Rangeland Wildlife

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Chapter 10
ELK
Michael J. Wisdom and Jack Ward Thomas

INTRODUCTION

Elk (*Cervus elaphus*) are an important herbivore on North American rangelands. Their large size, herding behavior, pioneering habits, and high mobility make them an especially conspicuous herbivore in such open areas. Moreover, the potential for elk to compete with livestock makes them an obvious source of controversy between stockgrowers and wildlife advocates.

In this chapter, we describe the history of elk on rangelands. We discuss the competitive interactions between elk and livestock, and identify methods of stocking allocation between both. We also provide concepts, prescriptions, and examples for managing rangelands for elk, particularly through the use of livestock grazing systems.

HISTORY OF ELK ON RANGELANDS

Historical Distribution

Before European settlement, elk were among the most common and widely distributed of the wild ungulates in North America (Seton 1927, Guthrie 1966, Bryant and Maser 1982). Six subspecies inhabited areas from Atlantic to Pacific coasts: eastern elk (*C. e. canadensis*) in eastern North America, Manitoban elk (*C. e. manitobensis*) in the northern lakes and central prairies, Rocky Mountain elk (*C. e. nelsoni*) in the plains and Rocky Mountains, Merriam elk (*C. e. merriami*) in the mountains and chaparrals of the Southwest, tule elk (*C. e. nannodes*) in the valleys and bottomlands of California, and Roosevelt elk (*C. e. roosevelti*) along the Pacific Coast (Bryant and Maser 1982) (Fig. 1).

Considerable controversy exists about whether elk once occupied rangelands of the Great Basin and Desert Southwest. This controversy centers on recent transplants of elk and/or recent colonization by elk into these areas (Bunnell and Hancock 1985, Hess 1985) and the potential for competition with livestock (U.S. Dep. Agric. For. Serv. 1990).

According to Guthrie (1966) and Bryant and Maser (1982), elk originally occupied most grassland biomes throughout western North America, including major areas of the Great Basin and Desert Southwest. However, lack of permanent water likely restricted elk occurrence in the driest portions of these regions (McCabe 1982, O'Neil 1985). These dry areas presumably are outside the historical range of the species (Bryant and Maser 1982) (Fig. 1); this premise agrees with Mack and Thompson (1982), who provided compelling evidence favoring hypotheses that large, wild ungulates historically were absent from or sparsely distributed across large areas of the Intermountain West.

Population Declines and Extirpations

Seton (1927) estimated numbers of North American elk at 10 million before the arrival of European settlers. McCabe (1982) also believed that population size was significant, numbering in the range of at least several million. By contrast, with the exception of the Rocky Mountain and Roosevelt subspecies in the West, elk are now distributed in small, disjunct populations across much of their former range (Bryant and Maser 1982, Witmer 1990) (Fig. 2).

Declines in elk numbers, subsequent reductions in their distribution, and ultimately the extirpation of populations and entire subspecies occurred across large expanses of North America as European settlers moved west in the seventeenth, eighteenth, and nineteenth centuries. By the early 1800s, the eastern subspecies was likely extinct (Boyd 1978, Bryant and Maser 1982). Tule elk, once abundant in valleys and bottomlands of California,

