FACTORS INFLUENCING AVIAN PRESENCE IN THE SHORTGRASS PRAIRIE OF NEW MEXICO

A Thesis

by

SARAH JAMES TURNER

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Chair of Committee,	Roel R. Lopez
Co-Chair of Committee,	Nova J. Silvy
Committee Member,	Russell A. Feagin
Head of Department,	Michael Masser

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ABSTRACT

The Department of Defense owns the management rights to over 12 million hectares of land used for training maneuvers in the name of national security. A caveat of using these lands is the requirement to comply with federal environmental legislation, even when this conflicts with the successful attainment of the military mission. One complex ecological issue dealt with by the Department of Defense is the monitoring of migratory birds, as their presence serves as an indicator of ecological viability and additionally creates a major training impediment.

Melrose Air Force Range, located in the high plains of eastern New Mexico, is a live fire bombing and gunnery range administered by Cannon Air Force Base. It is a highly disturbed subset of the shortgrass prairie subject to intense land modification actions. In order to comply with federal mandates, migratory and breeding bird surveys were conducted in spring, summer, and fall of 2015 and 2016. From these surveys, variation between survey years, seasons, and vegetative subsets were determined using CAP discriminant analysis and redundancy analyses were conducted to determine which environmental, locational, or anthropogenic factors provided the most influence on avian presence. My study found that soil composition, precipitation, and temperature explained the highest proportion of variation in avian presence. Additionally, it was determined that anthropogenic factors were able to explain a portion of the observed variance, although the true extent of anthropogenic influence was not able to be assessed due to the fact that Melrose Air Force Range itself is the product of extensive anthropogenic modification. My study suggests that while the vegetative structure and associations that emerge as a function of biotic and abiotic conditions (temperature, precipitation, soil composition) are important determinants of avian community composition, the introduction of

anthropogenic factors (land use and management) alters the underlying spatial distribution of resources (i.e., function as a disturbance to create more exploitable niches), and therefore can increase avian richness and diversity. This change is inversely proportional to scale, with higher diversity at finer scales and increased homogeneity at broader scales.

DEDICATION

I dedicate this work to my parents for their unconditional love and support. Thank you for always believing in me.

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NOMENCLATURE

C	Celsius
CAFB	Cannon Air Force Base
CAP	Canonical Analysis of Principal Coordinates
cm	centimeter
°	degree
DOD	Department of Defense
ha	hectare
km	kilometer
m	meter
MAFR	Melrose Air Force Range
mm	millimeter
mS	millisiemens
PCoA	Principal Coordinate Analysis
RDA	Redundancy Analysis
USFWS	United States Fish and Wildlife Service
WH/m^2	Watt hour per square meter

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CHAPTER I

INTRODUCTION AND JUSTIFICATION OF RESEARCH

AVIAN/VEGETATIVE RELATIONSHIPS

Class Aves, commonly known as birds, consist of over 10,000 extant species (Gill 2007), making it one of the largest classes of amniotic vertebrates (Pough et al. 2009). Birds also are one of the most dispersed animal groups, as they are present on all 7 continents (Gill 2007). This widespread diffusion leads to immense diversification of characteristics and behaviors by individual species, which facilitates increased survival and reproduction in a particular habitat. One factor influencing this speciation is differences in habitat structure, as different ecoregions of the world have distinctive ecological conditions that inhabitants must endure. When these ecoregions exhibit higher habitat complexity, species richness also escalates due to increased availability of a diverse assemblage of exploitable resources (food, shelter, space, etc., also called a niche; Karr and Roth 1971). This complexity is the product of the increased availability and competition for environmental variables (more vegetative species, available water sources, etc.), and can arise due to natural or anthropogenic land modifications (Blair 1996).

Vegetative complexity and structure of a locale has been proven to influence the composition and frequency of species that inhabit an area, acting as a determinant of distribution, abundance, and habitat selection due to the availability of critical resources (Rotenberry and Wiens 1980). MacArthur et al. (1962) proved that while the plant species richness of a site is valuable to know, it is the structural complexity of the vegetation present in a setting that better determines avian diversity (in the sense of species richness). This is because more spatially dynamic vegetation (i.e. tall trees, understory cover, etc.) provides a higher quantity of exploitable resources, and thus provides more niches for different avian species to fill (MacArthur et al. 1962). However, determining the relationship between vegetative structure and avian diversity is a bit trickier. MacArthur and MacArthur (1961) found that avian species richness is linearly related to foliage height, indicating that as plant height increases in a specific habitat type, species richness will follow suit. Conversely, James and Wamer (1982) found that, in general, species richness is highest per unit area when an area exhibits an intermediate value of vegetation species richness, canopy height, and density, indicating a quadratic relationship.

Along with structural complexity, disturbance within a vegetative community can influence avian species diversity. In an ecological sense disturbance can mean many things, but in its simplest form is a cause that results in a perturbation, or a change in the system state (Rykiel 1985). Typical vegetative disturbances could include natural occurrences such as fire, flood, and drought, or anthropogenic influences such as land development (urbanization) and habitat modification for specific purposes. Disturbance is a double-edged sword in the sense of promoting diversity, as some disturbance can benefit an ecosystem (Blair 1996) and too much disturbance or a too rapid rate of disturbance can negatively impact the system (Huston 1979, Melles et al. 2003). This point is accentuated by Robert Blair’s (1996) study comparing avian species diversity across an increasingly disturbed ecological gradient. Blair analyzed avian species distribution and abundance at 6 increasingly urbanized sites in Santa Clara County, California, with the goal of determining the level of disturbance that promoted the highest rates of avian species richness and evenness. Blair’s sites ranged from an undisturbed wildlife sanctuary to moderately disturbed residential suburban developments and highly impacted sites such as industrial parks. Blair (1996) found that, "species richness, Shannon diversity, and bird biomass was highest at moderately disturbed sites," a notion aligning with the

Intermediate Disturbance Hypothesis (IDH). The IDH, whose origin can be traced back to Hutchinson (1953) and Horn (1975) and was proposed by Connell (1978; as cited in Townsend et al. 1997), states that maximum diversity is attained when habitats are subject to disturbances at intermediate spatial, temporal, and intensity scales (Blair 1996). This is plausible due to the fact that ecosystems never truly attain a climax state (a notion that is based on Gleason's individualistic succession theory; Gleason 1926), and are thus capable of supporting various levels of ecological activity in 1 physical location. This could theoretically imply that a location able to provide multiple successional stages of vegetative levels (as brought on by disturbances of varying intensity) could thus support more species of animals able to exploit the different apparent niches, to a certain extent. At a specific threshold (particular to each site), a lack of disturbance could lead to a homogenous late successional stage vegetation composition resulting in a narrow range of environmental conditions exploitable by different species. At the other extreme, too much disturbance could lead to complete vegetation removal or facilitate a homogenous array of first stage successional species, both of which could hypothetically result in fewer exploitable niches and in turn lower species diversity. In summary, it is theorized that with variable (in the sense of timing and method of delivery) and moderate (in intensity) disturbance, an ecosystem will exhibit an increased number of exploitable niches, thus facilitating higher species diversity (diversity meaning species richness, evenness, biomass, etc. depending on the metric being tested).

THE DEPARTMENT OF DEFENSE AND THE UNITED STATES MILITARY

History

The United States Military consists of 5 separate branches: Army, Navy, Marine Corps, Air Force, and Coast Guard. This dynamic array of national protectors was initially founded on 14 June 1775 with the creation of the Continental Army, whose mission was to act in concert to defend American colonial interests during the American Revolution (Stewart 2009). This early Continental Army was structured to consist of slightly over 20,000 soldiers broken down into: 28 regiments (containing 728 men each) of infantry soldiers, 1 regiment of riflemen, and 1 regiment of artillery soldiers (Stewart 2009). Shortly thereafter on 13 October 1775, the Continental Congress approved a proposal to outfit 2 vessels with artillery capabilities to intercept British supply ships, and thus the Continental Navy was born (Naval History and Heritage Command 2015). Finally, on 10 November 1775, the Continental Congress approved a request to form 2 battalions of "marines" capable of fighting both on land and sea (U.S. Marine Corps 2016), thus giving birth to the Continental Marines. Shortly after the conclusion of the American Revolution, the Continental Navy and Marines were disbanded and were reactivated on an as-needed basis (Stewart 2009).

During the post-Revolution period of national establishment, it was clear the nation needed a full-time maritime law enforcer. On 4 August 1790, President George Washington singed the Tariff Act into law with the goal of enforcing federal tariff and trade laws on the high seas (U.S. Coast Guard 2016). To implement this act, the President authorized the creation of 10 armed vessels to be manned by the newly created Coast Guard housed under the Department of the Treasury (where it remained until 1967 when it was transferred to the Department of Transportation and again reassigned in 2003 to its current peacetime home within the Department of Homeland Security; U.S. Coast Guard 2016). At this point in time, the Continental Army, Navy, and Marines were housed under the Department of War, but on 30 April 1798 Congress approved the creation of a separate Department of the Navy, effectively creating a full-time naval force (Department of the Navy 1990). Quickly thereafter, on 11 July 1798 Congress authorized the creation of the United States Marine Corps, a separate entity from the other military branches until it's incorporation into the Department of the Navy in 1834 (Department of the Navy

1990).

The youngest military branch, the Air Force (originally called the Air Service) rose out of the need for aerial warfare tactics in the First World War, and was technically a division of the U.S. Army until after the Second World War (U.S. Air Force 2008). Throughout the Air Service's time within the Department of the Army, the entity saw frequent fluctuation in monetary and manpower resources depending on the wartime status of the nation. Finally, on 26 July 1947 the National Defense Act formally created the United States Air Force, housed separate from the other military branches in the Department of the Air Force (U.S. Air Force 2008). Additionally, the National Defense Act consolidated all 3 existing military branches (War Department, Department of the Navy, and Department of the Air Force) into 1 entity initially called the National Military Establishment and later renamed the Department of Defense in 1949 (Department of Defense 2015*a*).

Mission and Goals of the Department of Defense

The mission of the Department of Defense (DOD) is just what its name states, to provide defense. Specifically, the DOD's purpose is to provide military support to deter war and to protect the security of the nation (Department of Defense 2015*b*), an undertaking guided by the DOD's 6 core values of: duty, integrity, ethics, honor, courage, and loyalty (Department of Defense 2015*b*). The successful completion of this mission is achieved by the implementation of 5 strategic goals (Department of Defense 2015*b*):

1. Defeat our Adversaries, deter war, and defend the nation,
2. Sustain a ready force to meet mission needs,
3. Strengthen and enhance the health and effectiveness of the total workforce,
4. Achieve dominant capabilities through innovation and technical excellence, and

5. Reform and reshape the defense institution.

Additionally, the DOD has 10 core mission areas, which are (Department of Defense 2015*b*):

1. Provide a stabilizing presence,
2. Operate effectively in cyberspace and space,
3. Defend the homeland and provide support to civil authorities,
4. Conduct stability and counterinsurgency operations,
5. Conduct humanitarian, disaster relief, and other operations,
6. Maintain a safe, secure, and effective nuclear deterrent,
7. Counter terrorism and irregular warfare,
8. Counter weapons of mass destruction,
9. Project power despite anti-access/area denial challenges, and
10. Defeat and deter aggression.

The successful accomplishment of these guidelines is crucial to the continued protection of American security and interests. Without the support of the DOD (including the 4 military branches housed within DOD as well as the Coast Guard), the United States would surely not be the preeminent democratic and humanitarian nation. This reputation, however, does not come without substantial economic, political, and ecological costs.

Requirements, Acquisition, and Management of Military Lands

In order to be the world's foremost peacekeeping force, the DOD must obtain a massive array of landholdings for training maneuvers, as our soldiers may face any type of combat situation and must be able to successfully complete all missions under any circumstances. This necessity has led to the attainment of over 12 million hectares of land across the world (Department of Defense 2015*b*). The DOD's landholdings range in size and complexity from 0.2 ha unmanned sites to the over 1.45 million ha White Sands Missile Range in New Mexico (DOD 2015a). Each site functions for a specific mission, whether it be supporting a navigational aid or sustaining a missile testing facility. The requirement for every site, however, remains the same: the unhindered, all-encompassing use of the land in any manner that may support the military mission.

Military landholdings can be acquired in 3 ways: outright purchase, acquisition through condemnation, or through federal land withdrawals (United States Code 1956).

- Under outright purchase, the Secretary of any military department may purchase landholdings that are deemed (1) needed in the name of national defense, or (2) needed solely to correct a life, health, or safety-threatening deficiency (10 USC § 2663). The Secretary of said department is authorized to expend up to $750 thousand for parcels falling under requirement I and $1.5 million for requirement II. Additionally, lands may be purchased when deemed urgent in the sense that its acquisition is: (1) vital to national security, (2) imperative to continue the operations of an existing military facility, and (3) when considerations of urgency do not permit the delay necessary to include the required acquisition in an annual Military Construction Authorization Act (10 USC § 2663).

- The process of acquisition through condemnation is a bit more complex. The Secretary of any department may acquire lands through condemnation if: (1) in wartime, or (2) when necessity is seen for the creation/operation of military training facilities, the creation/operation of plants producing volatile compounds, explosives, or other warfare munitions, or for the creation/operation of power transmission facilities for said installation (10 USC § 2663). Before land can be obtained during peacetime acquisition by condemnation, however, the Secretary of the acquiring department must provide documentation that all other avenues of acquisition have been pursued (i.e. purchase, land exchange, etc.) and must submit a report detailing: the land to be attained, that extensive negotiation measures have occurred on the behalf of the DOD, and why other land acquisition measures are insufficient (10 USC § 2663).

- Withdrawn lands are federal lands held by the Bureau of Land Management that a government agency may lease and subsequently obtain the management rights to operate and/or manage. Under the provisions of 43 U.S.C. § Chapter 6, the approval of the Secretary of the Interior is needed for DOD withdrawals less than 2,023 ha and congressional approval is needed for DOD withdrawals over 2,023 ha. With the acquisition of these lands the DOD obtains not only the management rights to the parcels, but also the obligation to comply with any federal statute possibly pertaining to the land. These withdrawals are valid for up to 15 years, and can only be renewed through congressional action for an approved period of time (United States Congress 1986). According to H. Rep. No. 113-671 (2014) the DOD has approximately 1.86 million ha currently withdrawn for training purposes located mainly in Alaska, Nevada, and New Mexico.

DOD Obligation to Follow Federal Environmental Laws

Since the DOD is a government agency, it is required to comply with and enforce all federal laws unless otherwise excluded by a special clause, including all environmental and ecological monitoring mandates. While there are hundreds of applicable legislative actions the DOD must comply with, the most notable ecological statutes are: Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, Sikes Act, National Environmental Policy Act, and Endangered Species Act:

- Migratory Bird Treaty Act, 1918: Originally, the Migratory Bird Treat Act was an international agreement between the United States and Great Britain (acting on behalf of Canada which at the time was a territory). It is an omnibus act calling for the protection of migratory birds, making it illegal to kill, harass, take, sell, or possess any migratory bird part, nest, egg, or other associated object (16 USC § 703). Eventually, the treaty was extended between the United States to include agreements with Mexico, Japan, and Russia (16 USC § 703). There are currently 1,026 avian species protected by the Migratory Bird Treaty Act (U.S. Fish and Wildlife Service 2013). The U.S. Fish and Wildlife Service (USFWS) allows for the take of specified migratory birds through a series of federally designated permits, laws, and treaties (U.S. Fish and Wildlife Service 2015).

- Bald and Golden Eagle Protection Act, 1940: In the early 20th century the nation's symbol, the bald eagle (*Haliaeetus leucocephalus*), faced severe population declines attributed to harvesting and habitat encroachment (Wisch 2002). To curtail the downward spiral of the species, congressional action was warranted. At the time of it's passage, the Eagle Act made it illegal for any person to "knowingly or with wanton disregard to the consequences of kill, possess, harm, manipulate, or barter any specimen or parts thereof" (including nest and eggs) of a bald eagle (The Wildlife Society 2014). In 1962, an amendment to the Eagle Act extended the law to protect the similar looking (in juvenile stages) golden eagle (*Aquila chrysaetos*), who also was facing population declines as a result of harvest and habitat decline as well (Wisch 2002, Iraola 2005, The Wildlife Society 2014). Under the Bald and Golden Eagle Protection Act, the Department of the Interior has the authority to issue take permits for scientific, educational, Native American religious ceremonies, falconry (only for golden eagles), and depredation purposes (The Wildlife Society 2014).

- Sikes Act (1960), Sikes Act Improvement Act (1997): In addition to housing the nation's troops and military supplies, DOD installations also are home to a plethora of wildlife and other natural resources. In fact, DOD landholdings have a higher rate of endangered species per 100,000 ha than any other federal landholding entity (including Bureau of Land Management, U.S. Forest Service, USFWS, and the National Parks Service; Benton et al. 2008). This realization led military personnel and conservationists alike to propose a collaborative planning process to protect these resources, and thus the Sikes Act was born. Under the Sikes Act, military installations are required to engage in collaborative planning with USFWS, state fish and game agencies, and all other parties with a vested interest in order to plan, develop, and maintain fish and wildlife resources (May and Porier 2006). The act was amended in 1997 (also called the Sikes Act Improvement Act) to require that installations develop, in collaboration with all appropriate agencies, an integrated natural resource management plan (INRMP; United States Code 1997). An INRMP is essentially a stepwise manual of how an installation plans to delineate, protect, and manage its wildlife, land, and other natural resources (including how the installation will provide enforcement of natural resource laws; May and Porier 2006).

- National Environmental Policy Act, 1969: The most impactful piece of legislation to be produced during the environmental awareness movement of the 1960s and

1970s was undoubtedly the National Environmental Policy Act. It was the federal government's all-encompassing effort to take responsibility for the impact the actions of their subsidiaries have placed or will place on natural resources. There are 3 clauses under the National Environmental Policy Act: (1) federal agencies must take environmental costs and/or consequences into consideration during the planning and execution of agency actions, (2) it established the Council on Environmental Quality, an executive level entity to aid the President in all environmental matters, and (3) all federal agencies must complete an extensive environmental review (known as an environmental impact statement) of any planned action significantly affecting the quality of the human environment (Rosenberg and Olson 1978). While the DOD is subject to comply with the act's initial environmental assessment clauses, certain exclusions can be applicable to negate the requirement of choosing an action alternative with the least environmental impact (also called a categorical exclusion, which may come about for a plethora of reasons; U.S. Government Printing Office 1989).

- Endangered Species Act, 1973: The Endangered Species Act is one of the most controversial environmental legislation measures in effect today. It was born out of the need to protect species that were visibly facing population declines, and acted as the culmination and reinforcement of the federal government's interest in wildlife management (Stanford Environmental Law Society 2001). Two pre-existing laws influenced the creation of the Endangered Species Act, the 1966 Endangered Species Preservation Act and the 1969 Endangered Species Conservation Act. The 1966 act called for the protection of threatened species insofar as is practicable, and required the Department of the Interior to consult with other federal agencies and encourage compliance with the act (Stanford

Environmental Law Society 2001). The 1969 act expanded the reach of the prior item by including imperiled species worldwide, banning the import and trade of listed species, and expanding the definition of covered species to include amphibians, reptiles, and invertebrates (Stanford Environmental Law Society 2001). These measures were deemed still too lenient, and to redress this concern the Endangered Species Act was born. Essentially, the act provides a platform that: (1) defines what makes an animal or plant species threatened or endangered, (2) provides a criteria checklist to determine if a species should be listed under the act, (3) describes how the species should be protected (in the sense of defining unlawful activities associated with the species and its habitat) and delineates the process of assigning critical habitat, (4) assigns federal and state responsibility and outlines financial assistance for compliance, (5) outlines exceptions to the coverage of the act, and (6) determines enforcement measures for the Act. One of the most impacting sections of the act is Section 7, which states that all federal agencies (including the DOD) must comply with the measures of the Endangered Species Act, and requires that actions authorized, funded, or carried out by that agency do not "jeopardize the continued existence of a listed species or adversely modify critical habitat" (United States Code 1973). Additionally, if an agency action is deemed to impact a listed species, a series of consultations must occur between the action agency and USFWS or National Marine Fisheries Service (depending on if the species is terrestrial or aquatic) with a final goal of developing an action plan that minimizes or eliminates any potential impacts on the listed species (United States Code 1973). There are few scenarios that would allow for an agency to ignore Section 7, however Section 7(j) provides the DOD with an exclusionary clause allowing them to disregard the measures of the law if the proposed action is deemed critical to national security (United States Code 1973).

