RESTORING HETEROGENEITY ON THE TALLGRASS PRAIRIE PRESERVE: APPLYING THE FIRE–GRAZING INTERACTION MODEL

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ABSTRACT

The interaction of fire and grazing is an important ecological process in the Great Plains grasslands of North America. The fire–grazing interaction promotes a shifting mosaic of patches that support a diverse array of grassland flora and fauna. This ecosystem variability, or heterogeneity, has been identified as critical to the maintenance of biological diversity and therefore should serve as the foundation for conservation and ecosystem management.

Landscape heterogeneity has been a primary focus of the ecological management plan at The Nature Conservancy's Tallgrass Prairie Preserve in northeastern Oklahoma. Since 1993, an expanding bison (*Bison bison*) herd has been interacting with randomly selected burn patches that reflect the historical seasonality and frequency of fire. The fire–bison interaction produces vegetation structural and compositional heterogeneity in an ever-shifting landscape patch mosaic. Research and monitoring has confirmed that this heterogeneity provides for the full array of tallgrass prairie biodiversity.

The larger-scale conservation challenge is to develop cattle management regimes that incorporate some of the same ''biodiversity friendly'' elements as fire–bison. To that end, The Nature Conservancy is in the sixth year of a research partnership with Oklahoma State University to investigate ''patch-burning'' with cattle. Results thus far are very encouraging: increased heterogeneity and biodiversity can be realized with little or no decrease in livestock production.

keywords: biodiversity, bison, *Bison bison,* cattle, fire–grazing interaction, heterogeneity, Oklahoma, tallgrass prairie.

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INTRODUCTION

Ecosystem variability, or heterogeneity, has been described by numerous authors as the root of biological diversity at all levels of ecological organization, and should therefore serve as the foundation for ecosystem and conservation management (Christensen 1997, Ostfeld et al. 1997, Wiens 1997, Fuhlendorf et al. 2006). The Great Plains of North America evolved with fire and ungulate grazing, and these two agents of natural disturbance are considered by grassland ecologists to be keystone processes of the prairie ecosystem (Axelrod 1985, Milchunas et al. 1988, Knapp et al. 1999). In addition, the interaction between grazers and fire is believed to be the primary means of achieving heterogeneity and the full range of natural variation in Great Plains grasslands (Biondini et al. 1989, Vinton et al. 1993, Steuter et al. 1995, Hartnett et al. 1996, Fuhlendorf and Engle 2001). Steuter (1986) and Fuhlendorf and Engle (2004) present conceptual models of the fire–grazing interaction that demonstrates how fire and grazing, interacting through a series of positive and negative feedback loops, result in a shifting mosaic of vegetation patches across the grassland landscape (see figure 2 in Kerby et al., *this volume*).

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SITE DESCRIPTION

The Tallgrass Prairie Preserve is a 15,700-ha natural area located in northeastern Oklahoma (36°50′N, 96°25′W), which is owned and managed by The Nature Conservancy. The cornerstone property, the historic 11,800-ha Barnard Ranch, was purchased by the Conservancy in late 1989, with additional property acquisitions since that time bringing the preserve to its current size. The Barnard Ranch managed for both cow–calf and yearling cattle production and used prescribed fire on a roughly 4- to 5-y rotation. Aerial application of broadleaf herbicides on a 4- to 5-y rotation was practiced since the 1950s until the ranch was purchased by the Conservancy, and is still a common regional range management practice. However, with 755 species of vascular plants collected thus far (M.W. Palmer, Oklahoma State University, unpublished data), the preserve's botanical diversity appears to be relatively intact.

