Biodiversity and its Management on the National Elk Refuge, Wyoming

Noah P. Matson
Defenders of Wildlife

ABSTRACT
The National Elk Refuge is home to 178 species of birds, 49 species of mammals, 382 species of vascular plants, five species of native fish, five species of reptiles and amphibians, and unknown numbers of species of invertebrates and non-vascular plants. The refuge is charged with protecting, enhancing, and restoring populations and habitats of all the species found on its grounds. Since its inception, however, management has focused on elk. Supplemental feeding has supported higher numbers of elk than the refuge ecosystem can handle, and it has long been recognized that the large concentration of these ungulates has had negative impacts on a number of biotic communities. Elk have reduced and eliminated woody tree and shrub cover along riparian areas, limited aspen regeneration, reduced sage-grassland structural diversity, and rendered areas prone to exotic plant invasion. If current management continues, these vegetative communities and their associated wildlife species will continue to decline. This paper recommends that the refuge needs: (1) to define its commitment to the protection of biodiversity before it can manage biodiversity more sustainably; (2) to manage on a regional level and coordinate with other agencies and private landowners; (3) to establish a comprehensive monitoring and data analysis program to determine if management prescriptions are successful and to adapt management to changing information and conditions; (4) to reduce supplemental feeding and the size of the elk herd; (5) to take measures to restore degraded communities; and (6) to build a constituency for biodiversity. The report is designed to be a resource for future activities and a summary of past trends in management and biodiversity.

"Biodiversity is the variety of life and its processes. It includes the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting" (Noss and Cooperrider 1994: 5).

Just a brief field trip to the National Elk Refuge (NER) reveals that this 25,000-acre area is habitat for much more than elk. One hundred seventy-eight species of birds, 49 species of mammals, 382 species of vascular plants, five species of native fish, five species of reptiles and amphibians, and potentially thousands of species of invertebrates and non-vascular plants use the refuge for all or part of the year (Appendix B). Almost all these species are found throughout the Greater Yellowstone Ecosystem (GYE), many migrating between winter and summer ranges as well as to points far north or south. These species are associated with six main biotic communities on the refuge: sage-grasslands, sedge-marshlands (wetlands), aspen forests, woody-riparian, irrigated domestic grasses, and aquatic communities (Figures 1 and 2).

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Since its inception, the NER has focused its management activities on elk and other game species. Without the attention on the Jackson elk herd, there would likely be no wildlife refuge in Jackson Hole, so the importance of elk cannot be ignored. However, the status and trends for biodiversity as a whole have never been studied. Many agencies are moving away from single species management, including the U. S. Fish and Wildlife Service (USFWS), which under the National Wildlife Refuge System Improvement Act (NWRSIA) of 1997, is mandated to "maintain the biological integrity, diversity, and environ-

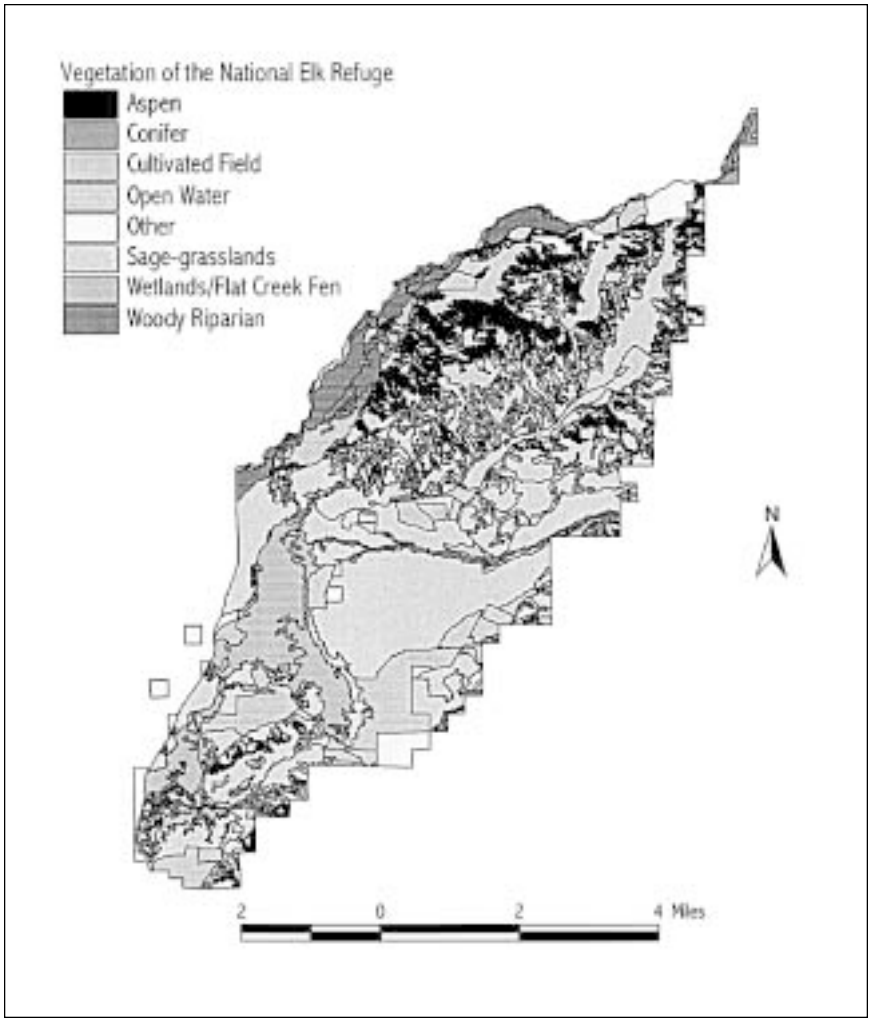

Figure 1 Map

As part of the comprehensive management plan required by the NWRSIA, the distribution, migration patterns, and abundance of fish, wildlife, and plant populations and related habitats within the refuge must be identified and described.

mental health of the Refuge System." In addition, the NWRSIA requires the USFWS to "monitor the status and trends of fish, wildlife, and plants in each refuge."

This paper describes the historical and present status of biodiversity on the refuge, identifies specific populations and procedures for monitoring and provides recommendations and products to help manage biodiversity sustainably. As part of the comprehensive management plan required by the NWRSIA, the distribution, migration patterns, and abundance of fish, wildlife, and plant populations and related habitats within the refuge must be identified and described. In addition, significant problems that may adversely affect populations and habitats within the NER and actions necessary to correct or mitigate such problems must also be identified. This report is designed to be a resource for future activities and a summary of past trends in management and biodiversity.

METHODS

To assess biodiversity and biodiversity management on the NER, twenty personal interviews were conducted, refuge records and other literature were reviewed, and qualitative data were collected during field trips on the refuge. I interviewed individuals (Appendix A) who had researched or spent extensive time on the NER or dealt with refuge-related problems. During each interview, I asked about trends in different species and species groups and about management recommendations for biodiversity.

Refuge records contained valuable information on wildlife populations, particularly game species. The annual narrative reports provided population estimates, breeding information, unusual species occurrences or trends, and information on habitat management. Individual files on waterfowl breeding pair counts dating back to 1978 and on waterfowl brood counts dating back to 1988 were compiled. Various other records provided additional information. Literature reviews were used to gain insight into specific topics.

I made six field trips to gather observational and interview data: (1) an initial tour of the NER, led by refuge biologist Bruce Smith; (2) a feasibility study for a range survey of the NER to be conducted by Bridger-Teton National Forest vegetation biologist Deborah Deslaurier; (3) a bird survey along Flat Creek; (4) a tour of the refuge organized by the Teton County Natural Resource District highlighting ecologically stressed areas and other NER-related issues; (5) a Native Plant Society field trip led by Walter Fertig of the Wyoming Natural Heritage Program to collect information on unique plants and the Flat Creek Fen; and (6) a personal reconnaissance of the northern section of the refuge to gather qualitative data on aspen and other communities.

As early as 1941, it was recognized that the elk wintering on the NER were affecting the ecosystem. Since then, little has been done to curb these effects and certain species and communities have declined.

TRENDS IN BIODIVERSITY

"*On these lands along the Gros Ventre River there is a heavy growth of willows and many patches of aspen. This winter, before the elk feeding began, there were at times as many as 3000 elk staying on those lands with a number remaining there the entire winter. The willow and aspen growths in the area already show signs of being heavily browsed. As time goes on it is very probable that the willows and aspen growths in that area will be destroyed from overbrowsing. This condition is already true of the willow, aspen, and shrubbery growths on the old portion of the refuge area" (Almer P. Nelson, Refuge Manager, 1941 Annual Narrative Report).*

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The NER has been collecting population data on game species since its inception. Although survey methods have changed over time, making comparisons difficult, some species have quantitative data dating back to the 1930s (Appendix C). Some species data sets are missing many data points because

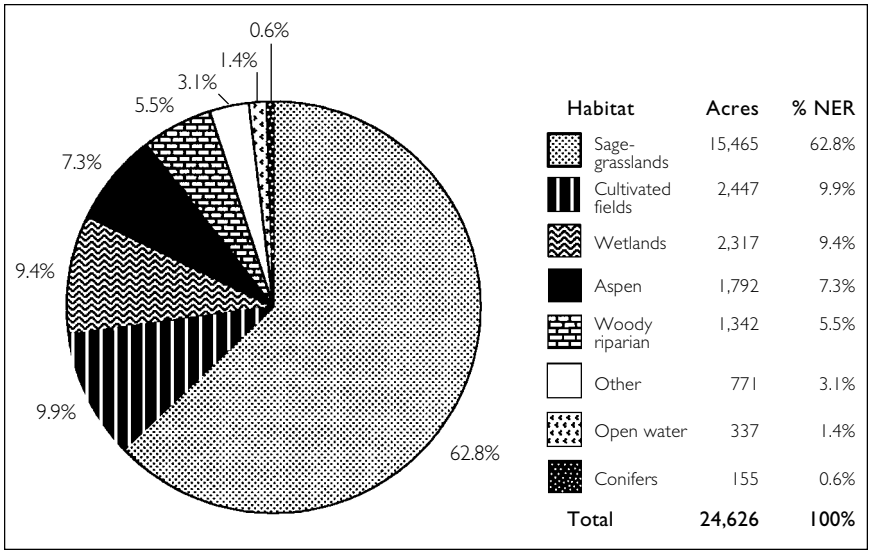

Figure 2 Areas of habitat types on the National Elk Refuge, Jackson, Wyoming. *(Source: 1986 Digital vegetation map of the NER prepared by Bruce Smith)*

data either were not reported in the annual reports or were lost over the decades and through a move in headquarters, making analysis difficult. Table 1 shows trends and status of individual species and species groups that have quantitative or qualitative data available.

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The species most likely affected by habitat changes caused by elk are habitat specialist passerine birds and small mammals, which have not been monitored regularly or systematically in the past. Wildlife populations are "intricately related to the quantity and quality of habitats required for their maintenance" (Kirsch *et al.* 1978: 486), and there have been many attempts to model these relationships (Merrill *et al.* 1996; Verner *et al.* 1986). This section documents and summarizes what is known about the vegetative and aquatic communities on the NER and relates their condition to other species. Areas and distributions of the community types were analyzed using a digital version of a 1986 NER vegetation map imported into a geographic information system (ArcView by ESRI). Although some of these community types have likely changed in area, this is the most up to date and accurate information available.

WOODY RIPARIAN

Woody riparian areas, constituting 5.5% of the refuge (1,342 acres) (Figure 2), are concentrated along the two main tributaries on the refuge, Flat Creek and the Gros Ventre River. Because they remain above snow level, shrubs and trees are vulnerable to browsing in winter when concentrations of browsers are highest. Concerned about woody shrubs, refuge manager Almer P. Nelson in 1941 photographed willows directly inside and outside refuge fencing "in order to substantiate the necessity of having the number of elk that come onto the refuge for winter feed reduced to a number that the refuge area will reasonably

Table 1 Summary of status of species and groups on the National Elk Refuge, Jackson, Wyoming, where information is known.

