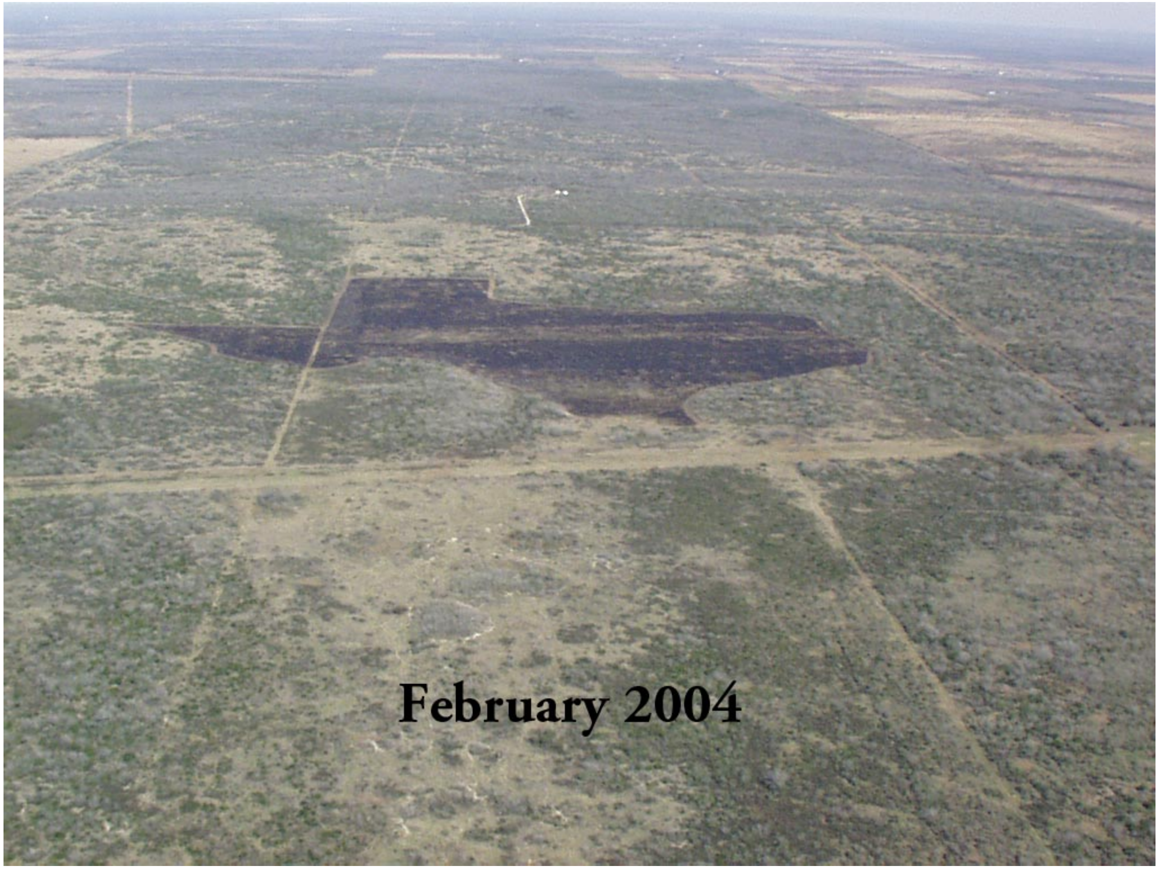
Fire as a Tool for Managing Wildlife Habitats in Texas

A Symposium for Land Managers

September 14 – 16, 2005

Kerrville, Texas

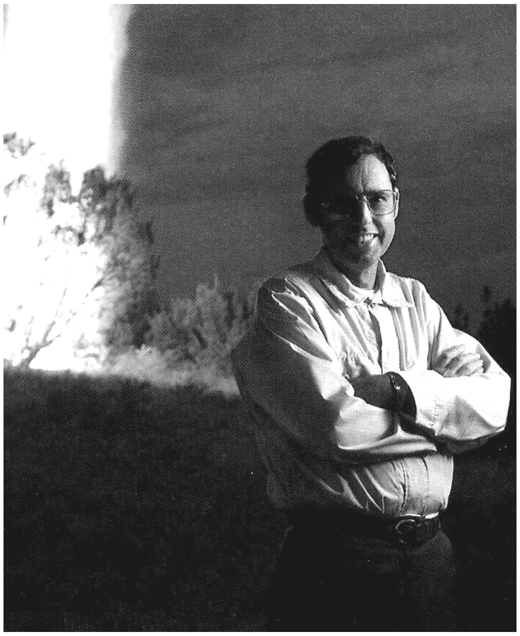


State of Texas design that was sculpted mechanically and subsequently burned, La Copita Range Research Area, Alice, Texas. (Courtesy C. W. Hanselka)

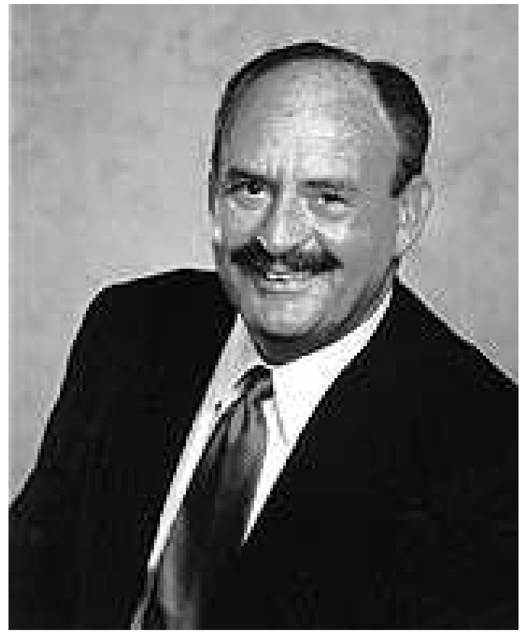
Texas Cooperative EXTENSION
The Texas A&M University System

September 2005

DEDICATION

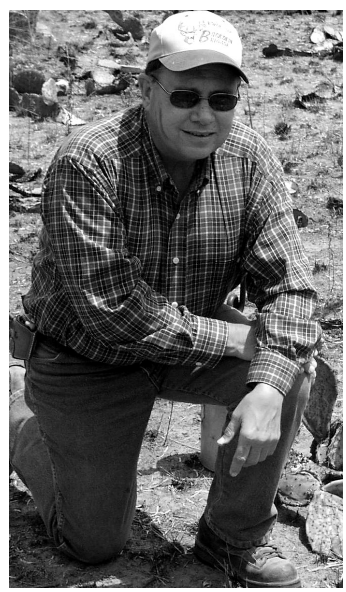


Dr. Henry A. Wright (*deceased*)



Dr. Charles J. Scifres (*deceased*)

Mr. W.E. (Bill) Armstrong



Mr. Alan Heirman

DEDICATION

This symposium is dedicated to 4 "firebrands" whose collective efforts have fostered our understanding and application of fire as a management tool on Texas rangelands: Dr. Henry A. Wright (deceased), Dr. Charles J. Scifres (deceased), Mr. W. E. (Bill) Armstrong, and Mr. Alan Heirman. Without their respective contributions to the art and science of prescribed burning, the tool would likely still be relegated to *conversation*, and not broadly applied to *conservation*. I consider myself fortunate that I have known and worked with each of these men during their respective tenures.

I met Dr. Henry A. Wright during my doctoral program at Texas Tech University, and was introduced to his landmark class on prescribed burning on rangelands. We applaud his foresight and tenacity to empower a tool that generates heat – both literally and figuratively. He was a rather frail man; but he must have had a strong back. I'm sure there were times when his administrators would have just as soon he had undertaken range reseeding rather than prescribed burning.

Dr. Scifres and I met rather late in his career. He had already climbed the administrative ladder and took big strides therein. Charlie was known as a man of action – he attacked range renovation, graduate students, and administrative bureaucracy with the same zeal. His contributions to the science of brush management and systems approaches laid a foundation that continues to be applied in thornland-scrub habitats worldwide.

W. E. "Bill" Armstrong will always be a champion in my eyes. He helped me numerous times with plant identification during my doctoral study, and has provided me counsel on both biology and biopolitics throughout my career. I think I read somewhere one time where Bill, along with his long-term partner Donnie Harmel, had given over 5,000 educational programs at the Kerr Wildlife Management Area. But in any given group, you would have thought you were the first ones to tour the area. Bill always kept his messages fresh despite likely having answered the same question at least 4,900 times. And when one of those questions involved fire, it always brought a sparkle to Bill's eyes.

Alan Heirman is a "good dog", and being a personal friend and avid quail hunter, knows that when I use that phrase my context is one of superlative service. I credit Alan for being largely responsible for the promotion of fire across the Rolling Plains ecoregion. I suspect Shackelford County burns more country (in a prescribed manner) annually than any county in the U.S., and without Alan's "pestering", it would be just another good prospect for burning.

Drs. Wright and Scifres passed away within the past couple of years, and Bill and Alan are retiring this year. While we will miss them on the fireline, we applaud their careers and wish them a productive, and sometimes smokey, retirement.

■ Dale Rollins
14 September 2005

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FOREWORD

"The urge to comprehend must precede the urge to reform."
- A. Leopold

Nothing draws visibility, and evokes passions, quite like a column of smoke against a Texas sky. To some it means sound the alarm and gather the locals to rush to the scene with the pumper rigs. To others it kindles a fascination from the "original Agent Orange". When the phrase "prescribed burning" is mentioned, the former group mutters "pyromaniacs" – the latter boasts "pyromanagers."

While a student at Texas Tech University in the early 1980s, a fellow graduate student introduced me to the term "pyromancy" – using fire to foretell the future. Over the past 100 years the future of rangelands without periodic doses of fire has been defined quite vividly. The "future" may be quite apparent, i.e., a drastically altered landscape (via proliferation of Ashe juniper [*Juniperus ashei]* or eastern redcedar [*J. viriginiaus*]), or more transparent as in the demise of various pyrophilous species like prairie chickens (*Tympanuchus* spp.) and black-capped vireos (*Vireo atricapillus*)

Most of us have an appreciation of, if not fascination for, fire as a management tool. It seems so much more "natural" than a crawler tractor or a spray plane. Carrying a drip torch along a headfire brings a sense of power probably not unlike that when Neanderthals held their first torch. As my colleague Butch Taylor often writes "happiness is smoke on the horizon." But we know there are situations where the bulldozer and herbicide are better habitat management tools than a drip torch.

Fire has its place, and its purpose – but it isn't a nostrum. We gather here this week to continue our education about the how's, when's, why's, and where's that fire can become a positive tool for shaping wildlife habitat in Texas. Texas is a diverse state, and the role of fire intuitively changes from one ecoregion to another.

School is in session for the next 2 days. I encourage you to take the opportunity to observe and question our speakers. They bring years of experience to the lectern . . . but we all have more to learn.

-- Dale Rollins, Chair
Steering Committee

THE SPREAD OF FIRE

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Abstract: The past 25 years have witnessed a resurgence in the popularity and application of fire as a tool for managing wildlife habitat in Texas. Research efforts like those contained this proceedings have helped to define (and refine) appropriate applications and prescriptions for using fire effectively. Certain species are (at least historically) fire-obligate species (e.g., black-capped vireos [*Vireo atricapillus*]) while others are fire-facultative (e.g., white-tailed deer [*Odocoileus virginianus*]). Vegetation shifts (e.g., encroachment of junipers [*Juniperus* spp.]) and the expense of controlling such brush with mechanical or chemical means have done as much as anything to promote the use of fire. Contributions to our understanding about fire by change agents such as H. A. Wright and C. J. Scifres, and its application by practitioners such as W. E. Armstrong and A. Heirman have demonstrated the utility of burning. The future of fire as an accepted tool hinges on our ability to promote it effectively and safely. Educational programs like this one help secure the underpinnings of the continued use of fire as a tool in Texas.

Introduction

I had my first experience with an out-of-control fire when I was about 9 years old . . . and it scared the bejabbers out of me. I had my first experience with a prescribed burn in 1981, and by comparison it provided a sense of nirvana.

My escape came at the hands of my best friend Mike and my younger brother Kent. We'd walked the half mile from our house to the local convenience store. Our trek took us adjacent to the local sale barn. Somehow or another (details are sketchy) we had possession of some matches. On our return from the Quickie Mart we caught a horny toad (*Phrynosoma cornutum*), and for reasons I cannot defend today, decided that it should burn at the stake. That was our first mistake. Our second was that we built the funeral pyre adjacent to a stack of grass hay. Immer schlimmer. Before you could say "*Phrynosoma cornutum*" the side of the haystack was ablaze. Last thing I remember was beating my two comrades in crime back to the house. We confessed our crime to Mom, who made us tell Mr. Dennis at the salebarn. After such trauma, it's a wonder I ever picked up a driptorch later in life.

My first prescribed burn was also a bit of a ritual I reckon – burning cedar (*Juniperus ashei*) slash piles on the Y.O. Ranch right here in Kerr County – in late July nonetheless. But this time, our madness had method. My doctoral research at Texas Tech University involved quantifying the response of white-tailed deer (*Odocoileus virginianus*) to mechanical brush control. So, after chaining various areas, we burned the resultant slash piles. We'd initiate our fires nightly about dark when the relative humidity edged above 40 percent. We burned off slash piles bigger than your house without incident. Sometimes when we'd light off a 20-acre clearing full of slash, the surroundings would become so bright that the songbirds would give a daylight serenade – at 1 a.m.

Dawn would find me patrolling the burned areas to check for any lingering stumps that might cause problems later. Deer and turkeys (*Meleagris gallopavo*) could be seen investigating the still smoldering burns. I remember one particular herd of 3 bachelor bucks that spooked from their bedding spot – a bed of ashes where a pile of juniper had stood just 8 hours earlier. It was then that I began to appreciate a lesson in "patternology" (i.e., "a scientific study of patterns") — where there's smoke, there's wildlife.

I was fortunate to have served a tour of duty with Drs. Henry Wright and Fred Bryant during my tenure at Texas Tech University in the early 1980s. Both instilled in me the knowledge that the difference between a prescribed fire and a wildfire is (paraphrasing Mark Twain) "the difference between lightning and the lightning bug." A fire can be a pit bulldog, or an English setter, depending on which conditions you unleash it in.

Smokey Bear is an American icon for baby boomers. Smokey, in concert with Disney movies like Bambi, painted a message that fire was universally bad. Conjure in your mind the forest animals fleeing from a fire in stampede fashion. I've done a fair amount of burning over the past 25 years, and have never seen anything like that. The only animal I can recall really hightailing it from advancing flames was a jackrabbit (*Lepus californicus*). During a study to document responses of bobwhites (*Colinus virginianus*) to prescribed burning, we observed several times when quail would flush just in front of an advancing headfire only to fly a short distance to the side or back over the flame front (Carter et al. 2002). I can recall seeing only 1 animal fricasseed – an armadillo (*Dasypus novemcinctus*). J. F. Cadenhead forwarded a photograph of a coyote (*Canis latrans*) that was thoroughly scorched during a prescribed burn near Vernon (note: both of the above situations were observed during fires with a heavy canopy of common broomweed [*Amphiachyris dracunculoides*]). On the contrary, I've seen deer resting in the smoking ashes of a prescribed burn, and quail sifting through the cinders in search of seeds.

Back in March 1986 I was assisting with a prescribed burn on a private ranch located at the southwestern corner of the Wichita Mountains National Wildlife Refuge (WMNWR) west of Lawton, Oklahoma. It was a cloudy day and the smoke hung low as it blew from the ranch across the Refuge (which boasts a large herd of bison [*Bison bison*]). About 11 o'clock that morning, 1 member of our burn crew called our attention to a herd of bison that was approaching downwind of our location. Their path of travel took them directly upwind into the smoke trail. It appeared as if the bison were headed for the source of the smoke like a moth to a flame. Now, this may have been purely coincidental, or maybe it was a yearning for something more historically ingrained in the prairie herbivores. But interesting nonetheless.

Fires caused by Native Americans or lightning were a driving force in vegetation management in the Southern Plains for thousands of years. The tallgrass prairies of the Great Plains probably had the highest frequency while the more arid Trans-Pecos region had less frequent fires. But we changed all that when we fenced the range and introduced domestic livestock. 'Fire' literally became a four-letter word that was to be tamed at all opportunities. Such landscape-level fire suppression changed the look of the landscape. Look at a Texas hillside covered with juniper (*Juniperus* spp.) and you can see firsthand consequences of fire suppression. As my preacher puts it "you're free to choose your actions, but you're not free to choose the consequences."

Wildlife response to burning varies with the species involved, and the region of interest. Fires in late-winter tend to favor grasses, while fires conducted in the fall tend to favor forbs (Hansmire et al. 1985). Case studies for several species of Texas wildlife are addressed in these proceedings.

I can think of no habitat management tool more important for deer than fire . . . period. An instructor (P. A. Vohs) during my tutelage at Oklahoma State University used to recommend "a hot fire and a windy day" to reverse the decline of mule deer in the Rocky Mountains. Fire increases palatability of browse plants and increases their nutrient composition for a short period following. Fire can also stimulate certain plants within the community. Perennial legumes are promoted, especially on coarse-textured soils. If you're seriously into deer management and live east of the 100th meridian, fire should be a key component of your habitat management toolbox.

In the southeastern U.S., the bobwhite is sometimes referred to as the "bird of fire." Frequent fires (perhaps every 2 years) are prescribed to enhance bobwhite habitat in pine (*Pinus* spp.) - bluestem (*Schizachyrium* spp.) ranges (Brennan et al. 2000). As one moves westward, the desired frequency of fire for bobwhites decreases. In the western Rolling Plains, fire would be appropriate perhaps 1 year in 10 in the absence of grazing. Fire promotes certain seed-producing forbs that are important for game birds, and attracting insects (which are the "perfect" quail food).

Smoke signals

"*The role of education is to replace an empty mind with an open one*."
– D. Cavett

I remember attending my first symposium on prescribed burning as a management tool in the fall of 1980 in Junction (White 1980). I suspect some of you were there. It was headed up by Texas Cooperative Extension (then Texas Agricultural Extension Service) range specialists L. D. White and C. W. Hanselka. Over the next decade demonstration burns by Extension, Natural Resource Conservation Service, and Texas Parks and Wildlife Department reinforced the message that the timely application of fire was an integral tool for managing rangeland habitats in Texas.

Dr. Wright and his graduate students at Texas Tech put up smoke columns on the High and Rolling Plains while Dr. Scifres and his students echoed with fires in South Texas and the Coastal Prairie. Alan Heirman was promoting fire in the Rolling Plains and Bill Armstrong and his associates at the Kerr Wildlife Management Area were fanning the flame in the Edwards Plateau. Smoke is highly visible, and with such visibility is afforded the venue to address the role of fire as a management tool.

As an Extension range specialist for Oklahoma Cooperative Extension during the mid-1980s, I promoted prescribed burning at every opportunity in Oklahoma. The expansion of eastern redcedar (*J. virginiana*) provided a podium from which to advocate the return of fire to the prairie. I likely made some chemical companies squirm when I referred to fire as "the original Agent Orange", and surely made my administrators nervous traveling the state as a "Johnny Drip Torch."

If you burn very much, you will inevitably have an escape. I've had 2 escapes during my involvement with about 40 prescribed burns – together they burned about 10 acres outside our fire lines. A trivial amount of acreage for sure, but you couldn't have told it by the media stir on the latter escape. We were burning on Angelo State University's Management, Instruction, and Research Center just north of San Angelo as part of Carter's (2002) study of bobwhites to prescribed burning. It was a blustery day, and just as we got within the final hour of our burn, a gust of wind carried flames across our fire break and onto the adjacent San Angelo State Park. The fire brought out volunteer fire departments like turkeys to a corn feeder. It also brought the local television station.

I wasn't the fire boss that day, but when the local reporter couldn't get an interview from anyone else, I visited with her. It was a blustery day, and one could rightfully question why we'd chosen to burn under such weather conditions. I told the reporter about our objectives for burning and admitted there are always inherent risks associated with rangeland fires. And then I asked that she return in 2 weeks to do a follow-up story about our research effort, and the role that fire had played. She did return and the resulting news story afforded an opportunity to make lemonade out of a lemon.

This past summer (2005) had much of Texas poised as a tinderbox. Good rainfall during 2003 and 2004 produced heavy fuel loads, and then a dry spring and summer set the stage for wildfires on a large scale. It was exactly the combination of weather conditions that must have witnessed some awesome conflagrations for thousands of years here at the southern end of the Great Plains.

But fences, overgrazing, and a general "pyrophobia" among landowners and the general public held prescribed burning at bay for 75 years. In 25 years of dealing with landowners, I've found that it's difficult to take the plow out of the farmer's hands, and to put a drip torch in a rancher's hand – it just tends to go against their grain. Hence we proceed deliberately realizing that there are several reasons for not implementing fire (e.g., liability concerns). But we are constrained to keep trying, and developing the knowledge base and technologies (e.g., prescribed burning cooperatives [Taylor, this volume]) that will permit the application of this powerful, and natural, management tool.

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HISTORY AND USE OF FIRE IN TEXAS

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Abstract**:** Fire was a significant force in the development of many of the natural ecosystems of Texas until the time of settlement by Europeans when fire suppression essentially removed this disturbance factor from the landscape. The result was an often rapid conversion from more open, not necessarily woody plant free, grasslands and savannahs to a greater density and stature of shrubs and trees. The occurrence and impact of fire, is, of course, highly interactive with climate/weather conditions, topographic features, grazing impacts and soil conditions. Ignition sources for fires of the past are debated, however, most evidence suggests that lightning and Native Americans together produced a high frequency of fires in most regions of Texas that produced sufficient fine fuels and were seasonally dry. For a period of time early settlers may have added to this burning culture to be later followed by fire suppression. Alteration of this major feature of the natural ecosystems of Texas and its impacts on the structure and composition of natural plant and communities may have allowed succession to cross thresholds that may be difficult to reverse when fire is re-introduced. Current knowledge of and interest in fire as a management tool makes it a highly desirable tool for natural resource management. Use of this tool is hindered by safety and legal issues, as the urbanization of our rangelands and forests increases.

Introduction

Ecosystems are the result, and expression, of a multitude of interacting factors. Climate, soil, landforms, plants, animals, microbes, fire and the historical, as well as the current interactions of these components all contribute to the landscapes that we observe today. To single out one factor such as fire, is to almost certainly error in interpretation since the impact of fire is tempered by climatic conditions, such as drought, soil and topographic factors, grazing impacts and other variables (Wells 1970, Norton-Griffiths 1976, Pyne 2001). Climate, soil and landforms establish the stage upon which ecosystems are displayed, while fire serves as a ubiquitous modifier of these systems primarily through its alteration of the structure and composition of the vegetation. Of course, wildlife populations are responsive to all these variables.

Fire must be considered a natural component of many modern ecosystems. Direct evidence of fires that occurred prior to recorded history is difficult to find, particularly where tree fire scars and other direct indicators may be absent or minimal. Indirect evidence in the form of the great many fire-adapted plant species, the presence of fire-adapted species on the margins of grasslands, savannahs and other seasonably dry ecosystems and the possible evolutionary selection of plant species for high flammability, suggests that fires have had a significant influence on the development of ecosystems throughout the earth's history (Komarek 1965, Mutch 1970).

The long-term

One of the first tools that ancient man employed to manipulate his environment was fire (Stewart 1955, Pyne 2001). Fire has been an ecological factor of importance since the early development of terrestrial ecosystems. For millions of years the presence of fusain (fossil charcoal) in Paleozoic, Mesozoic and Cenozoic sediments is generally considered to be the result of naturally occurring fires (Komarek 1968, Pyne 1995). The cause of these ancient fires is speculative, however, Komarek (1965, 1968) suggests that lightning, vulcanism and spontaneous combustion were completely adequate to account for a high frequency of fires in most ecosystems. While operating in the distant past these fires initiated the long selection process for our modern fire-adapted flora and fauna.

By early Holocene (last 10,000 yrs), man was using this tool to markedly influence the extent, composition and structure of existing ecosystems. It is the view of many observers that fire is the main factor in maintenance of tropical and subtropical grasslands and savannahs. Talbot and Kesel (1975) conclude that:

"Man using fire is the major factor in the maintenance, and if not in the formation, at least the expansion of savannahs. It is suggested that savannah grasses could have originated in ecologic niches resulting from climatic, soil or drainage conditions. Continued burning along forest-savannah boundary has allowed these grass species to spread into areas disturbed by fire."

Similar observations can be made for many North American temperate grassland, savannah and forest ecosystems (Komarek 1965, Kay 1995, Williams 2001). Sauer (1975) and Stewart (1955) propose that treeless grasslands of North America are the product of repeated fires set by Native Americans. Wells (1970) presented evidence that woody plants could grow in nearly all parts of the Great Plains grassland. Nonetheless, they were absent from all but the rougher more dissected topography. He feels that past fires have played a major role in restricting the amount and distribution of woody plants on the open, flat portions of the Great Plains.

Conditions

For fires to occur the requisite conditions must exist: fuel (variable in kind, amount and condition), favorable environmental conditions (dry fuel, low atmospheric humidity, oxygen availability, etc.) and an ignition source (lightning, anthropogenic, etc.). Considerable debate exists as to the primary ignition source of fire in Texas, or elsewhere in North America, prior to the advent of European man. It would seem from most historical accounts as well as documented occurrence of lightning strikes that this factor alone would account for high frequencies of fire in many regions of the State (Pyne 2001).

Komarek (1965) likewise states for modern ecosystems, "*that the potential for lightning-caused fires over the North American continent is so great that it fully fills the need for a meteorological basis for fire environments and fire ecology.*" Of course, lightning strikes must occur during the proper conditions for fires to occur. Taylor (2005) illustrated for the Edwards Plateau region of Texas that June through September has the highest frequency of lightning strikes. In most years this would follow the early growing season production of fine fuels and would occur during the hot, dry late summer weather conditions typical of that area. This suggests that the requisites for fire are commonly present at this time for a high frequency of fires.

Conversely, it is noteworthy that Native Americans and early Europeans may have applied fire in seasons that would not normally coincide with high fuel loads, dry weather and adequate lightning strikes. For example, Kay (1995) postulates that the fire regime for western aspen (*Populus tremuloides*), which is considered to be a fire-maintained species, has changed in terms of the timing of ignition. Today it is referred to as the "asbestos-type" or as a fire break during the time of normal high lightning strikes since it is usually moist and fire resistant during that period. Native Americans very likely burned these aspen woods during periods when aspen was dry and flammable and lightning strikes were absent or minimal.

Texas fires

No well-documented record of the extent and frequency of fire in Texas exists for the period of the Holocene or during the time of the early Native Americans. Evidence from similar environments in other areas of North America would suggest that fire was a common element in these regions (Swetnam 1988). Naturally started lightning fires, as well as accidental and intentional anthropogenic fires, would have likely contributed to a relatively high fire frequency (Pyne 2001). Broadcast fires over large areas could occur relatively infrequently and still have significant long-term impacts on the composition and structure of the native vegetation, particularly for non-sprouting woody species. Even sprouting species, such as Redberry juniper (*Juniperus pinchottii)* and mesquite (*Prosopis glandulosa)*, would be substantially altered in stature in the presence of relatively infrequent fires, especially if fires occurred during hot and dry conditions (Ansley and Jacoby 1998).

Following the entrance of Native American populations to North America some 12,000 or more years ago, it seems that their contribution to the frequency, extent and timing of fires would have been additive, in respect to lightning-ignited fire, thus increasing the impact on the fire regimes of Texas and elsewhere. When European man arrived, before their ultimate suppression of fire as a significant force in Texas, their early use of fire along with Native American and lightning ignited fires may have produced a maximum expression of fire frequency for a period of a century or more.

Historical records for the occurrence of fires are readily available but suffer from lack of temporal/spatial resolution (Lewis 1983, Williams 2001). There are, of course, no definitive historical records of fire frequencies for grasslands, however, the historical prevalence of fire cannot be denied (Humphrey 1958, Jackson 1965, Lehmann 1965, Cable 1967, Wright and Bailey 1980, Smeins 1980). Evidence from ecosystems that have woody plants present for analysis of fire scars suggest that fires have been widespread during the past several hundreds to thousands of years (Arno 1976, Martin 1975, Swetnam and Betancourt 1990). Fire frequency varies from 2 to 25 years for most forested areas with seasonably dry environments. There is no reason to believe that grasslands, shrublands, forests and other Texas ecosystems burned at any lower frequency. Exceptions to this generalization occur. There is debate as to whether arid regions of the Trans-Pecos experienced significant fire impacts (Buffington and Herbal 1965, Wright 1980, McPherson 1995, Drewa and Havastad 2001) and if they occurred whether they were positive or negative. Additionally, in many arid regions where overgrazing and fire suppression have resulted in dramatic vegetation/soil alterations it is unlikely, even if fire were historically important, that it could be reintroduced in any meaningful manner (Hennessy et al. 1983, Schlesinger et al. 1990).

It is well documented in other regions that Native Americans used fire as a vegetation and wildlife management tool (Lewis 1983, Gruell 1983, DeVivo 1990, Williams 2001). An early account (1528) by the shipwrecked Cabaza de Vaca would suggest that Native Americans indiscriminately, but often by design, used fire as a vegetation/animal population management tool in Texas prior to European settlement. From his diary comes this quote: (Bandelier 1905)

"The Indians go about with a firebrand, setting fire to the plains and timber so as to drive off the mosquitoes, and also to get the lizards and similar things they eat, to come out of the soil."

Likewise, Foster (1998), based on the 1684-1687 journals of the LaSalle expedition to Texas, indicates that fire was widely used by Native Americans to manipulate vegetation and animals. There are those who believe, however, that the widespread use of fire by the Native Americans was largely acquired from their association with European settlers (Weniger 1984); a view that appears inconsistent with most available information. As assessed by Pyne (1995) Europeans observed and followed the Native American approach to the application of fire as a management tool.

Whatever the cause, Native Americans, lightning or other factors, fire is considered by most to have been a common feature of the forests and rangelands of much of North America during the Holocene and up to the time of European settlement (Sauer 1975, Stewart 1955, Komarek 1965, Wells 1970). There is little argument; however, that the impact of fire on the vegetation is significantly controlled by the type of landscape in which it occurs. Heterogeneous landscapes of varying topography, rocky outcrops and patchy surface fuels are affected very differently from areas of level terrain with a continuous cover of fine fuels (Wells 1970). During the period from the late 1800's to the current time increases in the density and stature of woody plants is well-documented for most regions of Texas as well as much of North America. Frequent, severe fires prior to that time would have tipped the balance toward more open grassland/savannah type communities.

Certainly, the explorers and first settlers in Texas observed fire as a widespread phenomenon. From the 1700's to 1880 frequent and extensive fires were documented (Parker 1836, Olmsted 1857, Bandelier 1905, Roemer 1935, Williams and Lee 1947, Newcomb 1958, Box 1967, Krueger 1976, Wright and Bailey 1980, Goyne 1991). These fires would have maintained open, not necessarily woody-free, grasslands that are believed to have existed over much of Texas. Foster (1917) presents a summary of conditions for the Edwards Plateau in the early 1900's:

"The causes that have resulted in the spread of timbered areas are traceable directly to the interference of man. Before the white man established his ranch home in these hills the Indians burned over the country repeatedly and thus prevented any extension of forest areas. Almost unquestionably the spread of timbered areas received its impetus with the gradual disappearance of grassland fires".

For a period of time prior to intensive settlement, fires may have become more frequent and were applied to areas that would not have naturally been predisposed to fire. Clearing the land of woody vegetation to provide more open areas for grazing and to improve the growth and quality of the grass, clearing of areas for growing of crops and sometimes for ancillary reasons was commonplace. As an example Krueger (1976) reported that in the 1880's fire was used by the settlers to prevent wild pigeons that fed on the juniper berries from turning on their crops:

"...The farmers, being afraid that the pigeons were going to ruin their crops, decided to burn the beautiful cedar forests. For weeks and even months the sky was black with clouds of smoke and the fine particles of ashes carried along by the wind would settle in the lungs and make breathing painful. In this way some of the most profitable forests of mountain cedar in our state were forever destroyed."

Suppression of fire - changes and consequences

Historical reports and experimental data indicate that many areas that are densely wooded today were open grasslands or savannas prior to settlement (Inglis 1964, Weniger 1984, Schmidly 2002). Some areas were not conducive to repeated fires because of the highly dissected topography and fine fuel discontinuity. Woody plants were always present and often abundant within rocky outcrops, canyonlands or along waterways where fires were less likely; but, were also embedded within the grassland matrix (Kennedy 1841, Williams and Lee 1947, Johnston 1963, Scifres and Hamilton 1993) which created a grassland physiognomy but with considerable woody species present. Prior to settlement, the frequency and location of fires was probably highly variable resulting in vegetation changes from periods when closed canopy woodlands were common to times when frequent fires limited the abundance and stature of woody species. Certainly woody plants that occur today existed throughout the Texas landscape. Often there was a dynamic mosaic of local patches of woody plants that expanded and contracted through time to produce a shifting pattern of plant communities within a local landscape. Recent research suggests this may be an approach for improved livestock and wildlife conditions by using patch burning within managed pastures (Fuhlendorf and Engle 2004).

Historical data, short-term research studies and simulation models (Fuhlendorf et al. 1996) show that the elimination of fire can result in a change from a grass dominated plant community to nearly closed canopy woodland in one to a few decades (Smeins and Merrill 1988, Archer 1995) regardless of grazing intensity. Increased woody plant abundance results in decreased herbaceous production, amount and continuity of fine fuel on many Texas rangelands. Increase of woody plants is commonly caused by a decrease in fire frequency which is not directly dependent upon grazing, but encouraged by excessive stocking rates that lower the fuel load required to carry an intense fire (Fuhlendorf and Smeins 1997). However, other factors have contributed to the decrease in natural and prescribed fires, such as apprehension of fire and the development of second homes in rural regions of Texas. Foster (1917) saw this in a similar manner and described it adequately over 75 years ago:

"Before the white man established his ranch home in these hills the Indians burned over the country repeatedly and thus prevented any extension of forest areas. With the settlement of the country grazing became the only important industry. Large ranches in time were divided into smaller ranches and farms with a consequent fencing of ranges and pastures…The practice of burning has during the recent years, disappeared. The few fires which start are usually caused by carelessness, and with alternating wooded and open spaces and the close-cropped grass, they burn only small areas. These conditions have operated to bring about a rapid extension of woody growth. Almost unquestionably the spread of timbered areas received its impetus with the gradual disappearance of grassland fires."

This phenomenon has been exacerbated in recent years and continues at present with the marked "urbanization" of our rangelands and forests.

As Texas became settled, burning of rangelands and forests became unpopular for safety reasons as well as loss of livestock forage, destruction of valued timber, perceived loss of wildlife habitat and lack of understanding of the role of fire in maintaining our natural ecosystems. Even in the absence of purposeful fire suppression, the occurrence and impact of fires was greatly constrained due to "fire-proofing" of many areas as a result of overgrazing and concomitant loss of fine fuels to carry intense fires, fragmentation of the landscape by intermixing cropland with grassland and forest, creation of road systems. These and other contributions of civilization reduced the potential for fires to occur and limited their extent if they did occur.

Wildfires create safety problems, loss of resources and property when they occur at the wrong time and place. This, along with lack of understanding of the value of fire as a natural component of ecosystems, lead to a period of fire suppression. Fire suppression became the North American approach to fire management as settlement progressed (Pyne 1995) and Texas was no exception. As early as 1848 Texas law was passed that made it illegal to fire the prairies between July 1 and February 15. In 1884 another law made setting fire to any grass a felony. It was not until 1999 that a law was passed that unambiguously allowed a landowner to conduct prescribed burns on his or her property (Taylor 2003).

Our understanding of the ecological value and uses of fire has increased since the first settlers arrived to North America. Our dilemma today is to reintroduce fire into systems where it may have been absent for decades, and hence, deal with ecological changes that may be difficult to reverse (Briggs et al. 2005). We must do so in a manner that is safe and yet accomplishes desired goals for wildlife management and other ecosystem values. The remainder of this Symposium will deal with these practical matters and will hopefully provide the background for safe and ecologically sound re-introduction of fire as a management tool in many of the natural/semi-natural ecosystems of Texas.

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INTEGRATING COOL-SEASON PRESCRIBED BURNS INTO A TOTAL RANGE LIVESTOCK AND WILDLIFE MANAGEMENT PROGRAM

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Abstract: Twenty-six years of prescribed fire history on the Kerr Wildlife Management Area have demonstrated that prescribed fire is a tool that can be used to control noxious brush, improve vegetative species composition, improve vegetative nutritive value, and improve animal performance. In order for prescribed fire to be successful however, it must be integrated into a total range management program that includes proper stocking of both livestock and wildlife species (exotics and white-tailed deer (*Odocoileus virginianus*)), use of rotational grazing systems, and integration into planned noxious brush control program.

Introduction

Prior to the time of European settlement (1840-1880) natural and man-caused fires coupled with the grazing habits of bison (*Bison bison*), shaped the vegetation and natural systems of the Edwards Plateau. From 1900 to the 1940, major changes took place in the hill country. With settlement came perennial overgrazing by livestock and control of fire. Native grasslands gave way to brush lands. Increased numbers of white-tailed deer (*Odocoileus virginianus*) as well as the impacts of sheep and goat grazing removed the most palatable species of shrubs, leaving undesirable plant species such as juniper *(Juniperus ashei),* mesquite *(Prosopis glandulosa),* agarito (*Berberis trifoliolata)*, whitebrush (*Aloysia gratissima*), and persimmon (*Diospyros texana)* to become dominant species. Liveoaks (*Quercus virginiana*) that survived the early grazing also became dominate overstory species. By the 1940s, much of the region was dominated by large areas of mature juniper commonly referred to as "cedar brakes".

The Kerr Wildlife Management Area was purchased in 1950 primarily to study white-tailed deer. At the time of purchase, the area was dominated by mature juniper. Studies of deer diets indicated they were primarily forb and browse consumers. Juniper, mesquite, agarito, whitebrush, and persimmon were utilized little by deer. These diet studies on deer also indicated a high degree of overlap with sheep and goats. Carrying capacity studies indicated that over 3 times more deer could be carried on land where dense stands of juniper had been controlled.

As a result of these studies, over 2/3 of the juniper was removed from the area in the mid-1960s. Sheep and goats were also removed in the late 1960s and early 1970s. Deer numbers were controlled to balance numbers to existing quality vegetation. Also during this period, research was begun to study the benefits of various grazing systems on vegetation.

The combined effects of these management efforts were improved range conditions, more vegetative diversity, better quality deer and improved livestock performance. There was also an unintended consequence - a release of grazing pressure on juniper. Areas in which juniper had been removed began to reestablish and had to be hand-cut from the management area in 1972. By 1979, juniper control was again becoming a problem. Research conducted in the Rolling Plains in the late-1960s had observed that juniper could be selectively killed under certain prescribed burns. Prescribed burns conducted on the Harold Schmidt Ranch by Texas Parks and Wildlife and Natural Resource Conservation Service (NRCS) personnel from 1974-1979 further refined the prescription to control regrowth juniper (<1.5 inches in diameter). Using techniques learned on the Schmidt Ranch, in 1979, prescribed fire was used successfully on the Kerr Wildlife Management Area as a tool in the control of Ashe juniper. As a result of this success, a program was instituted whereby 20% of the Area would be burned each year. All burns on the Area were cool-season burns (January, February) and have averaged an 80-90% kill on regrowth juniper.

Under this program, a pasture was removed from livestock production in June of each year to ensure adequate fuel production to carry the fire at a sufficient intensity to kill regrowth juniper. Livestock numbers were adjusted to ensure the remaining pastures would not be overgrazed. In 1979, when the burn program was instituted, the management area was being grazed utilizing a 3-pasture-1-herd, and a High Intensity, Low Frequency grazing system. In 1984, a 1-herd, short duration, 90-day rotation system with 33 pastures was implemented. Pastures were grazed 3-7 days. This system greatly improved flexibility in the movement of livestock. and provided mangers with the ability to control grazing pressure as an integral part of the burn program.

For instance, pastures could easily be skipped during the growing season to provide fuel for the burns. Furthermore, concentrated cattle numbers could be fed along adjacent fence lines to reduce surrounding vegetation to insure safer burns. As a general rule pastures were usually grazed within 2-3 months following the burn. Grazing pressure within burned pastures could easily be controlled with the 1-herd system. In recent years where practical, cattle have been moved into pastures immediately following a burn to remove prickly pear whose spines were removed by the fire. Also, little bluestem (*Schizachyrium scoparium*) is greatly favored by the hotter fires. Little bluestem is a very palatable plant for livestock in the spring and early summer. In order to utilize this plant when it's at its nutritional best, cattle should be placed in the pasture by May or June.

Observations and conclusions

Over the 26 years in which fire has been used as a management tool on the Area, there have been several studies and many observations as to the effect of fire on vegetation. Here are some salient points.

(1) The most obvious is that with cooler fires (30% humidity, 3-5 mph wind, 1,200 pounds of grass per acre) can be very selective in removing ashe juniper without harming overstory plants. Hotter fires with lower humidities will began to top kill non-target plants.

(2) Fires tend to select against annual plants growing at the time of the burn and for annuals that will germinate after the burn. Fires also select for more perennial plants vs. annual plants. Cool-season burns tend to select for warm-season plants.

(3) There are certain plants such as flameleaf sumac (*Rhus lanceolata)* and little bluestem that are promoted by hotter fires. Some plants prefer the cooler fires and some plants just don't handle fire well at all.

(4) Leaf moisture as well as soil moisture also has great deal to do with the effectiveness of a fire. The length of time from the last rain and/or last freeze will noticeably effect the ignition of leaf litter under shinoak (*Quercus sinuata* var. *breviloba*) or live oaks. More research is needed on this aspect of predicting fire behavior.

(5) Studies have shown there is a release of both nitrogen and phosphorus during a burn providing the range with a short-term fertilization effect. This fertilization effect has a positive effect on both vegetative quantity and quality.

(6) Diets of deer following a burn have shown dramatic short-term increases in deer consumption of grass following a prescribed fire. Increases in domestic animal performance have also been attributed to prescribed burns. Animals tend to graze hot-burn areas over cool-burn areas over unburned areas.

(7) Frequency of burns may have as dramatic effect on vegetation as the intensity of the burns. Prescribed fires at 2-3 year intervals may select more for grasslands. Fires at 5-10 year intervals allow for more recovery of woody plants. Recovery rates for woody species are slower than grass and forb species. This is primarily due to the fact that the growing tip of a woody plant is above ground as opposed to that of a forb or grass which is often below ground.

Conclusions

The bottom line is that *fire is a tool*. When integrated into a combined range, livestock, and wildlife management program that addresses animal numbers, animal impact, and brush control programs, prescribed fire can have positive outcomes. Prescribed fire when not used in combination with other programs can produce mixed results.

All of the Kerr Wildlife Management Area experience has been with cool-season burns. Cool-season burns were initially desirable because most vegetative species are dormant during this period; the plants "energy" is stored in the root system and protected from fire. Top removal is not as detrimental to the plant, especially browse species. As we began to gain more experience with warm-season burns and their long-term effects on vegetation, we may see a long-term selection for cool-season vegetation as well as fewer browse species. This will be yet another tool in the range managers "tool kit."

To learn more about prescribed burns on the Kerr Wildlife Management Area, the Kerr WMA staff has produced a CD on white-tailed deer management. This CD contains a 48 page booklet entitled "Cool Season Prescribed Fires – The Kerr Wildlife Management Area Experience". The CD is available from the Kerr WMA. You can also download this publication from the Texas Parks and Wildlife Website at http://www.tpwd.state.tx.us.

PRESCRIBED BURNING: A REFLECTION ON MY EXPERIENCES

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Abstract: Ranchers in the Rollings Plains of Texas and especially Shackelford County have effectively utilized prescribed burning to suppress prickly pear and improve wildlife habitat. The use of picloram following a prescribed burn will increase the mortality of pickly pear and often adversely effects forbs and woody plants. Summer burns are more effective in controlling prickly pear than cool season fires; however, key wildlife plants can be harmed. Ranchers considering a prescribed burn need to develop a fire management plan and follow this plan. Prescribed burning is not a cure for poor range management.

The success of prescribed burning in Texas can be directly attributed to Dr. Henry Wright's drive, determination, hard work, and foresight. Without his guiding hand and support, I would never have finished my thesis in 1971 and would not gained such valuable experiences. I am sure that in many of his later prescribed burning lectures; he referenced some of my misadventures with fire.

The early years

My first introduction into the world of prescribed burning was on the Spade Ranch at Colorado City, Texas in 1969. Dr. Wright was burning small test plots of tobosa grass (*Hilaria mutica*). Early in the morning all was running smoothly, but as the day progressed relative humidity decreased, winds increased, and the air temperature increased. The fire jumped our fireguard and trouble ensued. None of our crew had experience or training in fighting a grass fire. We quickly learned that a livestock sprayer was not an ideal fire suppression tool. The hose was backed over, twisted around the tire and finally broke. Backfiring was quickly started from another plot and the day was saved. I thought this wildfire would be a one time occurrence.

However, in a few weeks, Dr. Wright was attempting his first juniper (*Juniperus ashei*) burn on the Bob Beckham ranch near Admiral, Texas. All was ready when we reached the burn site. Large piles of dozed juniper had been shoved back from the fireguard at least 100 feet. I was stationed on a hill in the next pasture with Dr. Wright's new fire fighting vehicle, a ¾ ton pickup equipped with a sprayer. When the juniper piles were ignited, firebrands literally drifted several hundred feet and ignited spot fires all over the hill. The new unit quickly exhausted its water supply and a bulldozer had to be called into action. I believe it took two days to completely control this fire. Undaunted by this setback, Dr. Wright started burning juniper piles at night when the humidity was higher, temperatures cooler, and winds very calm. Spot fires were no longer a problem.

After graduating from Texas Tech University in 1971, I headed to Arkansas and began work for the Natural Resource Conservation Service (NRCS), known as the Soil Conservation Service at that time. I relocated to the Albany, Texas office in 1982. Almost immediately I began assisting with prescribed burns in Shackelford County. One prescribed burn had been completed before I arrived at Albany and during my first year we completed another. The number of burns gradually increased over the next few years reaching a total of thirty-four burns by 1988. In 2004 alone Shackelford County ranchers completed fifteen prescribed burns encompassing approximately 13,000 acres.

History of prescribed fire in Shackelford County

Why has prescribed burning gained rapid acceptance in Shackelford County and a large portion of the Rolling Plains?

Before 1980, most ranchers had been concentrating their brush management operations on mesquite (*Prosopis glandulosa*). Many had utilized mechanical techniques to suppress mesquite, but in the process had inadvertently spread prickly pear (*Opuntia engelmannii*). In an attempt to control ever increasing prickly pear populations, ranchers had been aerially spraying with a ½ lb/acre dosage of picloram. At this application rate, prickly pear mortality was highly variable and expensive. Ranchers were looking for an economical method to suppress prickly pear. Some felt prescribed burning might just fit the bill.

By 1982, fire research completed under the guidance of Dr. Wright in the 1970's had evolved into a science. Prescriptions were developed containing specific guidelines for conducting burns. NRCS employees and others were receiving fire training. Fire management plans were being developed containing detailed instructions on how to perform a specific prescribed burn. Innovative practices developed by Dr. Wright included in fire management plans were strip headfiring of blacklines, double fireguards, the organization of fire crews assisting with the fire, and the "40-60 rule" (i.e., air temperatures < 60 degrees F, > 40% relative humidity). Ranchers were now more confident that burns could be safely conducted.

Following my first prescribed burn in Shackelford County, there was a tremendous interest in the origin of the vast columns of smoke. Our office received numerous calls asking: what are you doing and why?

With the interest from our landowners, a field day seemed appropriate. Dr. Darrell Ueckert with the Texas Agricultural Experiment Station in San Angelo was invited to be the keynote speaker for our field day held on the South Green Ranch near Albany. Over one-hundred attendees listened as Dr. Ueckert addressed prescribed burning and reviewed his preliminary findings regarding the aerial spraying of prickly pear with picloram following a prescribed burn. In his studies he reported prickly pear mortality figures which exceeded 90%. This revelation stunned the audience and questions quickly followed. How do I get started? Dr. Ueckert's presentation along with the newly developed confidence in safe prescribed burning started an upward trend for landowner participation in Shackelford County.

Many of the first ranchers who performed prescribed burns were prominent members in the community such as, Watt Matthews and Bill Green. Their success and encouragement to others in the community further accelerated acceptance and participation in our burn program.

Another possible reason for the success of prescribed burning in Shackelford County could be the size of our ranches. For the most part, ranches are large (tens of thousands of acres). Ranchers such as Watt Matthews had the attitude, "If the fire jumps and burns into the next pasture so what? It is still on us and that pasture needs burning too." Furthermore, with large ranches it often is easier for them to defer grazing from a pasture in order to accumulate enough fuel for a burn.

The NRCS field office staff in Albany and the Shackelford County Extension Agent are all experienced with prescribed burning. Quality technical assistance to Shackelford County landowners is readily available.

Prescribed fire and habitat

I would like to share some of my observations on the effect of fire on wildlife habitat. Fire rarely kills brush or wildlife. Most brush and forb species are adapted to survive fire by resprouting. Fire will kill blueberry cedar (*Juniperus ashei*), especially plants that are less than three feet high. Depending on the intensity of the fire, lotebush (*Ziziphus obtusifolia*), prickly ash (*Zanthoxylum fagara)*, hackberry (*Celtis reticulata*), elbow-bush (*Foresteria angustifolia*), bumelia (*Bumelia lanuginosa*), and others can be top-killed. Even with a top- kill, they will resprout. This new growth will provide high quality browse for deer; however, the food and cover these woody plants afford bobwhite quail maybe lost for several years.

Cool season fires (winter burns) often will not harm an appreciable number of woody plants. On the other hand, summer burns are more destructive, harming the vast majority of woody plants. I have seen areas after a summer burn that resembled a moonscape, devoid of life. Prickly pear control after a summer burn is excellent but the control was gained at the expense of wildlife habitat. There is no doubt in my mind that summer prescribed burns also caused some damage to desirable forbs and grasses as well. Recovery of these species was slow but they did eventually bounce back.

Cool season prescribed burns stimulate many perennial forbs, especially western ragweed (*Ambrosia psilostachya*) and engelmanndaisy (*Engelmannia pinnatifida*). Grasses also show a favorable response. In Shackelford County and surrounding areas, many pastures are dominated by Texas wintergrass (*Stipa leucotricha).* Following burning, cattle are often turned into these pastures and this cool season grass is heavily grazed. Prescribed burning and grazing pressure has not reduced Texas winter grass. Stands appear to thicken at the expense of warm season grasses.

The fire/picloram approach for controlling prickly pear does adversely affect forb species. Western ragweed, bush sunflower (*Simsia calva*), englamann daisy and others are removed from the plant community. It may take years for these forbs to recover. There are several factors that will influence the rate of their recovery but the two most important are grazing management and rainfall. An entire pasture does not have to be burned and sprayed. Selected areas can remain unburned and you can partially spray. Creating this patchwork effect within a pasture will minimize adverse effects on wildlife. Shackelford County ranchers have used the method of limited burning and spraying to create a patchwork to benefit quail (*Colinus virginianus*).

Conclusion

Dr. Wright on more than one occasion stated, “Prior Proper Planning Prevents Poor Performance.” The key to a successful burn starts with a good fire plan. Once you have a plan follow it.

I would like to list a few burning do’s and don’ts gained from my experiences.

- DO develop a comprehensive fire management plan well in advance of the burn and follow this plan.
- DO have clearly defined objectives.
- DO check your liability coverage.
- DO enlist the help of qualified workers; review the fire plan with each one, and clearly define their responsibility.
- DO plan for a grazing deferment both pre- and post-burn.
- DON’T get in a hurry and take shortcuts.
- DON’T burn with winds over 20 miles per hour, relative humidity less than 20%, or air temperature above 80° F.
- DON’T burn with light and variable winds.
- DON’T believe that a prescribed burn is a “silver bullet” that will cure all the ailments of your rangeland.
- DON’T forget the impact of your burn on wildlife habitat

I have had my share of wrecks during prescribed burns; however, I remember what went wrong with each one and try not to duplicate the mistake.

Over the years, I have been fortunate to work with very knowledgeable people who are conscientious land stewards. This combination has made for a very successful prescribed burning program in Shackelford County.

WHAT WE LEARNED FROM THE CAREERS OF HENRY A. WRIGHT AND CHARLES J. SCIFRES.

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Abstract: We would not be using prescribed fire to manage rangeland wildlife habitat in Texas without the contributions of Henry Wright and Charles Scifres. This symposium is based on the research foundation they provided through their work, the students and land owners they influenced. Henry Wright started us down the tract on how fire affects rangeland vegetation and habitats in the mid 1960's. In my opinion, his seminal contribution was the development of the prescriptions which allow us to safely and predictably implement fire on rangelands. Charles Scifres contributions also focused on the ecological aspects of fire on our rangeland habitats, primarily in central and south Texas starting in the mid 1970's. But his seminal contribution was the use of prescribed fire as part of an Integrated Brush Management System (IBMS) on rangeland habitats. Dr. Scifres put fire into the big picture in order to help managers across numerous habitats. Both of these individuals stepped outside comfort zones and lead us to new horizons. They provided us with the cornerstones and foundations for us to build upon. Wright showed us how to use prescribed fire and Scifres showed us when to use prescribed fire.

Introduction

I have been asked to summarize what we learned from Dr. Henry A. Wright and Dr. Charles J. Scifres in the use of prescribed fire for wildlife habitat management in Texas. These two individuals were pioneers that helped move fire from a feared accident to a useful valuable tool in managing rangeland wildlife habitat. Prior to their work most people were familiar with wildfires and generally viewed fire impacts from a negative perspective. These two men championed the use of prescribed fire as a management tool. They did this by providing a scientific and ecological basis to help managers make the decisions of when and how to use fire in Texas. Dr. Wright was a distinguished fire ecologist and published widely on the effects of fire throughout North America. He also realized very early on that a major limitation of using fire as a management tool was that people did not know how to apply it in a safe predictable manner. , Dr. Charles Scifres was a distinguished scientist who, throughout most of his career, focused on range improvement practices for Texas shrublands. He also looked at the ecological role of fire on rangeland environments. He had the "big picture" view of management and developed a systems approach to managing our rangelands. Dr. Scifres took fire from a single use single application to its rightful place as a component of an overall management program. It is hard to imagine fire being part of a management program today without the work these two scientists provided. I was fortunate to have worked with both of them, first as a student, then as a colleague.

Henry Wright

Dr. Wright moved to west Texas in the mid 1960's after a brief stay at the

USDA Agricultural Research Service Sheep Station near Dubois, Idaho and finished his career at Texas Tech University. When he started looking at the ecological effects of fire, people were very skeptical. Most were familiar with wildfire effects and the image of Smoky Bear. Fire had a stigma of destruction. He provided us the basic science on why all fires are not created equal. Fire could be beneficial and had a strong ecological role in our rangeland environments. Dr. Wright started looking at how fire affected grasses in the intermountain west (Wright 1971) but worked on numerous aspects of fire ecology and fire behavior.

Dr. Wright's original work helped us understand that the growth form of grasses could dictate the response of the plant to fire. His research did not just record the responses of what happened to rangeland vegetation, but also answered the question of why plants responded the way they did. Today we accept as common knowledge that tight dense bunch grasses are harmed more than open bunch grasses or rhizomatous grasses because the residual burn time at the crown base allows heat to be transferred down to the growing points as he showed with squirrel tail (*Sitanion* spp.) and needle and thread grass (*Stipa* spp.). His work on juniper (*Juniperus* spp.) and mesquite (Wright et al. 1976) communities opened the way for us to also start looking at how fire was a dominate disturbance in the maintenance of our grasslands. He also worked on some original brush sculpting to protect individual lotebush (*Ziziphus obtusifolia)* plants from prescribed fire for the maintenance of quail (*Colinus virginianus*) habitat (Renwald et al. 1978). Through his service, Wright became the public face promoting fire as a useful tool in rangelands.

As a fire ecologist he wanted to understand the complete effect of fire on the ecological system. His work ranged widely. It included the impact of fire on soils (Wright et al. 1976). This helped us understand the fertilizer effect found after burning. His students found that the darker soil (due to ash) increased soil temperatures following spring burns. by increasing microbial activity that broke down more organic matter for plants to utilize (Nueneschwander et al.1978). This work also made him caution against the indiscriminate use of fire. For example, soils from tobosa grass (*Hilaria mutica)* communities required five years to recover from a single burn.

While his initial work focused on the ecological understanding of the role fire had in our rangeland environments, he also understood fire was not going to be used unless people could use it safely and consistently. He knew that without systemic change, only a few people would and could use fire. To make use of fire as a tool, prescriptions had to be developed that would provide a predictable ecological response at an acceptable level of risk. His works on fire behavior lead to the prescriptions that have allowed us to become prescribed burning practitioners.

His original prescriptions on low and high volatile fuels developed in west Texas provided the bases of our prescriptions today (Figure 1). He promoted the use of weather and fuel prescriptions for preburned fire lines and headfires; redflag conditions, burning with soil moisture to ensure a predicted response. These were the first models that provided a safe predictable way to apply fire. We can safely use prescribed fire today, because he and his students stepped way outside the boundaries of conventional wisdom to describe where we should be working. Many practitioners have now altered these prescriptions to fit different environments but they still use the original basic components.

As he began to understand the ecological role of fire in our rangeland systems, he distinguished between wildfires and prescribed fires. In 1974 he published the article "Range Burning" in the Journal of Range Management (now Rangeland Ecology and Management). Many consider this the seminal paper that motivated the rangeland manager to start thinking of fire as a tool with an ecological role in rangeland habitats. In this paper he distinguished between wildfire and prescribed fire impacts, the role of fire in wildlife habitat and how to apply prescribed fire in a safe predictable manner. In 1982, he published his book *Fire Ecology: United States and Southern Canada* with A. Bailey. This provided a complete summary of fire ecological impacts in North America. It was the first complete reference which combined soil, plant, and wildlife effects on all the major particular plant communities in North America, including rangelands.

Wright's second major contribution was to teach people how to use prescribed burning. He did more than have a class exercise; his students participated in true management scale burns. There was no place in the country where students actually burned a 1000 ac pasture as a class project. Dr. Wright allowed students to burn 1000 acres and more. Nowhere was this followed or replicated. I was fortunate to be one of his students when he accepted two 10,000 acre units on the Triangle Ranch in West Texas. He was the first in North America to attempt and succeed at applying fire at a landscape scale. We then did similar sized units on the 6666's ranch. We came away knowing how to conduct a burn that size (Masters et al. 1986), and the economics of doing that type of burn (Rasmussen et al. 1988). He did not shy away from the unknown but strived to understand.

Charles Scifres

Dr. Scifres also started his career in west Texas with the Texas Agricultural Experiment Station, then moved to College Station. His research focused on range improvement practices. He worked on brush communities and different available tools (mechanical, herbicide, biological and fire) to develop the plant communities desired for specific management objectives. Like Wright, his first work with fire focused on understanding the impact of fire on plant communities, this time in central and south Texas. Early on Scifres realized that many plant communities needed more than one management technique; if you were going to be successful it must be done in a systems approach. The first publication I found where he used a systems approach, which included fire, was with Macartney Rose (*Rosa bracteata*)(Scifres 1975). He and his students worked on wide range of ecological impacts of fire ranging from gulf cordgrass (*Spartina spartinae*) (McAtee et al. 1976), huisache (*Acacia minuata*) (Rasmussen et al. 1983), to liveoak (*Quercus virginiana*) (Scifres and Kelly 1979) to name a few. His had a practical view of the world and wanted to help land managers solve their problems. This view and his broad spectrum of work lead him to attract people from a wide range of disciplines to work with him. His seminal contribution that has allowed us to be here talking about fire was to place fire as one component of his Integrated Brush Management System (IBMS) concept. This concept placed fire in the big picture. Prescribed fire had a role helping manage rangelands to achieve multiple objectives but that it was not a tool to be used by itself.

In 1980, he published *Brush Management: Principles and Practices for Texas and the Southwest*. His chapter on fire effects, wildlife and brush management systems brought things together. Before his work, we tended to looked at individual treatments that could be silver bullets if successful or something to discard based on their ability to remove the undesired plants. Fire did not work on resprouting shrubs (mesquite, *Prosopis glandulosa*) so generally was considered to only have a short-term affect. But in long term multiple system approach including wildlife and livestock, fire could provide a significant role. He recognized singular types of disturbance, had specific strengths and weaknesses, and that when used in combination land management objectives were achievable.

In the early 1980s he started assembling a research group to look at the Integrated Brush Management Systems concept (Scifres et al. 1983). They included experts in wildlife, economics, management, livestock, and range vegetation manipulation. This diverse group moved fire to a prominent role in rangeland wildlife management. They developed numerous models which helped land managers understand the consequences of prescribed fire, the type of habitat that would result, and how to view the consequences of different management actions. They removed much of the guess work and further refined when it was appropriate to use fire in Texas. An example (Table 1) would be the IBMS for huisache (Scifres et al. 1982). This example incorporates both livestock and wildlife together as multiple objectives. It first uses herbicides to reduce huisache then follows the herbicide treatment with a prescribed burn to achieved the desired mix of vegetation. But perhaps most importantly it recommends following the first fire with a repeated prescribed burn at a three year interval.

Dr. Scifres helped us move from the idea of single objective with a single treatment, to multiple objectives using different treatments in a management system. His second book, *Prescribed burning for brushland management* published in 1993 with W. Hamilton, further refined how fire fit into a management system. In chapter 9 – Burning-Based Vegetation Management Systems they summarized numerous examples where fire could be used to help meet objectives. Just as importantly they helped provide decision support when fire may not achieve the results wanted and suggested different techniques to meet the objectives. This big picture approach to help managers determine when and where prescribed fire is an appropriate tool is the most important contribution Scifres made to rangeland wildlife habitat management.

In conclusion these two scientists helped us understand the ecological role of fire in rangeland ecosystems and how to apply it is a safe predictable manner to achieve multiple objectives. Henry Wright provided us the prescriptions that gave us a safe repeatable response from burns. This allowed all of us to go out and start using fire, to gain experience and improve our capabilities. Charles Scifres provided us a template for which prescribed fire would fit in the big picture of our management programs. He taught us that it was not a silver bullet but a component of a management program. Both of these individuals complemented each other. Neither was intimidated by the unknown. They desired to provide solutions to help people and the rangeland wildlife habitat they lived on and managed.

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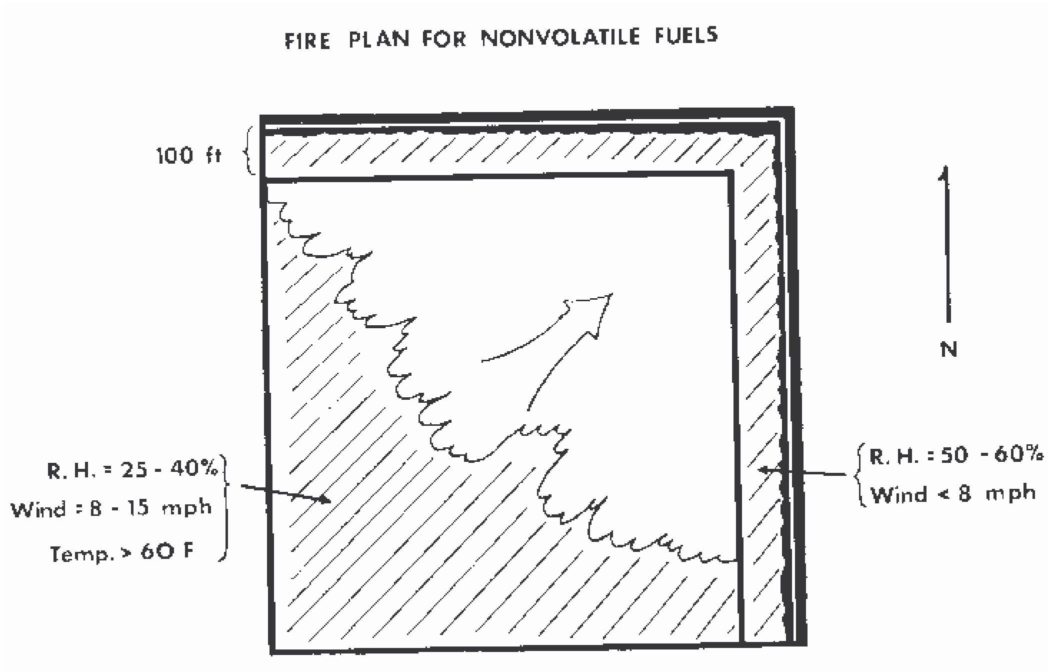

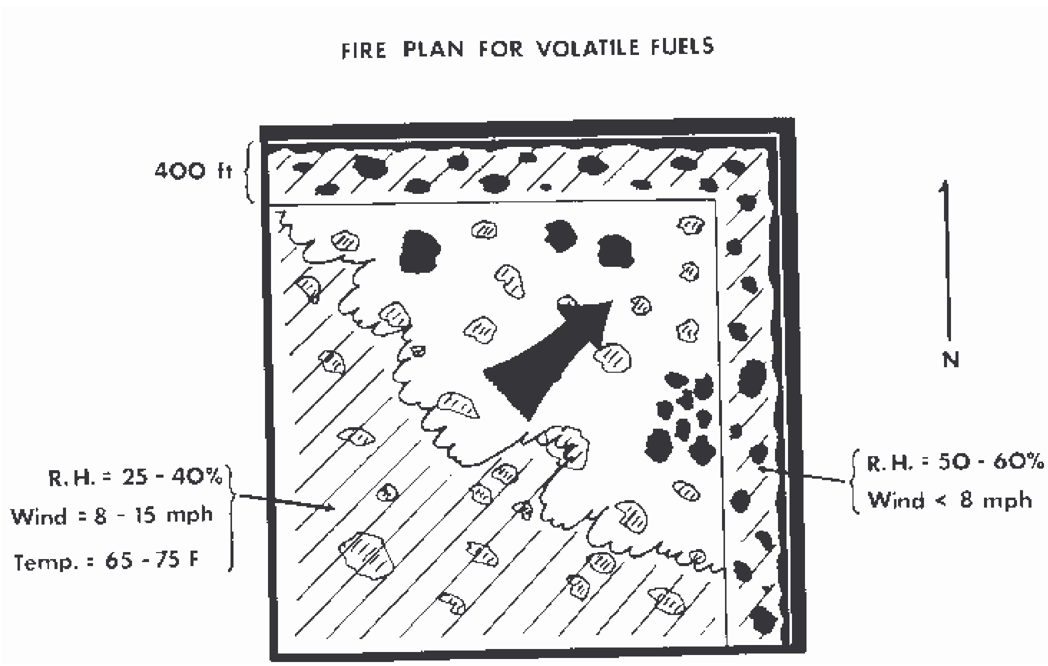

Figure 1. Volatile and non-volatile rangeland burn prescriptions (adapted from Wright 1974). Fire lines are preburned under cooler conditions to reduce the risk of a fire escaping. On the volatile fuels the fire lines are wider : 400 ft vs. 100 ft, the humidity is higher and the wind is lower.