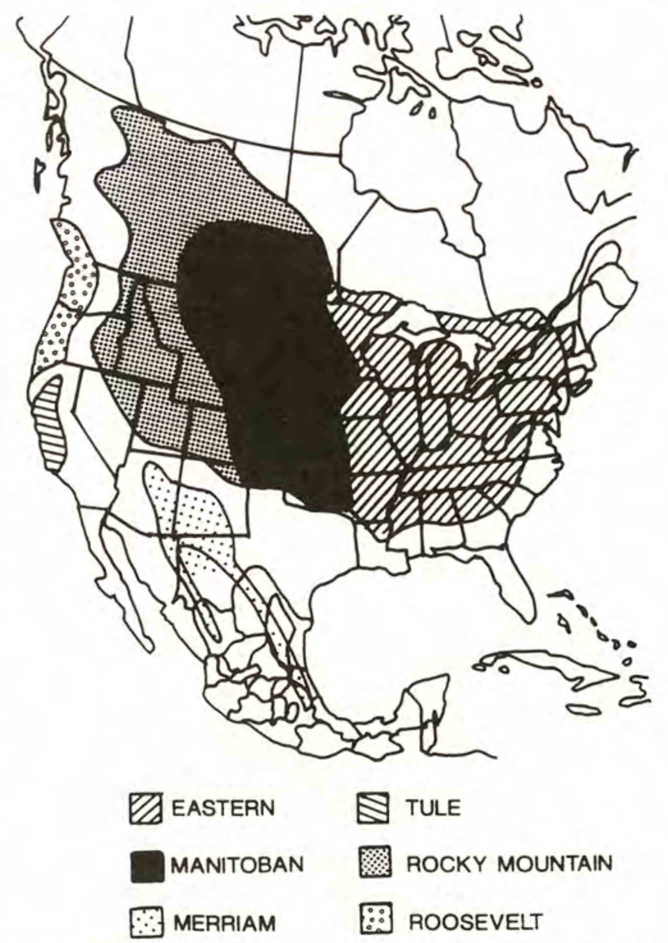


FIGURE 1. Historical distribution of elk in North America (Bryant and Maser 1982:24).

were reduced to ≤100 animals by 1875 (McCullough 1969). The Merriam subspecies was extirpated from the Southwest by 1906 (Byrant and Maser 1982). By the early 1900s, Manitoban elk of the northern prairies were close to extinction (Bryant and Maser 1982). During the same period, populations of Rocky Mountain and Roosevelt elk were reduced to scattered, isolated pockets within their former range (Murie 1951). Unregulated hunting, overgrazing by livestock, and conversion of habitat to agriculture and cities led to these broad-scale declines and extirpations (Boyd 1978, Bryant and Maser 1982, Skovlin 1982).

Current Abundance and Distribution

Jackson (1944) estimated that ≤60,000 elk remained in North America in 1910, with fragmented populations present in 7 western states. By this time, most states had enacted legislation that prohibited the hunting of elk; efforts to recover elk populations were initiated through active programs of translocation. From 1892 to 1939, >5,000 elk were live-trapped and transported from the Yellowstone area for release in 36 states and parts of western Canada (Murie 1951).

By the 1930's, these management changes were showing results. Elk numbers and distribution increased substantially, with the population estimated at 165,764 by 1937 and 236,787 by 1941 (Jackson 1944). By 1942, elk hunting was allowed in 11 states, and translocations continued throughout North America. By the 1960s the elk population in North America had grown to 440,000 (Swanson et al. 1969); it reached 500,000 by the late 1970s (Bryant and Maser 1982) and 600,000 by 1987 (Thomas 1990).

FIGURE 2. Present distribution of elk in North America (Bryant and Maser 1982:25).

Today, we estimate that ≥700,000 elk exist in North America. Our estimate is based on an annual rate of increase of 2% from 1987 to 1995, which is the approximate rate we calculated for increases in elk populations from 1977 (Bryant and Maser 1982) to 1987 (Thomas 1990). Populations are generally increasing and translocations continue. Elk are present in ≥22 states and 6 provinces (Fig. 2); additional states in the Midwest and East are implementing programs of restoration.

ELK-LAND USE ISSUES ON RANGELANDS

Elk on Public Versus Private Lands

Before European settlement, North American elk often made expansive seasonal movements in response to annual changes in weather and the availability of forage (Murie 1951, Adams 1982). Such movements are not possible today. Many seasonal rangelands used historically by elk are now privately owned and managed exclusively for agriculture, livestock, and timber production (Vavra et al. 1989, Vavra 1992). Elk use of these areas is not tolerated or tolerated minimally. In other cases, historic rangelands have been converted to cities, industrial developments, and recreation areas (Henderson and O'Herren 1992). Elk now reside in "ecologically incomplete" or "ecologically compressed" habitats across much of their historic range (Cole 1971).