In addition to the previous listed laws, service-specific instructions have been proclaimed to aid in the preservation of wildlife species, particularly avian species. Avian species typically require more intense protection measures, as they are predominantly migratory in nature and could potentially impact multiple DOD facilities simultaneously or within a close time span. In 2001, President Clinton issued Executive Order 13186 - Responsibilities of Federal Agencies to Protect Migratory Birds, requiring all federal agencies (especially the DOD) who conduct actions affecting migratory birds in any manner to enter into a Memorandum of Understanding with USFWS that promotes the conservation of migratory birds (National Archives 2001). This executive order, in confluence with the previously detailed environmental legislation, left the DOD with very stringent ecological monitoring rules to which it must either comply or be subject to training impediments (restrictions). This burden was eased in 2003, when the 2003 National Defense Authorization Act allowed the DOD to permit incidental take of avian species during military readiness activities if appropriate avian monitoring protocols were adopted and actively implemented (Department of Defense 2002). To take the utmost advantage of this exclusionary clause, all subsequent installation INRMPs delineated avian monitoring provisions as part of their ecological compliance regime. This exclusionary clause particularly benefits the Air Force, whose training activities create a direct conflict with the management of avian species. The Air Force has additionally created the bird/wildlife aircraft strike hazards program (or BASH), which actively attempts to minimize bird-aircraft interactions via behavioral modification, population control, and habitat modification in close proximity to airfields.

JUSTIFICATION OF RESEARCH AND OBJECTIVES

Ecological monitoring is a multidisciplinary field, requiring knowledge on not only the subject of interest, but of biotic and abiotic factors influencing said subject. In this case, to effectively study avian communities one also must understand how vegetative structure, resource availability, and anthropogenic factors can influence avian distribution and abundance. Likewise, to fully comply with government regulations pertaining to avian monitoring, scientists must approach the issue with a broad perspective. To effectively manage for avian species, all factors influencing their presence on military installations must be considered, from ecological factors to military training activities and all it implies (such as land disturbance and infrastructure creation). With this in mind, the analysis of variables influencing avian presence on a highly disturbed military installation would serve 3 valuable purposes. First, legally required avian monitoring mandates would be met, allowing for the installation to continue training maneuvers without interruption. Secondly, it would provide natural resource managers with an inventory of species occurring on the installation and regionally, aiding future avian monitoring and conservation efforts. Lastly, and most importantly, it would allow for the identification of factors that exhibit the greatest influence on the presence of avian species, and subsequently how military activities can affect this occupancy. This can then be applied to many facets of environmental management on military installations, including the protection of favorably selected factors promoting avian presence, the identification of potential critical habitat for endangered and threatened species, and the creation of management practices to maintain preferred vegetation types to sustain avian populations.

I formulated 3 testable hypotheses *apriori* concerning the presence and distribution of avian species on Melrose Air Force Range, New Mexico: (1) there would be no differences in species present among survey locations between years, seasons, and vegetative classes, (2) environmental variables (biotic and abiotic) would not explain any of the observed variance in avian species presence, and (3) anthropogenic influences would not explain any of the observed variance in avian species presence. These hypotheses would allow me to determine the homogeneity of factors within survey years, survey seasons, and vegetative classes, as well as identify what, if any, factors are prevalent in explaining the highest proportion of variance determining avian presence.

CHAPTER II

STUDY AREA AND METHODS

STUDY AREA

Location and History

Located in the western periphery of the high plains of New Mexico is Cannon Air Force Base (CAFB). Operated by the Air Force Special Operations Command, CAFB is one of the few United States Air Force live fire ranges. The installation is located in Curry County, New Mexico, approximately 11 km west of Clovis, New Mexico. CAFB originated in the 1920s as a civilian airfield that was quickly incorporated into the Army Air Corps during the Second World War (United States Air Force 2010). The field was deactivated upon the termination of the Second World War, only to be reactivated in 1951 under the operation of the Tactical Air Command as a specialized aircraft training facility. Since then, the base has undergone several command changes and is currently under the command of Air Force Special Operations Command, 27th Special Operations Wing (United States Air Force 2010). The installation's mission is to "develop, achieve, and maintain forces capable of meeting special operations needs" (United States Air Force 2010). All research for my study occurred on Melrose Air Force Range (MAFR; Fig. 2.1), a 28,723 ha training/bombing range administered by CAFB and the Air Force Special Operations Command (24,281 ha owned by the DOD and 4,442 ha state leased lands) (Fig. 2.1). The range is located in Curry and Roosevelt counties, New Mexico, approximately 48 km west of CAFB. MAFR has been in use since the Korean War (1950-1953) by the Air Force, Navy, and Marine Corps for bombing and gunnery training in support of the military mission. Contained within the range is a 4,046 ha impact area used for live fire training, as well as numerous ground combat training areas utilized by all DOD branches. Infrastructure on MAFR includes maintenance facilities, wells and water storage mechanisms, the bombing and gunnery operations headquarters, and various training zones containing an array of structures. In addition to serving as a bombing/gunnery range, MAFR formerly provided agricultural farming and ranching outleases exterior of the central impact area. However, to accommodate for expansion of training facilities, these outleases were terminated in 2012 and 2015, respectively. Remnant stock pens, tanks, and agricultural irrigation equipment are still present on the range. These former outleases also served as fuel load management techniques for MAFR, which is now accomplished through rotational prescribed burning regimes conducted by range personnel.

Climatic and Topographical Description

As stated, MAFR encompasses 28,732 ha in the high plains of Curry and Roosevelt counties, New Mexico. Elevations vary from 1,280 m to over 1,420 m, with the mean elevation increasing from the northeast to southwest (United States Air Force 2010). The tallest topographic feature on MAFR is a northeasterly trending mesa (aptly called "The Mesa") that reaches elevations of over 1,420 m. Topographic relief features include several small canyons, playas, and ephemeral drainages. Aside from the centrally located Mesa, the predominant landform of MAFR is flat land. The climate of MAFR is described as arid or semiarid, with normal conditions consisting of clear, low humidity days that experience large daily temperature fluctuations (United States Air Force 2010). Annual average temperatures for Melrose, New Mexico (the closest town, located approximately 20 km from MAFR) are highs near 23.2°C and lows near 6.28°C (US Climate Data 2016). Annual average precipitation is 44.20 cm of rainfall with the majority of rainfall occurring during the summer and early fall, and 33 cm of snowfall.

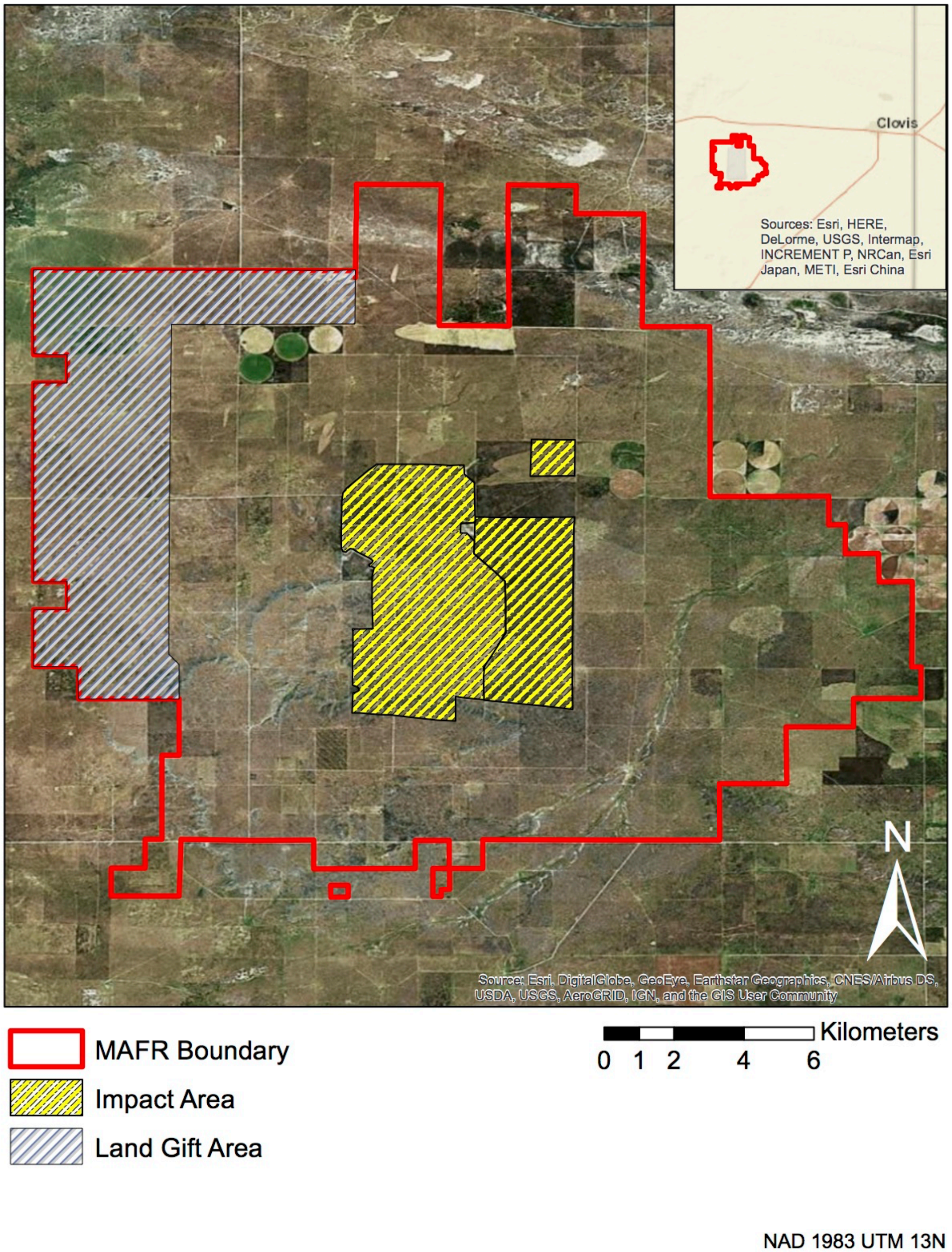

Figure 2.1: Location of Melrose Air Force Range in Curry and Roosevelt counties, New Mexico.

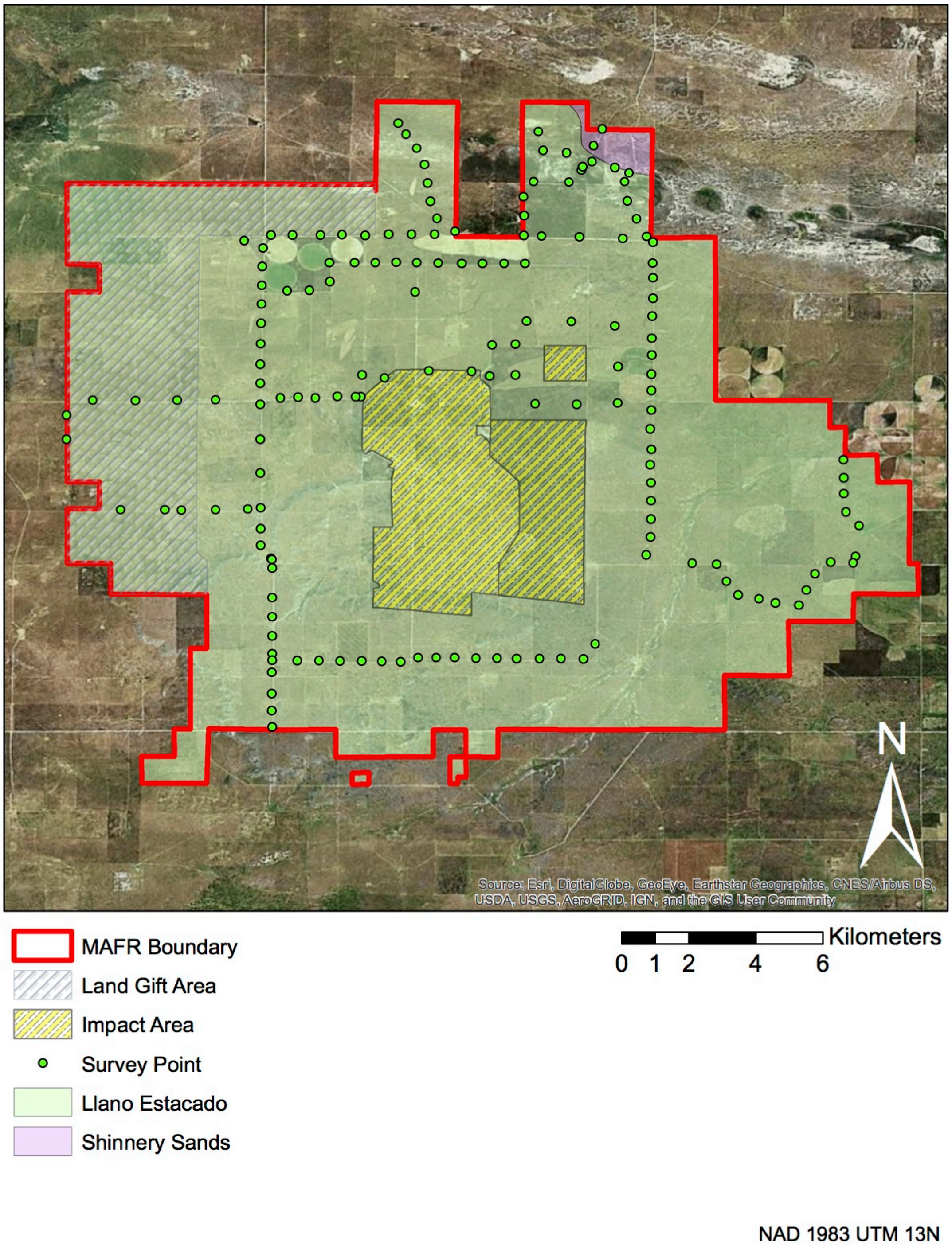

Figure 2.2: Level IV ecoregion classification on Melrose Air Force Range, New Mexico.

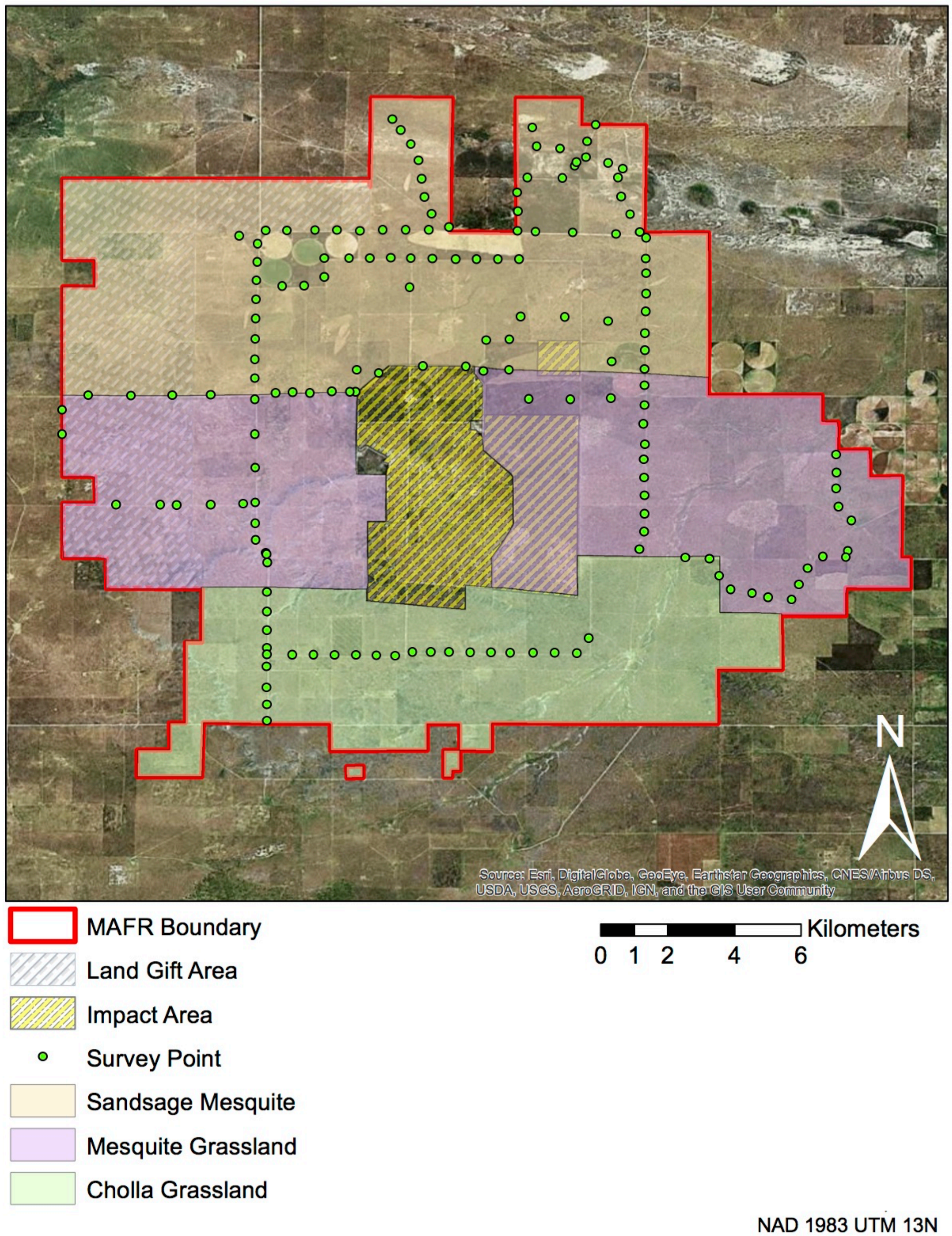

Figure 2.3: Vegetative subsets observed on Melrose Air Force Range, New Mexico.

Ecological Site Description

MAFR is located in the Southwest Plateau and Plains Dry Steppe and Shrub province (Bailey 1995), the High Plains Level III ecoregion, and the Llano Estacado and Shinnery Sands Level IV ecoregions (U.S. Environmental Protection Agency 2016; Fig. 2.2). Predominant vegetation on the range consists of: (1) grasses such as grama species (mainly blue grama, *Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), and threeawn grasses (*Aristida spp.*; Bailey 1995, U.S. Environmental Protection Agency 2016); (2) honey mesquite (*Prosopis glandulosa*) and sand sagebrush (*Artemisia filifolia*); and (3) succulent species including soapweed yucca (*Yucca glauca*), prickly-pear cactus (*Opuntia spp.*), and tree cholla (*Cylindropuntia imbricata*). There are 3 prominent vegetation zones on MAFR, with cholla-grassland occurring in the southern third of the range, mesquite-grassland occurring in the central third, and sandsage-mesquite grassland occurring in the northern third (Fig. 2.3). Soils are primarily horizontal Mesozoic and Cenozoic formations comprised of a thin layer of topsoil underlain by a clay-carbonate hardpan (commonly called caliche) at relatively shallow depths (United States Air Force 2010). The main soil associations are: Springer loamy fine sand, Clovis loam, Stegall loam, Mansker and Portales loams, and Olton loam (United States Air Force 2010). These soils are moderately to highly permeable and extremely prone to wind erosion.

METHODS

Seasonal Avian Surveys

Spring migratory bird surveys on MAFR occurred from May until June 2015 and during May 2016. Summer breeding bird surveys on MAFR were conducted in the month of June 2015 and in June and July 2016. Fall migratory bird surveys occurred throughout October and November 2015 and September to November 2016. For all surveys, extensive point count survey methods were employed following protocols similar to that of Ralph (1993) and the North American Breeding Bird Survey (Sauer et al. 2013). Fourteen survey routes were established across MAFR by referencing satellite imagery and physical observation (Fig. 2.4). Along each route, observation points were placed equidistantly at 1-km intervals traversing the length of the route. All routes were developed on graded or primitive (2-track) roads to facilitate widespread monitoring efforts, expedite travel between survey points, and reduce land impact. A total of 164 survey points was established (Fig. 2.4), with 53.7% occurring in the sandsage-mesquite, 29.3% in mesquite grassland, and 17.0% in cholla grassland (Table 2.1).

Location	# Points	%
Range-wide	164	100
Sandsage-Mesquite	88	53.7
Mesquite Grassland	48	29.3
Cholla Grassland	28	17.0

Table 2.1: Distribution of survey points across Melrose Air Force Range, New Mexico.

