EVALUATING THE GEOMORPHOLOGICAL ROLE OF THE FERAL HOG (*Sus scrofa*) IN GOLDEN-CHEEKED WARBLER (*Dendroica chrysoparia*) HABITAT

THESIS

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CHAPTER I

INTRODUCTION

Feral hogs are extremely adept at survival and have become well established in Texas because of their adaptability and amazing reproductive capability. They have become increasingly widespread, with the highest concentrations in East, South and Central Texas (Taylor 1991; Mapston 2004). Citing destruction of habitat and competition with native wildlife, Texas Parks and Wildlife has come to regard the feral hog as a "nuisance" and has accordingly assigned them an unprotected status (Taylor 1991). While it is certain that feral hogs can have a significant impact on habitat, soil dynamics, vegetation and other wildlife, it has not been determined how the presence of this species in Texas may be affecting the nesting and foraging habitat of the Golden-cheeked Warbler (*Dendroica chrysoparia*). Of particular interest, is how feral hog rooting may alter the landscape and vegetation composition and potentially affect the quality of habitat and thus the nesting success of the Golden-cheeked Warbler.

The purpose of this study is to search for evidence of hog rooting in Golden-cheeked Warbler habitat and non-warbler habitat and assess the extent of this perturbation to the soil and surrounding vegetation. Given the high density of oaks that typically comprise warbler habitat and the nutritional content they provide, it is expected that rooting will be fairly extensive. The aim of this research is to test the hypothesis that rooting will be more pervasive in warbler habitat as opposed to other areas not suitable for warblers to inhabit. In addition, the data collected will be used to determine whether feral hogs are having a geomorphic impact on warbler habitat within Fort Hood, Texas. Although this is only a preliminary study, this research may provide the impetus for an analysis to further examine the implications of hog rooting on the long-term habitat quality of the warbler.

CHAPTER II

BACKGROUND

Geomorphological Framework

Recognition of animals as influential structuring forces of geomorphic change in ecological systems has been steadily rising (Butler 1995). The coining of the term, Zoogeomorphology (Butler 1992), has likely further contributed to the increased interest in the role of animals as geomorphic agents. Animals can directly and indirectly affect biota by promoting or inhibiting ecosystem processes as well as modifying elements of the physical landscape via geomorphic activities. Within the context of geomorphic studies it is important to explore the spatial and temporal variations, as well as the intensity of these activities.

A wide variety of mammals engage in activities that serve to shape their surroundings, particularly the structure and composition of plant communities. Grazing is generally concentrated on areas of preferred vegetation, thus areas that have experienced intense grazing pressure can become gradually denuded of vegetation resulting in patches of bare soil (Evans 1998). Pocket gophers also play an important role in engineering their habitat by digging as well as herbivory. These behaviors result in a marked reduction in plant biomass (Reichman and Seabloom 2002). Bison also increase spatial heterogeneity of the landscape by modifying vegetation characteristics and soil dynamics by means of wallowing. McMillan (1999) found that soil nutrients and plant diversity within wallows were different when compared to neighboring undisturbed prairie. Likewise, grizzly bears can create large patches by digging for plant matter that results in the displacement of soil over large geographic areas (Butler 1992) and a change in both the distribution and abundance of vegetative ground cover when compared to adjacent areas of undisturbed meadow (Tardiff and Stanford 1998). Clearly the dynamics of an ecosystem can be changed by a variety of animals through geomorphic processes. The implications of such activities are manifold. It can facilitate the growth and coexistence of competing species, reduce net primary production, alter plant succession rates and generally restructure the vegetational components in disturbed areas.

The interconnectedness of organisms to each other and to their surroundings makes the value of understanding zoogeomorphic activity and its collective effects apparent in the broader context of species assemblages. Consequently, the purpose of this study is to analyze the geomorphic contribution of feral hogs, specifically how rooting impacts vegetation composition within the habitat of the endangered Golden-cheeked Warbler. Feral hogs routinely engage in landscape-altering behaviors resulting in them having a significant geomorphological role within the ecosystem. Destruction to habitat caused by feral hogs can occur as a result of rooting, wallowing, digging, and trampling (Tisdell 1982). Considering the ubiquity of these exotic hogs, the geomorphic significance of such activity cannot be underestimated.

Feral Hogs (*Sus scrofa*)

Feral hogs (*Sus scrofa*) have become a species of concern throughout the world because of their deleterious effect on natural ecosystems. Extensive research has been conducted on the impacts this species has on landscapes. Studies from all over the world have shown that feral hogs disrupt and alter endemic plant and animal communities (Bratton 1974, 1975; Ralph and Maxwell 1984; Singer et al. 1984; Drake and Pratt 2001). In general, it is believed that frequent rooting by these omnivores to exploit various food sources is destructive to plant communities. What is certain is that in areas where populations of this exotic and destructive species have been introduced and flourished the impacts to the environment are undoubtedly widespread.

Sus scrofa is an exotic species first brought to Texas over 300 years ago by Spanish explorers (Mapston 2004). Subsequently, these domesticated hogs became feral and interbred with the European wild boar, which was introduced as a game animal in the 1930's (Taylor 1991). The term "feral hog" can be applied collectively to three strains of wild hogs. These include previously domesticated hogs that have since become feral, the European wild boar, or hybrids of these two varieties (Mapston 2004). Today this ungulate has become the most prolific large, wild mammal in North America. An estimated 2 million feral hogs are believed to inhabit Texas alone. That is about 50% of the entire population of feral hogs in the United States (Mapston 2004).

This proliferation is due in part to their amazing ability to contend with the elements and use the resources in a variety of environments (Bratton 1975; Coblentz and Baber 1987). Extreme aridity and a scarcity of food seem to be the only things that limit the distribution of this habitat generalist (Mapston 2004). Further contributing to this population explosion is the extraordinary reproductive potential of feral hogs. Remarkable reproductive rates have been documented and, depending on availability of food and surrounding environmental conditions, a population can double in as little as four months (Coblentz and Baber 1987; Mapston 2004). In fact, feral hogs have the greatest reproductive capacity of any large North American mammal (Engeman et al. 2001). Due to the massive propagation of these exotics, the feral hog population has continued to flourish over the past decade throughout Texas (Richardson and Simpson 1997).

Feral hogs have adapted well to a wide assortment of ecosystems in Texas and currently inhabit many areas. Their range extends from as far south as the Gulf coast to the northernmost parts of the panhandle. Similarly, populations can be found spanning from the arid southwest to the Pineywoods in east Texas (Mapston 2004). As evidenced by this broad range, feral hogs inhabit a variety of habitats including swamps, forests, brushy areas and deserts (Kinsey 2002; Mapston 2004). Although habitat types vary, hogs prefer mesic conditions often found in riparian areas, canyon bottoms and other bottomlands (Baber and Coblentz 1986; Engeman et al. 2001). Furthermore, they generally exploit densely vegetated areas with a mostly continuous canopy to protect themselves from extreme temperatures (Coblentz and Baber 1987; Taylor 1991; Mapston 2004). These areas, in addition to providing protection from the elements, supply an abundant source of food (Coblentz and Baber 1987). Feral hogs tend to concentrate where food is plentiful, and home range is thought to vary inversely with resource abundance and density (Baber and Coblentz 1986). Since wild hogs are omnivorous, their diets differ considerably depending on habitat and geographic location (Ickes et al. 2001).