The Tallgrass Prairie Preserve is located within the southern end of the Greater Flint Hills—the largest extant intact landscape of native tallgrass prairie in North America (Knopf 1994, Steinauer and Collins 1996). The 2.0-Mha Greater Flint Hills landform runs from northeastern Oklahoma through eastern Kansas and consists of two distinct vegetation associations (Figure 1). The northwestern 1.5-Mha tallgrass prairie landscape is underlain by limestone and shale, while the southeastern 0.5 Mha of crosstimbers (tallgrass

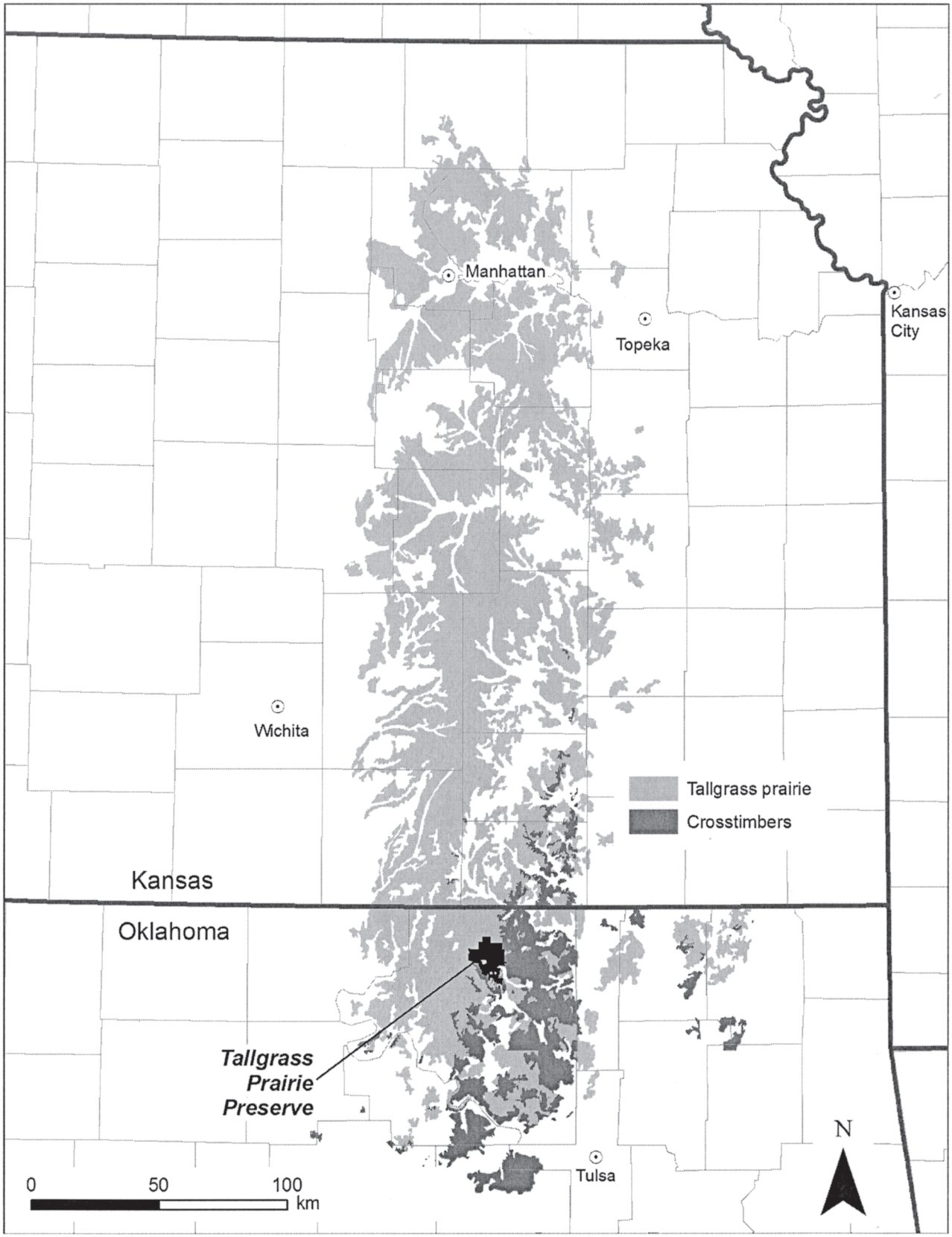

Fig. 1. The Greater Flint Hills region of eastern Kansas and northeastern Oklahoma, with the location of The Nature Conservancy's Tallgrass Prairie Preserve in Osage County, Oklahoma. Figure modified from The Nature Conservancy (2000). Reprinted by permission of The Nature Conservancy.

