11. Conservation of Grassland Vertebrates

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The Great Plains and Conservation History

The Great Plains grasslands of North America have historically been referred to as the western hemisphere counterpart of the Serengeti Plains of Africa, with herds of roaming ungulates including bison (*Bison bison*), elk (*Cervus elaphus*), deer (*Odocoileus* spp.), and pronghorn (*Antilocapra americana*) and an associated large carnivore assemblage including grizzly bear (*Ursus arctos*), gray wolf (*Canis lupus*), and coyote (*Canis latrans*). Native peoples lived in harmony within this landscape, growing vegetables on the central and eastern Plains and nomadically hunting the bison herds of the western Plains. Estimates of bison numbers have been as high as 60 million. Although we will never know for certain, surely they numbered in the tens of millions (Shaw 1995). The number of carnivores also is uncertain, but Native Americans noted that wolves alone killed one-third of all bison calves each year (De Smet 1905).

The lure of open spaces and the western frontier drew adventurous Easterners to the Plains. The first zoologist to cross the continent was J.K. Townsend who, in accompaniment of the noted botanist T. Nuttall, rode with the Wyeth expedition in 1832 (Townsend 1839). Many naturalists accompanied other exploration and survey expeditions onto the Plains. These included T. Say (Long Expedition, 1819–1820), S. W. Woodhouse (Creek Boundary Expedition, 1849–1850), E. Coues (Hayden Expedition, 1855–1857), and J.A. Allen (North Pacific Railroad Expedition, 1873) (Allen 1874, Coues 1874, James 1966, Tomer and Brodhead 1992). Others came not so much to describe the biota but to experience the thrill of the buffalo hunt, often joining Pawnee, Cheyenne, and other tribes on their hunts. Most significant of these was George Bird Grinnell.

George Bird Grinnell was the key individual in the founding of natural resource conservation in North America (Reiger 1975). From his early concerns over the demise of the bison herds (Grinnell 1873), Grinnell went on to develop the foundations of wildlife management, working closely with his good friend and political spearhead, President Theodore Roosevelt. Products of their activities included founding the U.S. Forest Service and U.S. National Park Service, the Boone and Crockett Club, the predecessor to The National Audubon Society, and state wildlife agencies. The essence of the Grinnell/Roosevelt team was their common love for the Great Plains and the American frontier. Modern-day conservation of natural resources grew from their collective experiences on the central and northern Great Plains and their shared vision that America's most endangered natural resources were those of the Plains. That vision was realized within their lifetimes with the demise of the bison and again a half century later during the nation's greatest conservation disaster, the dust bowl.

The tragedy of the dust bowl brought soil conservation into the forefront of Great Plains programs. Despite repeated pleas (Weaver 1954, Risser 1988) for attention, however, conservation programs have generally ignored the native terrestrial biota. Today, grasslands of the Great Plains remain the nation's most threatened ecosystem (Samson and Knopf 1994).

Ecological Drivers on the Great Plains

The science of ecology was born with the recognition of the orderly process of succession within biotic associations (Clements 1916). Beginning with primary invaders colonizing abiotic substrates, ecological succession fosters progressively more complex species assemblages and energy cycling within the biotic food chain. Succession ultimately approaches a state generally known as a "climax" biota that was once believed to represent long-term stability and enhanced diversity in ecosystems (Brookhaven National Laboratory 1969). More recently, the role of major disturbances on the landscape has been recognized as critical to maintaining the health of ecosystems (Pickett and White 1985, Turner 1987). In grasslands specifically, recent evidence also indicates that biotic diversity begets stability in periods of disturbance (Tilman and Downing 1994). Probably the most "disturbed" North American ecosystem historically was the Great Plains.

The forces of ecological disturbance on the Great Plains have been drought, fire, and grazing. These forces played major roles in directing evolution of the grassland biota. In that sense, they are more "drivers" of the ecosystem than "disturbances" per se (Evans et al. 1989), and it is the prevention of drought (via irrigation), the suppression of fire, and the removal of grazers that represent the true ecological disturbances of prairies. The interaction of these ecological drivers at varying intensities and scales are fundamental to maintaining landscape heterogeneity and biotic diversity within native grasslands (Collins and Barber 1985, Coppock and Detling 1986, Collins 1987, 1992, Howe 1994). Historically, drought has been a relatively universal ecological driver across the Great Plains, with grazing being the secondary driver on the westerly shortgrass prairie and fire the secondary driver on the easterly tallgrass prairie.