Species/Group	Status/trend
Badgers	Populations stable or increasing.
Beavers	Beaver populations are down from historical populations, both on the refuge and across the country. "Through the enlargement of the refuge the Biological Survey has also become the custodian of a considerable colony of beavers that inhabit lands along the Gros Ventre River" (NER 1937). Today, there are only a handful of beavers in the area. Beavers were heavily trapped for their fur during the early part of the century. Their dam building also interferes with human activities and currently populations are controlled to limit their impact. Beavers are directly controlled on the northern section of the refuge along the Gros Ventre River to prevent them from damming water diversions to South Park and mitigation ponds on the refuge. There is also evidence that severe browsing by elk, deer, and moose may limit forage for beavers and drive down their populations. Beavers are considered a keystone species, modifying habitat. Many ecosystems and communities have evolved to deal with the dynamic hydrologic conditions created by beavers. Restoration of beaver populations would have positive effects on biodiversity, but would also make management of water resources extremely difficult.
Bighorn sheep	The population wintering on Miller Butte has increased in the last few years, but is much lower than a peak in the early 1960s. Throughout the region, bighorn sheep populations have declined from diseases contracted from domestic sheep and potentially from competition with the increased elk population.
Bison	Almost an exponential increase in the wintering population since the late 1970s (Appendix C1). Cromley (this volume) discusses the management of the bison herd.
Coyotes	Populations fluctuate, but are not threatened. Coyotes were controlled in the late 1940s and early '50s. As many as 85 were killed in 1949.
Moose	Have maintained a fairly stable wintering population of 25 animals for 60 years, even though GTNP scientists report their numbers are down (Figure C1).
Mule deer	The wintering population has decreased since the 1960s (Figure C1). Mule deer may compete with elk for certain resources.
Muskrats	"Previous to 1936, when the refuge added 700 ac of ideal muskrat habitat, private trappers are said to have taken off about 250 'rats' annually" (NER 1957). Before 1960, the estimated population averaged 700 muskrats. After 1960, the estimated population averaged 100 muskrats. All estimates were to the nearest hundred, and thus not particularly accurate. This drop may have been a change in protocol or personnel. However, if the population was as robust as to yield 250 muskrats a year, there certainly is not that type of abundance today. It is unknown what could have caused the population to decline.
Mountain lions	There has been an increase in lion predation on and near the refuge in recent years.
Uinta ground squirrels	The population fluctuates, but is not threatened. Ground squirrels are an extremely important food source for coyotes, badgers, and birds of prey.

Species/Group	Status/trend
Shorebirds	There has been a decline in shorebirds using the refuge in the last two decades. Raynes (1998) reports a decrease in mud flats along Flat Creek that provided habitat to shorebirds.
Songbirds	There is very little known about songbird populations on the refuge. From related studies elsewhere, there has likely been a dramatic decrease in warblers, wrens, and flycatchers because of the deterioration of willows. The only songbird study took place in aspen stands for a span of 5 years. This report found a decrease in house wrens, olive-sided flycatchers, western wood peewees, and yellow warblers and concluded that the house wren and yellow warbler decreases were localized.
Raptors	Populations appear to be stable, possibly still increasing since the ban on DDT. The refuge has the closest (densest) red-tailed hawk nests documented in the literature, presumably from the abundance of prey and the low number and close proximity of appropriate nest sites.
Waterfowl	Waterfowl species have had the best and most extensive data collected, including fall migration, breeding pair, and production counts, particularly since 1978 (Appendix C2). Populations have gone through cycles, most of which seem to cor relate with regional and national trends. The creation of six mitigation ponds in the northern section of the refuge in 1990 was intended to increase waterfowl habitat and thus waterfowl use. Comparing the means of total duck breeding pairs five years before and five years after pond construction, the mean number of breeding pairs using the refuge had increased ($p=0.076$, one-sided t-test). Unfortunately, without additional temporal data, comparison with a control, or more detailed information on water fowl spatial use of the refuge, it is impossible to attribute the increase to the ponds. In fact, most ducks have increased regionally and nationally during the same time period. Waterfowl production is limited by spring floods which often wipe out the first brood. This is exacerbated by the timing of water diversions to South Park.
Herptiles	An amphibian and reptile survey of the refuge was conducted in 1998 and found all expected species: boreal chorus frogs, Columbian spotted frogs, boreal toads, blotched tiger salamanders, and garter snakes. Although no trend data is available, their presence is a good sign because of amphibian sensitivity to environmental changes. There may have been a decline in amphibians with the installation of the mitigation ponds, which disrupted natural wetland areas, although amphibians are still found there.

support" (Nelson 1941: 5). Willows inside the fencing, where elk had access, were severely overbrowsed. Not only was this a problem for willows, but "it is questionable as to what effect it will have on the refuge herd should all of the willows, aspen and shrubbery growth on the area be destroyed from over browsing" (p. 6).

The number of elk wintering on the NER since then has remained about the same or larger (Figure 3). Today, numerous dead willow stumps can be found along Flat Creek and the other drainages. According to NER records, historical photos, and personal accounts from long-time residents, willow cover has declined dramatically on the refuge since its inception (Cannon 1998; Fertig 1998b; Griffin 1998; Hudelson 1998; Nelson 1941; NER 1940-1995; Galbraith *et al.* 1998; B. Smith 1998a). In 1997 NER biologist Bruce Smith installed a demonstration exclosure along a section of Flat Creek to measure vegetation growth and browse and to document the presence and potential changes in birds and small mammals. There is another exclosure on the southwestern section of the NER near the visitor center. Both exclosures show increased growth of riparian shrubs in the absence of elk and other large herbivores.

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This decline in woody vegetation has occurred in other areas with high densities of elk and other ungulates. Kay and Chadde (1991), Kovalchik and Elmore (1991), Ammon and Stacey (1997), and Case and Kauffman (1997) all document decreased willow growth, cover, and reproduction in grazed areas compared with ungrazed areas. Kay and Chadde (1991, 1994) examined willow conditions in relation to the large elk herd on Yellowstone National Park's northern range. Using long-term exclosures, they found that ungulate browsing reduced potential willow seed production by 100%. "Moreover, based on photographic evidence, few willows on Yellowstone's northern range appear to have produced seeds for the last 50 or so years" (Kay and Chadde 1991: 96).

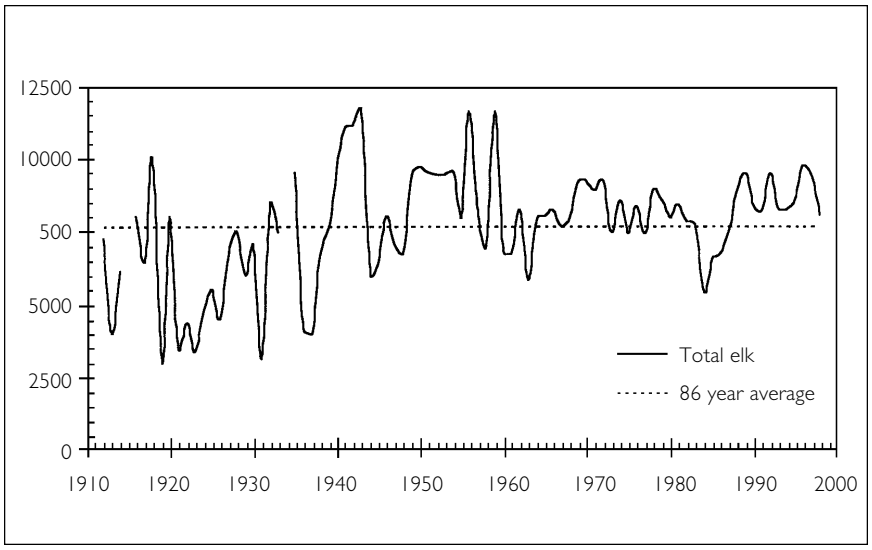

Figure 3 Yearly total and 86-year average of wintering elk on the National Elk Refuge, Jackson, Wyoming.

They found that seed production was limited by winter browsing in three ways: direct removal of flower buds, allocation of resources to vegetative growth instead of seed production following browsing, and individual plant size limitation with subsequent reduction in seed production. Without regeneration, the suppressed shrubs that have survived to this point are becoming old and decadent, continually drawing on energy reserves stored in their roots.

The same holds true for cottonwood trees on the NER. The largest concentration of cottonwoods on the refuge is along the Gros Ventre River, although they are also found along Flat Creek and some other water courses. Like other woody vegetation on the NER, most new growth in cottonwoods has been severely browsed. In their Flat Creek riparian rurvey, Galbraith *et al.* (1998: 1) write that "the lack of cottonwood reproduction ensures that in 50 to 100 years those trees bordering Flat Creek will be evident only as partially decomposed logs with just historical photographs to record their previous existence." The threats to cottonwood communities are identical to the riparian shrub communities, and in fact the two communities overlap, with willows and other shrubs often found in the understory of cottonwood stands.

Besides the direct improvement to vegetative communities and unknown benefits to ungulates themselves, restoration of riparian shrubs will have enormous effects on biodiversity.

Riparian trees and shrubs have evolved with frequent natural disturbances. Stream banks continually shift and riparian vegetation has developed productive and reproductive adaptations to cope with the dynamic environment. One study found that after more than one hundred years of grazing, willow growth increased dramatically when grazing pressure was removed (Case and Kauffman 1997). The current NER exclosure demonstration project shows significant shrub recovery in only the first year, and willows in an exclosure erected in 1982 near the hatchery attained heights of four to five feet two years after protection from browsing (Cannon 1998). These systems can easily be restored passively just by removing or diminishing the heavy pressure of ungulate browsing.

Besides the direct improvement to vegetative communities and unknown benefits to ungulates themselves, restoration of riparian shrubs will have enormous effects on biodiversity. While making up only a fraction of the landscape, riparian habitats are disproportionately important for birds and mammals (Kovalchik and Elmore 1991; Taylor 1986). Riparian zones provide preferred habitat because they contain"easily accessible water, more favorable terrain, hiding cover, soft soil, a more favorable microclimate, and an abundant supply of lush palatable forage" (Kovalchik and Elmore 1991: 113). Over 80 vertebrate species and likely over 140 species of terrestrial arthropods are associated with willows (Moran and Southwood 1982), over 200 vertebrate species are associated with riparian shrubs in general, and over 90 vertebrate species are associated with cottonwoods (Kohley *et al.* 1998). Cottonwood stands on the NER are surrounded by lower-lying vegetative communities, like sagebrush and grasslands, and provide perches for raptors and other bird species. Six red-tailed hawk nests were found in the cottonwoods along a short reach of Flat Creek, the highest density found in the literature (R. Smith 1998). All these species are threatened by declines in their habitat.

Bird diversity seems to be down in riparian communities on the refuge (Wile 1998). Five birds are particularly sensitive to grazing and browsing in the riparian zone: willow flycatcher, white-crowned sparrow, Lincoln's sparrow, yellow warbler, and Wilson's warbler (Ammon and Stacey 1997; Knopf *et al.* 1988; Shultz and Leininger 1991; Taylor 1986). These five species may be valuable indicators of willow health and should be monitored closely.