Feral hogs are opportunistic and take advantage of any food source that is readily available (Bratton 1974; Kinsey 2002; Mapston 2004). A substantial portion of the hog's diet is subterranean in origin (Ickes et al. 2001). A variety of mammals engage in "digging activities" in order to obtain food (Butler 1995). Hogs use their flattened snouts, to root through soil, leaf litter, and low vegetation searching for virtually anything edible (Wilson 2003; Mapston 2004). The fundamental feature of rooting is the creation of patches. This patchy phenomenon reduces vegetative cover and exposes a variety of substrates, such as humus, mineral soil, roots, and rocks (Welander 2000). Feral hogs are unrelenting and will methodically root an area until the food source is exhausted. Considerable sized excavations are often the result of omnivores digging for underground plant matter (Butler 1995). Inevitably, such persistent rooting is bound to have geomorphic effects.

Spatial and Temporal Dynamics of Hog Rooting

Variations in hog rooting that exist reflect a seasonal variation in diet (Baron 1982). Their diet fluctuates depending on the nutrient levels of the foods available at any given time (Mapston 2004). Likewise, rooting will be spatially concentrated in areas of preferred vegetation. Therefore, knowledge of their eating habits is useful for gaining a better understanding of the spatial and temporal aspects of hog rooting (Wood and Roark 1980). Besides the opportune feast on domestic agricultural crops and carrion, biota such as soil dwelling invertebrates and succulent underground parts of plants such as roots, bulbs, and tubers make up a large share of the hog's diet (Bratton 1974; Kotanen 1995). In addition to this subterranean forage, hogs eat a wide variety of woody and herbaceous plant material such as browse, twigs, buds, and leaves (Bratton 1975). In fact, content analysis of the stomach of hogs shows that all plant parts are consumed, with roots making up the largest percentage (Everitt and Alaniz 1980). Since a large majority of the hog's diet consists of plant matter, annual growth cycles of vegetation and vegetative propagation often dictate patterns of rooting.

Much of the research conducted on feral hog rooting documents that the frequency of rooting increases from mid-autumn to early spring (Baron 1982; Kotanen 1995). During this time when other food supplies are not as plentiful, hogs will typically eat mast (Wood and Roark 1980; Baron 1982; Mapston 2004). Mast is food, generally nuts such as acorns, which have accumulated on the forest floor but may also include soft mast such as prickly pear cactus. However, in the latter part of the spring when mast becomes scarce, hogs become more dependent on new shoots of herbs and foliage (Wood and Roark 1980). As a result, a large portion of their diet is composed of grasses and forbs in the spring (Mapston 2004). Consequently, the availability of preferred foods largely determines their diet at any given time, and thus is a good indicator of which plant communities will likely be disturbed via rooting.

Rooting is not only believed to be related to season and diet, but may also occur more frequently and with greater intensity in association with physical features such as habitat type and soil category (Kotanen 1995; Welander 2000). Though abiotic factors do play a role in the magnitude and spatial variability of rooting, such increases in rooting are likely attributable to obtaining an adequate source of nutrition. For example, hogs tend to favor moist soil because it is easily workable and allows them to almost effortlessly uproot vegetation, providing quick and easy accessibility to nutrients (Everitt and Alaniz 1980; Kotanen 1995). One study found that rooted patches were much larger in mesic soils when compared to patches in dry soils. Results from this same study also showed that hogs more frequently and extensively root in deciduous forests when compared to coniferous forests and grasslands (Welander 2000). This may be a result of habitat preference, but is more likely a result of availability of high-quality nutritional resources. Their preference for rooting in deciduous forests, specifically forests with high densities of oak, arises from the fact that in the fall and winter the bulk of the hog's diet is comprised of acorns (Wood and Roark 1980; Welander 2000). Considering the wealth of information available on the diet and habitat preferences of feral hogs, rooting is, to some degree, a fairly predictable disturbance regime. Likewise, these variations that are a result of growth and propagation cycles provide insight into the geomorphic effectiveness of hog rooting (Butler 1995).

As the aforementioned studies have shown, rooting varies not only in frequency but also extent. Significant differences exist between the surface area and depth of rooted patches. Upon breaking through the exposed layer of vegetation, patches can be relatively shallow or extend well beyond the surface. These excavations typically range between 5-15 cm (Kotanen 1995). Excavations as deep as 90 cm have been documented. However, these usually occur when the soil is soft (Mapston 2004).

Not only can rooted areas extend well below the surface, they can also be very widespread and cover several acres (Mapston 2004). Generally, rooted areas consist of small overlapping patches that are approximately 1 m^2 (Welander 2000).

However, heavily exploited areas may stretch for well over one hectare. Severely rooted areas can encompass a swath nearly a kilometer long and 80 meters wide (Bratton 1974). Kotanen (1995) found that hogs annually rooted an average of 7.4% of the area in California meadows. By comparison, all native animals collectively (moles, pocket gopher, ground squirrels, skunks, and ants) disturbed less than 1% annually. The fact that these exotics can cause so much damage, and on such a large scale when compared to native animals, is cause for concern. For this reason, conservation biology must work to enhance its understanding of the spatial and temporal dynamics of these disturbances. This will in turn enable better prediction of when, why, and to what extent certain plant assemblages might be damaged.

The Effects of Rooting on Vegetation

Rooting is a severe disturbance that recurs on an annual basis and both directly and indirectly affects the health of ecosystems. Though consumption of vegetation is clearly harmful to some plant communities, hogs also damage vegetation indirectly through disturbance (Sweitzer and Van Vuren 2002). Rooting may negatively impact plants via mechanical damage (Bratton 1975). Knocking over and essentially uprooting small saplings (faunalturbation) (Butler 1995) can have profound effects on vegetation. Uprooted vegetation along with soil may be displaced, smothering otherwise intact vegetation (Kotanen 1995). In addition, rooting frequently exposes plant roots, causing them to dry out and eventually die (Bratton 1974). Therefore, rooting poses a compound threat because even unsavory plants that are largely ignored by hogs may be injured or killed (Bratton 1974).

The preponderance of evidence in the literature demonstrates that hog rooting significantly jeopardizes endemic plant species. Extensive rooting may result in at least partial removal of many plant species in regions that hogs inhabit (Everitt and Alaniz 1980). In a study of hog rooting in a deciduous forest, plant cover was reduced an average of 80% (Singer et al. 1984). Rooting is particularly detrimental to herbaceous vegetation (Howe et al. 1981). In one study of disturbed sites, rooting reduced the cover of the herbaceous understory by more than 95% (Bratton 1974). In addition, some of these sites failed to regain their herbaceous cover (Bratton 1975). Such degradation causes marked changes in the landscape and can involve probable local extinction of individual species (Bratton 1974).