Drought

Periodic drought and fire are primarily responsible for the development of the grasslands (Weaver 1954, Anderson 1990), although each individually is mostly inadequate to maintain a grass landscape (Anderson 1982). In North America, the prevailing westerly winds rise to cross the Rocky Mountains, dropping moisture in passing and creating a rainshadow on the western Plains. Precipitation in Montana, Wyoming, Colorado, New Mexico, and the Oklahoma/Texas panhandles comes primarily from vernal thunderstorms; native grasses generally do not green until late May. The northward movement of Gulf of Mexico moisture results in increasing precipitation eastward. Thus, average annual precipitation increases from west to east across the Great Plains (Parton et al. 1981, Risser et al. 1981). In addition, relative humidity increases and wind speed, solar radiation, and potential evapotranspiration decrease from the western to the eastern Plains (Risser 1990).

The average rates of precipitation, however, are only partial drivers of evolutionary processes on the Great Plains. Rather, the inherent unpredictability of precipitation among years also has driven evolutionary processes within the biota (Mock 1991). Many changes in vegetation attributed to grazing may, in fact, be driven as much by drought (Branson and Miller 1981, Branson 1985). Infrequent, severe drought can cause massive local extinctions of annual forbs and grasses that have invaded stands of perennial species, and recolonization of those sites is quite slow (Tilman and El Haddi 1992).

Fires

Historic fires were ignited primarily by lightening in summer thunderstorms (Higgins 1984) and by native peoples (Higgins 1986) to protect villages from wildfire or to attract herbivores such as bison and pronghorns that respond positively to greening grasses after a burn (Coppock and Detling 1986, Higgins 1986, Shaw and Carter 1990). Early expeditions in the tallgrass and mixed-grass regions ignited the prairie during westward movements to ensure that nutritious forage would be available for their horses on the return journey (Tomer and Brodhead 1992, p. 205).

The role of fire as an ecological driver has been well researched on these prairies (Bragg and Steuter 1996, Steinauer and Collins 1996). Fire invigorates stands of grasses by recycling nutrients and destroying invading woody species, thus resulting in increased production. Destruction of the litter layer by summer fires especially opens the stand to seedling establishment, which favors cool-season grasses that enhance plant species richness and landscape heterogeneity. Both the role of historical fire on the shortgrass prairie (Wenger 1943) and its value as a management tool are less well understood.

Grazing

Grazing is the third major ecological driver on the Great Plains. Whereas dominant tallgrass prairie species such as big (*Andropogon gerardi*) and little (*Schizachyrium scoparium*) bluestems and indiangrass (*Sorghastrum nutans*) decrease under regimes of prolonged grazing, dominant shortgrass species such as blue (*Bouteloua gracilis*) and side-oats (*B. curtipendula*) gramas and buffalograss (*Buchloe dactyloides*) increase (Weaver 1954). In the tallgrass prairie, the behavior of grazing animals favors among-site heterogeneity of vegetation, especially where grasses are also subjected to periodic fire (Glenn et al. 1992). In the shortgrass prairie, which evolved with a major herbivory driver, heavy grazing promotes homogeneity of the landscape and inadequate grazing pressure results in enhanced heterogeneity (Larson 1941, Milchunas et al. 1988) (Fig. 11.1). In the latter situation, dominant grasses are stimulated by grazing and grow rapidly afterward, thus maintaining a competitive edge over invading grasses and forbs. Basal cover of grasses increases and cover of forbs decreases after grazing.

