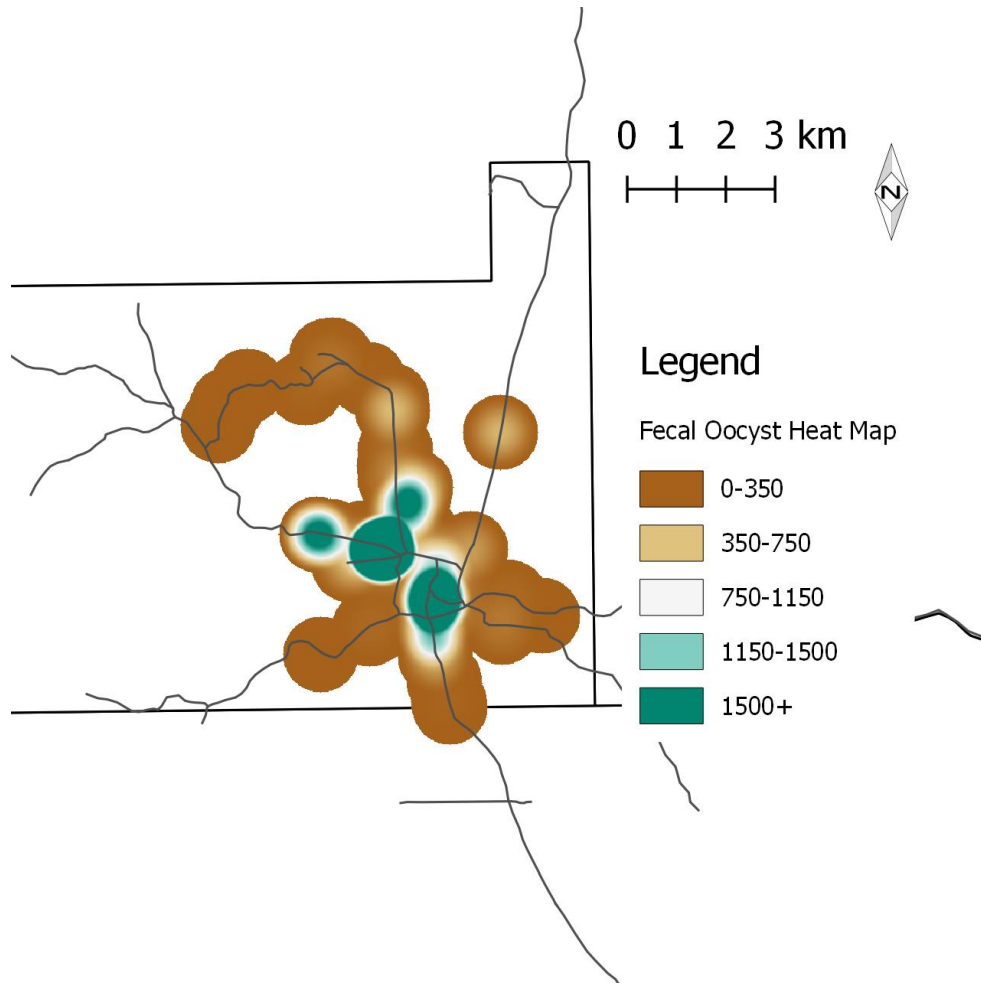
Figure 1: Coccidian oocyst numbers in Ocellated Turkey feces are not evenly distributed across the Gallon Jug Belize study site.