Table 1. Example of an Integrated Brush Management System (IBMS) for huisache infested rangelands (adapted from Scifres et al. 1982 as cited in Scifres and Hamilton 1983).

	Phase 1 Initial reduction of brush cover	Phase 2 Fine fuel development-burn preparation	Phase 3 Installation of prescribed burns	Phase 4 Maintenance
Objective	Increase forage production for livestock; maintain/improve habitat quality for white-tailed deer	Improved botanical composition of herbaceous stands, build adequate uniform load of fine fuel	Improved botanical composition of forage stands, suppress regrowth from treated plants, missed plants, and invading seedlings; improve browse nutritive values	Maintain huisache canopy cover which will allow best mix of cool/warm season forages; offer improved browse supply to white-tailed deer
Activity	If huisache density ≤ 160 trees/acre low-energy grub or oil: 160-250 trees/acre of plants ≤ 6 ft tall on clay loam-sandy loam soils low-energy grub:< 250 large (>6 ft) trees/acre aerial apply triclopyr+ picloram at 1 lb/acre	Develop fire plan; construct fire lines; adjust stocking rate to forage production potential; plan deferment of targeted pastures for 90-120 days in the fall prior to installation of winter burn	Install prescribed fire according to fire plan; burn with headfire 10-12 mph wind speed≤ 60% RH; if RH <20%, fine fuel moisture ≤10% wind speeds should be reduced 5-8 mph	Schedule prescribed burns as needed approximately 3-year intervals
Consideration	Removal of ≤ 15% canopy cover reduces abundance of cool-season grasses; grubbing may be accomplished when soil water content conducive to maximum effectiveness; grubbing slower on clay so restricted to < 160 trees/acre. Aerial spraying should leave > 30% brush cover for deer; may apply in fall or spring	Adjust deferment period to rainfall conditions: under drought conditions utilize accumulated fine fuel as appropriate, and delay burn until next year	Adjust postburn deferment of grazing to rainfall conditions and spring growth: usually defer burned areas until late April after February burn	Schedule cool-season burns following wet falls when soil profile contains adequate water to promote spring growth: set burning schedules to match grazing system
Expected Results	Grubbing or oiling will kill about 95% of the treated plants; pits left from grubbing will not fill for several growing seasons, especially on clay sites, Aerial sprays reduce overall canopy by 90%;kill >20% of trees	Accumulate at least 2,700 lb/acre of standing fine fuel of uniform distribution	Huisache regrowth ≤ 6 ft tall top-killed, stems 1 inch diameter consumed to ground line; rapid development of new stems form live stem bases	Range condition improvement; rough vegetation removed; grazing distribution optimized-huisache suppression, but regrowth offering browse of improved nutritional value

FIRE ECOLOGY IN THE CENTRAL TEXAS AND EDWARDS PLATEAU REGIONS OF TEXAS

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Abstract: Fire once played a major role in shaping the vegetation, wildlife, and ecology of the Central Texas region. By the 20th Century, immigrants from Europe and pioneers of the US had carved farms and ranches from the Central Texas landscape. By the beginning of the 21st Century, and after 100-years of fire suppression, vegetation and wildlife had changed dramatically. Interest in using prescribed fire as a restoration tool has increased considerably. Understanding the role of fire in vegetation manipulation is critical for managing wildlife habitat and rangeland restoration. However, before we begin to understand fire ecology, we must first understand the factors that influence fire behavior, including the effect of fuels, weather, and topography. The re-introduction of fire into the Central Texas region will not be an easy task. The implementation of a sustained prescribed fire management regime by ranchers on privately owned lands will require cooperation and organization. This can be accomplished through the formation of burn associations.

What is fire ecology?

Fire ecology is a broad and complex subject. It encompasses the study of fire behavior as influenced by fuels, weather, and topography, and the effects of fire on flora and fauna. Fire ecology of a region is often described through the conceptualization of a historic fire regime (historic fire behavior; generally, the frequency, intensity, shape, extent, and source of ignition of fire that aided in maintaining the configuration of a specific plant community). The historic fire regime is useful in providing a general background to the interactions between fire behavior, flora (i.e. fuels), and the fauna that inhabited the region.

To begin to understand the fire ecology of central Texas and the Edwards Plateau, we must first become accustomed to the factors that influence fire behavior for this region; specifically, the effect of fuels, weather, and topography. This leads to an understanding of the effects of fire on the vegetation and wildlife of the area. At this point, it is important to clarify that the characterization of a historic fire regime is dependent on the fuels that were present at that time. A change in fuel characteristics inherently produces different fire behavior (e.g. intensity, propagation pattern, etc.), leading to alteration of the fire regime for a region. This change may have profound effects on vegetation and wildlife dependent on the historic disturbance regime as demonstrated by the dramatic decline of grassland and savanna avian species.

The decline of grassland and savanna ecosystems has led to a surge in restoration efforts largely focused on reintroducing the historic fire regime to convert back to an "original" plant community. Traditionally, these attempts have failed to take into consideration changes in vegetation composition, fuel continuity and arrangement, and their interaction with fire behavior. To be successful, one must consider: How does current land management influence the type, arrangement, and continuity of fuels, and how is this different from historic fuel characteristics? How does this influence the frequency, intensity, shape, and extent of fire? How did fire frequency, intensity, and shape interact to maintain grassland and savanna ecosystems? How did this influence other disturbances like grazing? How does this effect wildlife and vegetation?

This review will compare and contrast the current and historic fire regimes, describe mechanisms responsible for their differences, and demonstrate how these differences influence vegetation and wildlife populations.

Area, climate, and original vegetation

The area of interest includes the Edwards Plateau, Llano uplift, Balcones canyonlands, and Lampasas Cut Plain. Approximately 10-million years ago the Edwards Plateau was uplifted along the Balcones fault. Since then, stream erosion has carved into the Edwards Plateau, exposed the Llano uplift, and created the "Hill Country". Hereafter the sum of these regions will be referred to as the Central Texas region. Most of this area is considered to be in the southern part of the Great Plains, represented mostly by a mixed grassland savanna. This mixed grassland savanna is comprised of mesquite-oak savanna (*Prosopis-Quercus-Schizachyrium*), juniper-oak savanna (*Juniperus-Quercus-Schizachyrium*), mesquite-buffalograss (*Prosopis-Buchloe*), and mesquite savanna (*Prosopis-Hilaria*).

For the uplands and divides of Central Texas, the landscape appeared open with stubby thickets of liveoak (*Quercus virginiana* Mill.) and shinoak (*Quercus* spp.) and an occasional larger liveoak and honey mesquite (*Prosopis glandulosa*). In the valleys, slopes, and shallow soils, the dominant grasses were little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Indiangrass (*Sorghastrum nutans*), cane bluestem (*Bothriochloa barbinodis var. barbinodis*), Texas cupgrass (*Eriochloa sericea*), common curlymesquite (*Hilaria belangeri*), Texas wintergrass (*Stipa leucotricha*), and others. Warm season perennial forbs were also abundant with a diverse mixture of desirable woody shrubs. Kidneywood (*Eysenhardtia texana*), littleleaf leadtree (*Leucaena retusa*), Carolina buckthorn (*Phamus caroliniana*), Texas mulberry (*Morus microphylla*), white honeysuckle (*Lonicerna albiflora*), plum (*Prunus* spp.), bumelia (*Bumelia lanuginosa*), sumacs (*Rhus* spp.), are just a few of the more desirable woody shrubs that were abundant.

Primary plant growth usually occurs in late spring and early summer, then slows with hot dry weather until a secondary growth period follows the early fall moisture. The tall grasses of the pre-settlement period adapted their flowering time and seed production to correspond with fall moisture. Mid- and short grasses tend to flower earlier and more frequently than the tall grasses while annual forbs germinate seed in wet falls and winters and flower in the spring.

The climate of the Central Texas region can be described as mesothermal, subhumid to semiarid, with potential evapotranspiration exceeding rainfall in all months. Average rainfall exceeds thirty inches on the eastern margins, declining gradually to 15-inches on the west. Peak rainfall usually occurs from mid-April to mid-June as general rains associated with frontal activity. A second peak usually occurs as tropical storms come inland from the Gulf from August to October. Drought is a common process for this region. The timing and sequencing of drought and wet cycles may predispose some areas to woody plant invasion. Distant events such as El Nino/southern oscillation off the west coast of South America are known to have major impacts on weather at great distances. Droughts in various areas are highly correlated with these events as are associated increased fire frequencies and other vegetation altering disturbances.

Fire history

It is estimated that grasslands occurred over approximately forty-five percent of the earth's terrestrial surface (Copeland 1978). Our current knowledge of grassland and savanna dynamics establishes that fire was a frequently occurring disturbance that was required to maintain these ecosystems (McPherson 1997, Frost 1998). Lightning may have been the primary ignition source of fire for the Central Texas region, which would have limited most fires to the growing season (Figure 1); however, other information indicates that American Indians burned extensively in all seasons and most pre-settlement landscapes and vegetation resulted from human activity (Pyne 1982). Regardless, fire was a common feature in Central Texas up to the time of European settlement (Komarek 1968, Frost 1988).

We hypothesize that American Indians and lightning produced disturbance patches of locally altered vegetation due to variation in fire frequency and intensity. This activity would have produced a diverse landscape, broken-up by patches varying in size and shape contributing to a shifting mosaic of burned and unburned areas. The amount of time since a patch burned would determine the phase of recovery as described by Fuhlendorf and Engle (2004). This hypothesis is supported by the response of grassland avian species to a landscape of spatially discrete patches that differ in structural and compositional characteristics (Fuhlendorf and Engle 2001, 2004). The response of grassland species to patch disturbance demonstrates the importance of considering fire behavior to effectively manage these ecosystems.

Reports of early American pioneers are provided. However, it is important to remember that the historical record is not consistent and sometimes contradictory about the kind of vegetation that existed at the time of European contact (Smeins 1980). In evaluating the historical records of central Texas, it is apparent that the vegetation was highly variable ranging from closed-canopy woodlands to open grasslands (Smeins 1980).

The sum of the accounts suggest that woody plant abundance was greatest on the eastern and southern part of the central Texas region where rivers and creeks drain forming steep canyons separated by high divides (Balcones-Canyonlands region). To the north and west on the divide portion of the Edwards Plateau, there was much less woody vegetation with more of a savanna or grassland dominated landscape. Listed below are samples of descriptions of the central Texas landscape from the early pioneers.

Quoting Walter Prescott Webb in The Texas Rangers p 315 "*the whole country from the Llano via the head of the Guadalupe and Frio to the Nueces had been burned, and there were few places where water and grass could be found together. 'I have traveled a whole day at a time without finding any grass'* according to Major John B. Jones in early Sept 1874."

In the early 1880s fire was an annual summer event in the western region of the Edwards Plateau. "*As often as not the fire ran uncontrolled, destroying a million acres of grass down to the roots and wiping out the herder's plans to graze his flock through the winter"* (Carlson 1982).

Olmstead commented on the suppressed growth of live oaks near Austin in A journey through Texas p 130 "*The live oaks are often short, and even stunted in growth, lacking the rich vigor and full foliage of those further east. Occasionally a tree is met with which has escaped its share of injury from prairie burnings and northers, and has grown into a symertical and glorious beauty. But such are comparatively rare"* (Olmstead 1857).

Based on his own observations Froebel discussed the relationship between fire and abnormal age grouping of the honey mesquite population in west Texas in 1853 in Seven Years' Travel in Central America, Northern Mexico, and the far west of the United States p 396. "*One peculiarity is the repeated occurrence of dead mesquite trees, of considerable size, with the growth of young ones, --there being no intermediate stage of size or age. This probably has been caused by repeated prairie fires, which destroyed the old trees, and prevented the growth of fresh ones…..At Chihuahua a man who had been a great deal into this locality told me that for a long period no Indians had lived there, during which it was covered with a thick mesquite wood. Subsequently, certain hordes came here, and with them the prairie fires began. In later times the advance of the whites into Texas has driven back the savages, and restrained their visits; and the prairie fires ceasing, trees and shrubs have again appeared. It is asserted that this process may be watched throughout West Texas"* (Froebel 1859).

Quoting Gray in 1854 about the lack of woody plants in Central Texas *"Much of the soil is good, and I question of the grass set on fire annually by the Indians…together with the' Northers,' which sweep with such violence over the plains are not to a great degree causes for the total absence of timber"* in Survey of a route on the 32nd parallel for the Texas Western Railroad p18.

In 1923, V.L. Cory became a botanist at the Texas Agricultural Experiment Station at Sonora where he met an elderly cowboy who told of driving a flock of sheep from Junction, Texas through the area of the Experiment Station and on to Juno 50-years before when the vegetation was much different (Cory 1949). Cory reported the cowboy's description as: "*….There were no fences, nor was the country timbered then, as is now the case. This valley and all the other valleys then were free from woody plants; and the entire country was a prairie of tall bunch-grass, reaching at least to ones stirrups….The only short-grass was around water holes and in depressions in the valleys."* When asked about the abundance of juniper 50-years before, he remembered the cowboy's reply as: "*These were few in number and confined to the headers (the gully or ravine-like beginnings of the branches of the draws, or drainage courses, on the escarpment bordering the valleys)…..the tall grass had gone, trees had spread everywhere, and the valleys, once having grass only, now were occupied chiefly by weeds, thorny shrubs, and prickly pear."*

Impact of settlement

By the late 1880's settlement of the area by Europeans and their descendents dramatically reduced the impact of fire. This came about because of the reduction of tall and mid grasses through livestock grazing which reduced the amount of fuel and by the prevention and suppression of fires when they occurred.

With widespread suppression of fire throughout the region, especially in conjunction with fencing, drilled wells, and increased livestock numbers, woody plants, especially juniper, mesquite, and prickly pear, began to increase at the turn of the century. In the next few decades the problem of woody plant increase was recognized, but many government-sponsored programs and dedicated ranchers trying to eliminate, control, manage, and eventually, sculpture woody plant distribution failed, and the "brush problem" continues to increase (Archer 1994). This scenario is accurately described by Foster (1917). *"The causes which have resulted in the spread of timbered areas are traceable directly to the interference of man. Before the white man established his ranch home in these hills the Indians burned over the country repeatedly and thus prevented any extension of forest areas. With the settlement of the country grazing became the only important industry. Large ranches in time were divided into smaller ranches and farms with consequent fencing of ranges and pastures. Overgrazing has greatly reduced the density of grass vegetation. The practice of burning has during recent years, disappeared. The few fires which start are usually caused by carelessness, and with alternating wooded and open spaces and the close cropped grass, they burn only small areas. These conditions have operated to bring about a rapid extension of woody growth. Almost unquestionably the spread of timbered areas received its impetus with the gradual disappearance of grassland fires."*

With the development of the livestock industry, fires were suppressed and vegetation changed along with numbers and distributions of native animals (Smeins 1984, Weniger 1984, Doughty 1983). For example, bears (*Ursus* spp.), which were common in the Hill Country of the Edwards Plateau, were locally driven to extinction. The bison, which was abundant and widespread, was hunted to local extinction across most of the region (Doughty 1983). Prairie dogs (*Cynomys ludovicianus*) were largely eliminated as were their impacts on the ecosystem. Most of these animals were reduced or eliminated by the 1870's.

During the period between 1870 and 1885, before livestock were confined in fenced pastures and after the loss of the bison, the ranges were relatively free of grazing by large herbivores. This was also a period of favorable precipitation, which misled early ranchers into thinking that these rangelands seemed capable of supplying unlimited amounts of forage for their livestock. As a result there was a rapid and severe overstocking of central Texas rangelands (Smith 1899).

As barbed wire fences were being established across the central Texas region, grass was being burned in retaliation for alleged grievances held against the ranchers who were fencing the range. In response to the burning and for the second time, Texas passed a law making the burning of grass a felony (Hanley 1929). These laws were passed to protect grass; unfortunately, they had the opposite effect.

Despite the legislation, large fires continued to sweep the western part of Texas during the early development of the livestock industry. The potential for fire was greatest during period of dormancy or drought. An interesting story is reported by the Crosbyton Review published on February 29, 1912:

"*A very destructive fire occurred during the month of June, 1879. The fire originated on the Z-L Ranch in Crosby County, where there was considerable shinery. Hundreds of wild hogs ranged this dwarf oak country, prolific and hardy upon the acorns that grew there. Hank Smith, the first settler in the South Plains region, described this fire and the hogs. Once day a cowboy decided he would set fire to the shineries and run the hogs out. He did it all right, but is to be hoped that no one else will ever try to drive wild hogs out of a shinery country with fire. The fire got away and started on a wild rampage in a northeasterly direction. No one has ever learned for certain which way the hogs went. The fire swept the country now occupied by Crosbyton, Emma, Ralls, Lorenzo, and spreading as it went sped across the Blanco (canyon) moving before a terrific wind from the southwest. At that time there was practically no cattle in the country, and few people cared where the fire went or what it did. Crossing the Blanco on it went into the Quitaque, Boggy Creek, North and South Pease river and Tule Canyon country, while before it fled and swarmed countless thousands of antelope, turkeys, hundreds of deer and a sprinkling of cattle and horses. The fire swept thousands of square miles of country to the south and southwest, north and northeast of Mount Blanco. All through the country at that time, especially along the streams, where hundreds of magnificent groves of fine timber, particularly cottonwood and hackberry. This fire killed the timber and in effect literally wiped it out.*"

Although the initial development of the livestock industry was a success, it created some of the major problems of today. Continuous stocking of pastures with excessive stocking rates resulted in complete utilization of an area, resulting in reduced fine fuel loads. The structural and compositional variation characteristic of the shifting mosaic was reduced due to the loss of variation in fire behavior. Specifically, the variation in fire frequency, intensity, size, shape, and propagation pattern was removed from the region resulting in a transition from a grassland-savanna matrix to a woodland state.

Current fire regime

The Edwards Plateau Burn Association, Inc., (EPPBA) is the primary source of fire on the landscape today, and is responsible for reintroducing fire to the landscape over large spatial scales. Modern day lightning-ignited wildfires contribute to the amount of area burned only during drought conditions and are generally quickly extinguished. The association was initiated in 1997 as a private landowner cooperative that was responsible for pooling equipment and personnel in order to begin conducting prescribed burns (Taylor 2005). The development of the EPPBA solved multiple problems that prevented landowners from burning in the past, including: (1) insufficient personnel and equipment, (2) high costs associated with purchasing equipment, and (3) a lack of knowledge on prescribed burning technique and safety. The 50 members responsible for the program's initiation in 1997 have since seen the EPPBA grow to more than 250 members with approximately 1-million acres.

Due to fuels management since European settlement, the EPPBA is still in the restoration process. Management tasks of the association are to reduce woody plant abundance, especially with respect to invasive and exotic species. In its restoration efforts, the fuels that created the historic fire regime are attempting to be restored. Burns are prescribed to be high intensity in order to maximize the primary objective of reducing woody plants.

The EPPBA sets the majority of its fires during the summer months of July through September. These dates correspond to months of the year when drought occurs frequently. Burning during the occurrence of drought takes advantage of lower live herbaceous fuel moistures which reduces the low heat of combustion of fine fuels, resulting in higher fire intensities and greater fire effects on woody plants.

Although fire has been reintroduced to the landscape in the Central Texas region through the development of burn associations, prescribed fire is much different than historical references. Currently, fire application is limited to a specific range of conditions. Will this change once the target community has been obtained? Or will the current application of fire become a conventional technique that is the basis for all fire prescription in this region? Grassland and savanna ecosystems were maintained due to variation in the frequency, intensity, and extent of fire across the landscape. If these ecosystems are to be restored, fire must be applied in a manner that recreates the spatially discrete patches that provided a shifting mosaic of habitats that was present historically.

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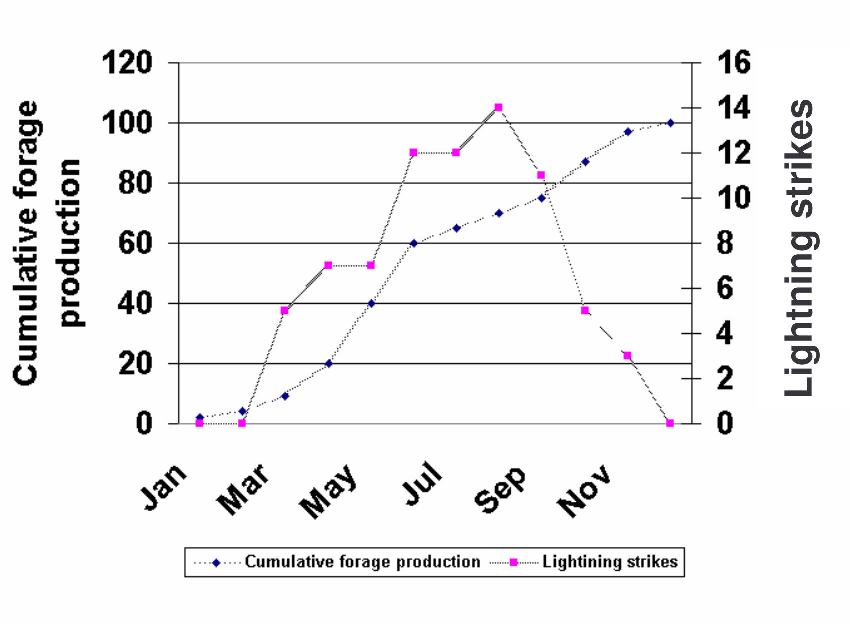

Figure 1. Nature's burning system. Lightning frequency and long-term monthly cumulative forage production for the Edwards Plateau. Lightning frequencies represent the percentage of 24-h periods (days) with two or more lightning flashed per 28-mile grid square 1987-90 (Climatology of lightning frequency – Scientific Services Division, National Weather Service). Forage production determined from various studies on the Texas A&M University Research Station at Sonora, Texas.

OBSERVATIONS ON FIRE AND WILDLIFE

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Abstract: The skillful application of fire on Texas rangelands requires 2 separate but related activities. First is setting realistic objectives based on a critical evaluation of ecological sites within the burn unit. Second is safe application of the burn using established rules for blacklines and headfires. I will discuss implications of prescribed burning on habitat management for white-tailed deer (*Odocoileus virginianus*) and bobwhites (*Colinus virginianus*). I will also discuss written burn plans, fuel load and grazing concerns and the pros and cons of summer burns.

The skillful application of fire on Texas rangelands requires two separate but related activities. First is setting realistic objectives based on a critical evaluation of ecological sites within the burn unit. Second is safe application of the burn using established rules for blacklines and headfires.

The written fire plan

Prescribed burning requires a great deal of organization and preparation, which should start with a written fire plan. This plan should include at least the objectives you hope to achieve, maps of the burn area, and prescriptions for the ignition of blacklines and headfires. Writing this plan will help you think through every aspect of the prescribed burn. While completing your plan, ask "Is fire the most appropriate and effective method to achieve the objectives? What will happen to target and nontarget plants in the pasture? Are the resources available to safely apply a fire treatment?"

The first step in the skillful application of fire is to analyze critically the pasture to be treated. I always consult the county soil survey for the area I want to analyze. From this we can understand the soils and the potential vegetation for sites involved. Understanding the climax plant community for a given site will help determine what plants you might manage and how fire should impact this pasture.

Next, we should determine the hierarchy of wildlife for which we want to manipulate the vegetation. This could be a juniper (*Juniperus* spp.)-infested pasture where our primary species is white-tailed deer (*Odocoileus virginianus*). The second species could be bobwhites (*Colinus virginianus*). Third might be a small interest in other species such as mourning dove (*Zenaida macroura*), songbirds, butterflies, and horned toads (*Phrynosoma cornutum*). For each species we should evaluate habitat requirements of food, cover (hiding, thermal, nesting, etc.), and water. Fire has the potential to increase the quality of food plants and cover or to virtually destroy them for a period of time.

Looking at the topography and slope will point the way to a cost-effective solution to the amount of cover to leave. Areas with rough broken slopes over 25% should be excluded from the burn unit. These areas will provide only small increases in food items because of the shallow soil, and burning them may slightly increase erosion for a short period of time.

The soil survey will delineate these areas so you can make quick decisions in the field. For example, consider a pasture with various levels of juniper infestation. If the mature juniper canopy cover is not over about 5%, there will be little increase in herbaceous yield resulting from fire application and the reduction in juniper actually may be detrimental to the habitat. As large juniper canopy cover increases from 5 to 20%, the most dramatic decrease in herbaceous yield occurs. However, if the pasture has numerous young junipers scattered throughout, then it is definitely time to burn. Another critical situation occurs when a pasture has over 40% juniper canopy cover. At this point grass and forb production is virtually nonexistent in this pasture.

What would happen if we burned our juniper-infested rangeland in the summer? The grasses and forbs would be severely damaged and would take up to 3 years to recover. Redberry juniper (*Juniperus pinchotii*) would be top-killed, but the root mortality would be nil, not much different than a winter burn. And I know of no quicker way to increase cool-season grasses than to conduct summer burns. I cannot think of one wildlife species and certainly no livestock that would thrive in a thick stand of Texas wintergrass (*Stipa leucotricha*). Since humidities are very low in the summer, temperatures are usually in the upper 90s, and plant conditions with no green in the base of the grasses, our fire environment is extremely dangerous in the summer. The chance of a fire escape is entirely too great to accept, especially in light of the fact that the fire is doing more harm than good.

White-tailed deer and fire

Since deer are of primary interest in our example, we will want to leave some juniper for cover. But the question is: how much and where? Suggestions from experts suggest that cover from less than 20% to as high as 80% is optimum. Remember, in portions of the Rolling Plains it is not uncommon to have deer density estimated at 1 per 100 acres. This means it really does not take many juniper trees to satisfy cover requirements.

Bobwhites and fire

Next, let us take a look at the world from a quail's point of view. Quail are about 6 inches tall and weigh in at 6 ounces, so everything in their world is really big. When we burn the quail's habitat in late winter, we cause a tremendous change. All nesting cover is burned to the ground. If the area had received over 4 inches of rainfall from October to December, the tighter soils would have an abundance of annual broomweed (*Amphiachyris dracunculoides*) in the rosette stage. All this broomweed would be killed, and the pasture would be free of this prolific quail food producer. Is all lost? Not as much as it would first appear. The perennial forbs and late-germinating forbs would grow rapidly and produce an abundance of seeds. Many seeds that were at the soil surface but covered with litter would be exposed for consumption. Because of the abundant new growth, insects would find a favorable habitat. Thus, fire would increase the quality of many aspects of quail habitat, but nesting cover would be gone.

Quail densities of 1 bird per 2 acres are good in the Rolling Plains. In a 1,000 acre pasture, we should plan our burn to leave several 5 to 10-acre areas with tall vegetation to minimize the shock to the reproductive process. This may require some extra fire lines and maybe some additional blacklines, but the dividends will be worth it. If the burn was solely for quail, I would use a cool fire that would leave islands of unburned grass for nesting cover. Conditions would be similar to the “40-60 rule” (i.e., air temperatures < 60 degrees F, > 40% relative humidity and light winds of 3-6 mph. This obviously would rule out summer burning for quail management.

What if our quail is living in a sand shinnery oak (*Quercus havardii*) pasture? Fire will generate a completely different scenario of habitat changes. First, we should remember that burning shinnery is quite dangerous. The leaves are large and thick and tend to float a long way on wind currents created by the fire increasing chance for fire escape. Shinnery loves fire and will produce more stems than before the fire in a short period of time. Unfortunately, the first year after burning shinnery the acorn crop is reduced to nothing. The abundant sprouting and rapid growth of shinnery exerts an overwhelming competition on tall grasses so important for nesting. Thus, fire alone is not a beneficial treatment for shinnery. If the shinnery stand had been opened up with spot treatments of Spike, fire might be used to replace periodic grazing to rejuvenate tall grasses such as little bluestem (*Schizachyrium scoparium*).

What would happen if we used a summer fire instead of a late winter fire? As with most of the plant communities in Texas, there are no data available on summer burning. Observations tell me that on a sandy soil a summer burn would be excessively damaging to the grasses. It might take 3 years to recover. The shinnery would suffer some damage but not enough to declare it good or bad. Two acorn crops generally would be lost.

Fuel load

It is mandatory to have grass fuel sufficient to carry a fire across a pasture. When the juniper canopy cover approaches 40%, the fine fuel is so low that a prescribed burn generally is not possible. To reclaim a pasture in this condition, some mechanical treatment is necessary to increase the grass fuel necessary to carry the fire.

At least 1 year prior to burning a pasture, the grazing management must be altered. The pasture must be allowed to accumulate as much grass as possible. Therefore, no grazing should occur at least during the fall growth period, and, if a good burn is to be made, the pasture should be rested during both the spring and fall growth period. Remember, the more fine fuel (grass) in the pasture, the greater the damage to the juniper and the easier the pasture will be to burn. With abundant fine fuel, the fire can be conducted under safer conditions with lower temperatures and higher humidities. With minimal fine fuel, such as found when a rancher removes the livestock the day before the burn, there is an unreasonable temptation to burn with higher winds, lower humidities, and higher temperatures.

For additional safety, pastures on the north and east edge of the planned burn should be grazed closely in the months prior to the planned burn. By reducing fine fuel (grass) in these areas, the potential for spot fires and fire escape will be greatly reduced. This will require a long-term grazing plan, and in some cases, a good working relationship with neighbors.

We use Texas rangeland for grazing livestock and for wildlife habitat. Thus, during the course of a year, herbaceous vegetation is forage for grazing animals as well as fine fuel for fire during the winter months. The management of our herbaceous vegetation to serve these purposes depends on stocking rate. If we do not fully come to grips with all the implications of this concept, we cannot be effective livestock or fire managers.

To properly use fire, we must accumulate an adequate amount of fine fuel (grass) to conduct a safe and effective prescribed fire. Over the past 30 years, the main problem we have encountered is lack of fine fuel to conduct prescribed fires. Therefore, it is mandatory to rest a pasture that is to be burned. If fine fuel is not present in adequate amounts, fire will not carry evenly and cannot generate the heat and flame lengths necessary to accomplish the objectives. Lack of fine fuel forces fire ecologists to burn with higher air temperatures, lower relative humidities, and higher wind speeds. This pushes the upper limits of fire safety and risks a fire escape.

The use of fire in dry years is not recommended for a number of reasons. First, if a fire is to be conducted the winter following a dry year, fine fuel load is not sufficient to achieve the beneficial effects desired. If grasses did not produce tiller buds during the fall because of drought, the plants will not respond favorably even with good precipitation the following growing season. Plants weakened by insufficient carbohydrate storage will always have difficulty recovering rapidly from fire. Thus, we should limit the use of prescribed fire during and immediately after dry years.

Planning for prescribed fire following a drought is a complex process. We must allow the grasses to recover from stresses caused by drought and then produce sufficient tiller buds to ensure good growth the following growing season. This must be accomplished concurrently with providing adequate forage for livestock. The pasture to be burned must be deferred from grazing during the fall to allow for fuel accumulation so a safe and effective fire can be conducted. Therefore, after a drought ends, we must wait through one good growing season for grasses to regain the root system lost in the drought and initiate new tiller buds for the next growing season. This will allow grasses to have the maximum opportunity to perform after the use of prescribed fire.

Grazing and fire

Another planning tool is a proper grazing system. If a grazing system is in place, we can survive drought better because our range is in good condition.

I am convinced that the Merrill 4-pasture, 3-herd system is the best in Texas. There is no doubt this system improves the condition of our rangeland. It also provides the greatest flexibility in incorporating prescribed fire into the total management of a ranch. If you concentrate on pastures that are deferred in the fall, this allows accumulation of grass fuel for a late winter burn. An improvement on a 4-pasture system would be a 5-pasture system. This would allow a pasture to be taken out of the grazing rotation for a full year until the fire treatment program is complete.

Fire and drought are linked in history and in ecological precept. However, this linked relationship is not practical in a ranching environment as we cannot allow fire to occur naturally over the entire ranch. Today we must reintroduce fire to its natural role, but in a planned method that maximizes fire's benefits and reduced burning risks while enabling the ranch to function in drought years. First, we must stock at a conservative rate and utilize a good grazing system such as the Merrill 4-pasture.

This allows us to improve the condition of the range and accumulate a healthy reserve of forage which in drought years allows us to sustain the base herd and in wet years gives us fuel for prescribed fire. Conservative stocking of the range is the key to surviving drought and improving our rangeland.

Summer burning

In previous portions of this section, you have learned the general principles, management uses, and safe practices of prescribed burning. There is a desire, though, to push prescribed burning to accomplish a broader range of resource or management objectives. This has meant burning at higher temperatures and/or lower humidity, conditions which are not validated by research. This is popularly referred to as "summer burning" even though burning beyond the currently "accepted" practices can take into account almost any season of the year. I will, however, refer to it as summer burning throughout much of the following text for ease and brevity.

The implied reason for summer burning is to produce desired vegetation effects. Burning at higher temperatures and/or lower humidity often allows fire to have a greater negative impact on undesirable species such as juniper or pricklypear. This increased negative impact is not limited to the target species. It is equally shared with the warm-season perennial grasses and forbs. Fire can be considered the most severe form of top removal in the herbaceous layer. Thus, it is equivalent to extreme over use by grazing animals.

The wealth of knowledge on the relationship of top removal and its interaction with season clearly explains this impact on plants. Top removal by fire or grazing is least damaging during the winter dormant period. Some negative impacts occur during initiation and early growth during spring. The greatest damage to warm-season perennials occurs during seed set and the fall growth period.

To date, we do not have an adequate understanding of what burning during the growing season dry period will do to desirable vegetation. Are we promoting better livestock forage and wildlife habitat by simply damaging undesirable shrubs, or are grasses, forbs, and browse species detrimentally affected as well? Burning desirable forage and browse plants when they are stressed from summer heat and low soil moisture may be damaging those plants beyond their acceptable limits. Some type of vegetation returns following a fire though we are not even reasonably sure what that vegetation may be following summer fire. Experience has shown both positive and negative cases of plant recovery following summer fire. We must remember that prescribed fire is not a selective tool that just hurts the bad plants and favors the good plants.

Summer burning usually is carried out during a part of the summer when plants are going through summer dormancy due to lack of moisture to keep plants growing. When there is adequate soil moisture, grasses and other fine fuels are green and do not carry fire well. Therefore, summer burns require that soil moisture be very low in order to simply carry the fire consistently. This works well for the actual burning process, but the low soil moisture conditions dictate that plant response following burning is not going to occur until is rains. If plant regrowth does occur immediately following the burn with limited soil moisture, plant carbohydrates could be diminished critically. This type of plant stress can lead to mortality.

Another reason for summer burning is because many areas cannot produce the fuel load to carry a fire. We normally defer grazing up to one year on areas prior to burning in order to allow fine fuel loads to increase in order to provide better burn coverage and more desired vegetation effects. Many areas do not have the ability to produce an adequate fine fuel to carry a fire under "normal" weather conditions. This inability to produce fine fuel (grass and forbs) may be due to long-term overgrazing, inadequate precipitation, plant species composition, or a combination of these factors. For example, if an area around Kerrville was grazed heavily for many years, this could provide an opportunity for juniper to establish in areas where it normally did not occur. Once these junipers gained a foothold in an area, they would continue to increase if not treated. The juniper will outcompete the grasses and forbs, thus reducing the ability of fire to carry through an area except under more extreme conditions.

Summer burning might be useful if weather patterns or vegetation compositions dictate that prescribed fire cannot be accomplished under more benign weather conditions. Some areas have wet winters and vegetative conditions that make winter burning difficult in many years. An example of this is along the coastal plains. The area normally does not have killing freezes that create plant dormancy during the winter. When we would usually burn an area for optimal plant responses, the coastal plains are to green to burn. The vegetation dries out later in the growing season and is able to be burned and still provide improvements. However, at this time, we are above the temperature restrictions of standard prescriptions.

Another example is in the Edwards Plateau. If adequate fall/winter moisture exists to give good soil moisture conditions for burning in the spring, numerous cool-season annual grasses and forbs will be germinated making it too green to carry a fire. Also in this area, if it is not too green to burn during the winter/spring, it is difficult to plan for target plants like juniper to have low enough green leaf moisture to meet resource objectives in a prescribed burn. There are some years when juniper leaf moisture is low enough, but there are many when it does not decrease enough to obtain desirable results. Deferring grazing on areas to be burned is extremely important. As previously discussed, summer burning often is chosen as the tool to use on areas where fine fuel loads are inadequate or marginal to carry fire even after a full year of deferment. The summer burn in these conditions is conducted with low soil moisture, and herbaceous plants do not respond until precipitation occurs. Good precipitation and growing conditions following the burn would limit the return of grazing to the pasture until the next growing season. If favorable conditions do not occur, grazing may have to be deferred in the pasture for up to two years following the burn. This means that the pasture, at a minimum, would not be grazed for nearly 2 full years (fuel accumulation and plant recovery), and it is possible that the pasture could be removed from its normal grazing pattern for 3 years if precipitation is low. Livestock operations must take this huge obligation into account before planning a summer burn.

Even though we can choose weather conditions when a summer burn might be conducted, that is not the only aspect of safety. Simply working in the hot and sometimes humid conditions during summer burns is a real hazard to people. Dehydration, heat exhaustion, and heat stroke are likely to occur when burning at temperatures in the 90 – 110 degree range. This is especially true if escape fires occur and personnel are required to exert large amounts of energy. The risk of injury to people in this situation should cause practitioners to think twice about use of summer burns. If the decision is made to continue with a burn during the summer, crew members should be hand-picked as personnel in good to excellent condition, experienced in working under extremely hot weather conditions, and have no major medical problems that could affect them under extreme weather and stress.

Smoke management

Prescribed burning has become a valuable tool in land/habitat management. The pros and cons of prescribed burning make it controversial at times. Issues like smoke management concern more than just the managers conducting the burn. Smoke can have a detrimental effect on people and property a great distance away from the burn. Improper smoke management can affect air pollution, smoke sensitive health issues, and public safety. These problems are not simply something to be disregarded. Liability of prescribed burn managers can be incurred if smoke management is properly attended. Therefore, it is best to burn when atmospheric conditions promote rapid dispersion of smoke.

Conclusion

In conclusion, prescribed burning can be a valuable tool for managing vegetation for resource and wildlife objectives. Proper planning, proper grazing management, and responsible use of fire will keep prescribed fire from becoming unusable due to regulations, laws, or fear. Good fine fuel (grazing) management, installation of proper blacklines, and use of proper prescriptions for burning help ensure that prescribed burning will continue to be a useful tool. Keep a diary detailing every aspect of your individual burns. This will help you determine if objectives were achieved and help you minimize mistakes in the future. In wildlife habitat management there is a place for hot winter burns, cool winter burns, and summer burns. Make sure the fire you set is the fire you need.

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Figure 1. This is a typical Texas roadside scene, the beginning and the end product of failed brush management. The thicket on the left is a sterile habitat that only provides cover to a passing coyote.

Figure 2. This fire is being conducted late in the evening, January 2, 2005, with the humidity over 70% and air temperature below 65°F with light wind and the soil wet. We were burning in blacklines with excellent fine fuel and all juniper less that 6 feet was killed even though the leaf moisture was 95%.

Figure 3. This pasture is ready for fire to thin the juniper. The area has not been grazed for five years and has excellent grass, especially little bluestem (*Schizachyrium scoparium*), in the interstitial spaces.

Figure 4. From 1990 until 2004, this gentle slope has gone from a few scattered small juniper with the large plants in the background to a thicket that is useless for any purpose.

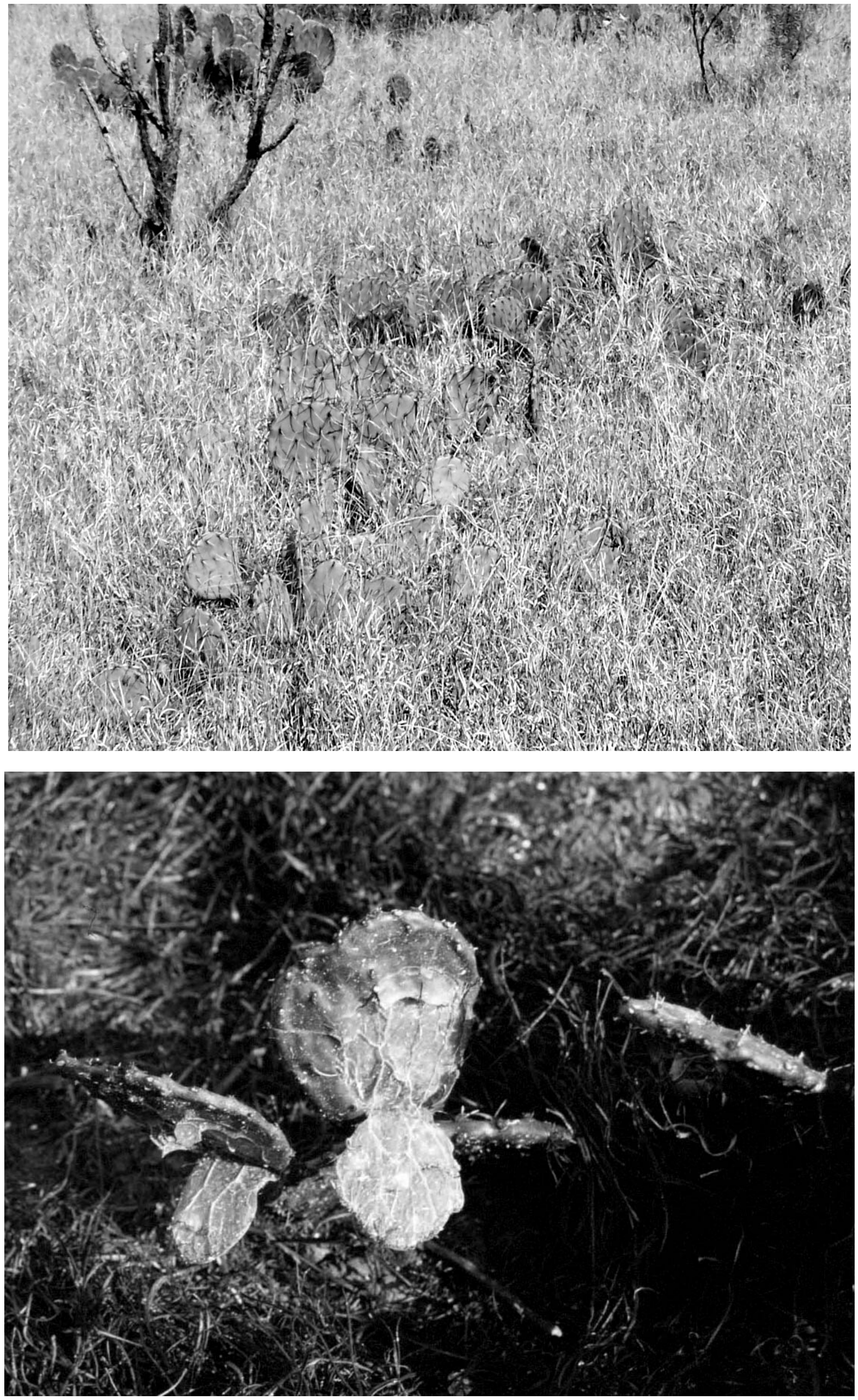

Figure 5. Brown spine pricklypear (*Opuntia phaeacantha* var. *phaeacantha*) (top) is easily killed by fire (bottom) if the pads are surrounded by fine fuel regardless of season of application. Large pricklypear such as Englemann (*O. phaeacantha* var. *discata)* provide and food for wildlife and small mammals.

Figure 6. When grazing management (fine fuel management) is a priority in wildlife management, fire can be used effectively and safely to improve habitat for everything from deer to butterflies.

FIRE ECOLOGY OF PINEYWOODS AND OAK WOODS AND PRAIRIE ECOREGIONS OF TEXAS

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Abstract: Fire coupled with other environmental factors, such as topography and climate, created and maintained a mosaic of pre-settlement (18^{th} to mid-19^{th} century) vegetation communities in Texas, including grasslands, savannahs and forests. Lightning and Native American fires both played an important role in shaping the oak dominated woodlands and tallgrass prairie ecosystems found in the Oak Woods and Prairie ecoregion of Texas; and the once abundant pine grassland communities of the East Texas Pineywoods, which historically extended throughout the southeast. Early European settlers attempted to suppress the fires that had been an important force in these ecosystems. This suppression, coupled with agricultural development and widespread timber harvest, changed the historic vegetation composition and structure. More recently, prescribed fire has been used as a management tool to mimic the historic natural fires. It can be used for numerous objectives, including reduction of fuel loads, woody brush control, improving forage for livestock, promoting desirable herbaceous species, wildlife management, increasing species diversity and richness, controlling parasites and pests, improving nutrient cycling and site preparation before reforestation. Site-specific factors will influence response to prescribed fire. Effectiveness of fire to meet management objectives can be influenced by choosing proper season, frequency and conditions of fuel and weather.

Introduction

Fire is an ecological force and natural disturbance in nearly all upland habitats across Texas (Pyne 1982, Wright and Bailey 1982, Waldrop et al. 1992). Fire coupled with other environmental factors, such as topography and climate, created and maintained a mosaic of pre-settlement (18^{th} to mid-19^{th} century) vegetation communities in Texas, including grasslands, savannahs and forests (Pyne 1982, Wright and Bailey 1982). Lightning and Native American fires prevented the invasion of eastern forests into the central grassland region (Adams et al. 1982, Axelrod 1985, Ewing and Engle 1988, Sparks and Masters 1996). These naturally occurring fires played a important role in shaping the oak dominated woodlands and tallgrass prairie ecosystems found in the Oak Woods and Prairie ecoregion of Texas (Anderson 1990); and the once abundant pine grassland communities of the East Texas Pineywoods which historically extended throughout the southeastern U.S. (Buckner 1989, Platt et al. 1988, Waldrop et al. 1992).

Native Americans occupying the current Texas Oak Woods and Prairies and Pineywoods ecoregions routinely used fire as a tool to attract game for harvest, reduce brush and dense vegetation near their communities, and achieve numerous other objectives. Henri Joutel [a member of La Salle's expedition in the late 17th century] documented Texas Indians using fire in the tallgrass prairie to attract bison to the more palatable and nutritious growth (Jurney et al. 2000). Joutel noted that between the Colorado and Brazos Rivers (Blackland and Grand Prairies) bison were numerous: "In addition the grass was burned and almost none had appeared. But these animals seem to delight in searching for the small sprigs of grass just beginning to sprout" (Foster 1998). The Caddo Indians, which occupied eastern Texas, used fire to maintain prairies, which also provided grass thatch for building materials and forage for their horses (Jurney et al. 2000).

Euro-American settlers of the Oak Woods and Prairie and Pineywoods regions attempted to suppress the majority of natural fires that had been such an integral part of these systems. Fire suppression allowed once open herbaceous dominated communities to become quickly invaded by numerous fast growing woody species. The increase in woody species reduced the amount of light reaching the ground, causing a dramatic decrease in the herbaceous layer. Fire suppression coupled with agricultural development of nearly all native prairies, and widespread timber harvest without regard to regeneration dramatically changed the landscape and vegetation composition and structure of these two ecoregions.

In more recent times, prescribed fire has been a commonly used management tool in the Oak Woods and Prairies and Pineywoods regions of Texas to achieve numerous objectives including fuel load reduction; woody brush control; improving forage for livestock; controlling undesirable herbaceous species; wildlife management; increasing species diversity and richness; controlling certain parasites and pests; improving nutrient cycling; and preparation of sites for reforestation. A site's response to a prescribed fire and the effectiveness of meeting planned management objectives is influenced by site-specific factors. These factors include prior and post management techniques; fuel type and load; moisture regime; individual plant and vegetation community condition at the time of burn; the site's vegetation structure (basal area, stem density, canopy cover, etc.); and the site's slope, aspect and soil type. Other common factors affecting the effects of fire on a site are intensity, season and frequency of fire; and the weather conditions before, after and during the fire. Generally the ecological effects of fire on soils, water, vegetation and wildlife in these two ecoregions are similar so further discussion of fire effects will be combined.

Effects on soil and water properties

Prescribed fire affects soils by altering their physical, chemical and biological characteristics (Robbins and Myers 1992). Removal of surface litter raises soil temperature and creates drier microclimates, and increased temperatures may promote increased microbial activity (Wright and Bailey 1982). Burning releases nutrients tied up in slowly decomposing organic material (Robbins and Myers 1992). Released nutrients raise soil surface pH, altering the environment for soil microorganisms. Mobilized nutrients are either taken up by plants and soil microorganisms or exported from the ecosystem by volatilization, leaching and surface runoff (Robbins and Myers 1992). Nitrogen is frequently cited as the nutrient most subject to fire induced losses, because it is readily volatilized in the combustion process (Wright and Bailey 1982). However, studies conducted on soil nitrogen have failed to show that prescribed burning adversely affects ecosystem nitrogen capital (Robbins and Myers 1992). Apparent conflicts in research on nitrogen loss can be contributed to variations in methodology (Christensen 1987). One long-term study on the Santee Fire Plots in South Carolina discovered total nitrogen capital to be greatest in annual burn plots, when compared to periodic and no-burn controls (Christensen 1987). Keep in mind that this study was conducted in a forested ecosystem without grazing. Nitrogen capital may be reduced in annually burned grazed prairie situations.

Fire consumes litter and herbaceous ground cover, therefore possibly altering erosion and runoff rates (Wright and Bailey 1982, Robbins and Myers 1992). In forested sites the "duff" is usually not consumed and protects the soil from soil loss. While in grasslands, the roots remain in the soil holding the soil together. Water infiltration may be temporary reduced while the surface vegetation is recovering, but topographic relief in the Oak Woods and Prairies and Pineywoods ecoregions is minimal. Therefore, nutrient and soil losses caused by fire are considered negligible.

Effects on vegetation

Fire effects on vegetation depend on the type of plant; phenology at time of burn; fire intensity and other fire behavior parameters; and site-specific factors. Overstory trees generally have high growing points and thick bark which protect them from low to moderate intensity fires. Therefore our discussion will concentrate on brush and understory species response.

The control of undesirable woody brush is one of the most common objectives for the use of prescribed fire in the Oak Woods and Prairies and Pineywoods ecoregions. Fire effects on woody species is dependent on species, bark thickness, height or age of tree, canopy cover, season of fire, fire intensity and fire frequency. Many woody species are adapted to survive low to moderate intensity fires through their ability to resprout, or type of bark. Bark is an excellent insulator against fire, and resistance increases as bark thickens (dependent on species and age). Decreased density, increased moisture content (Spalt and Reifsnyder 1962), and fissured or corky bark, such as the majority of southern pine species possess are all fire-resistant qualities. The majority of woody species within these ecoregions are sprouters, meaning they are capable of re-sprouting from roots stocks after the above-ground stem is killed. The only non-sprouters within this ecoregion are Eastern red cedar (*Juniperus virginiana*), Ashe juniper (*Juniperus ashei*) and loblolly pine (*Pinus* *taeda*). Re-sprouters typically sprout multiple stems after being top killed, often more than 20 sprouts for a single top-killed stem. A single fire may top-kill a large portion of a population, but surviving plant bud crowns will recover and produce an even higher number of stems per plant. Therefore a single fire, without burning on regular intervals can create a greater problem than no fire at all.

Many studies suggest growing-season burns are more effective than dormant-season fires at controlling hardwoods (Waldrop et al. 1987, Boyer 1990, Robbins and Myers 1992). However, studies that calculated actual fireline intensity, using Byram's fireline intensity formula (Byram 1959), determined fireline intensity to be the primary controlling factor affecting the size of woody stems capable of being top-killed by a prescribed fire (Glitzenstein et al. 1995, Sparks et al. 1999). Many growing season fires will produce higher fireline intensities, because of higher ambient air temperatures, direct solar radiation and longer days which produce lower fine dead fuel moistures. Also, there are numerous woody species with volatile or flammable leafs that are only leafed-out during the growing season. The presence of these volatile leaves allows the fire to climb, and even possibly move through the crown of some woody species, when in the dormant season the fire would creep or not burn at all because of such light fuel loads.

Winged elm (*Ulmus alata*) is an example of such a species in the Oak Woods and Prairie ecoregion. In the dormant season fuel loads under dense stands of winged elm are very low, often dominated by lush green, cool-season grasses. In contrast, in the late growing season, the cool-season grasses are dormant and the winged elm are fully leafed. The fire will carry under the elm stand in the cured fine fuels, and many times climb into the canopy moving through the canopy of the dense stands. This produces a very intense fire that effectively kills stems as large as 6-12" dbh (J. Sparks, Texas Parks and Wildlife, personal observation). Larger stems killed by this type of fire produce few re-sprouts and, in many situations, none at all.

Another benefit to burning during the growing season is that burns can be conducted when juniper live fuel moisture (JLM) of trees 4' to 8' tall are at levels where the tree can be consumed and killed (Blair et al. 2004). Typical summer JLM in the Oak Woods and Prairies ecoregion ranges from 75 to 90% depending on moisture regimes. JLM of 76-85% and a fine fuel load > 2000 lbs/acre will produce a successful headfire consuming a good proportion of 4' to 8' Juniper stems (Blair et al 2004). Only 1,200 lbs/acre of fine fuel is required for a successful headfire when JLM are between 60 and 75% (Blair et al. 2004)

Fire acts as a defoliater much like grazing with timing of the burn being critical. Perennial plant death caused by fire is rare. Herbaceous species actively growing at the time of a fire are more susceptible to heat injury than dormant species or species in the early stages of development. Late spring fires tend to reduce cool-season species such as brome (*Bromus* spp.) and wild rye (*Elymus* spp.), and favor warm-season species such as little bluestem (*Schizachyrium scoparium*) and Indiangrass (*Sor-*

ghastrum nutans) that are dormant or just beginning to initiate growth (Towne and Ownesby 1984, Hulbert 1988, Howe 1994a; Sparks et al. 1998). Summer fires, depending on timing, will suppress actively growing warm-season species such as goldenrods (*Solidago* spp.), while favoring cool-season species or species that grow later in the growing season and through the winter such as blackeyed- susan (*Rudbeckia hirta*) (Towne and Owensby 1984; Sparks et al. 1998). Summer fires compared to winter fires increase the number of annuals and promote cool-season forbs and grasses such as Panicums (*Panicum* spp.) (Towne and Owensby 1984, Howe 1994b; Sparks et al. 1998). Early to mid-winter fires also tend to increase forb abundance (Bidwell et al. 1990). Summer fires increase the number of flowering stems and increase synchronization in forb flowering habits (Platte et al. 1988). Grasses such as little bluestem and other bluestems (*Schizachyrium* spp.) flower more profusely in response to summer fires (Lewis 1964, Robbins and Myers 1992). In general, dormant-season fires benefit warm-season grasses and forbs, and growing-season fires benefit cool season species that grow later in the growing season through the winter.

Fire, regardless of timing, tends to increase community species richness and diversity, with fires conducted in the fall, early winter, or summer being cited as the best time to burn for species diversity objectives (Brown and Smith 2000, Glitzenstein 2003, Gray et al. 2003). Fire return interval recommendations vary greatly depending on site and management objectives. Typically, more frequent burning will result in increases in herbaceous plant dominance, particularly grass species, and decreases in woody plants (Beckage and Stout 2000, Glitzenstein et al. 2003). Control of the dominance and stature of woody shrub species that shade and out-compete herbaceous species is essential in managing for diversity and richness. Within these two ecoregions of Texas, a 2 to 5 year burn rotation is sufficient for most management objectives.

Effects on wildlife

The majority of upland habitat types in Oak Woods and Prairie and Pineywoods ecoregions are fire-derived and maintained, with native wildlife species being adapted to this natural disturbance. The effects of fire on wildlife are generally indirect causing temporary displacement by altering habitat structure and food availability, quantity and quality (Komarek 1963, Wright and Bailey 1982, Smith 2000). Growing-season fires have the greatest potential to cause direct impacts specifically to nesting birds, insects and slow-moving reptiles. Limiting the size of growing season fires (< 500 acres), and burning later in the growing season after the majority of nesting birds have finished nesting will reduce direct impacts.

Most species of wildlife require specific habitat characteristics. Without some form of successional redirection or method of disturbance such as fire, these habitats would change progressively, eventually becoming undesirable by many species (Komarek 1963, Sparks and Masters 1996). As habitat quality decreases for one species it may be increasing for others. Many breeding birds require specific habitat structure and composition for foraging and nesting. Depending on species, preferred habitat structure may vary from a dense shrub layer with little to no herbaceous growth on the ground to an area with few shrubs and an extensive herbaceous growth at ground level. Periodic fires (3-6 year return interval) can be used to suppress woody species and induce sprouting, creating a recurrent shrub understory to benefit species such as the prairie warbler (*Dendroica discolor*), painted bunting (*Passerina ciris*) and other shrub nesting and foraging species (Wilson et al. 1995). In comparison, a frequent fire interval (1-3 year return interval) can be used to reduce woody species stature maintaining an open herbaceous layer. This benefits many ground-nesting and foraging species such as the Bachman's sparrow (*Aimophila aestivalis*) and grasshopper sparrow (*Ammodramus savannarum*).

Many wildlife species benefit from a diverse mixture of grasses, forbs and browse, often preferring transition areas between different vegetation communities (Fuller 1991, Wade and Lundsford 1989). Habitat diversity can be obtained by utilizing low intensity fires that leave a mosaic of burned and unburned areas reducing food loss, and leaving patches of standing herbaceous material and shrubs which are beneficial to many species (Bidwell 1988). This mosaic of habitats at different successional seres can also be obtained by burning small areas in a patchwork fashion. Habitat diversity can be increased further by varying burn frequency, intensity and season; and depending on objectives, livestock grazing can be incorporated into the rotation. A patch dynamic approach to managing the landscape creates a shifting landscape that is constantly changing but always includes heavily disturbed communities, undisturbed communities and a matrix that varies in time since disturbance (Fuhlendorf and Engle 2004). The patch dynamic management system allows managing for multiple objectives (Fuhlendorf and Engle 2004).

Bobwhite quail and wild turkey both require periodic fire to maintain their habitat quality. The Oak Woods and Prairies and Pineywoods ecoregions have high precipitation levels (annual range from 76-142 cm) allowing vegetation to thrive, without periodic fire the herbaceous layer becomes too thick for young bobwhite poults to travel through. Periodic prescribed fire increases the amount of bare ground and allows for easier movement and foraging. Prescribed fire also increases the availability of lush herbaceous vegetation preferred by many insects, thus creating excellent bugging areas for bobwhite quail and wild turkey (Miller 1963). Periodic winter burns promote legumes benefiting bobwhite quail and other gallinaceous birds (Grelen and Lewis 1981, Landers 1987).

Natural area management

Contemporary fire regimes differ from pre-settlement fire regimes by eliminating fire or restricting it to specific seasons for specific management objectives (Sparks and Masters 1996). Fire exclusion has led to numerous vegetation structural changes including forest densification (Kreiter 1995) and increased woody shrub densities causing decreased herbaceous vegetation (Lewis and Harshbarger 1976, Ewing and Engle 1988). Many vegetation communities have progressed to a state where fire alone is not an effective restoration tool. Herbicides, mechanical removal, selective thinning and other management tools often have to be implemented before fire can effectively maintain the natural vegetation structure and composition. Restoration results are not instantaneous and often take multiple fire cycles before restoration objectives are achieved.

Areas under active fire management are often burned during different seasons from pre-settlement fire regimes to meet specific management objectives. This shift in season of fire may directly influence the site's vegetation composition and structure, therefore reshaping native plant communities that evolved under the influence of fire in a different season (Howe 1994b). Reestablishment of natural areas or ecosystem restoration requires resource managers to become knowledgeable of the sites fire history and pre-settlement composition (Wilson et al. 1995, Masters et al. 1995, Sparks and Masters 1996). If management objectives are to restore an area similar to pre-settlement times, contemporary fire regimes should mimic the pressettlement fire regime frequency, intensity and timing (Sparks and Masters 1996).

Management implications

Growing-season prescribed fires may be more effective at controlling undesirable woody species in both forested and prairie habitats in Texas. However, timing an effective growing-season fire is difficult because isolated and scattered thunderstorms, common during summer months vary precipitation distribution greatly across the landscape. This variable precipitation distribution causes fuel moistures to vary from one site to another, and require resource managers to monitor specific environmental conditions at the specific burn site, instead of across a larger landscape level. County and local burn bans also are common during growing season months, further limiting the number of potential burn days available in a growing season to initiate effective prescribed burns. In many counties, burn bans are initiated prior to fuel conditions becoming favorable for a successful prescribed fire, this requires resource managers to attempt to get exceptions to the burn ban or initiate prescribed burns before fuel conditions become optimal.

Overstory and midstory trees also are more susceptible to injury or death caused by growing-season fire. This increased risk of injury is due to the fact that during the majority of the growing season winds are light and air temperatures are high allowing heat from the fire to rise straight to the canopy, with very little heat dispersal. In this situation a seemingly low intensity fire (flames < 3' long) may produce enough heat and energy to cause terminal buds in the canopy to reach their terminal death point killing a large proportion of the overstory trees. This situation is especially common in pine dominated or oak-pine dominated stands.

Extensive research and gained knowledge of fire effects on vegetation communities and wildlife responses allow resource managers to be much more efficient in the execution of prescribed fires (Ansley and Taylor 2004). Research linking fire behavior to vegetation response has allowed managers to not just merely recommend the use of prescribed fire, but to recommend a specific type of fire that will produce desired fire behavior to meet management objectives. Burn plans can be finely tuned to include specific environmental conditions (e.g. fuel moisture, relative humidity, temperature, etc.), increasing the effectiveness of resource managers meeting burn objectives. Fire behavior modeling software also allows resource managers to quickly and easily determine the potential for spot fires; estimated flame length fireline intensity, rate of spread and other common fire behavior parameters; and determine what equipment is necessary to safely conduct a burn in some fuel types (Masters and Engle 1994, Sparks et al. 2002).

As the population of East and Central Texas continues to increase, the application of prescribed fire will become more difficult because of habitat fragmentation, increase in smoke-sensitive areas and the overall perspective of the public to fire. Resource managers should use prudent judgment in the application for prescribed fire to ensure its long-term use in the future. Proper smoke management procedures and planning are essential in the heavily populated areas of East and Central Texas. Patience is required of resource managers burning in this heavily populated area. There will be potential burn days that the application of fire for a given site will not be possible because of the risk of affecting smoke sensitive receptors in the area.

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FIRE ECOLOGY IN THE RIO GRANDE PLAINS AND COASTAL PRAIRIES OF TEXAS[1]

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Abstract: Management of vegetation is key to the successful management of wildlife and prescribed fire is proving to be an effective tool in managing South Texas Rangelands. Prescribed fires were conducted on honey mesquite (*Prosopis glandulosa*) dominated Mixed brush rangelands on the Rio Grande Plains and Coastal Prairie of South Texas. Fire successfully suppresses but does not kill many woody plants. Multiple winter burns are more effective in suppressing brush than a single fire. Summer fires and combinations of winter and summer burning are more effective in reducing woody plant cover than are cool season burns alone. In managing brushlands, it may be necessary to manipulate the brush for fire fuel release before fire can be used. Sequential treatments of roller chopping, foliar spraying of regrowth, and prescribed fire reduce brush densities and increases plant diversity. Timing of burning can have a strong influence on the plant community composition following the fire although summer and winter prescribed fires generally produce similar responses from herbaceous vegetation. Grass density may decrease following summer fire; yet, productivity is similar on recently burned areas or areas a year post-burn. It also increases the wildlife value of the habitat as a result of woody plant resprouting and increased forb growth. Fire also increases both chemical and mechanical defense mechanisms in certain woody species. Summer fires enhance insect communities but suppress tick populations. Timing of burning also can have profound effects on wildlife communities through its effects on habitat with general benefits to grassland species. Fire is a useful tool in managing native South Texas brushlands, while maintaining woody plant density.