Heterogeneity within shortgrass landscapes historically was favored by the nomadic nature of the large herds of bison creating differential grazing pressures locally. The major promoter of natural heterogeneity in the shortgrass landscape,

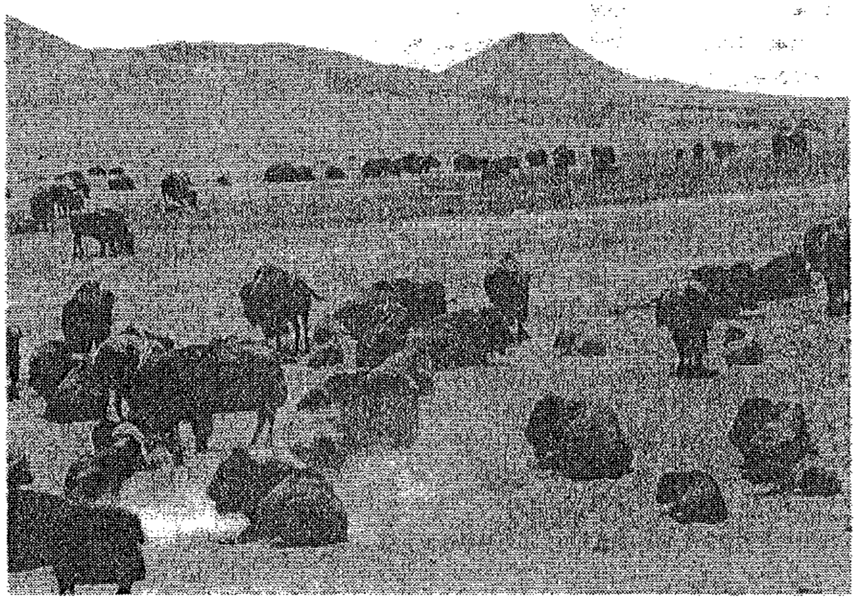

Figure 11.1. Intensive grazing pressure of herbivores on the shortgrass prairie favors grazing-adapted grasses and promotes more homogeneous vegetative landscapes (Campbell County, Wyoming) (Photograph by F.L. Knopf.)

however, remains the activities of prairie dogs (*Cynomys* spp.). Although drastically reduced in numbers (Summers and Linder 1978), prairie dogs still create a landscape patchwork of intensively grazed islands and disturbed soil surface (Whicker and Detling 1988). The grazing impacts and surface disturbances of prairie dogs were enhanced by the behavioral attractiveness of "towns" to bison and pronghorn, which preferentially forage and loaf on such sites (Coppock et al. 1983, Coppock and Detling 1986, Krueger 1986).

The Prairie Landscape in 1996

The arrival of European descendents on the North American grasslands drastically altered the face of the landscape as well as ecological relationships within the biota. The overwhelming influence has been to modulate the inherent range of natural variation in the ecological drivers of the prairies. Water management in the shortgrass and mixed-grass regions has locally removed the threat of periodic drought, resulting in increased cultivation and a westward extension of cereal grain agriculture. Fire suppression in the tallgrass and mixed-grass prairie has led to loss of species richness and, in the case of species like the blowout pentstamen (*Penstemon haydenii*) in the Nebraska Sandhills, the potential extinction of species.

Cultivation and residential and industrial development have obliterated potential habitats for many vertebrate species locally. Total losses of native prairie range from 20% of shortgrass prairie in Wyoming to greater than 99% of tallgrass prairies in Illinois and Iowa (Table 11.1). Overall, estimates of conversion of native prairie to either cropland or pastureland (seeded with non-native, tame grasses) in the United States range from 29% of shortgrass, 41% of mixed-grass, and more than 99% of tallgrass landscapes (U.S.Department of Agriculture 1987). Pastureland provides surrogate prairie habitat for some vertebrate species of the eastern Plains (Herkert 1993, 1994).

The loss of native grasslands as potential vertebrate habitats is even more devastating as remnant grasslands become more and more fragmented and isolated. The effects of fragmentation are threefold. First, many species of vertebrates require large, intact parcels of grassland for survival and reproduction (Samson 1980, Herkert 1994). As remnants decrease in size, these area-sensitive species are progressively extirpated locally. Second, as remnants become more isolated, the probability of colonization/recolonization of a patch decreases with distance from another patch (Kaufman and Kaufman, this volume). Third, populations in isolated patches suffer from genetic inbreeding and accelerated rates of genetic drift (Benedict et al. 1996).