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LIST OF APPENDICES

Appendix i – Home Range Maps

Appendix ii – Feather Spectrometry Schematics

Appendix ii – Sub-adult Male Pictures

APPENDIX i

Home Range Maps
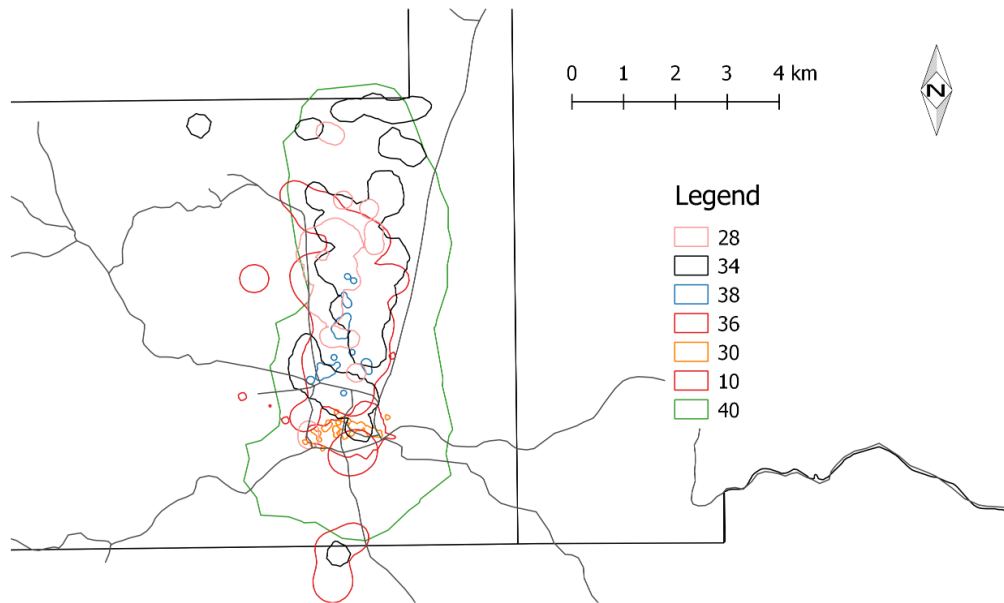
Map 1: 95%FK home range of the 2014 birds with 30 or more locality points at the Gallon Jug Study site in the Orange Walk district of Belize
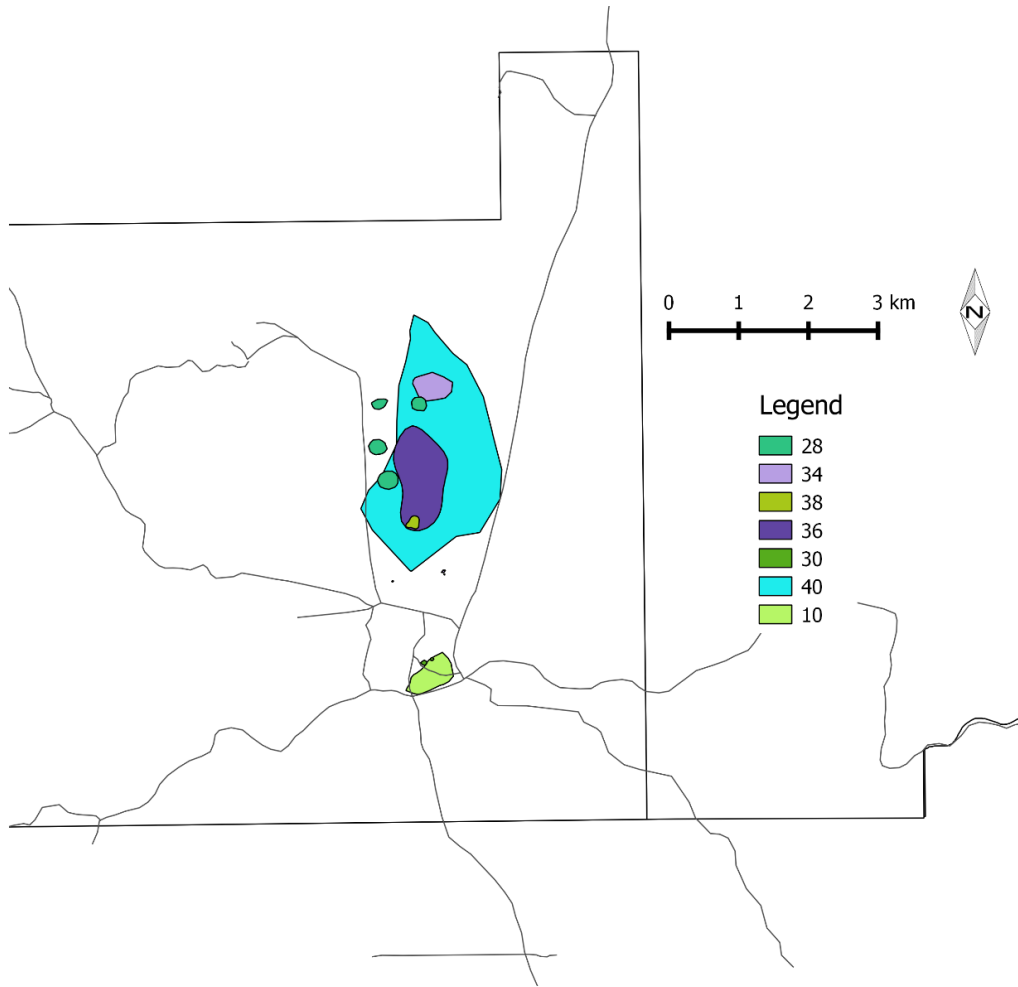
Map 2: 50%FK home range of the 2014 birds with 30 or more locality points at the Gallon Jug