Introduction

The Rio Grande Plains (RGP) and Coastal Prairie (CP) of South Texas is the southernmost extension of the Great Plains Grasslands. Fire, along with other climatic variables such as drought, presumably maintained mesquite (*Prosopis glandulosa*) savannas and interspersed grasslands of pre-European settlement South Texas. Frequency of fire appeared to be highly variable and ranged from 5-30 years (Wright and Bailey 1982). Following European settlement, the change from grassland to woodlands/shrublands was accelerated by introduction of livestock and fencing. Domestic animals served as ideal agents of seed dispersal for some species, notably mesquite. Removal of biomass by grazing also removed the fine fuel necessary to generate the intense, hot fires required to kill young woody plants. Where fuel was available to carry the fires, people worked to suppress them.

[1]This is Welder Wildlife Contribution Number 644.

Through time, woody plants gained a decided competitive edge over the grasses and forbs that had characterized the original grasslands, and the "brush country" was formed (Scifres and Hamilton 1993). Thus, suppression of fire, combined with heavy livestock grazing, led to the current thorn woodlands common throughout South Texas (Archer et al. 1988, Archer 1994).

In the mid-twentieth century, South Texas landowners began to convert thorn woodlands back to grasslands to enhance rangelands for livestock production. Treatments such as root plowing and herbicides were commonly used to achieve this goal. In recent years the size of individual landholdings has decreased and revenue from wildlife has increased (Wilkins et al. 2000). Brush management to enhance habitat has evolved into "brush sculpting" where brush is manipulated to increase edge, juxtaposition, and biodiversity. Mechanical, chemical, and prescribed fire treatments are used in this effort.

Fire provides an economical means of controlling woody species and maintaining the life of mechanical and chemical brush management treatments. Burning during late winter and early spring has been recommended for achieving many goals on South Texas rangelands (Scifres and Hamilton 1993), however, information on summer burning has been collected (Drawe and Kattner 1978; Ruthven and Synatzske 2003) and summer burning is now being utilized more frequently.

Although fire has been used as a management tool for over a hundred years, the effects of fire on South Texas rangeland have not been studied until relatively recent times. In a thorough review of the literature, the earliest study mentioned by Vogl (1974) was that of Box et al. (1967). However, since 1967 much work has since been conducted in the region. Certainly, a landmark publication that documents the state of the art of the use of prescribed fire in the region is Scifres and Hamilton's (1993) book titled *Prescribed Burning for Brushland Management: The South Texas Example*.

Study sites

Information in this paper was collected mainly from three South Texas locations (Figure 1). The Chaparral Wildlife Management Area in the western RGP is characterized by hot summers and mild winters. The growing season is 249 to 365 days, and the precipitation pattern is bimodal with peaks in late spring (May-June) and early fall (September-October). The 11-year (1989-2000) average precipitation is 21.3 inches (54 cm).

The second study area was on La Copita Demonstration Ranch and Research Area in the eastern RGP. The climate is subtropical with mild winters and hot summers. Mean annual temperature is 72.3° F and the growing season is 289 days. Average annual rainfall is 26.8 inches (68 cm) with peaks in May and September.

The third area was the Rob and Bessie Welder Wildlife Foundation Refuge, located on the transitional zone between the CP and RGP. Average annual precipitation (1956-1985) is 35.8 (91 cm).

Although generally considered a historic grassland, South Texas today is a brush-grass complex; a grassland with brush of various densities covering almost all sites except the deep sands of the Nueces soils.

Vegetation at all three locations is dominated by honey mesquite with various mixtures of broad-leaved evergreen and deciduous shrubs in its understory. Herbaceous vegetation between shrub clusters is composed of C4 grasses such as thin paspalum (*Paspalum setaceum*), knotroot bristlegrass (*Setaria geniculata*), Texas grama (*Bouteloua rigidiseta*), and hooded windmill grass (*Chloris cucullata*), which give way to grasses such as threeawns (*Aristida* spp.), red grama (*Bouteloua trifida*), sandburs (*Cenchrus incertus*), and windmillgrass (*Chloris verticillata*) under prolonged, heavy grazing by cattle.

The major woody species in mixed brush communities are honey mesquite, black brush (*Acacia rigidula*), agarito (*Mahonia trifoliolata*), brasil (*Condalia hookeri*), Mexican persimmon (*Diospyros texana*) lime pricklyash (*Zanthoxylum fagara*), spiny hackberry (*Celtis pallida*), pricklypear cactus (*Opuntia engelmannii*), and lotebush (*Zizyphus obtusifolia*), among others. Huisache (*Acacia smallii*) is also a component of these communities.

Rangeland response to fire

Historically, fires burned in the summer and early winter in the RGP and CP. Currently, summer fires are more effective in suppressing woody plant growth than are cool season burns. Prescribed fire has been used successfully to suppress woody plants in the eastern RGP and CP; however, fire does not kill brush. Research indicates that fire does reduce brush cover (Box et al. 1967, Dodd and Holtz 1972), and 2 or more burns are more effective in reducing brush than a single fire (Box and White 1969). Gordon and Scifres (1977) found that prescribed burning, particularly when combined with chemical or mechanical methods, was effective in restoring rangeland heavily infested with Macartney rose (*Rosa bracteata*). Rasmussen et al. (1983) found that in a fire regime the cool season Texas wintergrass (*Stipa leucotricha*) increased with increasing huisache canopy up to approximately 40% canopy coverage of the woody invader, but that total herbage production declined beyond 40% canopy. Therefore, to promote cool season plants, a certain amount of properly spaced woody cover maintained by prescribed fire may be desirable for both cattle and wildlife.

To suppress brush, the most effective burns are those used in combination with chemical or mechanical treatments. For example, huisache can be removed with chemical or mechanical means, but is only temporarily reduced by fire alone. So, fires reduce canopy cover and productivity of woody plants and enhance herbaceous growth. It can be used to increase the wildlife value of the habitat by causing resprouting of woody plants and by increasing forb growth. Fire also increases both chemical and mechanical defense mechanisms in certain woody species (Box and Powell 1965).

Since fire suppresses but does not kill most species of resprouting brush, it is of benefit in wildlife habitat management. Top growth removal of brush stimulates succulent regrowth for consumption by browsing wildlife and it can create habitat diversity. Hot fires may be used to create a patchwork design, alternated within burned areas. Cool fires, burned over a whole range interspersed with mottes, will burn around mottes and leave portions of the range unburned thus creating greater diversity.

Timing of burning has a strong influence on the composition of the plant community following the fire and has profound effects on animal communities through effects on habitat. Plant species composition can be altered by timing of burning, thus the manager can create a plant community desirable for wildlife. Late winter burning reduces forb populations and benefits grasses; whereas, early winter burning is followed by normal forb populations (Hansmire et al. 1988). In addition to reducing forbs, late winter burns may reduce the amount of other cool season plants, particularly Texas wintergrass.

Several studies have concentrated on the influence of repeated fires on both woody and herbaceous vegetation. Recently, summer prescribed fire has been implemented in an attempt to suppress woody plant encroachment. An area was established on the Welder Wildlife Refuge in 1975 to assess the effects of repeated cool season fires on CP vegetation. A non-burned control was located adjacent to the burned block. The area was initially burned in the winter of 1974 and then was subsequently reburned in 1977 and 1980.

Repeated burning effectively suppressed woody vegetation. After the 1974 fire there was almost total top removal of woody species. The 1977 fire, which was extremely hot, burned through most of the smaller chaparral mottes. On the windward side of a motte the 1977 fire removed 100% of the cover. On the leeward side of a motte, depending upon wind speed during the fire, there were protected areas where some woody plants avoided top-kill. In the larger mottes, i.e., those greater than 20 feet in diameter, woody plants survived in the center and on the leeward side of the motte. Fine fuel was essentially nonexistent within mottes. Only crown fires burned completely across a large motte. Whole mottes survived in the cooler 1980 burn, even some of the smaller mottes less than 20 feet in diameter. Individual woody plants between mottes were top-killed. Following the third burn, canopy cover was reduced from the original 40% to less than 2%. By the summer following the third burn, there appeared to be a reduction in the amount of cover of all woody species. However, one year after the burn, all species were growing vigorously. Weedy herbaceous vegetation was abundant in the mottes totally top killed by the fire.

Long periods between burns allow brush to regrow to its former height and density and possibly increase in density (Hamilton et al. 1981). To suppress woody plants in South Texas prescribed fire should be used every 3 to 4 years. Otherwise, brush regrowth is so rapid that any greater time sequence between burns will allow the brush to grow to the point that fire can no longer be used as an effective tool for suppressing regrowth.

Fire is also an effective tool in removing excess mulch accumulations that occur during wet cycles under conservative grazing. On the Welder Refuge, fine fuel loads from 4,500 pounds per acre to 16,000 pounds per acre were burned (average 5,500 pounds per acre). Large amounts of fine fuel form a mat that may not be penetrated by light and actually acts to suppress plant growth. There is an increase in herbage production in the year following the initial burn; because more light penetrates to the soil surface and nutrients are released to the soil from decadent plants.

On the Chaparral Wildlife Management Area, rangeland was subjected to two winter prescribed burns and a winter burn followed by a summer fire. Prescribed burning can manage woody vegetation without dramatic reduction in woody plant diversity, which is common with many traditional mechanical treatments. However, percent woody plant cover was reduced by 50% and 41% on winter and winter-summer combination burned sites, respectively. Woody plant density declined by 29% and 23% on winter and winter-summer combination burned sites, respectively (Ruthven, et al. 2003). Density of guayacan (*Guaiacum angustifolium*), wolfberry (*Lycium berlandieri*), and tasajillo (*Opuntia leptocaulis*) was less on all burning treatments. Percent cover of spiny hackberry and density of pricklypear declined on winter burned sites. Burning creates a post-fire environment which causes a decline in many woody plant species. It is unclear to what degree other environmental factors, such as herbivory and competition between woody plants and among woody and herbaceous vegetation, may have interacted with fire to produce post burn woody plant declines. Inclusion of summer prescribed burning in the burning scheme did not increase the decline in woody plants.

Combinations of winter and summer burns can effectively reduce the cover of honey mesquite, twisted acacia, Texas persimmon, lotebush, wolfberry, and tasajillo. Canopy cover of spiny hackberry and density of pricklypear cactus decline following multiple winter burns. Soil moisture at the time of fire application may have a greater impact on woody vegetation response than season of burn.

Both summer and winter burning are effective in reducing honey mesquite cover which may promote increases in herbaceous vegetation following fire. Summer burning following significant rainfall is effective in managing honey mesquite, while maintaining desirable woody species such as spiny hackberry. If reducing total woody plant cover is a management goal, burning during winter following periods of little or no rainfall is recommended.

Summer and winter prescribed fire produce similar responses from herbaceous vegetation (Ruthven et al. 2000; Ruthven and Synatzske 2002). Warm season annuals such as croton (*Croton* spp.) were more prevalent on burned sites. However, increases in annuals did not persist into the second growing season following burning. Cool season annuals demonstrated little response to summer or winter burns. Perennials such as erect dayflower (*Commelina erecta* var. *erecta*) and beach groundcherry (*Quincula cinerascens*) increase following summer and winter burns; whereas, silky evolvulus (*Evolvulus sericeus*) and hoary blackfoot (*Melampodium cinereum*) decrease following summer fires. Grass density decreased following summer fire; yet, productivity was similar among treated and nontreated sites one-year post burn.

Initial burns on native RGP rangelands should be conducted on a 2-year interval until the desired structure of woody vegetation is achieved. Once desired goals are met maintenance burning on a 3-5 year frequency is adequate. Grazing strategies that allow for substantial deferment to produce adequate fuels to carry fire are critical to the successful application of fire on both CP and RGP rangelands. Another consideration is the highly unpredictable weather pattern in South Texas. Short-term periods of drought are common and rainfall can be highly variable between locations. Drought can severely impact production of fine fuels necessary to carry fire and requires flexibility in burning schedules. Because of the vagaries of climate burning in South Texas must be done as the opportunity arises since, if a critical burn is missed, conditions may not allow burning for several more years.

As discussed earlier, fire may be integrated with other practices in brush management systems. An evenly distributed, fine fuel load of 2,500 to 3,000 lb/acre is considered adequate for an effective burn. However, rangeland supporting moderate to heavy brush cover is characterized by seriously reduced and patchy herbaceous cover (Scifres et al. 1982; Scifres et al. 1983), resulting in inadequate fine fuel load. Because of the dependence on an adequate load of evenly distributed fine fuel, burning of brushy South Texas rangelands usually is a treatment subsequent to an initial method that uniformly reduces the brush canopy and encourages the growth of fine fuel. Moreover, prescribed burning often increases the effective life of initial treatments and compensates for characteristic weaknesses of several of the methods. Because of this utility, fire-based Integrated Brush Management Systems (IBMS) can take maximum advantage of several methods, including fire, over a relatively long time period. (Scifres et al. 1985).

Prescribed burning has been evaluated following applications of herbicide sprays and pellets as broadcast or individual plant treatments. It has also been effectively used in conjunction with various mechanical methods for brush management as both herbicide and mechanical applications reduce brush canopies and release fine fuel for prescribed burning. Prescribed burning then suppresses surviving woody plants, removes rough forage plants, promotes legumes and other desirable forbs usually damaged by sprays, promotes uniform distribution of livestock grazing, expedites secondary succession and improves botanical composition of grass stands. South Texas mixed brush is characterized by all of the problems and potentials described above. In most cases, burning is impossible until the brush canopy is reduced and fine fuel is produced.

In 1999, an IBMS was installed in a mixed brush community on La Copita Demonstration Ranch and Research area. An outline of the State of Texas was superimposed on a DOQQ map of a pasture and coordinates around the perimeter of the map were recorded. Using a backpack GPS unit these coordinates were located around a 35-acre parcel of rangeland and staked. A D-8 Caterpillar tracked tractor then pulled a "rolling chopper- aerator" around the perimeter before chopping the area within the perimeter.

As expected, brush regrowth after top removal was rapid. In September, 2002, the 35 acres were divided into several plots and a variety of herbicides and mixes of herbicides were applied to each. Efficacy varied dependent upon species and herbicides treatment but, overall, canopy was reduced by 90% the first year. By the second year plants/acre were reduced by 50%. In spite of being part of a grazing program, air dried forage production in the fall of 2003 was 280 lbs/acre in the control - open pasture; 320 lbs/acre in the control - brushy pasture; and 1500 - 2800 lbs/acre in the chopped and sprayed pasture.

Brush regrowth of those species not killed by the herbicide treatments was rapid. In February, 2004, the "State of Texas" was burned with a prescribed fire. The fire further thinned the brush stand, the species mix of forbs and grasses was enhanced, and wildlife such as Northern bobwhite quail (*Colinus virginianus*) and white-tailed deer (*Odocoileus virginianus*) now prefer this pasture to non-treated pastures. Measurements of cattle grazing distribution also indicate a preference for this pasture.

Although wildlife response to fire is well documented in many ecosystems, very little data is available for the CP and RGP. Prescribed fire on South Texas rangelands can provide short-term benefits to bobwhite quail by opening up herbaceous canopies to facilitate travel by foraging birds (Wilson and Crawford 1979; Koerth et al. 1986). Response of nongame birds to winter fire in South Texas varies with species such as common ground dove (*Columbina passerina*), mourning dove (*Zenaida macroura*), and lark sparrow (*Chondestes grammacus*) increasing following fire and grasshopper sparrow (*Ammodramus savannarum*), Le Conte's sparrow (*Ammodramus leconteii*), sedge wren (*Cistothorus platensis*), and Bewick's wren (*Thryomanes bewickii*) decreasing in abundance post fire (Reynolds and Krausman 1998, Ortego and Ruthven 2003). Suppression of woody vegetation and short-term increases in bare ground benefit ground foraging species; whereas, species dependent on shrubs for foraging and nesting decrease following fire. Both winter and summer fire appear to improve habitat for the Texas horned lizard (*Phrynosoma cornutum*) by creating a suitable mosaic of herbaceous and woody vegetation and bare ground for thermoregulation and escape cover, as well as increasing the abundance of harvester ants (*Pogonomyrmex rugosus*), their main prey (Burrow 2000; Moeller 2002; Burrow et al. 2002). Fire, summer fire in particular, appears to improve habitat for other grassland reptiles such as the six-lined racerunner (*Cnemidophorus sexlineatus*), which increase following burning (Ruthven and Kazmaier 2003).

Summary

Fire affects vegetation by suppressing woody growth, removing excess buildup of litter, and stimulating herbage production. Fire will not kill the majority of South Texas woody plants because of their resprouting characteristics, although there are indications that repeat burns may kill a small percentage of plants of certain species. Timing of burning is one of the most important factors to consider in planning a burn. Fire stimulates growth of forbs following the top removal of woody plants in dense mottes of brush. Precribed fire appears to improve habitat for grassland wildlife species; however, further research into the response of wildlife to fire in the RGP and CP is needed to fully assess fire as a management tool.

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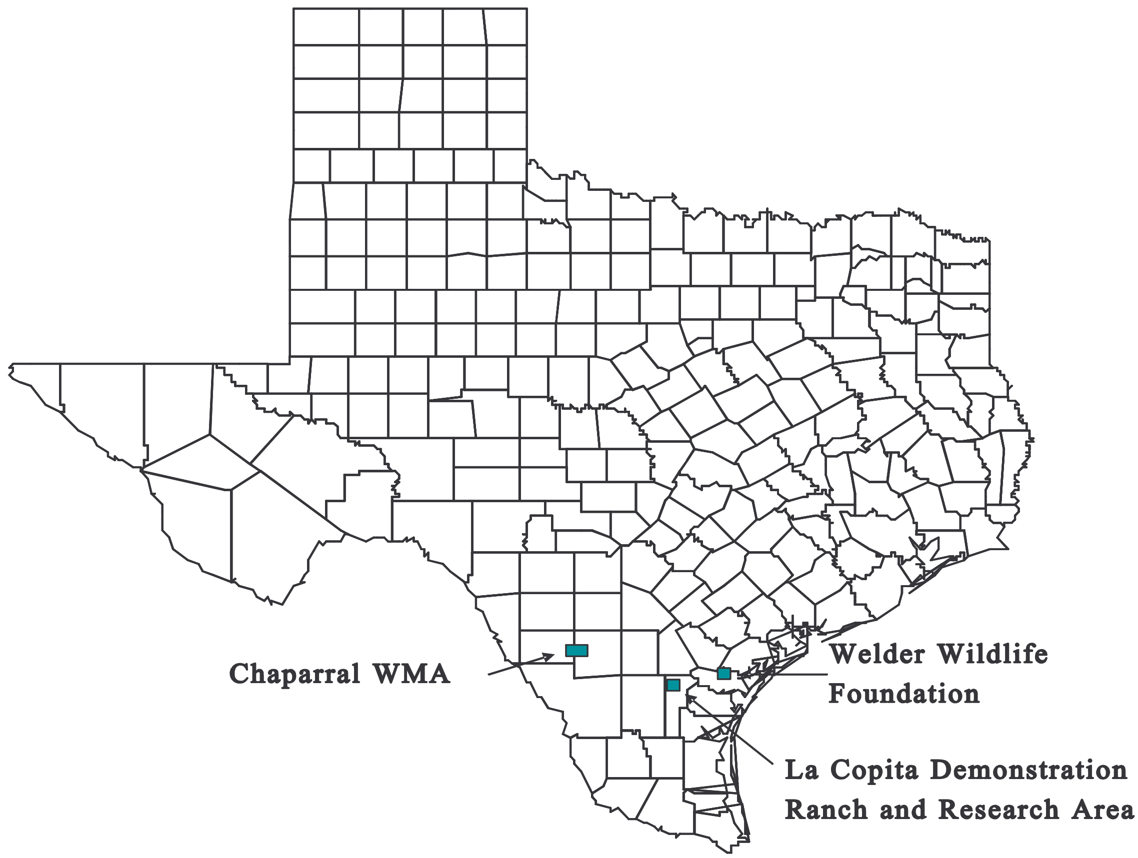

Figure 1. Location of Study Sites on the Rio Grande Plain and Coastal Prairie.

DOES FIRE HAVE A ROLE IN THE TRANS-PECOS OF TEXAS?

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Abstract: Trans-Pecos Texas is located within the Chihuahuan Desert containing a wide variety of vegetation and fire regimes. Over the past century the landscape has been greatly altered by over utilization from livestock and the lack of naturally occurring fire. Reduction in naturally occurring fires has lead to an increase in brush densities and reduced herbaceous cover. The introduction of exotic grass and forb species can negatively alter the natural fire patterns, both in intensity and frequency. Vegetation production following a fire is a nutritious food source for wildlife species from insects to mule deer. Today few areas contain sufficient amounts of fine fuel (grass) to support adequate fire intensities to reduce brush densities, thus the use of fire may not be the first management step to reduce excessive brush densities.

The Trans-Pecos region of West Texas is encompassed by the larger Chihuahuan Desert Ecoregion. Vegetation communities vary greatly within the Trans-Pecos – from the Pecos River basin to the Mountain Sky Islands to expansive black grama and blue grama semi-arid grasslands. With the variety of vegetation types there is also a wide variety of fire ecology, history and needs. Historically, it is likely that fire helped shape the structure and extent of Chihuahuan Desert grasslands, as fire shaped other grasslands of North America. Although fire is often a vital component to healthy rangelands, fire is not the only process that has shaped the desert southwest. Periodic drought, climatic oscillations, insects, diseases, rodents and rabbits each play contributing roles in maintaining the grasslands. Many people have attributed the vegetation changes of the southwest over the past one hundred years to climatic change of increasing aridity; however there does not seem to be conclusive evidence that contemporary changes in precipitation or temperatures have been significant enough to singularly influence the rapid shrub expansion and encroachment into grasslands (Van Auken, 2000).

Fire is critical to the natural maintenance of desert grasslands. Fire size and frequencies have diminished greatly during the past century. Photos before 1880 indicate that shrubs were absent or inconspicuous in desert grasslands, which indicates naturally occurring fires prevented widespread shrub establishment, since most desert shrubs are susceptible to fire as seedlings. Thus a fire return interval of 7 to 12 years would have maintained the Chihuahuan Desert in a relatively brush free grassland (McPherson, 1995). Over the past 150 years, livestock grazing has reduced fine fuel amounts to the point where natural fires are rare, thus allowing brush species to increase densities or expand in areal extent.

For a fire to occur three components must be present: 1) an ignition source, 2) adequate fine fuel (grass), and 3) fuel moisture content must be low enough to burn. In the desert there are plenty of ignition sources from convection thunderstorms which frequently produce lightning, but little or no subsequent rainfall. When previous seasons' rainfall has been adequate there is usually sufficient quantity and continuity of fine fuel present to support fire spread where grazing is not or has not been excessive. And to satisfy the third component, the low relative humidity desiccates fine fuel sufficiently enough to ignite and spread. Post-fire recovery of desert grasslands generally occurs in one to three years, almost entirely dependent upon rainfall.

Without periodic fire, grasslands generally convert to dominance by woody plants, species like mesquite (*Prosopis glandulosa*), yuccas (*Yucca* spp.), cane chollas (*Opuntia imbricata*) and various shrub species. Therefore, in order to maintain grasslands as grasslands we simply need to allow natural fires to burn (McPherson, 1995). However, today land ownership configuration makes this impractical: additionally with the economic demands placed on rangelands to produce vegetation for livestock forage, there is little fuel remaining to carry fire.

An increasing concern in desert fire ecology is the establishment and proliferation of exotic species. Many pervasive exotics (grasses primarily) prosper with fire, thus increasing the fuel beds' extent and biomass and the likelihood of altered landscape-level fire spread and post-fire distribution, possibly to the detriment of some native grasses (Brooks and Pyke, 2001). This post-fire result also may reduce the value to indigenous wildlife and usually reduces the forage quality of the vegetation to all herbivores.

Over the past 100 years, grassland health in the Chihuahuan Desert has declined; in fact some are now seriously degraded. This degradation has resulted from the removal of vegetation by livestock and the subsequent preclusion of naturally occurring fire. The over-utilization by livestock generally results from a lack of recognition or familiarity with driving ecological processes. One example of this can be found in Arizona; during the early 1900's overgrazing was encouraged by forest administrators to reduce fire hazards and to promote tree growth (Griffiths, 1910). The severe wildfires of the 2002 summer demonstrated what happens to these same Arizona forests following the lack of periodic fires. Therefore as we learn more about how the ecological processes work collectively to shape the desert grasslands the better we can manage in and for the future.

As landowners are aware, there is a decrease in grass production with an increase in brush densities. There is a real (and inevitable) cost to doing nothing. We find that the longer we wait to control excessive brush densities the more costly it becomes to do so; added to the fact that there has been a continuous decline in grass production over many decades. Today, prescribed fire is generally the most cost-effective broadcast method to treat large tracts of land ($1 to $15/acre) for shrub reduction. However, few areas of the Chihuahuan Desert presently have sufficient grass production to support the application of efficient or effective fire. That is, a fire with the desired ecological effects as opposed to just making the ground black. Understanding that many of the Chihuahuan Desert grasslands in their current state cannot sustain wildland fire, we must look at why and what to do about it. The simple fact is that there is not enough grass to support fires due to excessive grazing, increased brush densities, drought or a combination of many factors. Therefore something has to be done to produce more grass. More than likely a number of tactics will be needed; reduced stocking rates, mechanical and/or chemical brush control and most importantly, time. The degradation of much of the Trans Pecos has occurred over the past 130 years and the corresponding restoration will take time, perhaps just as long or longer, to rebound.

Timing of wildland fires has a dramatic influence on what happens next. Fires during the fall and early winter generally produce cool-season annuals and perennial forbs, most are beneficial to wildlife. Fires that produce an abundance and diversity of forbs meet a variety of wildlife needs. Wildlife are attracted to the nutritious forage and insects; insects are very important to the reproductive success of upland birds such as scaled quail and turkey (Richardson, 2001). Fires that occur in late winter, spring and summer are more conducive to perennial grass species. Seasonal timing of prescribed fire is dependent upon the desired ecological objectives and results. When producing a site-specific fire management plan, it is beneficial to alternate burning seasons periodically over time. That is, if a particular unit was burned the most recent two times in the fall, then it is reasonable for the next burn to be during the spring or late winter. This alternating burning regime will improve the constituent diversity and biomass production of Chihuahuan Desert rangelands.

Burning may not be the first (nor certainly only) answer to improving range condition on much of the Chihuahuan Desert; however, fire is an important landscape process that maintained portions of the Trans-Pecos landscape for tens of thousands of years. We cannot turn back the pages of time to improve our range condition, rather we need to look to the future and decide what we want 10 years, 20 years, 50 years from now and begin working toward that goal today.

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FIRE AS A TOOL FOR WILDLIFE HABITAT ON THE W.E. ALLEN RANCH

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The W. E. Allen Ranch encompasses 4,400-acres in the Llano-Guadalupe Divide region of southern Kimble County and northwestern Kerr County. The ranch has been owned and operated by 4 generations of the Allen family since 1898.

Like most Hill Country ranches, ours was severely overgrazed. During the last century, the original live oak savanna, abundant in various native grasses, forbs and shrubs, has changed drastically in character. Prolonged periods of drought in the 1910s, 1930s, 1950s and 1990s, coupled with overgrazing and the absence of fire, have accelerated a trend toward a monoculture dominated by Ashe juniper (blueberry cedar, *Juniperus asheii*). Prickly pear (*Opuntia engelmanii)*, persimmon (*Diospyros texana)* and agarito (*Mahonia trifoliolata)* have proliferated. Native species of forbs (bluebonnets (*Lupinus texensis)*, for example) are virtually non-existent. Per desirable shrubs, there are approximately 8 wild plum (*Prunus mexicana*) mottes, 6 redbuds (*Cercis canadensis*), no flameleaf sumac (*Rhus lanceolata)*, 1 Eve's necklace (Texas Sophora, *Sophora affinis)*, 1 evergreen sumac (*Rhus micropohylla*), 2 wild mulberries (*Morus microphylla)*, perhaps 2 dozen grapevines remaining, in an area once profuse in these species. Large-seeded grasses are sparse. The call of bobwhites *(Colinus virginianus)* which I enjoyed during my youth had not been heard on the ranch since the mid-1970s.

Early in his ranching career, my grandfather, Ed Allen, recognized the threat of encroaching cedar to his livestock operation. In the hard times of the 1930s, he employed dozens of men, who lived on the ranch in canvas tents with their families, to chop cedar. The cost was $1 per acre with a double-bit axe. Hard times. My father, Billy Ed Allen, continued the battle, hiring undocumented workers from Mexico, who cut cedar with axes and chain saws throughout the 1960s and mid-1970s. Daddy, my brothers and I also bulldozed hundreds of acres of cedar during that time period. Daddy's illness, multiple sclerosis, curtailed cedar control on the ranch during the late 1970s and 1980s. During that period, the majority of our place was overwhelmed by what I call "The Cedar Curtain."

Beginning in the early 1990s, I started cutting cedar with a chain saw. Since that time I have cut 1,000 acres of cedar. Overall, since the 1930s, I would estimate that our entire ranch has been cut at least 3 times. But the plain fact is, we are losing the battle. Hundreds of acres on our place are covered "wall-to-wall" with dense stands of cedar—too thick to ride a horse through. Areas I cut only 6 years ago are heavily re-infested with seedling cedars, ranging to 4 feet in height.

Recognizing the hopelessness of controlling cedar by conventional means, our family reluctantly became open to considering more drastic, some would say desperate, measures. We recognized the formation of the Edwards Plateau Prescribed Burning Association

(EPPBA) as an answer to our ranch's plight.

Beginning in 1997, we have burned, or attempted to burn, one pasture each year, with EPPBA assistance. Early on, we conducted only cool-season burns, with marginal results. Last year we conducted our first summer burn, with the help of Association members from Kimble, Edwards, Sutton and even one from Crockett County.

In total, we have burned 2,300 acres on our place during that period. Only one of these fires could be described as satisfactory; the others have produced marginal results. Even with less than desired burn results, a marked difference in rangeland conditions is evident on our ranch. Areas that once were bare except for limestone rock and cedar are now thoroughly turfed with a variety of grasses standing 2 feet tall. I am observing, for the first time in my life, the emergence of seedling Spanish oaks, redbud and wild plum. I even saw a few sprinklings of bluebonnets this spring.

At the present time and for the foreseeable future, our ranch will be a cattle and hunting operation, based roughly on the Kerr Wildlife Management Area model. We plan to continue using prescribed fire as a standard annual practice to suppress undesirable species – cedar, prickly pear, agarito and persimmon; and to enhance the reemergence of desirable grasses, forbs and shrubs.

We are observing satisfactory results in terms of wildlife quantity and quality. Deer, whitetail and exotic, are averaging 10-15 lbs of body weight increase since we began burning in the late 90's. The population of wild turkey has clearly increased. And from time to time in the last 3 years, I have seen bobwhites on the ranch, singly or in pairs.

As our ranch's habitat continues to be restored through prudent livestock stocking rates, continued cutting of cedar followed up by regular application of prescribed fire, I have, for the first time in my life, some realistic glimmers of hope, that the original beauty, variety, and productivity of our corner of the Hill Country may be restored.

INCORPORATING FIRE AS A NECESSARY TOOL FOR RANCH MANAGMENT

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***Abstract*:** The use of fire to manage and maintain range is the ultimate goal of McFaddin Enterprises. Brush encroachment is to the point that fire alone is not feasible. Use of sound grazing techniques, practical brush management, and patience has led to a systems approach in which we are managing for a prairie ecotype and not necessarily for any single species. This systems approach allows McFaddin Enterprises to maintain production of resources and decrease production costs. With increased production, drought periods are still hard times but not as detrimental.

Introduction

Many ranching operations spend 80% of time and money on what brings a 20 % return and 20% of time and money on what brings an 80% return. This is a function of what scale is used to focus management time and tools. McFaddin Enterprises wildlife revenues have changed from a supplemental income to a consistent and imperative cash flow that ranching operations are dependent on to stay in the black. It has become necessary to manage rangeland in a more natural holistic way with low expense in mind. In the Gulf Coast Prairies and Wetlands, brush encroachment has led to a drastic change in prairie type habitats with less diversity. In most cases, encroachment exhibits a monoculture of species such as huisache (*Acacia smallii)* or mesquite (*Prosopis glandulosa*) or a combination of both. McFaddin Enterprises operations are in a continuous struggle to reduce the brush species while maintaining native herbaceous cover for sustainable yield for both wildlife and livestock.

Location

McFaddin Division of McFaddin Enterprises Ltd. is approximately 15,000 acres located 15 miles south of Victoria, Texas in Victoria County. Soil types vary from deep sands to claypan prairie with loams predominating. The range was utilized from the late 19th century to 1996 for continuous grazing in large pastures and is now managed by the fifth McFaddin generation in a rotational grazing regime. There are three rotations consisting of 5 pastures in each rotation. Extensive fencing was planned to implement this grazing regime. Increased water development was necessary to facilitate the rotating of cattle and more importantly distribute grazing more evenly to protect and encourage higher quality species composition. Pastures average 840 acres in size. An extensive sampling of the species composition in 1998 determined the range to be in high fair to low good condition. Recent sampling indicates that the range is in high good to low excellent condition. This has allowed McFaddin ranch to use a high stocking rate with pasture deferment, maintain consistent wildlife cover, and produce an ample amount of fuel to schedule both summer and winter burns in each of the 3 rotations. Therefore, each pasture is scheduled to burn every 2.5 years.

Methods

Traditional methods of controlling brush have included mechanical, chemical, and burning. Mechanical treatments are selected according to size and type of brush, ground moisture, and cost. Mechanical treatments, alone, generally last from 3-15 years. Chemical treatments are expensive but more importantly not always applicable at recommended times due to proximity of agricultural crops. Chemical treatments by themselves may result in a 2-7 year control. Individual plant treatment is best for low brush density areas and aerial treatment used for higher density areas. Aerial applications at the recommended time and rate have not been successful. Fire is the cheapest and most natural method of maintaining prairie habitat, however implementation is subject to stocking rate and mostly controlled by climate. Use of rotational grazing and the ability to defer grazing has somewhat overcome droughts that usually limit fuel production for summer burns. Summer burns can be inhibited by a county instituted burn ban. Mild winters tend to yield high fuel moisture that limits winter burns. Historically, burning has been more of an opportunistic tool used only when yearly rainfall was extremely high. These burns were spur of the moment, poorly planned, and often out of control. Burning with prescription has now become a planned objective to meet twice a year. A prescribed burn with adequate monitoring can be used during a burn ban.

The drawbacks and limitations to each of these methods has led to the development a long term systems approach which include each tool used in series over a period of years. This systems approach is a methodical, planned management scheme that is constantly adapting to get the most sustainable use of our rangeland. A systems approach addresses problems of regrowth and new seedlings. When brush densities have increased to the point that fine fuel production is not conducive to a burning or cattle production, it is necessary to mechanically treat the area. A burn is planned one to 2 years post treatment. If a burn cannot be accomplished in that period, the mechanically treated area may then be treated with a herbicide to retard regrowth brush until a burn can be implemented. Blackland areas may need to treatment with a herbicide to increase fine fuel growth by retarding tree and shrub growth and eliminating forb production. The elimination of forb production can be detrimental to wildlife for a growing season, but is quickly regained when followed by a fire. The ultimate goal is to use fire as the main tool to maintain natural prairie habitat.

Results

McFaddin Division is now managing for annual burning of two pastures per rotation. While burns are scheduled to occur every 2.5 years on a pasture, climatic factors allow burns to occur 3.5 to 5 years on a pasture. Fireguards are a priority. Conditions of fuel moisture, humidity, and wind are closely monitored to compare to prescription requirements and burns are conducted at the best possible times. Increased fuel and forage production has offered a decrease in supplemental winter feeding of cattle. Wildlife populations dependent on herbaceous cover are less affected by drought periods. Burned areas consistently produce higher quality forage during stress periods for both wildlife and livestock. Mesquite bean production in pastures sprayed in the spring and burned in the summer has decreased. New seedlings are mostly eliminated until the next rain and regrowth brush is retarded. Burning of only half the pastures is detrimental. Cattle use only the burned areas the first year thus increasing the stocking rate on utilized portions of the pasture. This excessive utilization negatively impacts species composition in the pasture and decreases body condition scores of the livestock. Fire will be the main management tool with mechanical and chemical tools used as needed.

Cooperators

Initial costs of mechanical and chemical treatments are high. The Natural Resource Conservation Service, Texas Parks and Wildlife Department, United States Fish and Wildlife Service, The Nature Conservancy, and Grazing Lands Conservation Initiative have been instrumental in offering technical, monetary and physical support in formulation and implementation of management practices that occur on the McFaddin Division.

PRACTITIONER'S PANEL : USING PRESCRIBED FIRE IN WEBB COUNTY

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NOTES:

KEEPING FIRE AS A WILDLIFE MANAGEMENT TOOL

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Fire is well recognized by land managers as a tool for managing habitat. Land managers throughout Texas continue to use fire to manipulate rangelands to improve habitat for both livestock and wildlife. However, there are still many hidden battles being fought in order to keep fire as an available tool to manage habitat.

One of the original goals of the Texas Prescribed Burning Coalition (organized in April 1998) was to educate the public about the importance of fire to our landscape. The Coalition has been successful in lobbying for legislation that guarantees landowners a right to burn on their property. This same legislation allowed the formation of the Prescribed Burn Board and a Certified Burn Manager Program. However, due to numerous constraints put on the Prescribed Burn Board, the Coalition's goal of public education has never been fulfilled. On almost every burn conducted by Red Buffalo, LLC, we still endure battles with neighboring landowners and county officials.

The Prescribed Burn Board of Texas has diligently attempted to develop the Certified Burn Manager Program (CBMP) with two major goals: 1) to ensure that fire will remain a tool for land managers and; 2) to provide a training program to increase the professional application of fire. Unfortunately, due to unforeseen problems with insurance and other issues, the CBMP has neither improved nor increased the use of prescribed fire.

Currently, state agencies, federal agencies such as the Natural Resource Conservation Service and county officials have no system with which to establish a foundation for prescribed burning. Every county has different standards for allowing prescribed burns during burn bans. While burn bans are important, some counties remove a ban when grass is too green for prescribed fire. State agencies have developed their own fire training and standards independently; therefore there is no consistency across agencies. A system of education and training that will allow for similar standards to be used statewide would aide in accomplishing the goal of increasing prescribed fire use.

Again, the importance of burn bans in reducing the risk of wildfires is recognized. However, as fuel loads continue to increase across the state, it is critical that that an outlet is provided for reducing fuel loads, while providing standards for the continued use of prescribed fire for managing wildlife habitat.

Below is a proposal for a two-level system to help provide for a standardized method for the continued use of prescribed fire:

Burn Manager Level II

This level would be equivalent to the original Certified Burn Manager Program that meets all Prescribed Burn Board standards. This would include training, experience, and insurance requirements.

Burn Manager Level I

This level would simply be a registration process for state agencies, NRCS, landowners and caretakers. They must meet all the criteria of the Certified Burn Manager except for the insurance. The insurance here would still be secured by the landowner. This would provide a consistent method for county officials to allow for burns during burn bans, as well as increase the professional application of prescribed fire.

Prescribed burn associations have helped tremendously in bringing landowners and county officials together to perpetuate the use of prescribed fire. However, we still need to provide for a standardized method that will provide for the consistent use of prescribed fire. This may include the development of better education in our public schools about fire's role in nature.

FIRE AS A TOOL FOR MANAGING WHITE-TAILED DEER HABITAT IN TEXAS

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***Abstract*:** Suppression of natural fires that shaped the original plant communities in Texas has allowed the encroachment of woody plants into formerly open ranges. Changes in the relative amounts of woody and herbaceous cover directly affect the quality of habitat for deer. Prescribed burning is a management tool that can be used to create useful areas from areas that have deteriorated and no longer support the population in the best manner. Correct timing of burning can alter the availability of preferred foods and enhance the quantity of forbs and browse from woody plants. Nutritional quality is likewise enhanced for a time after burning. In dense habitats, open areas can be created that are favored as feeding areas and provide an environment for social interactions among the animals. Though optimum deer habitat can be a range of conditions, habitats where woody cover exceeds 50 % canopy cover, is between 3 and 5 feet tall and existing open areas are beginning to close would likely benefit from prescribed burning.

Introduction

White-tailed deer (*Odocoileus virginianus*) have evolved and adapted to surviving under a broad range of conditions. Because they are so adaptable, there is a tendency to think they can endure under any conditions and continually produce with unfailing consistency. Unfortunately, this type of thinking is unrealistic. Because of a long-standing ecological concept known as succession, habitats are constantly changing, albeit some faster than others. Therefore, as habitats change, their utility and their ability to maintain wildlife populations also changes. As Blakey (1947:179-180) stated: "*Encroachment of brush jungle upon formerly open forest and prairie range is insidious in that is has both good and bad effects upon certain wildlife species, and in some areas has the constant potential for near total exclusion of all valuable forms."* Thus, to maintain high quality habitat, it often becomes necessary to manipulate the habitat to create and maintain conditions conducive for the species in question.

Each species of animals is adapted to a particular range of plant structure and composition. Theoretically, peak animal abundance would occur at some optimum combination of woody and herbaceous cover for that species. As woody or herbaceous cover changes and goes above or below the optimum level, animal abundance will decline until it reaches a point where the habitat will no longer support the population in a healthy condition. Also, animals do not distribute themselves randomly across the landscape. Instead, they tend to concentrate in areas that provide for specific needs. For management to do no harm to a species, critical areas need to be pre-served. To benefit a species, useful areas need to be created from suboptimal areas (Koerth 1996:324). When properly applied, management strategies like prescribed burning can be used to produce and maintain high quality habitat with native plants. However, this means active input to mitigate natural deficiencies and changes in plant abundance, growth and development.

Changes in the vegetation complex

Historically, fire has played an important role in shaping biotic communities. Fires are thought to have retarded woody plant growth and helped maintain grasslands and savannahs in many areas of Texas (Beadel 1962). Suppression of fire on many rangeland areas may have been one of the many causes that led to the substantial increase in woody plants that likely will persist and continue to be the prominent vegetation without drastic disturbances (Archer 1989).

Long fire-free intervals commonly change canopy coverage and structure by allowing woody plants to gain dominance and increase in density. Production of warm-season herbaceous plants decreases inversely with shrub encroachment (Wilson and Tupper 1982). In a nutshell, as woody cover increases, production of forbs and grasses decreases. Also, there is a botanical shift from sun-loving species to more shade-tolerant species of lower vigor. Cool-season herbaceous plants are not as straightforward in their relationship with woody cover. Light-to-moderate woody cover sometimes can increase production of cool-season grasses and forbs until the woody cover reaches some threshold level after which total production is thereafter decreased (Scifres et al. 1982).

The ability to use a prescribed burn is closely related to these changes in the plant community. The loss of herbaceous cover as woody cover increases translates into reduced fine fuel necessary to carry a fire across the landscape. If woody cover is allowed to reach dense proportions, prescribed burning may not even be possible without drastic input. These drastic inputs are generally in the form of expensive mechanical treatments that open the woody canopy and allow sunlight to reach the soil level where herbaceous plants grow. However, even drastic mechanical treatments only temporarily suppress woody plants (Fulbright and Guthery 1996). Thus, a prescribed burning program needs to be planned and initiated within a relatively short time frame of the initial treatment to maintain the control effects of the mechanical treatment. Historical frequency of natural fires for a particular region may give some insights to the conditions that shaped the original plant community and aid in the planning process for subsequent burns (Table 1).

What deer eat

Probably the biggest influence of prescribed burning on deer productivity is its influence on their food source. Therefore, a basic understanding of what constitutes a good diet for deer is necessary. White-tailed deer are very different from cows in that they are picky in what they select to eat. A deer's nose is more pointed and their tongue is considerably narrower. Whitetails also have larger salivary glands than cows.

Deer are referred to as *concentrate selectors* (Huston and Pinchak 1991:36), meaning they tend to probe the vegetation, selecting only specific parts of the plant. Their digestive system is designed for plants and plant parts that are more easily digestible in comparison to what a cow might eat.

As the growing season progresses, the preferred foods of deer tend to become more fibrous or woody in nature. Whitetails search out the most digestible portions of each plant, as well as find the best plants among hundreds of shrubs, vines, weeds and grasses available. When it becomes too difficult to find enough preferred plants, deer will shift to less palatable second and third choice species. We assume that when deer consume a high proportion of second and third choice plants they are receiving suboptimum nutrition.

Basically, the foods of whitetails can be classified into the following forage classes: forbs, grasses, browse, mast, cacti and mushrooms. Deer will consume some of all of these categories. However, only a few of the hundreds of plants occurring on deer range actually have significant nutritional value in their diet and will vary by season and availability. Thus, maintaining a high diversity of plants is considered essential to allow the animals the opportunity to select the highest quality diet available.

Over most of their range, deer prefer many species of forbs if available (Drawe 1968, Bryant et al. 1981, Ortega et al. 1997). Forb is a fancy name for what most people know as a weed. Forbs are broad-leaved annual and perennial flowering plants. If given a choice, deer would rather eat forbs than any other forage class. This is because forbs are the most digestible plants when young and actively growing. That does not mean, however, every weed is eaten by deer. As with many other types of plants, some forbs have evolved to make themselves undesirable to grazing animals either by taste, smell or some other mechanism. A negative aspect of forbs is they tend to be ephemeral and usually are found in abundance only during or shortly after rainy periods. Also, as forbs mature, their nutritional quality and digestibility falls rapidly.

Grasses and grass-like plants (sedges and rushes) make up only a very small percentage of the diet of deer, and usually utilized only during the early stages of plant growth. For example, the first rosettes of panic (*Panicum* spp.) grasses are commonly eaten in late winter to early spring, but quickly fall out of favor once they start maturing. Certain grasses planted to "improved" pastures like bermudagrass (*Cynodon dactylon*) have little dietary value for deer although they may be used for other purposes such as hiding cover for newborn fawns. Deer seen feeding in native or improved grass pastures in most cases are carefully picking out the more preferred weeds from among the grass. That's not to say deer never eat grass. After all, popular cereal grains planted for supplemental food plots such as oats (*Avena sativa*), wheat (*Triticum aestivum*), rye (*Secale cereale*) and triticale (*X Triticosecale*) are species of grass. However, for the most part grasses are not on the preferred list for whitetails.

While many species of cacti occur in Texas, probably the only species that provides significant forage for deer is prickly pear cactus (*Opuntia* spp.).

Prickly pear is one of the few cacti that can provide a large amount of forage, as well as abundant mast. While prickly pear pads can be a large component of deer diets, its use tends to be seasonal and varies with location and availability (Arnold and Drawe 1979, Everitt and Gonzalez 1979). Because of its high water content, prickly pear is particularly relied on in times of drought.

Mushrooms are greatly overlooked as deer food, particularly in areas of the state that receive more rainfall (Miller and Halls 1969). Mushrooms are high in protein and phosphorus, two critical dietary elements for whitetails. Deer have the remarkable ability to eat even the species that kill humans. For example, the Destroying angel fungus (*Amanita verna*) is one of the deadliest mushrooms. One square centimeter will kill a human; yet, deer apparently can eat the entire plant with no problem. Mushrooms lack chlorophyll to make food like other plants. Instead, they feed primarily on decaying material of other plants and do not need direct sunlight for growth. Fire is necessary for some species of mushrooms to fruit. However, any management technique like burning that reduces plant debris and other organic components that these fleshy fungi need for growth, will ultimately cause them to decrease.

Browse, on the other hand, is the dietary mainstay of most deer throughout their range. Browse is defined as the leaves and twigs of woody plants and vines and is the most dependable portion of the plant community. This is the food deer depend on when other foods are unavailable (Arnold and Drawe 1979). Yet again, this plant group is not universally utilized.

Browse plants can be broken down into 2 basic groups: determinant and indeterminant plants. Determinant plants tend to put on the majority of their growth in early spring, when conditions are the most conducive for growing. As new growth diminishes later in the spring through early summer, the new twigs become woody and less digestible. Indeterminant plants, on the other hand, put on new growth each time conditions are favorable. Examples of indeterminant plants would be southern dewberry (*Rubus trivialis*) and Japanese honeysuckle (*Lonicera japonica*) in east and central Texas and Old man's beard (*Chionanthus virginica*) in southern Texas. After each significant rain, indeterminant plants add new growth. The obvious benefit of indeterminant type plants is a constant supply of new, tender growth after each rainfall.

Mast is the fruit of woody plants, including trees, shrubs and woody vines. Mast is represented by a spectrum of fruits, berries and nuts. The primary benefit of mast is the energy it provides. Acorns, for example, are rich in fats and carbohydrates. Although acorns are commonly known among hunters, there are many other mast types that are just as important. In the arid brush country, deer relish honey mesquite (*Prosopis glandulosa*) beans and prickly pear fruits (tunas). In the eastern part of the state, plants such as American beautyberry (*Callicarpa americana*) and grapes (*Vitis* spp.) provide important late summer mast crops. Unfortunately, mast tends to be highly variable in production and cannot be counted on no matter your management skills. Also, mast typically does not contain the high protein levels necessary to grow antlers or sustain nursing does. Most managers consider mast a welcome side benefit to their management program and not the cornerstone. Thus, management techniques employed to enhance the habitat generally are directed at woody and herbaceous forage.

While not a completely predictable pattern, deer food preferences normally follow a general sequence: 1) *forbs* (weeds) and *mushrooms* in the early spring and summer; 2) *browse* and some *mast* in late summer to fall; 3) *mast, browse* and *winter forbs* in fall to winter; and 4) *brows*e and residual *mast* in winter.

Food response to burning

In the absence of fire, or with long fire-free intervals, woody plants are allowed to age. Maturing stands result in plants of increased height with wider canopies, and it also allows young plants to establish and increase the density of the stand. Competition for light, space and other nutrients by the dominant woody plants causes herbaceous vegetation to decrease in productivity and diversity. Some woody communities can increase to the point where virtually all understory vegetation is lost because of the lack of sunlight.

For example, in the southern pine forest of east Texas the first few years following a timber harvest result in tremendous forage production. This production, however, is short-lived as pine (*Pinus* spp.) and other fast-growing trees such as sweetgum (*Liquidambar styraciflua*) and elm (*Ulmus* spp.) dominate the site.

East Texas is not alone in this respect. Other examples would be Ashe (*Juniperus ashei*) and red-berry (*J. pinchotii*) juniper, mesquite and eastern red cedar (*J. virginiana*) in the Hill Country, mesquite and juniper in the Rolling Plains, and a host of species in south Texas including mesquite and prickly pear on upland areas and whitebrush (*Aloysia lycioides*) in drainages or other low sites.

In the absence of fire or other disturbances, desirable browse species can quickly grow out of the reach of browsing animals. The effective feeding zone of a white-tailed deer is from ground level up to about 5 feet. Anything above that height has little meaning for a deer, yet water and soil nutrients are tied up in the production and maintenance of the woody canopy.

Prescribed burning is generally considered a top-removal method for shrubs or woody species. However, this depends on the size and age of the plants, and whether the species can resprout from below-ground buds. Top-killing brush plants forces the resprouting species to begin new growth at or near ground level. The lush, tender regrowth is the most nutritious. Perhaps more importantly, forage is again within reach of browsing animals and usually will remain for several years depending upon climatic conditions. Although some fast growing species like honey mesquite, huisache (*Acacia farnesiana*) and twisted acacia (*A. tortuosa*) have been shown to attain pre-treatment heights within 1 year after burning, follow up treatment for most species are not usually necessary for 3 to 5 years after using top-removal methods (Scifres and Haas 1974, Mutz et al. 1978, Hamilton et al. 1981).

Reducing the height and canopy cover of woody species is not the only benefit from prescribed burning. Ash deposited on the soil allows nutrients to recycle and be used by growing plants. Also, the reduction in competition for sunlight and nutrients allows grasses and forbs to flourish. The effect of fire on grasses and forbs varies and can be tied to the growth patterns of these plants. Grasses have their growing point at the base of the plant and are less harmed by fire. Perennial grasses in particular usually sprout quickly if there is sufficient soil moisture because food reserves in the roots allow for rapid recovery of the plant. Annual grasses can be damaged more, particularly if the fire occurs during full leaf development.

Most forbs, on the other hand, have their growing parts at the uppermost part of the plant. Fire can have a devastating effect on forbs if the burn occurs while the plants are growing. This difference in plant growth strategy allows managers the ability to affect the composition of the herbaceous layer as well as the woody layer. On a study conducted on the Welder Wildlife Refuge, Hansmire et al. (1988) found the timing of burns greatly affected the resultant composition of forbs and grasses. Early winter (December) burns increased forb yield while decreasing yield of grasses. Late winter (February) burns favored the production of grasses at the expense of forbs. Mid-winter (January) burns were a compromise in that forbs yields were increased while grass production was maintained. Scifres and Kelly (1979) also found forb production on areas burned in the fall was basically twice that of areas burned in the spring in the coastal prairie. Dodd and Holtz (1972) found that late summer burns in Goliad County decreased the density of forbs while increasing the production of grasses.

Basically, the different responses of forbs and grasses to burning can be explained by the differences in the phenological stages of the plants at the time of burning. Cool-season forbs generally germinate and initiate growth before most warm-season grasses. Thus, burns conducted in early winter before the forbs germinated allowed them the competitive advantage once they began growth. Burns later in the winter damaged the already growing forbs and allowed grasses to increase. Burning doesn’t allow you to manage for specific forb species. However, increasing the diversity of species through burning is considered a key to quality deer habitat management.

Other structural changes in plants following burning affect the quality of plants for food. In browse plants, leaves are more nutritious than twigs and twigs are more nutritious than stems. The amount of usable browse on any particular plant can be small, perhaps only a few ounces in dry weight (Rasmussen et al. 1983). Therefore, management strategies that increase the occurrence of the more nutritious portions of the plants will aid deer in selecting the best diet. McCall (1988) estimated up to 50 percent more usable dry matter from shrubs that had been subjected to top-removal methods. New growth from germinating or resprouting plants generally has a high leaf:stem ratio as the plant is trying to maximize its food production capabilities (i.e., leaf surface) to aid in growth. The high volume of leaves compared to the area of stems allows animals to more easily consume the available forage. In south Texas, Koerth and Stuth (1991) found foraging efficiency for deer can be up to 6 times greater for brush species with a high volume of leaves compared to stems. Also, burning tends to remove most of the dormant and accumulated dead material. Thus, the live:dead ratio is very high making it easier for animals to consume the nutritious plant parts without have to deal with the physical hindrance of avoiding dead material.

Aside from changing plant architecture and plant composition to make more food available, burning also can have a positive impact on food resources by changing the chemical and nutritional quality of the plants themselves. Most of these changes are basically related to plant age. Rapidly growing plant parts contain the highest concentrations of digestible nutrients. Concentrations of digestible fiber, minerals and proteins decline as plants mature and the cell walls form the indigestible structures that give plants their structural rigidity.

Laboratory analysis of fire-induced improvements generally indicates substantial differences in nutritional quality of the initial regrowth from burned plants compared to plants from unburned areas (Oefinger and Scifres 1977, McAtee et al. 1979, Hanselka 1989). However, duration of these enhancements for deer will vary with the amount of time necessary for burned sites to be restored to their pre-burn condition. In southern pine forests Thill et al. (1987) found declines in nutritional benefits in as little as 1 year. Others have shown benefits may be lost within a few months (Wood 1988) or essentially not measurable (Rogers et al. 2004). Most forage analyses are conducted on samples that are hand plucked from different sites. Arguably, deer can select a diet much higher in nutrition than researcher samples. However, it appears that long-term nutritional benefits from burning are unrealistic. Enhanced forage quantity may have a more durable time span, but increased quality seems limited.

Habitat use response to burning

Deer select a habitat based on its ability to provide for their basic needs of survival and reproduction. Habitat requirements for any animal are food, water, space and cover. Cover for deer may be further divided into screening cover and thermal cover. Screening cover is a place where deer can hide and feel secure from predators or perceived threats. Thermal cover provides protection from the elements.

As we have discussed, brush and other woody cover supply a great deal to the food equation. However, unlike with food where specific species are important, brush forms that provide adequate cover can be provided by almost any species type. As McMahon and Inglis (1974:374) stated regarding cover requirements: "*Brush to deer is simply brush; the animals do not distinguish between compositional types of brush, or between any of the structural attributes of brush, such as height, pattern, or density.*"

While brush is important in quality deer habitat, there is an upper limit to the amount required. If the woody cover exceeds this threshold, it becomes desirable to suppress the woody cover to maintain the most desirable habitat conditions. Inglis (1985) suggested optimum brush cover for deer would allow the animal to disappear from view within a range of 50-75 yards when frightened. This recommendation as a whole is appropriate when considering the entirety of the management unit. However, there are special areas that may need to be considered differently. Major drainages and their main arteries are used extensively by white-tailed deer as travel corridors, and for loafing and bedding areas (Walsh 1985). In the Rolling Plains, Darr and Klebenow (1975) found local deer densities near drainages were approximately twice that of nearby areas without drainages. In addition, there is some evidence mature whitetail bucks in particular are especially intolerant of disturbance and prefer small areas of dense (≥85% canopy cover) thickets (Pollock et al. 1994). Considering the relatively small acreages represented by these distinctive areas and the high amount of deer use associated with them, it would seem appropriate to not disturb these areas any more than necessary.

Burning, as with any other top-removal method, creates a more open habitat. Where the fuel load is adequate to burn down the woody stems, clearings are created at least in the short term. Cleared areas seem especially favored as feeding areas by deer (Stewart et al. 2000), presumably from an increase in the availability of forbs and resprouts from brush species. Clearings may also function as relative safe zones where predators can be avoided or as sites for social interaction with other deer.

Prescribed burning reduces woody plant growth essentially to ground level in most cases. In other cases, large trunks and stems from older plants remain while small understory stems are removed. However, very few woody plants are killed by burning with the exception of a few (i.e. Ashe juniper and pine trees). The response of brush plants that resprout, however, is not to simply replace the conditions that occurred prior to the burn. For example, undisturbed honey mesquite normally occurs as a shrub with only a few stems originating at the base to a single-stemmed tree. A burn that is hot enough to damage the canopy will cause the undamaged bases to rapidly resprout with multiple stems. This multi-stemmed growth form will be maintained for the life of the tree and eventually increase the amount of woody cover.

Also, some species respond faster than others, thus gaining a competitive advantage over slower growing species. Ruthven et al. (2003) found spiny hackberry or granjeno (*Celtis pallida*), lotebush (*Ziziphus obtusifolia*), pricklypear, tasajillo (*O. leptocaulis*), wolfberry (*Lycium berlandieri*), desert yaupon (*Schaefferia cuneifolia*), and guayacan (*Guajacum angustifolium*) declined after either summer or winter burns in the western portion of south Texas. It was unclear from the study, but perhaps the increased foraging from browsing animals may have hampered regrowth attempts from some of the highly preferred species such as spiny hackberry and guayacan. However, while the above species declined, other species including twisted acacia, hogplum (*Colubrina texensis*) and common lantana (*Lantana horrida*) increased. Twisted acacia and common lantana are not considered preferred browse plants for deer, but hogplum can be an important forage species.

Therefore, by understanding the species involved and their response to burning, a specific burning program can be established with at least a somewhat predictable outcome. To benefit white-tailed deer, burning should be limited in areas dominated by preferred browse plants that decline following burning. Areas dominated by species vulnerable to fire but not preferred for browsing and preferred plants that are resistant to burning should be targeted (Table 2).

Care should also be taken in how much is burned at one time and how long the effects on screening cover will last. In most cases rangeland burns do not reduce deer cover in proportion to the amount of area burned. Inconsistent fuel loads often result in a patchy burn that contains some hot spots intermingled with areas that partially burn and other areas that do not burn. Thus, retention of adequate cover is usually accomplished. Ivey and Causey (1984) indicated $\geq$ 10% of an individual deer's home range could be almost completely burned without causing a significant shift in use. In the case of southern deer, completely burned areas of 75 acres or less within an individual home range should not have any negative effects.

How the animals are ultimately influenced by the burn will also be determined by the different stages associated with burning. The 4 stages can be classified as preburn, combustion, shock, and recovery phases (Scifres and Hamilton 1993:146).

The preburn stage, as the name suggests, is the conditions that occur prior to the fire. This period is the fuel development stage for the proposed burn. How the animals use the habitat in this stage is largely determined by the food and cover requirements discussed earlier.

The combustion stage is the burn itself. Research shows the direct negative effects of the fire are minimal as highly mobile animals such as deer easily escape even fast moving fires or find refuge in areas that do not burn. There appears to be little innate fear of the fire itself and deer can often be seen standing in the smoke or even walking across the fire line on slow moving fires (Drawe 1980).

The primary acute affect is on the food source during the shock phase which occurs immediately after the burn. The shock phase usually lasts a few weeks but can extend to several seasons depending upon soil moisture at the time of the burn, and rainfall and temperature following burning. Primary effects are loss of food in completely burned areas, higher soil temperatures and increased wind movement. Not all of these are negatives, however, as deer are frequently observed bedding and loafing in recently burned areas. This association with recently burned areas is presumably because of access to a consistent breeze and the lack of annoying insects.

More chronic aspects of the burn are associated with the recovery phase. The recovery phase may last for only a growing season or not be complete for several years depending upon conditions. This is the time when plants are growing and secondary succession stages are returning the opened areas back to a state resembling the preburn condition.

When to use prescribed fire and expected results

Prescribed burns are usually implemented with the goal of improving some perceived limitations in habitat conditions. Knowing exactly when and where to conduct prescribed burns only comes from management experience and intuition. Unfortunately, there is no set recipe that will work in all situations, particularly if livestock or other wildlife populations are considered simultaneously along with deer. However, we know deer prefer a fairly closed woodland situation. In south Texas, McMahon and Inglis (1974) indicated deer avoided areas with <10% or >85% canopy cover. In the Hill Country, Rollins et al. (1988) found higher deer use of areas where 50 to 70 percent of the brush had been removed. Removing 80 percent of the brush resulted in decreased use of cleared areas while clearing only 30 percent resulted in decreased forage availability from overgrazing. Thus, ideal deer habitat can be a range of conditions. Within that acceptable range, brush cover on the light end of the spectrum likely would not be improved by burning or other techniques that continued to open the woody spectrum. On the other hand, brush on the dense end of the spectrum would generally benefit from prescribed burning by opening the habitat and promoting the availability of food, especially forbs and regrowth browse for deer.

If increasing forbs is a management priority, then burns should be targeted for areas with a good probability of forb production. Mesic or lowland sites that retain better soil moisture are more likely to promote plant growth. Also, burning in fall or early winter increases the probability of forb growth over grasses. Burning at any time will top kill brush and increase the availability of brush sprouts within reach of browsing animals.

Deer would benefit from a more nutritious diet for a time following a burn. Higher quantity of forage from brush likely would persist for several years, but the length of time the forage is of higher nutrition is uncertain. Most research indicates a burning frequency of 3-5 years to maintain the effects of prior treatments. However, 1 option is to let the density, height and composition of the brush determine the timing for further treatments. Assuming enough rainfall to provide fuel, the optimum conditions of a stand to improve deer habitat is when the woody cover exceeds 50% canopy cover, is between 3 and 5 foot tall, and a treatment is needed to maintain openings as open areas. When these conditions exist the habitat likely would benefit from prescribed burning.

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Table 1. Historical frequency of natural fires in Texas[a].

Region	Fire frequency
Southern forests	2-10 years
Pineywoods	
Grasslands	2-25 years
High Plains	
South Texas Plains	
Gulf Prairies and Marshes	
Cross Timbers and Prairies	
Blackland Prairies	
Post Oak Savannah	
Grasslands bisected by breaks and rivers	20-30 years
Rolling Plains	
Edwards Plateau	
Semi-desert grass-shrub	>10 years
Trans-Pecos	

[a]Adapted from Wright and Bailey 1982.

Table 2. Selected woody plants by region in Texas[a] and their general susceptibility[b] to prescribed burning.

	Fire tolerant		Fire sensitive	
Region	Common name	Scientific name	Common name	Scientific name
Pineywoods	Common lantana	*Lantana horrida*	Agarito	*Berberis trifoliolata*
	Texas buckeye	*Aesculus glabra*	Texas prickly pear	*Opuntia lindheimeri*
	Yaupon	*Ilex vomitoria*	Eastern red cedar	*Juniperus virginiana*
	American beautyberry	*Callicarpa americana*		
	Macartney rose	*Rosa bracteata*		
Gulf Prairies and Marshes	Huisache	*Acacia farnesiana*	Agarito	*Berberis trifoliolata*
	Twisted acacia	*A. tortuosa*	Wolfberry	*Lycium berlandieri*
	Hog plum	*Colubrina texensis*	Granjeno	*Celtis pallida*
	Common lantana	*Lantana horrida*	Desert yaupon	*Schaefferia cuneifolia*
	Honey mesquite	*Prosopis glandulosa*	Guayacan	*Porlieria angustifolia*
	Yaupon	*Ilex vomitoria*	Texas prickly pear	*Opuntia lindheimeri*
	American beautyberry	*Callicarpa americana*	Tasajillo	*Opuntia leptocaulis*
	Live oak	*Quercus virginiana*	Brasil	*Condalia obovata*
	Lime pricklyash	*Zanthoxylum fagara*	Lotebush	*Zizyphus obtusifolia*
	Whitebrush	*Aloysia lycioides*	Blackbrush	*Acacia rigidula*
	Macartney rose	*Rosa bracteata*		
Post Oak Savannah	Huisache	*Acacia farnesiana*	Agarito	*Berberis trifoliolata*
	Common lantana	*Lantana horrida*	Texas prickly pear	*Opuntia lindheimeri*
	Honey mesquite	*Prosopis glandulosa*	Eastern red cedar	*Junipeus virginiana*
	Texas buckeye	*Aesculus glabra*		
	Yaupon	*Ilex vomitoria*		
	American beautyberry	*Callicarpa americana*		
	Live oak	*Quercus virginiana*		
	Macartney rose	*Rosa bracteata*		
Blackland Prairies	Huisache	*Acacia farnesiana*	Texas prickly pear	*Opuntia lindheimeri*
	Common lantana	*Lantana horrida*	Eastern red cedar	*Junipeus virginiana*

Table 2. Continued.