At each observation point, the biologist exited the vehicle and recorded any visual or audio observations of avian species for a time span of 5 minutes. Raptorial species were only counted at a point if they were observed utilizing resources within 500 m of the survey point. For each observed species the biologist recorded: survey point ID, time, species, sex (if possible), audio/visual confirmation, and species count. Any birds flushed during travel that were seen within 100 m of the survey point were recorded as occurring at the specified survey point. After a time period of five minutes, the biologist exited the site and proceeded directly to the next survey point causing as little disturbance as

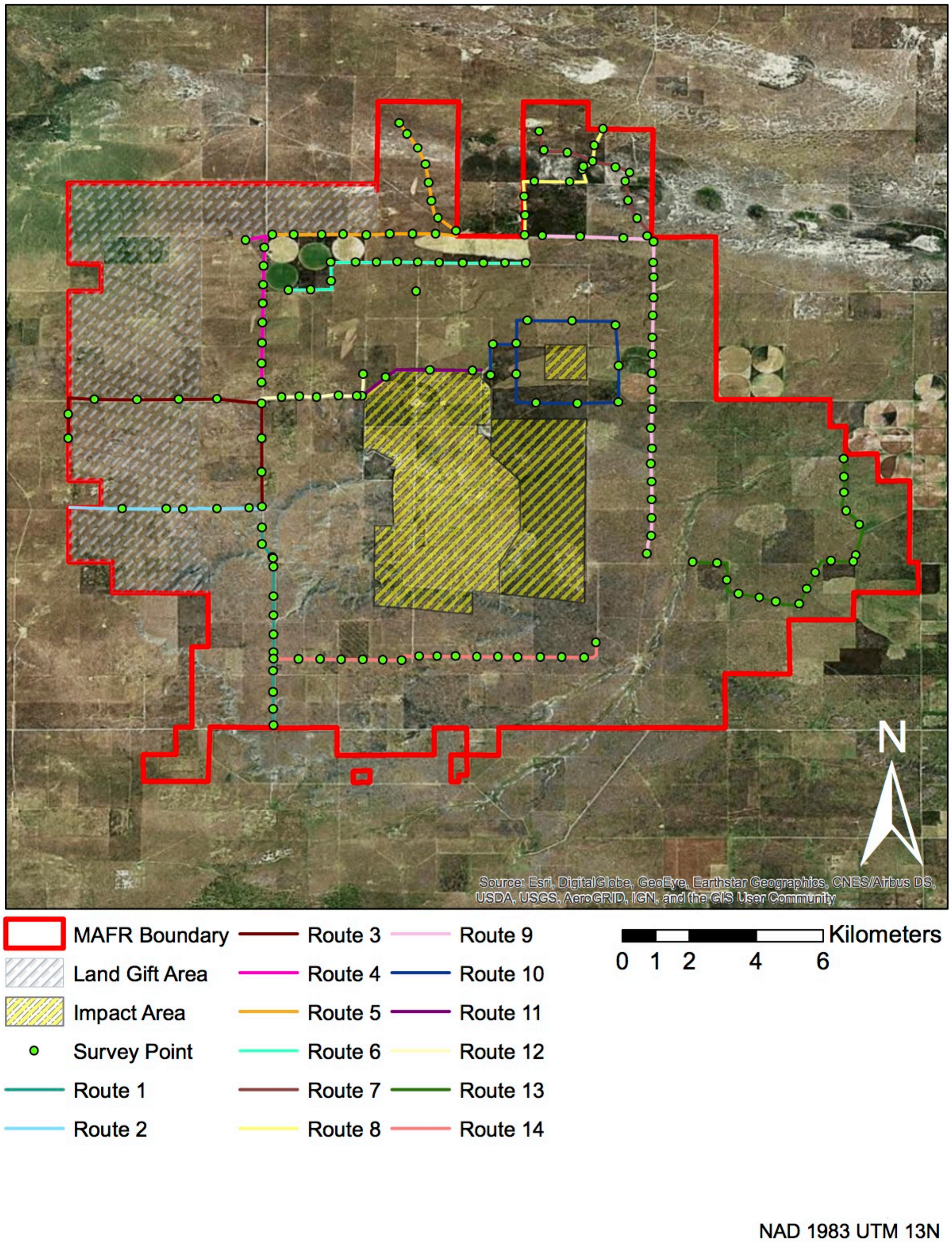

Figure 2.4: Location of survey points on established routes on Melrose Air Force Range, New Mexico.

possible. All surveys occurred in the time span from 0730 hours until 1100 hours, and were only conducted when wind speeds were below approximately 24 kilometers per hour. At wind speeds exceeding this, avian species tend to seek shelter and song becomes impossible to decipher (Ralph 1993).

Survey Point Characteristics

Upon initiating the first survey occurring at a location, the biologist marked the survey point on a Garmin Montana 650t™ GPS unit. Every survey point was checked for accuracy to within 5 m during each subsequent survey. These locations were then uploaded into ArcMap 10.3™, and converted from a .gpx file into a shapefile and projected in the Universal Transverse Mercator (UTM) coordinate system using the North American Datum of 1983 (Zone 13 North; NAD83, 13N). Three polygons depicting generalized vegetative community class (sandsage-mesquite, mesquite-grassland, and cholla-grassland) were then created using satellite imagery and appended with the survey point shapefile. Ecoregion shapefiles were obtained from the U.S. EPA website (U.S. Environmental Protection Agency 2017), clipped to the boundary of MAFR, and survey points were intersected with the layer to obtain the Level III and IV ecoregion each point resided in. Soil layers were obtained from the Natural Resource Conservation Service's Web Soil Survey (Natural Resource Conservation Service 2013, 2016), downloaded and extracted for Roosevelt and Curry Counties, and clipped to the boundary of MAFR. This layer was then intersected with the survey points layer to delineate the soil type at each survey point. From the SURRGO data, a Microsoft Access database of soil attributes was activated (Natural Resource Conservation Service 2013, 2016), and tables of physical and chemical properties of each soil type were created and combined with the previous ecoregion data. Next, a 60-m digital elevation model (DEM) of New Mexico was obtained from Earth Data Analysis Center (Earth Data Analysis Center 1996), from which an elevation and an aspect raster for MAFR were created in ArcMap 10.3™. These rasters were individually intersected with the survey points layer and elevation and aspect values for each point extracted. Insolation values for survey points during each survey month and year were calculated using the "Insolation" application in ArcMap 10.3™, and values extracted. Afterwards, a shapefile of trees with a vertical height greater than 3 m (as determined by ground truthing and physical observations) was digitized using satellite imagery (AcrGIS®). Finally, a map of MAFR published by the Range Management Office on CAFB (01 February 2017) was georeferenced to satellite imagery of MAFR. From this, digitized shapefiles of training and impact areas, wells, open water sources (defined as earthen impoundments or man-made water storage tanks with no well pump or windmill apparent), and power lines were created. Wells, open water sources, trees, and power lines were coded as being present (1) or absent (0) within a 500 m radius of a survey point (Fig. 2.5).

Data Compilation

All soil variables were initially compiled into a Microsoft Excel™ file. For variables that were provided in ranges (sand, silt, clay, and organic matter percentages; available water capacity [mm/mm]; pH; salinity [mS]), the mean was calculated and a new variable column created. Aspect was extracted from ArcMap in the format of 0–360°, with true North correlating with 0°. As aspect values were obtained in order to determine solar radiation's influence on soil, the values were reoriented to follow the direction of greatest to least insolation, with least in the northeast to greatest in the southwest (Jenness 2007). Values were transformed for northeast to read 0°, northwest and southeast to each read 90° (as they both receive equal time spans of insolation, only at different ground angles), and southwest to read 180°. Aspects of -1 (indicating flat ground) were assigned the value of 90°, as it was deemed these areas would receive intermediate amounts of insolation

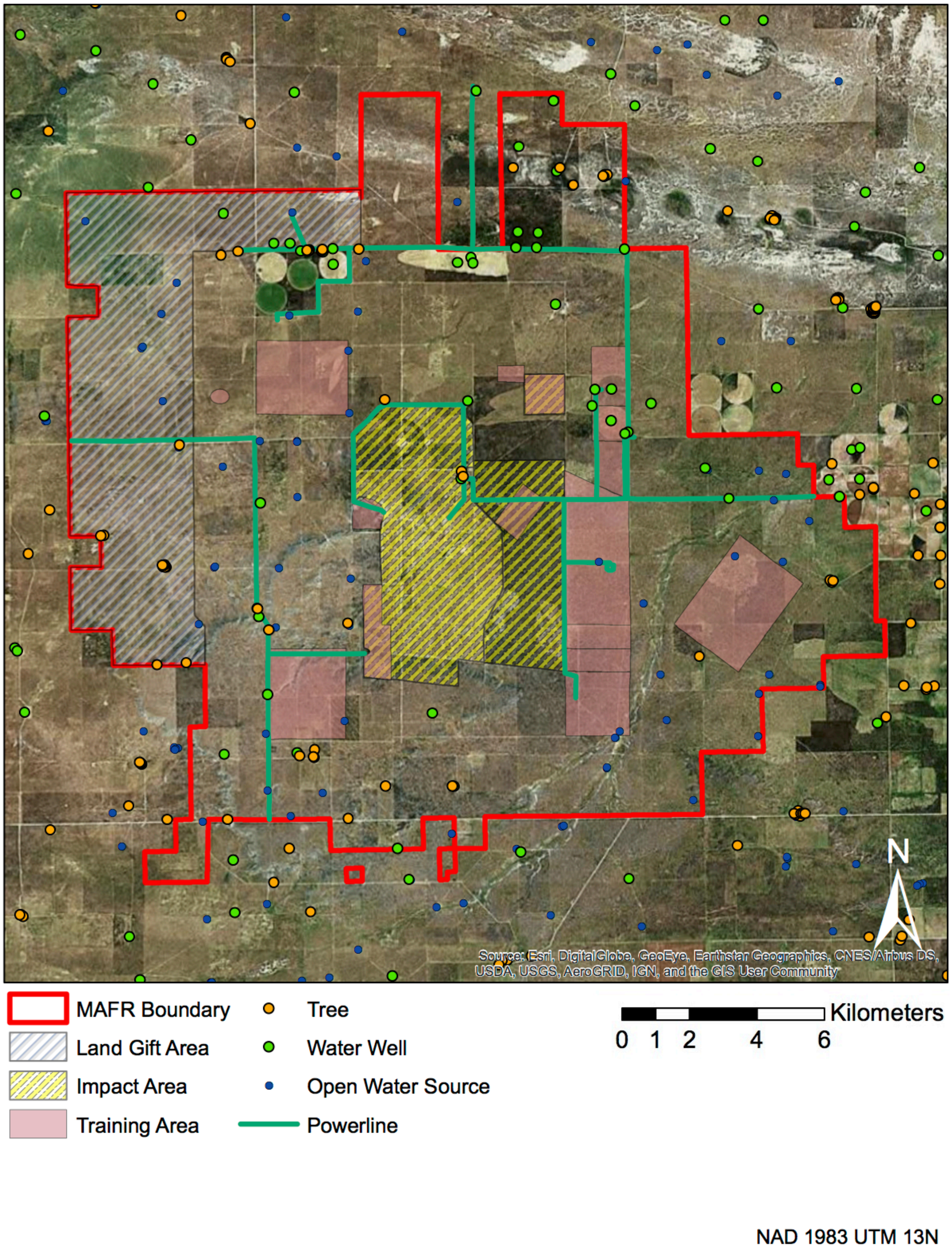

Figure 2.5: Location of anthropogenic factors on Melrose Air Force Range, New Mexico.

relative to tho se facing towards and away from the sun. Rainfall totals for each survey month were obtained from PRISM data for the region (Northwest Alliance for Computational Science and Engineering 2017) and then overlaid on survey point coordinates and values extracted. To detect prescribed fire freqency, time since burn was calucalted using change detection in LANDSAT imagery beginning in January 2014 and terminating December 2016. Dates were collected in Julian dates and converted into "base day" in order to calculate time since last burn. If a instance of burning was detected within 500 m of a survey point, the date of survey was converted into base days and subtracted from the LANDSAT-derived burn date. Avian survey data was tabulated by survey location into presence/absence occurrence of each avian species across all survey seasons, with a value of "0" indicating that a species did not occur at a survey point and a value of "1" indicating a particular species was observed at a point.

Analysis Methodology

All analyses were conducted in RStudio (RStudio Team 2015), using the BiodiversityR (Kindt and Coe 2005), RCmdr (Fox 2005), and Vegan (Oksanen et al. 2016) packages. Analysis began by delineating what variables were considered response and explanatory. Response variables were deemed to be the avian presence/absence matrices for each survey season, consisting of the name of the survey point and presence/absence (1/0 respectively) indications of avian species observed during each survey season. Explanatory variables were deemed to be location-dependent, physical, and chemical characteristics of the environment at a specific survey point (termed explanatory matrix). Variables tested in the explanatory matrix included: sand, silt, and clay percent; available water capacity (mm/mm); percent organic matter; pH; salinity (mS); slope percent; elevation (m); aspect; precipitation (mm); insolation (Wh/m^2); number of days since an instance of prescribed fire occurred within 500 m of the survey point; the presence of power lines, trees, water wells, or open water sources (i.e. man-made or earthen tanks with no well apparent) within 500 m of the survey point (Fig. 2.5). Explanatory variables were then subjected to linear regressions to assess any relationship between explanatory variables that were present regardless of the incidence of response variables. Next, all explanatory variables were transformed by z-score in order to standardize unit dimensions and measurement scales. Afterwards, a canonical analysis of principal coordinates (CAP) discriminant analysis was conducted comparing variation across seasons, years, and vegetative class following the guidelines in Anderson and Willis (2003). Finally, a redundancy analysis (RDA) was conducted for each survey season using the soil matrix as explanatory variables for avian presence/absence (the response matrix). Methodology for the RDA followed the protocol described in Oksanen et al. (2016), and Legendre et al. (2011) was consulted for output definition. Each RDA was the subject to a global and per-axis permutation test using 10,000 repetitions in each test. Euclidean distances were preserved due to the fact the response matrix was analyzed in presence/absence format, and as an inherent function of the nature of the RDA test (Anderson and Willis 2003, Legendre et al. 2011). From this analysis, distance triplots determining site/variable and species/variable ordination and correlation triplots depicting site/variable and species/variable relationship were generated. Additionally, survey points were projected using their generalized vegetative class to determine the homogeneity and inclusiveness of points within each vegetative class. Next, each survey season was subjected to additional redundancy analyses, first removing those species only occurring once per survey season, secondly comparing only spatially congruent survey points (i.e. points surveyed in all 3 seasons of 1 year or across both seasons of separate years), and finally combining both components. Final analysis was based on RDA tests with rare species removed that only compared spatially congruent points, as this provided a more accurate comparison of avian species utilizing the shortgrass prairie ecosystem without the bias of transient species among spatially consonant points surveyed in all attempts.

CHAPTER III

RESULTS

SURVEY SEASONS

The Spring 2015 survey season began on 4 May and ended on 18 May. Forty-five points were surveyed across 9 routes, for a total of 29 species identified and 20 species detected after rare incidences were removed (rare meaning a species was recorded only once during the survey season). Summer 2015 surveys began on 1 June and ended 15 June, with a total of 43 points surveyed across 10 routes. A total of 28 species was detected, and 21 species were retained after accounting for rare species. Fall 2015 surveys were conducted from 12 October until 19 November, resulting in 46 points surveyed across 10 routes. Twenty-nine species were detected total during this season, which was reduced to 22 species after accounting for rare species (see Table 3.1). A total of 51 avian species was detected in all survey seasons combined, which fell to 39 species after accounting for rare instances. A total of 78 points spanning 10 routes was surveyed across all surveys depending on access restrictions and weather limitations, only 14 of which were surveyed in all 3 seasons.

The Spring 2016 survey season began on 19 April and ended on 31 May. Ninety-six points were surveyed across 14 routes, for a total of 39 species identified and 27 species detected after rare incidences were removed. Summer 2016 surveys began on 13 June and ended 5 July, with a total of 147 points surveyed across 14 routes. A total of 23 species was detected, and 18 species were retained after accounting for rare species. Fall 2016 surveys occurred from 27 September until 4 November, resulting in 98 points surveyed across 14 routes. Thirty-nine species were detected total during this season, which was reduced to 27 species after accounting for rare species (see Table 3.1). A total of 66 avian species was detected in all survey seasons combined, which fell to 52 species after accounting for rare instances. A total of 164 points spanning 14 routes was surveyed across all surveys depending on access restrictions and weather limitations, 86 of which were surveyed in all 3 seasons.

Survey season	Survey dates	# Routes	# Points	# Species	# Species w/o rare
Spring 2015	4 May-18 May, 2015	9	45	29	20
Summer 2015	1 Jun-15 Jun, 2015	10	43	28	21
Fall 2015	12 Oct-19 Nov, 2015	10	46	29	22
Spring 2016	19 Apr-31 May, 2016	14	96	39	27
Summer 2016	13 Jun-5 Jul, 2016	14	147	23	18
Fall 2016	27 Sept-4 Nov, 2016	14	98	39	27

Table 3.1: Survey seasons on Melrose Air Force Range, New Mexico.

SOIL CHARACTERISTICS

Range-wide, the most common soil type found at survey locations was Elida Fine Sand. The average slope across all survey points was 2.5%. The mean elevation across all survey points was 1,321.7 m, with the lowest point being 1,268.1 m and the highest being 1,428.3 m. Average soil particle composition of the survey points was deemed to be 68.0% sand, 19.6% silt, and 13.7% clay, with actual percentages varying depending on specific location. The average water capacity of the soil across all survey points was 0.11 mm/mm, and average organic matter was determined to be 1.11%. The average soil pH across all survey points was 7.78, with a mean salinity of 0.72 mS. Finally, the average adjusted aspect was found to be 76.46°, indicating the landscape of MAFR typically receives moderate amounts of insolation. See Table 3.2 for a complete summary of soil characteristics on MAFR. After conducting regressions on each variable within the soil matrix, I found strong linear correlations between: sand and silt (R^2 = 0.96), sand and clay (R^2 = 0.92), clay and available water capacity (R^2 = 0.81), silt and clay (R^2=0.79), and sand and available water capacity (R^2 = 0.75). These correlations are expected, as sand, silt, and clay composition values are correlated with one another in any soil type, and soil water capacity varies depending on the porosity and permeability of soil components (Fig. 3.1).

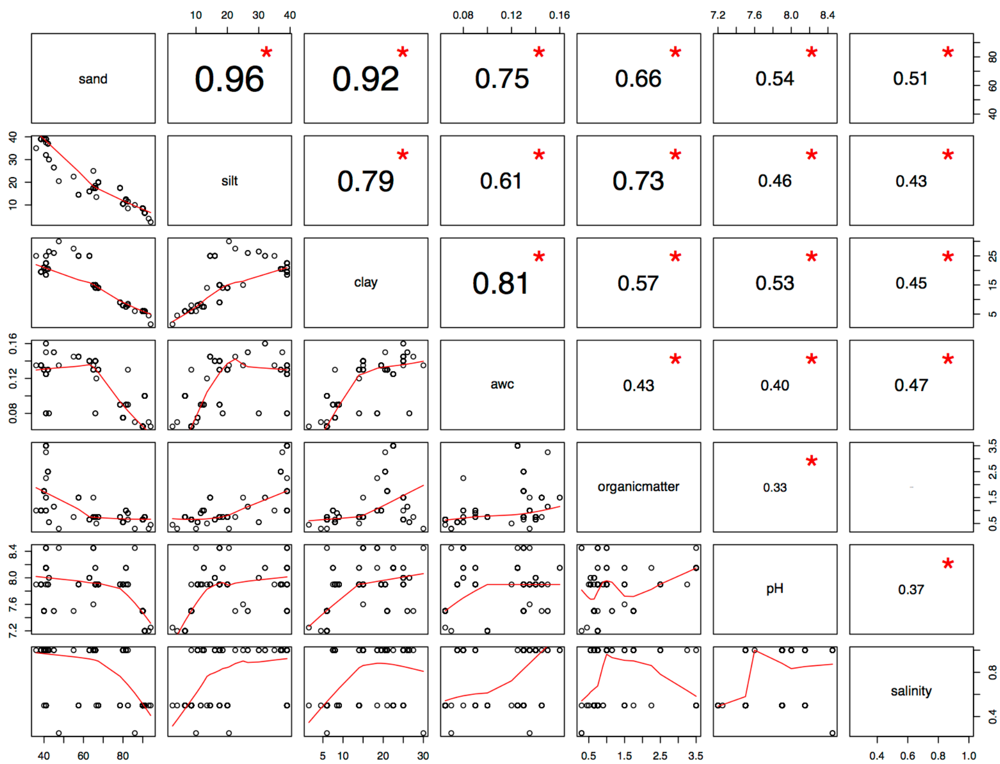

Figure 3.1: Observed correlation between variables on Melrose Air Force Range, New Mexico.

Vegetative subset	Soil [a]	Slope [b]	Elevation	Sand	Silt	Clay	AWC [c]	Org. Mat.	pH	Salinity [d]	Aspect [e]
Range-wide	Elida Fine S.	2.52	1,321.65	68.03	19.59	13.70	0.11	1.11	7.78	0.72	76.46
Sandsage-mesquite	Elida Fine S.	2.66	1,298.21	82.01	11.81	8.80	0.08	0.69	7.68	0.63	71.81
Mesquite-grassland	Amarillo Fine S.L.	2.26	1,327.10	58.36	23.46	17.74	0.13	1.19	7.88	0.85	84.95
Cholla-grassland	Chavaro L.	2.50	1,385.96	40.70	37.38	22.16	0.13	2.29	7.91	0.78	76.50

[a] Sand and loam are abbreviated by "S" and "L".
[b] Slope, Sand, Silt, Clay, and Org. Mat. (Organic Matter) are measured as a percentage.
[c] AWC is available water capacity of soil measured in mm/mm.
[d] Salinity is measured in millisiemens (mS).
[e] Aspect is adjusted to reflect solar insolation values as noted in Jenness (2007).

Table 3.2: Summary of dominant soil types on Melrose Air Force Range, New Mexico.