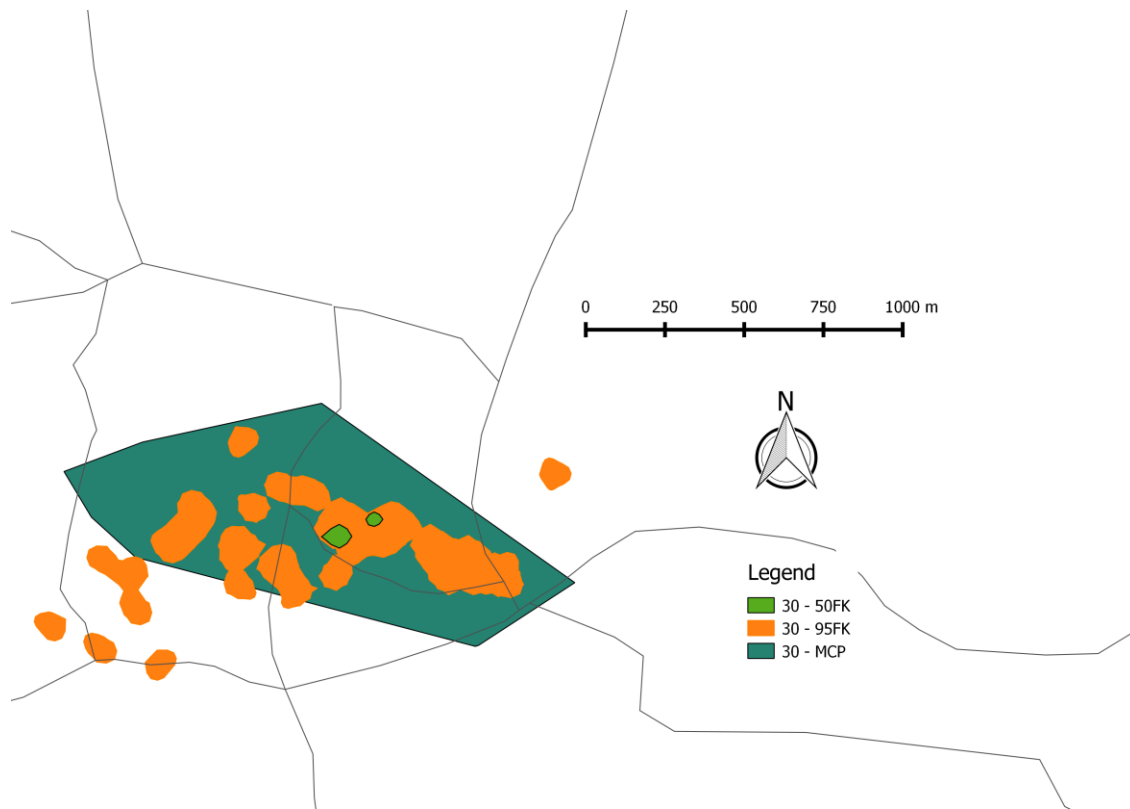Study site in the Orange Walk district of Belize
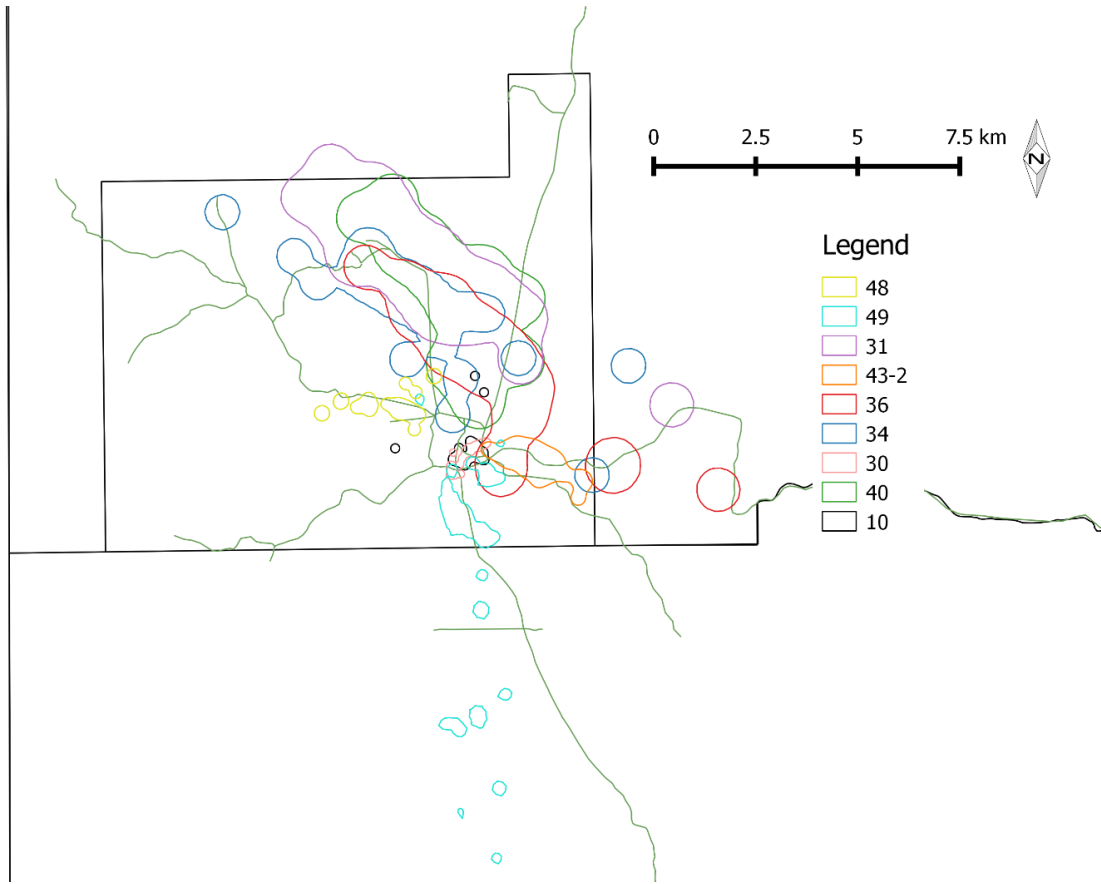
Map 3: 95%FK home range of the 2015 birds with 30 or more locality points at the Gallon Jug Study site in the Orange Walk district of Belize
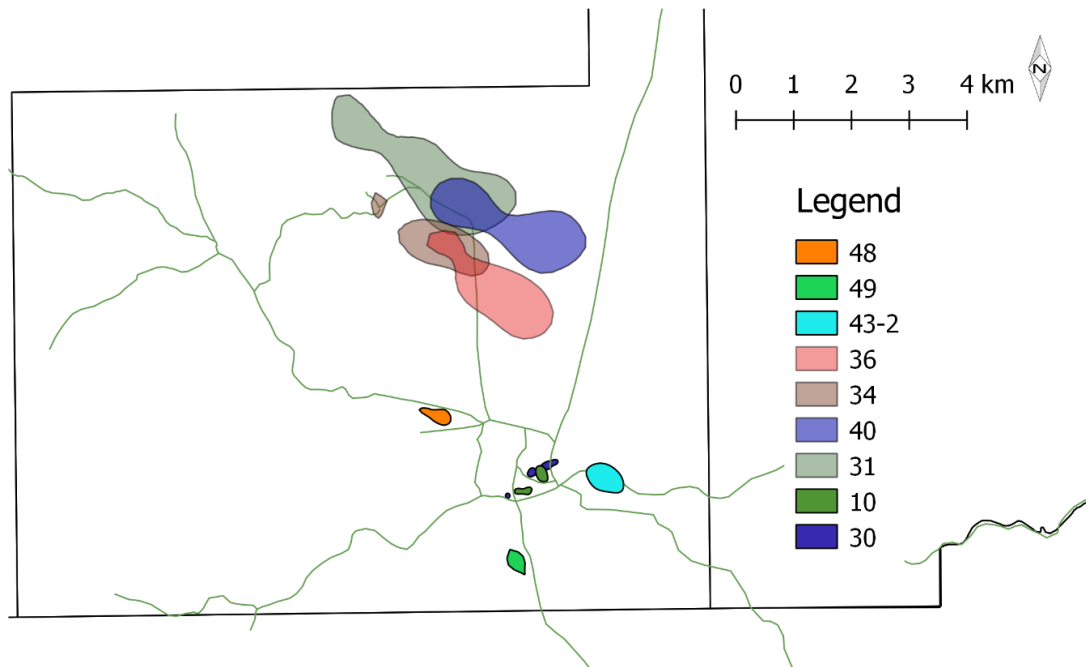
Map 4: 50%FK home range of the 2015 birds with 30 or more locality points at the Gallon Jug Study site in the Orange Walk district of Belize
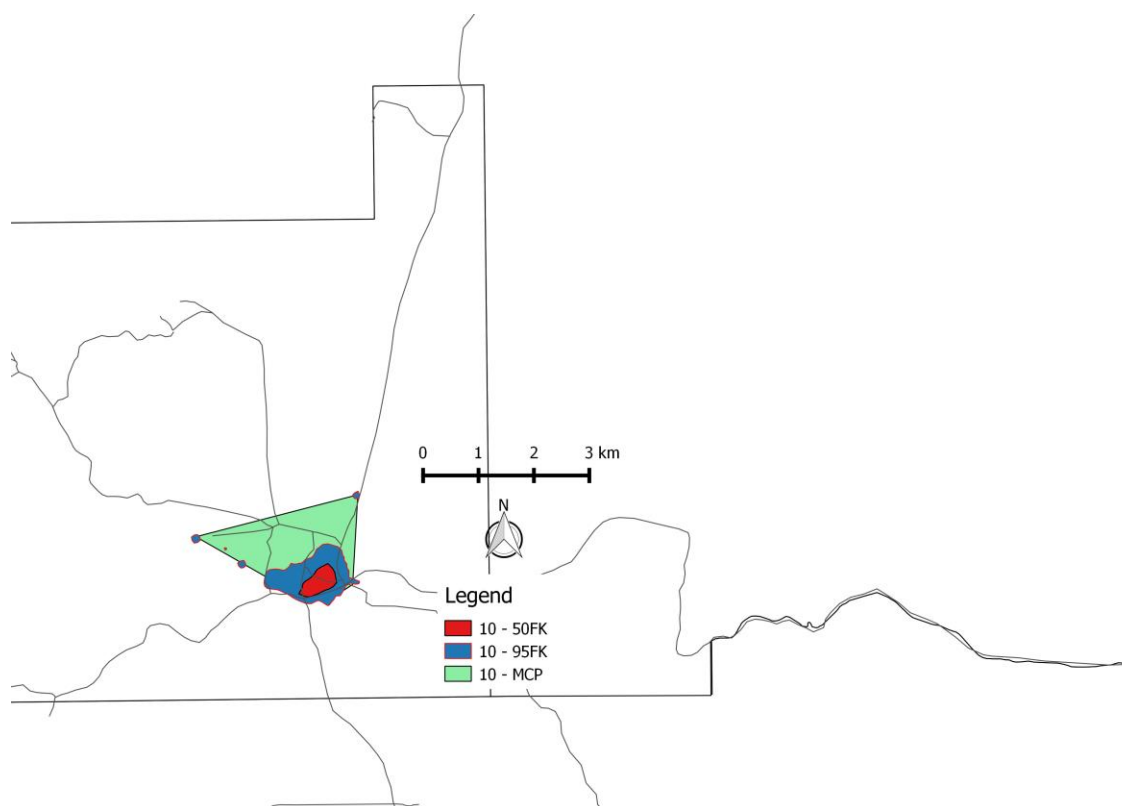
All 3 home range types for bird 10 (field)