	Fire tolerant		Fire sensitive	
Region	Common name	Scientific name	Common name	Scientific name
Blackland Prairies cont.	Honey mesquite	*Prosopis glandulosa*		
	Texas buckeye	*Aesculus glabra*		
	Skunkbush	*Rhus aromatica*		
	American beautyberry	*Callicarpa americana*		
	Whitebrush	*Aloysia lycioides*		
	Macartney rose	*Rosa bracteata*		
Cross Timbers and Prairies	Hog plum	*Colubrina texensis*	Agarito	*Berberis trifoliolata*
	Common lantana	*Lantana horrida*	Guayacan	*Porlieria angustifolia*
	Honey mesquite	*Prosopis glandulosa*	Tasajillo	*Opuntia leptocaulis*
	Whitebrush	*Aloysia lycioides*	Red-berry juniper	*Juniperus pinchotii*
	Texas buckeye	*Aesculus glabra*	Ashe juniper	*J. ashei*
	Skunkbush	*Rhus aromatica*	Lotebush	*Zizyphus obtusifolia*
	American beautyberry	*Callicarpa americana*		
	Macartney rose	*Rosa bracteata*		
South Texas Plains	Huisache	*Acacia farnesiana*	Agarito	*Berberis trifoliolata*
	Twisted acacia	*A. tortuosa*	Wolfberry	*Lycium berlandieri*
	Hog plum	*Colubrina texensis*	Granjeno	*Celtis pallida*
	Common lantana	*Lantana horrida*	Desert yaupon	*Schaefferia cuneifolia*
	Honey mesquite	*Prosopis glandulosa*	Guayacan	*Porlieria angustifolia*
	Live oak	*Quercus virginiana*	Texas prickly pear	*Opuntia lindheimeri*
	Lime pricklyash	*Zanthoxylum fagara*	Tasajillo	*O. leptocaulis*
	Whitebrush	*Aloysia lycioides*	Brasil	*Condalia obovata*
			Lotebush	*Zizyphus obtusifolia*
			Blackbrush	*Acacia rigidula*
Edwards Plateau	Macartney rose	*Rosa bracteata*	Agarito	*Berberis trifoliolata*
	Huisache	*Acacia farnesiana*	Wolfberry	*Lycium berlandieri*
	Hog plum	*Colubrina texensis*	Granjeno	*Celtis pallida*

Table 2. Continued.

Region	Fire tolerant		Fire sensitive	
	Common name	Scientific name	Common name	Scientific name
Edwards Plateau cont.	Common lantana	*Lantana horrida*	Desert yaupon	*Schaefferia cuneifolia*
	Honey mesquite	*Prosopis glandulosa*	Guayacan	*Porlieria angustifolia*
	Texas buckeye	*Aesculus glabra*	Texas prickly pear	*Opuntia lindheimeri*
	Vasey shin oak	*Quercus pungens*	Tasajillo	*O. leptocaulis*
	Skunkbush	*Rhus aromatica*	Red-berry juniper	*Juniperus pinchotii*
	American beautyberry	*Callicarpa americana*	Ashe juniper	*J. ashei*
	Live oak	*Quercus virginiana*	Eastern red cedar	*J. virginiana*
	Whitebrush	*Aloysia lycioides*	Brasil	*Condalia obovata*
			Lotebush	*Zizyphus obtusifolia*
			Blackbrush	*Acacia rigidula*
Rolling Plains	Honey mesquite	*Prosopis glandulosa*	Agarito	*Berberis trifoliolata*
	Skunkbush	*Rhus aromatica*	Brownspine prickly pear	*Opuntia phaeacantha*
	Whitebrush	*Aloysia lycioides*	Tasajillo	*O. leptocaulis*
			Red-berry juniper	*Juniperus pinchotii*
			Ashe juniper	*J. ashei*
			Lotebush	*Zizyphus obtusifolia*
High Plains	Honey mesquite	*Prosopis glandulosa*	Brownspine prickly pear	*Opuntia phaeacantha*
			Tasajillo	*O. leptocaulis*
			Red-berry juniper	*Juniperus pinchotii*
			Ashe juniper	*J. ashei*
Trans-Pecos	Honey mesquite	*Prosopis glandulosa*	Agarito	*Berberis trifoliolata*
	Vasey shin oak	*Quercus pungens*	Wolfberry	*Lycium berlandieri*
	Skunkbush	*Rhus aromatica*	Granjeno	*Celtis pallida*
	Whitebrush	*Aloysia lycioides*	Desert yaupon	*Schaefferia cuneifolia*

Table 2. Continued.

	Fire tolerant		Fire sensitive	
Region	Common name	Scientific name	Common name	Scientific name
Trans-Pecos cont.			Guayacan	*Porlieria angustifolia*
			Texas prickly pear	*Opuntia lindheimeri*
			Tasajillo	*O. leptocaulis*
			Red-berry juniper	*Juniperus pinchotii*
			Ashe juniper	*J. ashei*
			Brasil	*Condalia obovata*
			Lotebush	*Zizyphus obtusifolia*
			Blackbrush	*Acacia rigidula*

[a]From Gould 1975.
[b]Mostly adapted from Scifres and Hamilton 1993.

FIRE AND QUAIL IN TEXAS

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Abstract: Fire is one of the many tools that can be used to manage quail habitat. Texas is home to 4 species of quail. Northern bobwhites (*Colinus virginianus)* are the most popular and abundant species in Texas. Bobwhites are generally thought of as being an "early successional" species. However, the successional stage to which bobwhite are best adapted changes with climate. Bobwhites are clearly a lower successional species in rich environments – those with high rainfall, good soils, and long growing seasons. Higher successional stages, however, work best in more arid environments. This is an important concept to remember when choosing management practices. We review the 4 species of quail in Texas including location within the state and type of habitat in which native species of quail occur, the historic fire cycle in those habitat types and the use of fire as a management tool for quail.

Introduction

"*Prescribed burning .., may increase the quantity of structurally suitable* (bobwhite) *habitat and improve habitat type interspersion while simultaneously increasing food supplies.*" (Guthery 2002:149)

Historically, natural and set fires greatly influenced the composition and structure of vegetation across the ecological regions of Texas. Likewise, the suppression of fire along with changes in land use over the past 200 years has shaped the landscapes of today (Wright and Bailey 1982, McPherson 1997). Man's influence has, at times been either beneficial or detrimental to quail populations. There is little doubt, however; that over the past century quail have become far less common across much of the state (TGFOC 1945, Gehlbach 1981:67, Brennan 1991, Perez et al. 2005, Sauer et al. 2005). The 4 species of quail endemic to Texas are Montezuma (*Cyrtonyx montezumae*), Gambel's (*Callipepla gambelii*), scaled (*Callipepla squamata*), and northern bobwhite (*Colinus virginianus*). Herein we examine the relationship between fire and quail in Texas.

Montezuma quail

Montezuma quail (a.k.a. Mearn's, Harlequin, Fool, Massena or Codorniz pinto) can be found in the mountain ranges of Mexico, southeastern Arizona, southwestern New Mexico, and southwestern Texas. Montezuma quail habitat has been described as open canopy, evergreen Madrean woodlands of oaks (*Quercus* spp.) and junipers (*Juniperus* spp.) with an understory of perennial warm season grasses and forbs. These unique birds are highly specialized in their food and cover requirements. They utilize dry slopes (20-30°) where micro habitat conditions support an abundance of their main food source, underground bulbs and tubers, which they dig up with powerful feet and claws. A diversity of grasses and forbs provide cover and attract insects, a part of their summer diet. Grass cover is essential to survival because Montezuma quail freeze in place when faced with potential danger whether they are actually hidden in cover or not. Annual production is highly variable depending on summer rainfall and there are no reliable population indices in Texas. (Brown 1978, Brown 1989, Albers and Gehlbach 1990, Heffelfinger and Olding 2000, Hernandez 2004).

Pre-settlement populations of Montezuma quail in Texas ranged from the southern Edwards Plateau into the Trans Pecos but by the 1920s local populations were disappearing as a result of overgrazing. Today, Montezuma quail are highly restricted in their Texas distribution and are most numerous in the Davis Mountains. Relict populations can be found in other mountain ranges and in a few counties of the southwestern Edwards Plateau (Gehlbach 1981:67, Albers and Gehlbach 1990). The semi-arid desert and woodland ecosystems where they occur are extremely sensitive to heavy grazing and have likely been irreversibly altered to some degree from past land use. Continual grazing pressure reduces the ability of native vegetation to allow water infiltration, which leads to soil degradation and eventually a completely different plant community, which cannot support Montezuma quail (Albers and Gehlbach 1990, Schmidly 2002, Koppel et al. 2002).

Little is known about the effects of fire on Montezuma quail (Leopold and McCabe 1957, Gehlbach 1981:185, Harveson 2004). Although fires historically occurred in Montezuma quail range, they were infrequent (every 10-30 years) and may have been influenced by aboriginal man (Frost 1998). Logging and frequent fire in the pine-oak woodlands of Mexico did not eliminate local populations so long as right of ways, fencerows, and gullies were left undisturbed (Leopold and McCabe 1957). Gehlbach (1981:185) speculates that the role of fire may be similar to drought cycles in that some species, including Montezuma quail, benefit when the canopy is opened up by fire. As time allows the woodlands to become denser, bird species that favor closed canopy systems become more prevalent until the next fire. In altered plant communities it is difficult to predict the long-term effects of prescribed fire even at historical fire return intervals. Harveson (2004) suggests that any use of fire for Montezuma quail management must be planned carefully to leave patches of cover, otherwise local populations may be displaced or experience increased predation by raptors.

Gambel's quail

In Texas, Gambel's quail (a.k.a. Arizona, Desert, or Valley quail) are found along dry washes and major drainages that feed into the Rio Grande River from El Paso to about the eastern edge of Big Bend National park. These riparian areas provide the dense woody cover and forbs that typifies Gambel's quail habitat in the Trans Pecos. Mesquite (*Prosopis glandulosa*), acacia (*Acacia* spp.), and mimosa (*Mimosa* spp.) are used for cover and feeding sites. Gambel's quail are often seen on the ground, and roost in trees (Brown et al. 1998). Gambel's quail are far more common in a variety of habitats towards the center of their range in southwestern Arizona and western Sonora, although they experience boom-bust cycles of abundance similar to other species of quail (Brown 1989:165, Harveson 2004). Texas populations are on the extreme fringe of the distribution and are limited to riparian habitats where the effects of frequent drought are less severe (Brown 1989:180). Nonetheless, Gambel's quail are considered to be stable or increasing in Texas (Brown 1989:180, Harveson 2004, Sauer et al. 2005).

There is virtually no information regarding the effects of fire on Gambel's quail in Texas although it can be inferred that burning riparian areas would be detrimental (Wright and Bailey 1982:59). Historical fires may have occurred every 7-25 years and likely had less impact on protected riparian sites than on semi-desert grassland (Frost 1998). The suppression of fire in Arizona may have increased available habitat in the form of scrub-invaded desert grassland, but this is not the case in scrub-invaded semi-desert grasslands of the Trans Pecos (Brown 1989:165). Gambel's quail benefit most from management which includes protection of riparian areas by fencing, deferred-rotational grazing, and all forms of water catchments that slow runoff and increase soil moisture (Brown 1989:181, Tarrant 2002, Harveson 2004).

Scaled quail

The scaled quail (a.k.a. blue quail, cottontop, or scalies) natural distribution includes portions of Mexico, New Mexico, Arizona, Colorado, Kansas, Oklahoma, and Texas (Brown 1989). In Texas they occur primarily in the Trans Pecos, High Plains and the western portions of the Rio Grande Plains, Rolling Plains and Edwards Plateau (Rollins 2000). Despite its broad distribution in Texas relatively little scaled quail research has been conducted in the state and even less on the effects of fire (Stormer 1981, Wright and Bailey 1982, Leif et al. 1986). Good scaled quail habitat is characterized by low growing grasses and forbs with scattered low growing (< 6 ft) trees and shrubs (Schemnitz 1961). In general, as you go from east to west scaled quail do better in higher range conditions (Rollins 2000). In other words, it takes more disturbance (e.g. grazing) to create the open scaled quail habitat in higher rainfall zones than in areas with low annual rainfall.

The effects of long-term fire suppression were likely beneficial to scaled quail for some brief period in history by increasing the availability of loafing coverts (woody cover) and forbs (food) but eventually many plant communities were beyond the range of tolerance for the species. Scaled quail populations have declined range-wide over the past 40 years and in Texas are only considered stable in the Rio Grande Plains and perhaps portions of the High Plains (DeMaso 2002).

Semi-desert grassland

Natural lightning fires were infrequent in the Trans Pecos but still played an important role in maintaining semi-desert grassland. Grazing pressure in the late 1800s removed too much grass without allowing time for recovery and essentially eliminated the fine fuels needed for subsequent fires. Over the past hundred years, shrubs, increasers, and forbs became more prevalent as top soil was lost starting an irreversible process as described in regard to Montezuma quail habitat in the same ecoregion. As the plant communities began to shift from grassland-savanna to scrubland, some species like Montezuma quail have all but disappeared, while scaled quail have persisted. Part of the scaled quail's success may be attributed to its ability to survive in a range of cover types and cover densities (Naranjo 1993). Any scaled quail management today needs to incorporate appropriate grazing management (including deferment) aimed at creating higher range conditions with the eventual goal of returning prescribed fire to the system in areas where the soil has not been depleted. Moist soil management (water catchments) may also benefit scaled quail by increasing available brood habitat (Buntyn et al. 2001).

Southern short- and mixed-grass prairies

The Southern Shortgrass Prairie including most of the High Plains of Texas has undergone immense changes since European settlement. Over 70% of the region has been converted to agricultural fields, greatly reducing the amount of scaled quail habitat on the landscape (Schmidly 2002:392). Most of the remaining area is used for grazing and is hit or miss as potential habitat for scaled quail. Areas that are actively managed for grazing, including aerially applied herbicide and mechanical brush treatments, seldom leave enough woody cover for scaled quail. Unmanaged areas have shifted from prairie to savanna or desert scrubland as a result of past overgrazing and fire suppression and often have too much woody cover for scaled quail. Scaled quail management in the High Plains includes grazing deferment, light to moderate grazing that allows fuels to build up, patch burning (prescribed fire in rotation aimed at a 3-5 year interval for each management unit) (Fuhlendorf and Engle 2001), and protection of a minimum of 1 loafing covert (especially tree cholla [*Opuntia imbricata*]) per 50 acres (Stormer 1981,).

The Mixed Grass Prairies of the Rolling Plains are usually associated with northern bobwhite but in the western portions of this region and in areas with shallow or poor soils, scaled quail can be found. Although scaled quail are sympatric with northern bobwhite in the Rolling Plains, they occupy different parts of the landscape. Scaled quail prefer more open habitat that is typical of shallow soils or heavily grazed areas (Rollins 2000). Management for scaled quail in the region is usually not a consideration due to a higher demand for northern bobwhite. We do not encourage heavy grazing, which can lead to soil loss and an overall decrease in plant and animal diversity. Any reduction of woody cover by prescribed fire or other method needs to leave at least 20% in loafing cover, evenly interspersed.

Tamaulipan brushland

Scaled quail occur in the drier portions of the Rio Grande Plains on shallow or gravelly soils usually associated with dense thickets of blackbrush (*Acacia berlandieri*) and guajillo (*A. rigidula*) and in prickly pear (*Opuntia* spp.) flats. Much like the Rolling Plains, northern bobwhite and scaled quail partition the landscape where their range overlaps with scaled quail preferring areas with more bare ground and lower herbaceous cover than where you would typically find bobwhite (Rollins 2004). Cambell-Kissock et al. (1985), found that scaled quail were more abundant on areas that had a high intensity-short duration grazing treatment compared with continuous grazing, most likely as a result of greater forb and grass cover. Only the careful, infrequent, and small-scale use of prescribed fire should be considered for improving scaled quail habitat in the region.

Northern bobwhite

The most studied species of quail in North America is the northern bobwhite (hereafter bobwhite). Bobwhites occupy a variety of habitats ranging from savannah (ecosystems with a continuous grass layer and scattered trees and shrubs) to the Tall and Mid-grass prairies of the Great Plains, and certain agricultural landscapes (McPherson 1997, Brennan 1999). Although bobwhites can be found in several ecoregions of Texas, their habitat requirements remain relatively the same and include the even distribution (interspersion) of native vegetation, which provides nesting, brooding, escape, screening, and loafing cover types. If used properly, prescribed fire is 1 management tool that has the potential to increase the amount of habitat (usable space) available for bobwhite (Guthery 2002:149). Properly conducted prescribed fires can help shape the structure and composition of vegetation in favor of bobwhite. Depending on time of year of the burn, expected results can include: shift in dominance to favor native warm season grasses (late winter-early spring), shift in dominance to favor forbs (fall-early winter), reduction in the percent of woody species (cool-season fires), and elimination of fire-intolerant vegetation (summer fires). Burning alone is certainly not a cure-all for quail habitat problems and its frequency and expected benefit decreases along with the annual rainfall gradient from the subtropical southeastern pine forest to semi-arid western and southern regions of Texas (Hanselka 1994, Guthery 2000:70).

Pine savannah

Quail mangers have long recognized the importance of fire in creating and maintaining quail habitat in the pine (*Pinus* spp.)-savannas of the southeastern United States where fast growing vegetation can only be kept in check by frequent burning (Stoddard 1931, Lehmann 1937, Lay 1954). For example, longleaf pine (*P. palustris*) savannah needs to be burned every 1 – 3 years to keep it usable for quail. In many cases herbicides are also needed to control hardwoods and exotic grasses (Frost 1998, Whiting 2004). During the early 1900s, some of the best hunting in the state could be found in the Pineywoods of East Texas where sharecropping, burning, logging, and grazing practices inadvertently created a patchwork of excellent bobwhite habitat (TGFOC 1945:47, Whiting 2004). Ultimately, the modernization of agriculture and forestry along with the suppression of fire has led to the virtual disappearance of bobwhite and other pine savannah dependent species like the endangered red-cockaded woodpecker (*Picoides borealis*) (RCW). Management efforts aimed at increasing red-cockaded woodpecker numbers have been found to benefit other species that rely on the same habitat type, including bobwhite (Conner et al. 2002). It is no surprise that the methods used to create RCW habitat involve frequent prescribed fire and hardwood (understory) removal. Resource mangers understand how to create quail habitat in the southeast, but increasingly smaller land ownerships, Smokey Bear, and the economics of timber make quail recovery unlikely except on Federal, State and reclaimed lands, land trusts, and wildlife cooperatives (Masters et al. 2003, Wilkins et al. 2003, Perez et al. 2005).

Southern Great Plains

The savannah and prairie habitat types of the Southern Great Plains once found in the Edwards Plateau, Cross Timbers and Prairies, Rolling Plains, Post Oak Savannah and Blackland Prairie have been reduced to a mere fraction of their former distribution. Historically, this expanse of grasslands was a dynamic system driven by natural fire and grazing animals. At any given time, patches of burned, grazed, burned and grazed, or undisturbed prairie were strewn across the landscape in a patchwork quilt (TGFOC 1945, Dyksterhuis 1948, Wright and Bailey 1982:82, Bachand 2001, Fuhlendorf and Engle 2001). Bobwhites likely only utilized parts of the quilt, unable to persist in areas with no shrubs or in areas too thick/rank with undisturbed climax grasses.

Post-European settlement, fire suppression and grazing led to the encroachment of woody species from areas protected from fire. As prairie and savanna transformed to shrubland or woodland habitats, more permanent cover became available for quail. Grazing also created more seed-producing forbs that provided bobwhite with food and brooding cover. At 1 time or another, robust bobwhite populations have been recorded across the majority of the Southern Great Plains in Texas (TGFOC 1945:46-60, Dyksterhuis 1948). But much like the Pineywoods, woody cover gradually became too dense (>50%) and native bunchgrasses were greatly reduced by improper grazing or replaced by exotic grasses like Bermudagrass (*Cynodon dactylon*), which rendered much of the Southern Great Plains unusable by bobwhite (TGFOC 1945:46-60, Jackson 1965). Today, the only remaining stable bobwhite populations in the Southern Great Plains are in the Rolling Plains of Texas, western Oklahoma, and central Kansas where land use on native rangelands still produces suitable bobwhite habitat (Sauer et al. 2005, DeMaso et al. 2002). There are certainly bobwhites in other regions, especially where bobwhite needs, including prescribed fire, are a part of the overall ranch management objectives. Of course the timing and type of prescribed burn that most benefits bobwhites will vary across regions. Carter et al. (2002) found that survival and nest success did not differ in burned vs. unburned pastures in the northern Edwards Plateau where prescribed fires left behind islands of cover. During drought cycles or in areas of low rainfall it is critical to leave these areas of suitable cover to avoid any possible negative impacts on quail populations.

Gulf Coastal Prairie

The Gulf Coastal Prairie was once a vast area of mid to tall grass prairie populated by bison (*Bison bison*), pronghorn antelope (*Antilocapra americana*), prairie chicken (*Tympanuchus* spp.), and other species associated with fire-dependent prairie habitats. Early Spanish explorers described the area as a flat treeless plain, dissected only by heavily wooded riparian corridors. Early accounts do not mention bobwhite, but they were likely a part of the ecosystem in the few areas where woody cover had become established. It is estimated that <1% of the Gulf Coastal Prairie remains today as a result of the same processes that altered the Pine Savannah and Southern Great Plains regions in Texas (Inglis 1964:74, Smeins et al. 1991:270, Schmidly 2002:390). Bobwhites increased in abundance along with woody plant species and small farms up until the 1940s. Post-World II pressures on habitat have gradually transformed the Gulf Prairies into a region that provides very little usable space for bobwhites.

The bison and antelope have been long gone and only a handful of the endangered Attwater's prairie chicken (*Tympanuchus cupido attwateri*) remain, but the lower Gulf Coast still has areas of remnant prairie in Goliad, Victoria, and Refugio Counties where bobwhites are doing well. The Coastal Prairie Conservation Initiative, a partnership of state, federal, and non-governmental agencies and most importantly private landowners, has made great efforts to provide habitat in this area for viable prairie wildlife populations including bobwhite (T. R. Anderson, United States Fish and Wildlife Service, personal communication). Prescribed burning is an integral part of bobwhite management in the Gulf Coast but because of high rainfall, proper grazing management, and soil disturbance are also needed to create suitable bobwhite habitat (Guthery 2000:17).

Tamaulipan Brushland

The more arid Rio Grande Plains of the Tamaulipan biotic province supports stable landscape-level populations of bobwhite and is a popular destination for quail hunters from across the nation (DeMaso et al. 2002, Perez et al. 2005, Sauer et al. 2005). Early explorers described this region as a mesquite-savanna with smaller areas of dense chaparral (Inglis 1964). In 1722, Pena observed "a great number of turkey and quail" in Atascosa County and also mentioned numerous quail in Zavala County. Researchers hypothesize that the Rio Grande Plain has shifted from savannah to dense chaparral (brushland) over the past 150 years as a result of fire suppression and heavy grazing pressure (Johnston 1963, Archer et al. 1988).

Bobwhite are most abundant where diverse brush makes up <40% of a given area and range condition is high (Spears 1993, Guthery 1986). The semi-arid conditions of the Rio Grande Plains make burning improbable during drought years and beneficial to bobwhite only when combined with proper grazing management (Howard 1996, Ruthven et al. 2002). Estimated historic fire return intervals for the region are highly variable and range from 4 – 30 years and the recommended return interval for bobwhite ranges from every 2 – 7 years (Wright and Bailey 1982, Guthery 1986:75, Frost 1998, Ruthven et al. 2002). Since brush recovery can take 3 – 5 years before it provides loafing cover, most managers leave mottes or strips of brush to ensure adequate cover remains (Lehman 1984:259, Howard 1996).

Prescribed burning for bobwhite

Bobwhite are generally thought of as being an "early successional" species (Allen 1962:69, Dasmann 1966:86). However, the successional stage to which bobwhite are best adapted changes with climate. Bobwhites are clearly a lower successional species in rich environments – those with high rainfall, good soils, and long growing seasons. Higher successional stages, however, work best in poorer environments (Spears et al. 1993, Guthery 2000). This is an important concept to remember when choosing management practices. Some environments are more forgiving (i.e., east Texas), therefore, the management practice used and how it is applied are less important then when the practice is applied in a less forgiving environment (i.e., west Texas).

Scale

Scale refers to the extent relative to the resolution of a variable indexed by time or space (Weins 1989, Schneider 1994). In our case, the variable is the percentage (acreage) to be burned of the total area under management consideration. The amount of acreage burned will depend, largely on the goal of the manager. Quail managers may have 1or a combination of goals when using prescribed burning. These goals might include: 1) suppression of woody vegetation; 2) creating bare ground; 3) removal of ground litter or dense, rank vegetation; and 4) increasing food supplies (insects and seeds) (Reid 1953, Jackson 1965, Wilson and Crawford 1979, Guthery 1986, Koerth et al. 1986).

The decision of how much area to burn should be based on several considerations: the management goal, the total area of the property, the area of the property under management consideration, time of the year, and the amount of manpower needed to accomplish the goals of the burn.

There is no set percentage on the amount of acreage that should be burned annually to manage quail habitat. This number will vary annually from ranch to ranch depending on vegetation conditions, past rainfall, etc. Some advantages to burning smaller acreages more often include increased diversity of species in the plant community and a safety net against low rainfall and droughty conditions, especially in more arid environments (Fuhlendorf and Engle 2001). In Texas, some quail experts feel that probably 20 – 25% of an area under management consideration is the maximum amount of acreage that a manager would want to burn annually (DeMaso, Texas Parks and Wildlife Department, unpublished data).

Other considerations

Several things need to be considered when using prescribed burning as a management tool for quail habitat. First, burn “dirty,”, i.e., leave scattered patches of cover for quail to use after the area has been burned. This is especially important in drier climes like western and southern Texas where quail are dependent on these islands of refugia to meet their cover requirements (Guthery 1986:30, Carter et al. 2002). The area should not look like a parking lot. Second, quail should never be >200 – 300 yards from cover once a burn is completed (Lehmann 1984:259, Guthery 1986, Hanselka 1994). Third, place fireguards around mottes (about 50 ft. in diameter) of woody cover that serve as loafing coverts. Research indicates that fire can alter the structure of some quail-preferred shrub species and render them unusable by quail for a period of years. For example, lotebush (*Zizyphus obtusifolia*) and sand plum (*Prunus gracilis*) in the Rolling Plains can take up to 7 years to recover from fire (Renwald 1978). Remember, the most expensive and time-consuming cover component to establish for quail is woody cover.

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FIRE EFFECTS ON NONGAME WILDLIFE

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Abstract: Fire has been a naturally occurring process in North American ecosystems, but in recent times has been suppressed by humans as a destructive force of nature. The resulting ecological successsion has allowed many fire-dependent habitats to change. Such successional changes have affected wildlife populations that depended upon naturally occurring fire regimes. In this paper, we review the literature regarding fire effects on wildlife populations and habitat as it relates to birds, small mammals, amphibians and reptiles. Grassland birds exhibit only short term fluctuations to prescribed fire, while birds in shrubland habitats appear to be unaffected, or show time-delayed negative responses in shrubsteppe sagebrush (*Artemesia* spp.) habitats. Fire produces distinct changes in bird communities in forested ecosystems, favoring early successional species among the ground / low-shrub foraging and nesting guilds. Prescribed fire in forested systems appears to have a negative effect on nest success of ground-nesting neotropical migrants. Small mammals in tallgrass prairie exhibit strong responses to prescribed fire, which favors deer mice (*Peromyscus maniculatus*) but reduces populations of shrews (*Blarina* spp., *Sorex* spp.), western harvest mice (*Reithrodontomys megalotis*), and voles (*Microtus* spp.); small mammal response to fire in forested systems is mixed and often nonexistant. Amphibians and reptiles respond inconsistently to fire depending upon location, but there are few studies to rely on. Most studies across taxonomic groups were of very short duration, and few examined demographics (survival, reproductive success, habitat selection, body size) other than relative abundance, all of which may be more relevant metrics to measure than numerical responses.

Introduction

Fire has played a significant role in the development of vegetation in many of the world's ecosystems. North American grasslands in particular are thought to have evolved with and maintained by the interaction of fire with soils, climate, and biotic pressures (Wright and Bailey 1982). This grassland ecosystem extends from north-central Mexico into the Canadian provinces and is characterized by a diverse assemblage of vegetation types (Anderson 1990, Risser et al. 1981). Although fire was a universal disturbance regime in this ecosystem, the historic role of fire in maintaining these varied grasslands was not constant in time and space (Anderson 1990, Risser et al. 1981, Vogl 1974, Daubenmire 1968, Curtis 1959). This is likely true of other rangeland ecosystems as well. The degree to which fire impacted both the floristics and structure of rangeland vegetation was due in large part to the frequency with which it occurred in a particular ecosystem (Riggs 1996). Pristine grasslands of level to gently rolling topography likely burned at 5–10 year intervals, while coastal redwood forests on mesic sites burned every 200–500 years (Wright and Bailey 1982). The recent history of fire in grassland and many other rangeland ecosystems has been characterized by anthropogenic suppression of fire. As a major ecological process, suppression of fire in terms of its presence, frequency, and scope has led to the displacement of grasses by other forms of vegetation. In conjunction with excessive livestock grazing, fire suppression has contributed to the replacement of open grasslands and savannas to shrub lands and woodlands (Archer et al. 1988, Archer 1989, Scifres and Hamilton 1993).

Wildlife populations are often dependent upon the presence and frequency of fire because of its effect on habitat structure. Historically, fire in longleaf pine (*Pinus palustris*) forests maintained the open park-like understory required by red-cockaded woodpeckers (*Dendrocopus borealis*) (Wilson et al. 1995). Kirtland's warbler (*Dendroica kirklandii*) require stands of jack pine (*Pinus banksiana*) that have been recently burned as nesting habitat. When fire is suppressed, plant succession changes the physical structure of the habitat such that it is no longer suitable for either of these endangered birds.

Fire is a common prescription to control establishment of woody vegetation in many rangeland habitats and the techniques of its application are well documented (Scifres 1980, Scifres and Hamilton 1993, Wright and Bailey 1982). Intuitively, reinstating fire into a shrubland system would be a natural mechanism for grassland restoration. This logic is based on the premise that suppression of fire has upset the balance of nature, and reinstating fire should reestablish that balance. Scifres and Hamilton (1993) caution, however, that although wildfires and those set by Native Americans helped maintain grasslands against invasion of woody plants, they did not convert shrublands of present day proportions to grasslands. Nevertheless, prescribed fire has been shown to effectively alter the shrubland matrix to approximate a grassland or grassland savanna physiognomy (Ansley and Jacoby 1998, Ansley et al. 1998, Teague et al. 1997).

A relatively large body of literature exists regarding the efficacy of fire in controlling woody vegetation on Texas rangelands and elsewhere, but unfortunately, a paucity of research describing fire effects on wildlife populations still exists; long-term controlled experiments are especially lacking for some taxonomic groups (e.g., amphibians and reptiles), and data quantifying fire effects on demographics other than relative abundance are rare. In this paper, we provide a review and synthesis of the literature regarding the effects of fire on populations of nongame birds, small mammals, amphibians, and reptiles.

Birds

Grassland and savanna birds

Prior to the mid-1990s, most studies investigating fire effects on grassland birds were focused on existing native grasslands (Huber and Steuter 1984, Johnson 1997, Zimmerman 1992, 1993, 1997), or fragmented grasslands (Johnson and Temple 1986, 1990, Herkert 1994*a*,*b*). The general findings of these studies was that grassland breeding bird response to fire was often species-specific and area dependent. However, those studies employing a long-term approach showed that although species-specific, fire effects generally were minimal and short-term with populations quickly returning to pre-burn levels of abundance (Johnson 1997, Zimmerman 1993, 1997). These findings should not be surprising for species that have adapted to ecosystems maintained by periodic, if not frequent fire regimes.

Subsequent to the mid-1990s (1970-1990), there was little research interest regarding the response of grassland birds to application of fire in degraded (e.g., brush-encroached) grassland systems. In the mid-1990s, long term data from the North American Breeding Bird Survey indicated that many avian species were experiencing long-term declines across their range, and grassland birds were declining faster than most other avian groups (Knopf 1994, Peterjohn and Sauer 1999). Habitat loss and shrub encroachment were cited as primary reasons for declines (Johnson and Igl 2001, Vickery and Herkert 2001). For example, Bernstien et al. (1990) observed a decline in prairie nesting birds between 1940 and 1989; they concluded that woody succession had reduced the area of grassland habitat, and consequently the number of grassland breeding birds. Lloyd et al. (1998) observed few grassland bird species on former grasslands now dominated by velvet mesquite (*Prosopis velutina*) in southeastern Arizona. Madden et al. (1999), and Rosenstock and van Ripper (2001) further describe the problem of woody encroachment into grasslands of North Dakota and Arizona, respectively. Study plots in each of these 2 studies had greater shrub densities and fewer grassland birds with increasing time since burned. These studies posit the hypothesis that prescribed fire has the potential to recover grassland habitats and their characteristic bird communities.

Sufficient information now exists that describe the effects of fire suppression on grassland bird communities (Lloyd et al. 1998, Madden et al. 1999, Rosenstock and van Ripper (2001). It is imperative, then, to halt – and preferably prevent – woody encroachment into existing native grasslands. From a management perspective, this means maintaining an aggressive fire prescription to manage woody incursion. However, land managers must temper expectations with the realization that healthy, fully functional grasslands are structurally the least heterogeneous of any North American ecosystem (Payne and Bryant 1998:272), and breeding bird diversity in true grasslands is also correspondingly low (Johnson et al. 1980, Cody 1985:192). Breeding bird communities on the Konza prairie, for example, contained 9 and 6 species of grassland birds on burned and unburned prairie, respectively (Zimmerman 1997).

The research results regarding individual species or community assemblage response to prescribed fire is mixed, but most studies are compromised by short time frames (Petersen and Best 1999). Van't Hul et al. (1997) conducted a replicated experiment on the effects of summer and winter burns in *Spartina / Paspalum* grasslands on Matagorda Island of coastal south Texas. They found few differences in vegetation or bird communities on either summer or winter burns when compared to unburned controls. Collectively, sparrows remained higher on burned plots but differences were not statistically significant. Bock and Bock (1978) recorded the response of vegetation and wildlife to winter and early summer burns on ungrazed sacaton grassland (*Sporobolis wrightii*) in southeastern Arizona. Bird densities were higher on summer burn plots, especially for seedeaters, quail, and raptors. These authors felt that summer fires were beneficial to both plants and wildlife, but cautioned that such grasslands should be maintained in a mosaic of post-successional patches to accommodate late successional species like Botteri's sparrows (*Aimophila botterii*). In tallgrass prairie habitat of Kansas, Zimmerman (1992) observed dickcissel (*Spiza americana*), grasshopper sparrow (*Ammodramus savannarum*), and eastern meadowlark (*Sturnella magna*) densities slightly higher (13–22%) in burned prairie. In contrast, Halvorsen et al. (1980) documented density declines of 80% and 94% for savannah (*Passerculus sandwichensis*) and clay-colored sparrows (*Spizella pallida*), respectively, following late March-early April burning of a large tract of old-field habitat in central Wisconsin. Spring burning would seem to be deleterious to nesting birds, but Kruse and Piehl (1986) observed 69% of the active ground nests survived mid-June burns applied to mixed-grass prairie in North Dakota. In Saskatchewan, fire in a fescue (*Festuca*) grassland adversely affected the 2 most common grassland species, savannah sparrows and clay-colored sparrows (Pylypec 1991).

The results of Van't Hul et al. (1997), Bock and Bock (1978), and Halvorsen et al. (1980) are typical of most studies that quantify bird response to fire in that they were conducted over relatively short time frames. In contrast, longer term studies such as those conducted by Johnson (1997), Zimmerman (1993,1997), and Pylypec (1991) describe only immediate, short-term reductions in grassland bird abundance following fire, after which bird densities quickly return to pre-burn levels within 2 years post-burn. Such findings, then, properly define the context by which biologists and land managers should evaluate the effects of prescribed fire in existing grasslands, and perhaps shrub-degraded grasslands as well. Proper fire management for grassland birds must be predicated more on the continued presence and frequency of fire than on perceived or expected numerical responses by any 1 species or species guild. Indeed, increases in species richness and abundance are not likely to occur, and may be the wrong metric to monitor. The findings of Johnson and Temple (1986, 1990) are important in this regard. Their research showed that grassland bird nest productivity in Minnesota was not associated with areas of highest bird density and management based solely on high bird density would have favored areas of lower productivity. Van Horne (1983) has described both theoretical and empirical reasons why density can be a misleading indicator of habitat quality. To this end, Johnson and Temple (1986, 1990) argue that prairie management to maximize grassland birds should provide large, regularly-burned prairies with no nearby wooded edges, in essence maintaining the processes that originally produced the grassland pattern.

Fire may not be relevant to all grassland situations. This is especially true of grassland fragments that are spatially isolated from other similar tracts. In such cases, the size of the tract becomes more critical than the presence or frequency of fire since some bird species are area sensitive. Samson (1980*a*) conducted research on Missouri prairie fragments ranging from 1-500 ha (0.4 to 1,500 acres) in size, and showed that the number of breeding grassland birds was significantly correlated with fragment size. Some grassland species, like prairie chickens (*Tympanuchus cupido*), need more than 100 ha (250 acres) of grassland habitat, while Henslow's sparrow, vesper sparrow (*Pooecetes gramineus*), and lark sparrows need 10-100 ha (25 to 250 acres) of grassland habitat (Samson 1980*b*). Herkert (1994*a*) studied breeding bird communities on fragmented grasslands in Illinois. Although 3 species of birds were influenced by prescribed fire, habitat-area had a much greater influence on breeding bird community composition than prescribed burning. Five grassland bird species were identified as being area sensitive: savannah sparrow, grasshopper sparrow, Henslow's sparrow (*Ammodramu henslowii*), bobolink (*Dolichonyx oryzivorus*), and eastern meadowlark; minimal area requirements for these species ranged from 5 ha (13 acres) (eastern meadowlark) to 55 ha (138 acres) (Henslow's sparrow) (Herkert 1994*b*). Consequently, fire in grassland fragments may not be effective simply because the fragment is too small to hold an assemblage of grassland birds.

Can re-instating fire restore the grassland condition? This question lies at the heart of recovering degraded grasslands, and their avifauna. The critical piece of this puzzle lies in the species of woody plants that have become established. Re-instating prescription fire will likely succeed where *fire-intolerant* shrubs are the dominate invaders. Such is not the case on most of Texas rangelands, however, where the invading shrub is honey mesquite (*P. glandulosa*). This shrub is an aggressive arborescent legume that is difficult and expensive to manage once it has become established. Fire will top-kill mesquite, but the ability of this shrub to rapidly re-sprout in a multi-stem growth form often makes the situation worse (Scifres and Hamilton 1993). Further, with root-sprouting species like mesquite, fire can directly impact canopy cover and height, but will not dramatically alter absolute plant density, making recovery of heavily infested grasslands problematic without a significant long-term input of anthropogenic energy (Archer 1989).

Unfortunately, there is little experimental data to draw from in evaluating fire as a restoration tool on degraded grasslands; this knowledge gap is especially acute for Texas grasslands and related rangelands. Kirkpatric et al. (2002) experimentally applied fire to reduce velvet mesquite dominance on southwestern Arizona grasslands. They documented a declining trend in relative abundance of grassland birds compared to shrub affiliated species when subjected to prescribed fire. Shriver et al. (1999) documented an increase in breeding density of Florida grasshopper sparrow *(A. s. floridanus)* in response to mid-June burns. On the same study sites, however, Delaney et al. (2002) failed to document a density response in this species, but did document a higher probability of reproductive success at 0.5 years post-burn than at 1.5 and 2.5 years, respectively. These data suggest that the beneficial effects of fire may be short-lived (Shriver and Vickery 2001). On semi-arid grasslands (rangelands), woody shrubs often provide important nesting substrates for bird species typically thought of as grassland species, such as dickcissels (*Spiza americana*), lark sparrows (*Chondestes grammacus*), and Cassin's sparrows (*Aimophila cassinii*). The use of prescribed fire in such instances can have deleterious effects on such species. Renwald (1978) documented long-term negative effects of prescribed fire on lotebush (*Ziziphus obtusifolia*), a preferred shrub for nesting birds on Texas rangelands; fire reduced the height and canopy of lotebush in this study, limiting its utility to nesting birds for 6–7 years post fire. Reynolds and Krausman (1998) observed minimal effects of prescribed fire on bird communities in mesquite grasslands along the coastal bend of Texas, but did not monitor nest site selection nor reproductive success in context to their burns.

Given the challenges of managing woody encroachment with fire, how should fire be applied? First, where pristine grasslands (e.g., no woody plants) occur, a regular prescription of fire is essential to maintaining the habitat structure for grassland birds. A fire frequency interval should be based on the prior history of the ecological region in question**.** Late summer application of fire – so called 'hot' fires – likely is more ecologically relevant in maintaining existing pristine grasslands of the southern Great Plains, since such ecosystems typically burned this time of year from lightning strikes. Where shrub establishment is light to moderate, summer fires can probably keep woody encroachment in check, but more research is needed in this regard with respect to grassland birds. Prescription fires applied during late winter-early spring can also be effective (Ansley and Jacoby 1998, Ansley et al. 1998, Teague et al. 1997), especially when grazing can be deferred ($\geq$ 1 year) to build fine fuel loads. However, the results of Renwald (1978) and Bock and Bock (1978) must be kept in mind, and a mosaic of burned and unburned patches will likely be a best management strategy for grassland birds that have low to moderate shrub requirements for nesting and territorial displays (e.g., dickcissels and Cassin's sparrow).

Shrubland birds

While shrubland ecosystems may result from historic anthropogenic suppression of fire in native grassland systems, naturally occurring shrublands also occur in areas where fire was absent as an important ecological process or occurred at relatively low frequency. While conventional wisdom may embrace the use of prescribed fire as a positive influence, especially for livestock forage production, fire may not be suitable for managing wildlife on rangelands that developed under infrequent fire regimes. An example of such is the sagebrush (*Artemesia* sp.) shrub-steppe ecosystems of the western United States which experienced fire frequency intervals of every 20–100 years (Wright and Bailey 1982). In these shrub-steppe environments, bird species abundances tend to be highly correlated with attributes of shrub cover and shrub physiognomy (Rotenberry and Wiens 1980, Wiens and Rotenberry 1981).

While there are few studies that address fire effects in shrub ecosystems, existing studies point to the potential effects of disturbance regimes, including fire, that impact the vertical and horizontal structure of shrub communities. Best (1979) studied the effects of a spring fire on a population of field sparrows (*Spizella pusilla*). In this study, field sparrows increased their use of a shrubland-grassland area and reduced their usage of a grassland site; rates of nest desertion and cowbird parasitism (*Molothrus ater*) were lower after the burn. Arnold and Higgins (1986) quantified the effects of shrub coverage on bird species inhabiting mixed grass prairies in North Dakota and found greater species richness and density of birds in areas of higher shrub cover. Availability of woody nesting substrates best explained these differences in bird species abundances. Prescribed fire in California coastal sage-scrub communities reduced bird species diversity immediately post-fire, but bird diversity returned to pre-burn levels within the first year (Moriarity et al. 1985). Stanton (1986) expanded on Moriarity et al. (1985) and found that unburned coastal sage-scrub communities had greater species richness and number of individuals than did burned areas. These coastal scrub communities historically burned at a frequency of 20–40 years. Stanton (1985) concluded that fire is detrimental to habitat quality for most permanent resident bird species due to the reduction of structural heterogeneity (Roth 1976) and, therefore, of foraging opportunities. This conclusion, however, must be taken in context to the short duration of the study.

Several studies of breeding bird communities in the shrub-steppe ecosystems of western North America point out the inherent difficulties of interpreting fire effects. Given such long fire frequency intervals of these ecosystems (20–100 years, Wright and Bailey 1982), and the close correlation of bird abundances with structural attributes of shrub cover, one would predict that disturbance regimes that reduce the structure of the shrub community would have immediate negative effects on the avian community.

In Montana, fire converted an *Artemesia* spp. shrubsteppe into a pure high-plains grassland, which resulted in much lower variety and abundance of nesting birds than that found on unburned shrub steppe (Bock and Bock 1987). Lark buntings (*Calamospiza melanocorys*), lark sparrows, and Brewer's sparrows (*Spizella breweri*) completely avoided the burned area, and grasshopper sparrows were significantly more abundant on the unburned area. No species was more common on the burned site in this study (Bock and Bock 1987).

Castrale (1982) compared bird responses to burning, chaining and plowing. Bird species richness and total density did not differ among the treatments. Horned lark density (*Eremophila alpestris*) was greatest in the burn treatment, but densities of Brewer's sparrow were 50% and 86% less abundant in the burn than in the chained or plowed treatment, respectively. Peterson and Best (1987) documented that light mosaic burning of sagebrush-dominated stands enhanced species richness and density of nongame birds. Richness was consistently higher on burned areas than in controls, primarily due to increases in vesper sparrows (*Pooecetes gramineus*) and horned larks.

Wiens and Rotenberry (1985) studied the response of breeding passerine birds to rangeland alteration in a shrub-steppe environment in southern Oregon, USA. In 1980, a large area of sagebrush

(*A. tridentata* Nutt.) rangeland was sprayed with the herbicide 2,4-D, the dead shrubs removed and crested wheatgrass (*Agropyrum cristatum*) planted as part of a range improvement program. An immediate response by the bird community to the habitat changes was not observed. At 1 year post-treatment, the density of Brewer's sparrows decreased while the sage sparrows did not (*Amphispiza belli*). In post-treatment years 2 and 3, Brewer's sparrows fluctuated in abundance, sage sparrow abundance decreased gradually, horned larks increased, and vesper sparrows first appeared on the study sites. The failure of bird populations to respond rapidly to major changes in habitat structure may relate to the presence of time lags produced by site fidelity of breeding individuals (Van Horne 1983). Similar responses by shrub-steppe birds to both fire and mechanical removal of sagebrush have also been documented (Wiens et al. 1986, Wiens 1989), suggesting that the impact on the shrub structure is more important that the nature of the disturbance (fire, herbicide, mechanical).

Population time lags make interpretation of disturbance effects difficult and complicate formulation of management practices on the basis of short-term before and after surveys (e.g., the typical graduate research project) (Wiens and Rotenberry 1985). Unfortunately, the presence and duration of time lags in response to perturbations has not received much attention by avian ecologists since Wiens and Rotenberry (1985) conducted their study. The apparent lack of response to prescribed fire in historic grasslands currently dominated by shrub communities (Reynolds and Krausman 1998, Kirkpatric et al. 2002) may be an artifact of short study duration combined with time lags associated with breeding site fidelity.

The use of fire, then, to manage shrub rangelands must done carefully and with a detailed knowledge of habitat requirements of the associated avifauna. Habitat specialists-such as Brewer's and Sage sparrows-in sagebrush habitats are negatively impacted by fire when evaluated over several years post fire. Brewer's sparrows appeared to be affected minimally by partial kill of sagebrush, but a total kill of sagebrush can nearly eliminate this species (Best 1972). Thus, it is important to maintain alternate unburned habitat patches to accommodate the needs of some species. Where the goal of a prescribed fire program involves maintaining high species richness in small landscapes, burns should be conducted in strips, blocks, or mosaics (Castrale 1982, Peterson and Best 1987). We know very little about nongame bird response to fire on Texas shrublands.

Forest birds

Many, if not all, forest ecosystems were subject to some type of natural fire regime (Wright and Bailey 1982). Fire as a disturbance regime kept forests in a shifting mosaic of successional stages, increasing both horizontal and vertical structure of the vegetation, and higher bird diversity than in grassland and shrub-steppe habitats (MacArthur and MacArthur 1961). Like grassland ecosystems, fire in forested habitats likely occurred originally as summer fires, but where fire was frequent, such fires were not always high intensity stand replacement fires (Raphael et al. 1987). As a management prescription, fire is usually applied as cool-season surface fires designed to thin the understory, remove competition from more commercially desirable trees, or stimulate germination of high quality mast producing hardwoods.

Prescribed fires in forest systems can have differential, positive, and negative effects on forest birds, or groups (guilds) of forest birds. Prescribed fire favors species adapted to early seral habitats and can prolong early seral stages, thereby increasing habitat patchiness and structural heterogeneity from which birds can select food and cover (Raphael et al. 1987, Imbeau et al. 1999, Morissette et al. 2002). Bird species that nest on the ground or in low shrubs may be negatively impacted by fire through the removal of understory vegetative cover, resulting in higher nest predation and parasitism rates by brown headed cowbirds (*Molothrus ater*). The existing literature regarding fire effects on forest bird populations primarily has been focused in 2 areas: cool-season prescription surface fires, and naturally-occurring stand replacement fires. Most studies still rely on changes in relative numbers to assess fire effects, but a few have addressed the impact on other demographics such as nest success and cowbird parasitism.

Stand replacement fires likely have greater immediate impacts on forest avifauna simply because of their hotter intensity and spatial scale. Such fires provide valuable opportunities to study avian responses to fire, but not always in a replication-control type of experiment. Most studies evaluating naturally-occurring stand replacement fires have been restricted to conifer forests of the Rocky Mountains, mixed conifers of the Great Lakes region, or boreal forests ecosystems of Canada.

The existing literature regarding stand replacement fires consistently show distinct differences in avian assemblages when compared to unburned forest and forests that have been logged. Bock and Lynch (1970) studied wildfire in conifer forests of the California Sierra Nevada 6–8 year post fire. Twenty-eight percent (n = 32) of the regularly breeding avian species were unique to burned forest while 19 % occurred only in the unburned forest. Burned forests also exhibited slightly richer (28 vs 23 species) and more diverse avifauna, which was likely due to small unburned pockets of mature conifers which added to the heterogeneity of the burned plot. Species adapted to forage among the needles of living conifers were much more common on the unburned plot while species characteristic of low brush and open ground predominated on the burn.

Apfelbaum and Haney (1981) compared bird communities before and after fire in conifer forests of the Great Lakes region of Minnesota. Tree foliage searchers had the greatest importance value before the fire and ground brush foragers the greatest value afterwards. Fire decreased density, total biomass, and combined existence energy of birds 50%, 23%, and 41%, respectively, but species using the burned forest after the fire were 63% heavier on average. Few studies have addressed this functional response to fire. Fire apparently reduced the total food available for birds, but increased the kinds of food, especially at or near the ground. Spatial and structural diversity of the vegetation in the study increased markedly in the spring following wildfire, which was likely responsible for the post-fire increase in richness and evenness of breeding birds within the study area. The increased richness in the ground/brush foraging guild resulted from a different set of species than those representing this guild before the fire. Flycatchers (*Empidonax* spp.) and brown creepers (*Certhia americana*) favored the burned forest. Although density and biomass decreased after fire, species richness increased, not only in birds visiting the site, but also in those establishing territories.

Raphael et al. (1987) documented the change in breeding bird populations over 25 years of post-fire succession in conifer forests of the California Sierra Nevada. From 1969–1983, shrub cover on their burned plot increased during 1969–1983 from 22% to >43 %, and density of over-story trees increased by about 50%. Total breeding bird density during this period of rapid post-fire succession was nearly equal on the 2 plots, but species richness increased on the burned plot. Ground and brush foraging birds were more numerous on the burned plot, and their population size increased significantly during 1966–1985. Foliage-searching birds were more numerous and stable over time on the unburned plot; the abundance of birds in this avian guild increased significantly on the burned plot over time. Bark-gleaning birds declined on the burned plot, probably in response to the loss of snags used for nesting by most of these species. Avian community similarity between the burned and unburned forest was low in each time interval; similarity in avian communities within the burned forest increased over time, and remained high overtime in the unburned forest.

Hutto (1995) documented similar responses to Apfelbaum and Haney (1981) and Bock and Lynch (1970) in his spatially large study of 34 burned Rocky Mountain forests of Montana and northern Wyoming. Fifteen bird species were more abundant in early post-fire communities than in any other major cover type occurring in the northern Rockies. Bird communities in recently burned forests were different in composition from those that characterize other Rocky Mountain cover types – including early successional clearcuts – primarily because members of 3 feeding guilds were especially abundant therein: woodpeckers, flycatchers, and seed eaters. Standing fire-killed trees provided nest sites for nearly two-thirds of 31 species that were found nesting in the burned sites. For bird species that were abundant or relatively restricted to burned forests, stand-replacement fires may be necessary for long-term maintenance of their populations.

Morissette et al. (1999) examined differences of avian communities in unburned and burned stands of jack pine, mixed wood, and trembling aspen (*Populus tremuloides*) to characterize the post-fire bird community in commercially important forest types. These authors found that burned forests supported a distinct species assemblage of songbirds relative to unburned forests and that salvage logging significantly altered this community. In all forest types, the songbird species recorded typically occurred in both burned and unburned habitats. However, based on relative abundance estimates, several species were found to be strongly associated with unburned forests. In burned areas, the songbird community included both early successional species and species generally thought to prefer mature forests. Results indicated that salvage logging generates a community assemblage of songbirds distinct from the community found in burned forests. Hobson and Schick (1999) found that the bird communities in post-fire and post-harvest mixed-wood forests were distinct, and that these differences were greater than those between burned and unburned stands. In like manner, Imbeau et al. (1999) compared boreal forest bird assemblages in successional black spruce (*Picea mariana*) stands originating from natural stand-replacement fires and clear-cut logging. Species richness did not vary among forest developmental stages, but bird abundance was higher in recent clear-cuts. Recently disturbed areas were characterized by open-land bird assemblages dominated by neotropical migrants, which reached their highest abundance in clear-cuts. Cavity nesting birds were absent from clearcuts. Forest bird assemblages re-established themselves as soon as young spruces reached the sapling stage.

The published literature regarding bird responses to prescription fires in forested ecosystems is somewhat more varied, and negative than that for stand replacement fires. Most studies have examined cool surface fires as a disturbance regime, and some have looked beyond abundance measures and attempted to quantify reproductive success. Because prescription fires are usually low intensity and applied on a previously delineated area, the resulting effects are not always comparable to naturally-occurring stand-replacement fires. Indeed, at least 1 study documented no response by birds to prescribed fire. Vreeland and Tietje (2002) conducted a light-intensity prescribed fire in mixed blue oak (*Quercus douglasii*)-coast liveoak (*Q. agrifolia*) woodlands in coastal central California and detected no changes in breeding bird species.

Most other studies on bird-fire responses in forested systems have documented a prescribed fire effect. Stribling and Barron (1995) quantified short-term effects of cool and hot prescribed fires. Both fire types were conducted during March, but under different fuel loads, relative humidity and wind speeds. Cool fires left the mid and overstory trees and shrubs intact with little or no effect on available snags and their nesting cavities. As a result, cool fire treatments contained greater abundance of canopy-gleaning, shrub-gleaning, bark- gleaning and cavity-nesting birds. In contrast, ground-foraging and ground-nesting species were more abundant in the hot fire treatment. Rufous-sided towhees (*Pipilo erythropthalmus*), a ground-nesting species, was more than twice as abundant on the hot burn sites than on the cool burn site.

In Florida scrub and slash pine (*Pinus elliotii*) flatwoods, Breininger and Smith (1992) found that most shrub-dwelling birds preferred older stands (>10 years post-fire) with taller shrubs, or intermediate stands (4 yrs since last fire) than recently burned stands (1-2 yr). In their study, 5 species were correlated negatively with percent area burned in stands burned 1-2 years previously. The downy woodpecker (*Picoides pubescens*) was most abundant in recently burned areas. These authors speculated that extensive burns occurring every 4 years or less would likely have a negative influence on shrub dwelling birds that are a natural component of these coastal communities.

Red-cockaded woodpeckers (*Dendrocopus borealis*) require open pine grassland habitats historically maintained by natural fire, which kept the understory free of hardwoods (Wilson et al. 1995). Prescribed fire is an important technique in managing habitat for this species. Degraded habitat is often recovered using mechanical removal of the mid- and understory in conjunction with fire (Wilson et al 1995). Wilson et al. (1995) conducted an experimental study to evaluate the effects of this type of management (Wildlife Stand Improvements [WSI]) for red-cockaded woodpeckers on the other breeding birds in Arkansas. They documented highest total bird densities in the second growing season following WSI and fire, and lowest total bird densities in the control. Species richness did not differ among treatments. Density of ground-shrub foraging and shrub-nesting species increased the most following WSI and fire. Only ground-nesting species were more abundant in untreated stands than in treated stands.

Artman et al. (2001) studied the effects of repeated burning (1–4 years annual burning) and recovery (1 yr after burning) on the breeding bird community. In this study, 30 species were monitored, 4 of which were affected negatively, and 2 were affected positively by burning. Population densities of ovenbirds (*Seiurus aurocapillus*), worm-eating warblers (*Helmitheros vermivorus*) and hooded warblers (*Wilsonia citrina*) declined incrementally in response to repeated burning and did not recover within 1 year after burning, suggesting a lag time in response to the changes in habitat conditions. Densities of northern cardinals (*Cardinalis cardinalis*) fluctuated among years in the control units but remained low in the burned units. Densities of American robins (*Turdus migratorius*) and eastern woodpeewee (*Contopus virens*) increased in response to burning, but these increases were apparent only after several years of repeated burning. Burning generally improved habitat for ground and aerial foraging birds, although there were no overall changes in the composition of the breeding bird community. Total breeding bird populations were also unaffected by burning.

Two studies evaluated prescribed fire in context to reproductive success as well as abundance of breeding birds. White et al. (1999) quantified abundance and productivity of songbirds in prescribed burned and unburned mature pine forests at Piedmont National Wildlife Refuge, Georgia. Although the number of species that preferred the burned sites outnumbered those that preferred unburned sites, the preference was not exclusive; avian species richness and evenness were similar for burned and unburned sites. Burned sites were preferred for nesting over unburned sites, but productivity estimates were low in burned sites.

Aquilani et al. (2000) investigated the effects of prescribed fire on abundance and reproductive success of ground and shrub nesting neotropical migrant bird species. The abundance of neotropical migrants was greater in unburned areas for both years of their study, with the greatest difference in the abundance of ovenbirds. The probability of nest success for all neotropical migrants in the ground- and shrub-nesting guild combined was significantly lower in the burned area than in the unburned areas, but nest parasitism by brown-headed cowbirds did not differ.

Prescribed fires significantly reduced vegetative cover in the burned area. Nest sites in the burned area had higher vegetative cover than random points, but less cover than unburned forest, indicating that birds may have selected nest sites that were less affected by the fire. While prescribed fires that burn in a natural "hit or miss" pattern may retain nesting habitat for bird species in this nesting guild, lower nest success in the burned area indicated that management for desirable vegetation and for this nesting guild may not be compatible within the same forest stand at the same time. Their data argued for landscape level planning to attain objectives for both vegetation composition and maintenance of bird species diversity.

A major concern with respect to fire, prescribed or natural, is the effect on dead standing trees, or snags, because of their value as foraging and nesting substrates for a variety of avian species, but especially primary (e.g., woodpeckers) and secondary cavity nesters (chickadees, flycatchers). Natural, stand-replacing fires tend to produce large amounts of down and standing dead woody debris, increasing the habitat quality for woodpeckers, some which are strongly tied to burned forest. Horton and Mannan (1988) evaluated the effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. Nearly half of all snags burned down or were drastically changed by the prescribed fires. Very few large trees were killed immediately by the fires, which slowed the replacement rate of new snags. This delay produced a 45% net decrease in available snags in the first year after the fire. The diameter of a snag influenced its fate by prescribed fire. Snags >50 cm (20 inches) dbh were reduced by 56%, those 30–50 cm (12–20 inches) dbh by 51 %, and those 15–30 cm (6–12 inches) dbh by 34%.

The state of decay of snags also influenced whether or not they burned; snags in decay classes II and VI were least susceptible to burning, those in class III and V were intermediate, and those in class IV burned most frequently. No bird species disappeared in the first breeding season after the prescribed fire, but consistent changes in abundance suggested that northern flickers (*Colaptes auratus*) and violet-green swallows (*Tachycineta thalassina*) decreased on the experimental stands, relative to the control stands, whereas mountain chickadees increased. As a fire management strategy, active protection of large snags and logs be should be considered when planning prescribed fires in forests where silvicultural treatments have reduced the natural abundance of these important habitat components. Some snags from all stages of decay should be retained to provide habitat for animals other than birds.

Studies conducted in the western and north-central U.S. consistently illustrate the near exclusive occupancy of three-toed woodpeckers (*Picoides tridactylus*) and black-backed woodpeckers (*Picoides arcticus*) to recently burned forest (Hutto 1995, Murphy and Lenhausen 1998, Imbeau et al. 1999, Hobson and Schieck 1999, Morissette et al. 1999). Black-backed woodpeckers seem to be nearly restricted in its habitat distribution to standing dead forests created by stand-replacement fires (Hutto 1995). In Minnesota, black-backed and three-toed woodpeckers fed almost exclusively on severely burned jack pine, most of which appeared to be dead (Apfelbaum and Haney 1981). In Alaska, both species increased markedly after stand-replacement fires in June 1983, remained high for 2 years and then began to decline. Black-backed woodpeckers were absent from burned areas by late spring 1986 (Murphy and Lenhausen 1998). Murphy and Lenhausen's (1998) results suggest that the black-backed woodpecker is extremely specialized in its foraging niche, exploiting outbreaks of wood-boring beetles in dying conifers for only 2-3 years after fire. Consequently, this species may be particularly vulnerable to local and regional extinction as fire suppression intensifies and programs of intensive salvage logging are pursued following fires. Brown creepers (*Certhia americana*) and black-capped chickadees (*Poecile atricapilla*) were also found to be tied strongly to burned forests (Imbeau et al. 1999, Morissette et al. 1999), which is not surprising given that both species are cavity nesters.

Engstrom et al. (1984) evaluated fire effects on avian communities in a different and innovative manner than most studies. Their study focused on a Florida long leaf pine forest previously maintained by regular prescribed fires and evaluated breeding bird response to the subsequent exclusion of prescribed fire over a 15 year time frame. Their results showed dramatic changes in breeding birds over time. Bird species typical of open habitat, such as eastern kingbird (*Tyrannus tyrannus*), blue grosbeak (*Guiraca caerulea*), and Bachman's sparrow (*Aimophila aestivalis*), disappeared within 5 years after the burning was excluded. Within a few years after the establishment of a shrub layer (2–9 years post-fire), birds typical of shrub habitats, such as prairie warbler (*Dendroica discolor*) and yellow-breasted chat (*Icteria virens*), were observed on the study site; common yellowthroat (*Geothlypis trichas*), rufous-sided towhee, white-eyed vireo (*Vireo griseus*), and northern cardinal reached maximum numbers during this brushy seral stage (3–7 years), and then declined slowly. Species associated with mesic woods (yellow-billed cuckoo (*Coccyzus americanus*), wood thrush (*Hylocichla mustelina*), red-eyed vireo (*Vireo olivaceous*), hooded warbler) appeared after the establishment of a subcanopy of saplings. Canopy species such as eastern wood peewee (*Contopus virens*), great-crested flycatcher (*Myiarchis crinitus*), and summer tanager (*Piranga rubra*) seemed least affected by vegetation changes. With fire exclusion came a decrease in grass and herbaceous cover, and a concomitant loss of ground-nesting species. A low dense subcanopy of oaks developed under the pine canopy 8–11 years after fire exclusion and was associated with the lowest bird species richness recorded during the study. Bird species that utilized the high pine canopy for foraging and nesting remained in the study plot despite the hardwood growth, and species associated with mesic conditions (e.g., closed canopy, late seral stages) were becoming increasingly common.

Small mammals

Fire, whether prescribed or natural, has its greatest impact on habitat structure at ground level within the herbaceous layer (e.g., grass and forbs). Intuitively, fire should have a direct and immediate effect on small mammal communities (Order Rodentia: mice, rats, squirrels), given that most are ground or below-ground dwellers that forage in herbaceous plant matter or leave litter for seeds and arthropods, and rely directly on the herbaceous layer (grass) for protective cover and nest sites.

Most small mammal-fire research published up to the mid-1980s was unreplicated, short-term, and focused on strong numerical responses to fire, rather than the mechanisms of such responses (Kaufman et al 1990). Our knowledge of fire effects on rodents is better and more complete than for any other taxonomic group as a result of the long-term research of Kaufman et al. (1990) conducted in the tallgrass Konza prairie of Kansas. Their research has documented that tallgrass prairie rodents respond to fire in 1 of 2 ways. Those species that respond positively to fire are classified as fire-positive, while those that respond negatively are designated as fire-negative. Rodents and shrews that are associated with plant debris and/or are foliage feeders generally exhibit a fire-negative response and include northern short-tailed shrew (*Blarina brevicauda*), voles (*Microtus* spp.), woodrats (*Neotoma* spp.), and western harvest mice (*Reithrodontomys megalotis*). Species that require relatively open herbaceous layer and feed on seeds and/or insects, use ambulatory or saltational locomotion are fire-positive species; examples of such species include hispid pocket mouse (*Perognathus hispidus*), southern grasshopper mouse (*Onychomys torridus*), white-footed/deer mouse (*Peromyscus maniculatus, P. leucopus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), and Merriam's kangaroo rat (*Dipodomys merriami*) (Kaufman et al. (1990). The small mammal research at Konza suggests that there are few small mammals, if any, that are fire neutral.