Fragmentation is not specifically a cultivation issue. Throughout the Great Plains, tree plantings have resulted in a patchwork pattern of forest and grass, creating a pastoral landscape. Windbreaks are interspersed across the former grass landscape to the point that 3% of the Great Plains is now forested (Friedman et al., this volume). Trees are currently being planted at the rate of 20.7×10^6 per year

Table 11.1. Estimated Current Area, Historic Area, and Percentage Decline of Tallgrass, Mixed-Grass, and Shortgrass Prairies[a]

	Historic (ha)	Current (ha)	Decline (ha)
Tallgrass			
Manitoba	600,000	300	99.9
Illinois	8,900,000	930	99.9
Indiana	2,800,000	404	99.9
Iowa	12,500,000	12,140	99.9
Kansas	6,900,000	1,200,000	82.6
Minnesota	7,300,000	30,350	99.6
Missouri	5,700,000	30,350	99.5
Nebraska	6,100,000	123,000	98.0
North Dakota	1,200,000	1,200	99.9
Oklahoma	5,200,000	NA[b]	NA
South Dakota	3,000,000	449,000	85.0
Texas	7,200,000	720,000	90.0
Wisconsin	971,000	4,000	99.9
Mixed grass			
Alberta	8,700,000	3,400,000	61.0
Manitoba	600,000	300	99.9
Saskatchewan	13,400,000	2,500,000	81.3
Nebraska	7,700,000	1,900,000	77.1
North Dakota	13,900,000	3,900,000	71.9
Oklahoma	2,500,000	NA	NA
South Dakota	1,600,000	NA	NA
Texas	14,100,000	9,800,000	30.0
Shortgrass			
Colorado	NA	NA	NA
Oklahoma	1,300,000	NA	NA
Saskatchewan	5,900,000	840,000	85.8
South Dakota	179,000	NA	NA
Texas	7,800,000	1,600,000	80.0
Wyoming	3,000,000	2,400,000	20.0

[a]From Samson and Knopf 1994.
[b]NA, not available.

(Griffith 1976), many being exotics and mostly subsidized by state forest agencies (Olson and Knopf 1986). Fire suppression has led to brush and tree encroachment along the periphery of the Plains (Bird 1961, Pulich 1976).

The historic prairie landscape included patchy-to-linear stands of deciduous trees along streambanks. These associations were more common in the east and became infrequent moving west, especially on the southern Plains. Woody riparian associations also were common along the foot of the Rocky Mountains, where streams flowed seasonally into the Plains, some as headwaters emptying into larger systems as the Arkansas, Canadian, and Platte rivers and others drying or

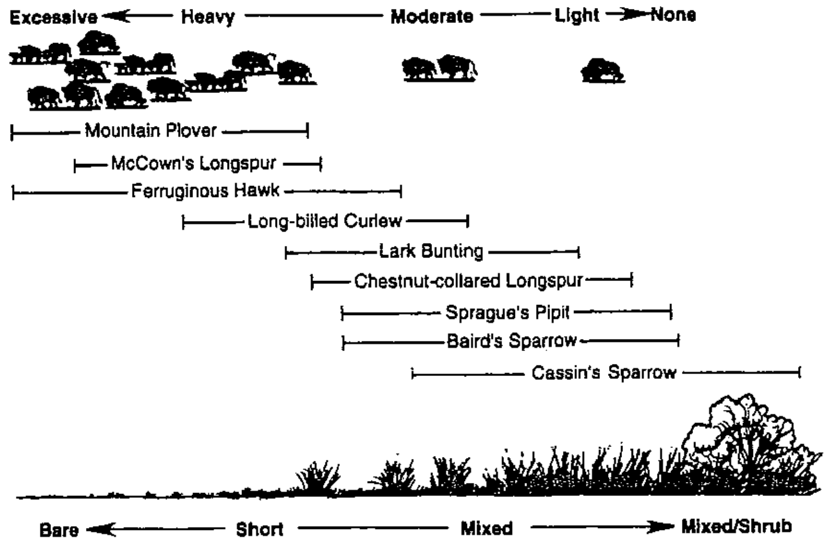

Figure 11.2. Distributions of endemic birds of prairie uplands on a shortgrass/mixed-grass and historical grazing pressure continua across the western landscapes of the Great Plains. (From Knopf 1996.)

seeping into the soils. These riparian forests on the Great Plains have become more extensive with fire suppression on the east (Abrams 1986, Rothenberger 1989) and ecological succession after water management on the west (Wedel 1986, Knopf and Scott 1990), resulting in ribbons of deciduous vegetation slicing the grassland sea. Similarly, clearing of the eastern deciduous forest for hayfields has created a patchwork of trees and grasslands through the historic prairie peninsula on to New England (Askins 1993). These trends will continue as population pressures homogenize landscapes across the nation.