Rooting causes significant damage not only to individual plant species but also to native plant assemblages (Bratton 1974; Singer et al.1984). Rooting promotes the growth and dominance of invasive non-native species, and in so doing can reduce the native components in floral communities (Kinsey 2002). One study documented that whereas species richness was greater in fenced experimental plots compared to control plots, species diversity was significantly lower (Ickes et al. 2001). After rooting, invasive species may out-compete native species and begin to occupy bare ground first (Spatz and Mueller-Dombois 1975; Kinsey 2002). By encouraging the growth of undesirable plants, the future structure and species composition of native vegetation could be significantly altered (Ralph and Maxwell 1984). This is especially important in areas where hog densities are fairly high, because competitive relations may be modified to an even greater extent (Sweitzer and Van Vuren 2002).

In addition to making areas more susceptible to invasion by non-native species, rooting is thought to reduce the seed crop for successive seasons, thereby limiting tree regeneration (Kinsey 2002). It has been well documented that seed predation in general may change the successional patterns of trees as well as limit the re-growth of trees (Cairns 2004; Castro et al. 2004). In fact, "physical disturbance may reduce the expected half-life of a seedling cohort to less than two years" (Drake and Pratt 2001). Drake and Pratt's (2001) study demonstrated that more seedlings were damaged in the presence of hogs (31.3%) than in the absence of hogs (20%). Juveniles are perhaps more susceptible to such damage because their root system has yet to expand enough to provide the support necessary to prevent uprooting (Ickes et al. 2001). One study specifically assessed the effects of rooting on the regeneration of potential oak trees. The findings showed that after almost 3 years, plots that had been protected from hogs by means of exclosures had twice as many tree seedlings in both oak and mixed woodland habitat when compared to control plots (Sweitzer and Van Vuren 2002). This disparity was attributed to the consumption of acorns in the control plot that might otherwise have germinated. Similarly, in a study of tree seedlings and saplings in a lowland rain forest, the number of recruits inside exclosures was three times more than those in the unfenced plots (Ickes et al. 2001).

It is clear that in areas that hogs currently inhabit, they are contributing to the reduced productivity of aboveground biomass. Although the effects of rooting may seem somewhat ephemeral, the long-term cumulative result could have a significant bearing on vegetation assemblages due to attrition in seedling populations. Therefore, because rooting is a major cause of seedling mortality, the regeneration of young plants may be precluded depending on that species' ability to tolerate physical disturbance.

Some studies address the positive impacts that feral hogs may have on ecosystems, as well as others that propose that the effects of rooting are benign (Baron 1982; Lacki and Lancia 1983; Kotanen 1995). Counter to the information of other studies, Baron (1982) found that her island ecosystem study area was not seriously affected by the presence of hogs. Instead, the damage was transitory in nature and the area experienced rapid recovery of vegetation after disturbance by rooting. Kotanen's (1995) study suggests that rooting may be replacing an important disturbance regime that his study area had depended on or adapted to over time. He implies that perhaps these small scale, high frequency disturbances may be facilitating succession. Disturbed areas can cause a shift in plant succession, which is beneficial to some wildlife (Everitt and Alaniz 1980). However, hogs may leave places in a chronically disturbed state, making long-term successional trends irrelevant (Kotanen 1995).

Geomorphological Role

It is clear that hog rooting can exert a strong influence on plant assemblages. Changes within plant communities can be caused by a combination of biotic and abiotic processes both acting on the landscape. Digging or rooting causes the landscape to become vulnerable to other geomorphic processes and the greatest impact to the terrain and surrounding environment results from the synergistic effects of animal activity and external factors (Hall and Lamont 2003).

Both direct and indirect effects are associated with rooting. One of the most apparent direct effects of hog rooting is the formation of micro-site landforms. Areas of hog rooting are very distinctive because of the micro-tread topography that is created (Imeson 1976). Likewise, in areas that experience intense rooting pressure, patches of completely bare ground are common. Singer et al. (1984) found that vegetative ground cover was reduced to such an extent that the amount of bare ground increased by 88%. This increase in bare ground after rooting could accelerate soil erosion and thereby affect the soil nutrient dynamics (Bratton 1975).

Rooting involves the direct removal of vegetation and sediment. The exposed substrate then becomes subject to subsequent erosion due to climatic factors like wind and precipitation (Hall and Lamont 2003). Rooted areas could experience increased erosion as the exposed material is transported away. In the absence of such animal activity the influence of these fluvial and aeolian processes on the soil might not otherwise occur (Hall and Lamont 2003). Extensive rooting of soils can indirectly cause serious erosion that has far reaching effects. This is especially true in riparian areas where erosion can result in changes in stream chemistry, ultimately affecting the species within them (Mapston 2004). Likewise, beyond directly destroying vegetation via trampling and rooting, hogs can indirectly disrupt vegetation by contributing to changes in soil properties. Indeed, Singer et al. (1984) found that in deciduous forests not only is vegetative ground cover negatively impacted, but rooting also accelerates the leaching of nutrients from the soil. However, other scholars have suggested that soil turnover caused by rooting may promote tree growth and enhance productivity by accelerating nutrient cycling and allowing more rapid nutrient uptake by trees (Lacki and Lancia 1983).

An in-depth discussion of the effects of rooting on soil penetrability and nutrient concentration is available in Lacki and Lancia (1983) and Singer et al. (1984). Whether the effects of rooting on the soil impede or encourage re-growth of vegetation is unclear.

Many changes to the landscape occur or are amplified as a direct result of animal activity. These biotic and abiotic interactions working in concert can result in significant degradation to affected areas. This is pertinent because in areas where hogs continually forage, rooting is likely more uniformly spread throughout the landscape. However, in places that seasonally supply preferred nutrients for hogs, rooting is more spatially concentrated. Therefore, areas that provide a seasonal food source for hogs are more likely to be zoogeomorphically impacted because of their recurrent use.

The Golden-cheeked Warbler (*Dendroica chrysoparia*)

The Golden-cheeked Warbler, a neotropical migrant bird, is a federally listed endangered species. Populations of these birds come to central Texas each spring after wintering in Central America. Occurring in only eighteen counties in Texas, populations of this endangered bird are limited by the availability of suitable habitat (Rappole et al. 2000; Dearborn and Sanchez 2001). These habitat specialists occupy mature juniper-oak woodlands in the limestone hills and canyons in central Texas along the Balcones Escarpment of the Edwards Plateau (Engels and Sexton 1994; Rappole et al. 2000; Dearborn and Sanchez 2001).

Golden-cheeked Warblers will only breed in mature juniper-oak woodlands (Rappole et al. 2000). Lower densities of Ashe juniper (*Juniperus ashei*) and high densities of a variety of oak trees dominate these short woodland habitats (Kroll 1980;

Dearborn and Sanchez 2001). Nests are typically located in patches of extremely dense vegetation. These patches are characterized by virtually complete canopy closure. Dense close-canopied woodland may be important for these birds (Dearborn and Sanchez 2001). Older, mature (>40 years) Ashe juniper trees typify good nesting habitat, primarily because warblers use the sloughed bark of these trees for nesting material and these trees do not begin sloughing until they are 20 years of age (Kroll 1980). In addition, these songbirds are dependent on this species of tree for suitable singing perches (Kroll 1980). Vegetation is therefore and important spatial control of where warblers can successfully nest (Dearborn and Sanchez 2001). Furthermore, hardwood species such as oak provide the preferred foraging habitat for these insectivorous birds (Kroll 1980). For this reason, information on nesting and foraging habitat is especially important.