AQUATIC COMMUNITIES

There are approximately 337 acres of open water on the refuge (1.4%). Although the total area is small, it is critical habitat to aquatic communities and most of the terrestrial species that use the refuge. Flat Creek, the main water course through the NER, is a nationally prized trout stream. Its water quality is generally high (TCNRD 1998). From 1934 to 1964, however, heavy sediment loads from a water diversion from the Gros Ventre River to Flat Creek filled up pools and made the creek wider and shallower. The sediment buried fish eggs and macro-invertebrates that provide forage for fish. Beginning in 1964, physical habitat improvements have been made that greatly improved productivity in the stream from 40 fish per mile to approximately 300 fish per mile (Hudelson 1998; Cannon 1998). The lack of shrub cover along most of the refuge section of the creek probably has reduced the number of trout it can support. The abundance and biomass of brown trout and the richness and diversity of benthic invertebrate species have all been demonstrated to be greater in willow-covered versus non-willow-covered sections of streambanks (Glova and Sagar 1994). Riparian shrubs moderate stream temperatures by intercepting solar radiation and by limiting radiation off the stream. Shrubs also provide important cover for trout and other fish species and are habitat for terrestrial invertebrates that provide forage for fish (Cannon 1998; Hudelson 1998). In addition, riparian vegetation is a major source of nutrients for the aquatic ecosystem, providing food for invertebrate detritivores and thus prey for fish and other species.[1]

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[1] See Cannon 1998 for a more more thorough description of the habitat quality of Flat Creek.

The trout fishery in Flat Creek has a large constituency, and management has been successful in maintaining natural stocks and improving habitat quality. As in much of the West, however, there is a complicated series of water rights that are not being addressed and will continue to have impacts on water flow and sediment loads. The NWRSIA requires the USFWS to "assist in the maintenance of adequate water quantity and water quality" and to "acquire, under State law, water rights that are needed for refuge purposes." As the demographics and the economy in Jackson Hole shift, the need to divert water through the refuge should be addressed.

FLAT CREEK FEN

The sedge-marshland, constituting 2,317 acres, or 9.5 % of the area, is located in the southwestern corner of the NER. Unique in Wyoming, it is in fact a calcareous fen created by ground water moving through a porous alluvial fan and upwelling at the intersection of fine sediments (Fertig 1998a; Galbraith *et al.* 1998). The ground water flows through the carbonate rocks that make up the surrounding bedrock, elevating the water pH and creating specialized habitats. Small differences in elevation in this system, even as small as an ant hill, have different moisture regimes, creating a diverse mosaic of plant species with varying hydrologic tolerances. Ten rare plants have been identified in Flat Creek Fen. Many are the only specimens known in Jackson Hole and some are found nowhere else in the state (Fertig 1998b).[2] The fen, or wet-meadow, is also habitat for muskrat, ducks, chorus frogs, and shorebirds.

The hydrology of this area has been affected by water diversions into and out of the fen, which may have an impact on plants with very specific hydrologic requirements. Elk populations may also have an effect on the wetland community by feeding and trampling (Hudelson 1998; Deslaurier 1998; B. Smith 1998c). Mechanical damage from elk and feeding equipment has created areas susceptible to invasions of exotic plants which may out-compete some of the rare plant species (B. Smith 1998c; Fertig 1998b).

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Although this community currently appears to be healthy (Fertig 1998b), there is little documentation of what this area once looked like. There may have been much more standing water, attracting many more waterfowl and shorebirds (Deslaurier 1998). The fine sediments and rich peat of the fen are fertile soil, and early settlers likely dug ditches to drain the high water table to make the land more suitable for crops. They could then control the water level of the fields by diverting water into or out of the ditches (Deslaurier 1998). Given the unique character of Flat Creek Fen, serious attention should be given to any future actions that may adversely affect its hydrology and plant species.

[2] See Fertig 1998b for a more thorough description of the plant species of special concern on the National Elk Refuge.

ASPEN FORESTS

There are over 1,650 acres of aspen habitat on the NER (6.5%), and the aerial extent and health of aspen groves have declined since the refuge's formation. Aspen seeds are small and fragile and require very specific conditions to germinate, and it is likely that most aspen clones seeded after the last ice-age glaciers retreated 10-15,000 years ago (Despain 1990). As a result, aspen trees rely almost exclusively on vegetative reproduction through root suckering to regenerate. Normally, through apical (stem tip) dominance, root suckering is suppressed by chemicals produced by the mature plants. When mature trees are killed by disturbance, adventitious shoots are released from the extensive root systems. In this way, entire stands of aspen can represent one genetic clone. Historically, fire was the main agent for disturbance and release of new regeneration. Fire removes large trees that may compete for resources with young trees, reduces the apical dominance of burned trees, and releases

nutrients into the soil, improving conditions for young trees to grow (Boyce 1989). The suppression of fire by humans during the last century has limited this process and created old stands with little regeneration. The refuge's aspens have not burned since 1879 (Dieni *et al.* 1997; Romme *et al.* 1995).

The lack of fire is not the only issue affecting aspen stands. Romme *et al.* (1995) studied aspen regeneration after the 1988 Yellowstone fires. They found that three years after the fires, sprout densities were similar in burned and unburned stands and all were equally browsed down to the height of the snow pack. Fire was unable to rejuvenate these stands in the presence of large elk numbers. Intense browsing that has limited aspens has been found throughout the GYE and the intermountain West (Boyce 1989; Kay 1997; Dieni *et al.* 1997; Baker *et al.* 1997; Despain 1990). In 1988 the NER conducted an experiment to improve aspen regeneration. Nine aspen stands were clearcut, three protected from elk by exclosures. Today, aspens within the exclosures are densely packed and exceed two meters in height. Almost all stems outside the exclosures are less than two meters tall, having been severely browsed (Dieni *et al.* 1997; TCNRD 1998).

Aspens provide habitat to over 120 vertebrate species (Kohley et al. 1998). Orange-crowned warbler and warbling vireo are aspen specialists and may be appropriate indicator species.

Elk, deer, and moose also eat aspen bark and damage bark when scraping velvet from new antlers. While browsing rarely girdles a tree, damage to the trunk makes aspen more susceptible to pathogenic infections that can cause mortality in the trees (Boyce 1989).

Aspens are extremely important in the intermountain West as the only upland hardwood (DeByle and Winokur 1985). In a study conducted on East Gros Ventre Butte, across Highway 89 from the refuge, aspen groves had numbers of bird species higher than any other community type (Clark and Campbell 1981). Aspens provide habitat to over 120 vertebrate species (Kohley *et al.* 1998). Orange-crowned warbler and warbling vireo are aspen specialists and may be appropriate indicator species.

SAGEBRUSH-GRASSLANDS

Sage-grasslands are abundant in Jackson Hole: native grasses and sagebrush communities account for 15,464 acres (63%) of refuge lands. Although they appear dry and structurally homogenous, over 100 vertebrate species and perhaps over 200 arthropod species are associated with this habitat type (Kohley *et al.* 1998; Christiansen *et al.* 1989). Elk graze heavily on the grasslands on the NER (Kremer 1998). Webster (1965) found that Hood's phlox, fringed sagebrush, rubber rabbitbrush, American vetch, tapertip hawksbeard, and prairie June grass were significantly decreased on elk range. Grazing decreases ground cover and structural heterogeneity as well as breeding bird abundance and species diversity (Kirsch *et al.* 1978; Wiens 1973). It is likely that certain species have been negatively affected by large concentrations of elk on the refuge. Many songbirds prefer sage-grasslands in specific stages of succession. Managing for structural and successional diversity will provide more habitat than is currently available.

Structural and successional diversity are also affected by fire. Sage-grasslands historically burned every 30-50 years, thinning sagebrush, replacing overly mature bushes, and maintaining a diversity of species and age classes (Ozenberger 1998). Fires have not been allowed on the NER for the last few years.

EXOTIC PLANT SPECIES

"An invasive plant is an alien plant spreading naturally (without direct assistance of people) in natural or semi-natural habitats, to produce a significant change in terms of composition, structure or ecosystem processes." (Cronk and Fuller 1995: 1)

Fifty-two species of exotic plants have been identified on the refuge, amounting to almost 14% of the refuge's plant species (Fertig 1998b; Appendix D). At least twelve of these species are recognized as invasive and have expanded their distributions on the refuge, particularly in the last two decades (Table 2).

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Invasive plants pose a serious threat to the NER ecosystem. They outcompete native species and replace diverse systems with single-species stands of aliens. Invasive aliens directly threaten native fauna by altering habitat structure and food resources. In addition, many invasive species alter soil chemistry, geomorphological processes, hydrology, and disturbance regimes, all of which can have profound effects on biodiversity (Cronk and Fuller 1995).

Exotic species are established by seeds carried by wind, water, animals, and humans. Knowing the dispersal mechanism is important in developing a control program. Some species, primarily domestic grasses for pastures, have been purposely introduced. Others have been accidentally introduced into Teton County by the increasing human activity in the valley. Others may have been carried by birds from areas already invaded by these species. Invasive exotic plants tend to have few predators, enormous reproductive potential, and structural or life history traits that give them a competitive advantage over native species.

The NER started battling invasive exotic plants early on. In 1958 a weed map was prepared which included quackgrass (*Agropyron repens*), white top (*Lepidium draba or repens*), and "a few plants" of Canada thistle (*Cirsium arvense*) (NER Narrative Reports 1958). In 1980, in a letter to the Wyoming Department of Agriculture, the acting associate director of the USFWS wrote that"there are currently no noxious weed control programs on the Elk Refuge, for these plant species [Canada thistle (*Cirsium arvense*), ox-eye daisy (*Chrysanthemum leucanthemum L. var. pinnatifidum*), dalmation toadflax (*Linaria dalmatica*), and musk thistle (*Carduus nutans*)] have not been considered a problem by the refuge staff." Three years later, in 1983, the refuge started using herbicides, primarily 2,4-D amine, in addition to mechanical control to curb the spread of invasive plants, which by that time had become a serious problem.

Since then, invasive species have spread and new species have established themselves. Today the most dominant invasive species are musk thistle, Canada

COMMON NAME	SCIENTIFIC NAME
Crested wheatgrass	*Agropyron cristatum*
Cheatgrass	*Bromus tectorum*
Musk thistle	*Carduus nutans*
Spotted knapweed	*Centaurea maculosa*
Canada thistle	*Cirsium arvense*
Houndstongue	*Cynoglossum officinale*
Flixweed	*Descurainia sophia*
Dalmation toadflax	*Linaria dalmatica*
White sweet-clover	*Melilotus albus*
Yellow sweet-clover	*Melilotus officinalis*
Field pennycress	*Thlaspi arvense*
Scotch thistle	*Onopardum acanthium*

Table 2 Invasive plant species on the National Elk Refuge, Jackson, Wyoming.

thistle, and yellow sweet-clover (*Melilotus officinalis*), which have formed dense stands in meadows and pastures and along riparian areas, irrigation ditches, and road sides. Spotted knapweed is found on the northern border of the refuge, scotch thistle on south-facing dry exposures, field pennycress is found extensively in southern pastures and flixweed is found in the middles of pastures. Crested wheatgrass, originally planted for early spring pasture and to reseed pasture after the Dust Bowl, has spread along game trails and roads and has encroached on cultivated and native fields (Kremer 1998). In three years it took over a Russian wild rye field at the McBride management unit (Kremer 1998), and its spread and dominance have necessitated the remapping of vegetative communities on the NER (B. Smith 1998b).

The NER needs to evaluate its commitment to biodiversity protection. Although the NER mission and the goals of the National Wildlife Refuge System are to protect all plants and animals on its lands, elk consistently receive priority consideration in the management of this refuge, to the detriment of other species.

RECOMMENDATIONS

Sustainable management of biodiversity, and everything that it encompasses, is extremely difficult. The following are recommendations to improve biodiversity management on the NER.

MAKE A COMMITMENT TO BIODIVERSITY

The NER needs to evaluate its commitment to biodiversity protection. Although the NER mission and the goals of the National Wildlife Refuge System are to protect all plants and animals on its lands, elk consistently receive priority consideration in the management of this refuge, to the detriment of other species. Given the historical context—elk were the impetus for the refuge's formation—and the huge constituency for the Jackson Hole elk herd, this has been an appropriate management priority. But with the recent establishment of a national set of principles for the refuge system (NWRSIA 1997), it is clear

that priorities need to shift. Elk will always be the centerpiece of the NER, but they can coexist with other species if management is committed to the protection and restoration of biodiversity.