The estimated tens of millions of bison on the western Plains were replaced by an estimated 45 million cows and an equal number of domestic sheep by 1890 (Fedkiw 1989). Replacement of bison with cattle has not, however, had a major impact on western grasslands (Hartnett et al., this volume), but management of cattle with fences has created endless homogeneous landscapes by removing the differential intensities of grazing among sites that historically created the mosaic of habitats needed to support many species (Knopf 1996a). Fences are used to regulate grazing pressure more precisely, primarily to reduce soil erosion while simultaneously maximizing long-term vegetative productivity of a site under the general range management paradigm of "take half and leave half" of the vegetation. Grassland birds (Wiens 1973), and especially the primary endemic species (Knopf 1996b), evolved within a gradient of differentially grazed landscapes (Fig. 11.2). The uniformity of grazing management on the Great Plains probably has a more negative effect on endemic avian assemblages than the actual presence of livestock or the consequences of grazing (Knopf 1996a).

Figure 11.3. Seasonal wetlands, some present less than 1 year in 10, provide critical foraging areas for long-distance migrants such as the Long-billed Dowitcher (*Limnodromus scolopaceus*) that cross the Great Plains to reach their breeding habitats within the arctic circle (Larimer County, Colorado) (Photograph by F.L. Knopf.)

Prairie streams had a strong riffle/pool structure that resembled more a series of seasonally connected small ponds or lakes during periods of low flow (Brown and Matthews 1996). Size of pools increased and length of riffles generally decreased moving down the drainage; all except the Missouri River periodically may have become intermittent in periods of drought. Today, water diversion and groundwater pumping have accentuated the intermittency of these streams on most of the Great Plains (Samson et al. in press).

A less noticeable, but equally pervasive, threat to native fishes has been the rampant accidental and deliberate introduction of alien (North American species native to biogeographic provinces other than the Great Plains) and exotic (species from other continents) fishes into native streams. Ross (1991) reported that more than three of every four introductions of exotic fishes resulted in declines in populations of indigenous species. Introductions of fishes indigenous to other biomes, however, may represent a larger threat to Plains fishes than introductions of game fishes (Fausch and Bestgen, this volume). Thus, both the loss of habitat and fish introductions seem critical to protecting the simplistic indigenous fish assemblages of the western Plains.

Across the northern Great Plains, historic natural wetlands have been destroyed at an alarming rate. Estimates of wetland loss range from 86% in tallgrass prairie states (Illinois and Iowa) to 40% in Montana (Dahl 1990). These losses are of most conservation concern in the Rainwater Basin and Sandhills wetlands of Nebraska and the Prairie Pothole region that extends from the Dakotas into Manitoba and Saskatchewan as prairie-parkland wetlands. Drainage of wetlands and conversion of the landscape to row cropping continues to destroy these major breeding grounds for waterfowl populations (Betheke and Nudds 1995). Smaller complexes to the south in Kansas and Oklahoma (e.g., Cheyenne Bottoms, Kansas [Zimmerman 1990]) are less extensive but especially critical to support transcontinental migrations of both waterfowl and other wetland species that breed in the Arctic but winter in South America (Skagen, this volume) (Fig. 11.3).

Focusing Conservation Action

Societies can protect portions of an ecosystem in nonuse preserves, but in the long term, partnerships addressing issues on lands managed for timber, grazing, and other commodities will play a major role in the conservation of the native biota (Raven 1990). A framework for conservation is developing for the Great Plains (Risser 1996). This framework is built on the principles that (1) past and current research is providing more sophisticated (especially geospatial) information to define and address conservation issues, (2) prairie conservation must be based on addressing multiple uses, (3) both short- and long-term economic values of prairies must be secured, and (4) conservation actions must extend across property lines. Prototypes for conservation action are currently seen in successful partnerships such as the North American Waterfowl Plan's Joint Ventures (Kresl et al. 1996), the Western Governor's Association's Great Plains Partnership (Clark 1996), and Canada's Prairie Conservation Action Plan (Dyson 1996). Each of these programs emphasizes proactive conservation through the building of working partnerships between the private sector and federal, state, and county agencies to define and address conservation issues.