Patterns of land ownership in the western United States exemplify the problem (Fig. 3). In the West, > 90% of the elk use public land during summer while the majority of winter range is privately owned (Peek et al. 1982, Thomas and Sirmon 1985). Typically, large numbers of elk are produced on publicly owned summer range, where they are desired for hunting and viewing. Animals then migrate to privately owned ranges at lower elevations each winter. On such ranges, elk often encounter severe shortages of habitat features and active programs of population control to minimize competition with livestock and damage to crops (Peek et al. 1982, Thomas 1984).

Efforts to control elk damage on privately owned ranges are intense and varied. Activities include hazing and harassment, live-trapping and transport of elk away from problem areas, fencing to exclude animals from private ranges, feeding to attract and hold elk on public winter ranges, government payments to landowners who experience significant economic damage, special hunts to reduce overall numbers, and leasing or acquisition of additional winter range to maintain winter carrying capacity (Lyon and Ward 1982).

In central and eastern North America, patterns of public and private ownership complicate elk-land use problems even more. Large expanses of public land do not exist. Elk cannot meet their seasonal requirements, let alone their year-round needs, on the fragmented public range. As a result, elk often cause damage to agricultural crops, tree seedlings, and livestock forage on nearby private lands throughout the year. Numbers of elk are thus controlled closely and their distribution is restricted to small areas in and near public land (Witmer 1989, 1990).

The shortage of year-round, ecologically complete habitats for elk and other wild ungulates poses significant management

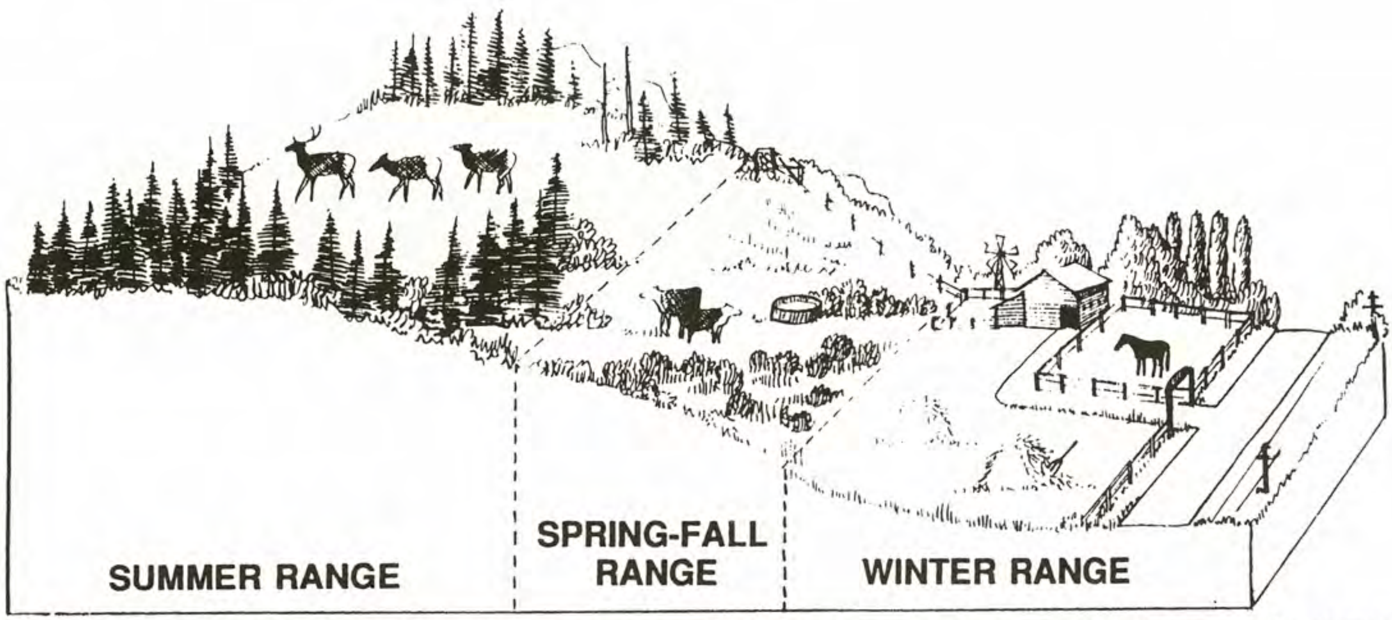


FIGURE 3. Elk produced on publicly owned summer range often face inadequate winter and spring-fall ranges due to conflicts with urban development, livestock management, and crop production on private lands.

problems on North American rangelands (Cole 1971). Many of today's management problems can be attributed to fragmented ownerships and the associated differences in land use goals across the interface of public and private lands (Vavra 1992).