MANAGE AT THE ECOSYSTEM LEVEL

The best way to manage for biodiversity as a whole is to manage at the ecosystem level. Over 90% of the bird species and over 24% of the mammal species on the refuge either migrate or have home ranges larger than the refuge, including the flagship species of elk and trumpeter swans. Clearly there is a need to coordinate efforts to maintain this biodiversity. It is unrealistic and not within the refuge's mandate to influence management of the Canadian Arctic or Central American and South American winter ranges. Coordination of ecosystem management within Jackson Hole and the GYE, however, is not only biologically necessary, but the National Wildlife Refuge System is required by NWRSIA to work with its neighbors to further its goals. The NER already participates in the Jackson Hole Cooperative Elk Studies Group, the Tri-State Trumpeter Swan Recovery Group, and the countywide pest management system. The NER should continue building these relationships and contribute staff expertise to issues outside its borders. Halverson (this volume) details some examples of how this could be accomplished for elk management. The same lessons can be applied to all biodiversity.

The best way to manage for biodiversity as a whole is to manage at the ecosystem level. Over 90% of the bird species and over 24% of the mammal species on the refuge either migrate or have home ranges larger than the refuge, including the flagship species of elk and trumpeter swans.

ADAPT MANAGEMENT TO CHANGING CONDITIONS AND NEW INFORMATION OBTAINED BY REGULARLY COLLECTING, COMPILING, AND ANALYZING DATA

Each species on the refuge has hundreds of direct and indirect interactions with other species and abiotic factors that affect its survival, distribution, and reproduction. Given the complexity of ecosystems and ecosystem management, sharing ideas, data, and skills with other agencies and individuals is the only way to begin to manage this task. Management has to accept the current uncertainty in ecological science, using the best information available at the time of decision making, and follow management prescriptions with monitoring to determine if management actions are effective.

The use of monitoring to learn from management experiments is termed *adaptive management.* Noss and Cooperrider (1994) outline five characteristics of adaptive management of biodiversity: (1) maintaining optimally functioning ecosystems with all their components is an overriding goal; (2) ecosystems are extremely complex, and human understanding of them is rudimentary; (3) human activities may have severe and largely unpredictable effects on ecosystems, and these effects can be irreversible or require centuries for restoration; (4) management should therefore be conservative, erring on the side of minimal risk to ecosystems; and (5) careful, systematic monitoring of ecosystems and how we affect them can help us learn how to avoid causing further harm.

Monitoring on the refuge in the past has never had explicitly defined objectives, which may account for the lack of compilation and analysis of the data. The implied objective is to monitor population trends and to take action if populations are too high or too low. Without explicitly defined goals and thresholds in a monitoring program, the data have often remained unused. In the past, the preparation of annual reports provided time and a structure to consolidate data for one year. This practice has been discontinued for lack of time and money (B. Smith 1998b). This report compiled all existing quantitative data on waterfowl, game mammals, and fur-bearing mammals that the NER has available. Some of these data sets go back to 1940 and may provide valuable insight into the ecology and management of these species.[3] Data should be periodically analyzed to determine if biological or management thresholds have been reached and necessary action taken. For example, the only quantitative study of passerine birds on the refuge identified a local decline of house wrens and yellow warblers (Dieni *et al.* 1997). No additional data were collected nor action taken. A local decline suggests that something about the refuge or the valley may have caused the decline, but without subsequent monitoring, it cannot be determined if the declining trend continued, whether it leveled out, or whether it was a stochastic event from which the population has since rebounded.

Keeping track of many different species and communities requires increased monitoring of previously overlooked species. The NER can take advantage of resources that do not require extra funding.

Keeping track of many different species and communities requires increased monitoring of previously overlooked species. The NER can take advantage of resources that do not require extra funding. The Teton Science School is interested in establishing a long-term relationship with the refuge to conduct monitoring and research. The Student Conservation Association (SCA) and the AmeriCorps programs attract talented college students and graduates capable of conducting analytical and monitoring work. Finally, Grand Teton National Park conducts extensive research on biota and community types similar to the refuge and has established thirty permanent bird plots in all habitat types found within the park. By establishing similar plots and protocols, the NER will be able to compare data with the park, which may provide information on differing management practices or ecological phenomena.

[3] These data are available on Microsoft Excel files at the National Elk Refuge.

REDUCE SUPPLEMENTAL FEEDING AND ELK HERD NUMBERS

Maintaining historical levels of elk on a fraction of their historical winter range has been the major cause of declines in several species groups on the NER, and it will continue to be so. A major step in the restoration and protection of biodiversity on the refuge is to reduce the number of elk wintering on refuge grounds. Cromley (on elk migrations), Kahn, and Halverson (all this volume) describe the social and political context for this largely social and political issue.

RESTORE RIPARIAN VEGETATION

Restoration of riparian shrub communities on the refuge is of paramount importance for sustainable biodiversity management. Limiting access of browsers, coupled with a reduction in browsing intensity, would quickly restore these communities. Galbraith *et al.* (1998) suggested studying the appropriateness of riparian pasture corridors, a series of riparian exclosures with well-placed water gaps, rest/rotation systems of animal grazing, and temporary electric fencing to achieve refuge goals. Although these involve intensive management and aesthetic considerations, the refuge has considered equally intensive management practices to deal with other issues. For example, the current irrigation plan involves the investment of millions of dollars, direct habitat manipulation, and the installation of obtrusive structures.

RESTORE ASPEN STANDS

Although lack of disturbance and browsing may not be the only factors contributing to the decline of aspens, given the tremendous growth of regeneration in the experimental clearcut exclosures on the refuge, these two factors appear to be the most limiting. Once aspens grow beyond the reach of elk, about two meters, they have a much greater chance of survival. It takes four to eight years for aspen to reach these heights (Boyce 1989; Dieni *et al.* 1997; Despain 1990). One management option would be to rotate existing exclosures to new stands over this time interval and clearcut the stands to slowly rejuvenate the aspens.

Restoration of riparian shrub communities on the refuge is of paramount importance for sustainable biodiversity management.

EVALUATE PRESCRIBED BURNS TO IMPROVE THE HEALTH OF THE SAGE-GRASSLAND COMMUNITY AND TO INCREASE FORAGE FOR ELK

Structural diversity has decreased on the NER as a result of over-browsing and lack of fire. Grand Teton National Park has implemented a prescribed burn program to simulate natural fires in sage-grasslands. The refuge has burned fields in the past, but in recent years has stopped the practice (NER 1940-1994; B. Smith 1998b). This management tool should be evaluated to ensure that management is maintaining community health and to increase natural forage available to elk. Prescribed burns may be difficult to carry out safely so close to the town of Jackson, however.

AGGRESSIVELY LIMIT INVASIVE SPECIES

Invasive aliens have increased under the current control program and will continue to spread. The refuge needs to take this threat seriously. No longer do managers try to eradicate invasive exotics completely. Canada thistle, for example, can produce 680 seeds per stem and its seeds can survive 21 years in undisturbed soil (Radosevich *et al.* 1997). Clearly, complete eradication would be so intensive and expensive that it is impossible. Therefore, invasive plants need continual control efforts, including mechanical, chemical, biological, and managerial methods.

The pesticide policy of the U.S. Department of the Interior states that pesticides are to be used only after full consideration of alternatives, that full consideration be given at all times to the safety of humans, fish, wildlife, and other non-target organisms, and that quality control monitoring be conducted before, during, and after any pesticide application in ecologically sensitive areas. Pesticides should be limited in the southern section of the refuge because of potential contamination of the main drinking water supply for the town of Jackson, which has three wells drawing groundwater from under the refuge. Chemicals should also be limited near all open water sources, particularly known amphibian breeding areas.

Most invasive species enter areas that have been disturbed, including roadsides, cultivated fields, irrigation ditches, mitigation ponds, and areas damaged by concentrated ungulates and feeding equipment. To avoid further spread of invasive species, future management actions should focus on limiting disturbance.

Leafy spurge, which already "plagues three million acres of rangeland throughout the country" (Stein and Flack 1996: 15), and other extremely invasive plants have already been identified in Jackson Hole (Vilalobos 1998). The control of these plants can only be accomplished by a coordinated effort throughout the valley.

To that end, the public needs to become aware of the incredible diversity found on the refuge. One method would be to expand current outreach efforts, such as slide shows, sleigh ride programs, and refuge brochures, to include more details of different species and their community and ecosystem interactions to begin to build a constituency for non-game species.

BUILD A CONSTITUENCY FOR BIODIVERSITY

Ecological complexity is only a part of the overall complexity of managing natural resources. The three related projects (Halverson, Cromley on bison management, and Kahn, this volume) explore the social, political, and decision-making processes affecting the NER and provide insight and recommendations. To that end, the public needs to become aware of the incredible diversity found on the refuge. One method would be to expand current outreach efforts, such as slide shows, sleigh ride programs, and refuge brochures, to include more details of different species and their community and ecosystem interactions to begin to build a constituency for non-game species.

PUTTING THE RECOMMENDATIONS TO USE: THE IRRIGATION PROPOSAL, A CASE STUDY

The large concentration of elk is the main factor in the decline of biotic communities on the refuge and has increased the rate of disease transmission (Halverson, this volume). The proposal to install a sprinkler irrigation system, which was evaluated in 1998-99, is designed to abate some of these problems, but does not address the central issue of elk numbers. In addition, the environmental assessment of the proposal (NER 1998) does not adequately address the direct and indirect effects on overall biodiversity. For instance, Flat Creek Fen is dependent on large groundwater inputs. What effects will the removal of large amounts of groundwater for irrigation have on the hydrology and, subsequently, the wetland plant species of the fen? How will the addition of

fertilizers and pesticides affect the system? These issues should be addressed.

If this project is carried through, it will represent a shift in management and an opportunity to learn. The immediate goals of the project are to increase forage for elk. Given the expertise behind the farming practices proposed, there is little doubt that the standing crop of grasses will increase in project areas, and this aspect may not require monitoring. The larger goals of the project and the refuge are to reduce the need for supplemental feeding of elk, to disperse elk to limit disease transmission, and to protect biodiversity. Targeted, well-designed monitoring programs are needed to judge the effectiveness of the irrigation program in achieving these goals.

The mission of the refuge is to protect, enhance, and restore populations and habitats of all the species found on its grounds. The NER needs to ensure that management activities do not have negative impacts on its biota. A monitoring program should be designed to detect trends in key species, such as passerine birds and small mammals, in relation to the irrigation project. Plots or transects could be placed within project areas and within appropriate controls. Data should be collected before project implementation to provide a baseline. If after a few years there appears to be a downward trend in a species or group of species, the project areas could then be separated into varying management experiments. For example, one management unit might be left as is, one might cease farming and irrigation activities, and one might delay the timing of farming activities. Since populations fluctuate from year to year, it is important to conduct management experiments in comparable units over the same time periods. In this way, the NER will either be able to validate its management practices or learn from practices that do not succeed to improve future management.

The mission of the refuge is to protect, enhance, and restore populations and habitats of all the species found on its grounds. The NER needs to ensure that management activities do not have negative impacts on its biota.

CONCLUSION

Riparian trees and shrubs, aspens, and sage-grasslands have all declined in cover, abundance, regeneration, and structural diversity since the creation of the National Elk Refuge. If current management practices on the refuge continue, these vegetative communities and their associated wildlife species will continue to decline. The ecological impacts of large concentrations of ungulates have been known by refuge managers for years, yet no changes in management for biodiversity have been implemented on the refuge. As shown in Kahn, Halverson, and Cromley on bison management (all this volume), this is largely the result of social, political, and economic pressures. Building on the research described in this volume, the NER has the opportunity to make improvements in its management and decision-making processes. First and foremost in the sustainable management of biodiversity is a commitment to biodiversity and to the refuge ecosystem as a whole. These principles should guide future decision making to prevent further damage to the species and communities that make the National Elk Refuge one of the most valuable protected areas in the country.