All 3 home range types for bird 30 (field)
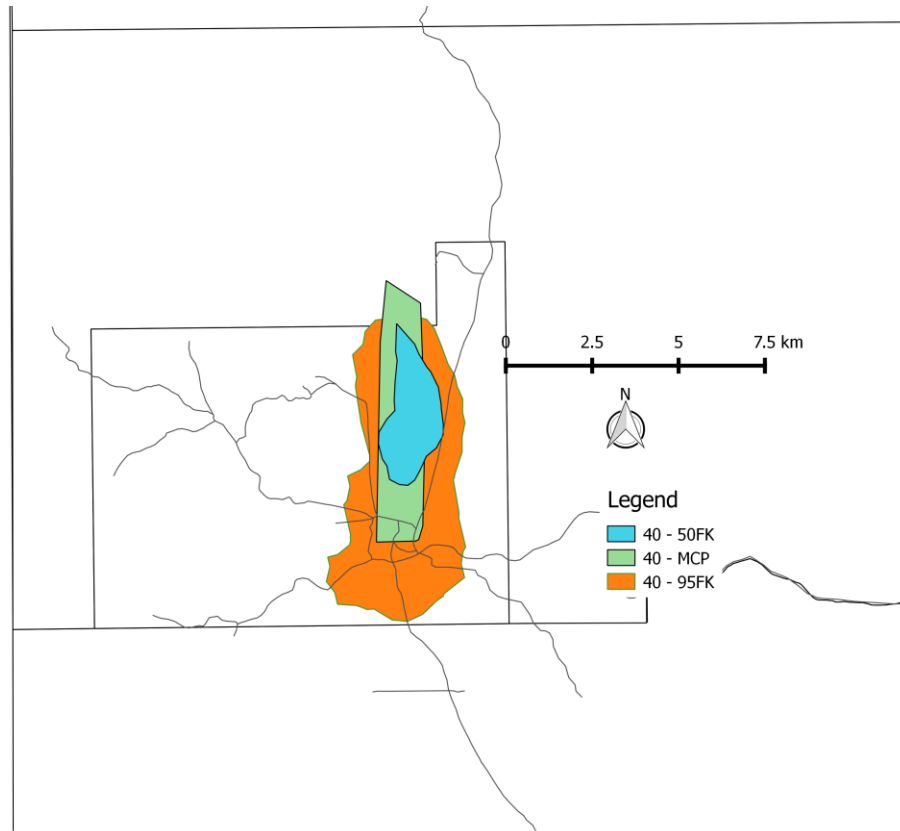
All 3 home range types for bird 40 (field)
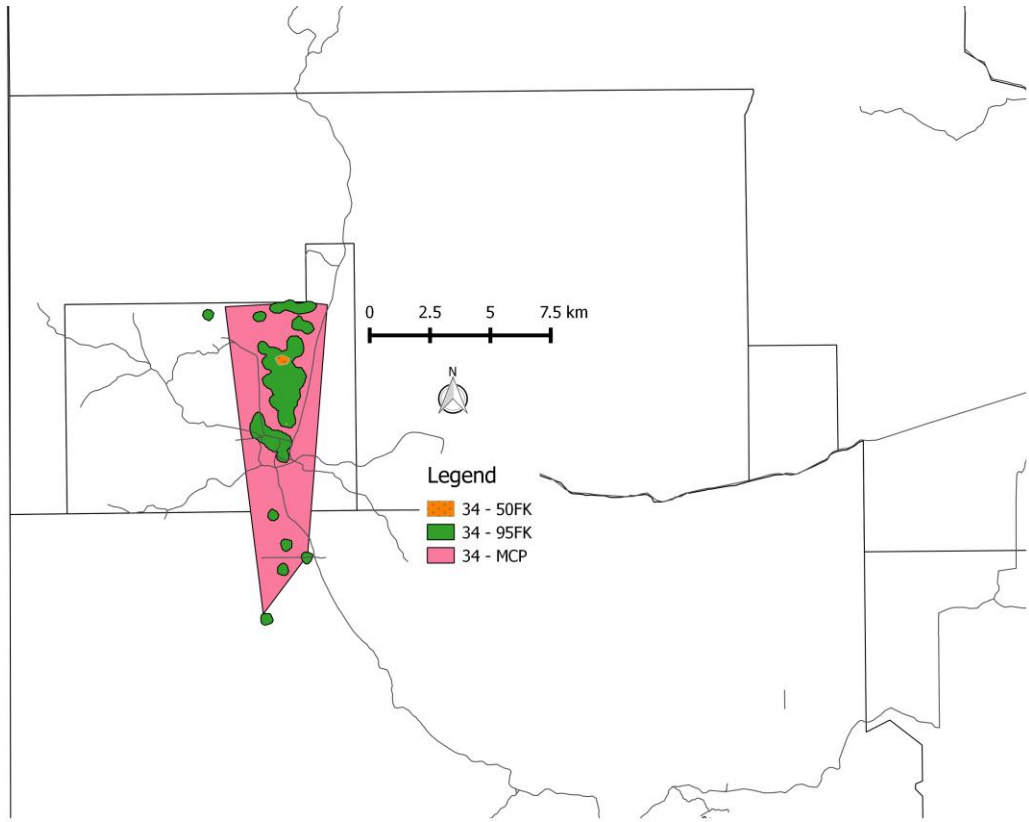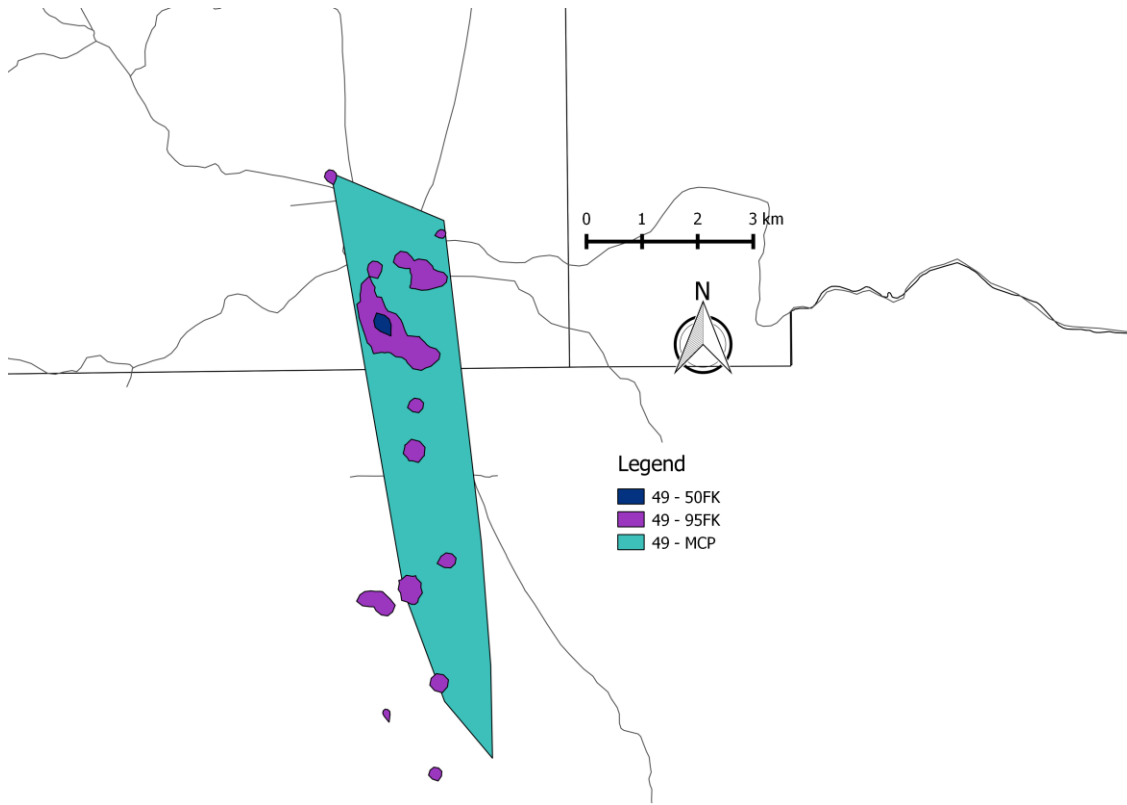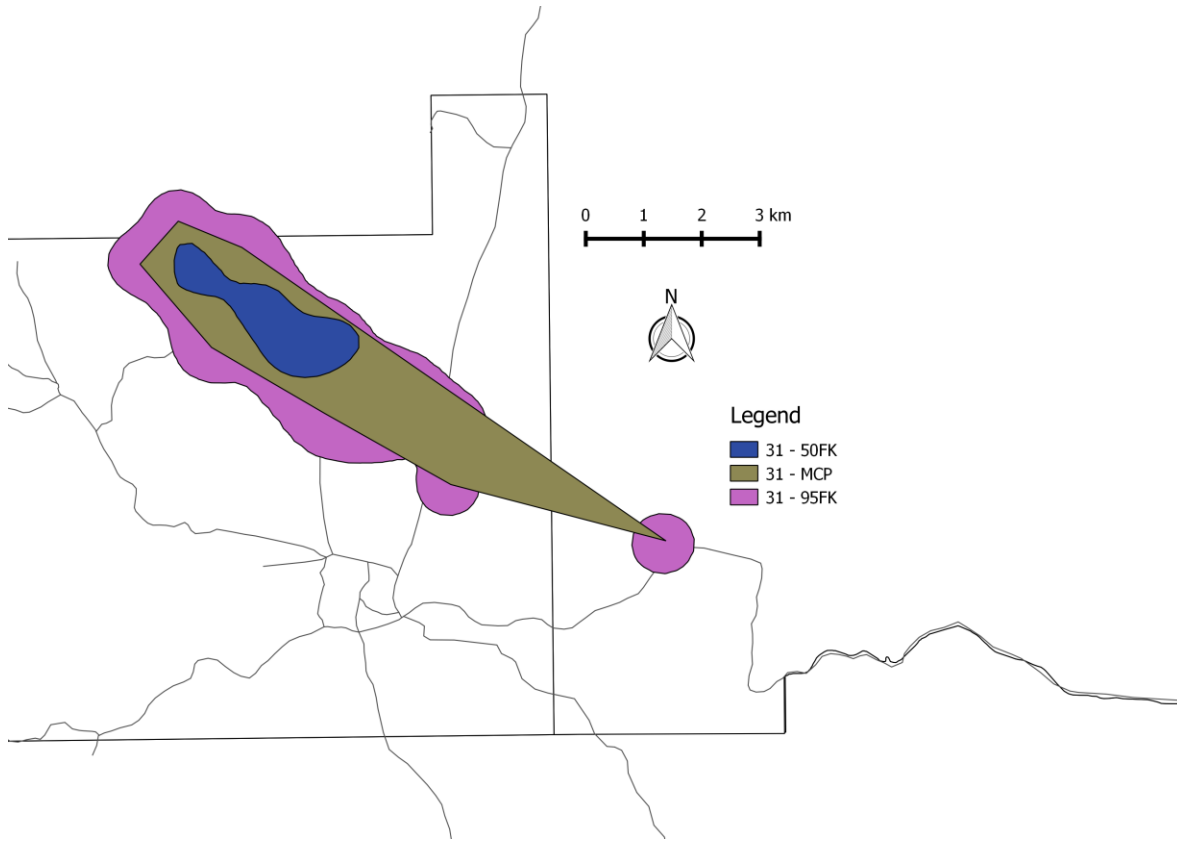
All 3 home range types for bird 34 (field)