prairie and oak woodlands of post oak [*Quercus stellata*] and blackjack oak [*Q. marilandica*]) is underlain by sandstone and shale. The Tallgrass Prairie Preserve is located on this ecotone and consists of approximately 90% grassland and 10% forest cover. Tallgrass prairie is the dominant grassland (big bluestem [*Andropogon gerardii*], Indiangrass [*Sorghastrum nutans*], composite dropseed [*Sporobolus compositus*], switchgrass [*Panicum virgatum*], and little bluestem [*Schizachyrium scoparium*]), but shortgrass prairies (dominated by grama [*Bouteloua* spp.]) occur on shallow soils and in ''grazing lawns.'' Most of the forested areas on the preserve are crosstimbers, but there are substantial areas of floodplain forests and mesic to xeric hardwood forests on the upper stream terraces above Sand Creek. Crosstimbers become the dominant regional vegetation type on the east side of the preserve.

Because of its rough topography and shallow, rocky soils, the Greater Flint Hills have not been cultivated as was most of the original tallgrass prairie on the continent. Ranching is the primary economic land use, with annual spring burning coupled with intensive early stocking (IES) of yearling cattle gaining in popularity over the last several decades (Launchbaugh and Owensby 1978, Smith and Owensby 1978, Vermeire and Bidwell 1998). The IES management regime involves the intensive early stocking of approximately 250 kg/head yearling cattle at twice the season-long stocking rate, but for only the first half of the growing season. The annual burn–IES range management practice results in uniform grazing use across the entire pasture, and thus a homogeneous landscape with lowered biodiversity potential. Homogenizing range practices are considered to be one of the leading sources of ecological stress in the Flint Hills (The Nature Conservancy 2000).

ECOLOGICAL MANAGEMENT PLAN

The principle of heterogeneity has been a primary consideration in the development of the ecological management plan at Tallgrass Prairie Preserve. The preserve's operating hypothesis is that the best way to achieve The Nature Conservancy's goal of biodiversity protection is through the maintenance of a heterogeneous mix of vegetation (habitat) patches that represent the full range of natural variation. Landscape heterogeneity will be realized through management regimes that couple fire with both native and domestic grazers. Responses of vegetation and grassland bird to management treatments are presented below in the Cattle–Fire section.

There have been several significant revisions to the ecological management plan at the Tallgrass Prairie Preserve since the original plan was published (Hamilton 1996). I describe those revisions and summarize some key research results to date.

Bison–Fire

American bison (*Bison bison*) was the dominant ungulate prior to settlement of the Great Plains (Axelrod 1985, Shaw 1995, Shaw and Lee 1997). Therefore, it is intuitive that a large-scale effort to restore prairie ecosystem dynamics would utilize bison. The Tallgrass Prairie Preserve bison herd was initiated with the donation of 300 bison in the fall of 1993, which were introduced into a year-round unit of 1,960 ha. The area of the bison unit has been expanded eight times since then to keep pace with the growing herd (internal recruitment). The bison herd is still growing and currently consists of approximately 2,400 individuals in the summer season with calves, occupying a unit of 8,517 ha. The final target herd size of 2,600 bison in the summer season will be reached in 2007 and occupy a unit of 9,532 ha (Figure 2). On a year-round basis, this herd will be equivalent to 20,200 animal-unit months (AUM; 1 AUM is the forage requirement for 1 mo for a 454-kg animal unit or its equivalent).

Both the initial bison stocking rate and fire return interval were modified in summer 1999. Observations over the first 5 growing seasons (1994–1998) in the bison–fire unit confirmed that the initial bison stocking rate (forage intake target of 12.5% of annual production) was a very conservative starting point (50% below U.S. Department of Agriculture–Natural Resources Conservation Service [USDA-NRCS] recommendations). Abundant standing forage was available to the herd in all seasons, including several drought years. The revised bison forage intake target is 20% intake of annual herbage production, which averages approximately 4,300 kg/ha (Bourlier et al. 1979). When combined with an expected similar forage loss from animal trampling, total annual forage consumption will be approximately 40%, which is 20% below USDA-NRCS recommended cow–calf stocking rates for the region. The revised bison stocking rate is calculated at 2.1 AUM/ha, or 5.7 ha/AU per year (14.1 acres/AU per year).