Fee Hunting

Not all private landowners view elk as a problem. Many ranchers earn significant income from entry fees charged to elk hunters (White 1987). Often, such fees supplement income derived from livestock operations, timber management, or farming. In other cases, ranchers use hunting fees as a means of offsetting economic losses caused by elk damage to fences, livestock forage, tree seedlings, and crops (Lacy et al. 1993).

Fee hunting is controversial. Many ranchers manage their rangelands to attract and "hold" elk for purposes of fee hunting. Wildlife agencies and elk users typically equate such management with a commensurate loss of hunting and viewing opportunities on adjacent public lands (Jordan and Workman 1989). Regardless, fee hunting is well established and a growing industry on private rangelands (White 1987). Options exist, however, to make it compatible with management on adjacent public lands. One suggestion has been to implement similar fees on federal lands (Thomas 1984) such as the Sikes Act Program in New Mexico (Morrison 1988).

Elk Ranching

Many rangeland owners have entered the business of game ranching. Elk and red deer (*C. e. elaphus*) are especially lucrative animals for such ventures; sale of meat and antlers from domesticated forms of these animals is a multi-million dollar industry in North America and New Zealand (White 1987). Ecologically, these ungulates may also make better use of North American rangelands compared to livestock that have not coevolved with the vegetation (Peek et al. 1982).

The emergence of elk ranching in North America is fraught with controversy. Domestic elk and red deer have transmitted diseases to wild elk and livestock (Lanka and Guenzel 1991, Lanka et al. 1992). For example, bovine tuberculosis (*Mycobacterium bovis*) was recently discovered in domestic elk on game ranches in Alberta, Colorado, and Montana; infected elk in Alberta subsequently transmitted the disease to cattle (Lanka and Guenzel 1991). Eighty-one people associated with these infected elk also tested positive for tuberculosis (Roffe and Smith 1992).

Domestic elk and red deer also have escaped from game ranches, raising concerns about hybridization with and subsequent genetic effects on wild elk (Geist 1985, Roffe and Smith 1992, Williams 1992). Some states and provinces have enacted strict legislation to control, monitor, and reduce such problems; others have banned game ranching of elk and red deer altogether. Holistic programs of disease control and prevention are needed to make elk ranching compatible with management of wild elk and livestock (Roffe and Smith 1992).

Other Economic and Social Values

Elk hunting and viewing are highly valued experiences, both aesthetically and economically (Duffield and Holliman 1988, Loomis et al. 1988, Brooks et al. 1991, Bolon 1994). Economic benefits of elk are being realized by rural towns and private landowners across western North America (Boyd 1978), as consumptive and nonconsumptive users of elk are drawn from nearby urban areas (Potter 1982).

New sources of revenue from consumptive and nonconsumptive users of elk and other wildlife, combined with growing political influence of such users, are causing shifts in economic and social values that affect management of public lands (O'Toole 1988, Conner 1991, Wondolleck 1991). The growing public advocacy for elk and other wildlife appears to be directed particularly at management of livestock (Ferguson and Ferguson 1983, Gillis 1992, Rennicke 1992). Calls for the elimination of livestock grazing on rangelands (Jacobs 1991, Rifkin 1992) are increasing.