Legend
38 - 50FK
38 - 95FK
38 - MCP
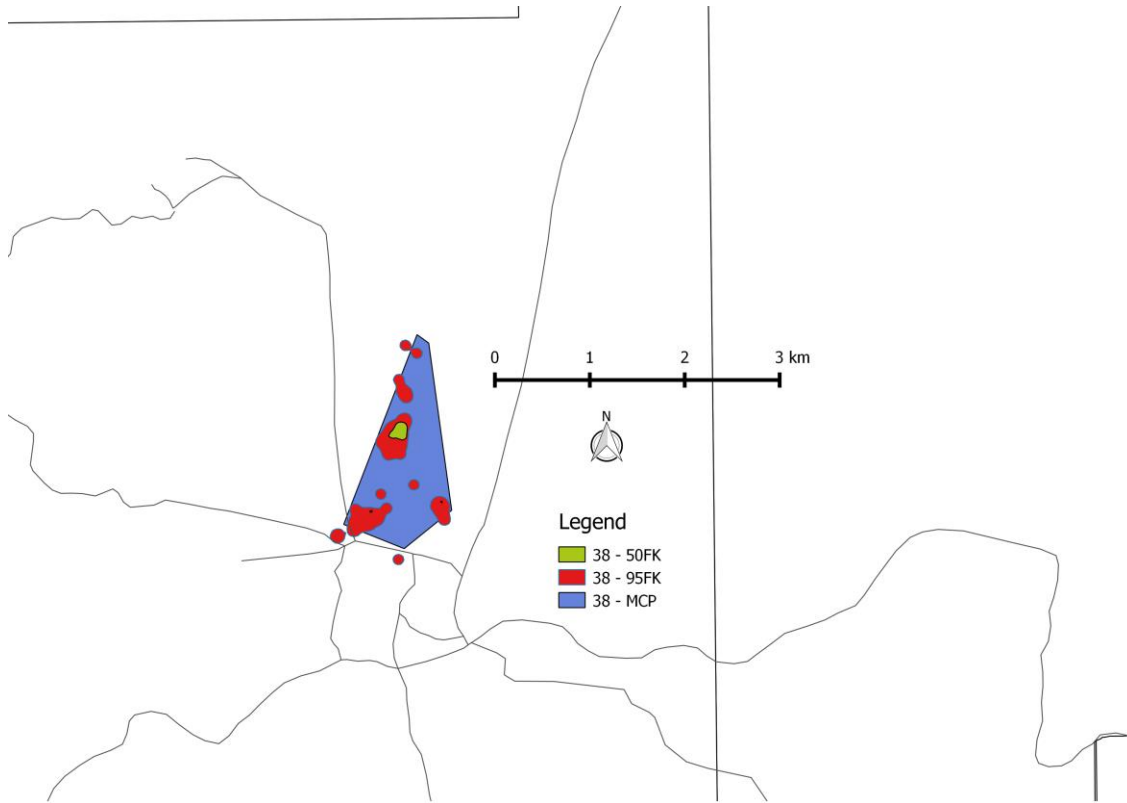
All 3 home range types for bird 38 (Intermediate)
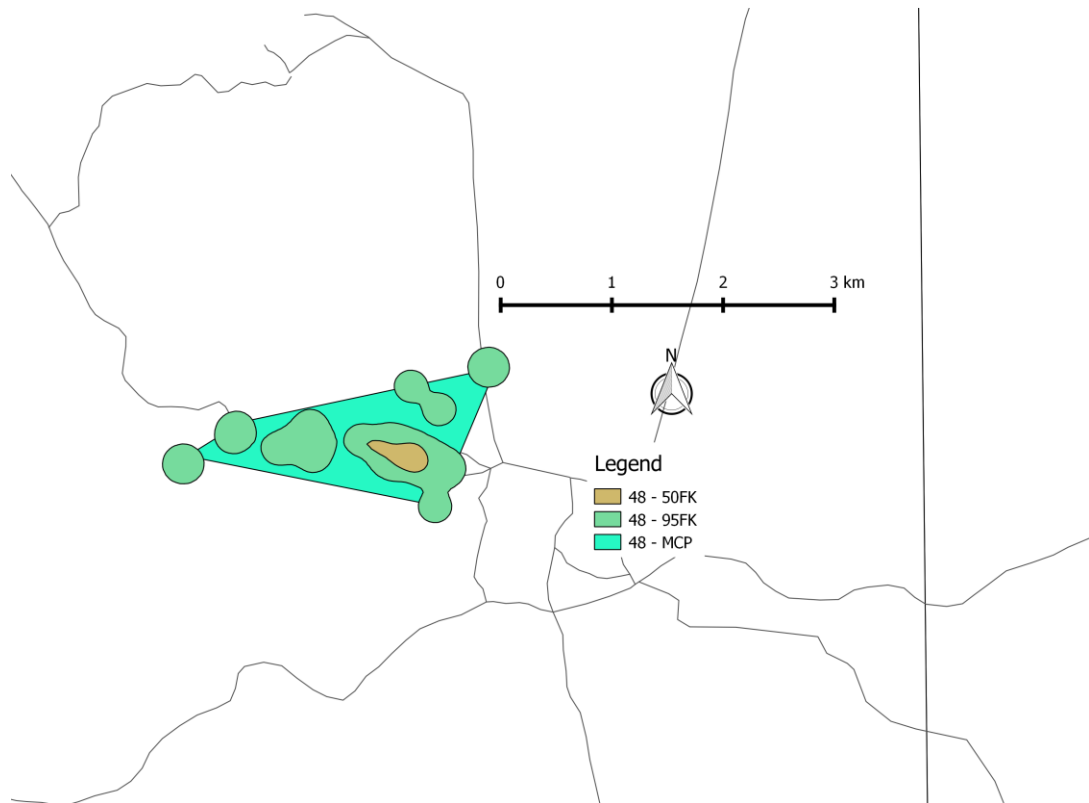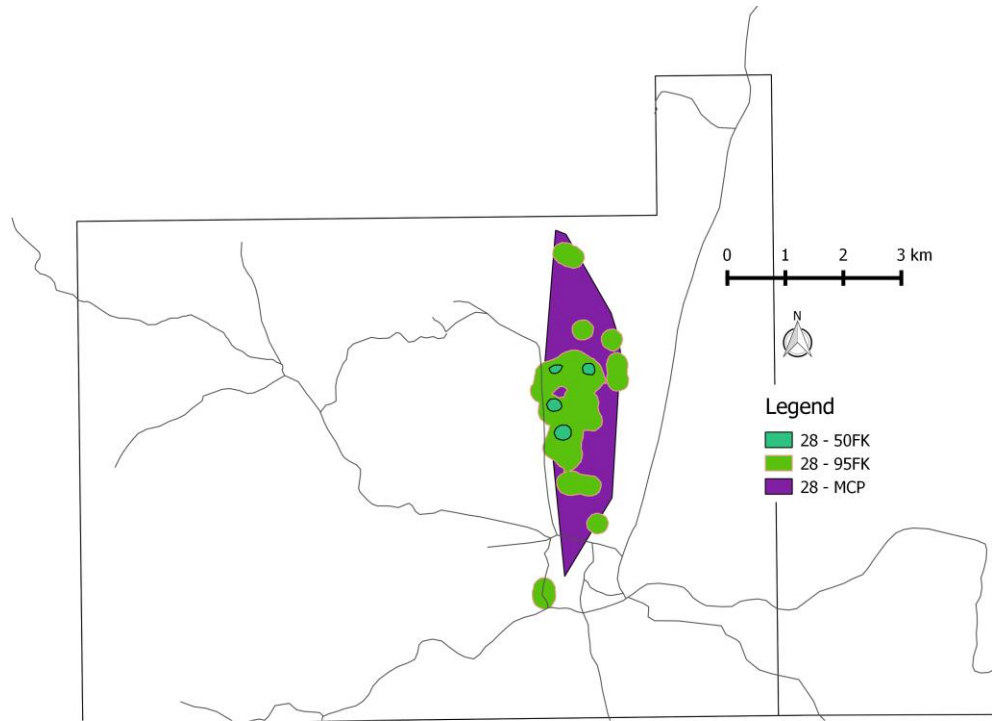
All 3 home range types for bird 48 (Intermediate)
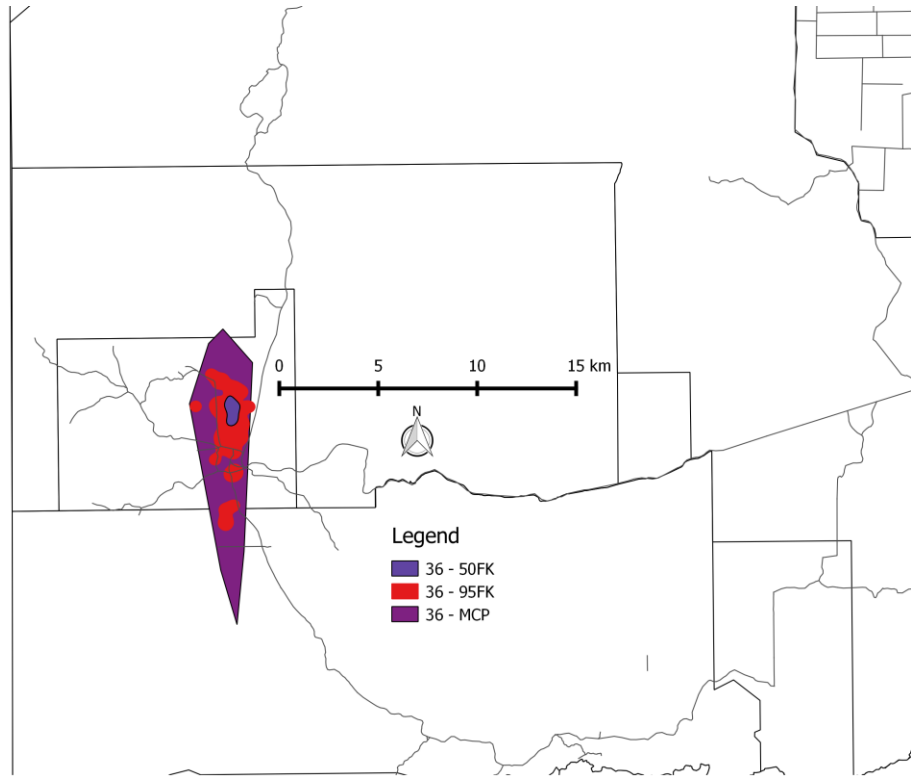
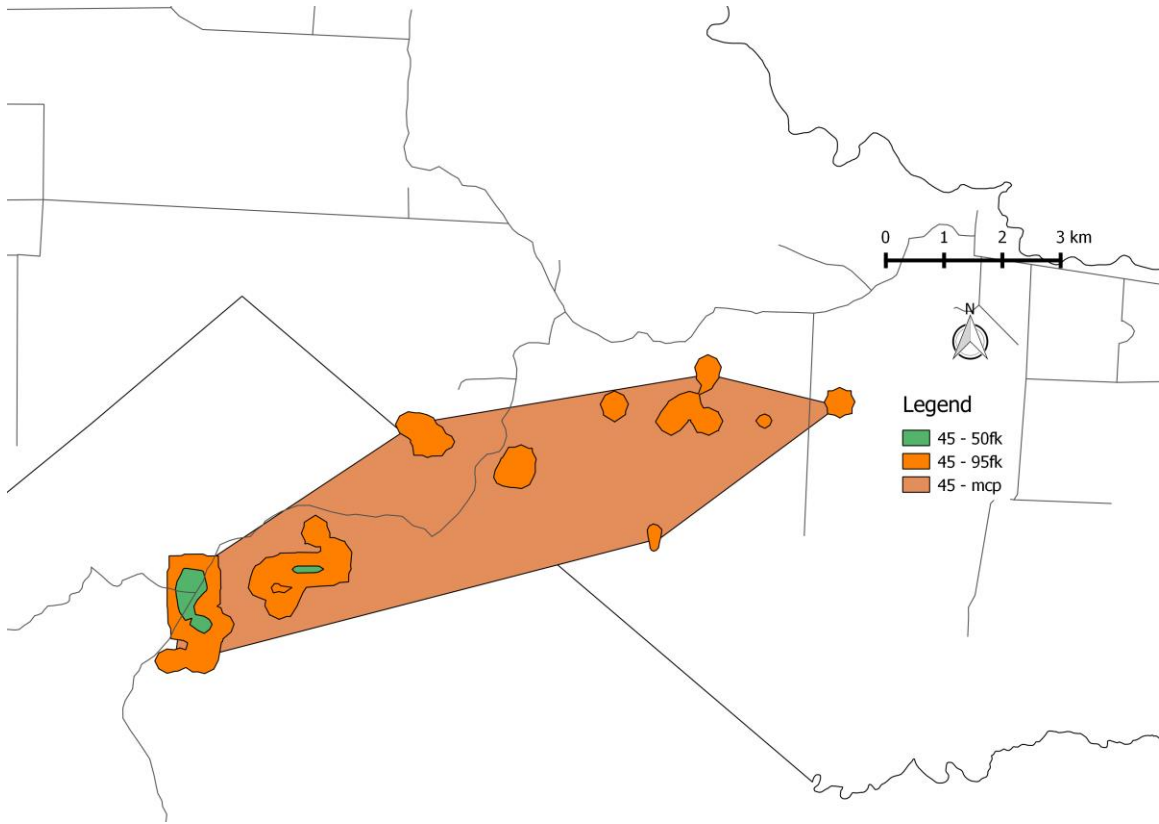All 3 home range types for bird 36 (Intermediate)