Tallgrass Prairie

The composition of small mammal communities among burned and unburned prairie on Konza was very different. This difference was manifested in the dominance of deer mice in the burned prairie sites, which contained very sparse litter and lush grass growth than the unburned prairie (Kaufmann et al. 1983). Such conditions occur in the first year after a spring burn. Tester (1965) also documented a positive response to fire by deer mice in tallgrass habitats in Minnesota. Fire apparently creates areas with open vegetation structure and relatively sparse litter cover which increases the availability of seeds and arthropods (Kaufman et al. 1983, Kaufman et al. 1988, Clark et al. 1989, Kaufman et al. 1989). In contrast, the Elliot's short-tailed shrew (*Blarina hylophaga*) and the western harvest mouse were more abundant in the unburned prairie; both of these species require leaf litter for foraging and nest building (Birney et al. 1976, Erwin and Stasiak 1979, Clarke et al. 1989, Kaufman et al. 1989). Fire had both direct effects (mortality) and indirect (habitat alteration) on these 2 fire-negative species. The response of deer mice to the burned prairie was largely due to immigration into the burned prairie from the unburned prairie (Kaufman et al. 1988).

Most of the work so far cited on Konza has dealt with spring fires. McMillan et al. (1995) observed small mammal response to autumn (November) fires at Konza to be similar to that documented for spring fires. Elliot's short-tailed shrew, prairie vole (*Microtus ochrogaster*), and western harvest mice responded negatively to autumn fire, whereas prairie deer mice responded positively. White-footed mice showed no response. The response by short-tailed shrews, prairie voles, and western harvest mice occurred within 2 weeks after fire, whereas the change in deer mice was not apparent until spring when abundance on burned sites had tripled, and abundance on control sites had decreased.

Forests

Fewer studies have examined small mammal response to fire in forested systems, and the results are not as consistent as those in tallgrass prairies. Krefting and Ahlgren (1974) studied small mammal assemblages on 2 burned and 1 unburned site in northeastern Minnesota after wildfire from 1955–1967. Deer mice were the most abundant species on the 2 burns the first 7 years. Later, as the vegetation changed, the red-backed vole (*Cleithronomys gapperi*) became more abundant. Other species were low and erratic on all areas.

Kirkland et al. (1996) recorded significantly more small mammals in unburned than burned oak forests in south-central Pennsylvania following a fire in November, 1991. This numerical difference only existed during the first 3 post-fire sampling periods (April, June, July); in contrast, 3 measures of small mammal community structure (Shannon's index, evenness, and species richness) did not differ between burned and unburned forest.

Simon et al. (2002) compared small mammal abundance between post-fire and clearcut plots representing 3 ages since disturbance (4, 14, and 27 years). Their results showed that only 1 species – the red-backed vole – differed in abundance between the disturbance types, being more numerous on the clearcuts than on the burns. With increasing time since disturbance, the relative abundance of all small mammal species in burned and clearcut stands became more similar.

One of the better studies from an experimental perspective is that of Masters et al. (1998). In this study, small mammal occurrence and abundance was compared over 2 winters in untreated pine-hardwood stands to stands with wildlife stand improvement (WSI–midstory removal) and with WSI-treated stands in the first, second, and third dormant seasons following prescribed fire. Overall, the WSI stands had the highest total abundance of small mammals, a response that was due more to midstory removal than to fire. Species richness and diversity increased in the second year and was strongly related to both WSI and fire. Untreated stands had the lowest total community abundance, richness, diversity. Small mammal communities tended to be more diverse, abundant, and species rich on burned WSI treatments.

Two studies found no effect of fire on small mammals communities. Vreeland and Tietje (2002) recorded no change in relative abundance of small mammals following a light-moderate intensity fire in California oak woodlands. Ford et al. (1999) investigated the effects of a high intensity prescribed burn in upper slope pitch pine (*Pinus rigida*) stands of North Carolina. They found no differences in small mammal abundances between the burned stand and unburned control prior to the burn nor after the fire for 2 years. Slope position accounted for more variation among the species of greatest abundance than did burning; the authors concluded that concern over fire effects in this ecosystem may be unwarranted.

Reptiles and amphibians

Intuitively, reptiles and amphibians would appear to be more vulnerable to prescribed fire than birds or small mammals due to their smaller size and lower mobility. Reptiles and amphibians are ectothermic and amphibians have highly permeable skin which restricts their ability to deal with fluctuating conditions and can render them more sensitive to habitat alteration (Blaustein et al. 1994). Amphibians are of particular conservation concern because many species have restricted geographical ranges, occur only in localized microhabitats that may be vulnerable to management activities or are listed under the Endangered Species Act (Smelitsch 2000).

In forested habitats, woody debris and leaf litter protect amphibians from desiccation, temperature regimes and predators, as well as providing habitat for an abundance of invertebrate prey. Prescribed burning may potentially remove these critical habitat elements. Much of the published data comes mainly from the southern U.S., but nearly all studies suggest that herptile responses to prescribed burning can be positive, neutral or negative depending on species-specific life histories, habitat associations and specific habitat requirements. Fire potentially impacts reptiles and amphibians in ways similar to small mammals: directly via mortality of the individual organism and indirectly through habitat modification (Russell et al. 1999).

From the available literature, it appears that direct mortality of individual reptile and amphibians is minimal in terms of total numbers documented post-fire; the overall effect on population dynamics however, is not well understood for most species. Russell et al. (1989) provides a thorough discussion and review of the available literature regarding direct and indirect fire effects on herpetofauna. Where data exists for North American herpetofauna, it appears that only the eastern glass lizard (*Ophisaurus ventralis*) incurs significant direct mortality from prescribed fires (Russell et al. 1989), although Smith et al. (2001) suggest fire-induced mortality for montane rattlesnakes (*Crotalus willardi obscurus*) in Madrean habitats of Arizona may be significant.

Data regarding indirect effects of fire on habitat structure and consequently on population dynamics are few in the peer-reviewed literature, vary by taxonomic group, and illustrate neutral, positive and negative effects. Ford et al. (1996) quantified pre-and post-fire abundance of herpetofauna to a high intensity fire in North Carolina pitch pine (*Pinus rigida*) and mid-slope oak stands; there was no difference in the numbers of species collected during pretreatment sampling or in 2 years of post-treatment collections. Vreeland and Tietje (2002) also failed to document a response among herpetofauna to a light-moderate intensity prescribed fire in oak woodlands of California. Burrow et al. (2001) described microhabitat selection by Texas horned lizards (*Phrynasoma cornutum*) on 5 south Texas sites with different grazing and burning treatments. There were no differences in microhabitat selection among land management treatments by horned lizards, suggesting that prescribed fire likely had a neutral effect.

Several studies have illustrated negative effects of prescribed fire to herpetofauna. Smith et al. (2001) used radio-telemetry to evaluate effects of a prescribed fire in Madrean habitats on mortality, behavior, and habitat of montane rattlesnakes. In their study, spatial descriptors of activity did not significantly differ before versus after the fire; however, individuals moved significantly less frequently and were found in subterranean retreats more frequently after the fire than before the fire. Wooded canyons and wooded steep slopes burned intensely because of high fuel accumulation, resulting in habitat loss for montane rattlesnakes. Smith et al. (2001) recommended managers consider reducing artificially high fuel loads before reintroducing large-scale summer fires to preserve habitat and reduce mortality of montane rattlesnakes.

Setser and Cavitt (2003) also studied snake response to prescribed fire in the Konza tallgrass prairie of Kansas. In this study, 2 species - (*Coluber constrictor* and *Thamnophis sirtalis)* - were captured more frequently on long-term unburned prairie than on recently burned prairie in late spring. This difference, however, did not persist during the fall. Their data suggest some tallgrass prairie snakes avoid freshly burned tallgrass prairie but can recolonize burned areas within a single growing season (Setser and Cavitt 2003). These authors recommend unburned areas be maintained adjacent to burns to serve as snake refugia.

In contrast to other studies in forested habitats (Ford et al. 1996, Kirkland et al. 1996,Vreeland and Tietje 2002), prescribed fire in South Carolina forests had a significant negative impact on amphibians (Schurbon and Fauth 2003). These finding are important given that the study sites were fire-adapted southeastern long leaf pine forests. Species richness increased in this study with increasing time since fire, but community evenness decreased primarily because salamanders were rare on recent burns (≤2 years). Recently burned sites had the shallowest leaf litter and highest soil temperature variances. Schurbon and Fauth (2003) concluded that extensive and frequent prescribed burns are not beneficial to all members of fire-adapted southeastern pine communities. They recommend decreasing the frequency of prescribed burns form the current 2–3 years to 3–7 years, and substituting growing season burns for the current practice of winter and spring burns. Such changes would better maintain diverse amphibian assemblages, and avoid repeated interruption of amphibian breeding activity, and still maintain the desired long leaf pine community.

Herpetofauna in the Cross Timbers region of Oklahoma showed differential response to fire in combination with application of herbicide (tebuthiuron), herbicide with fire, and neither herbicide nor fire (Jones et al. 2000). Jones et al. (2000) reported no differences among the 3 treatment types for relative total abundance and species richness, but there were differences among taxonomic groups. Untreated sites and herbicide-only sites had a greater abundance of amphibians; lizards were most abundant on the untreated sites, and snakes were-most abundant on herbicide and fire treatments. Herbicide without fire does not benefit most reptiles, whereas herbicide with fire appears to negatively affect most amphibians. Jones et al. (2000) recommended a mosaic approach at scales appropriate to herptiles is likely the best approach.

There are fewer studies that show clear-cut positive responses of herpetofauna to prescribed fire. Kirkland et al. (1996) studied the impact of fire on amphibians in an oak-dominated forest in south-central Pennsylvania following a fire in November 1991. They captured significantly more amphibians in the burned forest only during the June sampling period. This response was due largely to greater numbers of the American toad (*Bufo americanus*); no differences existed during other sampling periods of their study (Kirkland et al. 1996). Fair and Henke (1997) quantified relative abundance of Texas horned lizards, their scat, and active harvester ant (*Pogonomyrmex* spp.) mounds on 1-ha (2.5 acres) plots that were treated with prescribed burning, discing, burning and discing, grazing, or land in Conservation Reserve Program in southern Texas. Horned lizards used burned plots disproportionately more than other treatments, although there was no difference in the abundance of harvester ant mounds.

Brisson et al. (2003) tested the impacts of fire on the ecology of eastern collard lizards (*Crotaphytus collaris*) living on the Ozark Plateau of southern Missouri. This study was unique in that other demographics were assessed as well as effects on population size. Eastern collard lizards in this habitat are restricted to islands of rocky glade habitat located throughout the oak–hickory forests of the region. Anthropogenic suppression of fire has negatively impacted lizard populations by permitting the overgrowth and consequent disappearance of this glade habitat. Such post-fire succession also produces a dense forest understory that impedes inter-glade movement of lizards. This unique study demonstrated that prescribed fire increased glade-to-glade dispersal, colonization of previously unoccupied glades, and a significant increase in population size in the burned areas. In addition, Brisson et al. (2003) showed that populations within burned areas exhibit body sizes similar to those reported for populations living in healthy habitat as compared to those living in habitat that has deteriorated because of fire suppression. Fire, as an ecosystem process, is critical to the long-term sustainability of eastern collard lizards.

Summary

The published data regarding fire effects on nongame wildlife populations illustrate positive, negative, and null responses to fire, as they are indexed by relative abundance. The few long-term studies that exist indicate little impact on grassland birds due to fire. Other studies suggest measures like reproductive success may be a more appropriate index to fire efficacy (Johnson and Temple 1986, 1990). Fire in shrubland systems may be inappropriate for some taxonomic groups, given the low frequency of fire in these habitats. There appears to be a very different dynamic among small mammal communities inhabiting grasslands versus forested habitats with respect to fire, but research from forested sites are few. One consistent theme among studies common to all taxonomic groups is that the scale in which fire is applied is critical to maintaining species diversity; most studies recommend small scale application in a mosiac pattern that retains unburned tracts for those species that are negatively affected by fire. Further, some studies indicate that fire frequency intervals can be important, even in fire-maintained ecosystems like long leaf pine forests of the southeastern U. S. Fire applied too frequently can be as harmful to species diversity and populations as outright suppression of fire. More research addressing fire effects on reptiles and amphibians is needed, especially long-term manipulative studies.

As wildlife biologists and land managers increasingly embrace prescribed fire in managing habitat, dwindling funding and logistics mandate that we use fire in a manner that is appropriate and ecologically relevant. Our review of the peer-reviewed literature highlights a fundamental knowledge gap as it relates to prescribed fire effects on wildlife populations and their habitat: 1) too few studies, and 2) too much of our knowledge is based upon short-term studies which rely too heavily on the single metric of relative abundance. Such studies have been shown to provide misleading conclusions regarding prescribed fire (Johnson and Temple 1986, 1990, Peterson and Best 1999, Wiens and Rotenberry 1985, Wiens et al. 1986). This problem is particularly acute for Texas rangelands. We encourage wildlife research scientists in Texas to embrace prescribed fire as a major research paradigm within which to conduct manipulative long-term research on all facets of population dynamics. Further, we urge land managers and resource agencies currently managing habitats with fire to quantify wildlife responses; this can be achieved most efficiently by collaborating with the research community.

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PRESCRIBED BURNING FOR THREATENED AND ENDANGERED SPECIES

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Abstract: Many state- and federally-threatened and endangered (T&E) species exist in fire-dependent habitats. In the absence of fire these areas become less suitable as habitat for rare animal populations, leading to potential population declines and nonviability. Some populations may become locally extirpated. The Nature Conservancy, as well as many other public and private land managers, use fire and other management practices to restore and maintain habitat for at-risk populations in Texas. Currently, The Nature Conservancy is involved in projects, using prescribed fire, which benefit black-capped vireos (*Vireo atricapillus*), golden-cheeked warblers (*Dendroica chrysoparia*), Attwater's prairie chicken (*Tympanuchus cupido attwateri*) and red-cockaded woodpeckers (*Picoides borealis*). While some progress is being made, there is still a tremendous amount of work to be done to restore habitat which has been altered, at least in part, due to the absence of fire. We need to continue to develop tactics and strategies to encourage a landscape-scale approach to the use of fire. Presently, the ability of prescribed fire practitioners to accomplish large-scale fire treatments for threatened and endangered species habitat in Texas is limited by a variety of factors.

Introduction

Periodic wildland fire has shaped and maintained many different wildlife habitats in Texas. With the advent of systematic fire suppression many of these habitats have degraded or have converted to less desirable states through succession. Some species of wildlife with specific habitat requirements that could not adapt to the changes in the vegetative characteristics that occurred with fire exclusion, have experienced significant declines. Some of these wildlife populations have been reduced to the point where serious concern for the long term viability of the species required action by state and federal governments to assist in their protection and recovery. Listing of these species as threatened or endangered by these governments highlights the concern and puts positive requirements for protection and maintenance of critical habitat for the listed species. State and federal agencies, nonprofit environmental organizations, commercial and private landowners and managers make special efforts to follow guidelines and rules developed as a result of listing under the Endangered Species Act.

The purpose of this paper is to discuss the efforts that The Nature Conservancy in Texas is making, using fire as a tool, to protect and restore habitats used by rare and declining species. Fire use alone, of course, is not the total answer to complex ecosystem issues. Habitat fragmentation from development or land conversion, the spread of invasive plant species and other threats have impacts for which prescribed fire may not be able to affect at all or is only a partial answer. For areas where fire is a viable alternative we must look for ways to increase the use of this tool in order to improve habitats on a landscape scale.

In this paper, I suggest some possible strategies and tactics to facilitate use of fire on a broader scale to the benefit of threatened and endangered species, and concurrently promote general improvement of wildlife habitat.

Golden-cheeked warbler and black-capped vireo

The Nature Conservancy currently is working in 2 areas of the Edwards Plateau to improve habitat for the endangered golden-cheeked warbler (*Dendroica chrysoparia*) and the black-capped vireo (*Vireo atricapillus)*. These species have experienced population declines primarily from habitat loss and degradation as well as nest parasitism by brown-headed cowbirds (*Molothus ater*). The Conservancy is working with the U. S. Army at Fort Hood, under a cooperative agreement, to monitor bird populations, assist with prescribed burning and reduce nest parasitism. The Conservancy is doing similar work at the Barton Creek Preserve near Austin.

The black-capped vireo generally prefers areas with shin oak, sumac and other low growing shrubs for nesting. In the absence of fire the shrubs may become too tall or include an excessive number of Ashe juniper (*Juniperus ashei*) and the birds may abandon the site. Periodic prescribed fire is being used at Fort Hood and Barton Creek to maintain this plant community and to prevent a large wildfire which might impact an excessive part of the nesting area in 1 event.

Golden-cheeked warblers nest in areas of mixed mature Ashe-juniper and oak (*Quercus* spp.) woodland. Prescribed fire is being used to treat grasslands adjacent to these nesting areas. The burn treatments protect the nest areas from wildfire and also control the spread of Ashe juniper into these prairies.

To date the program at Fort Hood is having positive effects with an increase in populations over the past decade. The program at Barton Creek has had some success also, on a much smaller scale, going from a loss of nesting vireos pretreatment, to 1, then 2 nesting pairs. This year 1 pair was confirmed to be nesting There were about 60 pairs of golden-cheeked warblers nesting this year.

Attwater's prairie chicken

The Conservancy is using prescribed fire to restore and maintain habitat for the Attwater's prairie chicken (APC). This species lives in coastal prairie grasslands, preferring a mix of tall and shortgrass areas for nesting, cover and mating activities. We are currently burning at the Conservancy's Texas City Prairie Preserve (TCPP), and on private lands, in the Victoria area, through an initiative which is called the Refugio/Goliad Prairie Project (RGPP) to improve coastal prairie habitat. The Texas City Preserve has one of the two known populations of wild APCs. Currently there are 20 birds at TCPP. The Refugio/Goliad Prairie area historically hosted a large population of APCs, but APC have been extirpated from the area for 8-10 years. The Refugio/Goliad project will be covered in greater depth in a separate presentation at this symposium. In both areas fire is used to maintain the grasslands, including removing or impacting woody species that encroach on the prairies, such as Chinese tallow (*Sapium sebiferum*), wax myrtle (*Myrica heterophylla*) and saltbush (*Atriplex acanthocarpa*).

Red-cockaded woodpecker

While The Nature Conservancy has no known populations of red-cockaded woodpeckers (*Picoides borealis)* (RCWs), on any of our Texas preserves, much of the east Texas longleaf pine (*Pinus palustris*) lands would likely have been suitable habitat prior to the time when timber was logged from these areas and they were replanted to loblolly (*P. taeda*) or slash pine (*P. elliottii*).

Fire suppression also allowed understory brush and hardwoods to become overly dense and tall. The woodpeckers prefer an open pineland with old growth pine and little brush in the understory. At the Roy E. Larson Sandyland Sanctuary and the Timber Lake Preserve in East Texas the pinelands are being converted back to longleaf pine habitat and over time should become suitable habitat again for RCWs. Prescribed fire has been used at Sandylands for a number of years and most of the area has had multiple prescribed fires. We have conducted our first prescribed fire at Timber Lake on a small portion of the preserve. There is a RCW colony in an area known as Woodpecker Hill adjacent to the Timber Lakes Preserve. Nest inserts have been placed in 6 trees within the preserve in the event that the Woodpecker Hill population expands. Timber Lake Preserve was established as part of a cooperative effort between partners to demonstrate ecosystem based forestry, increase and improve habitat for RCWs and to serve as a potential reintroduction site for woodpeckers.

Epilogue

Each of the projects we have noted represents some level of progress but only on small fragments of what previously was available habitat for rare and declining species in Texas. We continue to partner with governmental agencies and private organizations and landowners to increase restoration efforts. But more needs to be done to restore habitat on a landscape scale.

Landowner cooperative burning associations are a positive step. More education of potential burners and the general public on the need for and benefits of prescribed fire is needed. Some states have regional prescribed fire councils whose memberships are composed of prescribed fire users, governmental land managers, private land owners, developers, contract burners, fire protection managers and others interested in the use of prescribed burning. These councils can become a force and a unified voice to promote the use of prescribed fire for multiple benefits.

The Conservancy's relationships with land owners on properties adjacent to ours indicate that there is great interest in burning on their properties but they either don't have the burning expertise or they have concerns for liability should their fire escape. Some states, notably Georgia and Florida, have enacted prescribed burning laws which afford burners, who have successfully completed a state certified course in prescribed burning, considerable liability protection as long as they burn within the prescription parameters of a burn plan. The state division of forestry has the responsibility for issuing daily burning authorizations and periodically monitors compliance by these certified burners to insure they are burning in accordance with open burning regulations and with a burn plan in place. A point system used by the Florida Division of Forestry can revoke burner certification for those who do not follow the requirements of the law. These certified burner programs are not specific to burning for threatened and endangered species, but burns conducted for hazard fuel reduction, or to improve forage for cattle frequently have the additional benefit of improving habitat for listed species. In contrast to the Florida law, the Texas Administrative Code requires that certified prescribed burn manager must carry an insurance policy with a minimum aggregate limit of $2 million for liability.

The Nature Conservancy of Texas is committed to promoting and increasing the use of prescribed fire as a tool to manage diverse habitats in this state. Reestablishing fire as a process on large portions of the landscape is 1 positive step towards insuring the recovery of populations of threatened and endangered species and the general health of ecosystems for native wildlife and flora.

Table 1. Number of acres burned on various properties owned or cooperatively managed with Texas Nature Conservancy, July 2004 – June 2005.

Location	Prescribed fire	Wildfire
Fort Hood (in cooperation with U. S. Army)	19,237	
East Texas (Sandyland, Timber Lake)	602	
West Texas (Davis Mountains)	1,072	
Gulf Coast (Mad Island, Texas City Prairie)	1,737	
North Texas (Clymer, Tridens, Cowleech)	354	
Refugio/Goliad Initiative	16,119	
Assist on burns with USFWS[1] and USNPS[2]	5,318	13,100

[1]U. S. Fish and Wildlife Service
[2] U.S. National Park Service

PRESCRIBED BURNING FOR WILD TURKEY MANAGEMENT IN TEXAS

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Abstract: Prescribed fire is a valuable tool for manipulating vegetation to benefit wild turkeys (*Meleagris gallopavo*). Although spring and summer burning can kill poults and destroy nests, fire during other seasons has little direct effect on wild turkeys. Winter burning can stimulate forb production as well invertebrate communities, but unburned patches should remain to provide protected areas for invertebrates. Frequent, intense fires can be used to promote brood-rearing habitat, while more moderate fires can create nesting sites. Managers should be cautious about using fire to control invasive vegetation around roost sites, as intense fires may top-kill roost trees. Examination of the literature suggests that patchy fires conducted during the fall and early winter are the most beneficial to wild turkeys.

Prescribed fire is a valuable vegetation management tool. Wild turkeys (*Meleagris gallopavo*) require a variety of vegetation types and plant species to fulfill their life-history requirements. Herein, we discuss habitat requirements of wild turkey, use of fire to manipulate vegetation to fulfill these requirements, and the direct and indirect effects of fire on wild turkeys.

Direct effects on adults and poults

Adult wild turkeys are highly mobile animals. Thus, they are able to escape oncoming flames and should suffer few direct effects from fire. However, nests and young poults can be killed (destroyed) easily by fire. At ages <2 weeks, turkey poults are unable to fly. Moreover, when threatened, young poults often freeze and remain motionless (Healy 1992), thus making them vulnerable to fire.

Turkey hens tend to place nests in areas of dense vegetation, often using standing dead material and leaf litter as nesting cover (Porter 1992). Prior to incubation, hens will cover nests with plant material to hide it from predators (Healy 1992). Thus, turkey nests are naturally situated within patches of heavy, fine fuels that would burn intensely during fires.

The immobility of poults and tendency of hens to locate nests in dense vegetation make these life stages particularly vulnerable to fire. Managers should consider the turkey life cycle when planning prescribed fires in order to minimize nest loss and poult mortality. Nesting in Texas varies across ecoregions and year to year, but tends to begin in early April and hatching has usually concluded by early July (Davis 1994). Thus, if turkeys are a management priority, prescribed burning of nesting and brood-rearing areas during the spring and early summer should be avoided.

Indirect effects on adults and poults

Food resources

Wild turkeys eat a wide variety of food items. Prescribed fire can have a substantial effect on the availability of wild turkey food resources, including both animal and plant material. Fire effects can be direct, by physically destroying or consuming food items, or indirect, by altering environmental conditions that effect food production.

Invertebrates. Wild turkeys consume invertebrates during all stages of their life (Hurst 1992). However, turkey poults are especially dependent on invertebrates to provide high levels of protein and energy that are required for rapid growth during the first few weeks of life (Hurst and Poe 1985). Poults tend to select large, soft-bodied arthropods such as spiders (*Araneide* spp.) and grasshoppers (*Acrididae* spp.). Adult birds also consume such items, as well as snails (*Pulmonata* spp.), which laying hens use to replenish calcium lost during egg production (Beasom and Pattee 1978).

Because production of many herbivorous insect species important to turkeys (e.g., grasshoppers) respond positively to green, tender vegetative growth, management practices such as prescribed burning can be used to promote insect populations. Winter burning that removes rank, dead vegetation and recycles nutrients tends to promote a highly nutritious flush of green vegetation following spring green-up. However, because many beneficial arthropods overwinter in dormant vegetation, broad-scale burning might reduce spring populations of invertebrates despite favorable habitat conditions. Patchy burning can create areas of lush growth while retaining patches of dormant vegetation as refugia for overwintering insects, preserving source populations that can provide immigrants into the burned areas, as long as burned sites are not so large as to limit immigration due to excessive distance.

In general, the effect of prescribed fire on invertebrates is determined by season, intensity, and extent of the fire, and the vulnerability of a particular invertebrate life stage to fire. For example, many species of grasshoppers overwinter as eggs in the soil and are little-affected by fire. However, during the first few nymphal stages many species are wingless and live in the vegetation layer, thus they are unable to escape a fire. Finally, once mature, many species are excellent fliers and can easily escape oncoming flames (although there might by little vegetation left after the burn on which to feed). Burns executed in the winter and summer might have less effect on populations, while spring burns can be devastating (Warren et al. 1987).

Little information is available regarding the specific effects of fire on turkey food habitats. However, in Mississippi pine forests (*Pinus* spp.), Hurst (1978), reported the amount of insects and spiders in the diet of poults did not differ significantly between unburned sites and sites burned the previous November, whereas diets on the same burned sites the following year (2 growing season post-burn) showed significantly higher amounts of insect material.

The effect of fire on snails is poorly understood. Evidence suggests fire can alter snail communities (Severns 2005). However, those communities tend to be fairly resilient if there are unburned areas or other refuges from which snails can recolonize the burned areas (Kiss and Magnin 2003, Kiss et al. 2004). Thus, as with arthropods, patchy fire would appear to be the best approach for preserving snail populations. Hurst (1978) showed that consumption of snail shells by poults in Mississippi increased slightly immediately following a burn, but we suspect that this may be due more to the ability of poults to locate shells of dead snails on burned, bare ground than on snail abundance.

Plant materials. Wild turkeys consume a wide variety of plant items, including vegetative parts, seeds, and mast (Hurst 1992). In west and west-central Texas, Litton (1977) and Quinton and Montei (1977) found Rio Grande wild turkeys consumed large amounts of leaves and seeds of various grasses, tunas of tasajillo (*Opuntia leptocaulis*) and prickly pear (*Opuntia* spp.), and mast of various woody species such as pecan (*Carya illinoensis*), hackberry (*Celtis reticulata*), lotebush (*Condalia obtusifolia*), and *Bumelia* species. In southern forests, eastern wild turkeys selected herbaceous plant seeds and leaves, acorns (*Quercus* spp.), pecans (*Carya illinoensis*), grapes (*Vitis* spp.), blackberries (*Rubus* spp.), and other mast species (Hurst 1992).

Because turkeys depend heavily on woody, mast-producing species, prescribed burning to reduce woody plant cover can reduce available food resources. While mature trees are resistant to all but the most violent fires, shrubs and cacti are more vulnerable. In east Texas, Lay (1956) reported that understory mast-producing plants were significantly reduced on plots subjected to prescribed burning. Liveoak (*Quercus virginiana*) sprouts following prescribed fires on the Texas Gulf Coast produced significantly fewer acorns than did plants in unburned communities, and this effect was most pronounced on spring- versus autumn-burned sites (Springer 1977, Springer et al. 1987). In north Texas, density of tasajillo and prickly pear was significantly reduced following prescribed burning (Bunting et al. 1980). Finally, autumn burning in south Texas brush communities can significantly reduce the abundance of important mast-producing species such as lotebush, Mexican persimmon (*Diospoyros texana*), and brasil (*Condalia obovata*) (Box et al. 1967).

Annual grasses and forbs were generally reduced by prescribed fires in the Rolling Plains, especially if the fire occurred after emergence. However, recovery was usually rapid (within 2 growing seasons) due to a large amount of seed in the soil (Whisenant et al 1984). Likewise, early-winter burning in the Post Oak Savannah tended to produce a higher proportion of forbs in the plant community than did spring burning (Garza and Blackburn 1985). On the Texas Gulf Coast, fall-burned sites had significantly higher forb biomass than did unburned or spring-burned sites during the year following the burns; however, this effect had largely disappeared within 2 years of the burn (Springer 1977). Finally, Box et al. (1967) reported a significant decline in forb production following an autumn fire in south Texas; this decline was attributed to a dramatic reduction in western ragweed (*Ambrosia psilostachya*) and Texas broomweed (*Xanthocephalum texanum*), because no change was noted in the abundance of any other forb species measured.

In general, fire effects on wild turkey food resources appear largely to be an effect of timing and intensity. Effects on invertebrates are most pronounced during life stages when they are relatively immobile and occupy vegetation strata that are liable to consumption by fire or exposure to intense heat. In most cases, this life stage occurs during the spring. Likewise, fire effects on forbs are typically greatest following germination; thus late winter or spring burns might be expected to most significantly reduce production. Finally, high intensity fires that kill or severely injure mast producing woody plants appear to result in the greatest reduction in mast production, even when plants are able to resprout from root stock. Because timing of fires to meet diverse management goals is often difficult or impossible, we suggest that burns be planned and implemented in such a way as to create a natural "patchwork" of burned and unburned areas that are readily accessible to turkeys.

Fire effects on parasites and diseases

Just as prescribed fire might affect invertebrates that provide food for wild turkeys, so might it affect other invertebrate species that interact with wild turkeys. Invertebrates often are parasites or pathogens of both juvenile and adult wild turkeys, as well as acting as vectors for diseases. Hence, insofar as fire acts on populations of these invertebrates, it might indirectly affect turkey populations.

Parasitism and disease are not generally regarded as having serious population-level consequences for wild turkeys under most circumstance, although occasional instances of serous health effects have been documented. Detrimental invertebrates include ectoparasites and disease vectors.

Ectoparasites. Of the ectoparasites that affect wild turkeys, ticks appear to be the most serious (Davidson and Wentworth 1992). Jacobsen and Hurst (1979) reported that <2% of wild turkey poults (n = 59) exposed to recently burned plots in Mississippi carried lonestar ticks (*Amblyomma americanum*), whereas 35% (n = 57) of poults on unburned plots where infested with the parasite. In the coastal prairie of Texas, prescribed burning resulted in significantly lower post-burn Gulf Coast tick (*A. maculatum*) populations in 3 out of 4 plant communities (Scifres et al. 1988). In the community for which no response was reported (chaparral-mixedgrass), high relative humidity, low fuel load, and discontinuous fuel distribution were believed to have allowed significant numbers of ticks to survive in the litter and herbaceous layers. However, tick populations tended to rebound within a year, in some cases to levels higher than unburned plots, possibly because burned plots where attractive foraging areas for host species. Conversely, fire did not significantly reduce lonestar tick populations in eastern Oklahoma (Hoch et al. 1972).

The disparity in results suggests the importance of individual fire characteristics in controlling tick populations. Scifres et al. (1988) found tick mortality >90% when they were exposed to temperatures of 90–125ºC for 30 seconds, and 100% when exposed to temperatures of >150ºC for 15 seconds. Weather and fuel conditions all contribute to fire temperatures that exceed the lethal maximum for ticks. Moreover, duration of the control appears to depend upon removal of the litter layer and drying of the habitat following burning.

Disease vectors. Mosquitoes are vectors for numerous diseases of wild vertebrates, including avian pox in wild turkeys (Davidson and Nettles 1997). Mosquito control using prescribed fire has met with mixed success. In Kenya, Whittle et al. (1993) reported a significant reduction in survival of eggs of the mosquitoes (*Aedes* spp.) in seasonally-flooded wetlands. However, prescribed burning did not significantly affect *Aedes* larvae production in Bermudagrass (*Cynodon dactylon*) pasture in California (Wilder and Takahashi 1980).

Research suggests the effectiveness of prescribed fire in mosquito control is influenced by mosquito ecology and microhabitat fire conditions. For example, direct mortality of mosquito eggs requires that eggs be situated in areas dry enough to burn. While some genera of mosquitoes (e.g., *Aedes*) deposit eggs in dry vegetation above the waterline, others (e.g., *Culex* and *Anopheles*) deposit them at the water's surface where, presumably, fire would not affect them (Borror et al. 1989). However, prescribed fire can indirectly contribute to mosquito control by reducing emergent vegetation that acts as mosquito cover, and thus facilitating mosquito predation, even for species which lay there eggs beyond the reach of fire's direct effects (Thullen et al. 2002).

Although fire has been used to control harmful invertebrates, we suggest that concomitant damage to beneficial invertebrates (i.e., food items) will, in most circumstances, greatly outweigh any benefit derived from parasite/vector control. Thus, land managers should critically evaluate the application of prescribed fires during seasons when excessive damage to the invertebrate community might occur.

Fire effects on turkey habitat

The ability of managers to manipulate vegetation structure is 1 of the most powerful applications for prescribed burning in turkey management. Wild turkeys require a variety of vegetation types to fulfill their life cycle. The suitability of these vegetation types for turkeys is largely a function of vegetative structure, which in turn is dependent upon the seral stage of the site. Moreover, the seral stage most suitable as a particular habitat will vary depending upon the local climate, especially rainfall. For example, prime nesting habitat may be an early seral stage in east Texas where rainfall is high, but may be a mid to late seral stage in drier west Texas.

There are 3 specific types of habitat used by wild turkeys at various stages of their lives: roosting habitat, nesting habitat, and brood-rearing habitat. Each of these types has specific structural characteristics that can be manipulated using prescribed fire.

Roost sites. Wild turkeys are dependent on large trees (e.g., oaks, cottonwoods [*Populus* spp.], and pecans) and other structures as roost sites. A unique behavior of Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) is their congregation in large wintering flocks that use historic roost sites, sometimes several miles from their summer range. Aside from the requirement for large trees or other roosting structure, wild turkey roosts are characterized by a relatively open understory. This allows wild turkeys to fly down from the roost without encountering brush or other obstructions, and reduces cover at the base of the roost that might conceal predators.

Prescribed fire can be used to maintain usable roost sites. Prescribed fire is a potential tool for eliminating understory shrubs when applied correctly. However, high intensity fires can severely damage or top-kill large roost trees. When burning near roost sites, care should be taken to prevent understory woody vegetation, especially highly volatile species such as Ashe juniper (*Juniperus ashei*), from igniting and scorching roost trees. Fortunately, the coverage of many woody species can be reduced by simply burning the herbaceous vegetation and leaf litter beneath them and not completely igniting the plant. If this is not possible, then understory shrubs may be removed by other methods (e.g., mechanical) and placed away from roost trees for burning. Finally, prescribed fire and its associated activity may drive wild turkeys from roost sites; care should be taken to minimized disturbance of roost sites during winter burns.

Nesting habitat. Wild turkey nest sites are characterized by a high degree of lateral cover (Porter 1992). This cover is usually in the form of shrubs or large herbaceous plants. Also, wild turkeys tend to place their nests at the base of some "guard object,' such as a tree, shrub, or post. Although not as critical as lateral cover, overhead cover is another important element of nest sites. This is especially important in nonforested habitats. Finally, the presence of leaf litter and other plant material is required to provide nesting material.

For Rio Grande wild turkeys, the picture painted by this habitat description is a landscape with abundant herbaceous vegetation (primarily grasses), dotted with numerous trees and shrubs, and with a substantial layer of leaf litter. On sites with high shrub canopy, herbaceous vegetation may be insufficient to provide suitable nest sites. Prescribed fire can be used to reduce shrub cover and restore nesting habitat at such locations. However, it should be judiciously used, as excessive removal of shrubs can remove valuable lateral and overhead cover, as well as guard objects. Also, winter fires followed by below-normal rainfall can limit grass recovery and result in barren sites unusable by nesting hens during the following nesting season.

In eastern wild turkey (*M. gallopavo silvestris*) habitats in east Texas, herbaceous vegetation is often limited by closed canopy of understory shrubs. Undisturbed pine forest sites can become impenetrable stands of woody shrubs such as sweetgum (*Liquidambar styraciflua*) within 2–3 years. Frequent prescribed burning is required to keep the pine understory open and allow herbaceous growth.

Brood-rearing habitat. Brood-rearing habitat is characterized by a narrow range of structural habitat components. Young poults require sufficient open ground to allow mobility, yet there must be sufficient lateral cover to screen poults from predators. Moreover, lateral cover must be low enough for the brooding hen to see over and watch for preda tors. Because brood-rearing habitat is much more open than nesting habitat, more intense and frequent fires are necessary to maintain these sites.

Conclusion and management recommendations

The ability to manipulate vegetation structure and habitat elements using prescribed fire is a valuable tool for managing wild turkey. Evaluation of turkey habitat requirements and the effects of fire on the landscape suggest that burning can be used to achieve optimum seral stages to meet the needs of the full range of turkey life stages. Burning to promote more open communities can improve turkey habitat where woody plant encroachment is problem, with more intense and frequent burns being required to maintain brood-rearing habitat than are required to maintain nesting habitat.

Another critical element of planning prescribed burns for turkey management is the spatial extent of the burned area. Although turkeys are relatively mobile animals, close juxtaposition of important vegetation types is necessary to ensure easy access to important habitats. Intensively burned brood rearing sites should be interspersed with more moderately treated nesting areas, all the while maintaining roost sites close by. Further, patchy burning at even finer scales ensures refugia from which important invertebrate species can recolonize burned patches.

Finally, seasonality of burning plays an important role in the effect of fire on turkey populations. Spring and summer burning risks killing poults and destroying nests, damaging invertebrate communities, and reducing abundance of important forb species. Therefore, we recommend that fires be conducted during late-fall to early-winter, to maximize the positive effects of prescribed burning.

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COASTAL PRAIRIE CONSERVATION INITIATIVE

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***Abstract*:** The Coastal Prairie Conservation Initiative (CPCI) is a landscape-level cooperative effort that has made tremendous strides to maintain, enhance, restore and conserve one of the world's most imperiled communities, coastal prairie. The initiative is comprised of representatives from the Natural Resource Conservation Service, US Fish and Wildlife Service, Texas Parks and Wildlife Department, Grazing Lands Conservation Initiative, The Nature Conservancy, and cooperating private landowners. Through contributions from the US Fish and Wildlife Service, Texas Parks and Wildlife Department, The Nature Conservancy, and private landowners this initiative has been able to conserve and restore a significant amount of coastal prairie habitat on private lands through cooperative cost share habitat management practices with private landowners. Coastal prairie habitat is critically important in increasing and reestablishing populations of rare and endangered plants and animals associated with grasslands. Since its inception in 1995, the Coastal Prairie Conservation Initiative has undertaken 21 coastal prairie restoration projects on 18 ranches encompassing over 58,000 acres. Over 76,000 acres have been included in a Safe Harbor Agreement for threatened and endangered plant and animal species. Funding for CPCI projects totaled over $1.5 million in its 10-year history. Some examples of prairie restoration practices include the use of prescribed fire in combination with mechanical and chemical treatments to reduce invasive woody species and the use of prescribed grazing to enhance plant species diversity and structure beneficial for grassland species. Future projects funded through CPCI will also attempt to test new, innovative methods of prairie restoration that have not been traditionally used. Additionally, CPCI will attempt to increase the use of prescribed fire in the coastal prairie of Texas.

Introduction

Coastal tallgrass prairie is a globally imperiled community, one experiencing drastic habitat loss. Texas has lost roughly 99% of its coastal tallgrass prairie, with most of the loss due to the conversion of native rangelands to cultivation and urban/suburban expansion (Smeins et al. 1991). Within remaining coastal prairies, major habitat alterations including dramatic increases in woody plants have resulted from changes in critical ecological processes. Chiefly, the removal of fire combined with overgrazing has created habitat conditions that are unsuitable for grassland wildlife species. Several endangered species, such as Attwater's prairie chicken (*Tympanuchus cupido*) (APC) and northern Aplomado falcon (*Falco femoralis septentrionalis*), have suffered sharp declines as a result of habitat loss and alteration within coastal prairies. The majority of remaining, intact coastal prairie habitat in Texas is located within private lands, including some of the largest and oldest ranches in the southern part of the state. Thus, efforts to restore and conserve coastal prairie in Texas for the benefit of grassland wildlife species must be undertaken as cooperative efforts with private landowners to be successful.

Herein I describe a partnership effort consisting of state and federal agencies, non-governmental organizations, and private landowners designed to maximize resources available to restore and conserve coastal prairie in Texas.

Coastal Prairie Conservation Initiative: a new conservation model

The Coastal Prairie Conservation Initiative (CPCI), a landscape-level cooperative effort, has made tremendous strides to reclaim, restore, and conserve one of the world's most imperiled communities, coastal prairie and associated declining wildlife species (Morrow et al. 2004). The initiative team is comprised of representatives from the Natural Resource Conservation Service (NRCS), US Fish and Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD), Grazing Lands Conservation Initiative (GLCI), The Nature Conservancy (TNC), and cooperating private landowners. The initiative's purpose is to provide habitat for viable prairie wildlife populations. Private landowner cooperators enter into management agreements with one or more of the CPCI partner agencies and agree to implement specific habitat management practices on their property to restore and enhance coastal prairie important for grassland wildlife species. The unique partnership between public agencies, private organizations, and local community members enhances the probability of project success by maximizing financial and logistical project support.

Cost-share programs on private lands have been used to improve habitat conditions by various state and federal agencies in the past, but the extraordinary success of CPCI has come from the partnership of multiple agencies, conservation organizations, and private landowners that share a common goal of restoring coastal prairie and associated wildlife. Each participant in CPCI brings a different set of knowledge, abilities, and resources to the partnership, thus efforts to improve prairie habitat are more successful when done in partnership.

While all of the agencies and organizations participating have made valuable contributions to the initiative, the fact that several ranching families held tens of thousands of acres of coastal prairie together on their private ranches, some of them for >5 generations, has provided the basis for maintaining and restoring coastal prairie. Providing technical assistance concerning ranch management practices to landowners of coastal prairies and sharing the cost of implementing practices that maintain and restore wildlife habitat has been vital to the success of restoring and conserving coastal prairie habitat, and maintaining viable populations of prairie wildlife species. The relationships that various agency and NGO representatives from CPCI have developed from working one-on-one with the area's ranchers allows the sort of communication and interaction vital to maintaining trust among partners and effective implementation of the initiative. The initiative has grown by word-of-mouth among coastal prairie ranchers. Ranchers participating in CPCI have expressed their support for CPCI to their neighbors and have brought CPCI its greatest projects. Without private landowner participation and approval, this initiative would die rapidly.

Since its inception, the CPCI has undertaken 21 coastal prairie restoration projects on 18 ranches encompassing >58,000 acres. Over 76,000 acres have been included in a Safe Harbor Agreement for threatened and endangered plant and animal species.

An example of a prairie restoration project is the use of prescribed fire in combination with mechanical and chemical treatments to reduce invasive woody species. Prescribed grazing has also been used to enhance plant species diversity and structure beneficial for grassland wildlife species. Measuring the success of CPCI prairie restoration project through scientific monitoring allows the cooperating agencies organizations and landowners to develop better methodology for future projects through adaptive management.

CPCI history

The Coastal Prairie Conservation Initiative began in 1995 when the USFWS issued a Safe Harbor permit to the Sam Houston Resource Conservation and Development Area, Inc. (RC&D) for the endangered Attwater's prairie chicken, Houston toad (*Bufo houstonensis*), and Texas prairie dawn (*Hymenoxis texana*). The Sam Houston Resource Conservation and Development Area, Inc. has issued Certificates of Inclusion to extend Safe Harbor Protection to landowners that create habitat for endangered species. This safe harbor permit was one of the first 3 issued by the USFWS.

In 1999 the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) granted money to the Sam Houston RC&D to contract the services of a range management consultant to provide technical assistance to landowners such as developing and implementing management plans. By 2002, the RC&D had used grants from the wildlife refuge system to undertake 19 projects on 17 ranches in the coastal prairies. Over 76,000 acres had been included in the Safe Harbor agreement with Sam Houston RC&D, and APCNWR had granted $1.05 million to the RC&D to share the cost of implementing management practices on >44,000 acres of private land in cooperation with private landowners and TPWD. Developing new management plans and agreements, and assisting with implementation exhausted the initiative's financial and human resources at that point, and the initiative was still short of accomplishing its objectives. For instance, additional technical assistance was needed to apply prescribed fire to the landscape at scale and the effectiveness of implemented practices needed to be monitored. Accomplishing CPCI's objectives required expanded capacity, so CPCI expanded its partnership. In 2003, the USFWS entered into a cooperative agreement with the GLCI, TNC, TPWD and NRCS for the purpose of implementing the goals and objectives of CPCI.

In the spirit of that cooperation, GLCI applied for and was awarded a $430,000 Private Stewardship Grant through USFWS. Grazing Lands Conservation Initiative has used the grant to share the cost of implementing habitat management practices on 7,245 acres with 3 private landowners, purchase equipment, provide technical assistance to landowners participating in CPCI, and is currently working with an additional landowner to develop to develop a management plan to conserve an additional

15,000 acres of coastal prairie. The Nature Conservancy was an early participant in CPCI. TNC's Texas City Prairie Preserve is home to the last population of wild Attwater's prairie chickens and is covered by the Safe Harbor permit issued to RC&D. The Nature Conservancy has hired a prescribed fire specialist to prepare prescribed burn plans and assemble and deploy a prescribed fire crew to install firebreaks and conduct prescribed burns on CPCI projects. To date, the fire crew has burned >25,000 acres of coastal prairie on private lands, with many of these prescribed fires done under a CPCI management plan. TNC also hired a prairie ecologist in 2003 to assist with the development of population goals and habitat models for target species, and design a monitoring protocol to measure the effectiveness of private lands projects. The Nature Conservancy has pledged $100,000 to GLCI to share the cost of implementing habitat management practices and has funded the expansion of a captive breeding facility for Attwater's prairie chickens. Texas Parks and Wildlife Department has supported the initiative through its Landowner Incentive Program that has been a model for similar programs throughout the nation. Texas Parks and Wildlife Department biologists have provided valuable technical assistance and assisted with project monitoring. From the onset of the Initiative, NRCS District Conservationists have promoted the initiative at NRCS field offices and provided much needed technical assistance to landowners. In addition to the Safe Harbor permit for private landowners, the Fish and Wildlife Service grants awarded to RC&D and GLCI, and the labor of the wildlife refuge fire crews, the Service also supports the initiative through its Partners for Fish & Wildlife and Coastal Programs, and its ecological services field offices in Clear Lake and Corpus Christi.

Future CPCI efforts

The successful application of prescribed fire is a critical element in coastal prairie restoration efforts, and while CPCI has been successful in applying fire on private lands, the extent of prescribed fire use must increase from 15,000-20,000 acres a year to 50,000 + acres a year if we are to truly restore ecological function to portions of the coastal prairie of Texas large enough to support viable grassland wildlife populations. To increase the extent of burning, CPCI must work to develop innovative ways to increase the application by multiple partners. One such method may be to implement a private landowner prescribed burning association similar to the Edwards Plateau Prescribed Burning Association, Inc. (Taylor 2005). By using cooperative labor and equipment, increasing the use of prescribed burning as a habitat management tool in coastal prairies of Texas can become a reality. Another way to increase the application of prescribed fire in Texas coastal prairie is for CPCI to assist with the development of MOUs that allow multiple state and federal agencies with differing prescribed burning policies and procedures to work together on prescribed burns. State and federal natural resource agencies and conservation organizations alike should continue promoting the use of prescribed burning on private lands to improve wildlife habitat. They should also strive to increase the actual application of prescribed fire within there own agencies and organizations by removing roadblocks to successful implementation.

Future projects funded through CPCI will attempt to test new, innovative methods of prairie restoration that have not been traditionally used, such as patch burning/grazing. Patch burning/grazing may be useful in increasing heterogeneity in coastal prairie that is critical to grassland wildlife species (Fuhlendorf and Engle 2001). Monitoring habitat changes and wildlife population response to new, innovative methods such as patch burning/grazing will be crucial in determining the usefulness of such restoration techniques.

The eventual long term goal of this project is to restore and maintain a coastal prairie landscape that can support self-sustaining grassland wildlife populations including endangered species such as Attwater's prairie chicken and Aplomado falcon. Thus, cooperation with private landowners to reintroduce endangered species into coastal prairie for the enjoyment of future generations is also a critical next step for CPCI.

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FORT SILL MILITARY RESERVATION MOLDED BY FIRE

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Abstract: Historically the Fort Sill area was greatly impacted wildfires. With settlement and fire suppression there were major vegetative changes in much of the area. Now under military control, Fort Sill has remained ungrazed and still has many wildfires caused by the military mission. These events, along with prescribed burns, have kept the post vegetation molded by fire.

Introduction

Historically Southwestern Oklahoma, including Fort Sill, was a grassland prairie traversed by wooded streams. This was probably maintained by wildfires set by lightning strikes and Native Americans of the area. The native prairie was subsequently overgrazed as settlement increased, somewhat changing the climax grassland communities. Mesquite (*Prosopis glandulosa*) has encroached on the prairie and is competing with native grasses. Eastern red cedar (*Juniperus virginiana*) has encroached in both wooded and prairie areas where fire has been controlled.

Vegetation on Fort Sill's 94,000 acres constitutes an ecological transition area where tall grass prairie merges with short grass prairie. In addition mesquite and oak thickets (occurring on much of the western two-thirds of the installation) and soil variations create a diverse plant community.

Many upland areas with tall grass are well suited and used for native grass hay production. Much of the unimproved area is suitable for livestock grazing, but severe interference with military training activities would occur, therefore no grazing has been allowed since Fort Sill took control of areas. The wide variety of vegetation and topography make Fort Sill a desirable area for military training, wildlife and associated recreational uses.

Mission of Fort Sill

Fort Sill's military mission is field artillery. The mission of the Field Artillery is to destroy, neutralize, or suppress the enemy by cannon, rocket and missile fire and to help integrate all fire support assets into combined arms operations. To accomplish the field artillery mission, they must train field artillery soldiers and Marines in tactics, techniques, and procedures for the employment of fire support systems in support of the maneuver commander.

Fort Sill is home of III Corps Artillery, the nation's only Corps artillery, which is comprised of four Field Artillery Brigades; consisting of nine Multiple Launch Rocket System Battalions, three Paladin Battalions, a Combat Support Battalion, and a Maintenance Battalion. Their mission is to be prepared to deploy to any theater of operations and provide fire support.

Fort Sill is responsible for the organization and training of National Guard units, Reserve Officer Training Corps, Army Reserve units, and Marine Corps artillery personnel. Air Force

Reserve and Air National Guard units also use Fort Sill.

Wild fires

Fire is both a threat to natural resources and, if used properly, a valuable ecosystem management tool. The climate at Fort Sill is such that the danger of wildfire exists throughout much of the year. When you add the ignition ability of military training it is understood why the installation averages over 300 wildfires annually. Thousands of acres burn each year and are cause for concern and management.

Firebreaks

A network of firebreaks is maintained to help control wildfires, especially in areas where access is difficult. There are 233 miles of boundary and interior firebreaks, generally 60 and 40 feet wide, respectively. About 208 miles are disked, generally twice annually. The remaining 25 miles are unsuitable for disking due to rocky, steep terrain and must be bladed with graders or bulldozers, once per year minimum. Because firebreaks must remain void of vegetation, erosion is sometimes a serious problem.

From 1992 - 1998 significant efforts were expended to construct various structures to help reduce firebreak degradation. The work included emplacement of culverts, construction of water diversions and terraces to direct runoff away from firebreaks, and establishment of hardened crossings. In addition, some firebreaks located in highly erodible areas, such as hillsides, were moved to more suitable locations.

Prescribed burning

Most prescribed burning on Fort Sill is done to manipulate wildlife habitat. However, in certain cases, closed training areas may be burned to temporarily remove vegetation for land rehabilitation tasks, such as rut leveling, surveying for new access roads and drainages, and other related tasks.

Opportunities to prescribe burn are weather-dependent. Mid-February until vegetation greenup is the preferred burning period if adequate soil moisture exists. Even with adequate soil moisture, high winds often prevent burning.

Restoration of native ecosystems sometimes requires the use of hot season burns as historically occurred in this area. Good results have resulted in many areas using this type of burn.

Two types of areas are generally prescribed burned, tall grass prairie and bottomlands. Areas with shallow topsoils are seldom burned. Since tall grass prairie is harvested if it is available, the only significant burnable prairie is either in hay deletions or impact areas. Hay deletions (areas where hay harvest is not permitted) are located on East and West ranges. These are burned about every three years when possible if sufficient tall grass remains in the vicinity for wildlife cover.

Bottomlands (and some other wooded areas) are often well protected from wildfires. These areas tend to develop excessive undergrowth and accumulate litter cover. Savanna areas are particularly susceptible to woody invasion, not advantageous, particularly for turkey and quail. Den trees in these areas are also susceptible to fire. This, may be somewhat offset by hastened den tree status of trees already dying prior to the burn. Cool season burns often stimulate brushy oak invasion rather than opening savanna. Thus, the choice between hot season burns to control invading woody vegetation or allowing a savanna to "close in" must be made.

Wildfires have kept the black-capped vireo (*Vireo atricapillus*; an endangered species) habitat in a successional stage that provides quality nesting habitat. If wildfires become too infrequent that quality habitat is not provided the vireo, it may be necessary to use prescribed burning in this area, but only after consultation with the US Fish and Wildlife Service.

Long range scheduling of prescribed burning is not feasible. Annually, over 300 wildfires affect burning schedules as do burning conditions. Thus, burns are normally scheduled in late summer for the following year's burning if conditions are suitable. This is done to give agricultural lessees a chance to plan their cutting programs. In the past, about 20-30 sites, 20-600 acres each, were scheduled annually. However, due to organizational cutbacks, only about 10 sites from 20-600 acres are currently scheduled annually. Site size is dependent upon the location of firebreaks, roads, and creeks to control prescribed burns.

Wildfire suppression

Wildfire suppression evolved into a major mission for Natural Resources and Enforcement personnel in the late 1970s and early 1980s, and this mission has remained important to the Branch. Despite early conflicts with the Fire Department over wildfire suppression, a reasonably stable informal agreement evolved, which appears to work well for both organizations. Important concepts regarding this relationship are as follows:

This system allows Fort Sill to use its Natural Resources personnel as needed for larger wildfires, even during normal off-duty hours. It also gives Natural Resources and Enforcement the opportunity to fight fires, with or without Fire Department support, in portions of impact area buffer zones and more rugged areas of Fort Sill. Most Natural Resources and Enforcement personnel have backpacks and/or slappers in their personal vehicle to allow rapid response from residences

Certain areas are known to burn annually, and if they are burned early when fire equipment is available and weather conditions are ideal, surrounding areas may be saved from later wildfires. Prescribed burns may also be used to provide a wider firebreak. These prescribed burns are best done after grass dies, generally late July through August. Prescribed burns are particularly helpful in saving impact area buffer zones.

Impact area fires present certain dangers. Fires are not be fought where there is either a high density of duds or where anti-personnel duds (mortar, grenade, M-79, etc.) exist. Some duds are susceptible to heat, and there is always the possibility of stepping (or driving) over a sensitive dud. Personal safety is a major consideration before fighting an impact area fire. Knowledge of impact areas and types of duds likely found is essential.

Natural Resources and Enforcement developed a plan to notify the Fire Department of “let burn” areas for a particular year. These areas are ones in which fires are unlikely to spread beyond let-burn boundaries. Let-burn has a risk factor, but potential gains in terms of native ecosystem integrity are worth certain controlled risks. Let-burn areas also include areas scheduled for prescribed burning during a particular year. Fires, particularly in let-burn areas, require monitoring so that over-burning does not occur.

Goal

Fort Sill’s goal is to manage wildfires in a manner to maintain ecosystem biodiversity and functionality. Wildfire control and management is essential to minimize loss of habitat, loss of soil, increased sedimentation, and spread of noxious weeds

Fort Sill is committed to a wildfire prevention/suppression program that supports the military mission and protects ecosystem functionality. Fort Sill’s commitment is high since the military mission has the potential to create conditions conducive to wildfires.

A CASE STUDY OF THE USE OF FIRE AS A TOOL FOR MANAGING WILDLIFE HABITAT ON THE CHAPARRAL WILDLIFE MANAGEMENT AREA

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Abstract: Changes in the South Texas ecosystem are resultant of both natural selection and the direct influences of humans, notably heavy continuous grazing and the suppression of fire. The resulting brushland stimulated brush control efforts, creating the need for maintenance and restoration efforts. The Chaparral Wildlife Management Area has been the site of both extensive and intensive research on the effects of commonly utilized habitat management tools: 1) grazing, 2) mechanical brush treatments, and 3) prescribed fire. These data have been used to prepare a burn plan and burn prescriptions. The use of prescribed fire should provide for a mosaic and diversity of wildlife habitats. A "holistic" approach to wildlife management best benefits from burns small in size and interspersed among non-burned habitats. In South Texas, the "window of opportunity" for burning is often small. Burn prescriptions often, due to low fuel loads and poor burning conditions, exceed parameters normally prescribed. Prescribed burns in South Texas must address the impacts on both herbaceous and woody vegetation. Cool season and warm season burns both have their place; when you burn dictates vegetation response. While data presented addresses short-term effects of prescribed burns, much is still unknown of the long-term effects on vegetation and wildlife. Effects of summer burning remain poorly documented. Research indicates that wildlife is minimally impacted and that positive habitat restoration and maintenance effects of fire provide for an enhanced diversity of wildlife. Fire appears to be an important tool, notably in combination with grazing and mechanical brush management, in creating and maintaining a diversity of habitats and the resultant diversity of wildlife that comprise the South Texas ecosystem.

The Rio Grande Plains of southern Texas are the southern most extension of the Great Plains grasslands. As with most grasslands-savannas, it is a fire dependent ecosystem. Overgrazing by domestic livestock and fire suppression has resulted in the thorn woodlands (brushlands), which now dominate much of South Texas. Historically, natural fires (predominately started by lightning strikes generally occurring during late spring through early fall with the peak of thunderstorm activity) aided in maintaining these grasslands "brush free". Prescribed fire, although the effects of which are not fully understood, is becoming a more accepted and utilized tool to manage woody vegetation and enhance wildlife habitat. Most prescribed burning is conducted during the winter months when burning conditions are less volatile, with little data available on the effects of summer burns on wildlife.

Changes in the rangeland ecosystem of South Texas are resultant of both natural succession and the direct influence of humans. The activities of pre-European man and climatological events resulted in a rangeland ecosystem that evolved with both grazing of native herbivores and frequent wild fires. (Lehmann 1969, Scifres 1980, Hamilton and Ueckert 2004). With the arrival of European man came the impacts of wild "exotics", notably wild horses and wild cattle. These animals' periodic intensive grazing patterns, along with those of native herbivores, would follow fresh forage brought on by rainfall and/or fires (Hamilton and Ueckert 2004). This natural cycle of grazing and periodic wild fire was disrupted by the introduction of domestic livestock and the increasingly heavy continuous grazing of native rangelands which, when coupled with reduction of naturally occurring fires and fire suppression efforts, essentially limited fire as an ecological factor on rangelands (Scifres 1980, Hamilton and Uecter 2004)

Lehmann (1969), in his historical review of grazing in the Rio Grande Plains, stated "Woody plants increased and spread as white man settled the country and broke the age-old cycle of fire". By 1870, brush had increased materially in the Rio Grande Plains. Combustible plant material and range fires decreased as livestock numbers increased. While domestic livestock numbers, first sheep then cattle, were at "low ebb" from 1800 to 1850, the livestock industry in the Rio Grande Plains was at "full tide" during the period from 1850-1890. Steers became the livestock of choice in the early 1900's to take advantage of the brush now congested on many rangeland sites. Following the vegetative succession, ranchers of the Rio Grande Plains in the post 1940's "re-tooled" once again, this time shifting to the production of calves and lightweight feeder cattle. Many ranches at this time set out to convert the South Texas brushland to grassland (Lehmann 1969).

Study area

The Chaparral Wildlife Management Area (CWMA) serves as a research and demonstration area located in the South Texas Plains (Rio Grande Plains) ecological area. Owned and operated by the Wildlife Division of the Texas Parks and Wildlife Department (TPWD) since its purchase in 1969, this 15,200 acre facility represents a diverse community of South Texas brushland and the wildlife species associated with such. A "holistic" approach to management (Savory 1988) is followed on the WMA, with "prescribed" grazing and prescribed burning among those tools utilized in habitat management for wildlife.

The climate at CWMA is characterized by hot summers, mild winters, and periodic droughts. Average annual precipitation is approximately 21 inches, with peaks normally occurring in late spring (May to June) and early fall (September to October). Frequency and timing of precipitation events frequently impact native vegetation more than precipitation amounts.

Soils consist of Duval fine sandy loams gently undulating, Duval loamy fine sand, 0-5% slopes and Dilley fine sandy loam, gently undulating. Topography is nearly level to gently sloping with elevation ranges between 546 and 585 feet. Soils are well drained, affecting CWMA's ability to deal with drought.

Plant communities are characteristic of the honey mesquite (*Prosopis glandulosa*) - granjeno (*Celtis pallida*) association with a wide diversity of brush species represented. Prominent herbaceous species include introduced perennials Lehmann lovegrass (*Eragrostis lehman-*

niena) and Bufflegrass (*Cenchrus ciliaris*) in addition to a wide variety of native grasses dominated by hooded windmill grass (*Chloris cucullata*) and hairy gramma (*Bouteliua hirsuta*). Prominent forbs include partridge pea (*Cassia fasciculata*) and croton (*Croton* spp.).

The WMA is enclosed by an eight-foot high fence with interior high fences resulting in four high-fenced compartments (Baldy 685, Mare 650, East 7,487, and West 6,378 acres). Interior cattle fencing further divides the WMA into twelve grazing units ranging in size from 370 acres to 1,854 acres. Two deer-proofed pastures are excluded from grazing resulting in grazing controls of 685 and 650 acres (not grazed since 1976 and 1984 respectively).

Beginning in the 18th century, grazing by domestic livestock (sheep) likely was implemented on CWMA. Since 1870, cattle have been the major domestic species (Lehman 1969). Lehmann (1969) describes the progression of livestock in the Rio Grande Plains from sheep to steers to cow-calf operations, largely respondent to vegetative changes brought about by continuous grazing and the reduction of fire. In many portions of South Texas a return to stocker operations is becoming evident in efforts to better deal with periodic droughts.

On the CWMA, as is the general pattern of livestock use of South Texas rangelands, grazing by cattle prior to 1969 was continuous without rotation of livestock. Cattle were grazed from 1969 to 1984 with a yearlong cow-calf operation utilizing a modified Merrill four-pasture rotation system. Because of extreme drought conditions from 1982 – 1984 cattle were removed from the WMA in 1984. Grazing resumed in 1990 and continued to the present with the exception of 2003 when a one-year deferment from livestock was brought on by drought conditions.

Since 1990, grazing on the WMA has followed a high intensity-low frequency (HILF) format, utilizing stocker animals in a graze cycle of October to May/June annually. From 1990-1997, this involved two herds, one on each side of the WMA, each herd under a HILF format. Stocking rates were considered moderate during this period but varied annually with forage availability. From 1998 to the present the HILF grazing program utilized grazing of one herd of stocker animals through a rotation of twelve pastures. Livestock were not grazed in the 2003 graze cycle due to extreme drought conditions.

To facilitate research activities, notably documentation of the impacts of grazing on wildlife and habitats, 2 pastures (Baldy-685 acres and Mare-650 acres) have been excluded from grazing since 1976 and 1984 respectively. Additionally, 10 half-acre deer exclosures and 10 one-acre cattle exclosures were created to further document impacts of grazing.

Changes in plant communities, resultant of grazing and reduction of fire, created a “thorn brush” community. Brush “control” efforts on the Chaparral WMA, not unlike many ranches in south Texas, were extensive during the middle of the 20th century. Indications are that at least half of CWMA was subjected to chaining activities, with root plowing activities generally confined to some drainage or in small block applications.

Additionally, historic "truck" farming occurred on portions of the CWMA during this time period, when this portion of the state was referred to as the "winter garden." Reduction in readily available water during this time period resulted in these "old fields" reverting back to brushland. The last mechanical brush management documented on the CWMA was root plowing of some 400 acres in 1965. Approaches to dealing with unwanted woody plants had evolved from the desire to eradicate to the desire for brush management (Scifres 1980).

Prescribed burning on South Texas rangelands

Fire played an important role in determining the distributions of many plant and animal communities in South Texas. With the settlement of Texas came the introduction of domestic livestock and reduction in the occurrence of natural fires.