Sandsage Mesquite Grassland

The most frequent soil type within the sandsage mesquite grassland was Elida Fine Sand. This soil is characterized by moderately permeable soils that are very deep and well drained (Natural Resource Conservation Service 2010). Common plant association for this soil type are: little and sand bluestem (*Schizachyrium scoparium*, *Andropogon hallii*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), sand lovegrass (*Eragrostis trichodes*), fall witchgrass (*Digitaria cognate*), hairy grama (*Bouteloua hirsuta*), perennial threeawn (*Aristida purpurea*), and sand sagebrush (U.S. Department of Agriculture 2010). The mean slope of this vegetative subset was 2.7%. Elevation of these points averaged 1,298.2 m, with a low point of 1,268.1 m and a high point of 1,352.8 m. Average soil composition was determined to be: 82.0% sand, 11.8% silt, and 8.8% clay. The mean soil available water capacity was 0.08 mm/mm, with an average organic matter percentage of 0.69. Average pH of survey points within this subset was 7.68, with a mean salinity of 0.63 mS. Finally, the average adjusted aspect was 71.81°.

Mesquite Grassland

The most frequent soil type within the mesquite grassland subset was Amarillo Fine Sandy Loam, characterized by nearly level ground with moderately permeable soils that are very deep and well drained (Natural Resource Conservation Service 2010). Common vegetative associations are: blue grama, buffalograss, plains zinnia (*Zinnia grandiflora*), soapweed yucca, and sand sagebrush (U.S. Department of Agriculture 2010). The mean slope of this vegetative subset was 2.3%, with an average elevation of 1,327.1 m. Elevations ranged from a low of 1,286.4 m to a high of 1,411.0 m. At survey points across the mesquite grassland, the average soil composition was found to be: 58.4% sand, 23.5% silt, and 17.7% clay. The average water capacity of the soil at these points was

0.13 mm/mm, with an average organic matter composition of 1.2%. The mean pH of points within the mesquite grassland subset was 7.88, with an average salinity of 0.85 mS. Of the points within the mesquite grassland, the average adjusted aspect was found to be 84.95°.

Cholla Grassland

The most common soil type within the cholla grassland was Chavaro Loam, characterized by moderately permeable soils that are deep and well drained (Natural Resource Conservation Service 2010). This soil mostly supports rangeland species like tree cholla and grasses such as: blue grama, black grama (*Bouteloua eriopoda*), buffalograss, tobosa (*Pleuraphis mutica*), and silver bluestem (*Bothriochloa saccharoides*; U.S. Department of Agriculture 2010). Across points within this subset, the mean slope was 2.5%. The average elevation was 1,386.0 m, with a low point of 1,290.6 m and a high point of 1,428.3 m. Soil composition of survey points within this vegetative subset was determined to be: 40.7% sand, 37.4% silt, and 22.2% clay. Mean available water capacity of soils at these survey points was 0.13 mm/mm, with an average organic matter composition of 2.3%. Mean pH of the soil at these points was 7.91, with an average salinity of 0.78 mS. Finally, the average adjusted aspect of points within this vegetative subclass was 76.50°.

CAP DISCRIMINANT ANALYSIS RESULTS

Seasonal Variation

To delineate any separation between survey seasons, a CAP discriminant analysis (Anderson and Willis 2003) of 12 common points (12 from each of the 3 seasons in both years; $n = 72$) resulted in an overall classification success of 68.1% (m = 11; Fig. 3.2). Fall had the highest classification success at 95.8%, followed by summer at a success rate of 62.5%, and lastly by spring with 45.8% success. The canonical test statistic indicated there was a significant difference between the mean of at least one of the vector variables compared across seasons ($P \leq 0.001$; Table 3.3).

Test	n	m	Class. Success	Pr(>)F	Spring	Summer	Fall
Seasonal	72	11	68.06	5.2e-9	45.83	62.50	95.83

Table 3.3: Summary of CAP discriminant analysis comparing survey seasons.

Differences Between Vegetative Subsets

In order to determine if visually delineated vegetative subsets seen on MAFR influence the presence of avian species, a CAP discriminant analysis was performed using spatially congruent points from all 6 survey seasons of both years (30 from sandsage-mesquite, 30 from mesquite grassland, and 12 from cholla grassland; n = 72). A CAP discriminant analysis using commonly surveyed points from each vegetative subset resulted in an overall classification success of 63.9% (m = 11; Fig. 3.3). Cholla grassland had the highest classification success at 75.0%, followed by sandsage-mesquite at a success rate of 70.0%, and lastly by mesquite-grassland at 53.3%. The canonical test statistic indicated there was a significant difference between the mean of at least one of the vector variables compared across vegetative subsets ($P \leq 0.001$; Table 3.4).

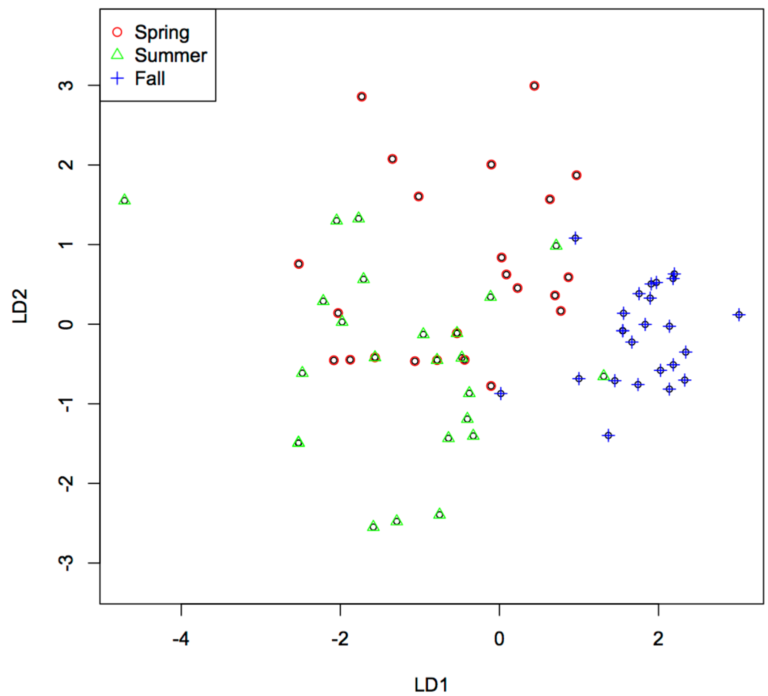

Figure 3.2: CAP discriminant analysis plot exhibiting the variation in survey points grouped by season.

Test	*n*	m	Class. Success	Pr(>)F	CG	MG	SM
Veg. Subset	72	11	63.89	0.00000163	75	53.33	70

Table 3.4: Summary of CAP discriminant analysis comparing vegetative subsets.

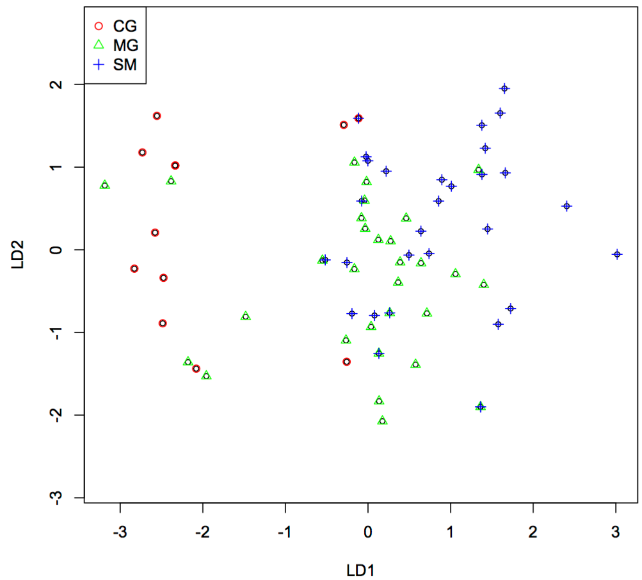

Figure 3.3: CAP discriminant analysis plot exhibiting the variation in survey points grouped by vegetative subset.

Annual Variation

In order to delineate differences between survey years, A CAP discriminant analysis using commonly surveyed points from each survey year (36 points per year; *n* = 72) resulted in an overall classification success of 59.7% (m = 13; Fig. 3.4). Survey year 2015 and 2016 had successful classification percentages of 61.1% and 58.3%, respectively. The canonical test statistic indicated there was a significant difference between the mean of at least one of the vector variables compared across years (*P* = 0.048; Table 3.5).

Test	*n*	m	Class. success	Pr(>)F	2015	2016
Across Years	72	13	59.72	0.04883	61.11	58.33

Table 3.5: Summary of CAP discriminant analysis comparing survey years.

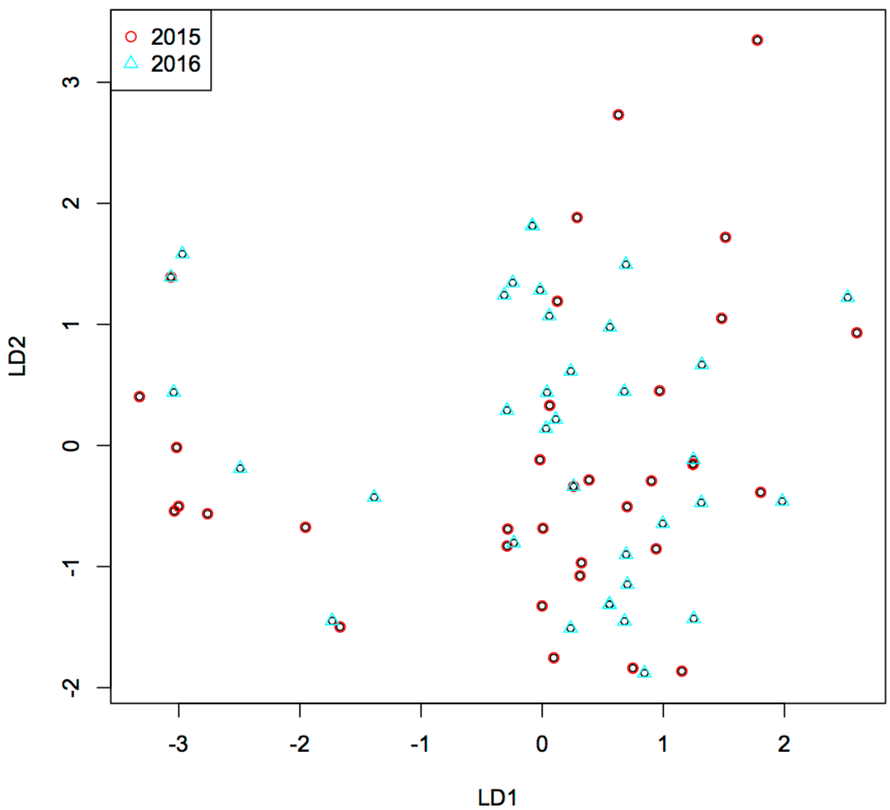

Figure 3.4: CAP discriminant analysis plot exhibiting the variation in survey points grouped by survey year.

RDA RESULTS

Environmental Variables

For this analysis, RDAs were conducted that compared each survey year individually, across both years, and across survey seasons to determine if influential factors varied across seasons or years. Response matrices were the presence/absence data for each respective test, with the explanatory matrix consisting of the following variables: silt, clay, and sand percent; elevation; organic matter percent; available water capacity;

slope; salinity; insolation; aspect; precipitation; pH; time since burn; power lines; trees; wells; open water sources. Table 3.6 summarizes all tests conducted using environmental variables, and Appendix A contains triplots for each test.

Comparison of Avian Presence Among Seasons in 2015- RDA analysis of 14 common points ($n = 42$) indicated that environmental variables explained 48.7% of the variation ($\delta 1 = 27.8\%$, $\delta 2 = 17.0\%$) in avian species occurrence among seasons within 2015 ($P \leq 0.001$), with differences defined by a negative relationship between temperature and permanent water sources (axis 1) and a positive correlation of elevation, silt, and organic matter to a negative correlation of sand (axis 2).

Comparison of Avian Presence Among Seasons in 2016- RDA analysis of 86 common points ($n = 258$) indicated that environmental variables explained 15.9% of the variation ($\delta 1 = 51.0\%$, $\delta 2 = 21.1\%$) in avian species occurrence among seasons within 2016 ($P \leq 0.001$), with differences defined by a positive correlation of precipitation (axis 1) and a positive correlation of sand to a negative correlation of silt, clay, organic matter, and available water capacity (axis 2).

Across Years- In order to determine what factors influenced avian presence over both years, a RDA was conducted that compared spatially congruent sites surveyed in all seasons between both 2015 and 2016. Analysis of 36 common points ($n = 72$) indicated that environmental variables explained 28.6% of the variation ($\delta 1 = 24.0\%$, $\delta 2 = 16.3\%$) in avian species occurrence between 2015 and 2016 ($P \leq 0.001$), with differences defined by a positive correlation of temperature (axis 1) and a positive correlation of precipitation (axis 2).

Spring Variation- RDA analysis of 38 common points ($n = 76$) indicated that environmental variables explained 32.7% of the variation ($\delta 1 = 27.3\%$, $P \leq 0.001$; $\delta 2 = 14.5\%$, $P = 0.145$) in avian species occurrence among spring seasons ($P \leq 0.001$), with differences defined by a positive correlation of trees and wells to a negative correlation of elevation (axis 1) and a negative correlation of soil available water capacity (axis 2).

Summer Variation- RDA analysis of 40 common points (n = 80) indicated that environmental variables explained 29.1% of the variation ($\delta 1$ = 18.8%, $\delta 2$ = 16.2%) in avian species occurrence among summer seasons ($P \leq 0.001$), with differences defined by a positive correlation of trees and open water sources (axis 1) and a positive correlation of wells and power lines (axis 2).

Fall Variation- RDA analysis of 43 common points (n = 86) indicated that environmental variables explained 27.9% of the variation ($\delta 1$ = 22.4%, $\delta 2$ = 17.1%) in avian species occurrence among fall seasons ($P \leq 0.001$), with differences defined by a positive correlation of the presence of trees (axis 1) to a negative correlation of slope and elevation (axis 2).

Test	n	Con. Var. [a]	Pr(>)F	Axis 1 [b]	Pr(>)F	Axis 2 [b]	Pr(>)F
2015	42	48.69	0.00009	27.81	0.0002	16.99	0.0047
2016	258	15.93	0.00009	50.95	0.00009	21.07	0.00009
Across Years	72	28.62	0.00009	24.01	0.00009	16.25	0.00009
Spring	76	32.71	0.00009	27.29	0.00009	14.52	0.1452
Summer	80	29.09	0.00009	18.79	0.00009	16.19	0.00009
Fall	86	27.93	0.00009	22.40	0.00009	17.05	0.0009

[a]Con. Var. is the constrained variance explained by the explanatory matrix measured in percent.
[b]Axis 1 and 2 are a measure of the percent of constrained variance explained by each RDA axis.

Table 3.6: Summary of RDAs testing all environmental variables.

RDA Separated by Variable Type

For the first test, there were 17 environmental variables measured and tested in each RDA. A crucial requirement of RDA is the number of explanatory variables does not exceed the number of samples (m < n) (Legendre et al. 2011), and testing a high number of explanatory variables at one time that potentially exhibit colinearity can reduce or otherwise muddy the proportion of constrained variance (Legendre et al. 2011). Given the nature of the collected environmental factors, a clear separation in variable type was distinguished between soil characteristics and location attributes. Soil characteristics were determined to be: sand, silt, and clay percentages; available water capacity; organic matter; pH; salinity. Location attributes were identified as: slope; elevation; aspect; trees; wells; open water sources; precipitation; insolation. My goal for this analysis was to determine if soil or location attributes of the sampled survey locations provided more influence on the proportion of constrained variation. Table 3.7 summarizes each RDA conducted, broken down by soil and location (loc) characteristics, and Appendix A contains triplots for each test.

Comparison of Avian Presence Among Seasons in 2015- RDA analysis of 14 common points ($n = 42$) indicated that soil variables explained 26.5% of the variation ($\delta 1 = 40.9\%$, $\delta 2 = 27.3\%$) in avian species occurrence among seasons within 2015 ($P \leq 0.001$), with differences defined by a positive correlation of available water capacity (axis 1) and positive correlations of silt and organic matter to a negative correlation of sand (axis 2). Location variables explained 34.72% of variation ($\delta 1 = 36.4\%$, $\delta 2 = 20.2\%$) in avian species occurrence among seasons within 2015 ($P \leq 0.001$), with differences defined by a negative correlation of temperature (axis 1) to a negative correlation of elevation (axis 2).

Comparison of Avian Presence Among Seasons in 2016- RDA analysis of 86 common points ($n = 258$) indicated that soil variables explained 3.6% of the variation ($\delta 1 = 33.1\%$, $P = 0.007$; $\delta 2 = 17.4\%$, $P = 0.001$) in avian species occurrence among seasons within 2016 $P \leq 0.001$), with differences defined by a positive correlation of sand to a negative correlation of silt, clay, organic matter, and available water capacity (axis 1) and a

Test	n	Con. Var. [a]	Pr(>)F	Axis 1 [b]	Pr(>)F	Axis 2 [b]	Pr(>)F
2015 soil	42	26.47	0.00009	40.88	0.0012	27.32	0.00009
2015 loc	42	34.72	0.00009	36.36	0.00009	20.15	0.00009
2016 soil	258	3.59	0.0014	33.06	0.00009	17.42	0.0077
2016 loc	258	9.05	0.00009	34.38	0.00009	25.16	0.00009
Across Years soil	72	14.92	0.00009	37.91	0.0003	22.77	0.00009
Across Years loc	72	16.04	0.00009	33.50	0.0003	24.14	0.00009
Spring soil	76	14.59	0.0002	37.23	0.00009	22.42	0.0004
Spring loc	76	23.22	0.00009	33.12	0.00009	17.77	0.00009
Summer soil	80	10.62	0.0659	36.08	0.0005	18.57	0.0594
Summer loc	80	19.98	0.00009	26.17	0.00009	20.44	0.00009
Fall soil	86	10.96	0.0144	34.99	0.0004	22.10	0.0029
Fall loc	86	19.57	0.00009	28.90	0.00009	21.06	0.00009

[a] Con. Var. is the constrained variance explained by the explanatory matrix measured in percent.
[b] Axis 1 and 2 are a measure of the percent of constrained variance explained by each RDA axis.

Table 3.7: Summary of RDAs separating soil variables from location (loc) variables.

negative correlation of pH (axis 2). Location variables explained 9.1% of variation ($\delta 1$ = 34.4%, $\delta 2$ = 25.2%) in avian species occurrence among seasons within 2015 ($P \leq 0.001$), with differences defined by a negative correlation of precipitation (axis 1) to a positive correlation of the presence of trees (axis 2).

Across Years- RDA analysis of 12 common points (12 points in each of the 6 survey seasons; $n = 72$) indicated that soil variables explained 15.0% of the variation ($\delta 1$ = 37.9%, $\delta 2$ = 22.8%) in avian species occurrence across 2015 and 2016 ($P \leq 0.001$), with differences defined by a positive correlation of available water capacity and a positive correlation of silt and clay (axis 1) and inverse relations of sand and organic matter to silt (axis 2). Location variables explained 16.0% of variation ($\delta 1$ = 33.5%, $\delta 2$ = 24.1%) in avian species occurrence across 2015 and 2016 ($P \leq 0.001$), with differences defined by a negative correlation of temperature (axis 1) to a positive correlation of precipitation (axis 2).

Spring Variation- RDA analysis of 38 common points (n = 76) indicated that soil variables explained 14.6% of the variation ($\delta 1$ = 37.2%, $\delta 2$ = 22.4%) in avian species occurrence across spring seasons ($P \leq 0.001$), with differences defined by a positive correlation of sand to a negative correlation of silt, clay, organic matter, and available water capacity (axis 1) and a negative correlation of salinity (axis 2). Location variables explained 23.2% of variation ($\delta 1$ = 33.1%, $\delta 2$ = 17.8%) in avian species occurrence across spring seasons ($P \leq 0.001$), with differences defined by inverse correlations of elevation to the presence of wells and trees (axis 1) to opposing relationships of aspect to power lines (axis 2).

Summer Variation- RDA analysis of 40 common points (n = 80) indicated that soil variables explained 10.6% of the variation ($\delta 1$ = 36.1%, $P \leq 0.001$; $\delta 2$ = 18.6%, P = 0.059) in avian species occurrence across summer seasons (P = 0.066), with differences defined by inverse correlations of silt and organic matter to sand (axis 1) and a negative correlation of organic matter (axis 2). Location variables explained 20.0% of variation ($\delta 1$ = 26.2%, $\delta 2$ = 20.4%) in avian species occurrence across summer seasons ($P \leq$ 0.001), with differences defined by a positive correlation of trees and open water sources (axis 1) to a positive correlation of the presence of wells and power lines (axis 2).