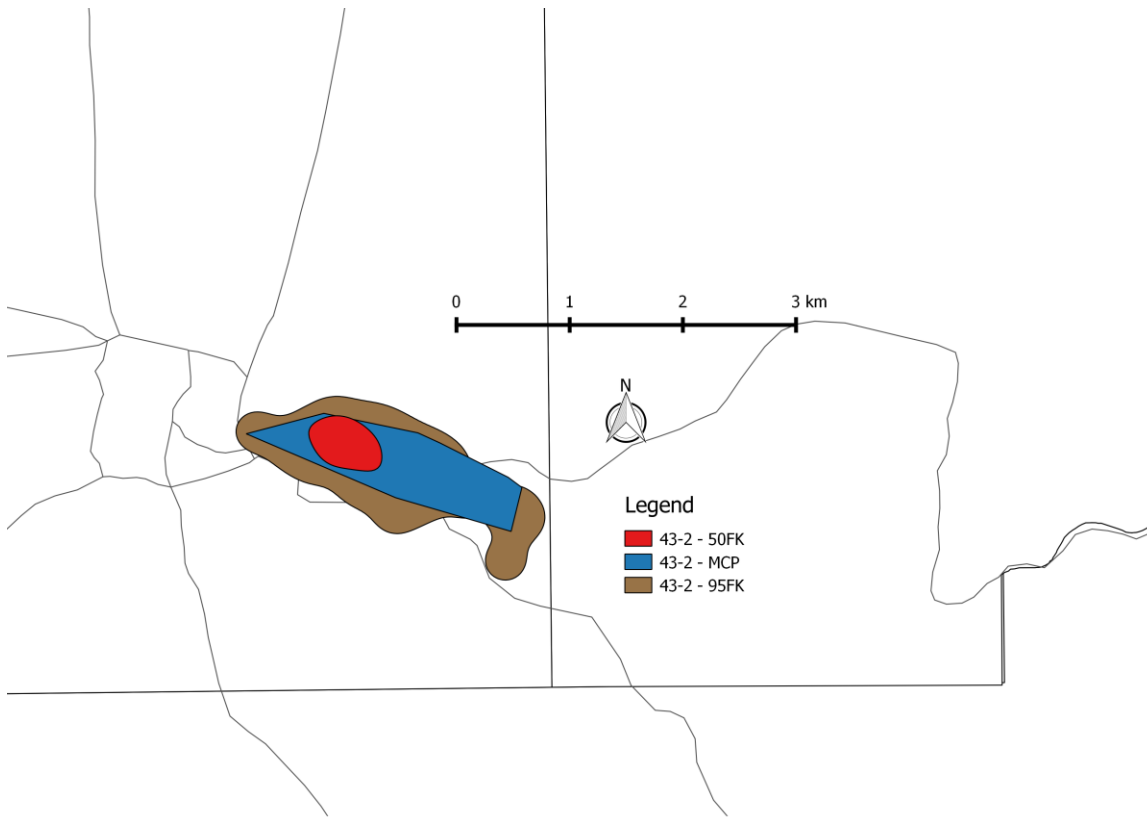All 3 home range types for bird 49 (Intermediate)