Prescribed burning applications to South Texas rangelands can be both diverse and limited. The dynamics of the application of fire is largely dictated by goals of the land manager. The cattleman may burn to enhance production and/or palatability of grasses and reduce competition between grasses and brush species; whereas the wildlife manager may desire to reduce canopy cover of brush species while maintaining brush diversity, enhancing brush palatability, forage quality and availability, and by enhancing forb production. Application of prescribed fire can be beneficial to both livestock and wildlife by balancing these needs, and by the application of fire, creating a mosaic of habitats.

The Chaparral WMA, not unlike much of South Texas, has been subjected to considerable mineral exploration activities. This has resulted in an extensive system of roads and senderos, many of which were originally cleared as seismic corridors. Approximately 250 miles of "senderos" and roads provide an almost ideal infrastructure of firebreaks to allow conducting "wildlife friendly" prescribed burns on CWMA. This ability to conduct small burns provides for interspersion of habitats of various successional stages, permits burning on a rotational basis, and allows for an enhanced level of safety in conducting burns, especially warm season burns.

Burn policy

All properties controlled by Texas Parks and Wildlife Department must adhere to established guidelines and procedures in the application of fire as detailed in the TPWD Burning Policy (Internal Policy LF-02-04-TPWD, revised 2002).

The statement of purpose in this Burning Policy is as follows:

"*The primary purpose of prescribed burning on TPWD lands is to simulate the effects of natural fire events. On TPWD lands the benefits of prescribed fire include: 1) reduction of excess fuel loads, 2) increased herbaceous species and available browse, 3) control of invading species, 4) increasing species diversity and richness and, 5) facilitation of the long term objectives for community restoration and maintenance.*

Prescribed burning on these lands is normally conducted in association with *these management objectives and/or research endeavors in order to document the long-term effects of prescribed fire on habitat quality or habitat restoration.*"

Chaparral WMA staff currently includes two fire bosses who develop or approve burn plans for each prescribed fire on the WMA. Fire bosses undergo formal prescribed fire training as approved by the Prescribed Burning Board of Texas (PPB) and a specialty course for the region(s) in which the prescribed burning will be conducted. In addition, fire bosses must have a minimum of three years prescribed burning experience within a region(s) and thirty days of actual prescribed burning experience (five days of which the individual must have been the responsible party for all aspects of the prescribed burn under the supervision of a fire boss). All additional staff participating in prescribed burns are well versed in responsibilities and safety considerations. All prescribed burns on all TPWD lands require a burn plan that must be approved prior to implementing a burn. The plan must include all elements of the plan provided by the Prescribed Burning Board Burn Plan Form A476 as available on the Prescribed Burn website (http:/www.agri.state.tx.us/pesticide/burnboard/pes_pbbmain.htm.)

Burn plans contain: a description of the area to be burned, purpose of burn, pre-burn factors, plan of action if fire escapes, environmental conditions for burn, fire behavior of burn, mop up plan after burn, and maps drawn to scale, including pre-fire actions, ignition strategy, and maps of individual burn units. Burn plans will include contacts to be made before burning: local Fire Departments, County Sheriffs Department, adjacent landowners, any oil and gas lessees, pipeline operators, the Texas Commission on Environmental Quality, and the Texas Forest Service (if in forested areas). Other contacts may include city, county, or volunteer Fire Marshal, county commissioners, or county specified notifications (check with local county regulations).

Often burning conditions in South Texas do not "become right" until burn ban conditions exist. Low fuel loads and/or high fuel moistures generally require those conditions normally encountered during burn bans to accomplish the burn. Under this scenario special attention must be paid to county burn bans. WMA's may request exemptions to burn bans if approved by staff designated by the Wildlife Division Director. Approval then must be obtained from the county commissioners court and/or county judge. Coordination with adjacent landowners is important.

Other important considerations include obtaining an accurate weather forecast including conditions for the day and any forecast changes within 24-48 hours, allocation of fire suppression resources, and smoke management. WMA managers are also responsible for coordination of prescribed burns with public use. This requires notification of visitors, installation of warning signs, and closure of areas to be burned (if not the entire WMA). The Chaparral WMA chooses to close the entire WMA so as to reduce risk to the public.

TPWD lands also require archeological clearances. While sites subjected to fire, in themselves, do not require clearance, any ground disturbing activities such as discing fire lanes, use of dozer, motor-graders or fire plows require such; thus such activities should be used only as a last resort. One of the best tools available in controlling prescribed fire is fire itself; a primary reason the Chaparral WMA utilizes backfires extensively. Properly planned and conducted prescribed fires should not require fire fighting activities but such events must be prepared for, with adequate equipment on site.

Fire as a management tool

Fire, notably wildfire, was considered to have been a major contributor toward maintaining a more open savannah in the pre-European settlement of the South Texas Plains (Scifres 1980, Hamilton and Uecter 2004). With the advent of grazing by domestic livestock, this element was removed or at least severally reduced; contributing to the brushland communities present in South Texas today (Scifres 1980, Hamilton and Uecter 2004). The Chaparral WMA, a working South Texas ranch prior to TPWD's acquisition, demonstrated the same vegetative progression. Upon acquisition, management strategies for habitat and wildlife changed to reflect a more "holistic" approach to management. The tools of grazing management and prescribed fire were recognized as important among those utilized in this "holistic" approach.

Burn prescriptions

In South Texas, low humidity and moderate winds generally are necessary to carry fire through the often, patchy fuel loads present (Ruthven, et al, 2000). Fuel loads, primary fine fuels, and the continuity of such on burn sites often dictate that prescribed burning, both cool season and warm season, "stretch" the parameters of what might be a "normal" burn prescription. Experience with warm season burns on the Chaparral WMA has contributed to development of the following burn prescriptions:

Blacklines (Warm Season)

Desired Prescription Range

Temperature (ºF)	=	< 95º F
Relative Humidity	=	40-50%
Wind Direction	=	SE
Wind Speed	=	3-8 mph
Fuel Load (lbs/acre)		> 1000
Dead fuel Moisture	(1 hr):	4-10%
	(10 hrs):	4-10%
	(100 hr):	5-12%
Live fuel Moisture		>70-100%

Generally, blackline fires result in a more manageable fire. Additionally, most warm season burns on the Chaparral WMA are accomplished with backfires or strip backfires in efforts to hold heat longer on the bases of woody plants, thus affecting a better top kill.

Headfires (Warm Season)

Desired Prescription Range

Temperature (ºF)	=	< 105º F
Relative Humidity	=	20-45%
Wind Direction	=	SE
Wind Speed	=	3-10 mph
Fuel Load (lbs/acre)		> 1000

Dead fuel Moisture:	(1 hr):	3-10 %
	(10 hrs):	3-9 %
	(100 hr):	5-12 %
Live fuel Moisture:		>65-100 %

Cool season burns are conducted within the following prescriptions on the Chaparral WMA:

Headfires (cool season)

Desired Prescription Range

Temperature (ºF)	=	60-85º F
Relative Humidity	=	15-35%
Wind Direction	=	N, S, E, W
Wind Speed	=	3-15 mph
Fuel Load	(lbs/acre)	> 1000
Dead fuel Moisture:	(1 hr):	3-11 %
	(10 hrs):	4-12 %
	(100 hrs):	5-13 %
Live fuel Moisture:		30-100 %

Improvements in fuel loads and continuity of fuels, brought about by a change in grazing strategies, presented the opportunity for use of prescribed fire as a management tool; a tool generally unavailable on the CWMA prior to the change to a HILF grazing format utilizing steers. Fire, following the above prescriptions, is used in achieving the goals of 1) reducing woody species canopy coverage, 2) providing a diversity of vegetation common to lower successional stages (vegetation which often is more beneficial to wildlife), and 3) providing a mosaic of habitats optimized for wildlife use.

Land use practices on CWMA

Prior to CWMA's acquisition in 1969, no history of the use of prescribed fire was evident, nor was documentation of wildfires which likely in the last century or so were not a major factor because of the lack of adequate fuel loads. Recognizing this limitation, changes in livestock grazing strategies were made which was a major contribution to the development of fuel loads conducive to the application of fire as a management tool.

Documentation of land use practices conducted on the Chaparral WMA, Synatzske and Federal Aid in Restoration Reports (1983-2004), yield the following historic overview. The period 1970 – 1988 did not include the use of prescribed fire as a management tool. Cattle grazing during this period shifted from continuous grazing prior to 1969 to a modified Merrill 4 pasture rotation in 1970. However, this system failed to produce the increased fuel loads necessary to implement fire as a management tool. Cattle were removed in 1984 and the WMA was rested from 1984 – 1990.

The first application of prescribed fire on CWMA occurred in the late winter of 1989 on open rangeland (370 acres) previously subjected to root plowing. The resultant burn was not uniform because of low fuel loads and the presence of green vegetation (high fuel moisture). A planned cool season burn in the Mare pasture, non-grazed since 1984, was cancelled due to even lower fuel load and higher fuel moisture of green vegetation. Vegetative responses to this limited application of fire were moni tored in 1989 and 1990. Winter burns were conducted during this period on 70 acres of old field and open rangeland. Half of the unsuccessful 1989 burn, approximately 150 acres, was subjected to a second prescribed burn in the winter of 1991. Efforts at prescribed burning on the CWMA were curtailed in 1991 until such time that burn conditions, notably fuel loads and continuity of fuel, improved.

The re-introduction of cattle grazing in 1990 featured a high intensity-low frequency (HILF) format, using large numbers of steers in one herd for short grazing periods to disturb soils, create seed beds, and contribute to increased fuel loads and continuity of such. This stocker operation, grazing the WMA from October-May, continued until the present. Fine fuel loads and continuity of fine fuels improved under HILF grazing resulting in the ability to make application of prescribed cool season fires to 573 acres on 7 sites in 1996. An additional 1,550 acres (12 sites) were subjected to cool season burns in 1997 with an initial effort at a warm season burn of 262 acres (3 sites) made late that summer. Cool season burns in 1998 totaled 1,345 acres (6 sites).

Mechanical treatments, with the objective of creating a greater diversity of habitats with more open access and interspersion with existing native habitats, were initiated in 1998. Aeration was selected as the tool of choice because of its ability to reduce brush canopies, stimulate herbaceous ground cover, permit enhanced water infiltration, and maintain diversity within the brush community. Aeration was applied over a period of 3 consecutive years and occurred in August 1998, April - May 1999, and August 2000. Treated acreage totaled 751 acres in 73 different plots. Blocks or strips ranged in width from approximately 60 yards to 100 yards and used existing deer stands as focal points. This resulted in the distribution of brush management applications on a variety of vegetative communities and sites subjected to historic (pre-1969) brush management treatments.

The application of aeration as a brush management tool, like all brush management treatments, requires periodic maintenance activities to sustain the desired results. The tools available to affect maintenance activities included grazing and prescribed burning. Ruthven et al. (2000), indicated that herbaceous vegetative response to aeration appeared to be adequate to allow the use of prescribed fire. Investigations into timing and frequency of maintenance, and impacts of both initial treatment and maintenance treatments on existing wildlife and vegetative communities were initiated on these sites. Both short term and long term effects of treatments were included in the monitoring plan.

Drought conditions precluded the availability of fine fuel loads needed to conduct prescribed burns in the summer of 1998. Improved range and burning conditions in 1999, however, allowed the application of fire to some 2,364 acres (1,262 cool season, 1,102 warm season). This included both open rangeland burns and cool season burns of aerated plots. The application of prescribed fire to aerated sites was initiated as soon as fuel load and burning conditions permitted, which also impacted regrowth brush early in the process. Cool season burns were conducted in 2000 on 922 acres (12 sites) including 10 aerated plots, with initial warm season burns (62 total acres) applied as a maintenance tool to 5 aerated plots the summer of 2000. An additional 5 aerated plots (30 total acres) were burned as warm season burns in 2001.

Poor burning conditions in 2002 and early 2003 limited cool season burns to only 8 acres (2002) with no burns conducted in the winter of 2003. Deferment from grazing during the normal graze period of October 2001-May 2003 allowed fuel load development resulting in application of warm season burns to 977 acres (7 sites) in 2003; 6 of which were on aerated plots. Carryover of the fuel load, resultant of the grazing deferment, allowed 2,745 acres (13 sites) to be burned as cool season burns in 2004. Warm season burns the summer of 2004 totaled 412 acres on 6 sites.

In May 2005, prescribed fire was applied to some 280 acres. These burns were conducted as warm season burns on previously aerated sites, some on which this was the initial application of fire and others that had at least one application of fire. Although conditions normally would not permit prescribed burning in May, unusual climatic conditions resulted in this unique opportunity. Ongoing monitoring efforts should provide valuable data on the use of early warm season burns on re-growth brush at a time when vegetation is in spring green up mode.

Research: building blocks for the future

Scifres (2004) noted that during the period 1970-1999 the Journal of Range Management contained 165 burning related articles. In evaluating the frequency of papers contributed by Texas range scientists, a pattern evolved which would indicate a resurgence of range burning in Texas in the late 1960's and early 1970's. By the mid 1970's, the following information had been accumulated about fire behavior and vegetation responses on ranges:

1) Certain kinds of fires were related to certain kinds of fuels and fire behavior can be predicted based on fuel characteristics.
2) Weather influences pre-burn, during the burn, and post-burn could be categorized relative to their influence on fire behavior and expected outcome on burning the vegetation.
3) Responses of woody plants to burning.
4) Impacts of burning on soils corrected earlier misconceptions and added to knowledge concerning environmental response.
5) Data on fire behavior greatly enhanced manager's ability to plan and execute burns in a safe manner to achieve very specific objectives.
6) Information was evaluated to allow the development of true prescriptions for burning.
7) Grazing management prescriptions were developed as an integral part of the burning and resource management plans.
8) Data on burning schedules and patterns were used in developing plans for optimal enhancement of game populations.
9) Realization was attained that rangelands must be managed as a system.

As the systems concept of rangeland management developed, a number of niches were formed for prescribed burning:

1) In many cases, prescribed burning determines the success of the system;
2) Burning removed some, if not all, dead woody top growth left by chemical treatments;
3) Burning created a more uniform forage stand by removing rank growth and promoting a flush of forbs and browse with values for both livestock and wildlife.

The Chaparral WMA is managed for wildlife with a "holistic" approach to management. The application of "habitat enhancement" activities and the monitoring of the effects of such tools as grazing and prescribed fire provide a better understanding of how these activities impact both wildlife and the habitats they depend upon. To accomplish this, research studies have become an integral part of the CWMA's objectives, supplementing ongoing extensive and intensive vegetative and wildlife monitoring activities conducted by CWMA staff. The knowledge gained will provide valuable information on not only game species responses but also species of concern such as the Texas tortoise (*Gopherus berlanderii*), Texas horned lizard (*Phrynosoma cornutum*), indigo snake (*Drymarchon corais*), and a wide variety of other wildlife components of this unique ecosystem we call South Texas.

Vegetative responses to fire

Research activities on CWMA in recent years included monitoring effects of habitat treatments,; including the effects of the application of fire to vegetative communities (Rogers et. al. 2003, Ruthven 2003a, Ruthven 2003b, Ruthven and Kazmaier 2003, Ruthven and Fulbright 2003).

Many of those studies also related to the use of fire, in conjunction with grazing, and as a maintenance tool to extend the life of mechanical brush treatments such as aeration. Efforts to date have resulted in findings relative to short-term effects; however, the principal value of the CWMA as a research site lies in its ability to serve as a site for long-term studies. Ongoing monitoring activities will provide data on these long-term effects of habitat treatments. Research studies on effects of prescribed fire and grazing conducted on the Chaparral WMA indicated both burning and grazing significantly increased total forbs cover (Ruthven et al. 2000). Richness and diversity of forbs species were similar between treatments, with burning increasing forbs frequency while grazing decreased forbs frequency. Forb density was increased by burning, but decreased under grazing. As a result of burning, annual forbs with high value for use by wildlife such as prairie sunflower (*Helianthus petiolaris*) and croton (*Croton* spp.) increased in percent cover. Perennial forbs such as dayflower (*Commelina erecta*) and ground cherry (*Physalis cinerascens*) had greater cover on burned sites.

Study results on effects of winter burns indicated that conducting winter burns on South Texas rangelands can significantly increase occurrence and density of import seed-producing annual forbs such as prairie sunflower and croton during the first year after burning

(Ruthven 2003b). Reported increase in forbs density may not, however, persist into the second growing season.

Ruthven et al. (2003c) also found that woody vegetation subjected to winter and summer burns did not exhibit any difference in species richness between treatments. Woody cover on winter burn sites was reduced by 50% while 41% reduction was observed on winter-summer combination burn sites. Woody plant density declined by 29% on winter burns and 23% on winter-summer burns. The inclusion of summer burns into the burning regime on CWMA did not increase the decline of woody plants. It was concluded that fire could be a useful tool in managing woody vegetation on native South Texas rangelands while maintaining woody plant diversity.

Ruthven and Synatzske (2002), in studying herbaceous vegetation response to summer fire, found that important wildlife plants, such as croton, responded positively the first growing season post-burn but by the second growing season post-burn showed no difference from control areas. Erect dayflower and beach ground cherry also responded positively, both first and second seasons post-burn. Grass densities were lowest on burn sites 3 months post-burn but yields were similar between treatments by the middle of the first post-burn growing season. Summer burning did not appear to provide additional benefits in forbs response over dormant season burns. (Ruthven and Krakauer 2003a).

Prescribed burning is a recommended maintenance treatment following mechanical treatment of South Texas brush lands. Rogers et al. (2001, 2003, 2004) found that in periods of low rainfall prescribed burning compared with re-aeration as maintenance tools did not exhibit any differences in standing crop of browse, forbs, grasses, succulents, protein precipitating and tannin concentrations in browse. White-tailed deer (*Odocoileus virginianus*) use (based on track density) did not differ between treatments.

Wildlife responses to fire

Baseline inventories and continuous monitoring of wildlife resources on the Chaparral WMA permit both short term and long-term evaluation of impacts of habitat treatments on wildlife including the impacts of prescribed fire. (Rogers et al. 2003, Kazmaier et al. 2003, Ruthven and Fulbright 2003, Ruthven and Ortego 2003, Burrow et al. 2001, Burrow et al. 2003, Ortego and Ruthven 2001, Moeller 2004).

Generally, most wildlife managers agree that prescribed fire is an important wildlife management tool (Guthery 1986, Guthery 2000, Lehmann 1984, Carter et al. 2002, Brennan 2005, Fulbright and Taylor 2001). There is often a misconception that fire is always good for game (Guthery, 1986). Generally, range managers prefer "hot" fires and bobwhite quail (*Colinus virginianus*) managers prefer "cool" fires. "Multiple treatments designed to convert brushland to prairie can likewise convert bobwhites to memories" (Guthery, 1986).

Carter et al. (2002) questioned the level of benefits offered to bobwhite quail by prescribed fire in the arid western reaches of Texas indicating that prescribed burning may increase the vulnerability to predators via reduction in escape cover. They also noted that although nesting success and survival rates on burned vs. unburned sites were similar that the scale and intensity of burns in the study may have minimized any potential adverse impacts on survival. They found that "islands" of unburned vegetation within burned areas and small burn plot size were important considerations for quail. Guthery (1986) stated "*you might expect that fire kills the brush that provides loafing cover for bobwhite. This rarely happens. However, top kill of woody species can, at worst, impact loafing cover for a few years*". He noted that cool season fires can result in loss of cool season forbs, damaging bobwhite quail populations, whereas warm season fires tend to promote the growth of cool season forbs. He also noted the benefits of prescribed burning, comparing the tool to discing, in producing bobwhite foods and that high diversity of plant communities favored bobwhites (this being the advantage of burning in small blocks).

Prescribed fire positively impacts bobwhite populations by:

-Removing rank, old growth grasses and woody vegetation;

-Allowing new more nutritious growth to sprout;

-Fixing nitrogen in the soil from burn debris;

-Controlling invasive vegetation;

-Opening vegetative overstory to allow light penetration for forbs and browse production;

-Speeding up nutrient and mineral cycles;

-Increasing moisture infiltration into the soil.

The degree of impact is dependent on whether fires are hot or cool. Cool season or warm season, timing of the fire, climatic conditions, and grazing deferment all must be addressed in the burn plan.

Fulbright and Taylor (2001) recognized the importance to white-tailed deer of leaving undisturbed local areas in dense brush, stating "*clearing a portion of a drainage system may impact a relatively small percentage of a ranch; however, fragmentation and loss of that vitally important habitat may reduce deer densities on a ranch*". Rogers et al. (2003, 2004) found that the use of prescribed fire was beneficial to white-tailed deer in maintaining previously mechanically treated brush sites and the forage value presented by such.

The effects of prescribed fire on non-game and species of concern such as the Texas tortoise, Texas horned lizard, and the Texas indigo snake have been studied to better understand the role prescribed fire plays in "holistic" resource management (Burrow et at. 2001, 2002, Montandon et al. 2003, Ruthven 2003a, Ruthven and Ortego 2003, Ruthven and Kazmaier 2003, Moeller 2004).

Ruthven and Ortego (2003), found prescribed fire to be an essential method of managing woody vegetation and enhancing rangeland productivity. Their study of the impacts of both cool season and warm season fires on winter and breeding bird populations indicated high breeding bird diversity on burned sites. They also found that burning appeared to have little effect on wintering birds.

In evaluating effects of prescribed fire on South Texas herpetofauna, including species of concern, researchers found that prescribed fire, in general, offered a benefit to these species. (Kazmaier et al. 2003, Ruthven and Kazmaier 2003, Burrow et al. 2001, Ruthven 2001b).

Ruthven (2001b) found that, if maximizing wildlife productivity is a desired goal, a network of woody plant communities with varying degree of cover need to be established and maintained. Species such as the Texas horned lizard and Texas tortoise prefer more open habitats and/or those devoid of woody vegetation while species such as white-tailed deer and javelina (*Tayassu tajacu*), generally require heavier brush densities. Kazmaier et al. (2000) found that fire suppression may negatively affect tortoises as canopies became closed. Guthery (1986), noted that bobwhite quail benefit from vegetation in earlier seral stages.

Burrow et al. (2001) noted that the Texas horned lizard use a variety of habitats including open deserts and grasslands, usually with sparse vegetation. They found that burning and grazing treatments as implemented on the CWMA did not have any effect on habitat selectivity in horned lizards. They also found that burning and grazing in south Texas at intensities studied in their research did not affect microhabitat selectivity in horned lizards. Kazmaier et al. (2003) found winter burns to be beneficial to the horned lizard, increasing harvester ant ([*Pogonomyrmex* spp.*],* the primary food source of horned lizards) activity and tending to reduce horned lizard home range size and increase survival.

Ruthven and Kazmaier (2003) found that summer burns appeared to enhance herpetofauna diversity and favor grassland species. Kazmaier et al. (2001) noted that following dormant season (winter) burns no differences were observed in small mammal abundance between treatments. They also found that summer burns appeared to enhance annual and perennial forbs as well as small mammal populations.

The continuation of the use of prescribed fire on CWMA is viewed, based on this research, as being positive to not only game species but non-game species as well.

The future

The Chaparral Wildlife Management Area, in its role as a research and demonstration site for the Rio Grande Plains, will continue monitoring and research activities in efforts to document and demonstrate the best management practices available to land managers interested in wildlife conservation in South Texas. This will include investigation of both short term and long term effects/impacts of prescribed fire. These efforts should provide valuable information on the application of prescribed fire in relation to burn prescriptions, timing of application, frequency of application, burn frequency and rotation, and both vegetative and wildlife responses to cool season and warm season burning.

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Table 1. Burn history of Chaparral Wildlife Management Area

Period	Application of fire	Acres/Sites Cool season	Acres/Sites Warm season
Pre-European	Periodic wildfire	?	?
European -1969	Likely diminishing	?	?
1970 – 1988	None	0	0
1989	1st Application of fire (unsuccessful)	370/1	--
1989 – 1990	Old fields	70/2	--
	Open rangeland	150/1	--
1990 – 1996	None – HILF initiated	--	--
1996	Cool season fire	573/7	--
1997	Cool season	150/12	--
	Initial warm season fire	--	262/3
1998	Cool season	1345/6	--
	No warm season	--	--
1999	1st Cool season burns - aerated sites	1262/7	1102/7
2000	Cool season (10 aerated)	922/12	--
	Warm season (5 aerated)	--	62/5
2001	Initial warm season application to aerated sites	--	30/4
2002	Poor burn conditions	8/1	--
2003	Warm season (aerated)	--	977/7
2004	Cool season	2745/13	--
	Warm season	--	412/6
2005	Cool season	14/3	--
	Warm season (May)	--	280/3

PRESCRIBED FIRE FOR WILDLIFE HABITAT MANAGEMENT IN THE LEON RIVER RESTORATION PROJECT

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The Leon River Restoration Project (LRRP) is a research brush control program within the Leon River watershed of Hamilton and Coryell Counties, Texas. The primary objective of the research component is to quantify the impacts of Ashe juniper (*Juniperus ashei*) removal and rangeland management on water yield and quality, wildlife habitat, and forage production for livestock. Juniper removal and rangeland management practices are implemented on selected private rangelands that are within habitat for the black-capped vireo (BCV; *Vireo atricapilla*) and golden-cheeked warbler (GCW; *Dendroica chrysoparia*), both of which are endangered species. The LRRP is significantly unique in the success it has accomplished by bringing together a large number of stakeholders to work effectively toward diverse goals in a common project. Over 25 partners are active in the project, including environmental NGO (Environmental Defense, Nature Conservancy, Audubon Texas), cattleman's associations (TSCRA, CTCA), the military (Ft. Hood), local organizations (SWCD, County Commissioners), Texas A&M University (TCE, TAES)., NRCS, TDA, Farm Bureau, TPWD, and others.

Phase I of the research project, a 2-year study quantifying pretreatment range vegetation composition, water (springs and small watersheds), wildlife habitat and economic parameters, was completed and published in September of 2004. Phase II of the project is currently funded and began in May of 2005 to document changes following juniper removal. Seven graduate students completed degree programs in Phase I and seven are participating in Phase II.

Juniper removal in the project is accomplished following development of a management plan prepared by or approved by the Texas Parks and Wildlife Department. Removal of juniper is commonly accomplished with skid-steer loaders that can be very selective in removing individual plants. Much of the work is done in the immediate vicinity, and often immediately adjacent to desirable oak and other tree species. Following removal, juniper is placed on the contour of the slope and left to desiccate for later burning. Where necessary to promote recovery of the cleared areas to herbaceous vegetation, seeding is done with a mixture of warm and cool season grasses and forbs. In areas that have limited topsoil, revegetation is accompanied by application of 2-3 tons/acre of dairy compost.

The LRRP provides cost-share for private landowners participating in the project. Funding for the cost-share comes from USDI US Fish and Wildlife Service (USFWS) and USDA Natural Resources Conservation Service (NRCS) , as well as other agencies and NGO. Cost-sharing is provided at the rate of 85% of the cost of juniper removal. A unique aspect of the project that has also gained attention is that the 15% of the cost paid by the landowner is paid into an escrow account managed by a nonprofit corporation. If the landowner has adhered to all provisions of the plan, at the end of five years the 15% in escrow is returned to the landowner less the cost of the planned prescribed burn that is part of all plans. In 2004 NRCS made EQIP funds available for use in the project.

Follow up management is required of landowners participating in the project. Prescribed fire is a critical component of that follow up management. Juniper infestations that have been in the region for decades have established a seed source that requires repetitive burning while the seedlings are small and will suffer mortality from cool season maintenance burns. All mechanical removal of Ashe juniper is planned with the assumption that a prescribed fire will occur 3 to 5 years after treatment. Light density Ashe juniper is left where cut, while medium and heavy density areas are windrowed. These windrows are situated to lessen short term erosion following treatment.

Much of the mechanical treatment of Ashe juniper occurs in and around habitat for the BCV and GCW. Operators are trained to understand the effects of fire on the habitats for both listed species. The training was accomplished by a workshop and demonstration in the LRRP where private landowners with their own equipment and contractors planning to do juniper removal commercially learned how to recognize habitat of the listed bird species and proper juniper removal techniques.

Black-capped vireos use habitat in early successional stages with scrub-oak growth of heterogeneous height and distribution that reaches close to the ground (Graber 1961, Grzybowski et al. 1994). In many instances BCV habitat has become marginal because desired species have grown past the early successional stage. In other instances Ashe juniper has choked out the desired species. In both cases fire is used to restore those habitats to increased suitability for occupancy. Ashe juniper is cut and situated within the habitat in such a way that prescribed fire will stimulate basal resprouting of desired species. By using a combination of selective mechanical removal of Ashe juniper and prescribed fire it is possible to create BCV habitat in 3 to 4 years. The project has documented this through the use of presence/absence surveys both pre- and post-treatment.

Golden-cheeked warbler breeding habitat is characterized by mature juniper-oak woodlands with rugged terrain such as in steep slopes, canyons, and uplands (Ladd 1985, U.S. Fish and Wildlife Services 1992, Ladd and Gass 1999). Most treatment of Ashe juniper in GCW habitat consists of thinning smaller (<15 ft) Ashe juniper with little or no reduction in canopy. Special care is taken to pull treated juniper away from remaining trees so fire will not damage canopy. In most cases canopy cover is so thick that little or no sunlight can reach the ground, limiting the occurrence of fine fuels. Therefore, in most cases, fire in GCW habitat is not practical. However GCW habitat does play an important role in the overall management of prescribed fire. Since little or no fuel load exists underneath GCW habitat, the habitat makes an excellent containment barrier. GCW habitat is useful in this way particularly in the case of cool season fires. The use of GCW habitat as containment reduces the amount of pre-burn management needed, thereby reducing costs.

Most of the landowners participating in the project are not familiar with the use of fire. In these cases the project furnishes the resources to carry out the burn. The project contracts with local volunteer fire departments to assist with the fire. The project has a certified burn master. All burning is done during the cool season, November thru mid-March. The project began clearing brush in 2001 and prescribed fire has been used in 2004 and 2005. We anticipate that after prescribed fires are conducted by the project on their land; landowners will feel more at ease with the use of burning and will continue its use in the future to provide long-term maintenance.

There have been some challenges in educating local authorities of the use of fire as a part of the project. During the first burns in 2004 on several occasions local volunteer fire departments were called out in spite of prior notice. This happened even when other volunteer fire departments were on location to assist with the fire. After several meetings with County officials a better line of communication was established between the project, the County and local volunteer fire departments. Most of the fires carried out in the 2005 season did not create this type of confusion.

Prescribed fire is an integral part of the wildlife habitat management component of the LRRP. Fire also provides juniper control that helps maintain rangeland production that benefits livestock producers. While it is too early to tell, it is anticipated that studies will show positive relationships between juniper control and spring flow, as well as watershed yield. All of these desirable changes are predicated upon the continuing, effective management of juniper. Fire is the best tool that we have for this purpose.

We recognize the need for a prescribed burning association, such as the Edwards Plateau Prescribed Burning Association, and have had contact with Dr. Charles Taylor to discuss the possibility of a chapter. Burning associations or cooperatives could potentially provide the means for landowners to participate in a long term management strategy. The use of this type of organization would allow landowners to reduce liability and costs associated with burning. Unfortunately landowners in this region of the state are not familiar with fire and no such organization exists.

In order to demonstrate the utility of burning associations the project has sought to develop relationships with other existing organizations. Wildlife management associations have played a useful role as an intermediary organization, providing some of the elements needed for a successful burning cooperative. Landowners belonging to these wildlife management associations are accustomed to working with other landowners and following TPWD management guidelines. Two such associations have been particularly useful in the LRRP. The Vista Mountain Wildlife Management Association in western Coryell County and the Leon River Wildlife Management Association in Hamilton County have been the coordinating mechanism for long term management. Several members of these wildlife management associations belong to the local volunteer fire departments in their respective sub-watersheds.

This provides an additional bridge between existing resources, relationships and long term management strategy. One possible result of the LRRP could be the formation of a burning association, this association becoming an umbrella organization for a number of wildlife associations.

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USING NRCS ASSISTANCE TO PREPARE AND IMPLEMENT PRESCRIBED FIRE

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Abstract: USDA – Natural Resources Conservation Service (NRCS) supports and encourages the use of prescribed burning when used within the context addressed in the NRCS prescribed burning conservation practice standards and specifications. Thirty-eight percent or 268 NRCS employees in Texas are authorized to provide prescribed burning technical assistance to land managers. NRCS employees are not allowed to be certified by the Texas Department of Agriculture as "Certified Prescribed Burn Managers." The requirements set by House Bill 2599 of the 76th Legislative Session in 1999 requires that each "Certified Prescribed Burn Manager" be insured and bonded in addition to meeting experience and educational requirements. NRCS can train its employees to meet the experience and educational requirements but it can not meet the requirements for bonding and insurance. Only trained and qualified NRCS personnel are authorized to provide assistance that includes prescribed burning as a conservation practice. To obtain planning authority, employees must successfully complete the formal NRCS (or other agency or organization) prescribed burning training course(s). Burns planned with NRCS assistance must adhere to all Federal, State, Local laws and Tribal requirements regarding outdoor burning, fire control, smoke management, and air quality. It is very important that managers interested in burning begin their planning process at least six to twelve months in advance of the planned burn date.

The use of prescribed fire to manipulate vegetation to benefit both livestock and wildlife is one of several management tools that land managers are utilizing on an increasing basis to battle Texas brush problems. USDA - Natural Resource Conservation Service (NRCS) supports and encourages the use of prescribed burning when used within the context addressed in the NRCS prescribed burning conservation practice standards and specifications. Prescribed burning is appropriate on all lands where its application will appropriately address specific resource management concerns and objectives as identified through the planning process used by NRCS. The public can obtain NRCS information on prescribed burning by accessing the Prescribed Burning (Practice Code 338) Conservation Practice Standard & Specification which is located on the Texas NRCS home page at www.tx.usda.gov under the eFOTG icon.

A successful prescribed burn must be planned at least 6 months to a year in advance of the planned burn date. The grazing land manager must insure that his grazing management system affords the necessary deferment to insure that enough grass (fine fuel) is left ungrazed to achieve your goals for vegetation manipulation. Carrying out grazing deferment and fireguard preparation efforts are critical to an effective burn.

In considering the use of prescribed fire, today's land manager must make numerous critical decisions. Determining when to burn - a winter burn versus a summer burn – your fuel load needs and those of your neighbor are important decisions needing to be addressed. Addressing every single safety concern to ensure a safe and effective burn is critically important. Safety considerations and planning requirements will vary for each type of burn, thus it is very important that land managers seek professional technical assistance in making these decisions.

How NRCS can help

NRCS can provide guidance on using fire as a management tool and can develop an in-depth prescribed burning plan for the land manager to follow. It is an NRCS priority to provide prescribed burning technical assistance to private land managers through its field office technical specialists. NRCS has developed an intensive training and authorization program to prepare employees technically to assist land managers to plan and implement prescribed fire in Texas.

Thirty-eight percent or 268 employees in Texas are authorized to provide prescribed burning technical assistance to land managers. Approximately 40 employees have attended week-long prescribed burn schools hosted by universities and burn consultants. Statewide, 76% of the field offices in Texas have at least one employee to develop prescribed burn plans for land managers. Ninety-five percent of the field offices in the Edwards Plateau region and 85 % of the field offices in the South Texas Rio Grande and Coastal regions have at least one employee trained to develop prescribed burn plans for land managers.

In an effort to support the strong producer interest in conducting summer burns, NRCS coordinated an Advisory Work Group during 2003 which consisted of extension, university and partner agency personnel. This group addressed summer burn research concerns and needs and provided technical guidance to NRCS in its efforts to revise the prescribed burn standard to allow for burning with warmer temperatures. Since 2003 NRCS has conducted two summer burn work sessions that have provided training to 45 NRCS employees plus several other partners. NRCS is partnering with Texas Nature Conservancy and other agencies to promote and apply prescribed fire.

Be aware that NRCS employees are not allowed to be certified by the Texas Department of Agriculture as "Certified Prescribed Burn Managers." The requirements set by House Bill 2599 of the 76th Legislative Session in 1999 requires that each "Certified Prescribed Burn Manager" be insured and bonded in addition to meeting experience and educational requirements. NRCS can train its employees to meet the experience and educational requirements but it can not meet the requirements for bonding and insurance. This requirement prohibits NRCS federal employees from seeking or qualifying for the Texas Prescribed Burning Board TDA designation. NRCS will continue to train employees to the educational level of the TDA certified prescribed burn manager. NRCS supports the development of a second level of TDA certification which would allow database tracking for individuals who meet all certification requirements except the bonding and insurance portions. This service would provide a valuable database resource for land managers interested in seeking prescribed burning assistance

NRCS prescribed burning training requirements

Because of the potentially dangerous and highly technical nature of prescribed burning, it is necessary to implement a system for job approval authority and certification to enable NRCS employees to assist with various levels of prescribed burning. Only trained and qualified NRCS personnel are authorized to provide assistance that includes prescribed burning as a conservation practice. Prescribed burn planning authority is granted to these individuals.

To obtain burn planning authority, an NRCS employee must attend at least 3 full days of indoor and outdoor training. A minimum of 16 hours of classroom training plus 8 hours of field training is required of every NRCS employee who provides prescribed burning guidance or assists with the development of a prescribed burn plan. In Texas, each employee must attend a prescribed burn refresher training every three years to maintain their burn planning authority. Any employee who does not successfully complete the refresher training and/or continuing education credit requirements may not develop prescribed burn plans for land managers nor participate with any phase of prescribed burning.

NRCS encourages employees to participate in prescribed burning training activities and workshops, including those conducted by other agencies or organizations. This training will include training on the following topics: fire ecology and behavior, fire safety, smoke management, fire effects on wildlife, soils, hydrology, and vegetation response.

The extent to which an NRCS employee may provide technical assistance will be restricted by the planning authority and certification level attained. The minimum level of authority for field employees is the Prescribed Burn planning authority. This authority allows the opportunity for the conservationist to discuss, recommend, and develop a prescribed burn plan. However, until the employee is issued job approval authority, he or she can not sign off on burn prescriptions. To obtain planning authority, employees must successfully complete the formal NRCS (or other agency or organization) prescribed burning training course(s). Burn plan approval authority is issued according to the type of training and amount of experience an individual has successfully completed and according to the classification of the prescribed burn job. Burn plan authority criteria are progressive in nature, allowing employees to plan or participate in more complex burns only when they are qualified to do so.

To move from one job approval authority level to another, an employee must have participated in at least three supervised prescribed burns. Additionally, the employee must demonstrate good judgment, knowledge, and skills in prescribed burning. Job approval authority must be recommended in writing by a certified trainer to the Assistant State Conservationist (FO) and to the State Rangeland Management Specialist. Full concurrence is necessary for job approval authority. Separate job approval authorities are required for cool and warm season burning. If an employee is transferred to another work area, re-certification is necessary. Job authority levels are documented on the TX-ECS-19 - Texas Prescribed Burning

Job Approval Authority and Criteria form.

Any NRCS employee who violates NRCS Prescribed Burning Policy will have their job approval authority immediately revoked.

Meeting NRCS prescribed burn plan requirements

Burns planned with NRCS assistance must adhere to all Federal, State, Local laws and Tribal requirements regarding outdoor burning, fire control, smoke management, and air quality. Adherence to the Clean Air Act (42 U.S.C. 7401 - 7671q) is required for all prescribed burns. Prescribed burns will be planned cooperatively and cleared through such groups as rural fire departments, county commissioners, law enforcement offices, adjacent landowners, U.S. Forest Service, and state forestry, wildlife, and natural resource agencies, as applicable.

NRCS requires that the landowner obtain all permits and clearances as required by law. If NRCS develops a burn plan for a manager or landowner, it must thoroughly addresses and meets the minimum prescribed burn plan standards. Separate prescribed burning plans must be developed for each identifiable prescribed burn and the prescribed burn plan is only valid only for the burning season planned. If the landowner decides to change the location of the burn or is unable to burn during the prescribed time frame, a new plan must be prepared prior to conducting the burn.

Safety *is* the first consideration in prescribed burning. NRCS requires that the landowner or cooperator be informed in writing that they may be liable for damages if the fire escapes or smoke damage occurs. If unfavorable atmospheric, fuel, or logistical situations exist, NRCS employees must advise the fire boss or landowner to postpone the burn. NRCS employees are required to inform the landowner and/or fire boss of any unsafe situation or act as soon as it is apparent. If an emergency situation develops, NRCS employees are to follow the direction of the designated fire boss and act responsibly to resolve the situation.

NRCS requires that the landowner or their designee must be on-site throughout the prescribed burn period. NRCS personnel will not serve as the landowner's designee. In cases where the fire boss or landowner is unwilling to apply the prescribed burn within the burning prescription, NRCS employees will discontinue providing on-the-ground assistance, document the fire boss or landowner decision, and leave the area immediately.

NRCS employees acting in accordance with all Federal, State, and local laws and within the scope of their work accept no greater or less liability than that associated with the performance of any other assigned duty and the approval authority granted to the employee defines the scope of work.

Taking advantage of training opportunities

Training in the use of prescribed fire is available to private land managers from a number of agencies. Agencies such as USDA- NRCS, can assist managers in development of burn plans and can train managers upon request. Texas Parks & Wildlife Department and Texas Cooperative Extension Service also train specialists in planning and conducting prescribed burns. Land managers interested in planning prescribed burns can contact their local conservation agencies for planning assistance and for training on conducting prescribed burn. Prescribed burn cost-share assistance may be available at the county level through programs such as EQIP and managers should check with their local NRCS constituents.

With the increasing number of prescribed burns being planned and conducted at the local level and with the heavy conservation workloads that local conservation agencies are experiencing, it is very important that managers interested in burning begin their planning process at least six to twelve months in advance of the planned burn date.

The development of Prescribed Burning Associations is critical to the success of prescribed burning in Texas. The frequency and total acreage of prescribed burns has increased where locally developed prescribed burn associations have been organized. Through local empowerment, Prescribed Burning Associations have provided training, shared burning knowledge and experiences, and bought equipment allowing for increase in the application of safe prescribed fire. NRCS strongly supports the development of local prescribed burning associations and is supporting this effort financially through its Grazing Lands Conservation Initiative program. In some parts of the state, NRCS is supporting the development of agency Prescribed Burning Cadre's to further the number of burn plans developed, and implemented.

TEXAS PARKS AND WILDLIFE DEPARTMENT'S ROLE IN PRESCRIBED BURNING

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Texas Parks and Wildlife Department (TPWD) supports and encourages the use of prescribed burning when used within the context of a habitat management practice recommended in a TPWD approved Wildlife Management Plan. Prescribed burning is appropriate on all lands where its application will appropriately address specific resource management concerns and objectives as identified through the planning process. TPWD employees are expected to focus their assistance on training landowners to be able to carry out safe, effective prescribed burns on their own, consistent with specific goals identified in their wildlife management plans.

Because of the potentially dangerous and highly technical nature of prescribed burning, it is necessary to implement a system of specialized training and experience requirements to enable TPWD employees to assist with various aspects of prescribed burning.

Only trained and qualified TPWD personnel are authorized to provide assistance that includes prescribed burning as a habitat management tool. The extent to which a TPWD employee may provide technical assistance will be determined by the level of training and experience attained.

TPWD staff working with landowners in detailed planning and implementation of prescribed burning must participate in formal prescribed burn training and attend and participate in prescription burns to gain experience. Prescribed burn training is offered periodically on Wildlife Management Areas throughout the state. In addition to introductory training on fire behavior, fire ecology and prescribed burn planning, certain requirements are necessary to properly train staff to assist private landowners with prescribed burning. TPWD staff assisting private landowners in carrying out prescribed burns on private lands must meet training and experience requirements as established by the Texas Prescribed Burning Board.

The landowner is responsible for acting as/or designating a Fire Boss for prescribed burns on private property. TPWD employees are not authorized to act as Fire Boss for prescribed burns on private land.

TPWD employees assisting private landowners with on site prescribed burning can provide advice and expertise; use all safety equipment including weather monitoring tools, drip torches, and light suppression equipment such as flappers, rakes, and hand sprayers. Whenever pos sible, TPWD employees will encourage the landowner or his agent acting as Fire Boss to ignite headfires. TPWD employees will avoid operation of motorized equipment such as ATVs, trucks with skid mount sprayers, and pumper trucks when assisting with prescribed burning on private lands. TPWD assistance to landowners will stress training for the landowner and his crew with the goal of empowering landowners to carry out safe, effective prescribed burns on their own.

TPWD employees assisting landowners will verbally discuss the liability release included in the Burn Plan with the landowner prior to implementing the prescribed burn.

TPWD has an approved policy that establishes the basic framework for fire management on TPWD lands, which include the burning of brush, debris, and prescribed burning. This policy also offers guidance for wildfire control and management.

The primary purpose of prescribed burning on TPWD lands is to simulate the effects of natural fire events. The application of fire fulfills numerous management objectives including reduction of excessive fuel loads, increased herbaceous species and available browse, control of invading species, increasing species diversity and richness, and facilitation of the long-term objectives for community restoration and maintenance. Prescribed burning on TPWD lands is normally conducted in association with these management objectives and/or other research endeavors in order to document the long-term effects of this practice on habitat quality or habitat restoration. Prescribed burning is the most effective and efficient method to reduce fuel loadings. Fire hazard is directly correlated to fuel loads, therefore, reducing the fuel loads will not only reduce the fire hazard, but also the impact a wildfire could have on a site, its facilities, and its natural communities.

All employees have access via the agency's Intranet site to TPWD policies and procedures concerning fire management on agency owned lands and prescribed burning assistance to private landowners.

THE ROLE OF TEXAS COOPERATIVE EXTENSION IN PRESCRIBED BURNING

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Abstract: Texas Cooperative Extension is the outreach agency for the Texas A&M University System. The Agency's role is to provide relevant, research-based educational programming to the people of Texas. Prescribed burning is part of that programming and several workshops are conducted annually, along with demonstration burns. However, demand is greater than the capacity to deliver programs. Suggestions are made to improve educational programming in prescribed burning.

Introduction

"Extension" means "reaching out," and - along with teaching and research - land-grant institutions "extend" their resources, solving public needs with college or university resources through non-formal, non-credit programs. These programs are largely administered through county and regional Extension offices, which bring land-grant expertise to the most local of levels. And both the universities and their local offices are supported by Cooperative State Research, Education, and Extension Service (CSREES), the U.S. Department of Agriculture federal partner.

The Morrill Act of 1862 established land-grant universities to educate citizens in agriculture, home economics, mechanical arts, and other practical professions. Texas A&M University was established in 1876. Extension was formalized in 1914, with the Smith-Lever Act and it established the partnership between the agricultural colleges and the U.S. Department of Agriculture. Extension work, according to the Act, was:

* Developing practical applications of research knowledge.
* Giving instruction and practical demonstrations of existing or improved practices or technologies in agriculture.

The name may be new, but Texas Cooperative Extension (TCE) has provided informal education to Texans for 87 years. Formerly known as the Texas Agricultural Extension Service, the agency's name was changed in July 2001 to better reflect Extension's broad responsibilities in environment and natural resources, family and consumer sciences, youth development, and community development, as well as production agriculture. Texas Cooperative Extension is part of the nationwide Cooperative Extension System and operates, like every state Extension agency, as a partnership between each county government, the land-grant university and the U.S. Department of Agriculture. Texas Cooperative Extension also collaborates with public and private organizations and with Prairie View A&M University's Cooperative Extension Program.

Texas Cooperative Extension offers education that transfers new knowledge and technologies from research, enhances communities and the environ ment, and enables individuals to improve the quality of their lives through better decision-making. The TCE mission is "Providing quality, relevant outreach and continuing education programs and services to the people of Texas". These programs focus on issues determined by local citizens through an established needs assessment process, called the Texas Community Futures Forum. This ongoing process ensures the responsive development of programs that: 1) are relevant to the people in each county and 2) support State of Texas goals to improve health, safety, productivity and well-being; improve stewardship of the environment and natural resources; contribute to economic security and prosperity and develop responsible, productive, and self-motivated youth and adults.

Extension serves all 254 Texas counties through 12 district centers and 250 county offices, employing more than 950 professional educators located across the state. County Extension agents serve as community educators and are supported by Extension specialists who provide research and educational resources.

Programming in prescribed burning

It is apparent from the preceding information that TCE is an educational/outreach agency. Accordingly, prescribed burning programs are conducted in an educational context. Actual prescribed burns are undertaken as part of the larger program to demonstrate fire behavior, proper safety procedures, firing techniques, etc. Fires may also be conducted as part of an applied research project or to demonstrate to interested persons the effects of fire on the landscape. In other words - this is not a service; we do not burn rangeland as a service to clientele.

Another point that should be made is that Extension transfers science-based technologies from research to the end user. As such, there are no problems with tried and proven prescriptions for rangeland fire (e.g. cool-season burns). However, if research has not studied and/or developed prescriptions under some circumstances (e.g. summer burning) then there could be some problems of acceptance, certainly of advocacy. It is also Extension's responsibility to take research results, modify as appropriate, and adapt to changing environments and include in management systems.

Prescribed burn training for rangeland managers and associated professionals has been conducted by the Extension Service since the early 1980's. Four symposia plus regional workshops first were used to help establish this practice in four respective areas of the State. Early on, TCE cooperated with other agencies/organizations (TPWD, NRCS, Nature Conservancy, etc.) in developing training programs in prescribed burning and for in-service training of their employees. Rangeland Ecology and Management (RLEM) specialists have conducted 5 - 10 burning workshops annually since the early 1980's. Most of these workshops included lectures and actual hands-on burning experience (weather dependent). Two major publications have been published by TCE and are widely used in educational programs (Landers 1994; White and Hanselka 1989).

Most prescribed burning programming is conducted by the RLEM Exten sion Program Unit. However, Specialists in both the Soil and Crops (Forages) and Animal Sciences Program Units may conduct small amounts of programming. There are presently 7 RLEM Extension Specialists in Texas - in College Station, Vernon, Ft. Stockton, San Angelo, Uvalde, Alice, and Corpus Christi.

The objectives of training to date have been to train practitioners how to safely and effectively utilize prescribed burning for management of range and forest ecosystems in Texas. This encompasses both the science and art of prescribed burning with due consideration of risks, liability, and potential benefits and negative impacts on and off-site. This includes:

a) Safe use of fire encompassing proper timing and application of fire following adequate preparation that reduces chances of escape and potential harm. It includes training on effective fire fighting and planning to minimize escape impacts, worker safety, equipment and facility protection, weather and fire behavior forecasting, liability issues, and prescribe burn regulations.

b) Effective use of fire encompassing realistic goals, different fires different responses for different vegetation and weather (pre, time of burn, and post) conditions, proper conditions and procedures for achieving desired responses and reducing negative effects, pre and post management requirements, and monitoring for improved application and management.

c) Provide hands-on field experience with all phases of prescribed burning to increase the art of applying fire to specific situations. This phase is essential if people are to begin to apply fire with minimal assistance from professionals. The practitioners must become comfortable but cautious so that they can and will plan, implement, control and monitor their prescribed burning program on their won place. This may include the development of burn cooperatives, shared resources and expertise, and refresher training or volunteerism for neighboring burns.

d) Develop support from the general public, insurance companies, regulatory agencies, etc. for the continued use of prescribed fire by citizens of Texas.

Programming issues

In the early 1990's, the RLEM Extension Unit in association with NRCS surveyed producers across the state and asked them “Do you use fire, do you plan on using fire and if so why or why not”? Many of the answers reflected liability and environmental concerns, but the main thing was the lack of experience. The basic situation is that many more would like to use fire than are using it now. But, they do not, or cannot; many can use fire and want to use fire, but don’t for many reasons, and there are a many more that can’t and really don’t want to. The demand is much greater than the ability of Texas Cooperative Extension to train them.

RLEM prescribed burning programs continue to be conducted as related to County Extension Agent and clientele requests in local areas. Requests are exceeding the ability of Specialists and CEA's to provide timely training and conduct of demonstration burns. In service training needs to be expanded for more effective assistance to clientele and "continuity" between groups including volunteer fire departments, fire marshals, county officials, air population control specialists, and agency personnel. The formation of Prescribed Burning Coops is an excellent vehicle for "Training the Trainer" and "People Helping People" efforts. Since County Extension Agents will rarely be "Fire Bosses" and carry the driptorch, perhaps their role would best be on how to develop and implement burning COOPs.

A coordinated effort to provide regularly scheduled training in key locations for clientele and professionals have been discussed and proposed for several years with various groups. An example of this that has been successful are the prescribed burning workshops conducted by the Academy for Range Management on the Sonora Experiment Station. Permanent training locations and scheduled sessions will allow Specialists and other resource people to more effectively meet the increasing needs for clientele to effectively and safely apply and understand prescribed burning for a variety of land resources areas and objectives.

Continuing research and experience with prescribed fire is promoting greater application for a wide variety of land resource objectives. Possible conflicts with air quality regulations, public concern, and liability issues require adequate training of clientele.

Literature cited

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TEXAS FOREST SERVICE PERSPECTIVE ON PRESCRIBED BURNING

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***Abstract*:** The Texas Forest Service is a small agency with statewide responsibility for all matters pertaining to forestry. One of our missions is wildland fire management and due to that involvement we have a great interest in promoting prescribed burning to reduce hazardous fuels. We fully support prescribed burning efforts by all parties practicing land management and believe it is one of the best tools we have for not only reducing hazardous fuel load, but also gaining other benefits of fire. Cooperative efforts are probably the very best way for the folks involved in delivering prescribed burning at whatever level to achieve the greatest results. Over the last several years the Texas Forest Service has assisted several different entities with burns all over the state: Texas Parks and Wildlife, The Nature Conservancy, Texas Army National Guard, Austin City Wildlands Division, Corps of Engineers and the U.S. Forest Service. These efforts have resulted in all parties being able to get goals accomplished; while working individually, we may not have been as productive.

Introduction

I believe that everyone at this meeting already knows a lot about prescribed fire; its uses, benefits, how it's applied and so on. Rather than provide technical information, I will share some practical experiences from the past few years of cooperative efforts between the Texas Forest Service (TFS) and other land management organizations. We have found that working with partners has yielded more burns being completed than would have been done otherwise.

Relationships with other agencies

USDA Forest Service

The major project we cooperate on stems from a grant from the national fire plan for hazardous fuel reduction on private land adjacent to the Sam Houston National Forest boundary. The grant pays landowners for burning on properties within 3 miles of the national forest boundary. Last year with funding for 2,000 acres we were able to burn a total of 4,700 acres. Our landowners took intitiative to burn an additional 2,700 acres. We are planning to expand this program for next year's burning season by including all four of Texas's National Forests.

Another area of assistance by the Forest Service is allowing the use of the Stephen F. Austin Experimental Forest for the East Texas Burn Manager training course. USDA Natural Resources Conservation Service also assists by allowing the use of the Plant Material Center as a classroom facility during the course.

The Nature Conservancy

We have provided personnel and equipment on two different Conservancy properties, the Davis Mountains Preserve and the Barton Creek Preserve. The Davis Mountain burn enjoyed assistance from the National Park Service, US Fish and Wildlife Service and the Fire Use Training Academy. Four thousand acres were burned in 2001 and

1,089 acres were burned this year with the objective of ecosystem restoration, cedar reduction for water yield and fuel load reduction. The Barton Creek Preserve objectives for burning were for endangered species habitat restoration (specifically Black Capped Vireo, *Vireo atricapillus*) and fuel reduction.

Austin City Wildlands Division

We assisted with firebreak construction on watershed tracts in Travis and Hays County for eastern red cedar (*Juniperus virginiana*) control to improve water yield and to reintroduce fire into theses areas.

Texas Parks and Wildlife

The TFS worked on the Devil's Sinkhole Natural Area to remove cedars on the perimeter to create a fire break for a future burn. Hope we get to come out for the burn! For several years we have assisted Texas Parks and Wildlife by providing personnel and some equipment when they are burning at Bastrop State Park. We also have a TFS office located at San Angelo State Park, where we assist in firebreak construction.

Corps of Engineers

Training courses patterned after the state certification course have been presented for personnel from Lakes: Whitney, Waco, Wright Patman and Lake of the Pines. The resource managers at these lakes are beginning to include fire in their plans and with some help with firebreaks and moral support I believe they will get a burning program going!

Texas Army National Guard

One of our major successes has been securing a Memorandum of Understanding for fire management services including prescriptions and delivery on Camps: Bowie, Walters and Swift. Over the last three years we have burned over 8000 acres on these camps. The objectives for burning are: reintroduction of fire to the landscape, cedar reduction and restoration of the Oak/Grass Savanna. A supplement to the burning program has been a mechanical cedar control project on 900 acres of dense cedar areas on Camp Swift.

Conclusion

Other lands TFS manages include state forests and General Land Office tracts in east Texas. Prescribed burning are important parts of our long term management plans and give us an excellent training tool for our personnel.

In conclusion, we believe that working in partnership with others allows us an excellent opportunity to exchange experience, personnel and equipment in order to increase the amount of burning across this great state.

PRESCRIBED FIRE IN ECOSYSTEM MANAGEMENT AT NATIONAL WILDLIFE REFUGES

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***Abstract*:** Prescribed fire is a fundamental land management practice used to emulate natural ecological processes at Fish and Wildlife Service (FWS) National Wildlife Refuges (NWR) across the United States. The FWS has been using prescribed fire on its lands since the 1930s, and treated an average of 240,000 acres per year from 1996-2000. In 2003, the FWS treated 35% of the total Department of Interior (DOI; FWS, NPS, BLM, and BIA) hazardous fuel acres, using only 13% of the DOI budget allocation. In 2004, over 1,000 projects were conducted with prescribed fire and mechanical treatments covering 371,470 acres at 175 Refuges. Prescribed fire is managed by Refuges to maintain and restore fire-adapted ecosystems, wildlife habitat, and biological diversity, and to control invasive and non-native species. Fire is used to manage ecosystems across the Refuge System including but not limited to coastal, tall-grass, mid-grass, mixed-grass, and short-grass prairies, desert grassland, woodland, forest, and wetland habitats. In Texas alone, fire is used to maintain and restore threatened, endangered, and sensitive species habitats including coastal prairie for the Attwater's prairie chicken (*Tympanuchus cupido attwateri*), peregrine (*Falco peregrinus*) and Aplomado (*F. femoralis*) falcon, coastal marshland for the piping plover (*Charadrius melodus*) and mottled duck (*Anas fulvigula*), live oak for the whooping crane (*Grus americana*), oak woodlands for the black-capped vireo (*Vireo atricapillus*) and golden-cheeked warbler (*Dendroica chrysoparia*), and subtropical thornscrub for the ocelot (*Leopardus pardalis*) and jaguarondi (*Herpailurus yagouarundi*). Case studies will be presented that illustrate the breath of the FWS prescribed fire programs including objectives, research, monitoring, and adaptive management.

NOTES:

THE TEXAS CERTIFIED PRESCRIBED BURN MANAGER PROGRAM[1]

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Abstract: Outdoor burning in Texas has historically been authorized under an exception to the Outdoor Burning Rule of the Texas Commission on Environmental Quality (TCEQ). However, no law existed which encouraged the use of prescribed fire in the state. The Texas Prescribed Burning Coalition was organized in April 1998 to influence positive legislation concerning prescribed burning, to foster and support training in the art and science of prescribed burning, and to disperse accurate information to the public on the subject of prescribed burning. The Texas prescribed burning law, HB 2599, is administered through the Texas Department of Agriculture. It guarantees every Texas landowner the right to burn on his own property. It set up a prescribed burn manager certification system, a Prescribed Burning Board (PBB), and an Advisory Committee to the PBB. The legislation places liability directly upon a certified prescribed burn manager, thus removing the landowner from a certain amount of liability. HB 3315 set up a mechanism for counties to grant permits to certified prescribed burn managers during county burn bans. HB 1080 limits damage claims to $2 million per insured per year. Prescribed burning rules have been written, certification training and re-certification have been established, and a number of individuals have been trained; however, no one has been certified because PBB has not located a company willing to insure prescribed burners.

Outdoor burning in Texas

Outdoor burning in Texas is controlled by the Outdoor Burning Rule of the Texas Commission on Environmental Quality (TCEQ 2005). The Outdoor Burning Rule first prohibits outdoor burning anywhere in Texas, then allows exceptions for specific situations in which burning is necessary or does not pose a threat to the environment. Special authorizations to conduct burning may be granted if burning seems necessary or does not fit an exception stated in the rule. Exceptions to the rule for prescribed outdoor burning are authorized for: (1) prescribed burning with no notification requirement to TCEQ for forest, range, wildland/wildlife management purposes, with the exception of coastal salt-marsh management burning, and (2) coastal salt-marsh management burning in Aransas, Brazoria, Calhoun, Chambers, Galveston, Harris, Jackson, Jefferson, Kleberg, Matagorda, Nueces, Orange, Refugio, and San Patricio counties. Coastal salt marsh burning is subject to the following requirements:

(1) Land to be burned shall be registered with the appropriate TCEQ regional office using USGS maps or equivalent upon which are identified significant points such as roads, canals, lakes, and streams and the method by which access is made to the site. The information must be received by TCEQ for review at least 15 working days before the burn takes place.

(2) Prior to any burning, notification, either verbal or written, must be made to and authorization must be received from the TCEQ regional office.

[1]This is Welder Wildlife Contribution Number 643.

Notification must identify the specific area and/or block to be burned, approximate start and end time, and a responsible party who can be contacted during the burn period.

Under the Outdoor Burning Rule all burning in Texas is subject to general requirements for burning:

(1) Notify the Texas Forest Service (TFS) on burns for forest management.

(2) Burn only outside the corporate limits of a city or town, unless the incorporated city or town has an ordinance that permits burning and is consistent with the Texas Clean Air Act Subchapter E.

(3) Begin or continue burning only when the wind direction and other weather conditions are such that the smoke and other pollutants will not present a hazard to any public road, landing strip, navigable water or have an adverse effect on any off-site structure containing “sensitive receptors”.

(4) Post someone to flag traffic if at any time the burning causes or may tend to cause smoke to blow onto or across a road or highway.

(5) Keep fires downwind of or at least 300 feet from any neighboring structure containing sensitive receptors. This can be waived with prior written approval.

(6) Begin burning no earlier than 1 hour after sunrise, end it the same day and no later than 1 hour before sunset, and make sure that a responsible party is present while the burn is active and the fire is progressing. At burn end, extinguish isolated residual fires or smoldering objects if the smoke they produce can be a nuisance or a traffic hazard. Wind speed requirements are at least 6 mph to dissipate smoke and 23 mph or less for the fire to be controllable. Burning is to be conducted only if no temperature inversions are expected. Approval for night burning can be obtained from TCEQ.

(7) Do not burn electrical insulation, treated lumber, plastics, construction or demolition materials not made of wood, heavy oils, asphalt, potentially explosive materials, chemical wastes or natural or synthetic rubber items.

Notification

It is important for prescribed burn managers to make the proper notifications prior to burning as follows:

(1) If burning on areas other than coastal salt marsh, burn managers should notify the nearest TCEQ regional office in writing and orally when possible, although this is not required.

(2) For coastal salt marsh burning, it is required to notify the nearest TCEQ regional office 15 days prior to burning, both in writing and orally.

(3) Check local ordinances and notify any other governmental entity having jurisdiction over the area; i.e., local fire departments or county fire marshal to ensure there is not a county burn ban.

(4) Notify TFS before conducting prescribed burns for forest management.

(5) Notify neighbors.

(6) Prior to igniting the burn, determine whether any "structures containing sensitive receptors" (residences, greenhouses, stables, etc.) are within 300 feet of and downwind from the burn. If these conditions exist, obtain written permission from occupants or operators of those structures before initiating the burn.

County commissioners have the authority to issue a burn ban for all or parts of a county. The county judge has authority to issue an emergency burn ban. A county fire marshal or emergency management officer may exist and should be contacted prior to burning to determine any special requirements for burning in the county.

There are certain guidelines to decrease liability to which prescribed burners should adhere:

(1) Develop or have developed a prescribed burn management plan.

(2) Use prudent, sensible judgment before, during, and after the burn.

(3) Follow TECQ rules.

(4) Seek qualified assistance or training if needed.

(5) Develop good relationships with neighbors and local fire departments.

Endangered Species Act

According to Section 7, Endangered Species Act, Federal agencies in consultation with the U.S. Fish and Wildlife Service (USFWS) are required to insure actions they authorize, fund, or carry out will not jeopardize species listed as endangered or threatened or result in destruction or adverse modification of critical habitat for these species. Federal agencies are required to confer with the USFWS for any action likely to jeopardize continued existence of any proposed or listed species or result in destruction or adverse modification of critical habitat for these species. Agencies have a responsibility to review their own actions to determine whether such actions "may affect" listed or proposed species or designated or proposed critical habitat for these species.

Texas Prescribed Burning Coalition

The Texas Prescribed Burning Coalition (TPBC), an ad hoc independent group, was organized in April 1998 at a meeting in Kerrville at which 50-60 interested individuals from throughout the state were present. From this initial meeting, a mailing list of approximately 60 organizations and individuals was developed. The goals of the organization are to influence positive legislation concerning prescribed burning in the state, to foster and support training in the art and science of prescribed burning in Texas, and to disperse accurate information to the public on the subject of prescribed burning. Three committees were named: legislative, education and training, and public information. The TPBC met twice on an annual basis following the initial meeting, but has not been active recently because of the success in obtaining the desired burning legislation.