Fall Variation- RDA analysis of 43 common points (n = 86) indicated that soil variables explained 11.0% of the variation ($\delta 1$ = 35.0%, $P \leq 0.001$; $\delta 2$ = 22.1%, $P \leq 0.003$) in avian species occurrence across fall seasons (P = 0.014), with differences defined by a negative correlation of temperature (axis 1) and a positive correlation of pH (axis 2). Location variables explained 19.6% of variation ($\delta 1$ = 28.9%, $\delta 2$ = 21.1%) in avian species occurrence across 2015 and 2016 ($P \leq 0.001$), with differences defined by a positive correlation of the presence of trees (axis 1) to a positive correlation of slope and elevation (axis 2).

Anthropogenic Influences

While analyzing soil and location variables provide an adequate overview of all influences present on a natural shortgrass prairie rangeland, this is not how MAFR should be classified. As MAFR is a highly disturbed military training facility, there are obvious anthropogenic influences that must be taken into consideration separately from variables that can be deemed strictly environmental (slope, elevation, sand, silt, clay, available water capacity, organic matter, pH, salinity, aspect, precipitation, and insolation). Anthropogenic influences that were taken into consideration were: power lines, trees, wells, open water sources, and proximity to training and impact areas. Table 3.8 summarizes the conducted RDA tests comparing environmental (env) and anthropogenic (anthro) variables, and Appendix A contains triplots for all tests.

Comparison of Avian Presence Among Seasons in 2015- RDA analysis of 14 common points (n = 42) indicated that environmental variables explained 41.6% of the variation ($\delta 1$ = 31.7%, $\delta 2$ = 18.8%) in avian species occurrence across seasons in 2015 ($P \leq$ 0.001), with differences defined by a negative correlation of temperature (axis 1) and inverse relations of elevation, silt, and organic matter to sand (axis 2). Anthropogenic variables explained 18.6% of variation ($\delta 1$ = 36.6%, $P \leq 0.001$; $\delta 2$ = 26.7%, $P \leq 0.007$) in avian species occurrence across 2015 and 2016 ($P \leq 0.001$), with differences defined by a negative correlation of training areas (axis 1) to a negative presence of wells (axis 2).

Comparison of Avian Presence Among Seasons in 2016- RDA analysis of 86 common points (n = 258) indicated that environmental variables explained 9.1% of the variation ($\delta 1$ = 34.6%, $\delta 2$ = 15.9%) in avian species occurrence among survey seasons in 2016 ($P \leq 0.001$), with differences defined by a positive correlation of precipitation (axis 1) and positive correlations of organic matter and clay to a negative correlation of sand (axis 2). Anthropogenic variables explained 4.7% of the variation ($\delta 1$ = 49.0%, $\delta 2$ = 16.9%) in

Test	n	Con. Var. [a]	Pr(>)F	Axis 1 [b]	Pr(>)F	Axis 2 [b]	Pr(>)F
2015env	42	41.55	0.00009	31.64	0.00009	18.77	0.00009
2015anthro	42	18.57	0.0007	36.60	0.00009	26.68	0.007
2016env	258	9.12	0.00009	34.56	0.00009	15.90	0.00009
2016anthro	258	4.69	0.00009	49.03	0.00009	16.88	0.0003
Across Years env	72	26.99	0.00009	25.08	0.00009	17.23	0.00009
Across Years anthro	72	10.54	0.0003	34.16	0.00009	22.61	0.013
Spring env	76	24.22	0.00009	27.70	0.00009	14.73	0.00009
Spring anthro	76	15.66	0.00009	39.63	0.00009	19.42	0.0003
Summer env	80	19.80	0.0217	20.86	0.0004	19.31	0.00009
Summer anthro	80	13.20	0.00009	37.40	0.00009	19.17	0.0018
Fall env	86	21.15	0.00009	21.98	0.00009	20.11	0.00009
Fall anthro	86	12.23	0.00009	41.30	0.00009	21.40	0.0003

[a]Con. Var. is the constrained variance explained by the explanatory matrix measured in percent.
[b]Axis 1 and 2 are a measure of the percent of constrained variance explained by each RDA axis.

Table 3.8: Summary of RDAs separating environmental variables (env) from anthropogenic (anthro) variables.

avian species occurrence among survey season in 2016 ($P \leq 0.001$), with differences defined by a negative correlation of trees (axis 1) to a negative presence of power lines (axis 2).

Across Years- RDA analysis of 36 common points (n = 72) indicated that environmental variables explained 27.0% of the variation ($\delta 1$ = 25.1%, $\delta 2$ = 17.2%) in avian species occurrence across 2015 and 2016 ($P \leq 0.001$), with differences defined by a positive correlation of temperature (axis 1) and positive correlation of precipitation (axis 2). Anthropogenic variables explained 10.5% of the variation ($\delta 1$ = 34.2%, $\delta 2$ = 22.6%) in avian species occurrence across 2015 and 2016 ($P \leq 0.001$), with differences defined by a negative correlation of the presence of training areas (axis 1) to a positive presence of wells (axis 2).

Spring Variation- RDA analysis of 38 common points (n = 76) indicated that environmental variables explained 24.2% of the variation ($\delta 1$ = 27.8%, $\delta 2$ = 14.7%) in avian species occurrence across spring surveys ($P \leq 0.001$), with differences defined by a negative correlations of elevation, silt, clay, and organic matter to a positive correlation with sand (axis 1) and a negative correlation of salinity (axis 2). Anthropogenic variables explained 15.7% of the variation ($\delta 1$ = 39.6%, $\delta 2$ = 19.4%) in avian species occurrence across spring surveys ($P \leq 0.001$), with differences defined by a positive correlation of trees and wells (axis 1) to a positive presence of power lines (axis 2).

Summer Variation- RDA analysis of 40 common points (n = 80) indicated that environmental variables explained 19.8% of the variation ($\delta 1$ = 20.9%, $\delta 2$ = 19.3%) in avian species occurrence across summer surveys ($P \leq 0.001$), with differences defined by a positive correlation of slope, elevation, silt, and organic matter to a negative correlation of sand (axis 1) and a negative correlation with precipitation (axis 2). Anthropogenic variables explained 13.2% of the variation ($\delta 1$ = 37.4%, $P \leq 0.001$; $\delta 2$ = 19.2%,P = 0.002) in avian species occurrence across summer surveys ($P \leq 0.001$), with differences defined by a positive correlation of trees and open water sources (axis 1) to a positive presence of power lines and wells (axis 2).

Fall Variation- RDA analysis of 43 common points (n =86) indicated that environmental variables explained 21.2% of the variation ($\delta 1$ = 22.0%, $\delta 2$ = 20.1%) in avian species occurrence across fall surveys ($P \leq 0.001$), with differences defined by a positive correlation between slope and elevation (axis 1) and a positive correlation of organic matter (axis 2). Anthropogenic variables explained 12.2% of the variation ($\delta 1$ = 41.3%, $\delta 2$ = 21.4%) in avian species occurrence across fall surveys ($P \leq 0.001$), with differences defined by a positive correlation of trees (axis 1) to a negative presence of power lines (axis 2).

CHAPTER IV

DISCUSSION AND CONCLUSIONS

EXPLAINING OBSERVED VARIATION AND TRENDS

Annual Variation

I can determine the first null hypothesis of no differences in species present among survey locations between years, seasons, and vegetative classes is false; MAFR exhibited different environmental conditions between the 2015 and 2016 survey years. The test statistic for the CAP discriminant analysis comparing annual variation and classification success between years act to reinforce this, although visual inspection of the ordination plot provides no clear distinction. This can be interpreted as: although there is not *apparent* separation in data points, there is a statistically significant difference between them. Additionally, some factor allowed for 2015 data points to be correctly classified within its respective survey year with more accuracy than the 2016 points (success rates were 61.11% in 2015 versus 58.33% in 2016). What then, can explain this visually inconspicuous, but proven, difference between spatially congruent survey points between the 2 years? Based on the CAP analysis and deductive reasoning, one can conclude the answer lies in differences in weather events, namely precipitation totals and sunlight exposure. All soil and anthropogenic factors remained constant in both years (with the exception of burn frequency, which was found to provide minimal influence), with the only fluctuating variables being the location variables of precipitation and insolation. Total precipitation obtained during the surveyed seasons (from March to November) in 2015 was 409.0 mm versus 156.3 mm in 2016, indicating a drastic difference in rainfall between years. Monsoonal, year-round rains characterized 2015 whereas in 2016 rainfall followed normal precipitation trends for the region of highest rainfall in late summer and early fall. Additionally, with an increase in precipitation comes a decrease in sunlight intensity, which was reflected to an extent in my data. Average monthly insolation values during the surveyed seasons in 2015 and 2016 were 227,725.3 WH/m^2 and 229,087.4 WH/m^2, respectively, indicating that more solar radiation reached the Earth's surface on MAFR in 2016 which could have facilitated higher average temperatures.

Vegetative Subsets on MAFR

While vegetative associations within a single ecoregion are fairly homogenous, local aggregations can be highly variable depending on both climatic factors (Newell 1997) and anthropogenic influences. I found this notion to be true on MAFR as well, indicating again the first null hypothesis was rejected. Since the CAP discriminant analysis detected a significant difference between the variables when grouped by vegetative class, there is statistical proof of 3 distinct vegetative regions on MAFR that can be visually reinforced upon on-site inspection. This dissimilarity in vegetation growth can be biologically attributed to differences in soil composition. Diverse climatic situations regulate the development of soil types, which in turn determines how much water and nutrients a soil type is able to hold (Ricklefs 2010). These differences are what facilitate plant growth in particular soil types. On MAFR, the soil composition changes from sand-dominant in the northern region to silt and clay dominant in the southern expanses, which in turn dictates what plants will grow in the substrate. In simple terms, sandy and well-drained soils found in the northern portion facilitate woody species establishment, and soils high in silt and organic matter found in the southern portion facilitate grass growth. This notion can be traced back to the individualistic concept of plant succession pioneered by Gleason (1926), in which he states that plant growth will occur if the needs for an individual species are met, and that any observed species associations are due to the fact the spatially proximate species share similar needs or can utilize different resources available within the same location.

Seasonal Variation

I again found the first null hypothesis of no differences in species present among survey locations between years, seasons, and vegetative classes to be rejected. This finding seems redundant, as a pre-established notion of seasons is varying environmental conditions. However, I found the spring and summer seasons to exhibit similar environmental conditions, whereas fall was clearly differentiated. Percentages of classification success reinforce this, with fall having the highest success, followed by summer and spring. This separation can be explained in part by the timing of surveys across the range. In both survey years, spring surveys occurred from April to May and summer surveys happened in June and July. This timetable potentially sets up the issue of conducting a spring survey on 31 May and a summer survey on 1 June. While defined as different seasons for the purpose of this study (when in actuality summer does not officially begin until mid-June), avian species present on the landscape within this 48-hour period are likely to be extremely similar, as are environmental conditions. The opposite of this logic can explain why the fall season exhibited differentiation from the other seasons. The fall surveys occurred in October and November, many months from the occurrence of other surveys. Environmental characteristics such as temperature and precipitation in these months were drastically different than April to July, aiding in the explanation of the observed difference. Likewise, by this point in the year avian species have already completed their fall migrations, leaving only the few resident species that inhabit MAFR year-round. This phenomenon may be termed temporal stationarity (i.e. differences are proportional to distance in time within the cycle of seasons defined by a year).

Environmental Factors Influencing Avian Presence

Based on the fact that all but 2 RDAs resulted in a significant test statistic, I can determine the second null hypothesis that environmental factors do not influence avian presence is false. In fact, I am able to generally state that water availability (whether natural or anthropogenically retained) and soil composition explain 30–50% of the observed variation in avian species depending on season. This determination is sensible as availability of water and soil composition determine plant development, which is in turn selected on by avian species depending on individual need. The only 2 tests in which I am unable to explain at least 30% of the observed variation due to permutation tests that were found to be statistically insignificant were when analyzing all environmental variables across spring seasons and when testing soil variables across summer seasons. Unfortunately, this analysis is impeded by the bias of sample size, as the number of spatially congruent survey points fluctuated greatly between years and seasons. This becomes problematic due to the fact that as sample size gets closer in value to the number of explanatory variables, colinearity and over-fitting of the explanatory matrix cloud the response matrix (Legendre et al. 2011).

Variable Types Influencing Avian Presence

Given the sheer number of tested variables in this study, it is ridiculous to expect to *not* see a portion of the variance explained. After all, if you measure enough variables you'll eventually find something that is significant in explaining variation regardless of its relationship or validity. By breaking down the explanatory matrix into soil and location factors, I was able to determine if biological/chemical elements provided more influence on avian presence than landscape characteristics. Across all analyses, I found that location variables explained a higher percentage of observed variance than soil variables. Location factors explained 9.1–34.7% of the observed differences, whereas soil factors only explained 3.6–14.9%. This indicates that within a subsection of an ecoregion where climatic factors are similar, soil variation bears less influence on avian presence than does the presence of situational factors specific to a particular point on the land. Within location variables, I found that the presence of trees, temperature, and water availability were the main factors explaining differences in avian presence. In particular, the presence of wells was a main determinant of avian association. This is understandable, as water wells across MAFR provide an annual, reliable water source on an otherwise xeric landscape.

The Influence of Spatial Scales

It also is important to note the spatial scale used in this analysis, as the geographic extent of comparison bears great influence on the amount of variation that can be explained. My study occurred solely on a 28,723-ha parcel completely retained within the shortgrass prairie. At this extent (approximately 18 by 20 km), spatial variation will be minimal in the absence of an unique geologic formation. Had this study compared factors influencing avian presence in the shortgrass prairie to that of the Pineywoods of east Texas, obvious differences would be apparent (soil types, vegetative structure, precipitation, and temperature to name a few). Differences in detection across MAFR, however, relied on minute-scale, often times situational, disparity between survey points (think to the extent of did a survey point have soil that was a bit more sandy or receive a few more millimeters of precipitation). When reviewing the observed percentages of variance explained in my study using this ideology, obtaining any measure above twenty percent can indicate an actual observable difference. It is basically stating that while species X resides in the shortgrass prairie because it thrives in the environmental conditions experienced within said ecosystem, the locally-fluctuating variable Y can influence whether species X is seen in this specific part of the shortgrass prairie and at what frequency.

ANTHROPOGENIC FACTORS INFLUENCING AVIAN PRESENCE

In the age of man, commonly called the Anthropocene (Regan 2016), human influence is all around us. Anthropogenic influences range from the obvious such as habitat alteration to unintentional actions such as the introduction of exotics species. While urban influences have the potential to negatively impact natural systems (Melles et al. 2003), it also can be of benefit depending on intensity and scale of impact (Blair 1996). As many anthropogenic modifications also can serve to expand available niches within a particular habitat (as observed by Blair [1996] in which moderately urbanized sites exhibited higher rates of avian richness and evenness), it was only sensible to test anthropogenic influences on a highly disturbed site such as MAFR. I found that my last null hypothesis (anthropogenic factors wouldn't explain any variance) was false, however, anthropogenic factors explained less of the constrained variance than environmental factors did (4.7–18.6% versus 9.1–41.6%). This is surprising, as location attributes (which share the variables trees, wells, open water sources, and power lines with anthropogenic factors) explained more of the observed variance than did soil characteristics. Identifying the factors that were included within location factors and not in anthropogenic can resolve this discrepancy: precipitation and temperature. Essentially, while the presence of situational and/or anthropogenic factors can explain some variance in species presence (and potentially increase the number of species within an area; Blair 1996), rainfall and temperature explain the greatest variation. These 2 factors are in turn vital aspects of vegetation growth and structure, which directly influences bird survival and reproduction (Azpiroz and Blake 2016). Additionally, the direct influence of anthropogenic factors may not be as readily testable on MAFR, as majority of the landscape is already in an anthropogenically modified state (i.e. the presence of training infrastructure) and has been for an extended period of time.

Assessing the Advantage of Anthropogenic Action

The findings of this study would indicate that "natural" influences such as soil composition and rainfall determine avian species association. This would not be incorrect to say; however, another far-reaching aspect can overshadow and alter our perception of what is natural– humans. To call many expanses of wilderness "natural" in today's age is a misnomer. Almost all of the contiguous United States has received some form of anthropogenic land modification, whether in the form of Native American fire regimes on prairies, the establishment of fences, or even modern land preservation strategies (Regan 2016). Regan (2016) notes that even one of the most seemingly untouched natural places, the Yosemite Valley, is actually the result of anthropogenic modification and cultural exaggeration.

Anthropogenic cultivation of "wilderness" has clearly occurred on MAFR. How else could a formerly homogenous parcel of the shortgrass prairie ecosystem be able to be so clearly broken down into distinctive vegetative types? While biological and chemical factors do have some bearing on this (plants will optimally grow in a specific type of soil containing the level of water retention and nutrients required by each species), anthropogenically-induced landscape modification and suppression of natural processes provides a much better explanation. MAFR has been influenced by humans for the better part of a century, from training maneuvers beginning in the 1930s, farming and ranching practices occurring from 1990 until 2015, landscape alteration as a result of range expansion, and most recently the designation of critical habitat for the previously threatened lesser prairie chicken (*Tympanuchus pallidicinctus*). This assemblage of varied land management practices necessitated by training requirements and federal mandate has created a hodgepodge of unnatural vegetative associations on MAFR, explained by several considerations. First, the simple presence of humans has facilitated the introduction of invasive and exotic species, which can drastically alter pre-established vegetative and animal associations. Secondly, the establishment of roads and fences has inhibited the natural dispersal of species and progression of organic processes. Third, the introduction of agricultural and ranching practices have altered soil compositions and created a near monocultural vegetation grouping due to frequent crop turnover and selective foraging. Fourth, the former practice of fire suppression has resulted in litter accumulation and altered vegetation succession phases, allowing for plant growth to continue unregulated. Lastly, the current practice of frequent rotational prescribed burning on MAFR has combated the litter accumulation conundrum only to potentially facilitate the establishment of an early successional stage vegetative monoculture (vegetation diversity can either increase or decrease depending on the intensity, frequency, and spatial scale of burning [Van der Maarel 1993], an anthropogenically determined factor when using prescribed burns). Now that MAFR has been relabeled as an anthropogenically modified shortgrass prairie, what does this mean? Will avian species stop utilizing this particular landscape because it isn't "natural"? Of course not; bird species typically associated with the shortgrass prairie such as Cassin's sparrow (*Peucaea cassinii*), western burrowing owl (*Athene cunicularia hypugaea*), loggerhead shrike (*Lanius ludovicianus*), Swainson's hawk (*Buteo swainsoni*), lark bunting (*Calamospiza melanocorys*), scaled quail (*Callipepla squamata*), and western meadowlark (*Sturnella neglecta*) will still utilize areas exhibiting the environmental characteristics associated with the shortgrass prairie (grassy, woody-limited expanses that have low precipitation levels and diurnal temperature variation; Gillihan and Hutchings 2000, U.S. Environmental Protection Agency 2016), given that available resources promote individual species viability and reproduction. Furthermore, this new human-influenced shortgrass prairie could actually have the potential to provide year-round support for species that do not normally reside within or are only migrants through this ecosystem. Trees (which are more often than not planted by humans in the prairie), power lines, and windmills facilitate nesting and perching sites usable by species such as hawks, eagles, and transient songbirds. Annual water sources such as wells and tanks eliminate the requirement of finding water, additionally facilitating the residency of birds that would otherwise migrate from the area (proven on MAFR by the multi-season residency of the Red-winged Blackbird and Bullock's Oriole). This introduction of new habitat components could increase the number of available niches, and in turn increase species diversity on MAFR. The aforementioned idea aligns perfectly with intermediate disturbance hypothesis in that moderate levels of disturbance (in this case, anthopogenically-influenced changes in vegetative association and resource availability in the form of land use modification, fire, and infrastructure development) can actually promote diversity (Hutchinson 1953, Connell 1978, Townsend et al. 1997). Blair (1996) reinforces this notion with his finding that avian diversity is highest in residential developments and golf courses, which could (with some obvious differences) mirror the modification seen on MAFR. Melrose Air Force Range, residential developments, and golf courses all exhibit the introduction of additional perches and nesting sites, annual water sources, and modified vegetative structure as a result of human land alteration. Thus, it is not a far-fetched thought to contemplate that anthropogenic influences can actually benefit what was formally considered a natural ecosystem.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

In conclusion, I have determined that avian presence on MAFR is influenced biologically by soil composition, precipitation, and temperature. These factors dictate what plant species will grow in a specific location, and it is this existence of preferred vegetation that determines if a bird species will inhabit that area. The presence of physically apparent anthropogenic factors on MAFR (wells, tanks, and trees specifically) also have been proven to explain a portion of the variation in bird assemblage, however, the extent of actual land modification induced by anthropogenic forces cannot be determined and could actually explain even more of the variance than realized in this study. On this particular landscape, I have reasonably concluded the current level of anthropogenic influence has served to aid avian diversity, however, this can be quickly reversed given increased (in intensity and frequency) manipulation. If restraint is not employed, land managers on Melrose Air Force Range could potentially, though unintentionally, create a homogenous vegetation assemblage low in avian diversity. This situation, while advantageous for immediate completion the military mission of preparedness, will ultimately result in training impediments facilitated by federal ecological compliance mandates.