All 3 home range types for bird 31 (Jungle)

All 3 home range types for bird 28 (Jungle)

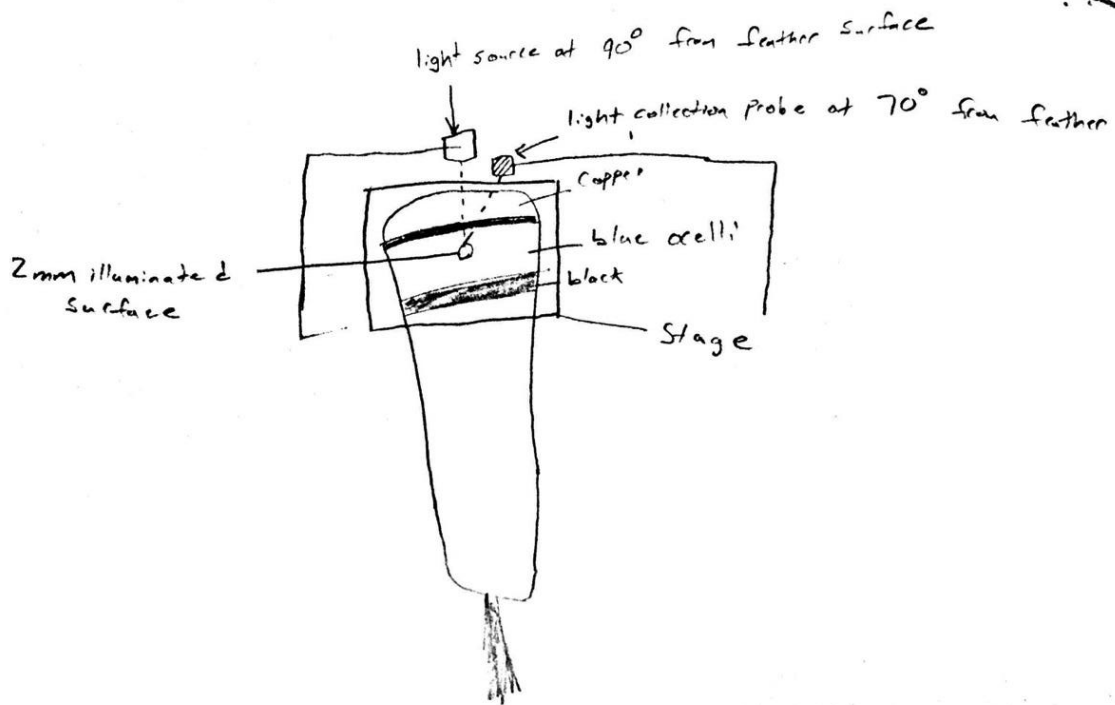All 3 home range types for bird 45 (Jungle)

All 3 home range types for bird 43-2 (Jungle)