Populations of Golden-cheeked Warblers are unfortunately still declining despite efforts to save them. It is mostly factors on the breeding ground as opposed to the wintering ground that are causing the decline of this species (Rappole et al. 2000). Reasons for decline are manifold and include habitat degradation (clearing of juniper), nest parasitism and oak wilt (Rappole, King, and Leimgruber 2000). Since these birds require a particular niche in which to nest, it is important to examine the potential threats to their required habitat. In certain areas, feral hogs may seriously imperil endangered or threatened wildlife species (Mapston 2004). Thus, the potential impact that hogs have on the nesting and foraging habitat of Golden-cheeked Warblers should at the very least be explored.

The Shared Habitat of Feral Hogs and Golden-cheeked Warblers

The prospect that an exotic species may be harming the habitat of an endangered species is quite intriguing. As previously mentioned, hogs are particularly fond of exploiting the resources found in areas of dense vegetation such as forested habitats similar to those of the Golden-cheeked Warbler. Hogs seek out these types of environments with dense canopies to shelter themselves from extreme temperatures (Coblentz and Baber 1987; Taylor 1991; Mapston 2004). Furthermore, acorns constitute the greater part of their diet in the fall and winter (Wood and Roark 1980; Welander 2000). Warblers favor woodlands predominated by oak trees which propagate by dropping their acorns. Therefore, given their affinity for this type of hard mast, it seems highly likely that hogs would root extensively in these areas during certain times of the year, resulting in these sites experiencing more zoogeomorphic disturbance. Research has revealed that seed predation can limit the survivorship of seedlings and thus hamper the regeneration of trees in oak woodlands (Sweitzer and Van Vuren 2002). The enduring effects of this could be reduction of forage and resource availability for native wildlife such as the Warbler. In their study, Sweitzer and Van Vuren (2002) suggested that widespread rooting had reduced aboveground plant biomass to such an extent in oak grasslands and woodlands that the availability of forage may have indeed been affected.

Although much of the data in this literature review regarding damage to plant communities applies directly to herbaceous vegetation and grasses, these data could be extrapolated to the types of vegetation commonly found in warbler habitat. It is highly likely that at the very least feral hogs are diminishing the seedling population of oak trees. Long-term, this could be detrimental to the sustainability of densely canopied woodlands necessary for nesting and foraging. It is also possible that severely rooted areas in these woodlands may expose the roots of trees, making them more susceptible to degradation and disease. Damage to tree roots via rooting has been documented (Bratton 1975). Additionally, maturation of juvenile trees may also be prohibited as hogs directly uproot them. Furthermore, if rooting is facilitating succession, recurrent rooting disturbances may keep vegetation in an early successional state, thereby reducing the potential for new growth of suitable habitat. Lacki and Lancia (1983) considered the changes in soil properties rooted by hogs, and suggested that it is at least possible that tree health and vigor will decline through continued drain of already limited nutrient supplies. This is one of two conflicting and untested hypotheses proposed based on the results of their study. What is certain is that physical alteration of habitats by organisms can influence the resources available to other organisms inhabiting the same areas. Human-induced fragmentation of landscapes will likely force hogs further in to protected areas, making these areas more susceptible to the damaging effects of rooting. Despite the fact that feral hogs have inhabited Texas for 300 years, their effect on the landscape has not been well documented. However, most of the research conducted on feral hog rooting in general lends credence to the supposition that this exotic species may potentially be negatively impacting the habitat of a rare and endangered bird. Therefore, because feral hogs and warblers share the same resource base, at the very minimum, it is important to determine if there is evidence of hog rooting in warbler habitat.

Summation

Conservation Biologists have ecological concerns as feral hogs interact with native wildlife species (Mapston 2004). As feral hogs encroach on areas, they inflict serious damage on native habitat and adversely impact endemic faunal species by competing with them both directly and indirectly (Bratton 1975; Baron 1982; Coblentz and Baber 1987; Taylor 1991). Given their widespread distribution, few areas in Texas are exempt from the devastating impacts caused by these invasive exotics. Hogs travel in large, semi-nomadic family groups called sounders consisting of one or more sows and their young. Considering that sounders that can range between 20-50 animals, it is easy to imagine that substantial and pervasive damage can be caused to habitats as they search for an abundant source of suitable food (Mapston 2004). As populations of hogs multiply and expand their range, the damage they cause to native habitats via rooting will likely increase too. The implications this has for the viability of Golden-cheeked Warbler populations are unclear.

CHAPTER III

STUDY AREA

Fort Hood, a U.S. Army post, is located in central Texas just 96 kilometers north of Austin (Figure 1). At 87,953 hectares, it is one of the largest federally owned Texas land holdings and one of the most sizable army installations (Fort Hood, About Fort Hood 2005). This landscape harbors lakes, rolling hills and a plethora of wildlife. Fort Hood is located in the Crosstimbers and the Southern Tallgrass Prairie Ecoregion near the interface with the Edwards Plateau Ecoregion. Typical of this junction, sixty-five percent of the area is perennial grassland; the remainder is characterized as woodland (U.S. Army LCTA program unpubl. data). Fort Hood is a mix of grassland, open savannah, hardwood thickets, and dense oak-juniper stands (Dearborn and Sanchez 2001). This physiogeographic province on the northern edge of the Texas Hill Country is known as the Lampasas Cut Plain. This is a very diverse area with shallow soils, rocky streams and Karst topography (Fort Hood, Natural Resources 2005).

Based on incident reports as well as evidence of rooting throughout the installation, it is certain that populations of feral hogs inhabit Fort Hood (Figure 2). In addition, a large population of Golden-cheeked Warblers nest in Fort Hood where a significant portion of their breeding ground is located. The Environmental Division at Fort Hood, in accordance with the Endangered Species Management Plan (ESMP) as mandated by the U.S. Fish and Wildlife Service (USFWS) biological opinion, develop monitoring protocols and identify potential threats to endangered species (Fort Hood, Biological Opinion 2005). The plan requires that Fort Hood maintain adequate habitat to support a minimum carrying capacity of 2,000 male Golden-cheeked Warblers. In accordance with this, Fort Hood has set aside 14,879 hectares of core habitat for the warbler. This is over 8,000 hectares more than is required to allow for 2,000 male warblers (Fort Hood, ESMP 2005). Based on a standard of at least 75% canopy closure and a contiguous stand of junipers and hardwoods extending for at least one hectare, Fort Hood has ~21,850 ha of viable warbler breeding habitat (J. Horne unpubl. data). In fact, they contain the largest breeding population under a single management agency. Consequently, this area has exceptional conservation value and much important research has been conducted on this species at Fort Hood. The presence of feral hogs in warbler habitat may warrant cause for concern, and because Fort Hood has been charged with the difficult task of managing natural resources on a multi–use property, this should be further investigated.