Melrose Air Force Range is a unique subset of the shortgrass prairie that exhibits drastically different vegetative compositions within a confined area, solely due to human influence. It is due to this manipulation that the seemingly conflicting interests of military readiness and ecological diversity are able to delicately cohabitate. In today's age of extreme human impact on "natural" landscapes, we should shift our logic to understanding that anthropogenic intervention, when implemented thoughtfully and with restraint, can actually promote diversity and ensure species survival.

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APPENDIX A

REDUNDANCY ANALYSIS PLOTS

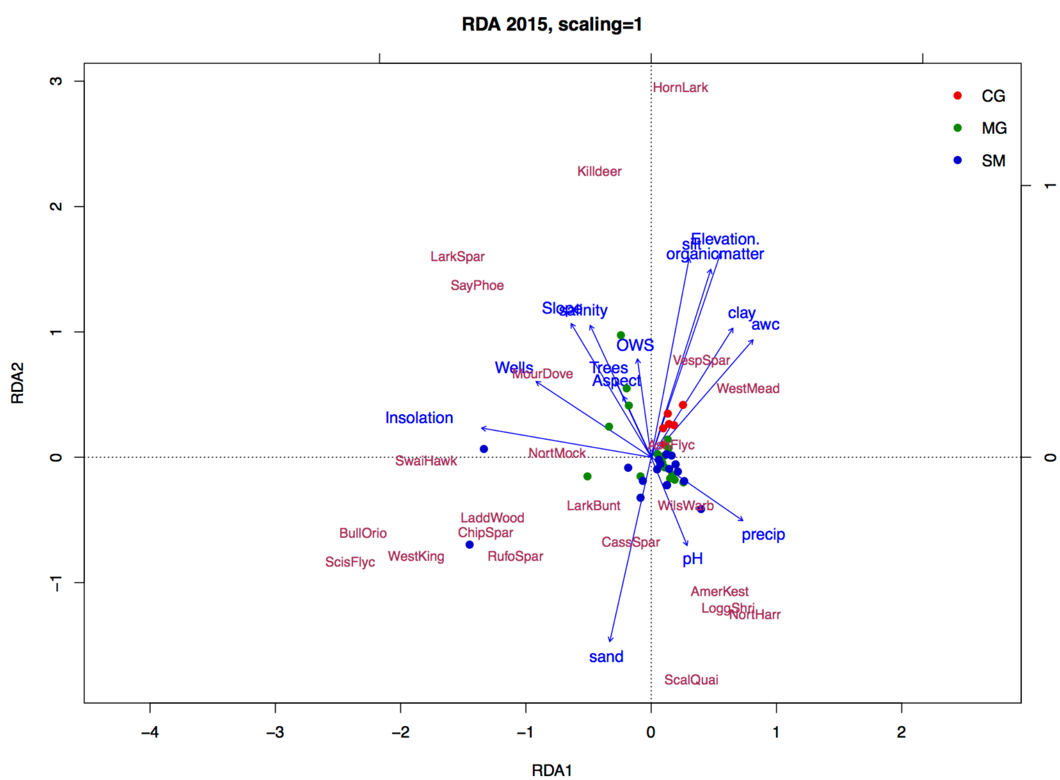

Figure A.1: RDA distance triplot comparing all environmental variables to 2015 avian presence.

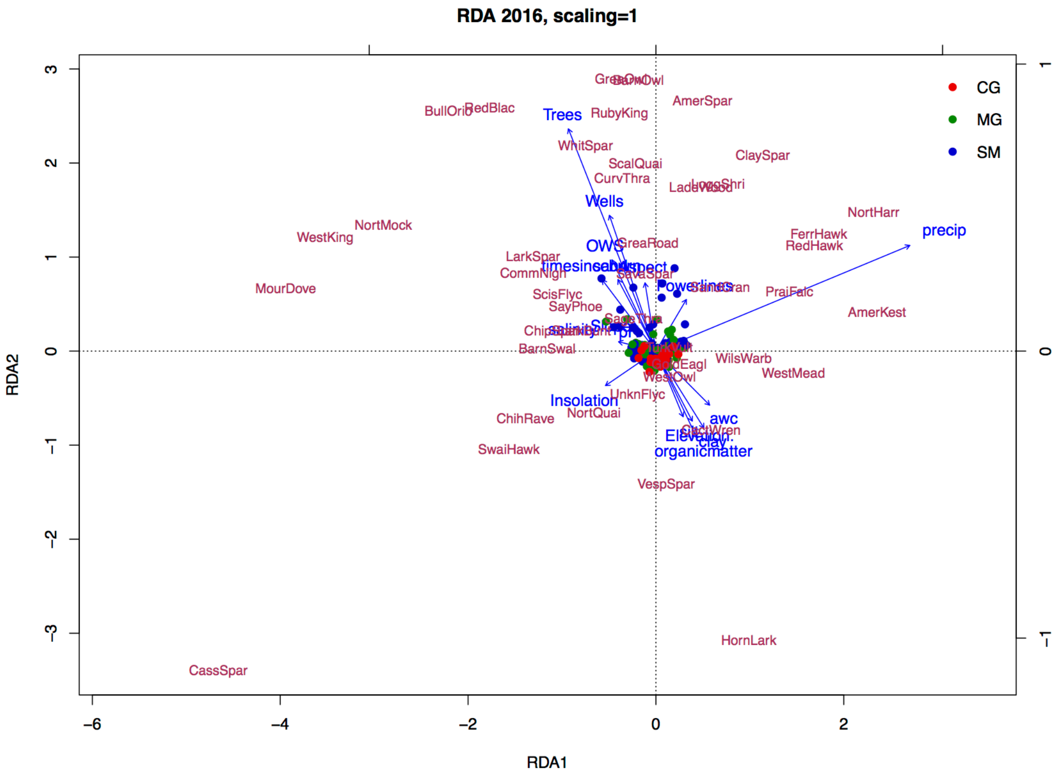

Figure A.2: RDA triplot comparing all environmental variables to 2016 avian presence.

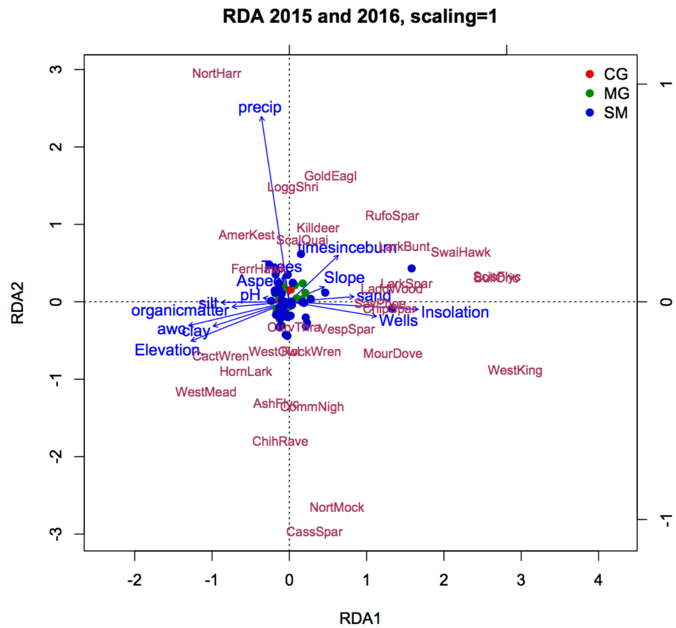

Figure A.3: RDA triplot comparing all environmental variables to 2015/2016 avian presence.

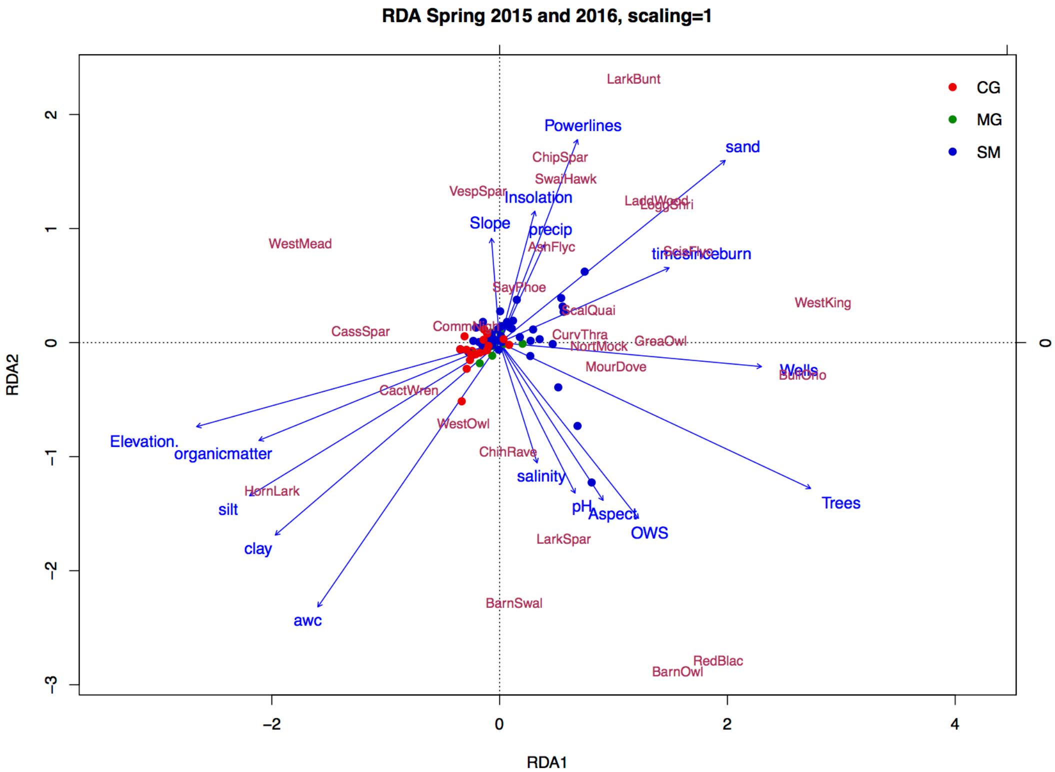

Figure A.4: RDA triplot comparing all environmental variables to spring 2015/2016 avian presence.

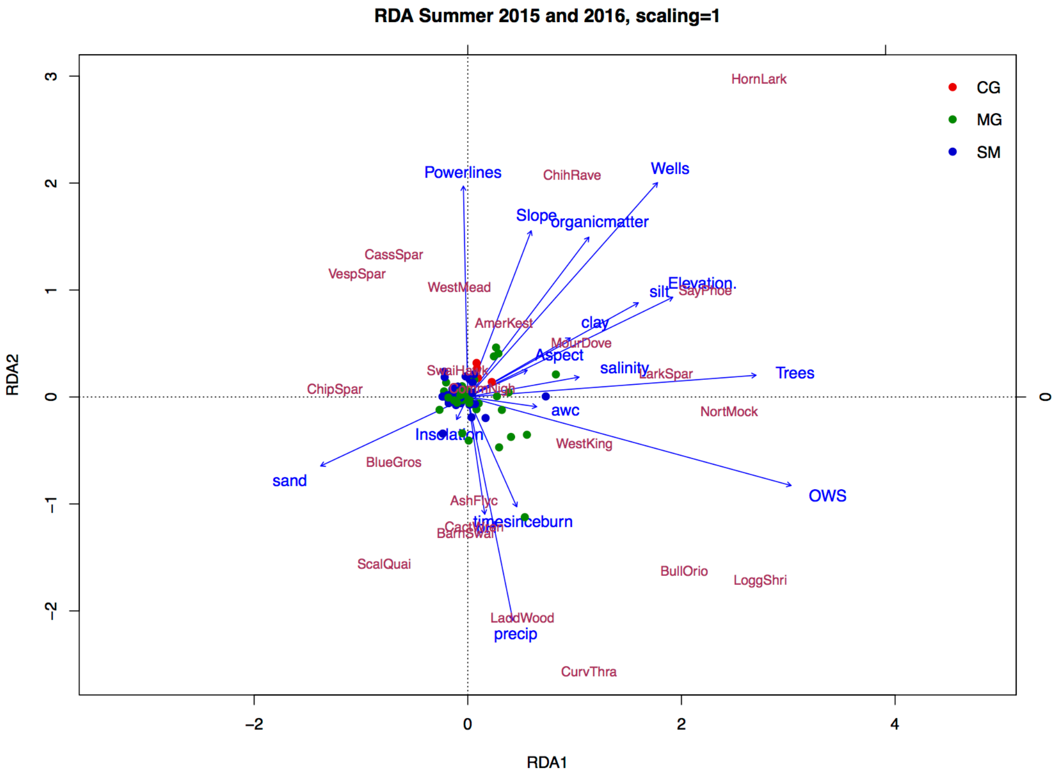

Figure A.5: RDA triplot comparing all environmental variables to summer 2015/2016 avian presence.

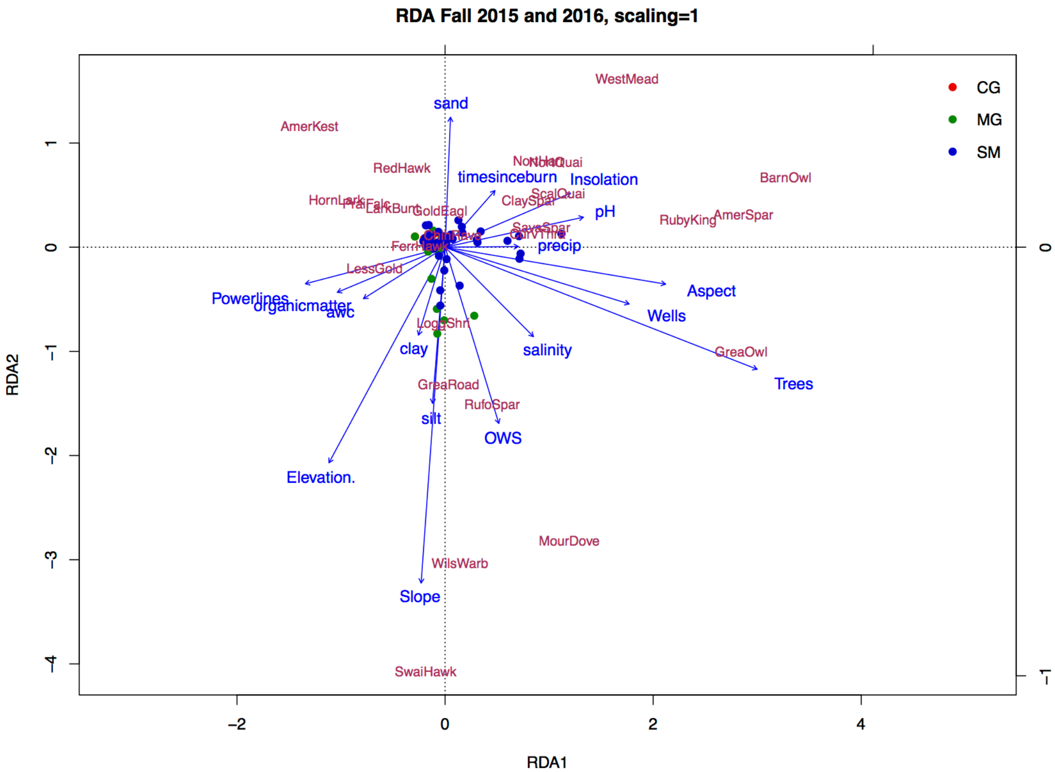

Figure A.6: RDA triplot comparing all environmental variables to fall 2015/2016 avian presence.

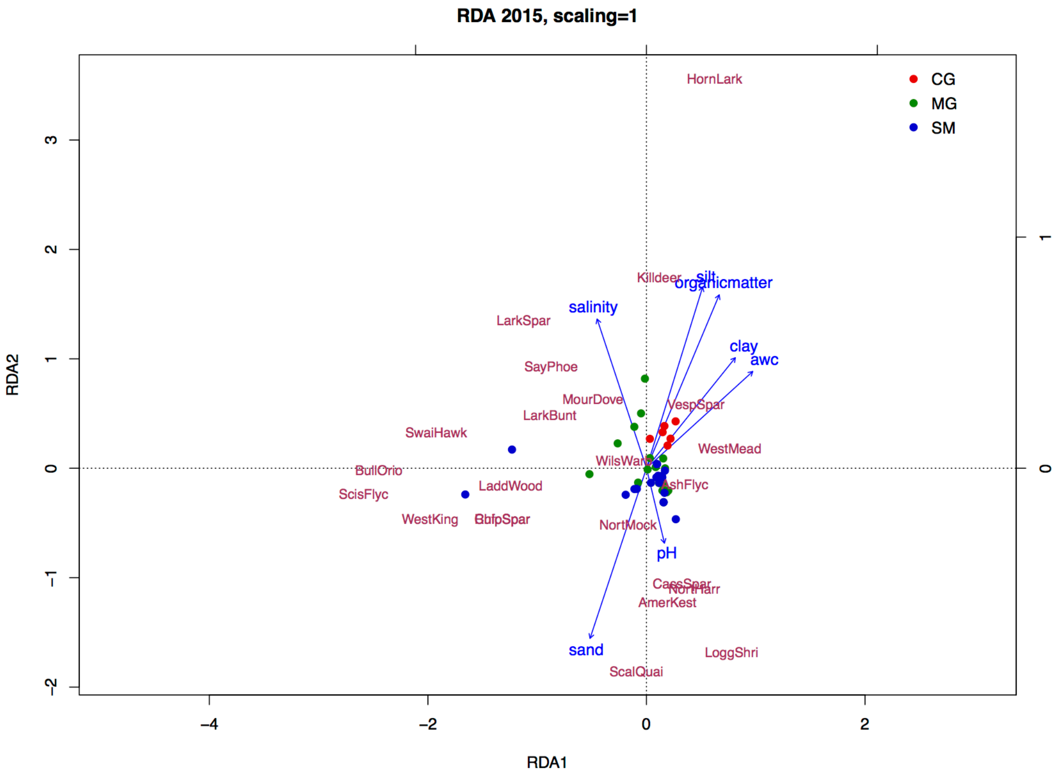

Figure A.7: RDA triplot comparing soil variables to 2015 avian presence.

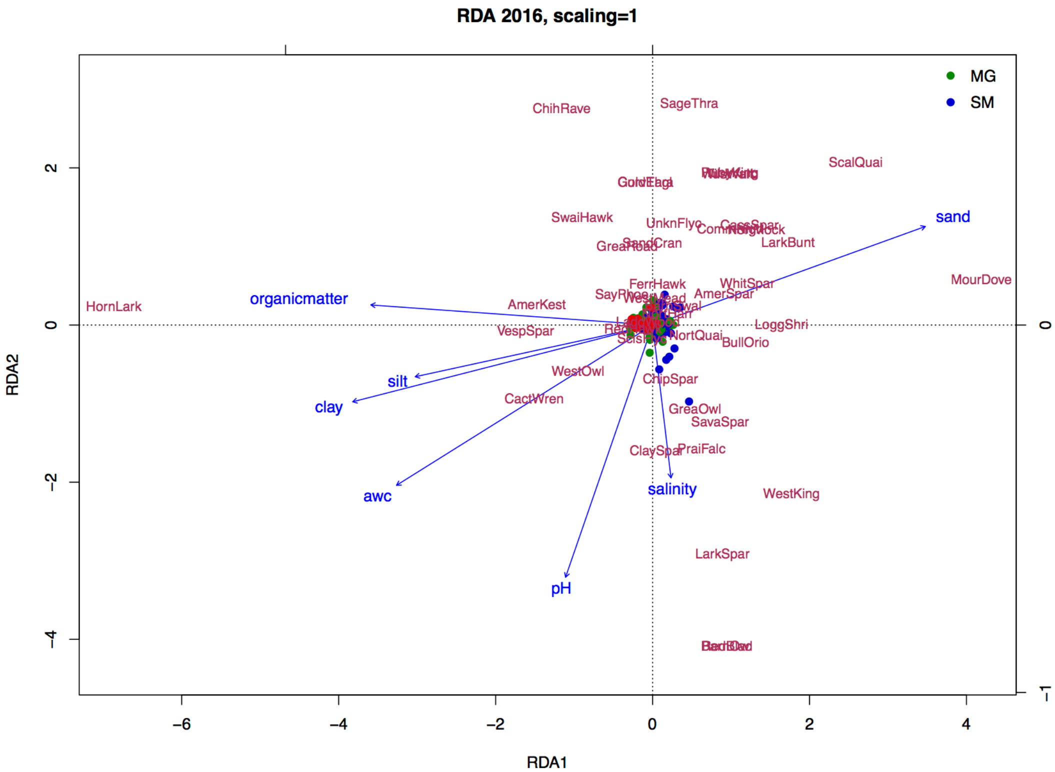

Figure A.8: RDA triplot comparing all soil variables to 2016 avian presence.