Elk-Livestock Interactions

Most western rangelands occupied by elk are also grazed by livestock. Common grazing by elk and livestock is perhaps the most significant land use issue affecting management of public rangelands in North America today (Williamson 1992). Issues of forage allocation and competition are subjects of unending debate (Vavra et al. 1989, U.S. Dep. Agric. For. Serv. 1990, Cool 1992, Vavra 1992, Wisdom 1992); few solutions seem imminent. Accordingly, relationships of elk and livestock and their management on western rangelands are the subjects of the rest of this chapter.

COMPETITION BETWEEN ELK AND LIVESTOCK

Definitions and Concepts

Elk potentially compete with domestic ungulates for food and space. Dual use of rangelands by elk and livestock, however, does not constitute competition in and of itself.

Birch (1957) postulated that competition can occur in 1 of 2 ways: (1) when individuals of the same or different species use a common resource that is in short supply; or (2) when individuals use a common resource that is readily available but the individuals "nevertheless harm one another in the process."

Miller (1967) and Nelson (1982) referred to definition 1 as "exploitive competition" because it involves direct use, or exploitation, of a limited resource between individuals. Nelson (1982) described definition 2 as "interference competition," behavior that includes any active defense of territory or other spatial resources by 1 animal against another. Definition 2 can also take a more passive form of "disturbance competition," which occurs "when the mere presence of an animal intimidates or annoys another animal into leaving the area" (Nelson 1982).

Wagner (1969) further stated that "for competition to occur between 2 species, each must share a resource that is in short supply and in using the resource, 1 or each species reduces the other's population performance to levels below that which would exist in the absence of the other species." Odum (1971) presented similar concepts.

These definitions have common elements applicable to the issue of elk competition with livestock: (1) common use of a limited resource by 2 different species, (2) disturbance or displacement of 1 species by another, and (3) reduction in population performance of 1 species by another because of competition for a limited resource or because of physical disturbance.

To demonstrate competition, either elements 1 or 2 must occur and result in element 3. A myriad of studies have examined element 1; these studies have focused primarily on food as the limited resource between elk and cattle (Nelson 1982). Likewise, numerous studies have examined element 2 regarding disturbance interactions between elk and livestock (Lyon 1985).

We know of only 1 study (Hobbs et al. In press *a*) that has evaluated element 3 for elk and livestock under field conditions. In that study, commonly used foods were the limited resource (element 1) between elk and cattle; winter grazing by elk was evaluated in terms of its subsequent effect on cattle performance during spring and early summer (element 3). We know of no studies that have documented the effect of disturbance of 1 herbivore by another (element 2) on population performance (element 3). Nelson (1982) concluded that studies of element 3 were probably impossible to conduct for large grazing animals under free-ranging conditions. Schoener (1982) concluded much the same for all studies involving competition among wild species.

Food as a Limited Resource

Many factors influence competition for food among large herbivores (Vavra et al. 1989). The most important include (1) consumption equivalence, (2) dietary overlap, (3) forage quantity and quality, (4) forage use, (5) timing of use, (6) height of foraging reach, (7) density or stocking rate of animals, and (8) spatial and temporal distribution of animals (Nelson 1982). These factors are not independent; they can interact in multiple ways to heighten or minimize the actual degree of competition (Fig. 4).

Space as a Limited Resource

Competition for space and other resources is assumed to be minimal among sympatric species of wild ungulates that have evolved together (Bell 1971; McNaughton 1985, 1991). On the other hand, competition may occur when ≥2 species have not evolved fully as separate species or when an exotic species is introduced to an environment already occupied by an ecological equivalent (Odum 1971, Davies 1979).

The latter is often the case when a domestic herbivore is introduced to a wild herbivore's range (Barnes et al. 1991); many researchers have documented an aversion by wild ungulates to the presence of livestock (Hood and Inglis 1974, Lonner and Mackie 1983, Wallace and Krausman 1987, Loft et al. 1991). We know of no studies in North America, however, that have documented livestock aversion to wild ungulates.

It is important to recognize that nonoverlapping use of rangelands by ≥2 ungulates does not necessarily mean that interference or disturbance competition is occurring. On the contrary, different species use landscapes differently.