Fig. 1. Relative Location of Fort Hood, Texas
(www.hood-meddac.army.mil/default.asp?page=communities&vi=n&mnu=0, 2006)

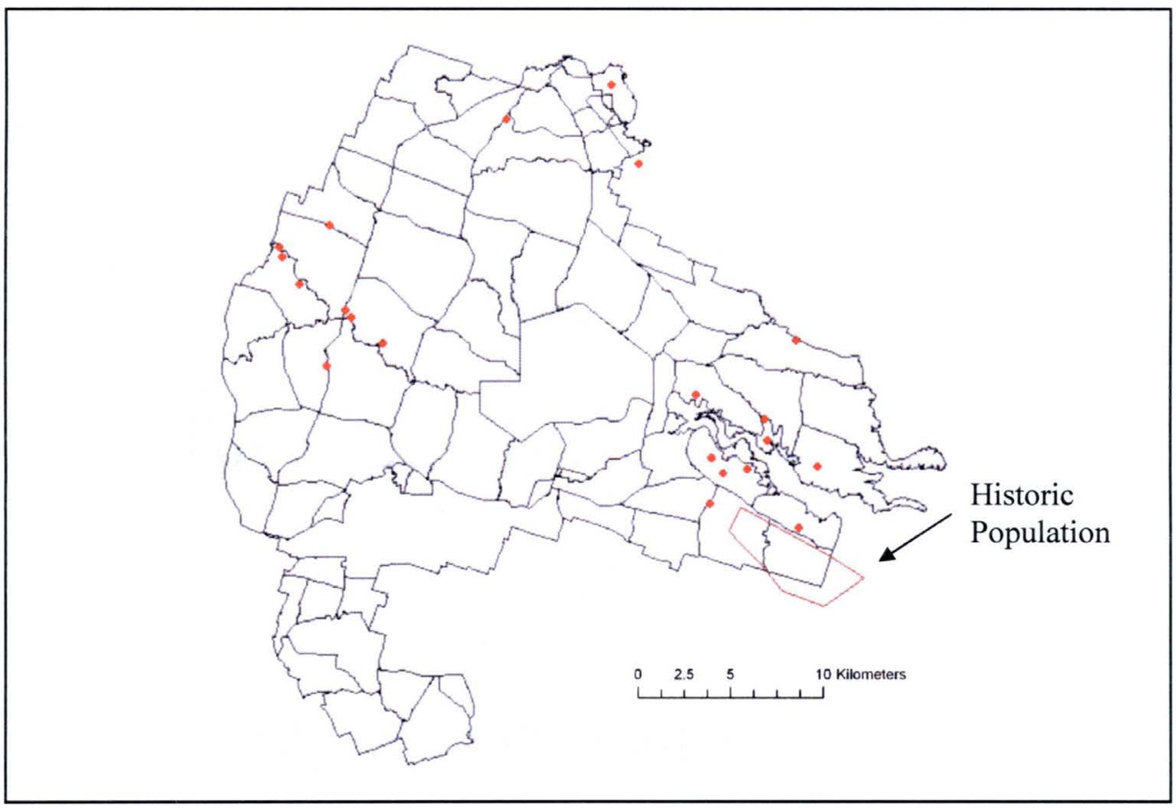


Fig. 2. Areas of Recent Hog Sightings or Signs of Hog Activity on Fort Hood
(Fort Hood unpubl. data)

CHAPTER IV

METHODOLOGY

Introduction

To support the assertion that hog rooting may be affecting the nesting success of the Golden-cheeked Warbler initially required finding proof that rooting was occurring in areas that warblers inhabit. A preliminary visit was made to Fort Hood in the summer of 2005 to search for signs of rooting within warbler habitat. However, because rooting is more frequent in the fall when oaks are propagating, the data obtained for this study were obtained during a subsequent visit to the area in early November of 2005. Initially, an extensive search throughout the base was conducted in both warbler and non-warbler habitat to look for evidence of visible signs of soil turnover that might indicate hog rooting.

Site Selection

After finding evidence of rooting, purposeful sampling was conducted and two one-acre plots where rooting was most prolific were delineated. One plot was within designated warbler habitat and the other was in an area not suitable for warblers to inhabit. Both of these sites were selected because of the considerable amount of rooting in each, as opposed to some of the other areas that were located where very minimal or seemingly no rooting had occurred. The first plot was in the Southeast section of the base that warblers are known to inhabit. The Nature Conservancy has designated this area Golden-cheeked Warbler habitat and has point count routes set up in the area to study the species. The other site chosen was further North within the installation. Due in part to routine training exercises and extreme weather conditions, this area was consumed by fires in 1996, resulting in the loss of 10,000 acres of warbler habitat. It is now an early successional environment and is no longer suitable for warblers to inhabit.

Techniques

At these rooted sites within the plots, I determined the surface area, depth and volumetric extent of displaced soil, estimated how recently the rooting may have occurred, recorded the types of vegetation growing in and around the patch and visually estimated the percent vegetation cover. These variables provided insight about the level of perturbation within each plot.

Within each plot, markers were placed at each rooted patch. Measurements were taken to determine the area of each patch. Relative to the size of each patch, multiple transects were established across the rooted area. Using a tape measure, the depth of individual pits was measured in centimeters at one-half meter increments to determine the mean depth of the excavation.

Using the numbers derived from these measurements, the volume of localized soil displacement for each rooted patch within both plots was calculated. With this volumetric data, a two independent sample t-test was used to test the null hypothesis that there is no significant difference in the extent of rooting in warbler habitat compared to non-warbler habitat. These statistics were also used to determine if feral hogs are having a geomorphic impact on warbler habitat by disturbing the soil and thus increasing the vulnerability of the soil to erosional processes.

Identification of Rooting

Hog rooting was distinguished from other types of disturbance by searching for evidence of large snout imprints at the edge of rooted patches. These can often be seen at the edge of rooting disturbances and set them apart from disturbance by other animals (Wilson 2003; Mapston 2004). In addition, the depth and areal extent of disturbed patches were an indication of hog rooting as opposed to some other small-scale disturbance (Welander 2000). Hog tracks in the rooted area or immediately adjacent were also used to identify the species causing the disturbance (Figure 3). Furthermore, the characteristic pits and mounds associated with rooting as documented in other studies of hogs (Imeson 1976) enabled more accurate identification of the cause of the disturbance.

Variables Analyzed

At each patch within both plots, the recency of rooting was documented. Markers such as the amount of litter accumulated in the patch and new growth served as an indicator of last use. Recently rooted patches are distinguishable from patches that are several weeks old because there are no mosses, shoots or seedlings growing in the freshly rooted patches, and all residual vegetation such as roots have withered and died (Welander 2000; Engeman et al. 2001). Additionally, patches that are several weeks old will have an accumulation of litter throughout (Welander 2000). The relative recency of rooting can also be gauged by examining the aridity of the overturned soil (Engeman et al. 2001). Soil that is still moist at the surface was considered fresh. Estimates of the time frame in which rooting occurred provided insight into the temporal aspects of this disturbance. This is important because if rooting within a given area can be determined to have occurred concurrently with oak tree propagation, this further reinforces previous research suggesting that these two phenomena are linked. Likewise, documenting the amount and type of new growth occurring in previously disturbed patches provides information about successional patterns.