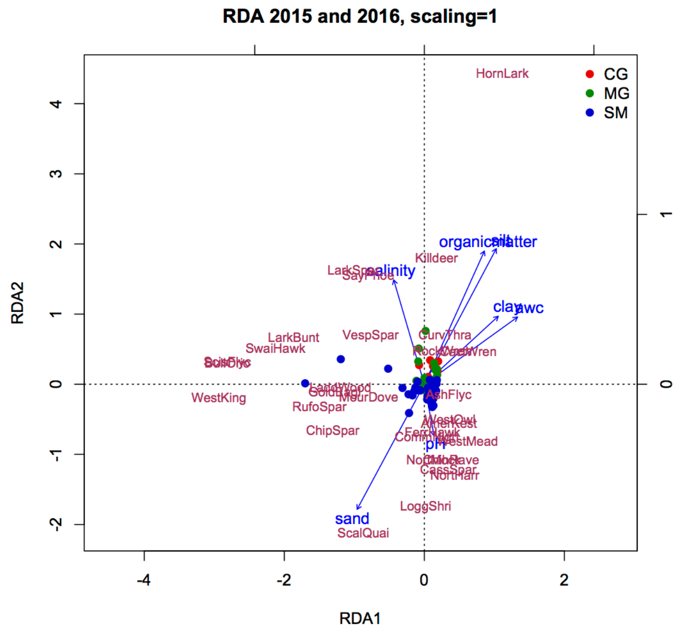

Figure A.9: RDA triplot comparing soil variables to 2015/2016 avian presence.

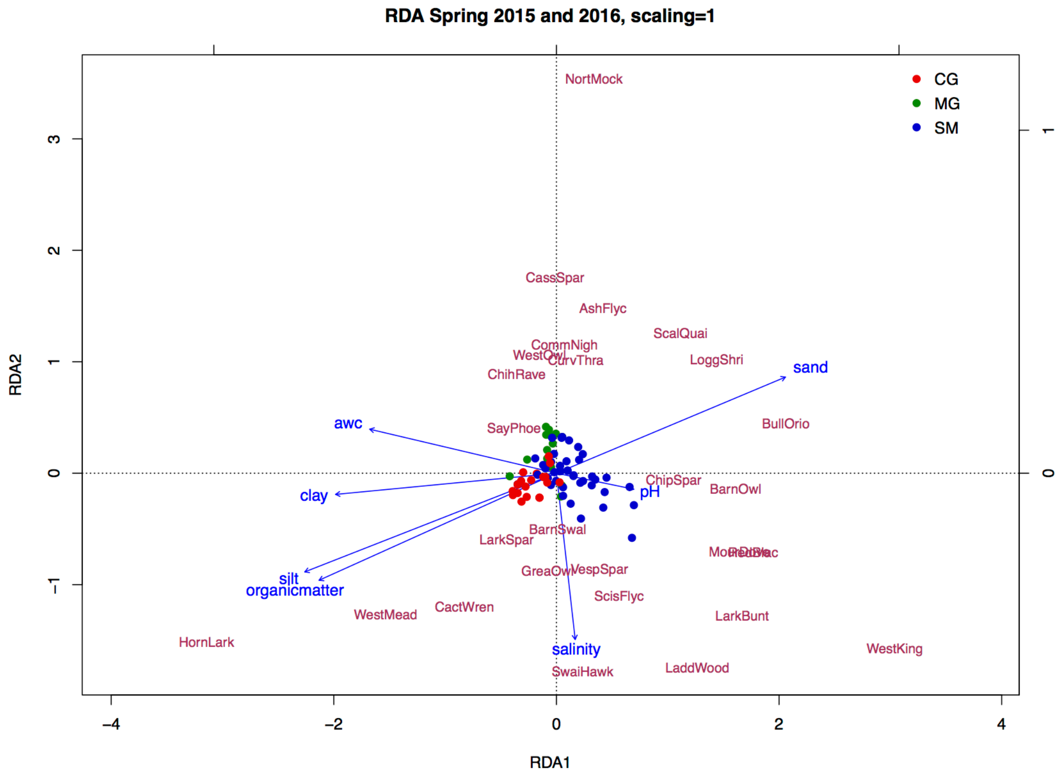

Figure A.10: RDA triplot comparing soil variables to spring 2015/2016 avian presence.

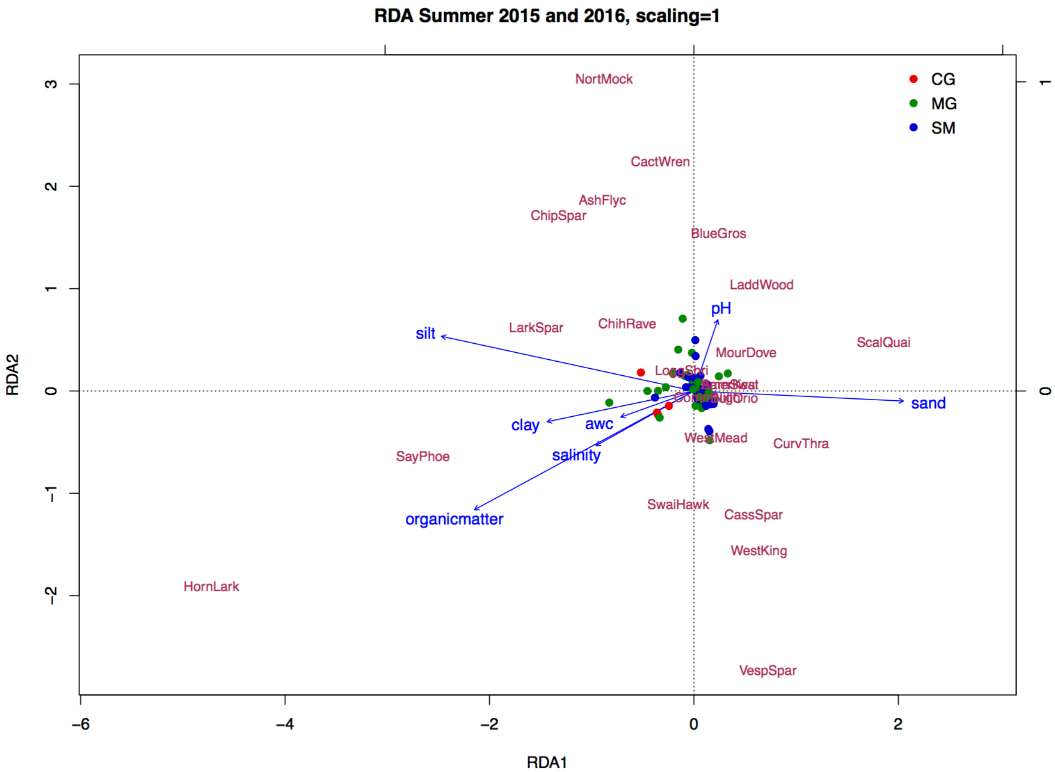

Figure A.11: RDA triplot comparing soil variables to summer 2015/2016 avian presence.

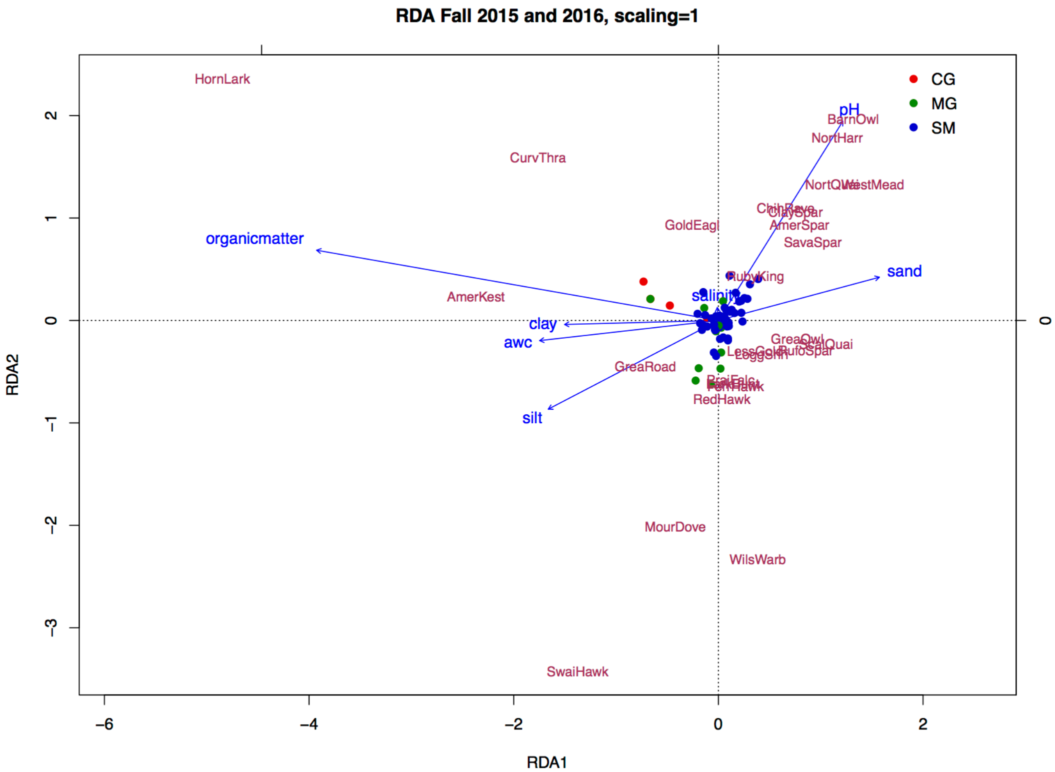

Figure A.12: RDA triplot comparing soil variables to fall 2015/2016 avian presence.

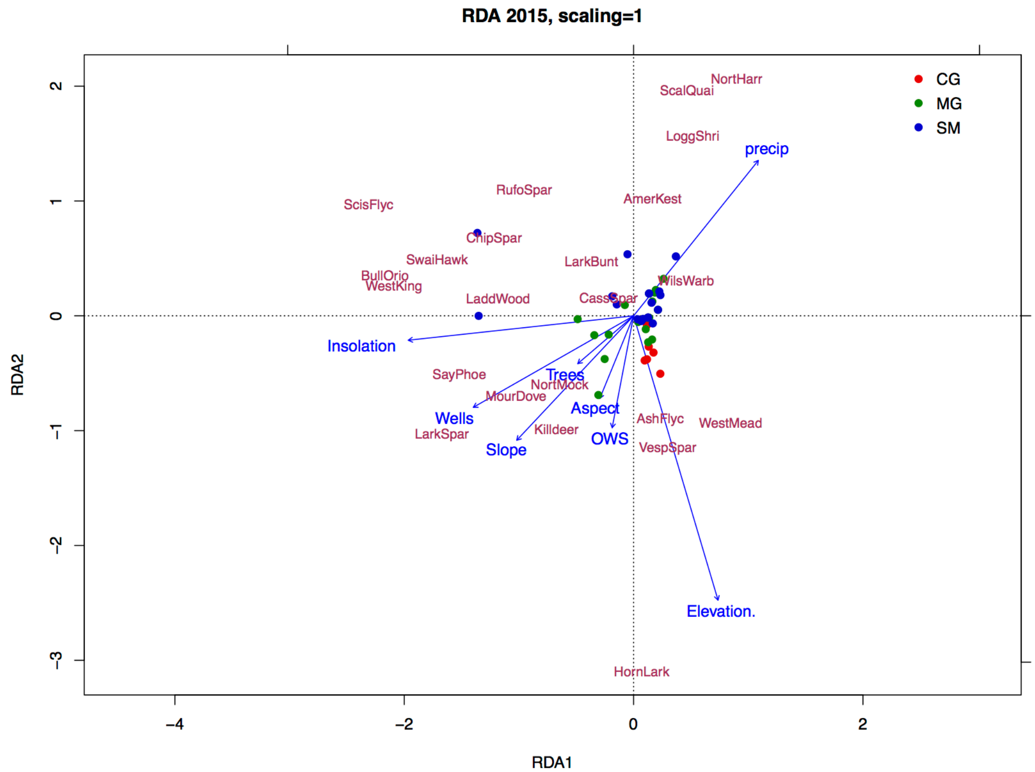

Figure A.13: RDA triplot comparing location variables to 2015 avian presence.

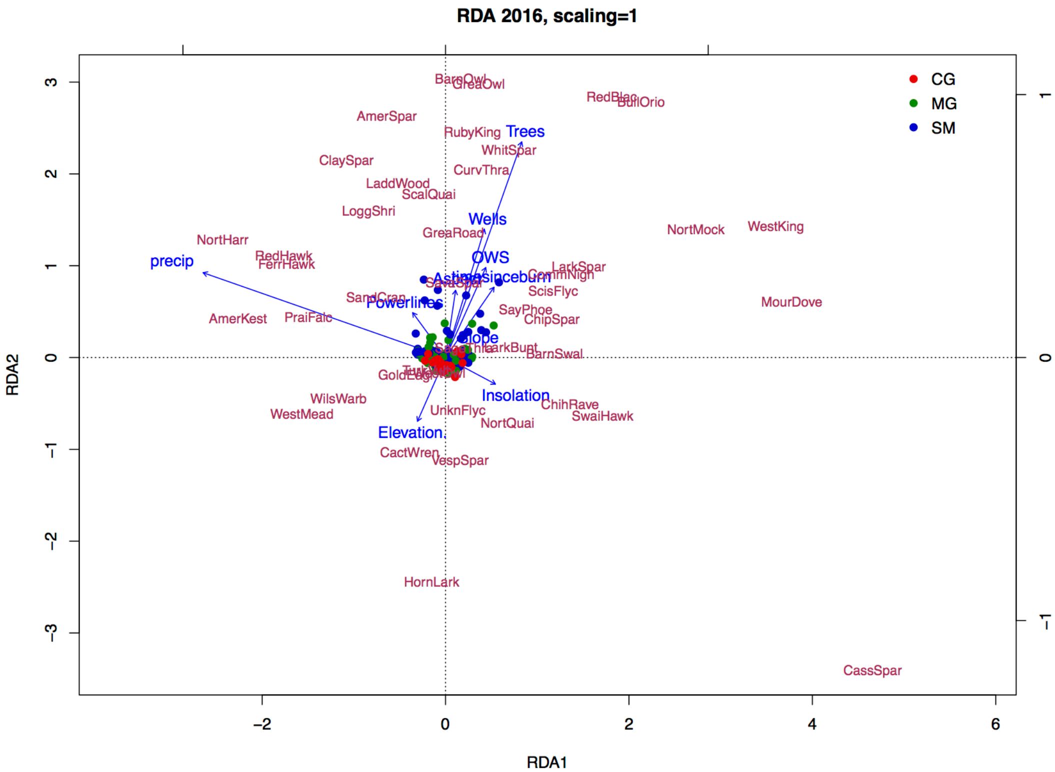

Figure A.14: RDA triplot comparing location variables to 2016 avian presence.

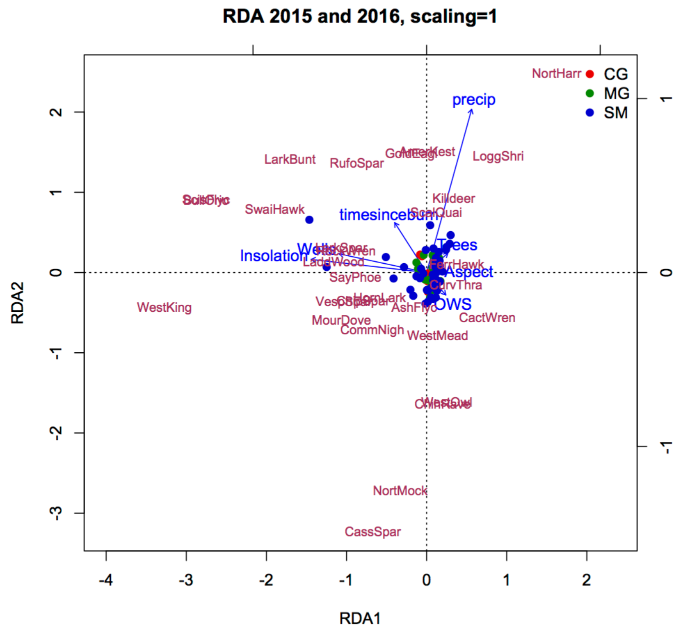

Figure A.15: RDA triplot comparing location variables to 2015/2016 avian presence.

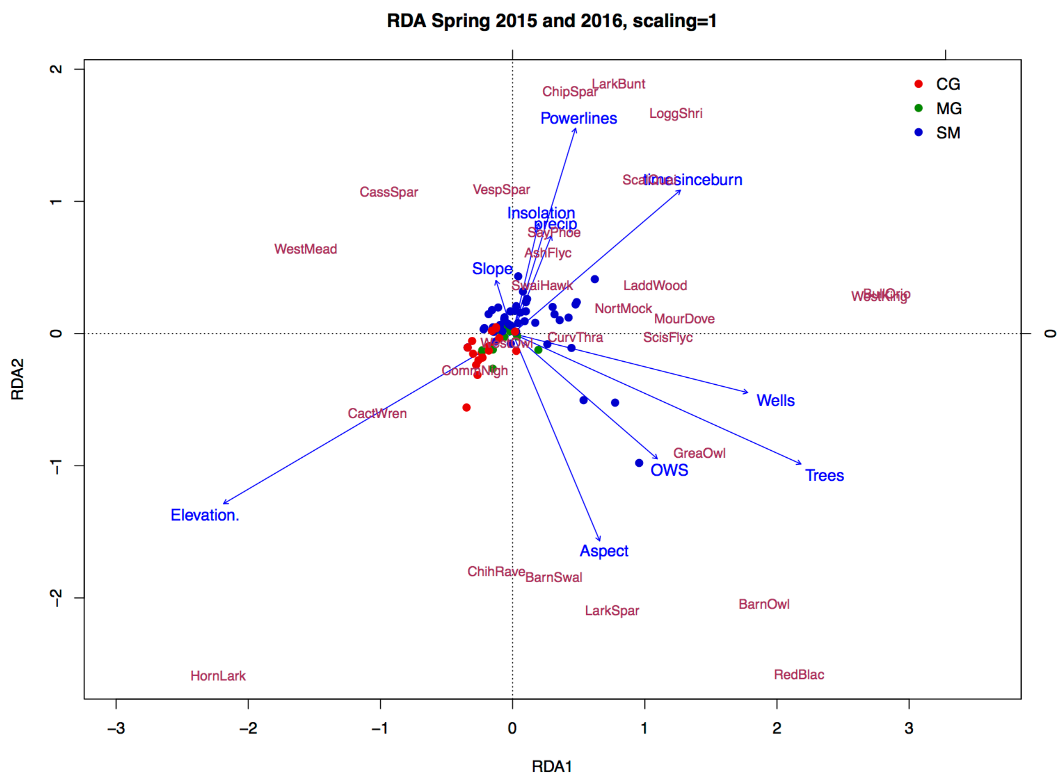

Figure A.16: RDA triplot comparing location variables to spring 2015/2016 avian presence.

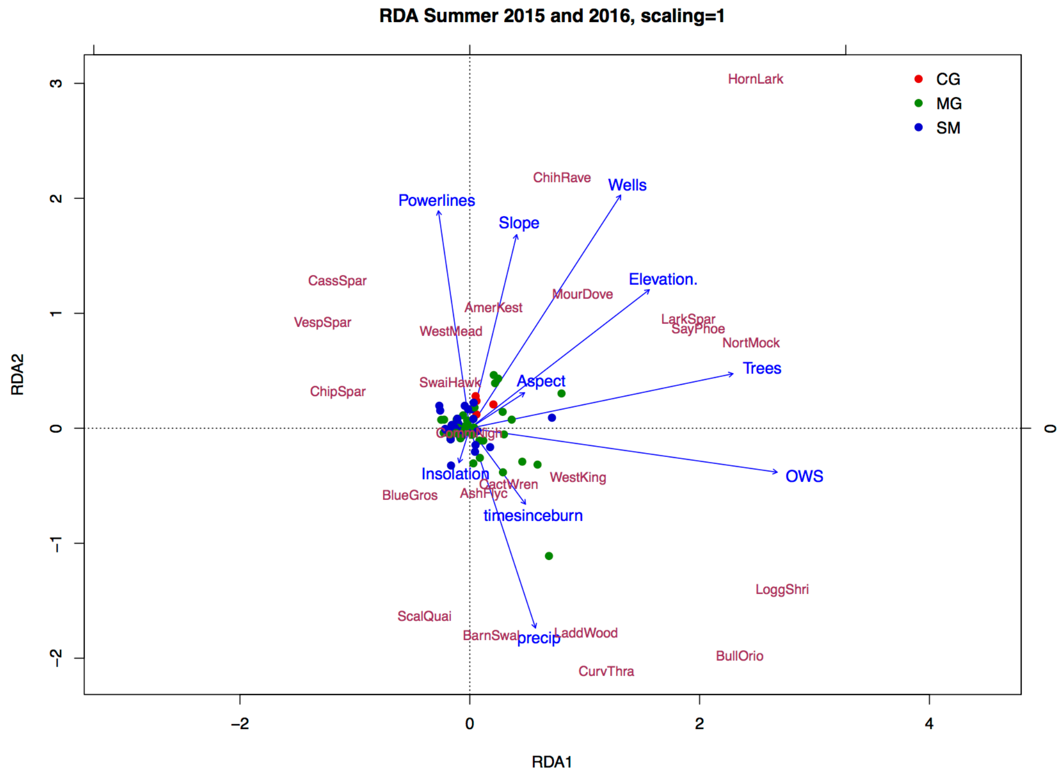

Figure A.17: RDA triplot comparing location variables to summer 2015/2016 avian presence.