ACKNOWLEDGMENTS

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Appendix A Interviews conducted by Noah Matson, Jackson, Wyoming, summer 1998.

Name	Affiliation	Position
Barry Reiswig	USFWS National Elk Refuge	Project Leader
Bruce Smith	USFWS National Elk Refuge	Biologist
Jim Griffin	USFWS National Elk Refuge	Assistant Manager
Debra Patla	Contract, NER; Univ. of Idaho	Biologist
Ralph Hudelson	Wyoming Game and Fish Dept.	Fisheries Biologist
Roger Smith	Teton Science School	Instructor, Researcher
Doug Wachob	Teton Science School	Research Director
John Kremer	USDA Natural Resource Conservation Service	Extensionist
Steve Cain	Grand Teton National Park	Biologist
Brian Vilalobos	Grand Teton National Park	Invasive Plant Manager
Susan Patla	Grand Teton National Park	Biologist
Tom Campbell	Biota Research Consultants, Inc.	Project Manager
Deb Deslaurier	Bridger-Teton National Forest	Vegetation Biologist
Eric Stone	Colorado State University	Ornithologist
Mike Ivie	Montana State University	Entomologist
Diane Debinski	Kansas State University	Biologist
Hank Harlow	University of Wyoming	Director, Teton Field Station
Bert Raynes	Local Audubon and birding clubs	
Darwin Wile	Local Audubon, volunteer	Refuge Biologist
Walter Fertig	Wyoming Natural Heritage Program	
Dana McDaniel-Bonham	Teton County Natural Resource District	Education and Outreach Coordinator

Appendix B1 Birds of the National Elk Refuge, Jackson, Wyoming.

Common Names

SEABIRDS
Eared grebe
Pied-billed grebe
White pelican
Double-crested cormorant

BITTERNS AND HERONS
Great blue heron
American bittern
Black-crowned night heron
White-faced ibis
Snowy egret
Cattle egret

WATERFOWL
Bewick's swan
Trumpeter swan
Tundra swan
Canada goose
Ross goose
Snow goose
American brant
Bufflehead
Canvasback
Gadwall
Barrow's golden-eye
Common golden-eye
Harlequin duck
Mallard
Common merganser
Hooded merganser
Pintail
Red head
Ring-necked duck
Ruddy duck
Lesser scaup
Greater scaup
Northern shoveller
Blue-winged teal
Cinnamon teal
Green-winged teal
American wigeon

RAPTORS
Bald eagle
Golden eagle
Peregrine falcon
Prairie falcon
Merlin
American kestrel
Cooper's hawk
Goshawk
Marsh hawk
Osprey
Red-tailed hawk
Ferruginous hawk
Rough-legged hawk
Sharp-shinned hawk
Swainson's hawk
Turkey vulture

GALLINACEOUS BIRDS
Blue grouse
Ruffed grouse
Sage grouse
Gray partridge

RAILS AND COOTS
Virginia rail
Sora
Yellow rail
American coot

CRANES
Whooping crane
Sandhill crane

SHOREBIRDS
Black-necked stilt
American avocet
Semipalmated plover
Mountain plover
Killdeer
Long-billed curlew
Long-billed dowitcher
Marbled godwit
Solitary sandpiper
Spotted sandpiper
Upland sandpiper
Western sandpiper
Common (Wilson's) snipe
Whimbrel
Willet
Greater yellow-legs
Lesser yellow-legs
Wilson's phalarope

GULLS AND TERNS
California gull
Franklin's gull
Bonaparte's gull
Ring-billed gull
Caspian tern
Forster's tern
Black tern

DOVES
Mourning dove

OWLS
Western screech owl
Barn owl
Burrowing owl
Great gray owl
Long-eared owl
Short-eared owl
Saw-whet owl
Great horned owl
Snowy owl

Appendix B1 Birds of the National Elk Refuge, Jackson, Wyoming *(continued)*.

Common Names		
NIGHTHAWKS	THRUSHES	FINCHES
Poor-will nighthawk	American robin	Black rosy finch
Common nighthawk	Mountain bluebird	Cassin's finch
KINGFISHERS	Townsend's solitaire	Gray-crowned rosy finch
Belted kingfisher	KINGLETS AND GNATCATHCERS	American goldfinch
WOODPECKERS	Blue-gray gnatcatcher	GROSBEAKS
Common flicker	Ruby-crowned kinglet	Black-headed grosbeak
Yellow-bellied sapsucker	PIPITS	Evening grosbeak
Downy woodpecker	Water pipit	Pine grosbeak
Hairy woodpecker	WAXWINGS	SPARROWS
Lewis' woodpecker	Bohemian waxwing	Dark-eyed junco
Red-headed woodpecker	Cedar waxwing	Oregon junco
FLYCATCHERS	SHRIKES	Lapland longspur
Eastern kingbird	Northern shrike	Pine siskin
Ash-throated flycatcher	Loggerhead shrike	Black-throated sparrow
Western wood pewee	STARLINGS	Fox sparrow
Western kingbird	Starling	Sage sparrow
Say's phoebe	WARBLERS	Lark bunting
LARKS	Orange-crowned warbler	Savannah sparrow
Horned lark	Townsend's warbler	Vesper sparrow
SWALLOWS	Common yellow-throated warbler	White-crowned sparrow
Barn swallow	Yellow warbler	Green-tailed towhee
Cliff swallow	Yellow-rumped warbler	Rufous-sided towhee
Tree swallow	BLACKBIRDS and ORIOLES	
CORVIDS	Bobolink	
Pinon jay	Brewer's blackbird	
Black-billed magpie	Red-winged blackbird	
Clark's nutcracker	Yellow-headed blackbird	
Common raven	Brown-headed cowbird	
Common crow	Common grackle	
CHICKADEES	Western meadowlark	
Black-capped chickadee	Northern oriole	
Mountain chickadee	TANAGERS and BUNTINGS	
DIPPERS	Western tanager	
Dipper	Indigo bunting	
WRENS	Lazuli bunting	
House wren	Snow bunting	
Long-billed wren		

Appendix B2 Mammals of the National Elk Refuge, Jackson, Wyoming.

Common Name	Scientific Name	Common Name	Scientific Name
Masked shrew	*Sorex cinereus*	Long-tailed vole	*Microtus longicaudus*
Vagrant shrew	*Sorex vagrans*	Montane vole	*Microtus montanus*
Northern water shrew	*Sorex palustris*	Sagebrush vole	*Lemmiscus curtatus*
Little brown myotis	*Myotis lucifugus*	Red-backed vole	*Clethrionomys gapperi*
Long-eared myotis	*Myotis evotis*	Muskrat	*Ondatra zibethicus*
Silver-haired bat	*Lasionycteris noctivagans*	House mouse	*Mus musculus*
		Western jumping mouse	*Zapus princeps*
Hoary bat	*Lasiurus cinereus*	Porcupine	*Erethizon dorsatum*
Townsend's bat	*Plecotus townsendii*	Coyote	*Canis latrans*
Pika	*Ochotona princeps*	Red fox	*Vulpes vulpes*
Whitetail jackrabbit	*Lepus townsendii*	Black bear	*Ursus americanus*
Snowshoe hare	*Lepus americanus*	Grizzly bear	*Ursus arctos horribilis*
Yellow-bellied marmot	*Marmota flaviventris*	Short-tailed weasel (ermine)	*Mustela erminea*
Uinta ground squirrel	*Spermophilus armatus*	Long-tailed weasel	*Mustela frenata*
Golden-mantled ground squirrel	*Spermophilus lateralis*	Mink	*Mustela vison*
		Badger	*Taxidea taxus*
Least chipmunk	*Tamias minimus*	Striped skunk	*Mephitis mephitis*
Yellow-pine chipmunk	*Tamias amoenus*	River otter	*Lutra canadensis*
Red squirrel	*Tamiasciurus hudsonicus*	Bobcat	*Felis rufus*
		Mountain lion	*Felis concolor*
Northern flying squirrel	*Glaucomys sabrinus*	Elk	*Cervus elaphus*
Northern pocket gopher	*Thomomys talpoides*	Mule deer	*Odocoileus hemionus*
Beaver	*Castor canadensis*	Moose	*Alces alces*
Deer mouse	*Peromyscus maniculatus*	Pronghorn	*Antilocapra americana*
		Bighorn sheep	*Ovis canadensis*
Bushy-tailed woodrat	*Neotoma cinerea*	Bison	*Bison bison*
Meadow vole	*Microtus pennsylvanicus*		

Appendix B3 Amphibians and reptiles of the National Elk Refuge, Jackson, Wyoming.

Common Name	Scientific Name
Blotched tiger salamander	*Ambystoma tigrinum melanostictum*
Boreal toad	*Bufo boreas boreas*
Boreal chorus frog	*Pseudacris triseriata maculata*
Columbian spotted frog	*Rana luteiventris*
Garter snake	*Thamnophis* sp.

Appendix B4 Trees and shrubs of the National Elk Refuge, Jackson, Wyoming (* indicates exotic species).

Common Name	Scientific Name
Water birch	*Betula occidentalis*
Engelmann spruce	*Picea engelmannii*
Blue spruce	*Picea pungens*
Narrowleaf cottonwood	*Populus angustifolia*
Quaking aspen	*Populus tremuloides*
Lodgepole pine	*Pinus contorta*
Limber pine	*Pinus flexilis*
Douglas fir	*Pseudotsuga menziesii*
Rocky Mountain juniper	*Juniperus scopulorum*
Western serviceberry	*Amelanchier alnifolia var. alnifolia*
Mountain big sagebrush	*Artemisia tridentata var. vaseyana*
Threetip sagebrush	*Artemisia tripartita ssp. var. tripartita*
*Pea-tree	**Caragana arborescens*
Rubber rabbitbrush	*Chrysothamnus nauseosus var. oreophilus*
Green rabbitbrush	*Chrysothamnus viscidiflorus var. lanceolatus*
Green rabbitbrush	*Chrysothamnus viscidiflorus ssp. viscidiflorus*
Red-osier dogwood	*Cornus sericea ssp. stolonifera*
Silverberry	*Elaeagnus commutata*
Broom snakeweed	*Gutierrezia sarothrae*
Common juniper	*Juniperus communis var. depressa*
Winterfat	*Krascheninnikovia lanata (Ceratoides lanata)*
Bearberry honeysuckle	*Lonicera involucrata*
Oregon-grape	*Mohonia repens*
Shrubby cinquefoil	*Pentaphylloides floribunda (Potentilla fruticosa)*
Chokecherry	*Prunus virginiana var. melanocarpa*
Bitterbrush	*Purshia tridentata*
Golden currant	*Ribes aureun var. aureum*
Wax currant	*Ribes cereum var. pedicellare*
Missouri gooseberry	*Ribes oxyacanthoides var. setosum*
Prickly rose	*Rosa sayi*
Woods rose	*Rosa woodsii*
Bebb willow	*Salix bebbiana*
Booth willow	*Salix boothii*
Small-fruit willow	*Salix brachycarpa*
Hoary willow	*Salix candida*
Drummond willow	*Salix drummondiana*
Geyer willow	*Salix geyeriana*
Yellow willow	*Salix lutea (Salix eriocephala var. watsonii)*
Dusky willow	*Salix melanopsis*
Planeleaf willow	*Salix planifolia*
Canada buffaloberry	*Shepherdia canadensis*
Mountain snowberry	*Symphoricarpos oreophilus var. utahensis*
Gray horsebrush	*Tetradymia canescens*

Appendix B5 Forbs of the National Elk Refuge, Jackson, Wyoming (* indicates an exotic species).