Upon finding patches of rooted soil, a qualitative analysis of vegetation features was conducted. The percentage of vegetation within the patch and outside the patch was visually estimated. This estimate was based on the amount of visible bare ground. The presence of certain types of vegetation in and around the patch was noted. While qualitative in nature, this provided rudimentary knowledge of specific plant assemblages that are used if not favored by hogs within this area. Accumulated data outlining individual plant species that hogs damage or consume within known Golden-cheeked Warbler habitat might enhance the ability to predict the long-term viability of warbler habitat.

Fig. 3. Hog Track near Non-Warbler Plot

Summation

In a state that is so overrun by these exotics, a study like this is especially important for obtaining quantitative data on hog rooting. Quantitative information on the effect of feral hogs in the predominantly oak woodlands they occupy is scarce (Kotanen 1995). In light of this paucity of data, assessing the geomorphic impact they are having on this region of the country is necessary and perhaps long overdue, especially considering that half the population of feral hogs in the United States resides within Texas. While other studies in Texas have focused specifically on the effects of rooting on vegetation, to my knowledge no studies have explicitly sought to assess the geomorphic role of hog rooting. Therefore, the aim of this study is to quantify their geomorphic impact in an exceptionally affected locale in a habitat niche that harbors an at risk species.

CHAPTER V

RESULTS

Introduction

It is suspected by wildlife biologists at Fort Hood that many of the hogs have migrated from historically occupied regions further northward on the base into the live fire zone, which is virtually devoid of human activity. For obvious reasons, this area could not be investigated to search for signs of rooting. However, a significant amount of rooting was still observed in the remaining areas. During this study, Central Texas, including Fort Hood, had been experiencing unusually dry weather. As previously mentioned, hogs favor moist soil that is easily workable and these arid conditions may have contributed to the lack of fresh rooting that was found. While much of it probably occurred well before this study, a few patches were relatively fresh. This allows for a comparison of the characteristics of freshly rooted areas with the residual effects of patches that were rooted the previous season.

Recency of Rooting

Most of the patches observed in warbler habitat were uprooted well before this study began. These patches had already been blanketed in fallen dead leaves; however, the pits and mounds associated with rooting were still visible and a contrast between these areas and the surrounding landscape was apparent (Figure 4). Noticeable new growth existed in these areas as evidenced by several juvenile oaks and ashe-juniper trees within each rooted patch. Based on these factors within the warbler plot, there was no observable fresh rooting activity.

Conversely, in non-warbler habitat, evidence of more recent activity was observed. Several patches within this plot were observed during the initial visit to Fort Hood in July of 2005. At that time the rooted patches were still relatively fresh, consisting of very little vegetative groundcover. Although the soil was no longer moist, the rooting had exposed a rocky substrate that was not as evident in adjacent unrooted areas (Figure 5). Rooted patches in this area were relatively large and most of the herbaceous vegetation was dead, although a few tufts of green grasses were still noticeable. Visible spots of completely bare ground were interspersed throughout the patch. This same area was chosen in the second visit to Fort Hood to serve as the plot within non-warbler habitat. Fortuitously, this allowed for documentation of the changes that had occurred within these patches in the three months that had passed since the first visit. Most all of the grass at this time of year was dead probably due to external seasonal factors. However, herbaceous vegetation in the three months that had passed had already begun to reoccupy spots of bare ground (Figure 6). This suggests that this area may be able to quickly recover after disturbance by hogs.

Two patches within the non-warbler plot seemed to have occurred much more recently. One of these two patches had experienced very little new growth and based on a visual estimation consisted of approximately 95% bare exposed soil. The other fresh patch in this plot was completely denuded of vegetation and the overturned soil was still extremely moist. This pattern of patches suggests that perhaps the rooting had occurred within a few days of the second visit. Little to no litter had accumulated within this patch and the soil was still loose and uncompressed (Figure 7).

Fig. 4. Rooted Area in Warbler Habitat Showing the Difference in Color between the Disturbed Area and the Surrounding Landscape

Fig. 5. Rooted Area in Non-Warbler Habitat with an Exposed Rocky Substrate

a.

b.

Fig. 6. Comparison of Photo (a) a Rooted Area with Visible Spots of Exposed Soil Taken in the Summer of 2005 to (b) the Same Area Three Months Later

Vegetation Characteristics

The warbler plot was primarily dominated by a variety of oak and ashe-juniper trees. Individual patches were generally located in areas with clusters of ashe juniper and several very large, mature oak trees. These oak trees undoubtedly produce large mast crops that may attract hogs to the area. This was a very densely canopied area that contained very little herbaceous groundcover. While very few areas of exposed soil were evident because of the tremendous amount of leaf litter, the percentage of herbaceous vegetation within rooted patches was visibly less than the surrounding unrooted landscape (Figure 8). Even though these patches were fairly old, there were still lasting residual effects as a result of hog rooting.

The non-warbler plot was characterized by patches of scrubby tree growth interspersed with areas of open grassland. Most of the rooted patches were located near flameleaf sumac and herbaceous vegetation. This plot had considerably more herbaceous groundcover than did the warbler plot. In fact, the most extreme differences in the amount of bare soil and vegetative cover were within non-warbler habitat (Figure 9). This is perhaps because this plot had far less canopy cover and the vegetation typical of this area could more quickly reoccupy after disturbance. Throughout the plot the percentage of vegetation within the patch was significantly less than outside the patch.

Fig. 7. Freshly Rooted Areas Observed in Non-Warbler Plot

Fig. 8. A Comparison of Vegetative Groundcover within the Rooted Patch with the Surrounding Unrooted Landscape in Warbler Habitat

Fig. 9. A Comparison of Vegetative Groundcover within the Rooted Patch with the Surrounding Unrooted Landscape in Non-Warbler Habitat