TPBC was organized to 'get ahead of the curve' on burning legislation in Texas because it had become obvious to those who organized the effort that urbanization, a general fear and misunderstanding of fire, and lack of information on the proper use and positive benefits of fire might soon preclude the use of this valuable wildlife habitat management tool. We were aware that recent court rulings in the Southeast had increased the potential liability associated with prescribed burning. These rulings defined prescribed burning as 'inherently dangerous' and stated that hiring a contractor to conduct the burn does not relieve landowners of the liability for an incident which may occur as a result of a prescribed burn on their property.

History of legislation and rules

The TPBC legislative committee went to work immediately because the 1999 Texas legislature met shortly after the organizational effort. A Prescribed Burning Bill (HB 2599) was introduced, passed both chambers, was signed by Governor Bush, and became law in September 1999. HB 2599 guarantees the right of every landowner in the state to burn on his own property. It also set up a prescribed burn manager certification system, a Prescribed Burning Board (PBB), and an Advisory Committee.

PBB membership consists of representatives of 7 state agencies (Texas Department of Agriculture, Texas Commission on Environmental Quality, Texas State Soil and Water Conservation Board, Texas Parks and Wildlife Department, Texas Cooperative Extension, Texas Agricultural Experiment Station, and Texas Forest Service), Texas Tech University, and 5 private landowners. The PBB, housed in the Texas Department of Agriculture (TDA), was set up to write the 'rules' for certified prescribed burn managers in Texas and to oversee the certification and recertification process.

HB 2599 addresses the landowner's right to burn and places liability directly on the certified prescribed burn manager, thus removing the landowner from a certain amount of liability. It was the desire of the TPBC to provide landowners with a more positive incentive to use prescribed fire on their properties. Two provisions of HB 2599 address this desire: (1) that Texas landowners have the right to burn, and (2) creation of the certified prescribed burn manager along with a system of training and certification. Within the Texas system is a liability insurance clause which protects the landowner from lawsuits up to the limit of the certified prescribed burn manager's coverage, i.e., $1 million. Few other states put this kind of protection between a landowner and the possibility of damage claims or lawsuits.

Since providing fire liability insurance with an upper limit on claims per insured burner would be more appealing to insurers, HB 1080 was introduced, the2001 Texas legislature passed, and the governor signed the bill which limits claims to $2 million per insured per year. Initially, the PBB interpreted the liability insurance requirement to mean that an individual must purchase the $1M policy; however, the PBB recently changed the insurance rule to allow a company or burn association to purchase the liability coverage and specifically name the individual(s) covered in the policy.

Another major stumbling block limiting the application of prescribed burns in the state was the inability of prescribed burn managers to obtain permits from county commissioners' courts to conduct prescribed burns during county burn bans. At best, the system was haphazard with some counties having an acceptable mechanism and others having no mechanism for the approval process. In some counties it has been impossible to obtain permits during burn bans. HB 3315 set up a mechanism for counties to grant permits to certified prescribed burn managers during county burn bans.

HB 2599 made the PBB responsible for setting up (1) an Advisory Committee to PBB, (2) prescribed burning standards, (3) certification, re-certification, and training standards for prescribed burn managers, (4) educational and professional requirements for burning instructors, and (5) minimum insurance requirements for certified prescribed burn managers. The PBB met monthly over a 2-year period beginning in December 1999 to write the rules outlined by HB 2599. PBB has completed 100% of its tasks, having appointed the Advisory Committee; set burning standards, certification standards, training standards; and set requirements for burning instructors.

In August 2001 the PBB approved the rules resulting from HB 2599 and in November 2001 the PBB added needed rule changes resulting from enactment of HB 1080 and HB 3315. The certification and training process is now in place and functional. A number of officially sanctioned prescribed burning schools have been taught since PBB's organization. Upcoming schools plus the rules and enabling legislation can be found on the TDA Web site: http://www.agr.state.tx.us/pesticide/.

The Advisory Committee consists of 12-15 professionals and others involved in prescribed burning on Texas rangelands. The charge to the committee has been to provide the PBB with technical information and advice on questions the PBB does not have the time or resources to address. The Advisory Committee has provided the PBB with valuable information throughout the process of rule writing.

Certification and re-certification

Certified prescribed burn manager standards address the need for a written plan, personnel requirements, notification requirements, and insurance requirements. The minimum liability insurance was set by HB 2599 at $1M and subsequently capped by HB 1080 at $2M.

Certification and training have been set up by the PBB on a regional basis. The PBB has divided the state into 5 training regions with similar vegetation requiring unique burning techniques (Table 1). Within each of these regions a contact agency has been selected to coordinate training and certification for the region. Each region has a certified burn manager training coordinator. These contact agencies and coordinators are responsible to TDA for coordination of training, issuance of certificates, and record keeping. TDA keeps certification records and coordinates statewide training and re-certification activities.

A prescribed burn manager is initially certified to practice only in the 1 region in which he has received training.

He may later decide to become certified in other regions. If so, then he must attend only the single-day specialized regional course for each new region.

Certification requirements include meeting minimum training requirements, meeting minimum experience requirements, making written application, and providing proof of insurance. Minimum experience requirements are 3 years of prescribed burning in a particular region and 30 days of prescribed burning with the applicant responsible for all aspects of the prescribed burn on 5 of these days. Training consists of a course that includes prescribed fire training, plus specialized training for the region in which the person is certified, using materials developed by PBB. The training course contains both formal classroom lectures and practical field sessions. Attendees are exposed to at least 1 hands-on prescribed burn. Following successful completion of the course and presentation of evidence of adequate liability coverage, $50.00 certificates valid for 5 years will be issued. Upon presentation of evidence of completion of all training and certification requirements, the insurance company will issue a liability policy which must accompany the certificate to be valid. The PBB has the authority to enter into reciprocity agreements with other states and/or federal agencies.

Re-certification is a continuing process sanctioned by the PBB. Courses must be approved annually by PBB. CEU's approved by the PBB may be offered by any approved private, state, or federal entity. Each certified prescribed burn manager must obtain a total of 15 CEU's during the 5 years of valid certification, or re-take the 5-day training course to be re-certified.

Future

A major impediment to completing the task of the PBB has been in finding insurance companies willing to offer liability policies for this specialized work. A company willing to insure prescribed burners has recently been located. This positive development plus recent rule changes made by the PBB should mean that certification of one or more certified prescribed burn managers will occur in the very near future. The insurance problem has not been unique to Texas. Other states that have recently approved burn certification have encountered similar problems obtaining insurance. Recently AGREN Inc., Carroll, Iowa and the Iowa Department of Natural Resources have teamed up to develop a prescribed fire insurance liability product. The study is funded by the U. S. Department of Agriculture to conduct a study of prescribed burners in 5 states. Texas is included in the study. The study was initiated in February 2004 and should be completed during 2005. Questionnaires were mailed to practicing burners in early 2005. The study proposes to build a foundation for constructing an insurance tool to protect private contractors from personal liability when conducting prescribed burns.

Prescribed burning is on its way to becoming a standardized, accepted practice on Texas rangelands. Currently there are approximately 100 individuals throughout the state who have completed PBB-sanctioned training courses and who may potentially become certified burn managers when insurance becomes available. This has been a grass-roots effort to enhance the wise and safe use of fire as a rangeland management tool in Texas.

Literature cited

Texas Commission on Environmental Quality. 2005. Outdoor Burning in Texas. RG-049 (Revised)

Table 1. Prescribed fire training regions in Texas and contact persons.

Region	Contact	Agency	Phone Number
1	Carlton Britton	Texas Tech University	806-742-2842
2	Darrell Ueckert	Texas Agricultural Experiment Station	325-653-4576
3	Jeff Sparks	Texas Parks and Wildlife Department	903-566-5698
4	Ernie Smith	Texas Forest Service	903-734-7007
5	Wayne Hanselka; Andy Garza	Texas Cooperative Extension; Texas State Soil & Water Cons. Board;	361-265-9203; 956-421-5841

A CASE STUDY OF THE EDWARDS PLATEAU PRESCRIBED BURNING ASSOCIATION, INC.

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Abstract: Prior to the formation and development of the Edwards Plateau Prescribed Burning Association, prescribed fire was being applied to Edwards Plateau rangeland, but the frequency and numbers of fires were low. The practice of prescribed burning by an association of volunteers is still in its formative stages (Taylor 2005). Even so, through the 8 years of its existence, the EPPBA has developed a tentative consensus regarding key particular duties of organization within a Chapter, preparation for burning, and methods of conducting burns efficiently. Association burning as it is practiced on the Edwards Plateau involves a mutual partnership of two groups – landowners and agency personnel (NRCS, Experiment Station, Extension Service, etc.).

Introduction

Prior to the formation and development of the Edwards Plateau Prescribed Burning Association, prescribed fire was being applied to Edwards Plateau rangeland, but the frequency and numbers of fires were low. Most ranchers were waiting for state and federal agency employees to conduct burns for them. For example, the Texas Cooperative Extension Service, Texas Agricultural Experiment Station, Texas Parks and Wildlife, and Natural Resource Conservation Service along with universities were helping a few ranchers do some burning. Most of the burns were conducted in the winter or spring, and the results were variable. Very few ranchers were actually conducting prescribed fires on their own, and most were advised not to burn during the hot summer time. Also, ranchers in west Texas had tried cool-season fires and were disappointed with the results.

Cool-season burning is more successful in higher rainfall areas, which can produce larger volumes of fine fuel. Most ranchers agreed that major obstacles to an active fire program were liability, insufficient help, and lack of proper equipment and experience. It was clear that ranchers did not need to be "sold" on the benefits of prescribed burning, but they needed to be educated, equipped, trained, and empowered to implement burning on their own ranches.

Following a prescribed burn tour held on the Texas A&M University Agricultural Experiment Station at Sonora, tour participants were asked if they wanted to form a group of like-minded individuals who would join together to implement a sustainable fire management program. Most of the ranchers agreed that an association would be beneficial, so by a unanimous vote, it was decided to start a burn association. Nominations were taken for officials, and a president and board members were elected. Guidelines were developed and approved on the same day and a name was decided for the organization, Edwards Plateau Prescribed Burning Association (EPPBA).

The burn association started with approximately 30 members but quickly grew to 60 members the first year and interest in joining the association has spread into other counties. As membership increased, distances between burns also increased, making it difficult for everyone to participate on each burn. A solution to this growth was the formation of county level Chapters. Chapters are a part of the EPPBA (they are governed by the EPPBA bylaws and guidelines), but they also can have their own president and board of directors and can draft their own guidelines.

The practice of prescribed burning by an association of volunteers is still in its formative stages (Taylor 2005). Even so, through the 8 years of its existence, the EPPBA has developed a tentative consensus regarding key particular duties of organization within a Chapter, preparation for burning, and methods of conducting burns efficiently. This portion of the paper is an attempt to report and/or discuss some points of that emerging consensus.

Organizational roles and duties

In general, one of the first actions taken by a prescribed burn Chapter is to purchase several skid-mounted sprayers for fire suppression. Pull-behind sprayers have proven to be ineffective because of their lack of maneuverability in brush and/or rocky terrain. Some Chapters have been able to acquire used fire trucks from their local municipalities or other sources.

The issue that immediately arises after this acquisition is, “Where will they be stored” and “Who will maintain them”. A crucial informal position within any Chapter is the keeper of suppression units. The primary concern is that the association’s sprayers be accessible. Secondarily is the need for the sprayers to be maintained in good working order. Every Chapter needs to identify and cultivate within its membership the person(s) with the place, aptitude and willingness to perform these functions.

Similarly, every Chapter will need to acquire a dozen or so 2-way radios. One person within the organization should be assigned the task of keeping the radios and making sure their batteries are charged. The Chapter’s radios may be checked out for use, pretty much like a book from a library. Collecting the radios after a fire and returning them to their appropriate location becomes, after a while, a routine part of burn-day operations.

A third key role that has emerged in our experience is that of burn coordinator. Here’s the problem: suppose 8 landowners intend to burn in one month. How do you resolve conflicts in the scheduling of burns? We are encouraging landowners to schedule their burns through one burn coordinator. Ordinarily, local NRCS personnel are well-suited for this role, if he/she is willing to accept it.

Last is the role of record-keeping after a burn. One record that is good for Chapters to maintain is a list of all personnel who participated in each burn. A second kind of record is data relevant to fire behavior (temperature, wind speed and direction, humidity, fine fuel availability, etc.). The more members that keep and understand these data, the more safe and effective their use of fire will become. A third body of data that is valuable concerns the amount of acreage burned by each Chapter. The day will surely come when this information proves useful politically and insurance-wise.

Landowner preparation for a burn

Everything presented in this section and the next is influenced by a factor peculiar to association burning. That factor is the nature of the volunteer fire crew. It is highly commendable and enjoyable to work alongside one's neighbors in a worthy common cause. The fact remains that every man or woman who comes out to participate with an association burn has plenty of other things they could be doing that day. Too much consideration cannot be given to avoid unduly imposing on the kindness of these volunteers. The greatest respect that can be paid to volunteers is to make the most efficient use of their precious time. Happily, such efficiency is also highly desirable for the landowner conducting the burn.

There are two things a landowner can do in advance of a burn to enhance efficiency. The first is bladed fire-guard preparation and blacklining. So far, there is no absolute standard in regard to fireguard preparation, although a single-bladed fireline around the perimeter of the area to be burned is a minimal expectation. Preferably, a double-bladed fireguard should be established along the perimeters that are anticipated to be downwind of the fire. The standard width between the double-fireguard can vary between 100 to 500 feet. In rangeland where grass predominates, the distance can be less. In areas of dense volatile fuels, the distance should be more.

Pasture size (or the size of the area to be burned) is probably the most important factor in deciding whether to blackline prior to the burn or on the same day as the main burn. In the rocky, brush covered, hilly Edwards Plateau, 500-600 acres is about the maximum size one could reasonably expect to blackline and burn on the same day.

Blacklining is normally the slowest and riskiest part of a prescribed burn. The constant danger to be monitored is embers blowing over the fireguard and igniting the neighbor's pasture. Blacklining should ordinarily be done during the cooler and more humid hours of the day. It is becoming more and more common for prudent landowners to increase the efficiency and lessen the dangers of blacklining by pre-burning brush piles or heavy accumulations of ember-producing materials on days that are cool, damp and still, months or years in advance of the main burn. It is an unacceptable risk to blackline in an area containing volatile standing brush (cedar) over 4 feet in height or large brush piles within 30 yards adjacent to the downwind perimeter fireguard.

The second pre-burn issue of association burning is scheduling the burn. There are two schools of thought about this. Some landowners prefer short-range scheduling: alerting their crew a day or two in advance of the burn. This method provides the great advantage of burning on a day when weather conditions are reasonably well-known to be advantageous. It carries with it the serious drawback of forcing volunteers to make radical changes to their personal plans on short notice. Other landowners prefer long-range scheduling. This involves selecting a burn-day some two weeks or even a month before the burn. This allows volunteers to arrange their schedules in a planned manner; and also reduces the possibility of conflict with other landowners who may also be planning to burn during that period. The disadvantage to this method is that burning conditions may turn out to be less than ideal on the day that was picked.

So far, no consensus has emerged as to the "right" way to schedule association burns.

Burn-day efficiency

Ideally, on the day of your burn, the pasture you have rested for months will get a thorough toasting. In reality, about all that gets burned on some occasions is daylight.

The following is a slightly exaggerated but not untypical morning at a burn site. The landowner has requested that volunteers arrive at 9:00 am. Folks start showing up at 8:30. Stragglers are still coming in at 9:20. No real problem. Everybody says howdy and discusses the kids, the weather and the markets – as they should. It's now 9:40. The fire boss makes a first attempt to rally the crew. But one bunch is at the tank filling up a sprayer. Another bunch is working on an ailing 4-wheeler. Finally, at 10:00, most of the crew is assembled for the indispensable map orientation and planning conference. Assignments are made, points of special concern are noted. "Let's go!" "Oops, the drip torches aren't fueled. Nobody has a radio." "What frequency are we on?" Finally, at 10:30 the cavalcade trundles toward the back pasture where the fire is to be set. The first match is not struck until 11:00. Nobody's really broke a sweat when it's time to stop for lunch.

Development of a pre-burn routine happens over time as volunteers grow accustomed to each other and learn what has to happen before any fire can be lit. In an attempt to shorten that learning curve, these are standard pre-burn tasks:

1. Skid sprayers and pumper trucks loaded with water, fueled and tested, as soon as they arrive.
2. Drip torches fueled.
3. Radios distributed.
4. Map and planning conference conducted; assignments made.

A worthy goal to strive for is that no more than an hour elapses between the scheduled time of the crew's arrival and the setting of the first fire.

At last we can consider conducting the burn. There are essentially two tasks of prescribed burning: making the fire go where you want it to go, and making the fire stop where you want it to stop. As my old football coach used to say, "There's only two sports worth playing – offense and defense."

Fire offense is about speed and aggressiveness. Fire defense is about slowness and caution. Peak fire efficiency is achieved when the proper balance is struck between speed and caution.

Association burning as it is practiced on the Edwards Plateau involves a mutual partnership of two groups – landowners and agency personnel (NRCS, Experiment Station, Extension Service, etc.). This is a necessary and precious working relationship. However, it is worth noting that the highest priority of prescribed burning for one group is not an exact match with the highest priority of the other. From the landowner's viewpoint, the aim of a prescribed fire is to burn as much acreage as possible in one day. For him/her, burning day is the payoff of many months of preparation and many thousands of dollars of expense. He is aware that changes in future weather may seriously alter or halt burning operations for the season. He would like to avoid, if at all possible, the unseemliness of having to ask volunteers to spend another of their days helping him to burn. So the landowner is inclined to take an aggressive approach to burning. From the agency person's viewpoint, the highest goal of a prescribed fire is to avoid a breakout. If a prescribed fire gets away on an adjoining landowner's property, this would result in severe repercussions at the time of his/her job performance evaluation. So agency personnel are inclined to take a cautious approach to burning. This tension may in the end bring about a healthy result – the balance of speed vs. caution required for peak fire efficiency. Tension does exist and can make for some interesting discussions during the course of a burn.

Four additional points regarding burn efficiency are worth noting. One concerns the noon meal, which is an important social highlight of an association burn. This meal is about all the pay that the volunteers get for their day's work, so it must be provided by the landowner hosting the burn. For good fire efficiency, the meal needs to be portable and it needs to be quick.

The second point involves drip torch fuel. Plenty of torch fuel needs to be available with ignition crews. On a number of occasions, just as an ignition crew is gaining momentum, the whole operation has to shut down for half an hour or more while one person drives back to headquarters to mix more torch fuel. Meanwhile, daylight is burning instead of pasture. Support vehicles carrying 10-12 gallons of torch fuel should accompany every ignition crew. These supplies of fuel should be replenished before they run out, not after, so the momentum of burning is not lost.

The third point involves the problem of keeping volunteers (fire crew) doing what they are assigned to do; for example, leaving their post without informing the fire boss is not good fire line etiquette. This rarely happens but it has, and when it occurs, it has the potential to result in a crisis situation. It is important for all of the volunteers to understand that only one person can act as the fire boss and that the fire boss is responsible for coordinating the fire crews, checking out all equipment, checking weather conditions, notifying the proper authorities, and directing the overall management of the fire. Teamwork and communication between the fire boss, the fire crew, the landowner, and the relevant authorities is essential for a safe and effective burn.

The fourth point involves the follow-up policing of the burned area after everyone else has gone home. This is the responsibility of the land-owner and must be taken seriously. As a general rule of thumb, short and mid-grasses do not burn very well once their fuel moisture reaches 12% (referred to as moisture of extinction). Moisture of extinction for 1-hour time lag fuels (i.e., dead grass) usually occurs when relative humidity reaches 60%. So, the landowner needs to monitor the burn into the night until the moisture of extinction is reached. Once the moisture of extinction is reached and the wind has settled, the landowner can retire for the night. However, it's important to return to the burn the next morning, especially if the humidity drops and the wind speed increases, and monitor the burn area periodically for any unsafe conditions.

Burn tactics

The following are some observations about burn tactics that are somewhat whimsical in nature and incomplete in conclusion. But it seems that a body of valuable information is emerging and will continue to emerge that will enable the development of some agreed-upon standard of prescribed burn tactics. This would be highly beneficial for the continued practice of association prescribed burning.

Conducting a prescribed burn is very akin to conducting a military battle. For the purpose of discussing tactics, let us assume that we have three units at our disposal – infantry, artillery and cavalry. Torch carriers correspond to infantry, suppression units correspond to artillery, and 4-wheelers correspond to cavalry. These units perform three distinct functions in the course of a burn. Torch carriers spearhead the offense, suppression units anchor the defense, and 4-wheelers primarily gather and report intelligence (though they may have offensive and defensive functions as well.).

Using this imagery, two tactical doctrines come to mind:

1. Never send out infantry without close artillery support.
2. Cavalry should be mobile, not stationary.

Four-wheelers are an extremely versatile tool in the conduct of a prescribed burn. As mentioned, in certain circumstances they are useful offensively in igniting fire; and they are handy defensively in suppressing spot fires, if equipped with small sprayers. But the function 4-wheelers are most suited for is patrolling the fire line, scouting for breakouts. If 4-wheelers are available, they should ordinarily be in constant motion as long as the fire is active, utilizing their greatest strength, which is mobility.

It is our hope that these rudimentary tactical observations will spur continued discussion and result in a more complete manual of tactics for use by all prescribed burn associations.

Meanwhile, we learn as we burn. "Happiness is smoke on the horizon".

Literature cited

Taylor, C.A. Jr., 2005. Prescribed burning cooperatives: Empowering and equipping ranchers to manage rangelands. Rangelands. February:8-23.

Table 1. Edwards Plateau Prescribed Burning Association, Inc. Guidelines (approved 1997)

1. Dues - $25.00/rancher/year. Income will purchase, repair, and maintain equipment and support activities such as newsletters.

2. Fire Training Education – Members should attend a burn school to learn the basics of prescribed fire and receive training on how to operate equipment.

3. Fire plans – Prescribed fires will have burn plans prepared by the rancher and reviewed by Edwards Plateau Prescribed Burning Association, Inc., (EPPBA).

4. Personnel – A critical number of trained personnel will be determined for each burn. The number will depend on the size and complexity of the prescribed burn as described by the prescribed burn plan.

5. Liability – Each rancher will be liable for fires on their property. Proof of insurance is required before the EPPBA will be able to assist on the burn.

6. Fire lines – Each landowner is responsible for preparing their own fire lines. Fire lines will be inspected before the initiation of the prescribed fire and should meet specifications outlined in the burn plan.

7. Equipment – Use of EPPBA equipment will be available to all association members.

8. Fire boss – Each rancher will be the fire boss on their own property unless other arrangements are made.

9. Participation – Members are encouraged to help on as many burns as possible. Participation provides members with fire-line experience, helps them become aquatinted with other members with the same goals and objectives, and builds an experienced team. Participation is recorded for each burn. Exceptions are made for members not physically able to actively participate on burns.

    a. Officials – Only ranchers can serve as officials for EPPBA (no agency personnel are allowed in an elected, official capacity).
    b. All agency and university personnel are encouraged to be members of the association and provide technical advice and assistance.

INTEGRATED BRUSH MANAGEMENT SYSTEMS: ENHANCING ADOPTION BY STAKEHOLDERS

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Abstract: The principles and processes of Integrated Brush Management Systems (IBMS) have application in areas where brush tends to become the dominant vegetation on rangeland following transition from a grassland or savanna domain. A logical question of resource managers should be, "what is the most efficient way to manage brush, taking into account the long-term biological, ecological, and economic consequences of my decisions." It is our opinion that such decision processes are best applied via the systematic, integrated planning and implementation process embodied in IBMS.

Introduction

Shrublands in Texas and in other rangeland areas of the world are often "steady state" ecological systems which resulted from alteration of the disturbance regime that produced the previous steady state systems of prairies and savannas, best illustrated by Archer (1989) (Fig. 1). In thick stands, brush can be a major deterrent to optimizing production from rangelands, whether objectives are for livestock production, wildlife habitat, water yield, recreation, or combinations of these and other uses. Conversely, brush is an economically and ecologically important component of rangeland habitat and should be considered in brush management decision processes to capture the benefits of species diversity and the physical and nutritional contributions of woody plants. After the "threshold" of transition from grassland to shrubland has been crossed, management objectives for reversal of woody plant dominance requires energy inputs via mechanical, chemical, biological, fire or combinations of these treatment alternatives – brush management.

There is no single, "silver bullet" answer to brush problems. Differences in resource potential and degree of emphasis on each rangeland product may vary widely between ranches and even between pastures. Thus, it is unlikely that generalized "prescriptions" are a viable approach, or that any 2 brush management programs should be exactly the same. There is no single "best" brush or weed management strategy for everyone. Management strategies may vary among pastures or ecological sites within a pasture because of inherent differences in the soils, species composition, canopy cover, or density of the brush component. Strategies may also vary among ranchers with similar brush problems because their management objectives, goals, and capital or labor resources differ. Moreover, the judgment of economic efficiency applied to brush management programs has mediated in recent times, with more emphasis placed on “benefits” that are less tangible than direct monetary benefits, but that still fulfill the stakeholder’s objectives, such as recreation and water yield (Ueckert and Hamilton 2004).

More than ever before, woody plant management must be carried out with a sense of importance and care for the immediate as well as the future welfare of the range habitat (Scifres and Hamilton 2003). Fortunately, much has been learned, especially during the past quarter century, about habitat management. For example, the dogma that any brush control is negative for wildlife habitat has given way to the understanding that vegetation can be managed in ways that are simultaneously positive for wild and domestic animals, as well as other uses.

Evolution of the IBMS concept

It is important to differentiate the term "brush management" from brush “eradication” or brush “control.” During the 1940s and early 1950s, researchers working on the brush problem proposed brush eradication. It soon became obvious that this goal was overly optimistic when attempted on stands of woody plants under field conditions. It was especially improbable when addressing mixed-species stands. Eradication was soon found to be an economic, if not biological, impossibility. Moreover, the concept of eradicating any plant species implies that it has no value – an obviously shortsighted and uninformed view (Scifres et al. 1985).

The concept of brush control, i.e., very high levels of control on targeted areas, became a philosophical alternative to brush eradication in the mid-1950's. While brush control remains a necessary part of brush management, 2 major shortcomings of this concept were a continuing failure to recognize the value of woody species and to look beyond the success of the initial treatment.

The concept of brush management evolved in the mid-1960s, but took more than another decade to fully recognize the potential values of woody plants in range management. This recognition was closely tied initially to realization by range researchers and managers in Texas that wildlife represented a viable economic entity and that management objectives should accommodate wildlife habitat needs.

Many woody plants, forbs, and cacti are important for food and cover for the array of game and non-game wildlife species which are important sources of ranch income (Inglis 1985, Nelle 1997, Rollins 1997). Currently, non-game species, such as the golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapillus*), and water quantity and quality are driving large-scale brush management projects in Texas. As values shifted, managers sought ways to manipulate woody plant stands to optimize the values of their rangeland resources for multiple use (Scifres 1980). This led to the understanding that resource goals for multiple uses could be best achieved by systematic application of technologies over relatively long-term planning horizons – by implementing *integrated brush management systems (IBMS).* These brush management systems taken to their logical end point became integrated, whole ranch resource management systems (Scifres and Hamilton 2003). The basic elements of the IBMS planning process are presented in Figure 2.

Land use and setting management objectives

The initial step in the IBMS planning process is to develop broad, generalized objectives that define the long-range goal for the rangeland or ranch resources. The setting of more specific objectives should follow a comprehensive inventory of the soil and vegetation resources and projected responses from the interactions with livestock, wildlife and other related enterprises. Each alternative treatment or combination of treatments may differ significantly in capital requirements, land appearance following treatment, follow-up maintenance requirements, and predicted economic performance.

Resource inventory

Accurate comparison of alternative practices for IBMS requires that resource potential and present state of the range be measured. The first step in this process is to conduct a comprehensive analysis or inventory of the resources.

Brush species differ in their value to planned range uses, response to control treatments, and relationships to potential production of the different kinds of land involved. Areas of the landscape with different production potentials are known as ecological sites. The level of increase in yield that can be projected from treatments in relation to costs will influence treatment selection because production potential varies among ecological sites (Scifres et al. 1988). Therefore, a survey of ecological sites is an essential element of the inventory process. The "state and transition" models contained in ecological site descriptions help decision-makers identify potential plant communities and the pathways that lead from and to steady ecological states (Figure 3).

Resource inventory should provide an accurate picture of brush species composition. In multi-species brush stands, measurement of the amount of each species by survey methods, such as canopy cover or density, will show the contribution of each species to the overall population and aid in the selection of practices necessary to reach management goals. Line transects are a common field method for estimating total woody plant canopy cover and cover by individual species. Density of woody plants can be determined by counting plants within a measured land area. Both density and canopy cover can be estimated using "belt" transects that include area. Other measures of the brush complex important in selection of treatments should include average height and stem basal diameter for the dominant (target) species.

Armed with this specific knowledge of the woody plant composition and spatial attributes, it is possible with digital images to create precise maps for brush management treatments using GPS and GIS. Coordinates for specific location of treatments can be programmed into GPS units carried in aircraft and on tractors to allow operators to develop "sculpted" brush management on landscapes that optimize habitat (Rollins et al. 1997).

In general, brush management practices change the character of the habitat by altering relative proportions (botanical composition) of plants, as well as their height, density, canopy cover and relative availability for use by animals. The inventory makes another important contribution. Appropriately matching resource capabilities and limitations with objectives based on information learned in the inventory reduces costly economical and ecological mistakes. For example, the manager/owner might learn he(she) cannot do what was originally intended with the resources and that he (she) must re-examine and refine the specific management objectives.

Selection of treatment alternatives

After the resources have been inventoried and assessed and the management objectives have been formulated, the next step is to select the initial (reclamation) and follow-up (maintenance) brush management treatments that will be considered as potential alternatives. Excellent overviews of the arsenal of mechanical, chemical, biological, or prescribed burning methods have been presented by Valentine (1971), Scifres (1980), Welch et al. (1985), Welch (199l), Scifres and Hamilton (1993), Ansley et al. (1997), Koerth (1997), Taylor (1997), Wiedemann (1997), McGinty and Welch (1995), McGinty et al. (2000) and recently summarized and refined by Hamilton et al. (2004). The resource manager should objectively evaluate all potential treatments based upon: (1) biological effectiveness; (2) characteristic weaknesses; (3) expected treatment life and forage response; (4) application requirements and practicality for the particular situation; (5) the density, age, and size of the specific brush problem being considered; (6) the re-sprouting ability of the target brush species; (7) the degree of selectivity needed; (8) secondary effects that could create new problems; and (9) their maintenance requirements (Welch et al. 1985, Whisenant 1997). Therefore, it is critical that those planning IBMS understand growth habits, mechanism of reproduction, and responses to the treatment alternatives of the target species and other plants that will be impacted.

The process of selecting treatment alternatives is facilitated by the Expert System for Brush and Weed Control Technology Selection (EXSEL) (Hamilton et al.1993), which is available for use free of charge on the internet at http://cnrit.tamu.edu/rsg/exsel/ or http://cnrit.tamu.edu/cgrm. This science-based program is "user friendly" and is updated regularly as new technology develops. EXSEL allows the user to pick a target brush or weed species, and then asks the user for specific information which would be available following a resource inventory. With a click on the "submit" button, a list of treatment alternatives is available, complete with information on expected response in brush regrowth, forage production, treatment life, and strengths and weaknesses of the treatments. Instructions are given on herbicide rates (for broadcast sprays) or concentrations (for individual plant treatment sprays), timing of spray applications, etc. The system will indicate whether prescribed burning is a viable option based on fuel load, continuity and distribution. EXSEL's "Ranch Checklist for Prescribed Burning", that will help the user plan, organize, and control a prescribed fire and control grazing on the burned area, can be downloaded and printed (Ueckert and Hamilton 2004).

After EXSEL has been used to select the technically appropriate initial (reclamation) treatments for the target species, the user can simply go back through the procedure and ask for the treatment alternatives for maintenance control to be used over time following the initial treatment. EXSEL is highly recommended to anyone planning to manage brush and weeds, and especially those who lack experience in brush and weed management. Very useful decision-aid flow charts have also been developed for mesquite (*Prosopis glandulosa* var. *glandulosa*), twisted acacia (*Acacia schaffneri* var. *bravoensis*), huisache (*Acacia smallii*), Macartney rose (*Rosa bracteata*), pricklypear (*Opuntia* spp.), and juniper (cedar) (*Juniperus* spp.) by Hanselka et al. (1996).

Recognizing the need for long-term planning horizons

The effective treatment life of many traditional brush control practices is too short to pay back the investment (Whitson and Scifres 1981, Hamilton and Conner 2004). Early brush control efforts were often approached as one shot (i.e., “single treatment”) "cure-all" solutions. There are millions of acres of rangeland on which brush control was applied that currently have regrowth infestations equal to or exceeding the problems caused by the original stand. In many cases where the least effective treatment alternatives were applied, biological and economic benefits of brush management efforts were lost within 3-5 years after treatment. Even the most effective, high-cost treatments seldom hold their maximum production levels more than 5 or 6 years. This problem of rapidly diminishing benefits is a major factor determining the economic feasibility of brush control and is of concern to many producers, particularly those who derive a significant part of their total income from the resource. The reality is that rangeland managers should not expect to ever be “finished” with their brush or weed management program because it is not likely that the problem will be solved within one’s lifetime. Seeds of many weedy species are long-lived in the soil, and they can easily be disseminated over substantial distances by wind, water, mammals, birds, and man’s activities. Therefore, brush and weed management is a never-ending necessity and should be viewed as part of the cost of managing rangeland for multiple uses and maintaining or increasing the value of the land (Ueckert and Hamilton 2004).

Brush and weed management strategies should be long term, based on sound ecological principles, and not simply focused on “controlling” the current stand of brush and/or weeds. Furthermore, they should involve the sequential application of combinations of mechanical, chemical, biological, and fire treatments rather than repeated application of a single treatment. The sequencing of treatments should be orderly, properly timed, and complimentary or synergistic, so that the inherent strength(s) of one treatment offsets the characteristic weakness(es) of the other treatment(s) (Scifres et al. 1985, Ueckert and Hamilton 2004).

Extending initial treatment benefits

One approach to extending the effective life of a brush management treatment is to periodically apply low-cost, secondary (follow-up) treatments that maintain original treatment effectiveness through a time period adequate for profits to be returned. There may be several possible alternatives for application of follow-up practices. Plans should include treating brush when it is in the most vulnerable stage and with practices that are ecologically sound and economically efficient. This usually means when brush is at low densities (number of plants per acre) and small in size. Densities of 300-400 plants per acre of several problem brush species can be effectively (greater than 90% mortality) and economically (less than $30 per acre) controlled with the popular "Brush Busters" individual plant treatment methods (McGinty and Ueckert 1999, McGinty and Ueckert 2001)

IBMS is based on the premise that an advantage can be gained by long-term planning of both the initial and maintenance treatments and by utilizing treatment combinations. Careful planning of IBMS includes selection of maintenance practices that compliment the initial treatments. Some treatment combinations are synergistic, that is, they result in greater range improvement than would be expected based on the performance of either treatment when used alone. This also provides an opportunity to capitalize upon the strengths of one practice to overcome the weaknesses of another. Essential to capturing these synergies is an understanding of the capabilities of each tool and then building a context—a plan—for achieving their best management use. These plans incorporate habitat potential and the dynamics of weather and economics. Such plans should be developed with the understanding that every available tool potentially may have a place in a long-term scheme to achieve the stated objectives (Scifres and Hamilton 2003). These are the elements of an IBMS. This type of planning produces treatment sets of technically feasible, alternative approaches to long-term brush management. The sets may be combinations of the same or different initial and follow-up treatments designed to overcome the brush problem—most often the sets will vary among ecological sites. The IBMS process requires that the entire system, including maintenance, be planned and analyzed prior to any treatment application.

Another important consideration of IBMS is that ultimate effectiveness of any brush management program will be influenced by the effectiveness of other land management practices. For example, the potential effectiveness of brush management may not be achieved if grazing management strategies are inadequate in intensity and timing.

Prescribed burning and IBMS

The focus of this symposium is prescribed fire for wildlife habitat. Prescribed burning to improve native rangeland for multiple uses has increased in popularity in the U.S. over the past 3 decades (Scifres and Hamilton 1993) and is frequently included in IBMS. Burning in sequence with other practices as part of a treatment combination is often the most economical maintenance method available to land managers. Depending largely on the amount and continuity of fine fuel to carry a fire, the type of fire (dormant-season versus hot, summer burns) and the environmental conditions at the time of the burn, the cover of most woody plants may be significantly reduced for the first year following burning. However, on *Prosopis, Acacia* and other resprouting species fire acts only as a top removal practice. Such troublesome woody plants resprout quickly from basal buds and regrowth rates are rapid, with several species recovering to 50% of their pretreatment height in the first postburn growing season (Hamilton et al. 1981, Hamilton and Scifres 1982). Rapid recovery of woody plants following burning can quickly diminish the positive response of the treatment unless additional burns or other follow-up practices are utilized.

The suppression of fine fuel growth and accumulation by dense infestations of woody plants often relegates prescribed fire to a role of maintaining the response from an earlier brush management treatment on many rangeland areas. Box et al. (1967) found that fire was more effective on areas where large mottes of brush had first been knocked down by mechanical means. The reduction of brush cover by chopping or shredding 3 years before the fire allowed grass and forbs to grow in the mottes, thus providing fine fuel and the potential to use fire.

An important exception to fire being effective only as a follow-up rather than an initial treatment is the use of summer burning for control of heavy Ashe juniper (*Juniperus ashei*) stands in the Edwards Plateau of Texas. Summer burns under conditions favorable for carrying crown fires are effective for high levels of mortality of Ashe juniper, even large, mature trees (Taylor 2004).

Effective prescribed fires can negatively impact screening cover for wildlife, albeit for a brief period in many cases. Springer (1977) found that although burning reduced brush cover, especially following mechanical or herbicide treatments, it also increased the nutritive value of browse plants. Increased browse availability and quality can benefit both livestock and wildlife.

Fire is one of the most effective habitat management techniques and is the oldest and least expensive option available. Fire can benefit deer by increasing palatability, utilization, availability, and nutrient levels of forage plants. It removes accumulated litter, exposes the ground and allows granivorous wildlife access to seeds (Fulbright and Taylor 2001). Rasmussen et al. (1983) reported increased crude protein and phosphorus levels in huisache (*Acacia smallii*) plants that were burned compared to unburned plants during the first 6 months after burning. Burned huisache plants produced about 6 fold more "browseable twigs" than unburned plants. These same authors concluded that huisache plants could be maintained in a low-growing bushy state by burning at 2-3 year intervals.

Discontinuities in fine fuel loads are almost certain in large areas of native rangeland that are planned for prescribed burning (Welch et al. 1985). Wildlife managers typically like the mosaic of vegetation effects that result from burns in areas with fine fuel discontinuities, commonly referred to as “patchy burns”. This variation is often desirable relative to quality wildlife habitat because it promotes greater vegetation diversity (Scifres 1980, Guthery 1986). Steuter and Wright (1980) suggested that deer would benefit most from small, hot burns within brush-dominated habitats. This scheme would increase forbs and valuable browse regrowth while maintaining security cover.

It is well known that deer heavily use burned areas, especially in early spring when succulent forb growth is available. Burning can also reinstate forb populations on areas where repeated applications of herbicides have reduced forb abundance and growth (Scifres 1975), thus promoting nutritional benefits to wildlife. Hamilton and Scifres (1982), like other researchers, observed that bundleflower (*Desmanthus* spp.), a nutritious legume, dramatically increased following cool-season burning.

Prescribed fire has been described by those familiar with its use as "hamburger helper", in that it makes an initial brush treatment go further and exhibit more favorable end results. Part of this synergism from fire coupled with initial mechanical or herbicide treatments is maintenance of woody plant cover at levels suitable for achieving management objectives and providing the longevity of woody plant control needed for economical brush management. All of the above are good reasons why prescribed fire is a significant component of IBMS.

Grazing management

Improper grazing, combined with inadequate follow-up treatments, has been a leading cause for failure of brush management – IBMS is no exception. Grazing management largely influences post-treatment response and the time required to obtain both ecological and economic benefits of brush management. Grazing deferments are particularly critical when using prescribed fire to provide adequate preburn fine fuel, as well as posttreatment recovery after burning. Some grazing systems accommodate such deferment periods better than others. For example, one-herd-multiple pasture systems are well adapted for deferring areas from grazing use during critical periods associated with brush management. Year-round grazing use will often constrain post-treatment response even at low stocking rates, particularly when only a portion of a pasture is treated and livestock concentrate on the post-burn forage resources.

Grazing systems are generally classified into 2 major categories. One category includes those systems where livestock occupy more than half of the land at any point in time and where the grazing period exceeds the rest period in each pasture in the system. These systems are often referred to as rotation deferred grazing systems and feature the deferment of each pasture in the system at a different period of the year until the cycle of deferments is completed and starts again. Examples of rotation deferred grazing systems commonly used in the southwestern U.S. include those with 4 pastures and 3 herds, known as the Merrill System, 3 pastures, 2 herds, and 2 pasture - 1 herd, or switchback systems.

Short duration grazing (SDG) systems are also popular in some rangeland areas. In these systems the livestock are on less than one-half of the total area in the system at any point in time and rest periods are longer than grazing periods. There are generally 2 subclasses of short duration systems. Intensive SDG, or rapid rotation systems, are those in which graze and rest periods are relatively short, perhaps grazing periods of 3-4 days and rest periods of 45-60 days.

Extensive short-duration grazing systems, also known as HILF, or high-intensity, low-frequency systems, may feature grazing periods of 14-30 days and rest periods of 3-6 months. There are, of course, many variations of these systems that grade from one to the other. The intensive, rapid rotation systems normally include special fencing configuration, commonly designed as a "wagon wheel" with a central watering facility and multiple (perhaps 12-30) pie-shaped paddocks radiating from the center. All of the above described types of grazing systems will fit into IBMS and should be developed as an integrated part of the planning process.

Wildlife habitat considerations

On rangeland with quality wildlife habitat, and with sufficient planning and marketing, income from hunting leases can be substantial and exceed that from livestock enterprises (Inglis 1985). Consequently, if a ranch firm plans to derive income from hunting leases, wildlife habitat concerns must be addressed during the planning and implementation of brush management strategies (Holechek 1981). Economically important game animals, such as white-tailed deer (*Odocoileus virginianus*) and upland game birds require certain amounts of brush for escape, screening, or thermal cover. However, excessive brush cover suppresses production of forbs, browse, and grass for game and livestock. Anyone planning brush management should learn to identify plants that are important habitat components and utilize selective brush control treatments to the maximum extent possible on sites where these plants occur in limited abundance (Nelle 1997).

An important habitat requirement for white-tailed deer is a mosaic of screening cover – brush distributed and structured so deer can break visual contact with perceived danger within a few seconds. Ideal screening cover has a thinned quality compared with most brush that would likely be targeted for treatment (Inglis 1985). Areas retained for screening cover should have grass and forb ground cover and browse at deer height so food supplies for deer are relatively abundant within the screen. Brush density and canopy cover in areas retained for screening cover should be sufficient to allow the deer to disappear when at about 50 – 75 yards within the screen. These habitat requirements should be addressed in the IBMS planning process.

An innovation in the use of herbicides on rangeland (and one that also has application with mechanical treatment or combinations of chemical, mechanical and prescribed fire) is variable rate patterning (VRP) and it illustrates land-use interactions in IBMS. To create a VRP using herbicides, an area would be treated with one-half of the recommended rate of application in alternating strips with untreated strips in perpendicular directions. This creates a pattern with blocks receiving no treatment, blocks receiving one-half the recommended rate of application, and and blocks receiving the full recommended rate. The varying application rates create a mosaic of different brush/grass/forb/cactus patterns on the landscape and much greater habitat diversity than the untreated areas.

Assuming that there is an effective herbicide or combination of herbicides for the major brush species, VRP will result in a vegetation mosaic with:

(1) areas that received no treatment that become "islands" of brush and provide heavy cover screen and shade;

(2) areas that received the full recommended treatment and become grass-dominated blocks; and

(3) areas that received the one-half rate that are patchy, have improved grass cover, and with those brush species remaining that are least susceptible to the herbicide (Scifres and Koerth 1986, Scifres and Koerth 1989, Scifres and Hamilton 1993).

Prescribed burning can be used within the VRP to improve the vegetation mosaic over time.

Some broadcast mechanical treatments, such as root-plowing, totally remove screening cover, but the soil disturbance promotes growth of forbs. Other mechanical practices, such as shredding, stimulate regrowth of palatable browse for deer. Chemical brush treatments can be more extensive (i.e. wider strips) because the standing dead (or partially killed) brush canopies serve as cover screen. Herbicides temporarily suppress forbs, but this is often followed shortly by a flush of low browse and forbs. Major drainages, which support taller woody plants and good diversity of grasses and forbs, should be dealt with carefully, because these sites are preferred by deer for midday loafing and bedding. Brush treatments such as selective thinning or segmented clearings should be considered for these areas. One or 2 brush thickets of several acres in area per square mile should be retained for escape cover for mature bucks. Grazing management which promotes improved range condition and increased plant diversity reduces the potential for competition between deer and livestock and favors the stability of deer forage. Information on integrating deer habitat concerns into brush management strategies have been presented by Inglis (1985), Richardson (1990), and Fulbright (1997), and Fulbright and Taylor (2001), and Rollins and Cearley (2004).

Guidelines presented by Guthery and Rollins (1997) for planning brush management for bobwhite quail (*Colinus virginianus*) included: (1) no point in the pasture should be more than 25 yards from woody cover (50 yard spacing between woody cover); (2) no more than 90% of a pasture should be treated; and (3) brush areas retained for quail should be about 75 square feet in area. Inglis (1985) felt that woody cover retained for escape and loafing cover for quail could be spaced 200 yards apart because the birds would never be more than their flight distance (100 yards) from escape cover. Other guidelines for managing brush for upland game birds include: (1) retain mottes of brush, rather than isolated single plants; (2) retain patches of taller, mature brush for animals to use to escape the heat; (3) preserve wild turkey roosts, such as tall oaks (*Quercus* spp.) and pecan (*Carya illinionensis*) trees and travel coorridors (strips of woody cover) radiating from the roosts; (4) identify and preserve "honey holes", such as sand plum (*Prunus gracilis*) and chittam (bumelia) (*Bumelia lanuginosa*) thickets (Guthery and Rollins 1997).

Economic analysis

The IBMS planning process also includes analysis of the financial considerations associated with the program. This includes determining the time period in which the investment in brush management is to be recovered and an acceptable rate of return on investment. Decision-makers should select a discount rate that considers opportunities for alternate investments, such as long-term certificates of deposit, municipal bonds, etc., as well as a risk factor associated with brush management compared to alternate opportunities. Both the costs of implementing the brush management program and the expected benefits must be obtained for the economic analysis.

Estimates of costs (labor, equipment rental, contractor charges, herbicide, equipment, etc.) required to implement the management strategies will be fairly easy to obtain, while post-treatment benefits are more difficult. Increased revenue will be based upon the expected forage production response to the treatments as this affects livestock carrying capacity, reproductive efficiency, the number of game animals that can be harvested, the price that can be charged for lease hunting, etc. Reduced costs for labor and supplemental feed that might occur after brush control should also be estimated. These "response curves" can be constructed to show the differences between treated and untreated areas over the planning period. Landowners will usually need assistance from qualified state or federal agency personnel or consultants to develop these curves for the economic analysis (Ueckert and Hamilton 2004).

The nature of brush management and animal production imposes time constraints on investment recovery periods. Most analyses of brush management systems should use no less than 15-year planning periods. This is because production increases seldom offset costs of the initial investment and added cost (e.g., livestock added to capitalize on forage increase.) until the maintenance period – that time period where production benefits are held near optimum with low-cost secondary treatments. For example, prescribed burning can be used to extend the life of initial treatments and allow more years of higher income potential. Many other maintenance practices, such as low-energy grubbing, goating, and individual plant treatments with herbicides, can help achieve this objective.

A hypothetical response curve showing the response of a brush infested area to no treatment, an initial treatment (a) and maintenance treatments (b) over a 20-year planning period is presented in Figure 4. Such information for projected responses is not always easily obtained, but can be derived from a combination of published research and demonstrations, records of technical agencies in the area, landowner's experience, or from observations on neighboring ranches that have used similar treatments on comparable areas.

An important element of the curve is the shaded area. Benefits from initial treatment reached the highest level in years 3 – 6, but declined thereafter to year 12. Initial treatment plus maintenance is expected to stretch benefits for the period from years 7 – 20 (dark shaded area). It is this additional effective life of benefits that gives most brush management systems the ability to show financial success. Hamilton and Conner (2004) concluded that regardless of the economic environment, the fundamental concept remains – that "stretching" the benefits from high-cost, initial brush management treatments with relatively low-cost follow-up practices continues to yield a higher return on investments compared to no maintenance of initial treatments.

An additional consideration is that not applying any treatment could result in a loss of carrying capacity over the planning period, given the aggressive nature of woody plants. It is quite possible also that individual animal performance could decline and variable cost increase, thus compounding production loss. Conversely, in addition to benefits from increased carrying capacity following application of the program, individual animal performance can often be expected to increase. For example, conception rates and weaning weights may increase as a result of improved forage quality. These increases should also be projected in the economic analysis for the planning period.

Once response curves have been constructed for all viable treatment alternatives, numbers of head of livestock and animal production can be converted to monetary value for comparison of economic performance (Fig. 4). Changes in wildlife revenues or costs that are attributable to the brush management program can also be included in the analysis. A partial budget format is commonly used for this purpose. Annual net cash flows from the partial budget for each year in the planning period are discounted at a selected rate and converted to net present value and an internal rate of return on investment. Risk associated with historic variability of rainfall can also be incorporated into the economic analyses. The Ranching Systems Research Group at Texas A&M University has developed a computer program, called "ECON" that can be used to make the economic analyses essential in IBMS.

Monitoring

Monitoring is the process of making observations, gathering data, and keeping accurate records after implementation of the brush or weed management treatments has been initiated (Hamilton 1985). Monitoring provides "feedback" that allows the decision maker to evaluate progress and assess the effectiveness of applied treatments. Such feedback provides management with the basis for adjustments to the original plan of action, or, in some cases, may influence modification of the original objective. In the final analysis, monitoring activities should feed both biological and cost/income data into an economic assessment to calculate actual versus projected returns from the brush/weed management plan.

Summary

Integrated brush management systems are basically a planning process – one that identifies and analyzes alternatives for decision-makers. It provides a basis for choosing, implementing, and evaluating the actions required to meet objectives for integrated range resource use. The best plans for meeting the objectives are developed from an information base provided by a comprehensive inventory and evaluation of resource potential. Using this database, IBMS then apply appropriate technology in the development of treatment alternatives to meet management goals.

The IBMS process includes feed back "loops" (i.e., monitoring) that provide a flow of new information or perspectives to decision-makers so that objectives and plans are continually compared to projected and/or actual resource responses. Economic analysis of alternatives can be used for selecting among alternatives, but in the final analysis the decision-maker's choice for a certain program over another remains the final judgment.

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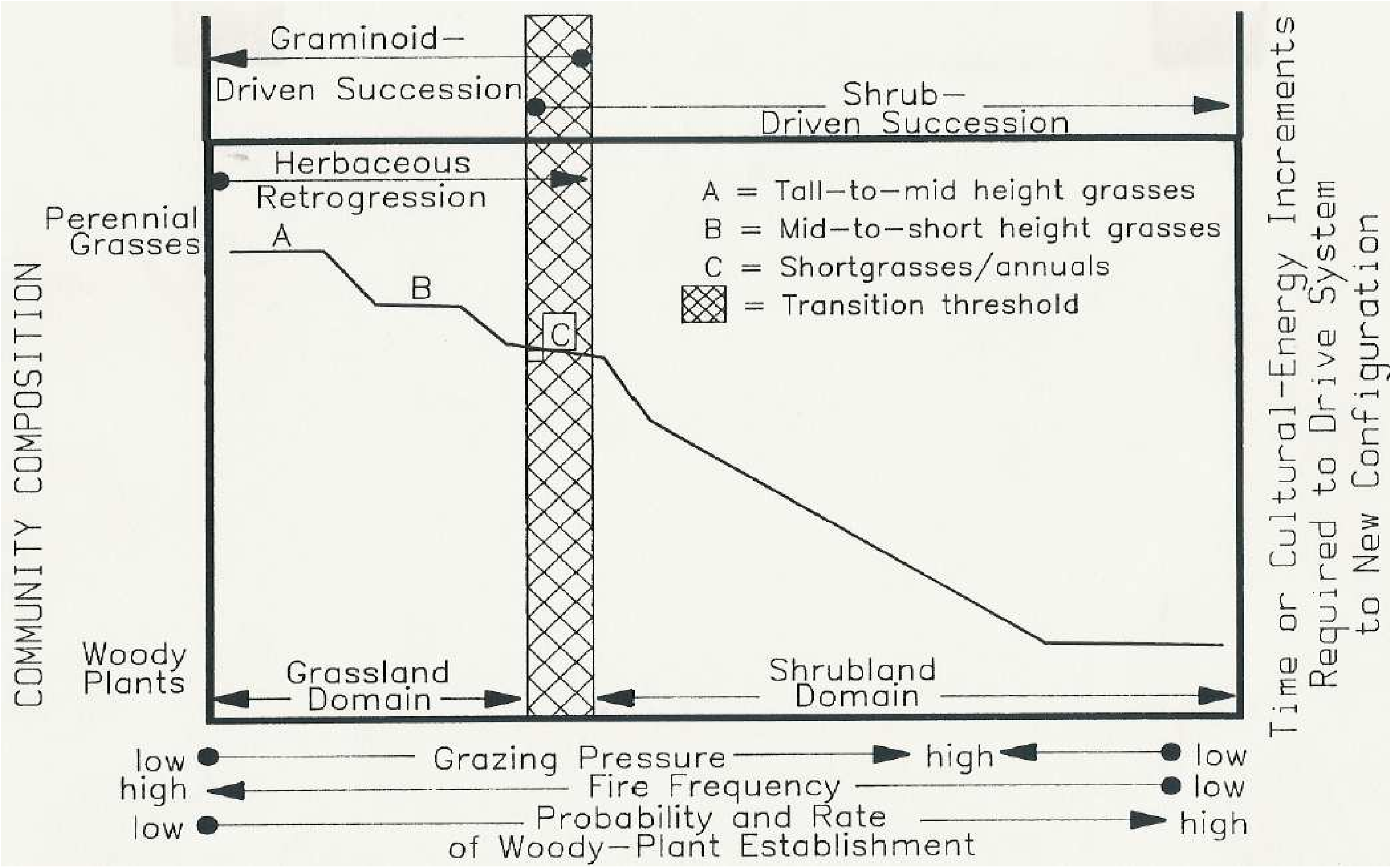

Figure 1. Conceptual diagram of threshold changes in community structure as a function of grazing pressure and fire frequency in thorn shrublands (from Archer 1989).

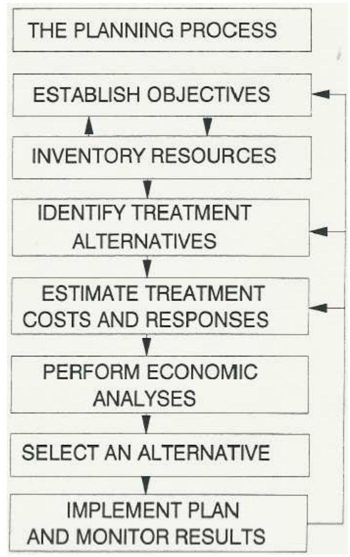

Figure 2. The IBMS planning process (from Scifres et al. 1985).

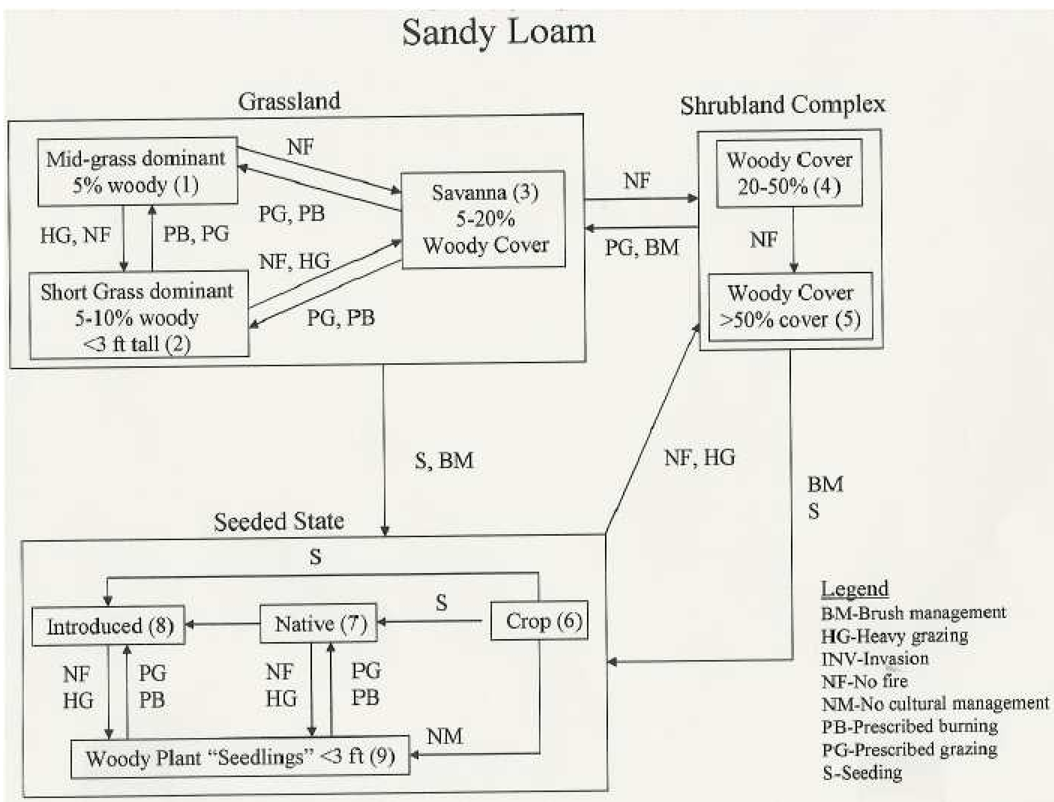

Figure 3. State and transition (S/T) model for a Sandy Loam ecological site description in the eastern South Texas Plains. USDA NRCS Unpublished data 2001. (The model is one of twenty-four S/T models developed by a consulting group working with the Center for Grazinglands and Ranch Management through a grant from USDA NRCS, Temple, Texas).

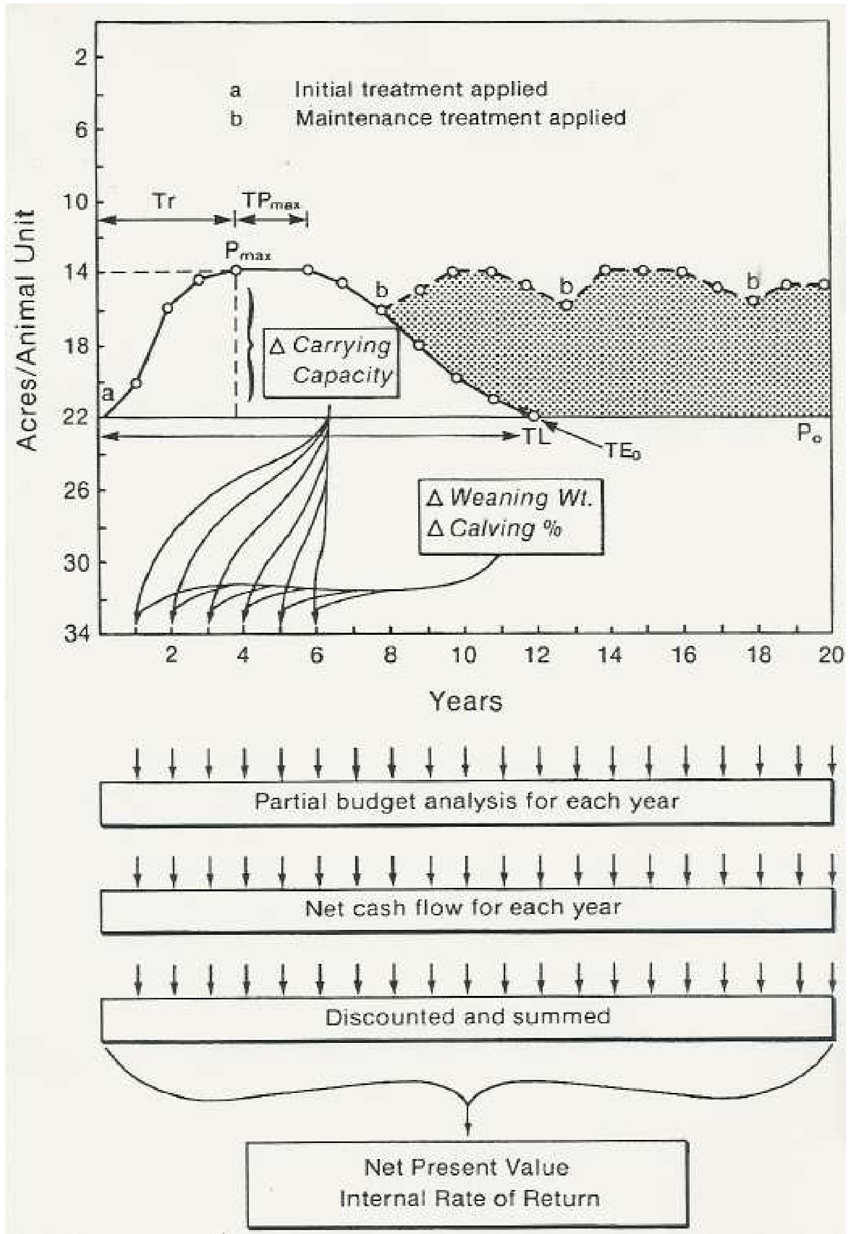

Figure 4. Generalized response curve depicting production change after an initial treatment for brush control and a series of maintenance treatments (adapted from Scifres and Hamilton 1989). Pmax = maximum production level, P_o = original production level, TL = treatment life in years, Tr = time to reach maximum production, TE_o = point in time when treatment effect is exhausted and TPmax = time for which maximum production is maintained.

A GUILD APPROACH TO THE MANAGEMENT OF GRASSLAND BIRDS

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***Abstract*:** Our purpose in this chapter is to provide a brief philosophical overview of how the guild concept can – and in some cases can't – be applied to the management of grassland birds. We point out some merits and limitations of the guild concept in the context of grassland birds while attempting to separate the political forces that are promoting application of the guild concept from the ecological relationships that the complicate applications of it. Additionally, we describe some important changing land use factors that have influenced grassland bird populations. Such factors are important to grassland bird habitat-relationships, and by extension to application of the guild concept for their management.

The researcher must clearly address the goal of the endeavor…before attempting to use guilds or indicator species for management purposes .

—Morrison et al. (1992:117)

Introduction

A paradigm shift is currently taking place in how natural resource managers view and act towards wildlife management. The days of so-called "Single Species Management" are giving way to a philosophy based on holistic management practices. Themes such as Comprehensive Wildlife Management Strategies are becoming ever more popular.

Managing entire guilds of wildlife rather than a specific species has become a politically acceptable – if not *de rigeur* – philosophical approach to management. Various approaches to wildlife management that use the guild concept have been around for nearly 3 decades (Thomas 1979, Severinghaus 1981, Short and Burnham 1982). The guild approach is appealing because the basic idea is that if the habitat needs for 1 member of a guild are met (i.e., a guild indicator) then habitat needs for other species within a guild – such as grassland birds – will also be met.

Unfortunately, in ecology, like economics, there is no such thing as a free lunch. Some of the early approaches to applications of the guild and guild-indicator concept suffered from oversimplification. Thus, critics of the guild approach have been around for about just as long (Mannan et al. 1984, Landres et al. 1988, Morrison et al. 1992) as the people who have been promoting it as a multi-species approach to management. If a guild approach to management is to be effective, habitat relationships for all species within a guild must be known. This basic tenet is often overlooked when people apply the guild concept in the context of multi-species management (Block et al. 1986, 1987, Brennan and Kuvlesky 2005).

Our purpose in this chapter is to provide a brief philosophical overview of how the guild concept can – and in some cases can't – be applied to the management of grassland birds. We point out some merits and limitations of the guild concept in the context of grassland birds while attempting to separate the political forces that are promoting application of the guild concept from the ecological relationships that the complicate applications of it. Additionally, we describe some important changing land use factors that have influenced grassland bird populations. Such factors are important to grassland bird habitat-relationships, and by extension to application of the guild concept for their management.

Politics, land use changes, and grassland birds

One political force that is promoting application of the guild concept in wildlife management is the Environmental Quality Incentive Program (EQIP). The United States Department of Agriculture (USDA) provides funding for specific areas of a state deemed to be EQIP management priorities. In the Rolling Plains of Texas, money originally was allocated specifically for northern bobwhite (*Colinus virginianus*) habitat improvement. This practice is no longer approved. The new EQIP priority in the Rolling Plains of Texas is habitat improvement for bobwhite quail ***and*** grassland birds. The practice of utilizing federal dollars to manage for guilds rather than a single species is also evident in other priority EQIP areas of Texas such as the Coastal Prairies where management focuses on the Attwater's Prairie-Chicken (*Tympanuchus cupido attwateri*) and bobwhites, and in East Texas with a focus on bobwhites and red-cockaded woodpeckers (*Picoides borealis*).