Common Name	Scientific Name	Common Name	Scientific Name
Yarrow	*Achillea millefolium*	Elegant aster	*Aster perelegans*
Short-beaked agoseris	*Agoseris glauca var. glauca*	Field milkvetch	*Astragalus agrestis*
Short-beaked agoseris	*Agoseris glauca var. laciniata*	Silver-leaved milkvetch	*Astragalus argophyllus var. argophyllus*
Nodding onion	*Allium cernuum*	Canada milkvetch	*Astragalus canadensis var. brevidens*
Chives	*Allium schoenoprasum*		
*Pale alyssum	**Alyssum alyssoides*	Lesser rushy milkvetch	*Astragalus diversifolius var. campestris (Astragalus convallarius)*
*Desert alyssum	**Alyssum desertorum*		
White pigweed	*Amaranthus albus*		
Cliff anemone	*Anemone multifida var. multifida*	Elegant milkvetch	*Astragalus eucosmus*
Pasqueflower	*Anemone patens var. multifida*	Sagebrush weedy milkvetch	*Astragalus miser var. decumbens*
Sharptooth angelica	*Angelica arguta*	Weedy milkvetch	*Astragalus miser var. tenuifolius*
Pinnate-leaved angelica	*Angelica pinnata*		
Low pussytoes	*Antennaria dimorpha*	Woolly milkvetch	*Astragalus purshii*
Small-leaf pussytoes	*Antennaria microphylla*	Railhead milkvetch	*Astragalus terminalis*
Showy pussytoes	*Antennaria pulcherrima*	*Red orache	**Atriplex rosea*
Rosy pussytoes	*Antennaria rosea*	Wedgescale orache	*Atriplex truncata*
Umber pussytoes	*Antennaria umbrinella*	Arrowleaf balsamroot	*Balsamorhiza sagittata*
Drummond's rockcress	*Arabis drummondii*		
Towermustard	*Arabis glabra*	Wyoming kittentails	*Besseya wyomingensis*
Holboell's rockcress	*Arabis holboellii*		
Ballhead sandwort	*Arenaria congesta*	Nodding beggarticks	*Bidens cernua*
Nuttall's sandwort	*Arenaria nuttallii (Minuartia nuttallii)*	Spring water starwort	*Callitriche palustris*
		Sego-lily	*Calochortus nuttallii*
Twin arnica	*Arnica sororia*	*Littlepod falsefax	**Camelina microcarpa*
Biennial wormwood	*Artemisia biennis var. biennis*	Harebell	*Campanula rotundifolia*
Fringed sagebrush	*Artemisia frigida*		
Louisiana sagebrush	*Artemisia ludoviciana ssp. ludoviciana*	*Shepherd's purse	**Capsella bursa-pastoris*
Long-leaved aster	*Aster ascendens*	*Chalapa hoarycress	**Cardaria draba ssp. chalapensis*
Boreal aster	*Aster borealis (Aster junciformis)*	* Plumeless thistle	**Carduus acanthoides*
Eaton's aster	*Aster bracteolatus (Aster eatonii)*	*Musk thistle	**Carduus nutans*
Leafybract aster	*Aster foliaceus*	Narrowleaf paintbrush	*Castilleja angustifolia var. angustifolia*
Western Mountain aster	*Aster occidentalis*		

Appendix B5 Forbs of the National Elk Refuge, Jackson, Wyoming (* indicates an exotic species) *(continued)*.

Common Name	Scientific Name	Common Name	Scientific Name
Desert paintbrush	*Castilleja angustifolia var. dubia*	*Flixweed	**Descurainia sophia*
		Dark-throat shooting star	*Dodecatheon pulchellum*
Yellow painbtbrush	*Castilleja flava*	Fireweed	*Epilobium angustifolium*
Scarlet paintbrush	*Castilleja miniata*	Panicled willow herb	*Epilobium brachycarpum*
Alpine chickweed	*Cerastium beeringianum var. capillare*	American willow herb	*Epilobium ciliatum var. ciliatum*
		Hornemann's willow herb	*Epilobium hornemannii*
Hoary dusty-maiden	*Chaenactis douglasii var. montana*	Swamp willow herb	*Epilobium palustre var. glabellus*
Pitseed goosefoot	*Chenopodium berlandieri var. zschackii*	Cut-leaved fleabane	*Erigeron compositus var. discoideus*
		Foothill daisy	*Erigeron corymbosus*
Smallhead goosefoot	*Chenopodium capitatum var. parvicapitatum (Chenopodium overi)*	Smooth daisy	*Erigeron glabellus var. glabellus*
		Spear-leaf fleabane	*Erigeron lonchophyllus*
		Shaggy fleabane	*Erigeron pumilus*
Mountain goosefoot	*Chenopodium pratericola*	Shortstem buckwheat	*Eriogonum brevicaule var. laxifolium*
*Canada thistle	**Cirsium arvense*	Mat buckwheat	*Eriogonum caespitosum*
Elk thistle	*Cirsium scariosum*	Cushion buckwheat	*Eriogonum ovalifolium var. purpureum*
Snowy thistle	*Cirsium subniveum*		
*Bull thistle	**Cirsium vulgare*	Sulfur buckwheat	*Eriogonum umbellatum var. majus*
Leatherflower	*Clematis hirsutissima*		
Rock virgin's-bower	*Clematis occidentalis var. grosseserrata*	Western Wallflower	*Erysimum asperum var. arkansanum (Erysimum capitatum)*
Narrowleaf collomia	*Collomia linearis*		
Bastard toad-flax	*Comandra umbellata var. pallida*	Treacle wallflower	*Erysimum cheiranthoides*
		Virginia strawberry	*Fragaria virginiana*
*Field bindweed	**Convolvulus arvensis*	Checker lily	*Fritillaria atropurpurea*
Bushy birdbeak	*Cordylanthus ramosus*	Northern bedstraw	*Galium boreale*
Golden-smoke	*Corydalis aurea*	Small bedstraw	*Galium trifidum*
Tapertip hawksbeard	*Crepis acuminata*	Prairie gentian	*Gentiana affinis var. affinis*
Siskiyou hawksbeard	*Crepis modocensis*	Water gentian	*Gentiana aquatica*
Meadow hawksbeard	*Crepis runcinata var. glauca*	Sticky geranium	*Geranium viscosissimum var. nervosum*
Broad-leaved meadow hawksbeard	*Crepis runcinata var. hispidulosa*	Sticky geranium	*Geranium viscosissimum var. viscosissimum*
Little larkspur	*Delphinium bicolor*	Large-leaved avens	*Geum macrophyllum var. perincisum*
Mountain tansymustard	*Descurainia incana var. macrosperma*		
		Prairie smoke	Geum triflorum

Appendix B5 Forbs of the National Elk Refuge, Jackson, Wyoming (* indicates an exotic species) *(continued)*.

Common Name	Scientific Name	Common Name	Scientific Name
Sea-milkwort	*Glaux maritima*	Nineleaf biscuitroot	*Lomatium triternatum ssp. platycarpum*
Licorice root	*Glycyrrhiza lepidota*		
Curly-cup gumweed	*Grindelia squarrosa*	Silvery lupine	*Lupinus argenteus ssp. argenteus*
Lowland cudweed	*Gnaphalium palustre*		
Northern green bog-orchid	*Habenaria hyperborea (Platantherahyperborea)*	Silvery lupine	*Lupinus argenteus var. rubricaulis*
Many-flowered stickseed	*Hackelia floribunda*	Silky lupine	*Lupinus sericeus*
Stemless goldenweed	*Haplopappus acaulis*	Hoary aster	*Machaeranthera canescens ssp. canescens*
One-flowered goldenweed	*Haplopappus uniflorus (Pyrrocoma uniflora)*	Starry false Solomon's seal	*Maianthemum stellatum*
Northern sweet-vetch	*Hedysarum boreale*	*Malcolmia	**Malcolmia africana*
Rocky Mountain helianthella	*Helianthella uniflora*	Pineapple-weed	*Matricaria matricarioides*
Cow parsnip	*Heracleum sphondylium*	*Black medic	**Medicago lupulina*
Teton golden-aster	*Heterotheca depressa (Heterotheca villosa var. depressa)*	*Alfalfa	**Medicago sativa ssp. sativa*
		*White sweet-clover	**Melilotus albus*
		*Yellow sweet-clover	**Melilotus officinalis*
Littleleaf alumroot	*Heuchera parvifolia*	Field mint	*Mentha arvensis var. canadensis*
Common mare's tail	*Hippuris vulgaris*		
Western St. Johns's wort	*Hypericum formosum var. scouleri*	Ciliate bluebells	*Mertensia ciliata*
		Leafy bluebells	*Mertensia oblongifolia*
Scarlet gilia	*Ipomopsis aggregata*	Yellow monkeyflower	*Mimulus guttatus*
Mountain spicate-gilia	*Ipomopsis spicata var. orchidacea*	Povertyweed	*Monolepis nuttalliana*
		*Common forget-me-not	**Myosotis scorpioides*
*Prickly lettuce	**Lactuca serriola*	Common water-milfoil	*Myriophyllum sibiricum*
Western Stickseed	*Lappula redowskii var. redowskii*	Tufted evening-primrose	*Oenothera cespitosa var. cespitosa*
*European stickseed	**Lappula squarrosa var. squarrosa*	Pale evening-primrose	*Oenothera pallida var. trichocalyx*
Lesser duckweed	*Lemna minor*	Plains prickly pear	*Opuntia polyacantha var. polyacantha*
Common peppergrass	*Lepidium densiflorum*		
*Clasping peppergrass	**Lepidium perfoliatum*	Yellow owl-clover	*Orthocarpus luteus*
Common prickly phlox	*Leptodactylon pungens*	Nodding locoweed	*Oxytropis deflexa*
Keeled bladderpod	*Lesquerella carinata var. carinata*	Northern grass-of-Parnassus	*Parnassia palustris var. montanensis*
Northern linanthus	*Linanthus septentrionalis*	Meadow lousewort	*Pedicularis crenulata*
Blue flax	*Linum lewisii*	Elephant's-head	*Pedicularis groenlandica*
Western gromwell	*Lithospermum ruderale*	Lowly beardtongue	*Penstemon humilis*
Fennel-leaved biscuitroot	*Lomatium foeniculaceum*	Small-flower beardtongue	*Penstemon procerus var. procerus*
		Matroot beardtongue	*Penstemon radicosus*

Appendix B5 Forbs of the National Elk Refuge, Jackson, Wyoming (* indicates an exotic species) *(continued)*.