Within the bison unit, there are no internal fences except for one imbedded pasture of 1,500 ha. However, its gates are left open at all times except for several weeks during roundup when it is used to move the herd towards the corral. The bison unit is a drive-through, ''open range'' situation, where visitors can drive 27 km of gravel county roads within the unit. Unfortunately, this public vehicle access within the bison unit usually results in the mortality of several animals each year from vehicle impacts.

General herd management follows the Conservancy's guidelines for bison management (The Nature Conservancy 2002), which emphasizes minimal handling and managing for the strengths of bison as a wild species. The herd does not receive any supplemental protein or energy; however, salt with trace minerals is provided free-choice because some elements may be lacking within the bounded landscape. Water is provided by natural stream flow and small, man-made stock ponds. The entire herd is rounded up each fall and processed through a bison corral system. Since the historic large predators were extirpated over a century ago, the proper ecological stocking rate is maintained by culling surplus bison during the roundup, which are

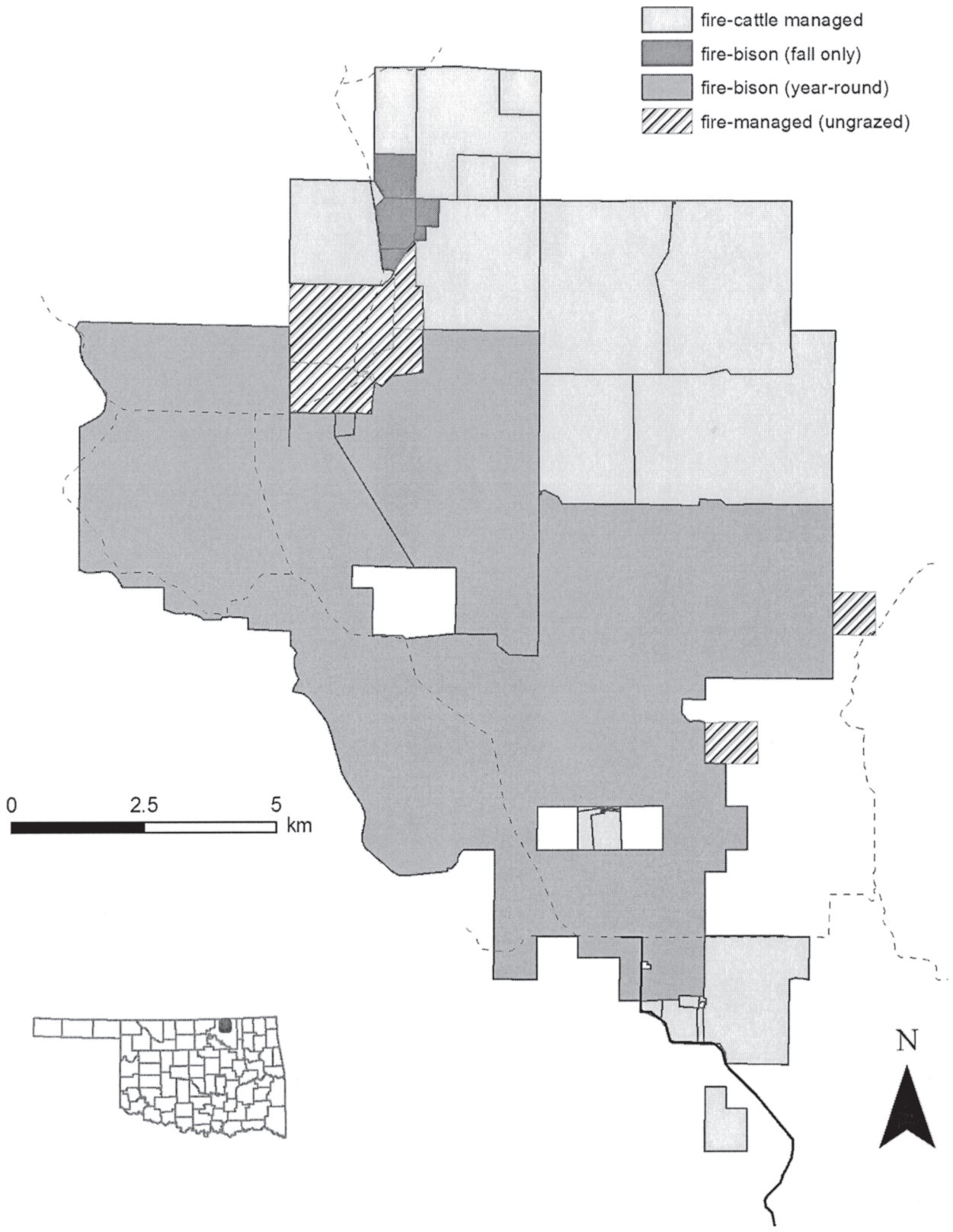

Fig. 2. Long-term management units planned for The Nature Conservancy's Tallgrass Prairie Preserve, Osage County, Oklahoma.

then sold to private bison ranchers or meat producers. Roundup is also the opportunity to apply health maintenance treatments (internal parasite control and vaccinations to prevent regional bovine diseases), with special emphasis on preventing brucellosis and tuberculosis. All heifer calves are vaccinated to prevent brucellosis. From 1995 to 2005, the reproductive rate of the herd has averaged a 72% weaned calf crop.

All year-round the bison herd is free to move over the entire unit, with unrestricted access to all burned and unburned patches on the landscape. Burn patches are randomly selected across the unit (no fixed or permanent burn units) and reflect the historical seasonality and frequency of fire (Figure 3). All prescribed burns are conducted by an on-site Nature Conservancy burn crew. From 1991 to 2005, 390 prescribed burns were conducted on the preserve, totaling 93,900 ha. During that same time, the Nature Conservancy burn crew has