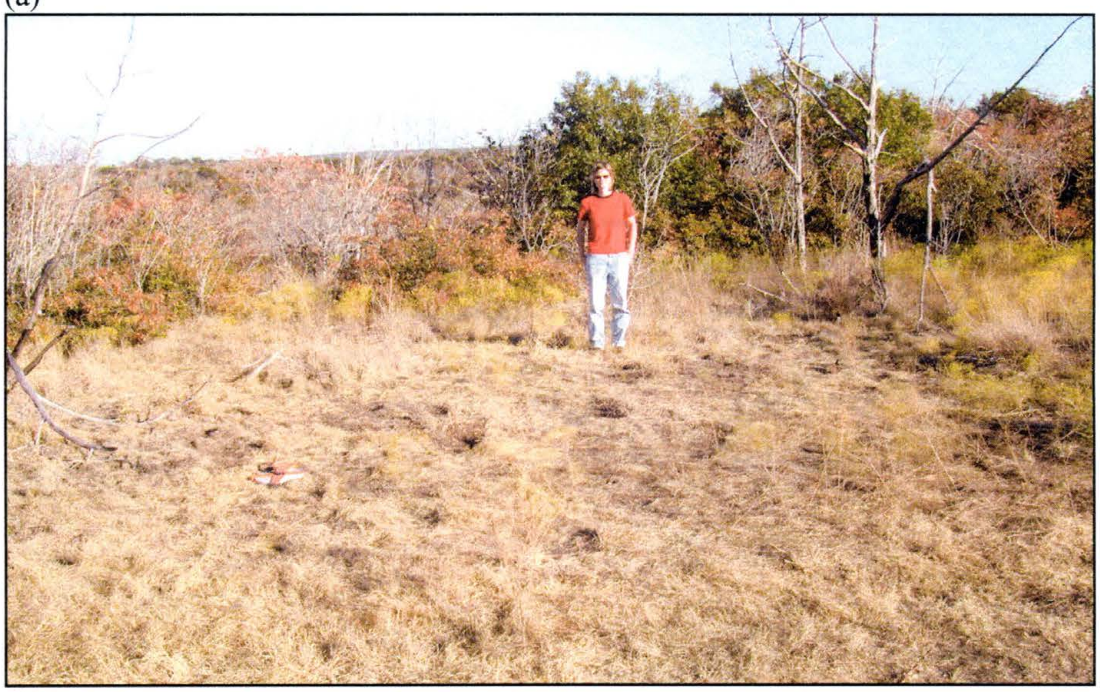
All but one of these rooted patches was located within these open areas of grassland vegetation. The exception was a freshly rooted patch located under a thicket of shin oak trees. Remnants of acorns were evident within this particular rooted patch. In addition, this area had numerous clusters of prickly pear cactus that had been uprooted by hogs, probably in pursuit of the soft mast that is provided by these succulents (Figure 10).

Geomorphic Impact

More rooted patches were observed within the one-acre plot in non-warbler habitat (6) compared to warbler habitat (4). The depth of these excavations was typical of most patches rooted by hogs (Appendix). Most of the excavations were fairly shallow, the most extreme mean depth recorded at 4.9 cm (Table 1). Often the depths would vary dramatically between each measurement, which resulted in the pits and mounds that are characteristic of hog rooting (Figure 11). For example, the depth of one pit was measured at 3 cm and one-half meter later the depth had increased to 17 cm. However, while the mean depths of rooted patches in warbler and non-warbler habitat were similar, 2.98 cm and 3.46 cm respectively, the areal extent of rooted patches was considerably different among the two habitat types. The mean area of ground surface that had been uprooted in warbler habitat (66.42 m^2) was more than twice that of non-warbler habitat (25.07 m^2). While some of the rooting was so confined that it was almost insignificant, other excavations were of considerable size.

Fig. 10. Uprooted Cluster of Cactus

(a)



(b)

Fig. 11. Pits and Mounds (a) and (b) within Rooted Patches

The range of the area of rooted patches was from 3.33 m^2 to 127.29 m^2 (Table 2).

Table 1. Descriptive Statistics for Overall Depth of Disturbed Plots

DEPTH in cm

Mean	3.274
Standard Error	0.285478935
Median	3.23
Mode	#N/A
Standard Deviation	0.902763658
Sample Variance	0.814982222
Kurtosis	0.840048887
Skewness	-0.044464661
Range	3.3
Minimum	1.6
Maximum	4.9
Sum	32.74
Count	10

Table 2. Descriptive Statistics for Overall Area of Disturbed Plots

AREA in m^2

Mean	41.607
Standard Error	13.63603006
Median	21.6
Mode	#N/A
Standard Deviation	43.12091322
Sample Variance	1859.413157
Kurtosis	0.058020931
Skewness	1.135943327
Range	124.16
Minimum	3.33
Maximum	127.49
Sum	416.07
Count	10

Patches were not always clearly defined, especially within warbler habitat, and often best judgment had to be used in delineating the confines of a patch.

Despite there being more rooted patches in non-warbler habitat, this did not prove to be indicative of a significant difference in the volume of displaced soil between the plots based on a *t*-test for equality of means. The variances within each plot were in fact the same. The volume of disturbed soil in each patch ranged from .12 m^3 to 3.19 m^3 (Table 3).

Table 3. Descriptive Statistics
of Overall Volume of
Disturbed Plots

VOLUME in m^3

Mean	1.316
Standard Error	0.405317982
Median	0.705
Mode	#N/A
Standard Deviation	1.281728
Sample Variance	1.642826667
Kurtosis	-1.474960314
Skewness	0.715034695
Range	3.07
Minimum	0.12
Maximum	3.19
Sum	13.16
Count	10

Statistical analysis revealed that although the mean volume of displaced soil in Golden-cheeked Warbler habitat (1.87 m^3) was almost double the amount of that in non-warbler habitat (.95 m^3), there was no significant difference in the extent of this disturbance (Table 4 and 5).

Table 4. Comparison of the Mean Volume in Warbler and Non-Warbler Habitat

	N	Mean	Standard Deviation
Warbler	4	1.8775	1.3785
Non-Warbler	6	.9517	1.2039

Table 5. Results of Test for Equality of Mean Volume of Disturbed Plots

H_0	t	df	Sig
Equal Volumes	1.127	8	0.292

The limited sample size in this study could not resolve the hypothesized assertion that rooting would be more prolific within warbler habitat. However, there is clearly enough data to support the hypothesis that feral hogs are having a geomorphic impact in Golden-Cheeked Warbler habitat as evidenced by the increase in exposed soil and decrease in vegetation in rooted patches.

CHAPTER VI

DISCUSSION OF RESULTS AND CONCLUSION

Summation of Results

Feral hog rooting produced geomorphically significant excavations resulting in an obvious disparity existing between the vegetative groundcover within individual patches and the surrounding landscape. Of the exotic species that do affect geomorphology, most tend to accelerate erosion (Dukes and Mooney 2004). These vegetation-deficient areas become increasingly susceptible to erosion due to the overland flow of water as well as wind action. In addition, the infiltration of water as well as nutrient concentrations in the soil are probably also affected. Rooting in these oak woodlands is likely also affecting successional patterns due to the consumption of large quantities of acorns and thus absence of successful seedling regeneration as well as death of juvenile trees within disturbed patches. Ultimately, this could result in significant changes in species' distributions and abundances. Furthermore, rooting created obvious changes in the terrain as evidenced by the micro-tread topography. Physical alteration of habitats such as that caused by rooting can indirectly influence the resources available to other organisms living in those same habitats. While this study did not show that rooting is necessarily more extensive in warbler habitat, there is undoubtedly strong evidence to suggest that hogs are playing a significant zoogeomorphic role as well as contributing to at least temporary shifts in the local plant assemblages within warbler habitat as well as Fort Hood at large. The relative sensitivity of warbler habitat to the cumulative effects of this persistent disturbance regime are yet unrealized.

Feral hogs are competitive generalists that have clearly successfully colonized as evidenced by their sheer numbers in Texas alone. These wild hogs are fairly large, wide-ranging and thus have an extraordinary intrinsic potential to influence other organisms and ecosystems at large. Continued range expansion and increasing populations of feral hogs could cause ecological havoc. As hogs continue to encroach on oak woodland habitats, increasing conflict with conservation activities like those occurring at Fort Hood is likely.