Common Name	Scientific Name	Common Name	Scientific Name
Subglabrous beardtongue	*Penstemon subglaber*	*Water cress	**Rorippa nasturtium*
Rocky Mountain rockmat	*Petrophyton caespitosum*	Western dock	*Rumex aquaticus*
Franklin's phacelia	*Phacelia franklinii*	Golden dock	*Rumex maritimus*
Hood's phlox	*Phlox hoodii*	Willow dock	*Rumex salicifolius*
Kelsey's phlox	*Phlox kelseyi var. kelseyi*	*Russian thistle	**Salsola australis*
Long-leaf phlox	*Phlox longifolia*	Flax-leaved plains mustard	*Scoenocrambe linifolia*
Many-flowered phlox	*Phlox multiflora*		
Alkali plantain	*Plantago eriopoda*	Marsh skullcap	*Scutellaria galericulata*
*Common plantain	**Plantago major*		
Western Jacob's ladder	*Polemonium occidentale*	Lance-leaved stonecrop	*Sedum lanceolatum*
Erect knotweed	*Polygonum achoreum*	Wooly groundsel	*Senecio canus*
Water smartweed	*Polygonum amphibium ssp. stipulaceum*	Alpine meadow groundsel	*Senecio cymbalarioides*
Common knotweed	*Polygonum aviculare*	Weak groundsel	*Senecio debilis*
Douglas' knotweed	*Polygonum douglasii ssp. douglasii*	Water groundsel	*Senecio hydrophilus*
		Western groundsel	*Senecio integerrimus*
Alpine bistort	*Polygonum viviparum*	Balsam groundsel	*Senecio pauperculus*
Slender-leaved pondweed	*Potamogeton filiformis*	Butterweed groundsel	*Senecio serra*
Fennel-leaved pondweed	*Potamogeton pectinatus*	Cleft-leaved groundsel	*Senecio streptanthifolius*
Silverweed	*Potentilla anserina*		
Glandular cinquefoil	*Potentilla arguta*	*White campion	**Silene latifolia*
Slender cinquefoil	*Potentilla gracilis var. nutallii*	*Tumblemustard	**Sisymbrium altissimum*
Soft cinquefoil	*Potentilla gracilis var. pulcherrima*	Western blue-eyed grass	*Sisyrinchium idahoense*
*Norwegian cinquefoil	**Potentilla norvegica*	Hemlock waterparsnip	*Sium suave*
Sheep cinquefoil	*Potentilla ovina var. ovina*	Canada goldenrod	*Solidago canadensis*
		Missouri goldenrod	*Solidago missouriensis*
Prairie cinquefoil	*Potentilla pensylvanica*	Low goldenrod	*Solidago nana*
Mealy primrose	*Primula incana*	*Marsh sow-thistle	**Sonchus uliginosus*
Self-heal	*Prunella vulgaris var. lanceolata*	Hooded lady's tresses	*Spiranthes romanzoffiana*
White water buttercup	*Ranunculus aquatilis*	Thickleaved starwort	*Stellaria crassifolia*
Shore buttercup	*Ranunculus cymbalaria*	Longstalk starwort	*Stellaria longipes*
Sagebrush buttercup	*Ranunculus glaberrimus*	Swertia	*Swertia perennis*
Unlovely buttercup	*Ranunculus inamoenus*	Green gentian	*Swertia radiata*
Macoun's buttercup	*Ranunculus macounii*	*Red seeded dandelion	**Taraxacum laevigatum*
Floating water buttercup	*Ranunculus natans*		
Bister buttercup	*Ranunculus sceleratus*	*Common dandelion	**Taraxacum officinale*
Wasatch yellowgrass	*Rorippa curvipes*		

Appendix B5 Forbs of the National Elk Refuge, Jackson, Wyoming (* indicates an exotic species) *(continued)*.

Common Name	Scientific Name	Common Name	Scientific Name
Alpine meadowrue	*Thalictrum alpinum*	Bracted vervain	*Verbena bracteata*
Veiny meadowrue	*Thalictrum venulosum*	American brooklime	*Veronica americana*
Panicled thelypody	*Thelypodium paniculatum*	*Water speedwell	**Veronica anagallis-aquatica*
*Field pennycress	**Thlaspi arvense*	American vetch	*Vicia americana var. minor*
Nuttall's Easter-daisy	*Townsendia nuttallii*		
*Yellow salsify	**Tragopogon dubius*	*Bird vetch	**Vicia cracca*
*Alsike clover	**Trifolium hybridum*	Early blue violet	*Viola adunca*
*Red clover	**Trifolium pratense*	Marsh violet	*Viola palustris*
*White clover	**Trifolium repens*	Upland yellow violet	*Viola praemorsa var. altior*
Stinging nettle	*Urtica dioica*		
Flat-leaf bladderwort	*Utricularia intermedia*	Horned pondweed	*Zannichellia palustris*
Greater bladderwort	*Utricularia macrorhiza*		
Tobacco-root	*Valeriana edulis*	Panicled death-camas	*Zigadenus paniculatus*
Western valerian	*Valeriana occidentalis*	Heart-leaved Alexanders	*Zizia aptera*
*Common mullein	**Verbascum thapsus*		

Appendix B6 Graminoids of the National Elk Refuge, Jackson, Wyoming (* indicates exotic species).

Common Name	Scientific Name
*Crested wheatgrass	**Agropyron cristatum*
*Redtop	**Agrostis stolonifera*
Shortawn foxtail	*Alopecurus aequalis*
*Meadow foxtail	**Alopecurus pratensis*
California brome	*Bromus carinatus*
Fringed brome	*Bromus ciliatus*
*Smooth brome	**Bromus inermis*
*Cheatgrass	**Bromus tectorum*
Bluejoint wheatgrass	*Calamagrostis canadensis*
Slimstem reedgrass	*Calamagrostis stricta*
Water sedge	*Carex aquatilis*
Golden sedge	*Carex aurea*
Buxbaum's sedge	*Carex buxbaumii*
Hair sedge	*Carex capillaris*
Thread-leaved sedge	*Carex filifolia*
Inland sedge	*Carex interior*
Wooly sedge	*Carex lanuginosa*
Small-winged sedge	*Carex microptera*
Nebraska sedge	*Carex nebrascensis*
Parry sedge	*Carex parryana*
Clustered field sedge	*Carex praegracilis*
Ross sedge	*Carex rossii*
Beaked sedge	*Carex rostrata*
Sartwell's sedge	*Carex sartwellii*
Canadian single-spike sedge	*Carex scirpoidea*
Analogue sedge	*Carex simulata*
Narrow-leaved sedge	*Carex stenophylla*
Green sedge	*Carex viridula*
Brookgrass	*Catabrosa aquatica*
*Orchard grass	**Dactylis glomerata*
Tufted hairgrass	*Deschampsia cespitosa*
Slender spikerush	*Eleocharis acicularis*
Common spikerush	*Eleocharis palustris*
Griffith's wheatgrass	*Elymus albicans*
Great Basin wildrye	*Elymus cinereus*
Bottlebrush squirreltail	*Elymus elymoides*
*Intermediate wheatgrass	**Elymus hispidus*
*Russian wildrye	**Elymus junceus*
Thickspike wheatgrass	*Elymus lanceolatus var. lanceolatus*
Riparian thickspike wheatgrass	*Elymus lanceolatus var. riparius*
*Common quackgrass	**Elymus repens*
Bluebunch wheatgrass	*Elymus spicatus*
Slender whatgrass	*Elymus trachycaulus*
Many-spiked cottongrass	*Eriophorum polystachion*
Green-keeled cottongrass	*Eriophorum viridicarinatum*
Idaho fescue	*Festuca idahoensis*
American mannagrass	*Glyceria grandis*
Fowl mannagrass	*Glyceria striata*
Common sweetgrass	*Hierochloe odorata*
Meadow barley	*Hordeum brachyantherum*
Foxtail barley	*Hordeum jubatum*
Baltic rush	*Juncus balticus*
Mountain rush	*Juncus ensifolius*
Long-styled rush	*Juncus longistylis*
Tuberous rush	*Juncus nodosus*
Slender rush	*Juncus tenuis*
Junegrass	*Koeleria macrantha*
Spikefescue	*Leucopoa kingii*
Pullup muhly	*Muhlenbergia filiformis*
Marsh muhly	*Muhlenbergia glomerata*
Mat muhly	*Muhlenbergia richardsonis*
Indian ricegrass	*Oryzopsis*
Reed canarygrass	*Phalaris arundinacea*
Alpine timothy	*Phleum alpinum*
*Timothy	**Phleum pratense*
*Annual bluegrass	**Poa annua*
*Bulbous bluegrass	**Poa bulbosa*
Nevada bluegrass	*Poa nevadensis*
Fowl bluegrass	*Poa palustris*
*Kentucky bluegrass	**Poa pratensis*
Canby bluegrass	*Poa secunda var. elongata*

Appendix B6 Graminoids of the National Elk Refuge, Jackson, Wyoming (* indicates exotic species) *(continued)*.

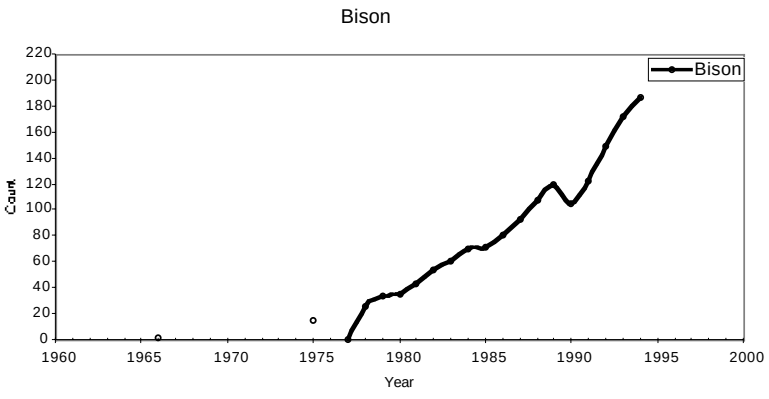
Common Name	Scientific Name
Sandberg bluegrass	*Poa secunda var. secunda*
Hardstem bulrush	*Scirpus acutus*
Pygmy bulrush	*Scirpus pumilis*
Soft-stem bulrush	*Scirpus validus*
Needle and thread	*Stipa comata*
Nelson's needlegrass	*Stipa nelsonii*
Green needlegrass	*Stipa viridula*
Seaside arrowgrass	*Triglochin maritimum*
Marsh arrowgrass	*Triglochin palustre*
Common cattail	*Typha latifolia*

Appendix B7 Ferns and fern fllies of the National Elk Refuge, Jackson, Wyoming.

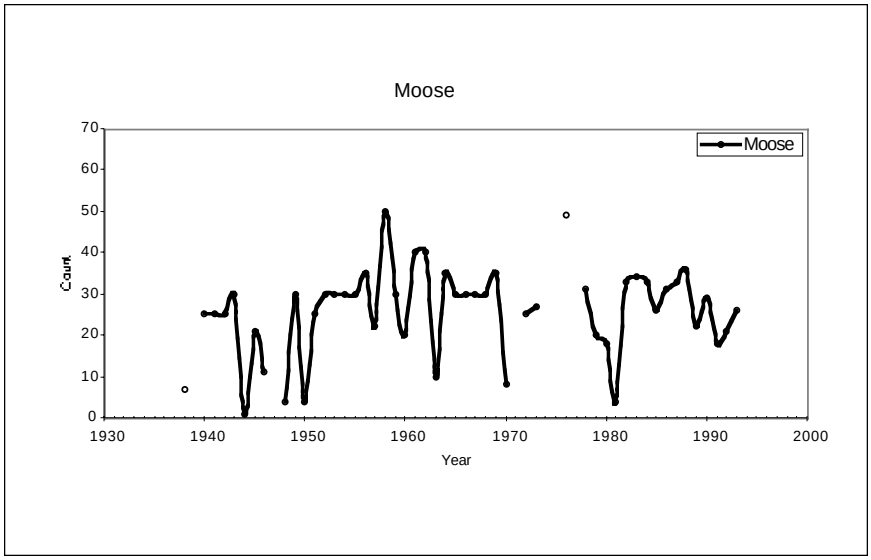
Common Name	Scientific Name
Common scouring-rush	*Equisetum hyemale*
Smooth scouring-rush	*Equisetum laevigatum*
Northern scouring-rush	*Equisetum variegatum*
Compact spike-moss	*Selaginella densa*

Appendix C1 Wildlife population graphs of selected wintering mammal populations and selected waterfowl breeding pair and production counts for the National Elk Refuge, Jackson, Wyoming.