Given the evolving foundations for progressive conservation on the Great Plains, a major hurdle remains to integrate the variety of social, economic, and biological issues into working conservation plans (Clark 1996, Johnson and Bouzaher 1996). However, scientists have had difficulty setting the biological priorities for the conservation of diversity (Roberts 1988), and the profession lacks any unified approach to evaluating conservation strategies (Erwin 1992). Much of the confusion can be attributed to the need to assess conservation actions across multiple biological, temporal, and spatial scales (Knopf and Smith 1992).

The embryonic science of ecosystem management (Samson and Knopf 1996) offers much hope for proactive conservation of biological diversity in the future. To date, however, hard science has played only a minor role in the conservation of biological diversity (Weston 1992), and the cost and time constraints necessary to understanding all aspects of ecosystem function are prohibitive. Samson and

Knopf (1993) suggest focusing ecosystem management with a mechanistic approach that (1) understands the differences between alpha and beta diversity, (2) defines the biotic integrity of an ecosystem, (3) protects ecological processes maintaining that integrity, and (4) assures that those processes are sustainable through time.

Diversity and Integrity

The extensive grasslands of North America have a long evolutionary history since they arose with increasing aridity more than 30 million years ago in the Miocene (Howe 1994, Brown and McDonald 1995). In more recent times, the Great Plains have experienced a series of glacial advances since the Pleistocene that have fostered periodic biogeographic barriers to dispersal of vertebrates. The recurring barrier favored accelerated adaptive radiation of forest species to the east and west and, through instability, resulted in the evolution of comparatively few species on the grasslands themselves (Mengel 1970, Wells 1970, Axelrod 1985).

Modern settlement and development of the Great Plains have been accompanied by a trend of ecological generalist species invading the Great Plains from contiguous biomes, with examples ranging from the obvious house mouse (*Mus musculus*) to more subtle range extensions such as those of the least shrew (*Cryptotis parva*) and Blue Jay (*Cyanocitta cristata*) (Knopf and Scott 1990, Benedict et al. 1996, Rabeni 1996). Thus, modern vertebrate assemblages contain more species now than historically. Whereas one would suspect enhanced faunas in heavily developed locales such as the current avifauna of suburban Tucson, Arizona, which is 95% synthetic (Emlen 1974), it is surprising that nearly 90% of the current breeding avifauna of rural northeastern Colorado has colonized the area since the turn of the century (Knopf 1986).

Conservation of biological diversity of the Great Plains has generally been hampered by a tendency to confuse species richness (alpha diversity) and species diversity (beta and gamma diversity) topically. The importance of Plains riparian areas has been promoted because of the habitats they provide for more species than surrounding grasslands (e.g., Tubbs 1980). Emphasizing the total number of species locally is short sighted, especially in riparian vegetation (Knopf and Samson 1994), and ultimately becomes counterproductive when viewed at larger scales (Murphy 1989, Martin 1992). The problem in using the total number of species lies in the observation that a large number of ecological generalists can overwhelm the unique elements of the vertebrate biota. As in northeastern Colorado, the collective vertebrate biota of the Great Plains comprises many species that are either ecological generalists (occurring across many biotic provinces of North America) or are peripheral to their main geographic distribution in contiguous biomes.

Evolutionarily, a small set of species and abiotic processes structures ecosystems across spatial and temporal scales. In his classic synthesis, Holling (1992) compared vertebrate assemblages of Canadian shortgrass prairies and boreal forests and suggested that only a few processes over a limited range of scales

Table 11.2. Numbers of Vertebrate Species Recorded on the Great Plains, Number That Are Endemic to the Great Plains, and Number with Strongly Western Great Plains Affinities