RANGELAND RELATIONSHIPS OF ELK WITH OTHER UNGULATES

Elk and Cattle

Elk and cattle often make similar dietary choices. Both can extract high nutritive value from grasses (Janis 1976, Hanley 1982). However, both are dietary opportunists, feeding readily on a variety of grasses, forbs, and shrubs (Kufeld 1973, Heady 1975, Leege et al. 1977, Nelson and Leege 1982, Holechek et al. 1989, Jenkins and Starkey 1992, Ralphs and Pfister 1992).

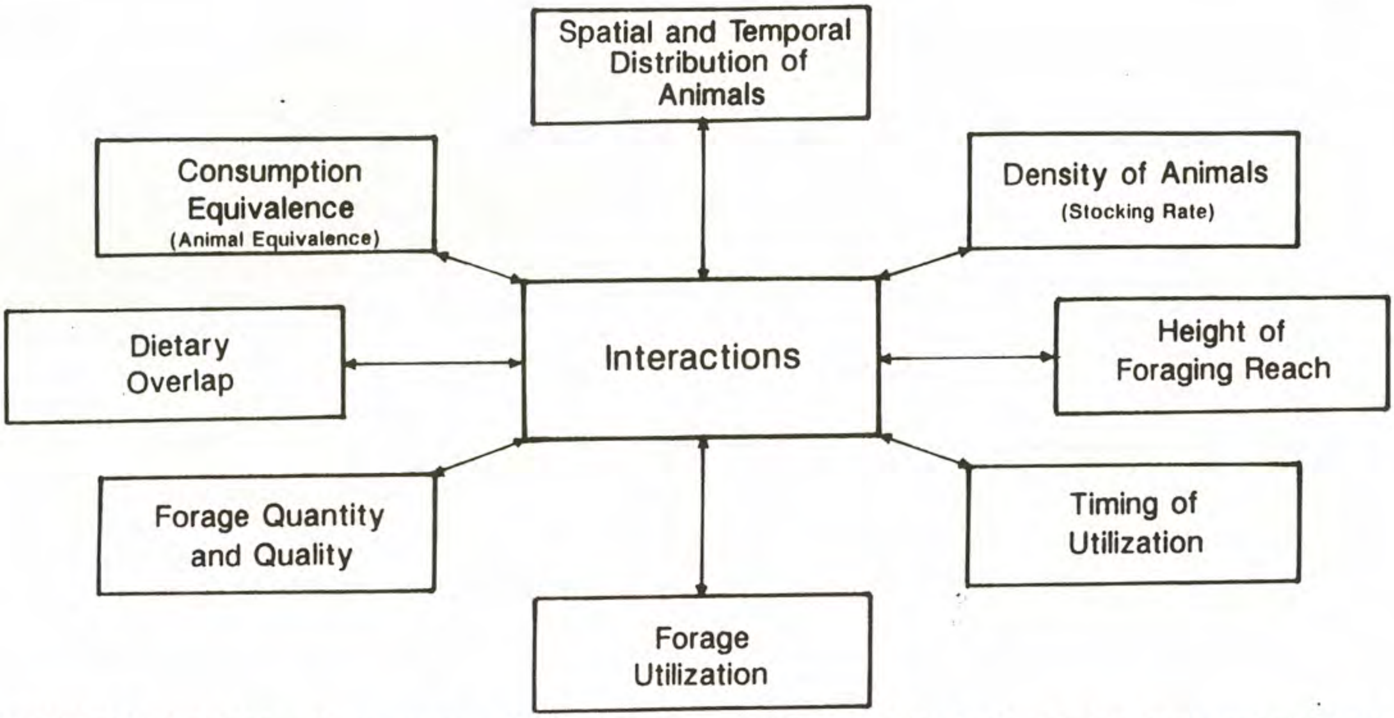


FIGURE 4. Potential interactions among variables that affect ungulate competition for food. Interactions can heighten or reduce the potential for competition in a myriad of ways that are not always predictable.

As a result, dietary overlap between elk and cattle can be high at specific times and places.

Because elk and cattle often share the same ranges and have similar diets, they are among the most likely of ungulate competitors on rangelands of North America (Nelson and Leege 1982, