EFFECTS OF PATCH BURNING ON NEAREST-NEIGHBOR RELATIONSHIPS AND SPECIES DIVERSITY IN GRAZED SOUTHERN TEXAS COASTAL PRAIRIES

A Thesis

by

FORREST FAY

Submitted to the College of Graduate Studies
Texas A&M University-Kingsville
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2025

Major Subject: Rangeland and Wildlife Science

EFFECTS OF PATCH BURNING ON NEAREST-NEIGHBOR RELATIONSHIPS AND SPECIES DIVERSITY IN GRAZED SOUTHERN TEXAS COASTAL PRAIRIES

A Thesis

by

FORREST FAY

Approved as to style and content by:

Sandra Rideout-Hanzak, Ph.D.
Committee Chair

David B. Wester, Ph.D.
Committee Member

Weimin Xi, Ph.D.
Committee Member

Bart Ballard, Ph.D.
Department Chair

Darin T. Hoskisson, Ph.D.
Associate Vice President for Academic Affairs and Dean, College of Graduate Studies

December 2025

ABSTRACT

Effects of Patch Burning on Nearest-Neighbor Relationships and Species Diversity in Grazed Southern Texas Coastal Prairies

December 2025

Forrest Fay, Bachelor of Science, Wildlife Ecology and Management

Auburn University

Chair of Advisory Committee: Dr. Sandra Rideout-Hanzak

Much of the historic vegetation in Texas was shaped by fire, and the removal of fire from fire-adapted ecosystems has led to numerous ecological consequences. Previous research on fire's effects in the Gulf Coast Prairies and Marshes ecoregion of Texas, USA, has largely focused on forage production and plant mortality. I evaluated effects of Winter and Summer burning on nearest-neighbor relationships in herbaceous vegetation on a private ranch with year-long livestock grazing at low to moderate stocking rates. Sixteen burn units (>150 ha each) were randomly assigned to Summer burn-short return, Summer burn-long return, Winter burn-short return, Winter burn-long return, or Control (no fire). I conducted modified step-point transects to record the nearest herbaceous plant species (focal plant), the nearest-neighboring herbaceous species, and the distance between them prior to burning and at ~6, ~12, ~18, and ~24 months post-burning. Data were analyzed using repeated measures and multivariate analyses to assess treatment effects on nearest-neighbor relationships, species richness, evenness, and diversity over time. Winter fires temporarily increased perennial-perennial herbaceous species associations. Summer fires enhanced species richness, and burning in both seasons increased species evenness and diversity relative to Controls, albeit at different post-burn times. These

outcomes reflect more than structural rearrangement, suggesting that fire modifies interactions that govern competition, facilitation, and resource sharing among plants. By acting as both a species filter and a spatial filter, fire altered the competitive, facilitative, and spatial interactions that structure herbaceous plant coexistence at fine ecological scales.
Keywords: Coastal prairies, Fire seasonality, Herbaceous species diversity, Nearest-neighbor relationships/associations, Patch burn grazing, Prescribed fire, Rangeland ecology

This thesis is formatted following the Journal of Pyrogeography's instructions for authors.

GLOSSARY:

Control (no fire): A treatment unit that has not received prescribed burning treatment or wildfire in the previous 25+ years, used as a baseline for comparison with burned treatments.

Distance Between Plants: The measured linear space between the base of a focal plant and its nearest neighbor.

Fire Return Interval (FRI): The average time between successive fires at a given location.

Microscale Processes: Ecological processes occurring at very small spatial scales, such as plant-to-plant interactions, root competition, or localized nutrient cycling.

Nearest Neighbor: The closest plant individual to a designated focal plant, used to analyze spatial associations and plant-plant interactions.

Nearest-Neighbor Associations: The relationship between a focal plant and its nearest neighboring plant, describing spatial proximity and association patterns among plants.

Patch Burn Grazing: A rangeland management strategy in which prescribed fires are applied to selected portions of a pasture or landscape at a given time, creating a mosaic of burned and nonburned patches to promote biodiversity and heterogeneous habitat structure, while livestock are allowed to graze freely.

Prairies: Temperate grasslands dominated by herbaceous vegetation, particularly grasses and forbs, with few trees or shrubs, often maintained historically by fire and grazing.

Rangelands: Lands primarily composed of natural vegetation, such as grasses, forbs, and shrubs, that are managed for livestock grazing, wildlife habitat, and ecosystem services.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

Texas Gulf Coast Prairies and Marshes Ecoregion

Southern Texas contains diverse ecoregions with distinct soils and vegetation. One of the most dominant ecoregions is the Gulf Coast Prairies and Marshes (Gould, 1975; Texas Parks and Wildlife Department, 2023; Tinker et al., 2010). The Gulf Coast Prairies and Marshes ecoregion stretches nearly 1,000 km along the Gulf of Mexico from Louisiana to Mexico, covering 9.7 million ha and ranging 32–130 km inland (Bezanson, 2000; The Nature Conservancy, 2002; Fig. 1). This region typically lies <15.25 m in elevation, is relatively flat, experiences mild winters, and receives 75–130 cm of annual rainfall, producing a growing season exceeding 300 days (Everitt et al., 1981; Gould, 1975; McAtee et al., 1979; Texas Parks and Wildlife Department, 2023). The Gulf Coast Prairies and Marshes provide a nearly year-round supply of cover and forage critical for wildlife and livestock (Hatch et al., 1990; Procházka, 2011). The common soil types in this area include clay, sandy soils, Mustang fine sand (Siliceous, hyperthermic Typic Psammaquents), and Falfurrias series soil (Mixed, hyperthermic Typic Ustipsamments) (Bezanson, 2000; Soil Survey Staff, 2023). Periodic flooding, storms, fires, and topography contribute to the diversity of soils and vegetation patterns (Diamond et al., 2024).

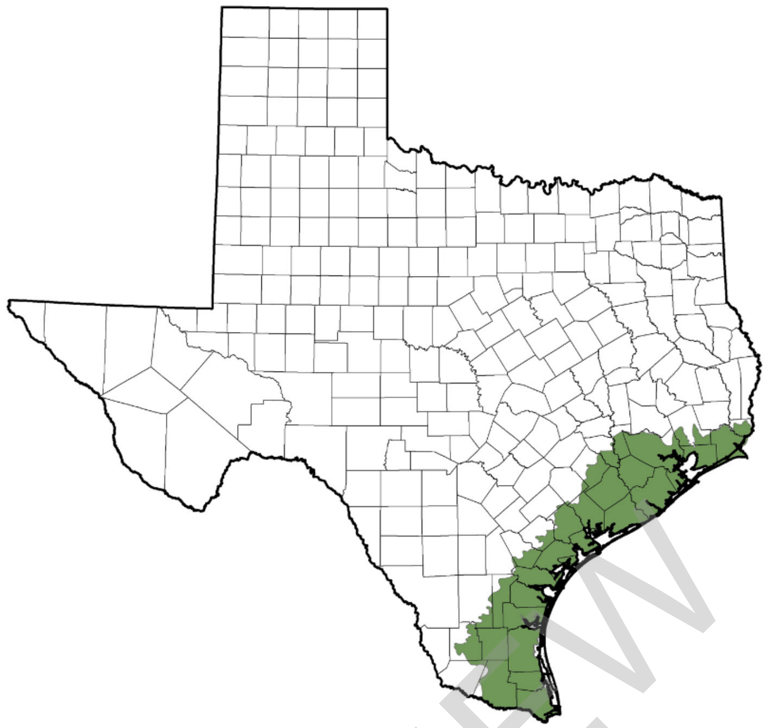

Figure 1. Gulf Coast Prairies and Marshes Ecoregions of Texas (Texas Parks and Wildlife Department 2023). https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/texas_nature_trackers/target_species/gulf_coast_prairies_marshes.phtml. Retrieved February 20, 2023.

Historic and Modern Vegetation

Before European settlement, vegetation patterns in southern Texas were shaped primarily by gradual climate changes (Tinker et al., 2000). European immigrants and subsequent urbanization altered species distributions and diversity, often favoring introduced species and impacting native flora (Hanselka et al., 2007; Ryan et al., 2013; Tinker et al., 2000). Historically, the Gulf Coast Prairies contained over 3.6 million ha of prairie, with ~36% now under formal conservation plans through collaborations among private landowners, organizations, and government agencies (Bezanson, 2000; The Nature Conservancy, 2002).

Modern Gulf Coast Prairie remnants maintain high plant diversity. Over 5,000 vascular plant species occur in Texas, ~400 of which are endemic (Hatch et al., 1990; Jones, 1997).

Nearly half of all grass species native to the United States are present in Texas (Hatch et al., 1990; Jones, 1997; Tinker et al., 2000). Key perennial, warm-season bunchgrasses in this region include Gulf cordgrass (*Spartina spartinae* [Trin.] Merr. ex Hitchc.), seacoast bluestem (*Schizachyrium scoparium* var. *littorale* [Nash] Bickn.), and Gulfdune paspalum (*Paspalum monostachyum* Vasey) (Diamond et al., 2024; Everitt et al., 2011). These species provide dynamic forage year-round, but nutritional quality and availability decline as plants mature (Everitt et al., 2011; Haynes et al., 2023). Strategic removal of unproductive biomass via mowing, grazing, or burning at appropriate growth stages promotes vigorous regrowth and improves forage quality for livestock and wildlife (Everitt et al., 2011; Haynes et al., 2023).

Nearest-Neighbor Relationships in Rangelands

In natural systems, plant distributions are often nonrandom (Pellissier et al., 2013). Organisms interact continuously with biotic and abiotic factors that influence spatial patterns at micro- to landscape scales (Clark and Evans, 1954; Kikvidze et al., 2005; Pottier et al., 2013). Phytosociology studies these patterns by examining key variables that affect distributions, such as plant age, growth form, life span, reproductive strategy, soil characteristics, nutrient availability, sunlight, hydrology, seed bank composition, and surrounding species assemblages (Cuena-Lombraña et al., 2020; Dubuis et al., 2013; Guisan and Thuiller, 2005; Pellissier et al., 2013; Weiher et al., 2011).

Nearest-neighbor approaches allow researchers to quantify plant-to-plant spatial associations and incorporate some of these variables. These studies measure distances between focal individuals and their closest neighbors to assess intraspecific and interspecific interactions, including competition, mutualism, and commensalism. Regeneration niches, created when a plant dies or is removed, provide opportunities for new individuals to establish, though the species identity of recruits may differ from the removed individual (Wester et al., 2018).

Experimental Evidence from Rangelands

Experimental studies in arid and semi-arid rangelands have repeatedly demonstrated the importance of nearest-neighbor relationships. At the Santa Rita Experimental Range in Arizona, removal of mesquite (*Neltuma veluntina* (Sw.) Raf.) or black grama (*Bouteloua eriopoda* (Torr.) Torr.) increased growth and survival of nearby grasses, including annual and perennial herbaceous species Removal of certain herbaceous species, such as burroweed (*Isocoma tenuisecta* Greene) or Arizona cottontop (*Trichachne californica* (Benth.) Chase), similarly enhanced growth of neighboring annuals, indicating competitive interactions among co-occurring grasses and forbs (Cable and Tschirley, 1961; Parker and Martin, 1952). Lehmann lovegrass (*Eragrostis lehmanniana* Nees) populations similarly reduced native perennial grass densities, showing competitive interactions in herbaceous rangeland species (Kincaid et al., 1959). In New Mexico, removing mature grasses increased growth and survival of 2-year-old threadleaf snakeweed (*Gutierrezia microcephala* (DC.) A. Gray.) seedlings (Parker, 1985, 1982; Parker and Salzman, 1985). In addition, in New Mexico grasslands, hoary tansyaster (*Dieteria canescens*) was nearly excluded in areas dominated by broom snakeweed (*Gutierrezia* spp.), highlighting competitive pressure among herbaceous annuals (Parker and Root, 1981). Density-dependent effects on survival and growth were also observed in the Sonoran Desert, where lower initial densities of annual Indian wheat (*Plantago ovata* var. *insularis* (Eastw.) S.C. Meyers & A.Liston) resulted in higher survival rates, emphasizing the role of competition in structuring herbaceous communities (Inouye, 1980; Klikoff, 1966). Tyler and D' Antonio (1995) demonstrated that post-disturbance water availability mediates competitive effects among herbaceous species, with seedlings achieving higher survival when nearest-neighbor distances increased. While competition is often the most common interaction between plants, mutualistic and commensal interactions also occur. Some perennial grasses benefit from proximity to shrubs or other species in rangelands (Yavitt and Smith, 1983).

Distance and Measurement Considerations

Distance between plants is a primary metric in nearest-neighbor studies. Plant-to-plant distance influences access to water, nutrients, and sunlight, thereby affecting growth, survival, and reproductive output (Casal et al., 1987; Fiorucci and Fankhauser, 2017; Hodge, 2012, 2009; Murphy and Dudley, 2007; Tyler and D' Antonio, 1995). Both above- and below-ground interactions matter. Root systems compete for water and nutrients, and above-ground structures compete for space and sunlight. Standardized methods, such as measuring distance from stem-to-root transition points, capture a more precise assessment of both above-ground (competition for sunlight and space) and below-ground interactions (competition for water and nutrients) between neighboring plants (Cottam and Curtis, 1956; Luo et al., 2012; Wang et al., 2018).

Fire Effects on Nearest-Neighbor Relationships and Vegetation

Fire acts as a large-scale disturbance that temporarily removes competitive constraints, releasing nutrients, eliminating biomass, and creating extensive regeneration niches (Anderson, 2006; Brockway et al., 2002; Green, 1989; Tyler and D' Antonio, 1995). The post-fire environment allows seeds and juveniles to establish in areas previously occupied, affecting spatial patterns and nearest-neighbor interactions.

Vegetation response to fire depends on three primary factors: plant traits, fire behavior, and weather conditions. Plant responses are influenced by fire tolerance, biomass allocation, chemical composition, age, growth form, reproductive strategy, and life span (Arthur et al., 1998; Castro and Leverkus, 2019; Phumsathan et al., 2022). Fire behavior factors include frequency, intensity, severity, scale, season, fuel load, patchiness, ignition technique, and residence time (Keeley et al., 2011; McLauchlan et al., 2020; Menges et al., 2021). Weather influences both fire behavior and post-fire conditions, affecting soil moisture, nutrient availability, and microclimate.

Season of Fire

Seasonality of burns influences plant competition and spatial patterns. Summer fires may coincide with peak biomass and reproductive activity, resulting in stronger reductions of dominant competitors, while Winter burns may primarily remove residual litter and have less immediate impact on plant mortality (Brockway et al., 2002; Grace et al., 2005). Seasonal timing interacts with plant life-history traits and water availability to shape nearest-neighbor relationships and post-fire community assembly. For example, fires during the wet season may facilitate germination and establishment of herbaceous annuals, whereas dry-season fires may favor perennial survival due to dormancy adaptations. Understanding these interactions is critical for predicting competitive dynamics and designing effective rangeland management practices.

Patch Burn Grazing in the Gulf Coast Prairies and Marshes Ecoregion

Patch burn grazing is a rangeland management strategy that integrates prescribed fire with livestock grazing to create a dynamic mosaic of vegetation patches across the landscape. By burning only portions of a larger area at a time, this management strategy encourages livestock to graze areas they might otherwise avoid, promoting spatial heterogeneity and enhancing biodiversity. This approach mimics natural disturbance regimes, fostering a balance between forage availability and ecological health. In the Gulf Coast Prairies and Marshes ecoregion of Texas, patch burn grazing has been shown to improve the nutritional quality of dominant grasses such as Gulf cordgrass and seacoast bluestem (Haynes et al., 2023). Research indicates that Winter burning enhances crude protein levels and reduces fiber content in these grasses more effectively than Summer burning, potentially offering better forage quality for livestock during critical periods (Haynes et al., 2023). Additionally, studies have demonstrated that patch burn grazing can influence cattle grazing patterns, leading to more uniform forage utilization across the landscape. This distribution helps prevent overgrazing in sensitive areas and promotes the regeneration of desirable plant species (Haynes, 2018; Haynes et al., 2023). Implementing patch burn grazing in the Gulf Coast Prairies and Marshes ecoregion offers a promising approach to sustainable rangeland management, aligning ecological restoration with agricultural productivity.

Project Objectives

There were four main objectives for my study.

1. Determine existing herbaceous relationships in the Gulf Coast Prairies and Marshes ecoregion of southern Texas in undisturbed areas by identifying nearest-neighbor plant relationships.
2. Analyze the effects of Summer burning and Winter burning on relationships identified in Objective 1.
3. Examine the effects of Summer burning and Winter burning on herbaceous species richness, diversity, and evenness.
4. Compare the distance between plants in burned vs. nonburned areas, as well as pre-fire and post-fire, to evaluate how fire influences spatial patterns of herbaceous vegetation.