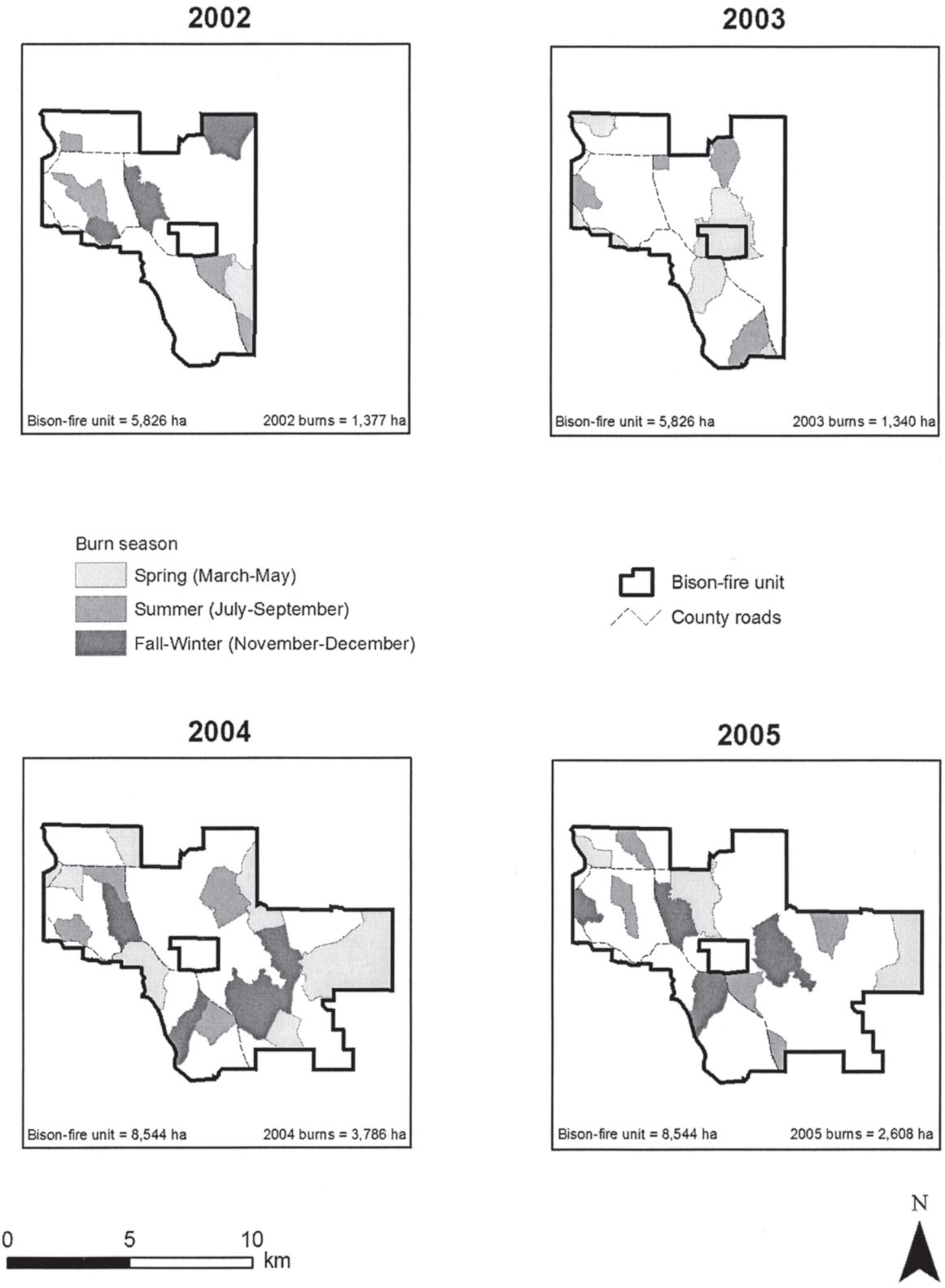

Fig. 3. Bison–fire unit burn history, 2002–2005, The Nature Conservancy's Tallgrass Prairie Preserve, Osage County, Oklahoma.

also assisted neighboring ranches in burning an additional 79,700 ha and assisted with the suppression of 52 wildfires.

The initial fire return interval in the bison unit was set at 5 y (20% of unit burned each year). However, because of the random selection system used to determine the locations of burn units, some areas were going unburned for a much longer period. Shrubs and tree seedlings were increasing in these long-unburned areas, suggesting a shorter fire return interval was needed. Therefore, the bison unit fire return interval was revised in the summer of 1999 to 3 y (33% of unit burned each year), but the seasonality of the burns will stay the same: 40% dormant spring (March–April), 20% growing season (July–September), and 40% dormant fall (November–December).

In general, the Tallgrass Prairie Preserve bison herd has reacted to fire as expected, but there have been some interesting findings from on-site research. In particular, diet selection: studies at various Great Plains sites have consistently shown bison to be strongly graminivorous, usually with graminoids making up >90% of their diets (Hartnett et al. 1997, Steuter and Hidinger 1999). However, Coppedge et al. (1998*b*) found that the preserve bison herd is extremely focused on grasses and sedges (*Carex* spp.) and obtain not <98% of their diet from graminoids on a year-round basis. As expected, there is a significant bison–fire interaction, with strong selection for recently burned patches during the growing season due to the increased forage quality of the regrowth following a burn (Coppedge and Shaw 1998, Coppedge et al. 1998*a,* Biondini et al. 1999). Interestingly, there was also a lesser but still preferential use of recent burn patches in the dormant season. Although the tallgrass prairie is dominated by warm-season grasses, cool-season sedges were accessible on burn patches in the dormant season and accounted for up to 39% and 62% of bison diets in winter and spring, respectively (Coppedge et al. 1998*b*). Due to this strong selection for graminoids, forbs increase dramatically within recently burned and grazed patches, but native warm-season grasses regain their dominance several years post-burn.