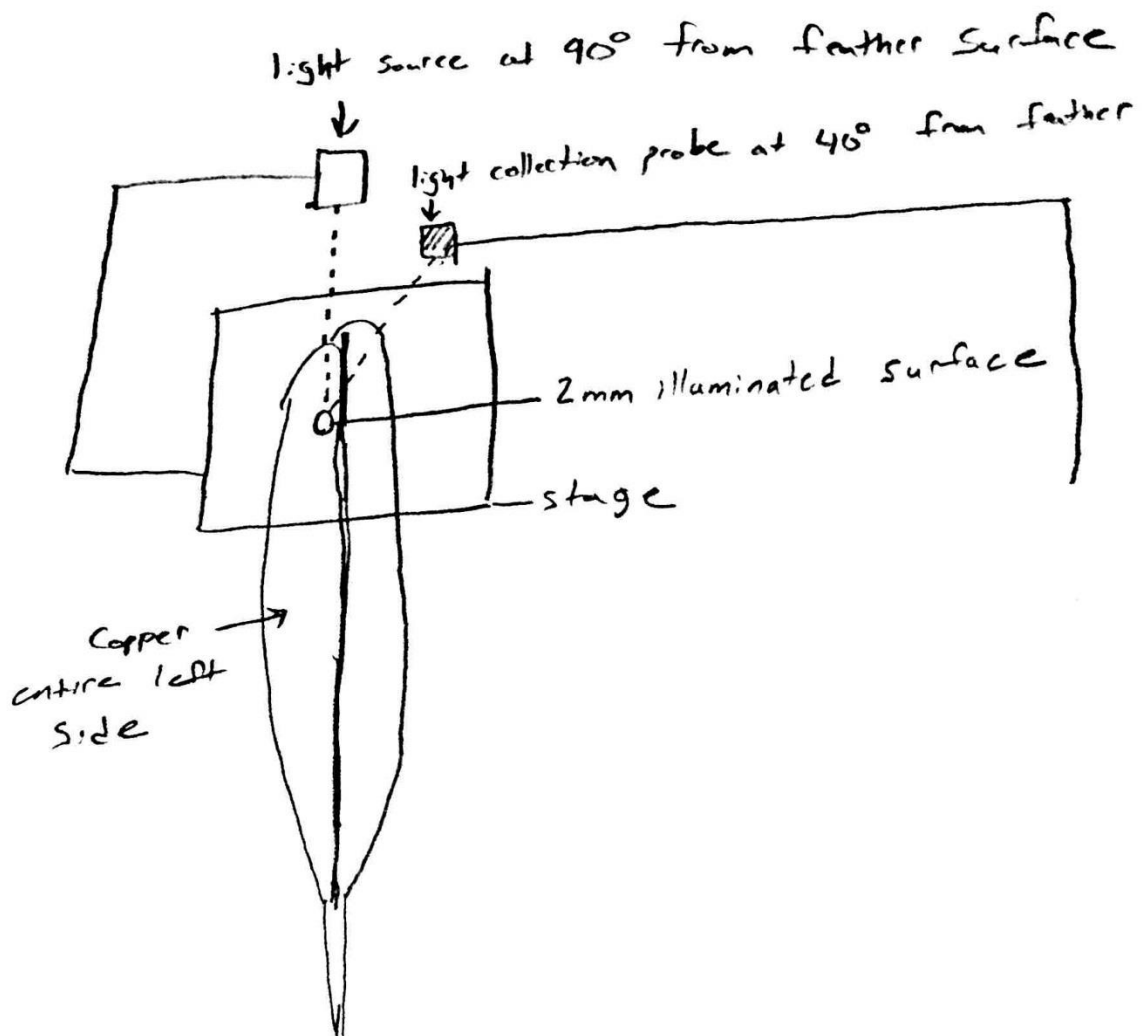# Appendix ii

Feather Spectrometry Schematics

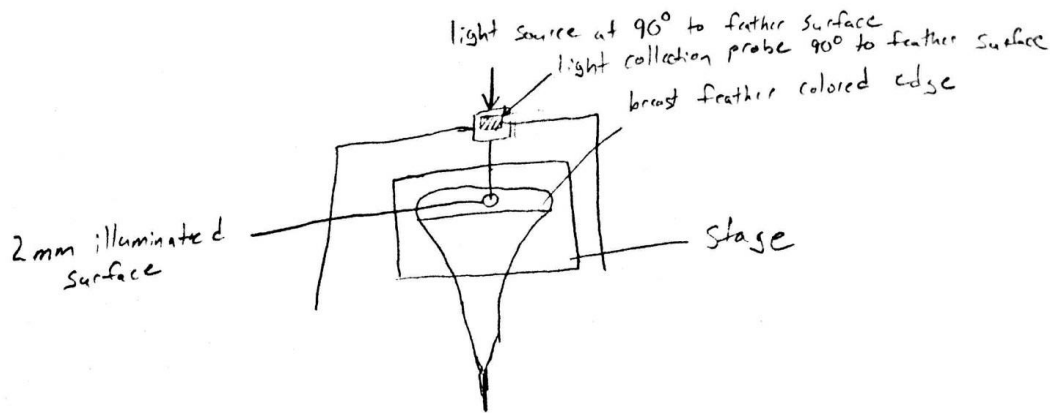Feather setup for the secondary tail retrices. The blue ocelli was measured at an angle of 70°.

Feather setup for the secondary wing covert measurements. The copper edge was measured at an angle of 40°.

Feather setup for the breast feather colored edges. The colored edge was measured at an

angle of 90°.

Appendix iii

Sub-adult Male Pictures

Sub-adult males observing Common Black Hawk eating prey

Thomas Martin

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EDUCATION

Masters of Science, Biological Sciences, University of Mississippi, May 2017
Advisor: Dr. Richard Buchholz

Bachelor of Arts, Biological Sciences, Millsaps College 2011

EMPLOYMENT

University of Mississippi   Oxford, Mississippi
Teaching Assistant, BISC 163   July 2015

University of Mississippi   Oxford, Mississippi
Teaching Assistant, BISC 161   June 2015

University of Mississippi   Oxford, Mississippi
Teaching Assistant, BISC 163   January 2015 – May 2015

University of Mississippi   Oxford, Mississippi
Teach Assistant, BISC 161   August 2014 – December 2014

University of Mississippi   Oxford, Mississippi
Teach Assistant, BISC 161   August 2013 – December 2013

RESEARCH EXPERIENCE

Behavior and Conservation Lab, University of Mississippi, Oxford MS.

PI: Dr. Richard Buchholz, University of Mississippi   August 2013 – Present

Ecology of elevational ranges in tropical birds, University of BC, Vancuver BC.
PI: Dr. Jill Jankowski, University of British Columbia   September 2013 – November 2013Diversification of *Aponaphelma* in the American South West, Millsaps College, Jackson MS.
PI: Dr. Brent Hendrixson   October 2010 – December 2011

Metabolic rates and distribution of tropical birds in Mexico and Ecuador, Millsaps College, Jackson MS.
PI: Dr. Markus Tellkamp, Millsaps College   June 2008 – December 2011

CONFERENCE PRESENTATIONS

Thomas Martin and Markus Tellkamp (2010) YQ Distribution of Birds in the Yucatan Peninsula of Mexico. Poster presentation at the 2010 AOU – COS – SCO annual meeting, San Diego, California.

PROFESSIONAL ASSOCIATIONS

Animal Behavior Society, 2013 - Present