	No. Species	No. (%) Endemic	No. (%) Western	References
Fish	250	34 (14)	0 (0)	Cross et al. 1986, Rabeni 1996, Bestgen, personal communication
Amphibians	34	2 (6)	1 (50)	Corn and Peterson 1996, Corn, personal communication
Reptiles	90	8 (9)	1 (17)	Corn and Peterson 1996, Corn, personal communication
Birds	604	12 (2)	12 (100)	Mengel 1970
Mammals	138	16 (12)	11 (69)	Benedict et al. 1996

uniquely characterize ecosystems and the morphology of their animals. Ecosystems are controlled and governed by a few species and abiotic processes that ultimately structure the landscape. Holling referred to this as the *Extended Keystone Hypothesis.* Certain species reflect ecological processes within an ecosystem, and those are the species historically indigenous to that system. These species evolved within the system and are referred to as the ecological endemics.

The degree of endemism (gamma diversity) among the vertebrate classes on the Great Plains ranges from 2% of bird species to 14% of fish species (Table 11.2). Of the endemic vertebrates, the aquatic classes (fish, amphibians) and reptiles (including three aquatic species also) are primarily species of the eastern Great Plains. Alternatively, the terrestrial classes (birds and mammals) are primarily western derived. Vertebrate endemism in the Great Plains follows the west-east gradient of increasing moisture, the primary ecological driver of the region. Thus, reducing drought effects is conservationally correct on the eastern Plains and ecologically short sighted on the western Plains.

Sustaining Ecological Processes

The first sign of degradation of an ecosystem appears at the population level of sensitive species (Odum 1992). The endemic vertebrates of the Great Plains can be argued to be the most sensitive to changes in the ecological drivers of the biotic province (Knopf and Samson 1996). Thus, they become indicators of ecosystem health. Rather than monitor and research the ecology of 1,116 species of fish, amphibians, reptiles, birds, and mammals, ecosystem health can be tracked by programs that monitor only 72 species (Table 11.3). Prolonged declines of some species would trigger research to define causes of those declines—a highly cost-effective approach relative to funding research on all 1,116 species and their supporting floral and invertebrate biota. The long-term monitoring of the 72 vertebrate species would not be conducted across the entire Great Plains. As noted,

Table 11.3. Endemic Vertebrate Species of the Great Plains

- Fish[a]
  - Acipenseridae
    - Pallid sturgeon *Scaphirhynchus albus*
  - Cyprinidae
    - Western silvery minnow *Hybognathus argyritis*
    - Sturgeon chub *Macrhybopsis gelida*
    - Sicklefin chub *M. meeki*
    - Redspot chub *Nocomis asper*
    - Red River shiner *Notropis bairdi*
    - Wedgespot shiner *N. greenei*
    - Blacknose shiner *N. heterolepis*
    - Kiamichi shiner *N. ortenburgeri*
    - Ozark shiner *N. ozarcanus*
    - Peppered shiner *N. perpallidus*
    - Duskystipe shiner *Luxilus pilsbryi*
    - Bleeding shiner *L. zonatus*
    - Slim minnow *Pimephales tenellus*
  - Ictaluridae
    - Ozark madtom *Noturus albater*
    - Checkered madtom *N. flavater*
    - Ouachita madtom *N. lachneri*
    - Neosho madtom *N. placidus*
    - Caddo madtom *N. taylori*
  - Amblyopsidae
    - Ozark cavefish *Amblyopsis rosae*
  - Cyprinodontidae
    - Plains topminnow *Fundulus sciadicus*
  - Centrarchidae
    - Ozark bass *Ambloplites constellatus*
  - Percidae
    - Arkansas darter *Etheostoma cragini*
    - Arkansas saddled darter *E. euzonum*
    - Yoke darter *E. juliae*
    - Yellowcheek darter *E. moorei*
    - Niangua darter *E. nianguae*
    - Paleback darter *E. pallididorsum*
    - Stippled darter *E. punctulatum*
    - Orangebelly darter *E. radiosum*
    - Missouri saddled darter *E. tetrazonum*
    - Bluestripe darter *Percina cymatotaenia*
    - Longnose darter *P. nasuta*
    - Leopard darter *P. pantherina*
- Amphibians
  - Pelobatidae
    - Plains spadefoot *Spea bombifrons*
  - Ranidae
    - Plains leopard frog *Rana blairi*
- Reptiles
  - Emydidae
    - Texas map turtle *Graptemys versa*
    - Ornate box turtle *Terrapene ornata*
  - Iguanidae
    - Dunes sagebrush lizard *Sceloporus arenicolus*
  - Scincidae
    - Prairie skink *Eumeces septentrionalis*
- Reptiles (*continued*)
  - Colubridae
    - Brazos water snake *Nerodia harteri*
    - Concho water snake *N. paucimaculata*
    - Plains garter snake *Thamnophis radix*
    - Lined snake *Tropidoclonion lineatum*
- Birds
  - Accipitridae
    - Ferruginous Hawk *Buteo regalis*
  - Charadriidae
    - Mountain Plover *Charadrius montanus*
  - Scolopacidae
    - Long-billed Curlew *Numenius americanus*
    - Marbled Godwit *Limosa fedoa*
    - Wilson's Phalarope *Phalaropus tricolor*
  - Laridae
    - Franklin's Gull *Larus pipixcan*
  - Motacillidae
    - Sprague's Pipit *Anthus spragueii*
  - Emberizidae
    - Cassin's Sparrow *Aimophila cassinii*
    - Baird's Sparrow *Ammodramus bairdii*
    - Lark Bunting *Calamospiza melanocorys*
    - McCown's Longspur *Calcarius mccownii*
    - Chestnut-collared Longspur *C. ornatus*
- Mammals
  - Canidae
    - Swift fox *Vulpes velox*
  - Mustelidae
    - Black-footed ferret *Mustela nigripes*
    - Spotted skunk *Spilogale putorius*
  - Antilocapridae
    - Pronghorn *Antilocapra americana*
  - Bovidae
    - Bison *Bison bison*[b]
  - Sciuridae
    - Black-tailed prairie dog *Cynomys ludovicianus*
    - Franklin's ground squirrel *Spermophilus franklinii*
    - Richardson's ground squirrel *S. richardsonii*
    - Thirteen-lined ground squirrel *S. tridecemlineatus*
  - Geomyidae
    - Plains pocket gopher *Geomys bursarius*
  - Heteromyidae
    - Olive-backed pocket mouse *Perognathus fasciatus*
    - Plains pocket mouse *P. flavescens*
    - Hispid pocket mouse *Chaetodipus hispidus*
  - Muridae
    - Northern grasshopper mouse *Onychomys leucogaster*
    - Plains harvest mouse *Reithrodontomys montanus*
    - Prairie vole *Microtus orchrogaster*
  - Leporidae
    - White-tailed jackrabbit *Lepus townsendii*

[a]Systematics of fish follow Robins et al. (1991).
[b]Not identified as grasslands endemic by Benedict et al. (1996).

the aquatic and semiaquatic species tend to be on the eastern Plains and the terrestrial species on the western Plains. Early detection of dysfunction in an ecological driver at an area would permit early corrective action and ensure ecosystem sustainability through time.

Monitoring unique vertebrate elements of the Great Plains as indicators of ecosystem health would operate on the assumption that major losses within lower biotic forms as invertebrates would produce detectable changes in vertebrate species. Certainly, declines in insectivorous vertebrates regionally would stimulate stepdown inquiries into the status of invertebrate indicator assemblages (Arenz and Joern 1996) that, in turn, may reflect changes in vegetative components of an ecosystem. Plant/invertebrate-grazing communities are the first to adjust to ecosystem disturbance and likely possess some resiliency to compensate impacts and, thereby, buffer consequences to vertebrates.

The use of narrow endemic species as biological indicators of the health of the Great Plains would help avert environmental "train wrecks" (Stone 1993) and simultaneously be compatible with other environmental legislation such as the Endangered Species Act (ESA). Endemic species, with their limited distributions and narrower ecological tolerances, dominate the national list of endangered species. Simply stated, endemic species are less resilient. Using research on endemic species to secure the future of all species is a proactive approach to keeping species from being listed under the ESA. Once listed, recovery of an endangered species is comparatively costly and often confrontational with human development of landscapes. Conservation actions using endemic vertebrate species as indicators of ecosystem health will ultimately minimize species loss, political confrontation, and economic compromise on the Great Plains. Implementing such an approach ensures that the North American Great Plains will continue to be the frontier of conservation theory and practice.

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