Cattle–Fire

The original management plan for the Tallgrass Prairie Preserve called for nearly complete elimination of cattle grazing once the bison herd covered most of the preserve (Hamilton 1996). However, the long-term bison/cattle plan was revised in late 2002 and now calls for a significant portion of the property to be kept in experimental treatments using cattle, while the ''core preserve'' bison–fire unit has been modestly scaled back (but will still constitute the dominant management treatment). This revision was prompted by the encouraging results from collaborative cattle ''patch-burn'' research initiated on 2,350 ha at the preserve in 2001 with Oklahoma State University (OSU). This project is comparing traditional intensive early stocking (IES) with patch-burn treatments. IES consists of annual spring burning coupled with stocking double the density of yearling cattle, but only for the first half of the grazing season. The patch-burn treatments consist of burning only one-third of a cattle pasture each year (entire pasture burned after 3 y) and still stocking it at IES levels. Results thus far are very encouraging: patch-burn treatments increased heterogeneity and biodiversity with little or no decrease in livestock production when compared with traditional IES treatments (Fuhlendorf and Engle 2004). Fuhlendorf et al. (2006: figures 2, 4) found from the cattle patch-burn research conducted on the preserve that increasing the spatial and temporal heterogeneity of grassland disturbances increases vegetation variability, thus supporting a greater diversity of grassland birds.

Although the above bison–fire regime has proven to be very attractive for biodiversity conservation, it is unlikely to be very exportable to the private ranching industry that dominates the Flint Hills. Instead, a more productive strategy is to engage with conservation partners in the development of progressive cattle management systems, such as patch-burning, in an effort to impact the conservation of the Flint Hills (and other native prairie) landscapes. Starting in 2008, the next generation of patch-burn research with OSU will begin on 4,350 ha and will be testing a wider array of fire return intervals (2–4 y) and season of fire (spring-only and spring-plus-summer) using season-long grazing with yearling cattle.

ECOLOGICAL RESEARCH

In May 2004, construction of the Tallgrass Prairie Ecological Research Station was completed at the preserve headquarters in a partnership with the University of Tulsa. This modern laboratory and classroom facility will greatly enhance applied and basic ecological research on the preserve. More than three dozen research projects are currently active on the preserve, and 95 articles in scientific journals have been published. Information regarding research facilities, policies, and GIS data layers can be accessed by going to The Nature Conservancy's website at http://www.nature.org, then navigating to Oklahoma, Tallgrass Prairie Preserve, then Prairie Science.

LITERATURE CITED

Axelrod, D.I. 1985. Rise of the grassland biome, central North America. Botanical Review 51:163–201.

Biondini, M.E., A.A. Steuter, and C.E. Grygiel. 1989. Seasonal fire effects on the diversity patterns, spatial distribution, and community structure of forbs in the northern mixed prairie, USA. Vegetatio 85:21–31.

Biondini, M.E., A.A. Steuter, and R.G. Hamilton. 1999. Bison use of fire-managed remnant prairies. Journal of Range Management 52:454–461.

Bourlier, B.G., J.D. Nichols, W.J. Ringwald, P.J. Workman, and S. Clemmons. 1979. Soil survey of Osage County, Oklahoma. National Cooperative Soil Survey, Washington, D.C.

Christensen, N.L. 1997. Managing for heterogeneity and complexity on dynamic landscapes. Pages 167–186 *in* S.T.A. Pickett, R.S. Ostfeld, M. Shachak, and G.E. Likens (eds.).

The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. Chapman and Hall, New York.

Coppedge, B.R., D.M. Engle, C.S. Toepfer, and J.H. Shaw. 1998*a*. Effects of seasonal fire, bison grazing, and climatic variation on tallgrass prairie vegetation. Plant Ecology 139: 235–246.

Coppedge, B.R., D.M. Leslie Jr., and J.H. Shaw. 1998*b*. Botanical composition of bison diets on tallgrass prairie in Oklahoma. Journal of Range Management 51:379–382.

Coppedge, B.R., and J.H. Shaw. 1998. Bison grazing patterns on seasonally burned tallgrass prairie. Journal of Range Management 51:258–264.

Fuhlendorf, S.D., and D.M. Engle. 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. BioScience 51:625–632.

Fuhlendorf, S.D., and D.M. Engle. 2004. Application of the fire–grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41:604–616.

Fuhlendorf, S.D., W.C. Harrel, D.M. Engle, R.G. Hamilton, C.A. Davis, and D.M. Leslie Jr. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. Ecological Applications 16:1706–1716.