Why are state and federal resource agencies, along with non-profit conservation organizations focusing on quail and other grassland birds? The answer is that the grassland bird guild, which includes bobwhites, is declining faster than any other group of birds in the United States today (Brennan and Kuvlesky 2005). The grasslands of the United States have seen dramatic changes over the past 150 years. Conversion to agriculture, urban sprawl, exotic plants and animals, the removal of fire, and declining range conditions associated with continuous grazing have all reduced the amount and quality of our nation's grasslands.

Approximately 10,000 years ago, forested areas in the western portion of Texas receded and became grasslands (Hamilton et al 2004). Fires ignited by lightning strikes and Native Americans periodically burned throughout much of the states rangelands and helped to maintain the grassland ecosystem. Large herds of herbivores, particularly bison (*Bison bison*), ranged throughout these vast grasslands. Areas were intensively grazed and then left for greener pastures. This system of burning and grazing maintained Texas grasslands and savannahs in a mosaic of successional stages.

Around the mid-19th century, Anglo settlers began occupying Texas grasslands. These settlers established fences, converted the land to agricultural crops, and extinguished grassland fires. Around this same time, the area began to cool, providing a more favorable environment for the establishment and encroachment of woody species (Hamilton et al 2004). Human presence and actions over the past 150 years have played a significant role in advancing the rate of encroachment of woody plants and the fragmentation of rangelands and savannas.

The introduction of exotic plants has also played a role in the reduction of Texas grasslands. Exotic plants can be found in every ecosystem throughout Texas. Coupled with excessive grazing, exotic grasses have played a significant role in altering the native landscape. Excessive or heavy continuous grazing practices and the pursuit for ever higher stocking rates have lead to the formation of monocultures and have reduced the value of grasslands for the wildlife that utilize these areas. Once established, pastures of exotic grasses can be extremely difficult and expensive to return to native vegetation.

Many factors have caused North American grasslands and savannahs along with the wildlife that depend upon them to suffer significant declines. Unfortunately, few studies have closely examined the declines in both grasslands and grassland birds. However, reports like Audubon's 2004 *State of the Birds* have identified some alarming facts. This particular report found that 85% of grassland birds are suffering from ongoing population declines. More than 70% of these grassland bird species have experienced declines >45% since 1966.

Species of particular concern include Cassin's sparrow (*Aimophila cassinii*), lark bunting (*Calamospiza melanocorys*), Clay-colored sparrow (*Spizella pallida*), Henslow's sparrow (*Ammodramus henslowii*), grasshopper sparrow (*Ammodramus savannarum*), common yellowthroat (*Geothlypis trichas*), Le Conte's sparrow (*Ammodramus leconteii*), bobolink (*Dolichonyx oryzivorus*), dickcissel (*Spiza americana*), Bachman's sparrow (*Aimophila aestivalis*), and red-cockaded woodpecker. There are many other species that share similar declines to the ones mentioned above. Some of these species utilize Texas grassland and savannah habitat seasonally, while others may stay within Texas borders year-round. Therefore, there is an opportunity to provide wintering, nesting, and brooding habitat for grassland birds within Texas borders.

The factors allowing for woody encroachment are well known, though the impact to grassland ecosystems and the wildlife associated with these areas is not. There are specific habitat requirements managers can utilize to sustain diversity and the continued occurrence of grassland birds within these grassland ecosystems.

Ecology and management

Although the Texas climate ranges from sub-tropical to semi-arid, management practices used to maintain grassland or savannah ecosystems are very similar across the state. The primary difference within the climate ranges is the frequency at which management practices must occur. Historically, management occurred naturally through the grazing of bison and natural and man-made fire. These practices are still the two primary management tools for maintaining much of our Texas grasslands. However, other tools, which have become important for returning areas to grasslands, include mechanized equipment such as dozers, tractors, and skidders, and chemicals that eliminate woody and exotic vegetation. Technologies have become both a detriment to grasslands and a potential solution for restoration.

As mentioned before, grassland management practices are similar throughout the state. However, habitat in the West Gulf Coast Plains Bird Conservation Region (BCR), which includes the Piney Woods of East Texas, will require a greater frequency of disturbances such as fire and logging than will areas such as the Oaks and Prairies BCR, which include the Post Oak Savannah and Blackland Prairies of Central Texas. As management areas are located farther west, the frequency of management practices decreases because of the change in climate across the state.

Although the frequency of many management practices decreases as one moves west across the state, practices often remain similar. The use of fire, rotational grazing, removal of exotic grasses, protection of native grasses, reduction of brush coverage, and a reduction in the area utilized for agricultural production are primary means for managing grasslands and savannahs.

Much of East Texas has been converted from mature old growth pine stands to industrial forests, typically consisting of genetically improved loblolly pine trees (*Pinus taeda*) grown at high densities on short duration rotations. Areas once dominated by open stands of longleaf (*Pinus palustris*) and shortleaf pine (*Pinus echinata*), which are conducive to a savannah ecosystem, have been replaced with genetically improved loblolly pine. This type of industrial forest management reduces the coverage of native grasses and forbs by shading out the forest floor. Species including the Bachman's sparrow, red-cockaded woodpecker, bobwhite quail, and eastern wild turkey (*Meleagris gallopavo silvestris*) have suffered significant declines in the area due to these practices.

A great deal of management has taken place in East Texas and other parts of the southeastern United States to improve habitat for the endangered red-cockaded woodpecker. Habitat management generally consists of restoring longleaf pine to its historic range, reducing or removing the hardwood midstory, thinning, long duration rotations, and frequent fire. Research has shown that avian species richness and total avian abundance is greater in areas managed for red-cockaded woodpeckers compared to areas under traditional industrial forest management (Wood et al 2004). Researchers at the Tall Timbers Research Station in Tallahassee, Florida, have found that management practices aimed at improving habitat for bobwhite quail also improve habitat for red-cockaded woodpecker and increase bird species richness. Therefore, it appears that a guild approach to management utilizing practices beneficial to bobwhite quail and/or red-cockaded woodpeckers will improve habitat and species richness within the Piney Woods of East Texas (Brennan 1991).

The concept of managing for guilds of birds applies beyond the grasslands and savannahs of Texas. The fundamental needs for grassland birds consist of large tracts of contiguous habitat that undergo frequent disturbances to sustain early to mid succession habitat. The species that best fit this management scheme include the lesser prairie chicken (*Tympanuchus pallidicinctus*), Attwater's prairie chicken, and bobwhite quail (Brennan and Kuvlesky 2004). These species are of state and national concern, and are popular species with landowners. Large contiguous acres can be improved for many grassland birds by managing for these species.

Within rangeland ecosystems, the highest densities and greatest diversity of grassland birds can be found in areas with <5% woody cover. Grant et al (2004) found that species richness of grassland birds declined significantly beyond 20% woody encroachment with woody plant height being the most important factor. Unfortunately, few replications of this study have occurred.

Enter the guild concept

As we mentioned earlier, application of the guild concept to the management of grassland bird – or any other group of wildlife for that matter – must be approached with caution. Categorizing groups of species with similar habitat relationships, foraging behaviors, or some other ecological relationship that defines a guild is a convenient way of conceptualizing how nature works. This is basic community ecology, and there is vast scientific literature that describes such relationships, especially for birds (Wiens 1989a, 1989b).

However, managers need to understand that basic elements of niche theory (the competitive exclusion principle) and biogeography complicate the guild approach to management rather than simplify it. Niche theory dictates that "2 similar species scarcely ever occupy similar niches" (Hutchinson 1978:153). Basic biogeography, the study of distributions of organisms, can complicate application of the guild concept for management, even when the guild is strictly defined by an indicator species with a fairly narrow range of habitat conditions. For example, using mountain quail as a guild-indicator, Block et al. (1987), found that this species was a poor predictor of the species present in a ground-brush foraging guild across 4 sites in California. Geographic distances and morphological traits of the species in this guild showed that within-guild species composition was highly variable across these four sites (Block et al. 1991). Using bobwhites as a guild indicator for predicting the effects of management on grassland birds would be even more variable – and hence less predictable – than the mountain quail example illustrated.

With these problems and limitations noted, how then can the guild concept be applied to the management of grassland birds?

First, managers need to be aware that the guild-indicator approach will do a poor job of predicting the magnitude and extent of how various grassland bird species will respond to habitat management for bobwhites. The fact that bobwhites can thrive in grassland habitats that contain from 5 to >40% shrub canopy cover dictates that the grassland guild response will be highly variable, area-dependent on the type of habitat configurations that are managed for bobwhites. In areas with 5-10% shrub cover, open-country species will likely do well, but this will most certainly not be the case on areas with higher percentage shrub cover.

Second, managers need to be aware that habitat conservation and restoration for bobwhites will most likely benefit numerous other species of grassland birds. But, which species are affected, and how they are affected will depend on the type of management conducted, the geographical area management is conducted, among many other things.

Third, monitoring the grassland bird responses to bobwhite habitat conservation and restoration is the only way that we will be able to learn how various members of this guild respond to quail management. Thus, the guild concept is a useful way for *organizing* concepts that relate to grassland bird management in relation to quail conservation, but is it a poor tool for *predicting* actual responses of individual species to such efforts. Appreciating this difference is essential for the successful application of the guild concept in wildlife management.

Conclusion

Within rangelands, species richness of grassland birds declines sharply as tall woody encroachment increases beyond 5 to 20% (Grant et al 2004). It is recommended that management be targeted around those areas presently with ≤20% tall woody cover because these grasslands will provide the greatest response to management. Areas within the Coastal Prairies and Marshes Ecoregion such as the Victoria-Goliad Prairie, Attwater Prairie Chicken Reserve, and Mad Island fit this description. Areas within the Cross Timbers Ecoregion including LBJ National Grasslands and Caddo National Grasslands fit this description. Some areas within the Coastal Sand Plains such as the Quates and Lagunitas Pastures within the Encino Division of King Ranch and adjoining landowners to the south and east fit this description. Other areas similar to the ones mentioned, those with wide expanses of grasslands, less than 20% brush canopy, and exhibiting short brush, should have the most rapid response to management. Private landowners surrounding these and other similar areas should be given priority for grant programs such as the Environmental Quality Incentive Program (EQIP), Wildlife Habitat Incentive Program (WHIP), and Conservation Reserve Program (CRP).

Management practices that may be useful for restoring or maintaining a grassland ecosystem include rotational grazing and cattle deferments, restoration and re-introduction of native grasses, and restoration and maintenance prescribe burns. When exotic grasses are not a dominant part of a particular parcel of land, management, in theory, is quite simple. Rotational grazing and periodic fire may account for 90% or more of the needed management practices in areas that are currently ≤20% brush or tree canopy coverage.

The guild concept may be a useful tool for organizing how management for species such as northern bobwhites might influence other species of grassland birds. However, the guild approach will most likely be a poor predictor of the magnitude and extent of how specific grassland birds respond to quail management. This is because things such as niche dynamics and aspects of biogeography are beyond control of the manager. Thus, how grassland bird species respond to quail management should be documented and monitored wherever possible.

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FIRE AND GRAZING TO PROMOTE HETEROGENEITY FOR WILDLIFE DIVERSITY

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Abstract: Rangelands are highly variable in space and time (heterogeneous). This heterogeneity is an important characteristic that has been overlooked by rangeland researchers and managers. Typically, when fire and grazing are applied to pastures they are applied uniformly with the intention of reducing variability and promoting uniform forage or habitat. Multi-use and diverse wildlife populations require heterogeneity, so we need to develop management approaches that promote, rather than reduce heterogeneity. We have developed an approach that uses the fire-grazing interaction to promote spatial variability in rangelands that has resulted in sustained livestock production and wildlife diversity. We apply patch fires that attract livestock. As the patches are shifted around the landscape and grazing animals follow we are able to create a 'shifting mosaic' where the pasture includes a recently burned and heavily grazed patch, some relatively undisturbed patches and everything in between. This increased heterogeneity, increases the diversity of small mammals, grassland birds and insects.

Introduction

Fire and grazing were historically interactive in space and time creating a heterogeneous landscape that was dynamic. Research and management has largely decoupled fire and grazing simplifying our understanding of grassland ecosystems and the disturbances that are critical to their development and maintenance. As independent disturbances fire and grazing have well defined effects on different ecosystems, but when considered as a dynamic, landscape-level interaction their influences become much more pronounced. It is clear that presettlement grazing by bison and other herbivores was influential on the structure and function of many grasslands, but the recent view is that the distribution of grazing animals within the landscape was not uniform and interacted with fire and inherent landscape heterogeneity (Kay 1998, Fuhlendorf and Engle 2001, 2004). This is particularly evident when considering habitat requirements for Great Plains species that evolved with bison grazing, such as grassland birds. Species that co-exist have very different habitat requirements suggesting that disturbance patterns and the resulting habitat patterns were not uniform and diversity of grassland fauna may be dependent on heterogeneity (Figure 1) (Knopf 1996).

Management of grazing animals typically focuses on stocking rate and grazing systems, while management with fire has largely been applied to be careful not to interfere with uniform distribution of livestock. Few studies have addressed the effects of fire and grazing on heterogeneity even though grasslands evolved with spatially variable disturbance patterns. As a result most rangeland management practices (i.e. brush and weed control, fertilization etc.) are designed to increase livestock production by promoting dominance of a few key forage species and maintaining uniformity in grazing patterns (Fuhlendorf and Engle 2001). Management for uniformity or homogeneity can transform a complex, heterogeneous prairie or savanna landscape to an agricultural landscape that more resembles an introduced pasture. The only time spatially variable management practices have been recommended is for attracting livestock to lightly used or unused areas with the objective of reducing spatial heterogeneity and increasing harvest efficiency (Hooper et al. 1969, Samuel et al. 1980, Valentine 1990, Holechek et al. 1998). This usually reduces inherent heterogeneity associated with topo-edaphic features and herbivore behavior. Collectively, management practices on rangelands suggest that there is a paradigm focused on the reduction of heterogeneity. Research on effects of treatments that promote homogeneity have been extensive but much of this research indicates problems when long-term sustainability issues are considered. There is a paucity of research that has evaluated the effects of heterogeneity on rangeland productivity and diversity. It is my objective to present an alternative approach to managing rangelands that promotes heterogeneity or variability through a fire-grazing interaction that can simultaneously maintain livestock production and wildlife habitat.

An alternative rangeland paradigm: The Tallgrass Prairie Preserve

An alternative paradigm has been proposed for rangelands, which suggests land management approaches that mimic historical fire-grazing interaction and produce a shifting mosaic landscape. When fire and grazing are allowed to interact in space and time, fire and grazing are co-dependent (Figure 2). Grasslands that have not been grazed or burned in several years have a higher probability of fire and a lower probability of grazing and grasslands that have recently been burned have a higher probability of being grazed and lower probability of burning again until fuel can accumulate. The result is a shifting mosaic landscape where there is high spatio-temporal variability among patches but from a landscape perspective there is actually high stability because the landscape always includes patches that are heavily disturbed and patches that are relatively undisturbed. These patterns are as critical to the function and structure of grassland ecosystems as the species that exist in these landscapes.

In 1989, The Nature Conservancy purchased the 14,000-ha Barnard Ranch in north-central Osage County, Oklahoma and renamed it the Tallgrass Prairie Preserve. A spatially and seasonally variable prescribed burning program was initiated in September 1993 and bison were introduced to a 1,973-ha portion of the Preserve in October 1993. Prescribed burning for the preserve consists of 80% dormant-season (40% fall and 40% late spring) and 20% growing-season burns conducted randomly in a regime designed to mimic pre-European settlement burn frequency and season. Burns are conducted on patches of varying size under a variety of fuel and weather conditions with an approximate three- to five-year return interval (Hamilton 1996). In keeping with the fire-grazing interaction, bison movement and selective grazing have been unrestricted.

The randomly located burn patches within the bison unit at the Tallgrass

Prairie Preserve (Figure 4) have created a shifting patchwork of areas grazed at different intensities by the free-ranging bison herd. The result is a corresponding out-of-phase succession among patches just as the fire-grazing interaction model predicts (Coppedge et al. 1998a, Coppedge and Shaw 1998). Even though stocking rate for the entire bison enclosure is moderate (6-7 ha/AU) (Coppedge et al. 1998a), bison use of recently burned patches is heavy (Coppedge and Shaw 1998). Bison are strongly gramnivorous (Coppedge et al. 1998b), so forbs, the primary contributors to plant diversity in tallgrass prairie (Howe 1994b, Collins and Glenn 1995), increase dramatically within the recently burned patches. This increases species richness and heterogeneity in the landscape. Without patch grazing, frequent burning as practiced on ranches in the region reduces plant diversity and increases homogeneity of tallgrass prairie (Collins 1992, Collins et al. 1995).

The objective of the management approach on the Tallgrass Prairie Preserve is to increase biodiversity, but the approach may have other advantages over traditional rangeland management. First, management for heterogeneity through patch burning followed by heavy grazing has not negatively influenced bison production. In fact, bison have maintained high reproductive rates without nutritional supplementation (R. Hamilton, personal communication), a contrast to reduced cattle performance under optimal traditional rangeland management (McCollum and Horn 1990, Hughes et al. 1978). By increasing plant diversity across the landscape, bison were apparently able to select greater amounts of cool-season plants during the primary nutritional stress period of the winter dormant season (Coppedge et al. 1998b), which limits production in cattle enterprises using reproducing animals. Second, patch burning (in all seasons) followed by heavy utilization from bison has not resulted in resource degradation, but rather short-lived pulses of early-seral vegetation across the landscape coinciding with burned patches. Following heavy utilization of the burned patches by bison, ruderal plant species not preferred by bison increase in the patches, but within 2 to 3 years the matrix tallgrass species recover and differences are not distinguishable (Coppedge et al. 1998a). This differs from negative influences associated with patch degradation from recurrent patch grazing by livestock under continuous grazing (Fuls 1992) in that burned and heavily utilized patches are rotated across the landscape. The result is a shifting mosaic that includes long-term ungrazed patches and patches that have been heavily grazed following burning interspersed in a matrix of patches in various stages of successional recovery following heavy grazing that coincides with time since burning (Coppedge and Shaw 1998). This approach is counter to traditional rangeland management in that grazing distribution is maximized over several years but minimized within individual years promoting structural and compositional heterogeneity.

Applying this approach to private land management

Recently our research has focused on taking the example from The Tallgrass Prairie Preserve and developing a new paradigm for management and conservation of Great Plains grasslands that are under private management (Fuhlendorf and Engle 2001, 2004). For our study we have replaced bison with cattle and removed the random nature of fires that is employed by the Tallgrass Prairie Preserve. We set up an experimental approach that compared patch burning (heterogeneity management) with traditional management that promotes homogeneity. In the patch burn pastures, each patch was delineated at the corners by permanent markers (metal posts) to facilitate ecological monitoring, but not to interfere with livestock or wildlife behavior and distribution. Fences surround each pasture but free movement of animals is allowed. In the Patch treatment, one-sixth of the experimental unit is burned each spring (March to April) and one-sixth each summer (July to October). Application of fires within each Patch treatment pasture is in sequentially contiguous fashion to assure a three-year return interval. We have conducted studies that evaluate plant community composition, livestock production, grassland birds, small mammals and insects. Analyses of these projects suggest that the fire-grazing model is applicable to livestock production systems on native rangelands. Many of the differences attributed to bison and cattle may actually be more dependent on the fire-grazing interaction than species differences. For example, analysis of species composition in areas with spatially applied fire and grazing by domestic livestock have resulted in the same shifting mosaic that is often attributed to patterns of historic bison herds or the current Tallgrass Prairie Preserve. Focal fire and grazing reduce the dominance of tallgrasses and increase the abundance and diversity of herbaceous dicots and bare ground immediately following the fire. Following the initial focal disturbance, tallgrasses eventually regain dominance resulting in a pattern best described as a shifting mosaic where the landscape includes patches heavily disturbed with fire and grazing, undisturbed patches for several years and a matrix of patches that very in time since fire and grazing.

Analyses of grassland birds, insects and small mammals suggest that species composition of these groups also follow similar patterns. Some species prefer sites that are recently burned and grazed and others prefer grasslands that are relatively undisturbed. We now have 3 years of grassland bird data and it suggests that species diversity is as dependent on pattern of disturbance as the intensity. We have also conducted preliminary analysis of soil nitrogen availability and it suggests that tallgrass prairie is similar to other ecosystems with long evolutionary histories of grazing where nitrogen availability is enhanced by focal grazing. Nitrogen is typically a limiting resource in mesic grassland ecosystems so greater availability could enhance production and diet quality. It also could contribute to greater stability by moderating seasonal limitations in availability of high quality forage in response to the seasonal variability of fires.

Conclusions

- Rangelands are heterogeneous with variable patterns of vegetation structure and composition dependent on inherent factors such as slope, aspect, soils and plant interactions, and variable disturbance patterns from factors such as fire and grazing.
- Most management approaches on rangelands were developed under the mindset of reducing variability and promoting uniformity.

This approach to management lowers diversity and converts complex native ecosystems into land that more resemble introduced pastures.

- Traditional management has also decoupled fire and grazing. When allowed to interact they create a shifting mosaic that includes recently burned areas that are experiencing increased grazing pressure and areas that are undisturbed by fire and grazing within the same landscape.
- The fire-grazing interaction and the associated management approach of patch burning can increase biodiversity by increasing landscape heterogeneity. Additionally this can provide numerous management benefits to livestock production enterprises. Benefits include greater fuel availability, maintained production, and reduced winter supplementation.
- Recent research shows that heterogeneity is required for multiple use on rangelands, maintenance of ecological processes, and biological diversity. Management approaches that promote heterogeneity instead of homogeneity are more likely to be sustainable.

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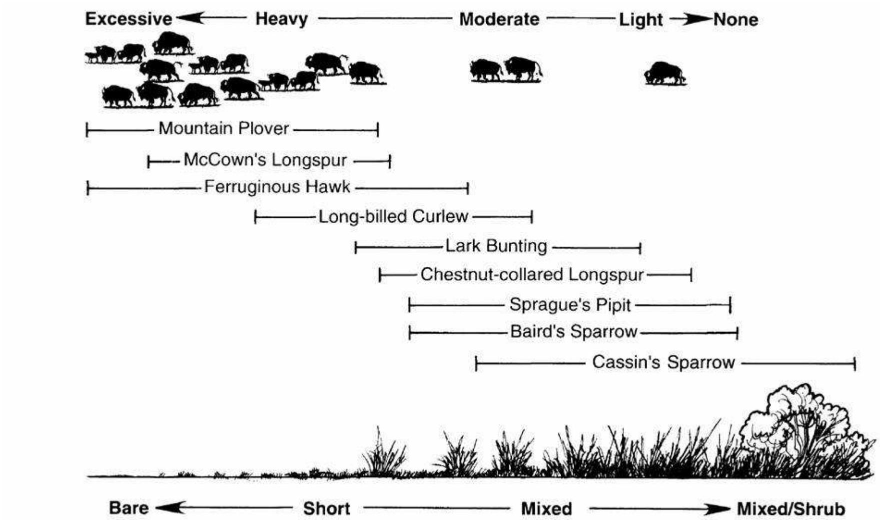

Figure 1. The response of a shortgrass bird community to changes in bison grazing intensity and vegetation structure (originally published in Knopf 1996). Different species have different habitat requirements so grazing has a positive, negative or no effect of different species. This suggests that in order to have a diverse community of birds the landscape needs to include areas that are heavily grazed, ungrazed and everything in between. It also suggests that a similar environment existed prior to settlement.

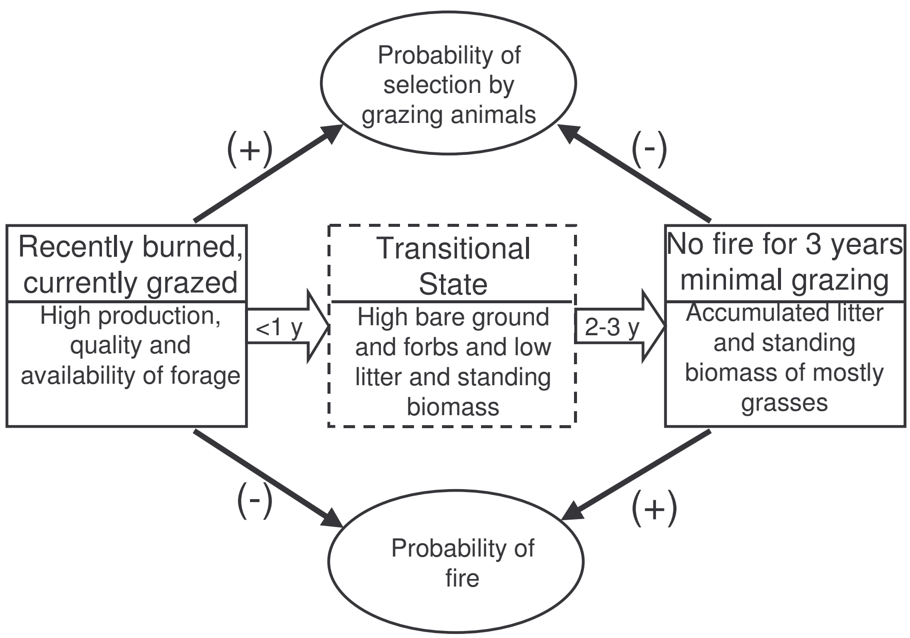

Figure 2. A conceptual model demonstrating the dynamics of a patch within a shifting mosaic landscape where each patch is experiencing similar but out-of-phase dynamics. Ovals represent the primary drivers (fire and grazing) while squares represent the ecosystem states within a single patch as a function of time since focal disturbance. All states have the potential for fire or grazing. Solid arrows indicate positive (+) and negative (–) feedbacks in which plant community structure is influencing the probability of fire and grazing (Fuhlendorf and Engle 2004).

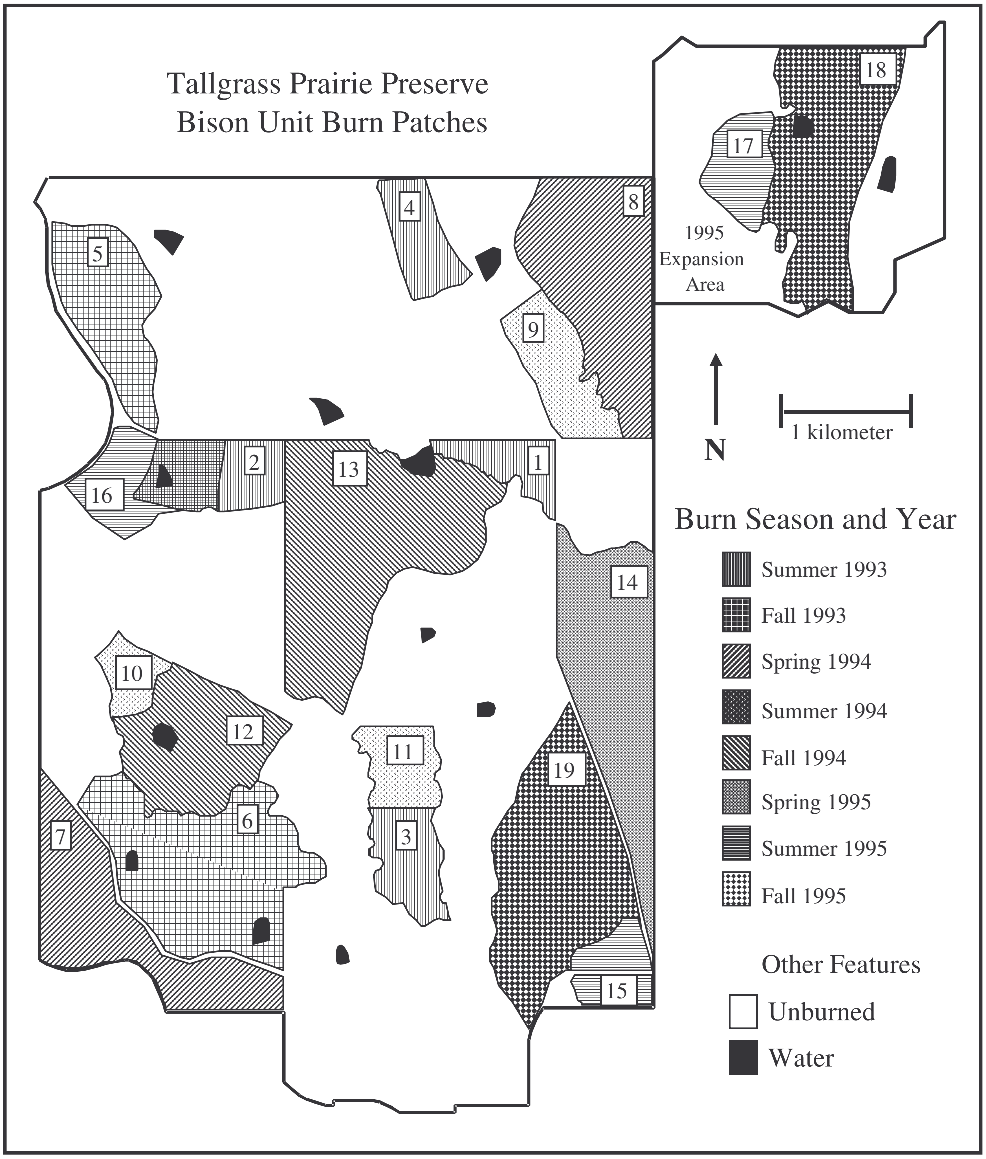

Figure 3. Prescribed fires on the Tallgrass Prairie Preserve, Oklahoma during 1993-1995. Numbers refer to the order in which burns were conducted. Bison within this area were allowed unrestricted selection of the landscape and primarily selected the most recently burned patches resulting in a shifting mosaic of patch types that were dependent upon time since fire (Coppedge and Shaw 1998).

SUMMER FIRE EFFECTS ON SOUTHERN GREAT PLAINS VEGETATION

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Abstract: This paper presents a review of responses of some of the key plant species found in the southern Great Plains and similar ecosystems to growing-season fires, referred to in this paper as 'summer' fires. Many of the studies mentioned have compared responses to summer fires and dormant season fires (i.e., 'winter' or 'spring' fires). Responses are highly variable and depend on numerous climatic and edaphic factors, as well as inherent fire tolerances within each species. In general, however, summer fires cause much greater short-term damage to vegetation than do dormant season fires. However, few species experience negative long-term effects (i.e., >5 years) from summer fires. Thus, post-burn management strategies should consider the greater delay in vegetation responses following summer than dormant season fires.

Introduction

Most prescribed fires in the southern prairie have historically been conducted during the dormant season (Feb.-March). Burns conducted during dormant season are safer and more manageable than are growing season, or 'summer' fires (Wright and Bailey 1982, Scifres and Hamilton 1993). However, there has been increasing interest in the use of summer-season fires because they have a greater ability to suppress noxious woody plants and cactus species (Ansley and Jacoby 1998, Taylor 2001, Ansley and Taylor 2004). While the potential controlling effects of summer fires on target noxious species holds promise, there is concern that summer fires may damage economically and/or ecologically important non-target herbaceous species (Bailey 1988) or drastically reduce grass production (Engle and Bultsma 1984, Engle and Bidwell 2001). Few data are available that document responses of target or non-target species in replicated studies that compare summer and winter fires against an unburned control. The purpose of this paper is to summarize the effects of summer fires on Great Plains vegetation, with particular emphasis on the southern Great Plains.

Historically, Great Plains vegetation was most probably maintained as a grassland because of the frequent occurrence of fires (Archer 1989, Van Auken 2000). This conclusion is not new and it is surprising how many early observers realized that the vast grasslands were maintained by fire and would experience woody plant encroachment if fire was removed from the ecosystem. As early as 150 years ago, and only a few years after the battle of the Alamo, Gregg (1844) commented on how fires (which he calls "conflagrations") maintained the southern prairie grasslands (I have emphasized particular sections):

"*It is unquestionably <u>the prairie conflagrations that keep down the woody growth</u> upon most of the western uplands. The occasional skirts and fringes which have escaped their rage have been protected by the streams they border. Yet, may not the time come when these* *vast plains will be covered with timber? ....Indeed there are parts of the southwest now thickly set with trees of good size that within the remembrance of the oldest inhabitants were as naked as the prairie plains and the appearance of the timber in many other sections indicates that it has grown up within less than a century. In fact, we are not witnessing the encroachment of the timber upon the prairie wherever the devastating conflagrations have ceased their ravages.*"

Shantz (1924) commenting on the Great Plains in general said:

"*In the eastern portion of the area fires have in all probability protected the grassland from the encroachment of the forests. . . . Trees and shrubs are killed by fires, and as a consequence the grasses are able to maintain themselves on land which would support a good forest growth if the trees were adequately protected.*"

Several early observations are from Texas. Bray (1901) in western Texas stated:

"*Apparently under the open prairie regime the equilibrium was maintained by more or less regular recurrence of prairie fires. This, of course, is by no means a new idea, but the strength of it lies in the fact that the grass vegetation was tolerant of fires and the woody vegetation was not. It was only after weakening the grass floor by heavy pasturing and ceasing to ward off the encroaching species by fire that the latter invaded the grass lands.*"

Cook (1908) in south Texas noted:

"*Before the prairies were grazed by cattle, the luxuriant growths of grass could accumulate for several years until conditions were favorable for accidental fires to spread. With these large supplies of fuel the fires which swept over these prairies were very besoms of destruction not only for man and animals but for all shrubs and trees which might have ventured out among the grass and even for any trees or forests against which the burning wind might blow.*"

Foster (1917) in central Texas wrote:

"*The causes which have resulted in the spread of timbered areas are traceable directly to the interference of man. Before the white man established his ranch home in these hills the Indians burned over the country repeatedly and thus prevented an extension of forest areas. With the settlement of the country grazing became the only important industry....Overgrazing has greatly reduced the density of grass vegetation. The practice of burning has during recent years disappeared. The few fires which start are usually caused by carelessness and . . . burn only small areas. These conditions operated to bring about a rapid extension of woody growth. Almost unquestionably the spread of timbered areas received its impetus with the gradual disappearance of grassland fires and has been hastened by the reduction of the grass cover itself.*"

Buechner (1944) in Kerr County, Texas wrote:

"*In most parts of the North American continent, before the advent of the white man, man probably had little or no influ* *ence on the vegetation or animal life; indeed, he himself was an integral part of the animal life. . . . But the Edwards Plateau was a notable exception to this general scheme, since the Indian burned the vegetation periodically to facilitate hunting by routing out the game and increasing its visibility. The effect of this practice was to destroy tree and shrub seedlings and produce a grassland in regions that would otherwise have supported arborescent vegetation . . . <u>As a result of the elimination of fires and the introduction of livestock, profound changes took place in the vegetation.</u> What was once a waving sea of grass as far as the eye could see was changed to a diversified arborescent vegetation."*

Recent review articles by Daubenmire (1968), Axelrod (1985), Anderson (1990), Bock and Bock (1995), Van Auken (2000) and Briggs et al. (2004) reaffirmed the basic tenet that fires were common and necessary to maintain the Great Plains grasslands. Sauer (1950) and Bock and Bock (1995) concluded that there is no climatic condition that favors grassland over woodland. In other words, there is no combination of precipitation and temperature that allows grassland to replace desert but is insufficient for woodland to replace grassland. Thus, without fire, the soils and climate that support grasslands could in most cases support a shrubland or woodland as well.

Frost (1998) suggested the fire return interval on most of the Great Plains was <6 years. In certain regions the return interval was <3 years. Most fires were caused by lightning strikes of dry vegetation, but fires in some areas were augmented by Native Americans. Because lightning strikes are more frequent during summer thunderstorms, many fire ecologists believe that summer wildfires were more common than dormant season (i.e., winter or spring) fires (Higgins 1986, Ewing and Engle 1988, Taylor 2001).

When, and to what degree, Native Americans ignited fires to manipulate bison migrations is largely unknown (Axelrod 1985). Higgins (1986) indicated that, in the northern mixed-grass prairie of the Dakotas, most fires ignited by Native Americans occurred during April and October. In the southern mixed-prairie regions of Oklahoma and north Texas, Frost (1998) suggested that burning by Native Americans coincided with the peak in lightning strikes (i.e., in mid-summer). However, it is my opinion that, under certain circumstances, it may have been easier for Native Americans in the southern prairie to execute a winter or spring fire than a summer fire, especially if the goal was to provide green growth in spring to attract bison. Thus, dormant season fires were probably also conducted.

For the purposes of this paper, it is assumed that summer fires were very common to the southern Great Plains prior to European settlement. For the remainder of the paper I will review what is known regarding responses of individual plant species or functional groups to summer fires. I have emphasized research that contrasts summer fire effects to that of dormant season (i.e., "winter" or "spring") fires within the same experimental framework. There are numerous papers that report responses to a summer wildfire, but, without knowing how a winter fire would have affected vegetation under the same post-fire growing conditions, these papers provide limited interpretation.

Emphasis is also on research conducted in the southern Great Plains. However, studies from the northern mixed prairie, the tallgrass prairie of the central Great Plains, and the southwest desert grasslands of Arizona clearly provide the majority of the published work on summer fire effects. Thus, results from many of these papers are included.

Finally, a common problem in assessing vegetation responses to summer fire is that most studies in the literature have been short-term, and responses within the first 1 or 2 years after fire are often used to make assessments regarding species susceptibility or resistance to fire (Wright and Bailey 1982). As Steuter and McPherson (1995) noted, calling a species fire "adapted" or fire "tolerant" almost always requires a qualification. Because of this problem, I will attempt to summarize species responses to fire within the context of number of years post-fire. Studies that observed responses over a longer time frame are given more weight. An excellent example of the kind of study that is most useful for a summary article such as this is presented by Mayeux and Hamilton (1988). In this paper, standing crop and frequency of several species were measured prior to burning and each year for 4 years post-fire. Effects of summer vs. winter fires conducted in 2 separate year sequences (summer 1979 vs winter 1980; summer 1981 vs. winter 1982) were compared to unburned controls.

Summer fire effects on woody plants

Mesquite

There is little evidence that single winter fires will kill mature honey mesquite (*Prosopis glandulosa*). Wright et al. (1976) found that 8 to 50% of mature mesquite were killed following single late-winter (March) burns on a variety of upland sites in west Texas. The mesquite in the Wright et al.(1976) study were large trees, 2 to 4 m tall, that had been sprayed with a top-killing herbicide (2,4,5-T) 2 to 5 years prior to burning, and had resprouted to 1 to 2 m heights at the time of burning. The reason for the high mortality, I believe, was because the standing dead stems from the herbicide treatment ignited and burned into live root crowns, killing the buds that would have developed basal sprouts. Mesquite mortality was greater as wind speed increased because of this enhanced combustion of the standing dead stems.

Because these fires occurred so soon after a herbicide treatment, these results should be viewed as responses to a combined herbicide/fire treatment, rather than to effects of winter fire alone. The herbicide treatment essentially "primed" the mesquite for the fire treatment to be effective. Our own studies (Ansley and Jacoby 1998) in the same region found less than 3% mesquite mortality following single or repeated winter season fires.

Several studies in Arizona observed responses of velvet mesquite (*Prosopis glandulosa* var. *velutina*) to summer fires. Most of these fires were conducted in June. Humphrey (1949) found that summer fires caused 50% mortality of mesquite. Glendening and Paulson (1955) found only 15 % mortality in large mesquite, but 52 % mortality in mesquite seedlings following summer fire. Cable (1965) reported that a June fire killed 25% of mesquite on a high herbaceous fuel area (5,000 kg/ha; 4450 lb/ac), but only 8% on a lower fuel area (2,400 kg/ha; 2140 lb/ac). However, this evaluation was conducted at the end of the first growing season post-fire and probably over-estimated mortalities. Cable (1967) reported that a June fire reduced mesquite density by 26% at 3 years post-fire. Reynolds and Bohning (1956) found 28% velvet mesquite mortality 2 growing seasons after June fires.In studies that contrasted effects of summer and winter fires, Glendening and Paulson (1955) found that summer fires in June killed 29% of mesquite, while winter fires killed only 4%. Blydenstein (1957) found that summer fires killed 5% of mesquite, while winter fires yielded only 1% mortality. Thus, in these studies in Arizona, mortality of mature velvet mesquite from summer fires ranged from 5 to 50%, ($\bar{x}$ = 23%).

Recent studies in the Chihuahuan desert in southern New Mexico found that summer fires caused only 1% whole plant mortality of honey mesquite that was estimated to be 10 years old (average height was 2.6 ft [0.8 m]) (Drewa et al. 2001). In another study in the same region, Drewa (2003) found no whole plant mortality (0%) of 1.6 ft (0.5 m) tall honey mesquite following low or high intensity summer and winter fires.

In south Texas, late summer (September) burns caused 10% honey mesquite mortality at <1 year post-fire (Box et al. 1967). In north Texas, mortality of mature honey mesquite trees was <4 % after repeated high intensity winter or summer fires. Above-ground mortality (i.e., top-kill) was greater following summer fires (86-97%) than winter fires (11-70%) (Ansley and Jacoby 1998). Similarly, in Arizona, velvet mesquite top-kill was 57 and 37% from summer and winter fires, respectively (Glendening and Paulson 1955).

Results from Texas indicate that because summer fires only top-kill mesquite and stimulate resprouting from stem bases, fire must be used frequently for sustained suppression of mesquite (Ansley and Jacoby 1998). Thus, an important concept in fire management systems is that repeated burning is necessary to maintain suppression (Scifres and Hamilton 1993).

Juniper

Fires easily kill eastern redcedar (*Juniperus virginiana*) and there would seem to be no advantage to burning in summer vs. winter to kill this species. Taylor (2001) has shown slightly greater mortality of Ashe juniper (*J. ashei*) with summer fires (98%) than with winter fires (90%) in the Edwards Plateau of south central Texas. There are no published studies I am aware of that have compared effects of summer and winter fires on the resprouting juniper species of northwest Texas, i.e., redberry juniper (*J. pinchottii*). Anecdotal observations of summer wildfire effects suggest mortality of mature plants is low (probably

<30%) and a management system that includes repeated burning would be important in maintaining suppression of regrowth.

Summer fire effects on succulents

Bunting et al. (1980) demonstrated that winter fires can be effective on killing prickly pear (*Opuntia phaeacantha*) in west Texas, but most ranchers are not satisfied with the level of prickly pear control winter fires yield. This is especially true in central Texas where the presence of C_3 grass species such as Texas wintergrass (*Nassella leucotricha*) and C_3 annual bromegrasses (*Bromus* spp.) are often green during winter and retard intensity of winter fires. Anecdotal evidence from prescribed summer fires and summer wildfires in Texas is that summer fires may be more effective than winter fires in killing prickly pear cactus, but the published research to support this observation is limited.

In Arizona, Reynolds and Bohning (1956) found only 9% prickly pear mortality 2 growing seasons after June fires. Cable (1967) found in Arizona that lower intensity June fires (burned between 6 and 8 am) reduced prickly pear density by 41% the third growing season following fire. On another site, summer fire reduced prickly pear density by 52% (Cable 1967). These studies did not contrast summer and winter fires.

In the Edwards Plateau of south central Texas, Taylor (2001) found that winter and summer fires reduced prickly pear density by 47 % and 97 %, respectively. Ansley et al. (2002) compared prickly pear response to summer fires, high intensity winter fires, low intensity winter fires, and unburned controls. At 3 years post-treatment, mortality of individual prickly pear mottes (ranging in size from 10-1000 pads/motte) was 86%, 16% and 2% in summer fire, high-intensity winter fire, and low intensity winter fire treatments, respectively. Prickly pear canopy cover increased or did not change in low intensity and high intensity winter fire treatments, but decreased from 19 to 1% following summer fires. Summer fires reduced canopy area of individual mottes by >70% (all sizes combined). In contrast, high intensity winter fires reduced canopy area of medium (21-100 pads) and large (101-1000 pads) mottes by 20 and 31%, respectively, but area of small mottes (<20 pads) actually increased and was 3 times greater at study end compared to pre-treatment values.

Summer fire effects on herbaceous species

The literature is quite varied on assessment of individual grass species responses to summer season fires. Part of the problem in interpretation arises from the variation in metrics used to assess herbaceous responses. At the ecosystem level, studies often measure changes in species composition following fire (Steuter 1987, Biondini et al. 1989, Engle et al. 2000). Common metrics used are species frequency of occurrence, richness and/or percent basal cover. Those species that decreased relative to other species within the community matrix were viewed as less fire tolerant. Other studies have taken a more autecological approach and measured post-fire production of individual grass species over time (Reynolds and Bohning 1956, Cable 1967, Whisenant et al. 1984, Engle and Bultsma 1984, Cox et al.1988). Those species that recover more slowly, usually in comparison to an unburned control, are generally viewed as fire intolerant (Wright and Bailey 1982). However, as mentioned earlier, this may be misleading due to the short term nature of many fire studies. The first section will assess community compositional trends and later sections will focus on particular physiological and/or growth form functional groups.

Community herbaceous composition

There is limited information on effects of summer fires on Great Plains herbaceous composition. Negative response to fire is hypothesized to increase if grass species are physiologically active at the time of burning (Daubenmire 1968, Howe 1994, Engle and Bidwell 2001). Thus, later-winter or early spring fires may adversely affect C_3 (cool-season) grasses and favor C_4 (warm-season) grasses, while summer fires may be more harmful to C_4 grasses and favor C_3 grasses (Anderson et al. 1970, Steuter 1987, Collins and Wallace 1990, Howe 1995). Thus, with respect to herbaceous species composition, in mixed stands of C_3 and C_4 herbaceous species, we might expect to see a shift toward C_4 species and away from C_3 species following winter or spring fires, and the opposite following summer or early fall fires.

In northern and central Great Plains communities, spring fires will shift a mixed C_3/C_4 grass community toward a greater C_4 presence (Anderson et al. 1970, Engle and Bultsma 1984, Steuter 1987, Howe 1994, 1995, 2000). There is less evidence that summer fires will shift mixed C_3/C_4 communities toward a greater C_3 dominance. Steuter (1987) found in northern mixed prairie in South Dakota that summer fires shifted composition toward C_3 species and Howe (1995) found in anthropogenically seeded C_3/C_4 mixed grass plots in Wisconsin that summer fires retarded C_4 grasses and favored C_3 species. However, in other studies in Wisconsin, Howe (1994, 2000) found that summer fires maintained a mix of C_3 and C_4 grasses, and thus increased diversity, but did not strongly favor C_3 grasses.

In the tallgrass prairie regions of Oklahoma, Engle et al. (2000) found that edaphic features and time since the last burn were the most important factors determining species composition on 2 Oklahoma prairie sites, but that summer fire did not necessarily cause long-term shifts in species composition. Ewing and Engle (1988) in Oklahoma found that a summer fire increased C_3 annual grass and decreased C_4 perennial grass production the first year post-fire but long-term responses were not available. Coppedge and Shaw (1998) found in Oklahoma tallgrass prairie that summer fires increased C_3 sedges (*Carex* spp.), annual bromegrasses and forbs and decreased C_4 tallgrasses and little bluestem (*Schizachyrium scoparium*) when compared to winter fires. However, these measurements were only made the first growing season post-fire and long-term shifts in composition are not known. Engle and Bidwell (2001) concluded that summer fires do not cause long-term changes in species composition.

In central Texas, Whisenant et al. (1984) found that late summer/early fall fires triggered an increase in C_3 Texas wintergrass on one site but not on a second site nearby. In south Texas Owens et al. (2002) found no major shifts in species composition following summer fires in south Texas.

In north Texas, Texas wintergrass basal cover increased following summer fires but, not to the detriment of C_4 grasses (Ansley, unpublished data). Texas wintergrass usually increased into areas that were bare ground or undefined litter prior to fire. We found only one situation, when summer fires were burned in 2 consecutive years, where Texas wintergrass actually replaced the dominant pre-fire grass, C_4 buffalograss (*Buchloe dactyloides*). This occurred in 1994 and the stand, which pre-fire had > 60 % buffalograss cover, has continued to have >80% Texas wintergrass cover and <5 % buffalograss cover.

We are thus left with a mixed interpretation of summer fire effects on herbaceous composition. But in general it appears that dormant season fires are better able to shift C_3/C_4 communities to C_4 dominance than are summer fires in shifting such communities toward C_3 dominance. Of those studies that do document summer fires shifting species composition toward C_4 dominance, most have been located in the northern Great Plains (Steuter 1987, Howe 1994, 1995). This may simply mean that there are more studies of this nature in the northern Great Plains, or it may indicate that such a response occurs more readily in the northern Great Plains than the southern Great Plains.

An interesting question is that, if grassland fires prior to European settlement were more common during summer than winter months because of the greater frequency of lightning storms and drier conditions in summer (Higgins 1986, Ewing and Engle1988, Howe 1994, Frost 1998), and, if summer fires are more damaging to C_4 than C_3 grasses, then how did C_4 tallgrass species such as big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and little bluestem maintain dominance in the tallgrass prairie regions? We might expect the herbaceous community to shift toward C_3 grass species if summer-season fires were common.

At the Konza tallgrass LTER site in eastern Kansas, frequent anthropogenic spring burning as a management strategy in recent decades has maintained C_4 grass dominance (Knapp et al. 1998). There is often a temporary increase in C_3 forb species following spring burning, but no C_3 grass has become dominant. However, historically, summer fires surely dominated (Howe 1994) and yet the C_4 grasses persisted. The C_4 tallgrass species mentioned above may be better adapted to a nutrient-poor, fire-based ecosystem than are C_3 grasses. C_3 grasses favor increased self shading and cooler soil temperatures that result from reduced fire frequencies (Ode et al. 1980). Conversely, as Howe (1994) argues, vegetation responses to summer fires challenge the concept of a historically stable tallgrass prairie dominated by C_4 grasses.

In the following sections I will quickly review some of the key papers that have measured responses of key species found in the southern prairie to summer fires. These sections are designed more to introduce the reader to some of the associated literature than to provide a comprehensive summary.

C_4 perennial tallgrasses and midgrasses

Several studies in the tallgrass prairie of the central Great Plains show a marked decline in C_4 grass production the first year after a summer fire, but a recovery to preburn or unburned levels by the second or third year (Engle et al. 1998, Engle and Bidwell 2001). Little bluestem standing crop was significantly lower for $\geq$2 years after late-summer fires when compared to unburned controls in Oklahoma (Engle et al. 1993). However, tallgrasses collectively (big bluestem, indiangrass, switchgrass) recovered the first year after summer fire. Ewing and Engle (1988) also found no reduction in tallgrass production following summer fires. In South Dakota mixed prairie, big bluestem tolerated summer fire fairly well with minimal reduction in production compared to winter fires or unburned controls (Engle and Bultsma 1984).

Sideoats grama (*Bouteloua curtipendula*) was considered by Wright (1974) as being sensitive to fire. Wright (1974) found that sideoats grama yields in west Texas were reduced by 40-45 % for the first 2 years after winter fires. These studies measured responses of the rhizomatous growth form of sideoats grama to fire and Wright (1974) concluded that this form "never benefits from fire," even if fires occur in the dormant season.

Wright's conclusions regarding sideoats grama responses to fire were based on short-term responses to winter fires. However, as stated earlier, duration of post-fire measurements can affect interpretation of species tolerance to fire. Taylor (2001), for example, found in central Texas that sideoats grama frequency of occurrence increased to a greater degree 6 years after a summer fire than after either a winter fire or no fire. Similarly, in north Texas, Ansley (unpublished data) found that it took 3 growing seasons before sideoats grama total weight (live + dead) recovered from summer fires, while it took only 2 growing seasons to recover from winter fires (Figure 1). By 5 years post-fire, however, total yield was significantly greater in both winter and summer fire treatments than the no burn treatment, with no differences between the 2 fire treatments. The additional stress of annual spring clipping + fire reduced total yields in unburned and winter fire treatments, but not in the summer fire treatment. In New Mexico shortgrass prairie, summer fires increased sideoats grama cover by over 100% (Brockway et al. 2002).

Tunnell and Ansley (1995) found in north Texas that tobosagrass (*Hilaria mutica*) recovery was slightly slower from summer than from winter fire, but by the end of the first growing season post-fire, tobosagrass total standing crop was similar between unburned and winter burned (4,000 kg/ha; 3560 lb/ac), but was 3,000 kg/ha (2670 lb/ac) in the summer burned treatment.

In Arizona, production of big sacaton (*Sporobolis wrightii*) recovered from summer fires within 2 to 3 growing seasons post-fire but remained lower than unburned controls in winter fire treatments (Cox et al. 1988). Thus, this C_4 midgrass appeared to respond more favorably to summer than to winter fire. Burning in either summer or winter favored standing crop and frequency of occurrence of white tridens (*Tridens albescens*) for up to 4 years post-fire in south Texas (Mayeux and Hamilton 1988).

Some bunch-type midgrasses like threeawn (*Aristida* spp.) have elevated growing points and may be highly susceptible to fire, especially summer fires. Because of this, the noxious bunchgrass, prairie threeawn (*A. oligantha*) is controlled by fall burning in central and eastern Kansas (Owensby and Launchbaugh 1977).

C_4 perennial shortgrasses

Stoloniferous shortgrass species like buffalograss and black grama (*Bouteloua eriopoda*) may be severely damaged by fire because their growing points are above ground. In Arizona, Reynolds and Bohning (1956) and Cable (1965) found that June fires killed up to 90% of black grama. In the Chihuahuan desert of southern New Mexico, June fires reduced black grama cover by nearly 20% compared to unburned plots 4 years post-fire (Drewa and Havstad 2001). This species, which is also very sensitive to grazing, does not appear to be adapted to summer-season fires and may take 50 years to recover from June fires.

Ford (1999) summarized responses of buffalograss and blue grama (*B. gracilis*) to fire, but of the 15 papers reviewed in detail, only 3 measured responses of these species to summer or late-summer fires in the southern Great Plains or south Texas. Blue grama plant height was greater in the summer fire treatment than the unburned control at one growing season post-fire in the Texas High Plains (Trlica and Schuster 1969). In New Mexico shortgrass prairie, summer fires did not change blue grama cover (Brockway et al. 2002).

Buffalograss increased significantly following late-summer (September) burns on the Welder Wildlife Refuge in south Texas (Box et al. 1967). However, in New Mexico shortgrass prairie, summer fires reduced buffalograss cover from 5.7 to 0.5 % (Brockway et al. 2002). In a recent study in north Texas, both summer and winter fires increased buffalograss total weight and live weight at 3 years post-fire (Ansley, unpublished data) (Figure 2). Clipping in addition to the fire treatments did not have a negative effect on buffalograss yields.

Burning in either summer or winter had little effect on standing crop or frequency of occurrence of common curleymesquite (*H. berlangeri*) during 4 years of post-fire measurements in south Texas (Mayeux and Hamilton 1988). However, both summer and winter fire greatly reduced production of the undesirable grass, red grama (*B. trifida*).

In summary, some shortgrass species such as black grama in the southwest desert grasslands, and red grama in Texas appear sensitive to fire, but most of the shortgrass species studied appear fairly tolerant of summer-season fires.

C_3 perennial midgrasses

In one of the few published papers that contrasted winter (spring) and late-summer fires, Whisenant et al. (1984) found in central Texas that Texas wintergrass standing crop was significantly reduced the first growing season following a winter or late-summer (September) fire. However, by the second growing season post-fire, there was no difference in standing crop between summer fire, winter fire and unburned treatments. In south Texas chaparral, Box and White (1969) found that Texas wintergrass herbage production was reduced to a greater degree by late summer fires than by winter fires.

In a recent study in north Texas, there were no negative long-term effects of repeated winter or summer fires on Texas wintergrass total or live weight and, in the long-term, summer fires increased Texas wintergrass total weight (Ansley, unpublished data) (Fig. 2). However, the additional stress of annual spring clipping alone and clipping + fire (either summer or winter) reduced total and live weights. Winter fire + clipping appeared to have the most negative effect on Texas wintergrass yields.

Engle et al. (1998) found that 2 late-summer fires in tallgrass prairie increased production of C_3 grasses (primarily Texas wintergrass) by 40% compared to unburned controls on both a shallow and a deep soil site in Oklahoma. In South Dakota, Engle and Bultsma (1984) found that the C_3 midgrass, western wheatgrass (*Agropyron smithii*), was more tolerant of summer fire than were other C_3 midgrasses, Kentucky blugrass (*Poa pratensis*) and needlegrass (*Stipa* spp.).

Forbs

Numerous papers report increases in forb populations following fires. This appears to be true following repeated spring fires in northern mixed prairie (Biondini et al. 1989, Howe 1994, 1995), the tallgrass prairie of eastern Kansas (Knapp et al. 1998), the tallgrass prairie in Oklahoma (Engle et al. 1993, Engle et al. 1998), and in south Texas (Owens et al 2002).

Summer fires may drastically reduce grass production for several years (Engle and Bultsma 1984), but also can greatly increase subdominant species diversity, largely through increases in C_3 forbs (Biondini et al. 1989, Howe 1994, Drewa and Havstad 2001, Copeland et al. 2002). Summer fires appear to increase forbs to an even greater extent than do dormant season fires (Biondini et al. 1989). For example, in north Texas, Tunnell and Ansley (1995) found much greater cover of annual broomweed the first growing season following summer (35%) than winter fires (3%). However, Box et al. (1967) found just the opposite result in south Texas; late-summer fires decreased forbs, while dormant season fires increased forbs. The increase or decrease in forbs in response to summer fires may be viewed as a positive or negative response, depending on the desired land use objective (Engle et al. 1993). Generally those with a wildlife perspective would view an increase in forbs and species diversity as a positive response.

Conclusions

An interesting perspective on the role of fire in an ecosystem has recently been provided by Bond and Keeley (2005). Instead of considering fire as a disturbance, they liken fire to that of a giant indiscriminating herbivore:

"*The effects of fire are, in many ways, analogous to those of herbivory, but have been missing from the trophic* *ecology literature. Although usually treated as a disturbance, fire differs from other disturbances, such as cyclones or floods, in that it feeds on complex organic molecules (as do herbivores) and converts them to organic and mineral products. Fire differs from herbivory in that it regularly consumes dead and living material and, with no protein needed for its growth, has broad dietary preferences. Plants that are inedible for herbivores commonly fuel fires.*"

With respect to summer fires, this concept of indiscriminate "herbivory" is scaled up and, to continue the metaphor, is analogous to a massive increase in stocking rate when compared to dormant season fires. The post-fire vegetative responses must be viewed in this context and, in many cases, adequate rest from further defoliation events is extremely important.

Little research has documented the combined effects of grazing and fire on herbaceous species (Engle and Bidwell 2001, Briggs 2005). Even fewer studies measured grazing and summer fire effects (Drewa and Havstad 2001). This is an area that needs more attention, especially in light of the dramatic shifts in rangeland species composition and production that have occurred since Europeans settled the western states.

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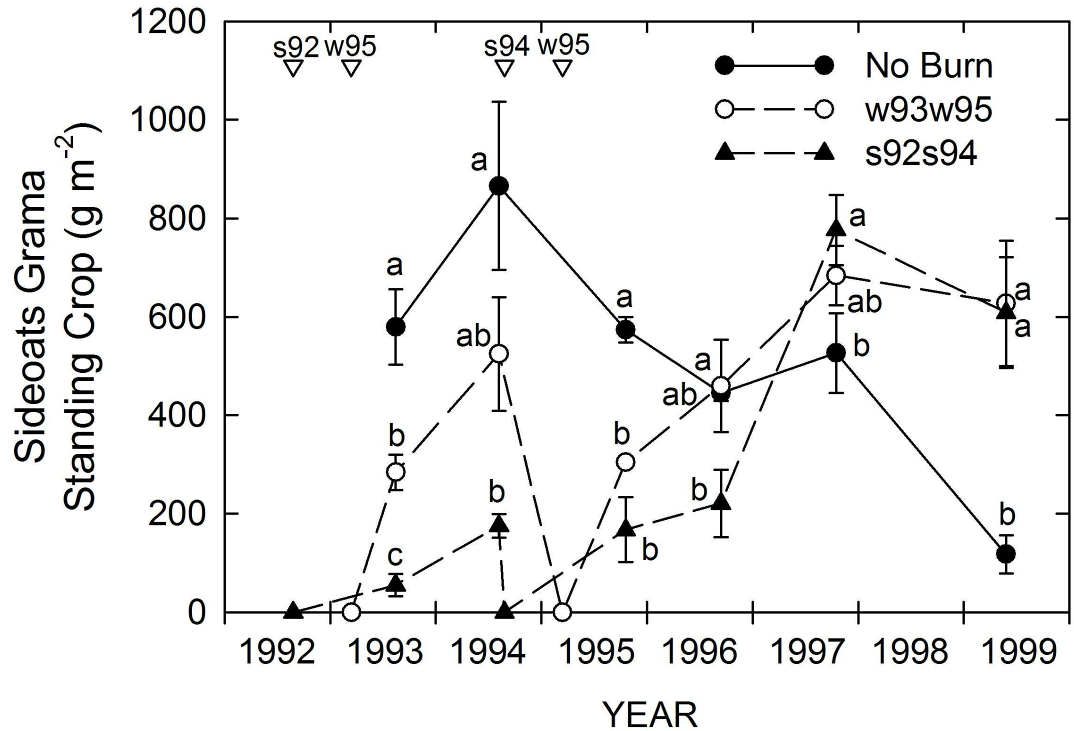

Figure 1. Sideoats grama dry matter standing crop (live + dead) following repeated winter fires in 1993 and 1995 (w93w95), repeated summer fires in 1992 and 1994 (s92s94) and no burn in an ungrazed exclosure in north Texas. Values are means of 3 replicate plots (vertical lines are ± 1standard error). Different letters within each date indicate significant difference between means. Times of the individual burn treatments are indicated in upper left corner. Each burn lowered standing crop to zero.

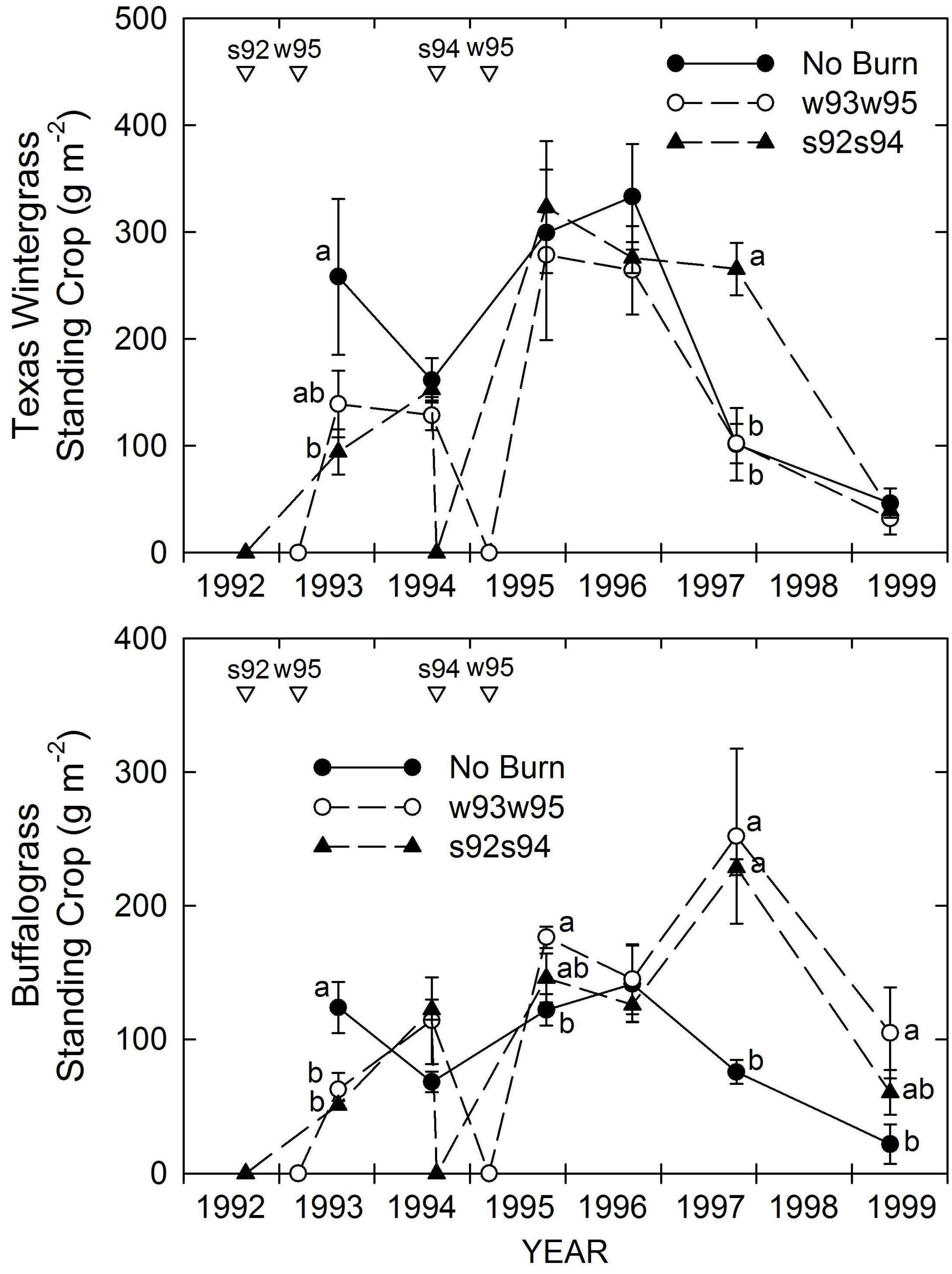

Figure 2. Texas wintergrass (top) and buffalograss (bottom) dry matter standing crops (live + dead) following repeated winter fires in 1993 and 1995 (w93w95) repeated summer fires in 1992 and 1994 (s92s94) and no burn in an ungrazed exclosure in north Texas. Details are same as in Figure 1.