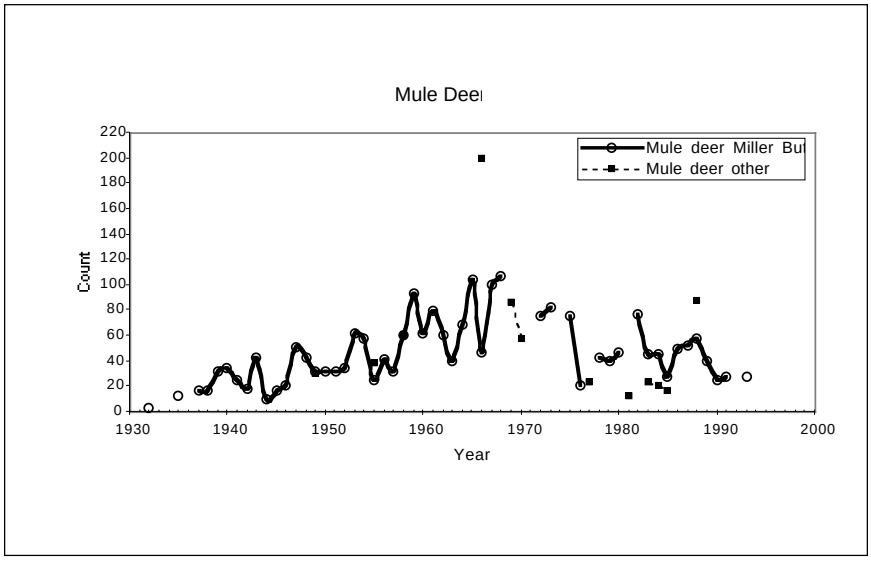
(a)



(b)

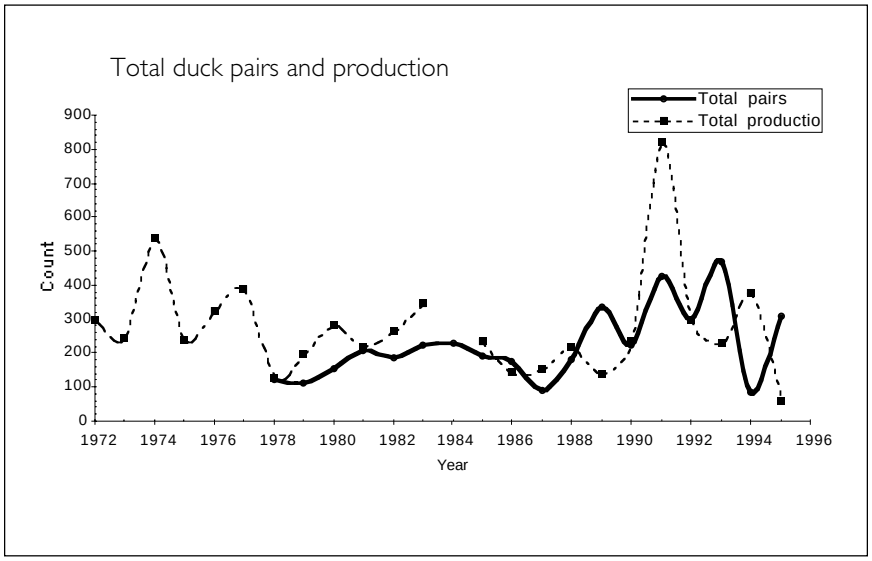


(c)

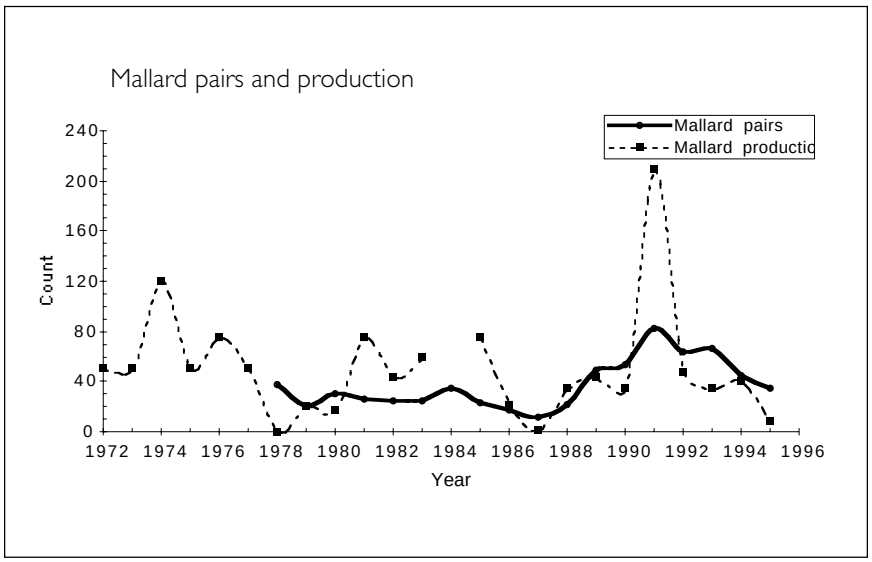


Appendix C1 Wintering populations of (a) bison, (b) moose, and (c) mule deer on the National Elk Refuge, Jackson, Wyoming.

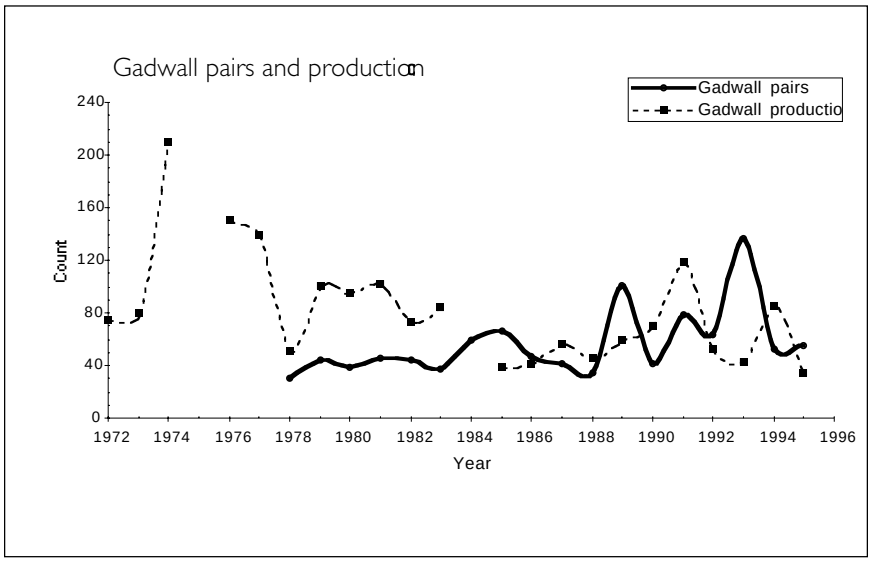
Appendix C2 Breeding pair and production counts of (a) total ducks, (b) mallards, (c) gadwalls, (d) green-winged teals, on the National Elk Refuge, Jackson, Wyoming.



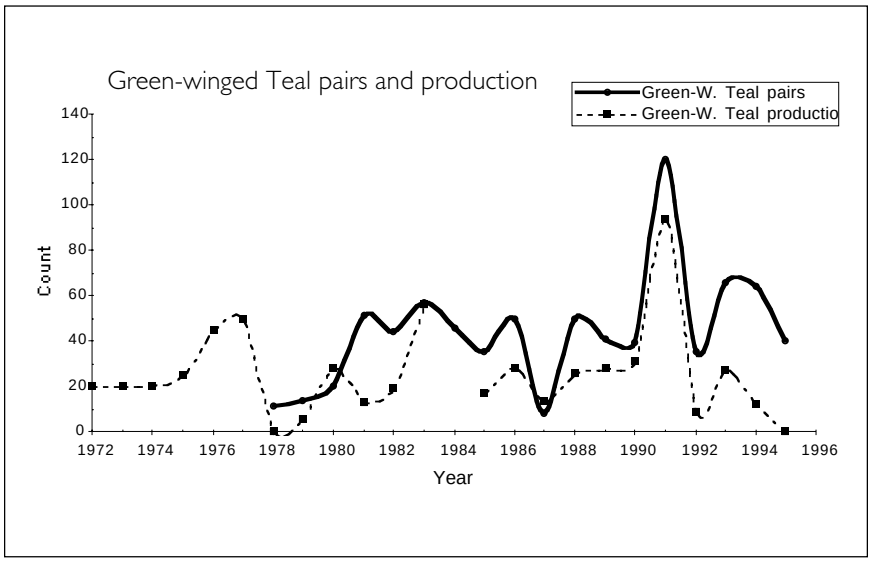
(a) Average duck pairs: 223+/- 108(SD), average production: 256+/- 16(SD)



(b) Average mallard pairs: 40 +/- 20(SD), average production: 45 +/- 48(SD)



(c) Average gadwall breeding pairs: 57+/- 108(SD), average production: 688 +/- 26(SD)



(d) Average green-winged teal pairs: 44 +/- 25(SD), average production: 24 +/- 23(SD)

Appendix D Exotic plant species on the National Elk Refuge, Jackson, Wyoming. Compiled from Fertig 1998b with additional species added.

Common Name	Scientific Name
Forbs	
Pale alyssum	*Alyssum alyssoides*
Desert alyssum	*Alyssum desertorum*
Red orache	*Atriplex rosea*
Littlepod falsefax	*Camelina microcarpa*
Shepherd's purse	*Capsella bursa-pastois*
Chalapa hoarycress	*Cardaria chalepensis*
Plumeless thistle	*Carduus accanthoides*
Musk thistle	*Carduus nutans*
Spotted knapweed	*Centaurea maculosa*
Canada thistle	*Cirsium arvense*
Bull thistle	*Cirsium vulgare*
Field bindweed	*Convolvulus arvensis*
Houndstongue	*Cynoglossum officinale*
Flixweed	*Descurainia sophia*
Prickly lettuce	*Lactuca serriola*
European stickseed	*Lappula squarrosa var. squarrosa*
Clasping peppergrass	*Lepidium perfoliatum*
Dalmation toadflax	*Linaria dalmatica*
Malcolmia	*Malcolmia africana*
Black medic	*Medicago lupulina*
Alfalfa	*Medicago sativa var. sativa*
White sweet-clover	*Melilotus albus*
Yellow sweet-clover	*Melilotus officinalis*
Common forget-me-not	*Myosotis scorpioides*
Common plantain	*Plantago major*
Norwegian cinquefoil	*Potentilla norvegica*
Water cress	*Rorippa nasturtium*
Russian thistle	*Salsola australus*
White campion	*Silene latifolia*
Tumblemustard	*Sisymbrium altissimum*
Marsh sow-thistle	*Sonchus uliginosus*
Red seeded dandelion	*Taraxacum laevigatum*
Common dandelion	*Taraxacum officinale*
Field pennycress	*Thlaspi arvense*
Yellow salsify	*Tragopogon dubius*
Alsike clover	*Trifolium hybridum*
Red clover	*Trifolium pratense*
White clover	*Trifolium repense*
Common mullein	*Verbascum thapsus*
Water speedwell	*Veronica anagallis-aquatica*
Bird vetch	*Vicia cracca*
Scotch thistle	*Onopardum acanthium*
Graminoids	
Crested wheatgrass	*Agropyron cristatum*
Redtop	*Agrostis stolonifera*
Meadow foxtail	*Alopecurus pratensis*
Smooth brome	*Bromus inermis*
Cheatgrass	*Bromus tectorum*
Orchard grass	*Dactylis glomerata*
Intermediate wheatgrass	*Elymus hispidus*
Russian wildrye	*Elymus junceus*
Common quackgrass	*Elymus repens*
Timothy	*Phleum pratense*
Annual bluegrass	*Poa annua*
Bulbous bluegrass	*Poa bulbosa*
Kentucky bluegrass	*Poa pratensis*
Trees	
Pea-tree	*Caragana arborescens*

NOAH P. MATSON earned his undergraduate degree in biology-geology from the University of Rochester. After graduating he rehabilitated wildlife—from orphaned squirrels to injured eagles—at HOWL Wildlife Center in Washington State. He later worked for the USGS in Washington, studying water quality throughout the state. At the Yale School of Forestry and Environmental Studies, he focused on conservation biology. His experiences at Yale and at the National Elk Refuge prepared him for his current position with Defenders of Wildlife, where he is working on strengthening the planning process for national wildlife refuges at the national level and at individual refuges.

Noah P. Matson, Defenders of Wildlife, 1101 Fourteenth St., NW, Suite 1400, Washington, DC 20005;
nmatson@defenders.org