The wide assortment of interactions among organisms is being increasingly recognized as exerting a powerful influence on biological diversity. While habitat destruction is generally regarded as the primary agent of species endangerment and extinction, the incursion of exotic organisms must also be acknowledged as playing a significant role on the population dynamics of indigenous species, especially for birds (Wilcove et al. 1998). In places where these populations interact in a mutually shared habitat, the influence that invasive species have on ecosystem processes may indirectly impact native species. Critical to understanding the ecological implications of these interspecific interactions is knowledge of the context in which they occur, as well as insight on how disturbance functionally shapes and alters ecosystems.

Implications for Future Research

The implications for further research of this phenomenon are manifold. The possibility that feral hogs have any contributory effect on Golden-cheeked Warbler populations is, of course, speculative and has not been studied in depth. By and large, quantitative information on the cumulative effect of wild hogs in the predominantly oak- dominated woodlands they inhabit is lacking. Evidence of rooting in areas that warblers inhabit could lead to an in depth study of long-term alteration of warbler habitat which could then be compared with known nesting success data based on habitat quality. Continued study of this recurring disturbance will undoubtedly require a reasonable amount of vegetation analysis. The importance of vegetation as a spatial control of when and where hogs root should be emphasized in future studies. A more in depth quantitative study could be conducted to compare the plant species composition in disturbed areas with the adjacent unrooted landscape. A long-term analysis of the spatial patterns of rooting could yield more information about changes in spatial heterogeneity.

Geographic Perspective

This type of research is inherently spatial and, therefore, an appropriate topic for biogeographic research. Clear patterns of hog rooting occur that coincide with the geographic distribution of physical features on the earth's surface. Small-scale disturbances such as rooting affect species composition, diversity and ecosystem function by enhancing structural and spatial heterogeneity (Welander 2000). The spatial and temporal variations in vegetation and the soil environment can often be a direct result of small-scale disturbances that are created by animals (Denslow 1985). The quality and spatial arrangement of the elements in a landscape influence a species' ability to effectively exploit its resources. If rooting is occurring in warbler habitat, the long-term effect may be a restructuring of their current habitat, resulting in reduced fecundity. Despite the wealth of information available on the diet and habitat preferences of feral hogs, knowledge of the spatial and temporal dynamics of rooting is still relatively limited (Welander 2000). Therefore, employing a geographic, landscape-scale perspective to analyze this phenomenon seems fitting.

Conclusion

In light of their alarming reproductive rates and continued proliferation throughout Texas, continued research on the effects of hog rooting is warranted. However, measuring the environmental impact of feral hogs can be complex because of the multitude of variables that must be taken into account. Whether the effects of rooting are necessarily harmful to ecosystems remains in dispute and likely varies by region. Because some of the research on hog rooting would indicate that this recurrent disturbance regime might be beneficial to some ecosystem processes, many possibilities exist that should be considered before conclusions are drawn. More ecological research on food preferences, population dynamics and seasonal movements, as well as methods for control, will be necessary to understand and limit the affect this species has on habitats.

Rarely are estimates of population density of feral hogs available, thus one of the chief inadequacies of feral hog management is the inability to measure their abundance (Everitt and Alaniz 1980; Engeman et al. 2001). Since research is only the means for better understanding the effects of this exotic species on the landscape, action must be taken before further indigenous species and habitat vanish. Fort Hood is currently testing the efficacy of radio telemetry to improve population control throughout the installation. Various approaches to control further spread of feral hogs have proved unsuccessful. "Eradication of exotic organisms, especially ferals, is an opportunity to do good science and good conservation; it is one of the relatively few areas to actually combine the two into functioning conservation biology" (Coblentz 1990).

The presence of the feral hog has undoubtedly resulted in significant environmental impacts throughout Texas, particularly in agricultural and forested habitats. Destruction of habitat, predation of wildlife, and competition for habitat has resulted in the feral hog population becoming a major management problem (Mapston 2004). However, eradication of this species is unlikely. Therefore, science must continue to study how the small-scale disturbances created by these extraordinarily aggressive omnivores are affecting biotic species and work towards alleviating their negative impact. The possibility exists, that in areas where these populations overlap, feral hogs may be indirectly affecting the nesting success of the Golden-cheeked Warbler by physically altering their habitat.

APPENDIX

Depth of Each Patch in Centimeters at One-Half Meter Increments

Patch 1*	Patch 2*	Patch 3*	Patch 4*	Patch 5	Patch 6	Patch 7	Patch 8	Patch 9	Patch 10
0 6	4 5	3	1 5	2 5	4 5	0 5	2	6	5
2	2	6	2 5	1	4	2	5	2 5	2 5
9	3	2	3 5	1 5	2	6	3 5	2 5	4 5
2 5	5 5	4 5	4	0 5	0 5	5		8 5	2 5
3	2 5	3	3.5	2	4	3		6	1 5
5	1	4	5	0 5	4	6		2	4 5
8	5	0 5	7	5	0 5	2 5		2	5 5
0 5	1 5	1 5	6	2 5	2	1		10	5 5
2	2 5	1	4 5	1	6	0		5	5
1 5	2 5	2 5	4	1	3	2		5	4 5
3	2	3	1	2	3 5	1 5		2	1 5
4	2	0 5	1 5	2	2 5	2		6 5	7 5
2 5	2 5	1 5	6 5	0 5	11	4		1	3
0 5	4	1	0 5	1	1	5		12	3
3	4 5	2 5	2		5	3		3	2
4	3	3	1 5		2 5	2 5		4 5	0
1	2 5	0 5	1 5		3			5	3
5 5	3 5	2	3 5		1				2 5
3 5		6	8		2 5				2 5
2 5		2	6		2 5				4
2 5		7	2 5		1 5				3
1 5		1	5		3 5				6 5
3		2	0 5		4 5				3
4 5		3	2		1				4
0 5		1	2		2 5				5 5
17		0 1	5 5		4 5				2 5
3		1 5	0 5		4 5				6 5
3		1	4		4 5				3
4		1	3		8 5				4
4		3 5	0 5		7 5				5 5
2		1 5	1 5		11				2 5

* Denotes Warbler Habitat

Patch 1*	Patch 2*	Patch 3*	Patch 4*	Patch 5	Patch 6	Patch 7	Patch 8	Patch 9	Patch 10
1 5		2	2		3 5				6 5
2		2	2		4 5				5 5
		4 5	5		7				1 5
		8	2 5		5				7
		5	3		1				7
		1	3		3 5				5
		2	2 5		1 5				10
		3	1		6				8 5
		3	2						2
		4	4						2
		2	4						3 5
		1 5	2 5						3
		2 5	1						3 5
		2							
		6							
		1 5							
		2							
		0 5							
		1							
		1 5							
		0 5							
		5 5							
		0 5							
		3							
		4							
		2 5							
		5							
		2 5							
		0 5							
		2							
		2							
		1 5							
		3							

* Denotes Warbler Habıtat

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