Hamilton, R.G. 1996. Using fire and bison to restore a functional tallgrass prairie landscape. Transactions of the North American Wildlife and Natural Resources Conference 61:208–214.

Hartnett, D.C., K.R. Hickman, and L.E. Fischer-Walter. 1996. Effects of bison grazing, fire, and topography on floristic diversity in tallgrass prairie. Journal of Range Management 49:413–420.

Hartnett, D.C., A.A. Steuter, and K.R. Hickman. 1997. Comparative ecology of native and introduced ungulates. Pages 72–101 *in* F.L. Knopf and F.B. Samson (eds.). Ecology and conservation of Great Plains vertebrates. Springer, New York.

Knapp, A.K., J.M. Briggs, S.L. Collins, D.C. Hartnett, L.C. Johnson, and E.G. Towne. 1999. The keystone role of bison in North American tallgrass prairie. BioScience 49:39–50.

Knopf, F.L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247–257.

Launchbaugh, J.L., and C.E. Owensby. 1978. Kansas rangelands: their management based on a half century of research. Bulletin 662, Kansas Agricultural Experiment Station, Manhattan.

Milchunas, D.G., O.E. Sala, and W.K. Lauenroth. 1988. A generalized model of the effects of grazing by large herbivores on grassland community structure. American Naturalist 132:87–106.

Ostfeld, R.S., S.T.A. Pickett, M. Shackak, and G.E. Likens. 1997. Defining scientific issues. Pages 3–10 *in* S.T.A. Pickett, R.S. Ostfeld, M. Shachak, and G.E. Likens (eds.). The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. Chapman and Hall, New York.

Shaw, J.H. 1995. How many bison originally populated western rangelands? Rangelands 17:148–150.

Shaw, J.H., and M. Lee. 1997. Relative abundance of bison, elk, and pronghorn on the southern Plains, 1806–1857. Plains Anthropologist 42:163–172.

Smith, E.F., and C.E. Owensby. 1978. Intensive early stocking and season-long stocking of Kansas Flint Hills range. Journal of Range Management 31:14–17.

Steinauer, E.M., and S.L. Collins. 1996. Prairie ecology—the tallgrass prairie. Pages 39–52 *in* F.B. Samson and F.L. Knopf (eds.). Prairie conservation. Island Press, Washington, D.C.

Steuter, A.A. 1986. Fire behavior and standing crop characteristics on repeated seasonal burns: northern mixed prairie. Pages 54–59 *in* A.L. Koonce (ed.). Prescribed burning in the Midwest: state of the art. University of Wisconsin, College of Natural Resources, Fire Science Center, Stevens Point.

Steuter, A.A., and L. Hidinger. 1999. Comparative ecology of bison and cattle on mixed-grass prairie. Great Plains Research 9:329–342.

Steuter, A.A., E.M. Steinauer, G.L. Hill, P.A. Bowers, and L.L. Tieszen. 1995. Distribution and diet of bison and pocket gophers in a sandhill prairie. Ecological Applications 5: 756–766.

The Nature Conservancy. 2000. Ecoregional conservation in the Osage Plains/Flint Hills Prairie. The Nature Conservancy, Midwestern Resource Office, Minneapolis, MN.

The Nature Conservancy. 2002. Guidelines for bison management. T.K. Bragg, B. Hamilton, and A. Steuter (eds.). The Nature Conservancy, Arlington, VA.

Vermeire, L.T., and T.G. Bidwell. 1998. Intensive early stocking. Oklahoma State University Extension Facts F-2875, Oklahoma Cooperative Extension Service, Stillwater.

Vinton, M.A., D.C. Hartnett, E.J. Finck, and J.M. Briggs. 1993. Interactive effects of fire, bison (*Bison bison*) grazing, and plant community composition in tallgrass prairie. American Midland Naturalist 129:10–18.

Wiens, J.A. 1997. The emerging role of patchiness in conservation biology. Pages 93–107 *in* S.T.A. Pickett, R.S. Ostfeld, M. Shachak, and G.E. Likens (eds.). The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. Chapman and Hall, New York.