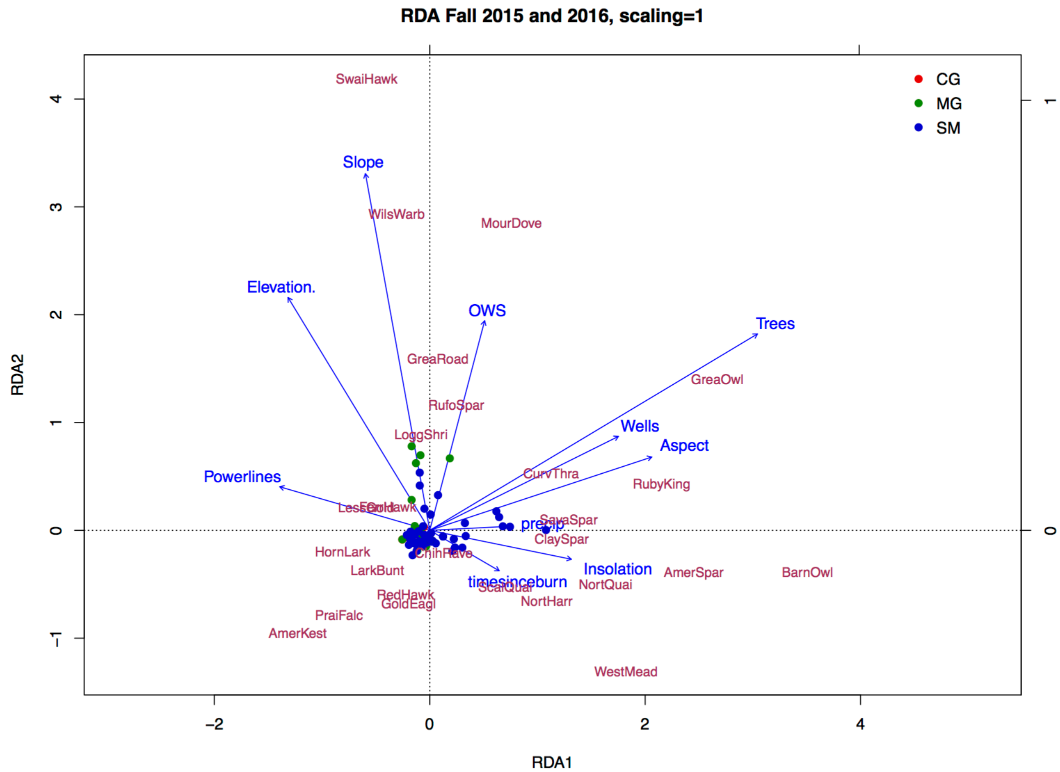

Figure A.18: RDA triplot comparing location variables to fall 2015/2016 avian presence.

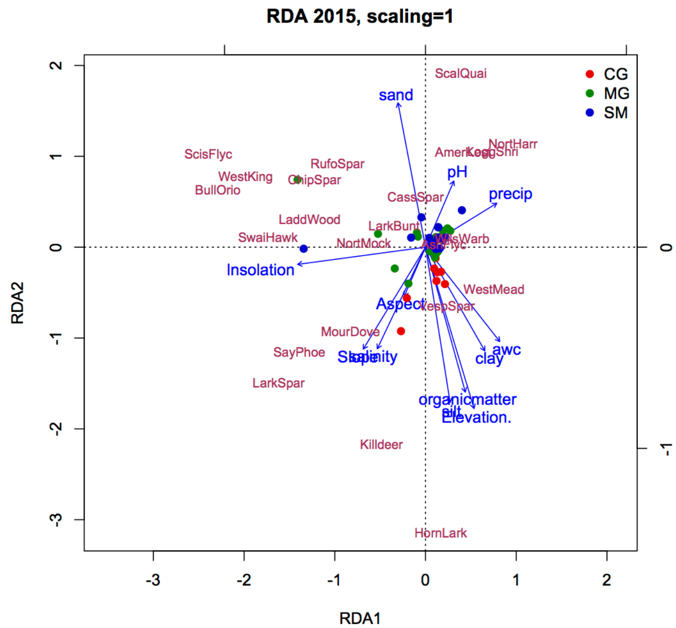

Figure A.19: RDA triplot comparing environmental variables to 2015 avian presence.

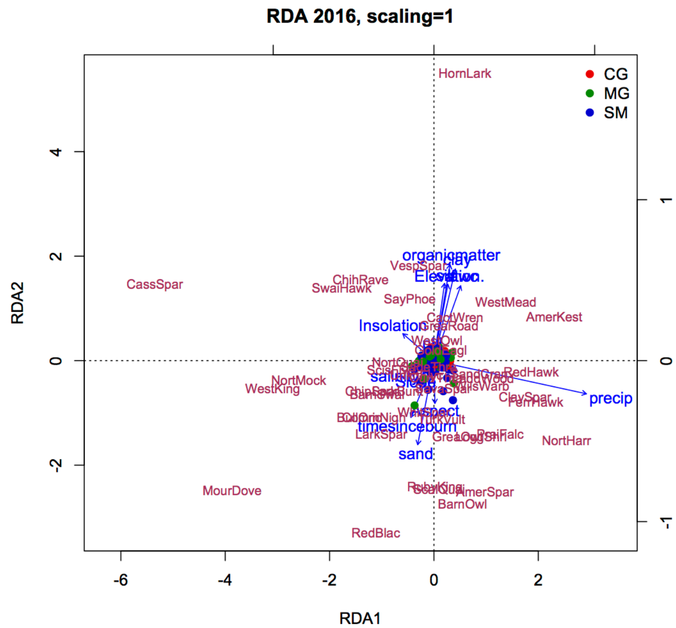

Figure A.20: RDA triplot comparing environmental variables to 2016 avian presence.

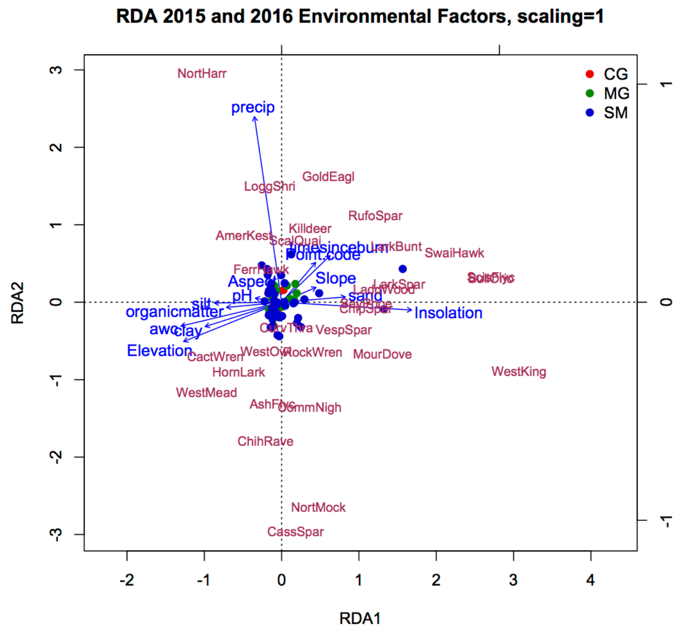

Figure A.21: RDA triplot comparing environmental variables to 2015/2016 avian presence.

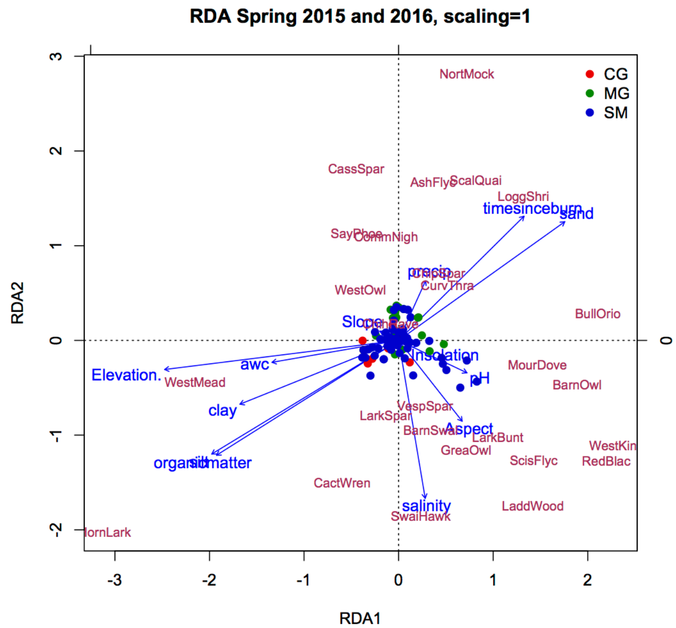

Figure A.22: RDA triplot comparing environmental variables to spring 2015/2016 avian presence.

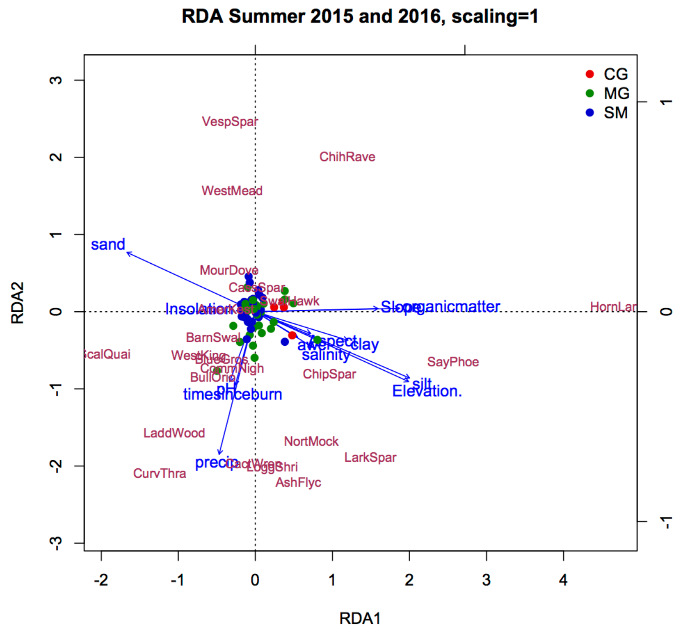

Figure A.23: RDA comparing environmental variables to summer 2015/2016 avian presence.

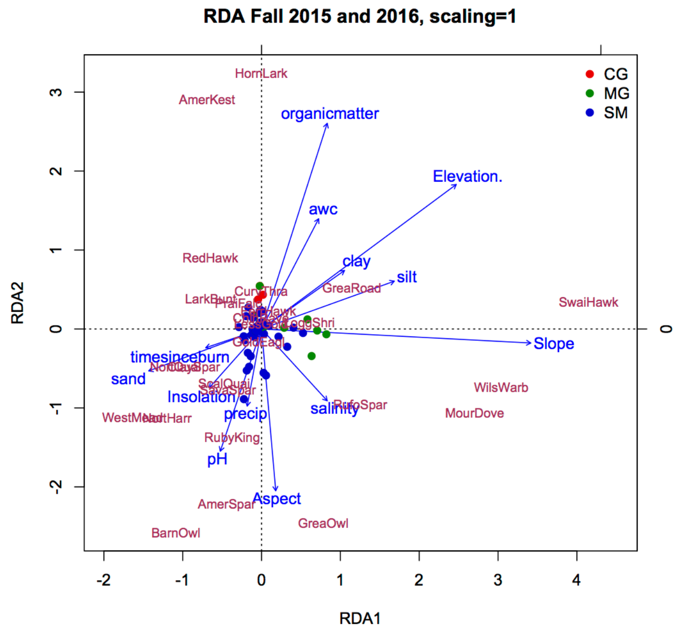

Figure A.24: RDA triplot comparing environmental variables to fall 2015/2016 avian presence.

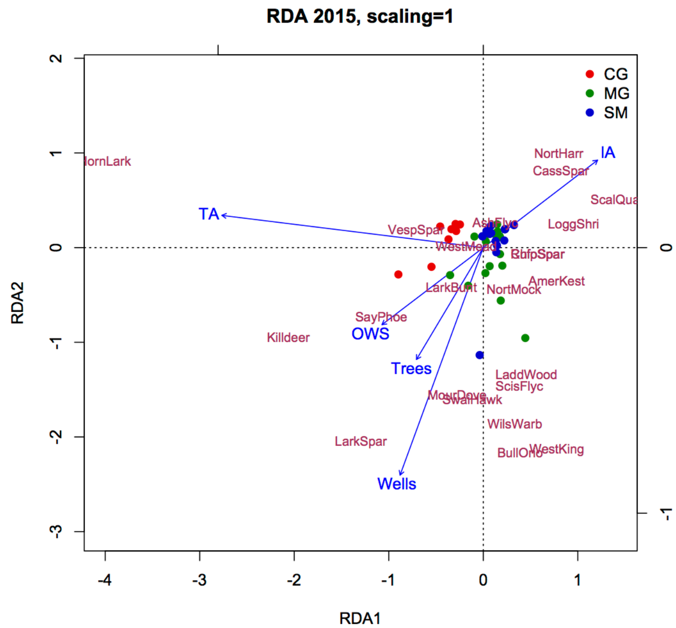

Figure A.25: RDA triplot comparing anthropogenic variables to 2015 avian presence.

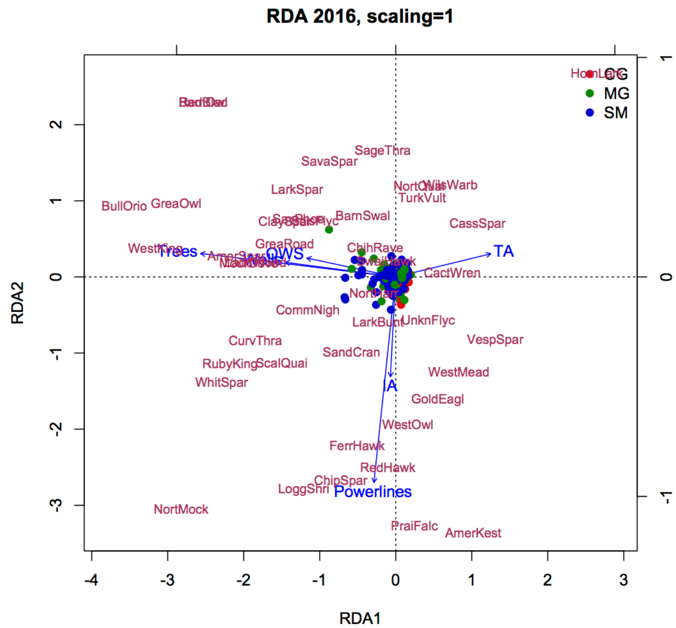

Figure A.26: RDA triplot comparing anthropogenic variables to 2016 avian presence.

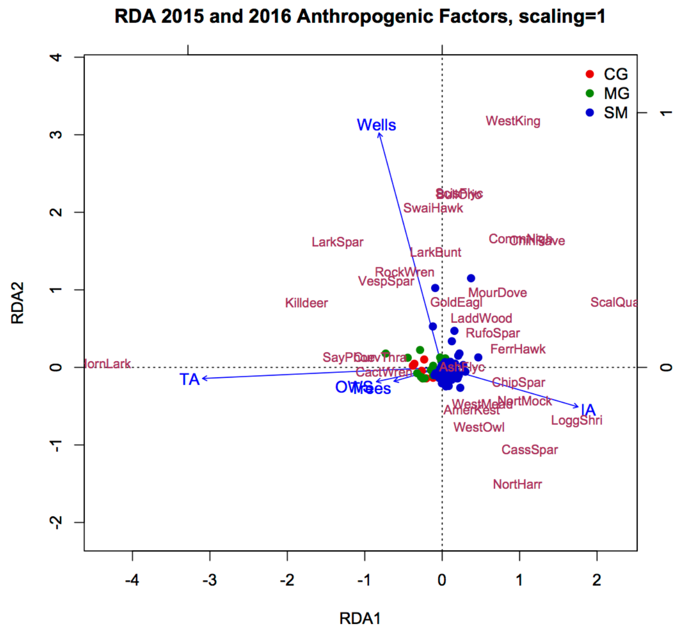

Figure A.27: RDA triplot comparing anthropogenic variables to 2015/2016 avian presence.

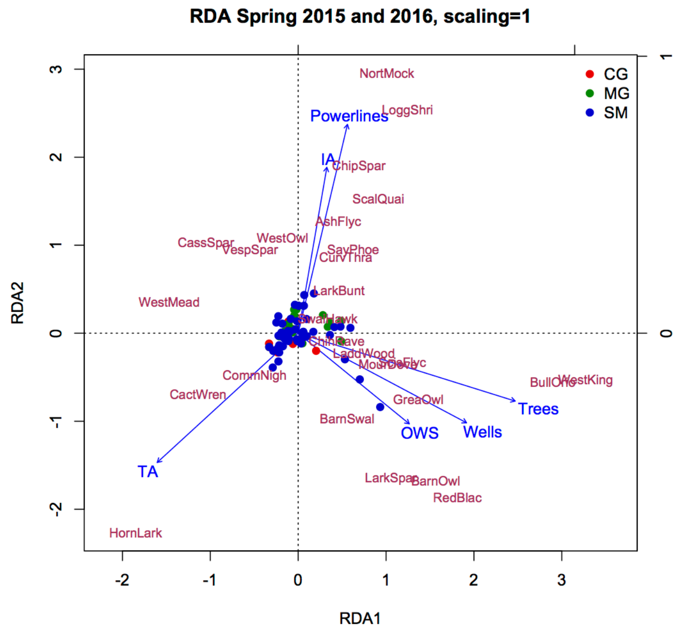

Figure A.28: RDA triplot comparing anthropogenic variables to spring 2015/2016 avian presence.

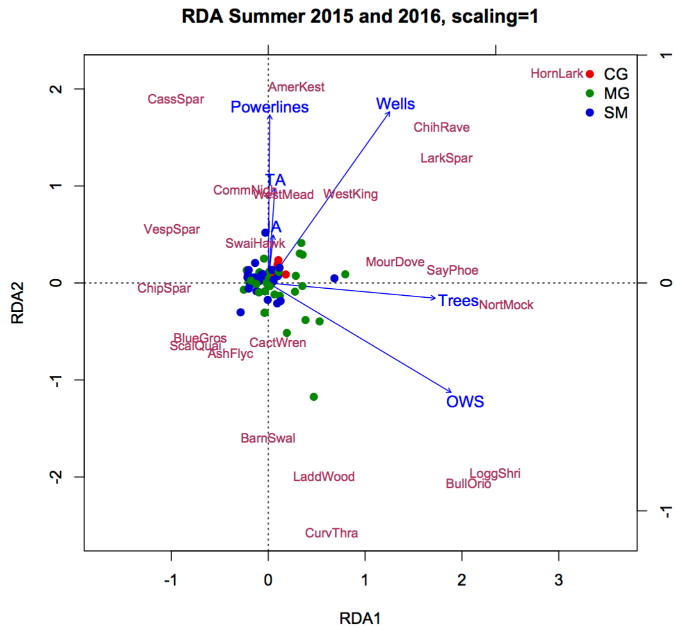

Figure A.29: RDA triplot comparing anthropogenic variables to summer 2015/2016 avian presence.

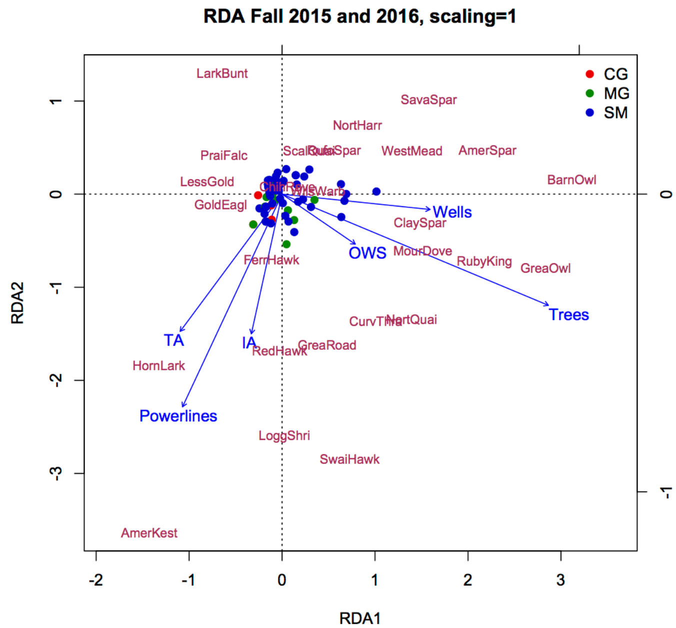

Figure A.30: RDA triplot comparing anthropogenic variables to fall 2015/2016 avian presence.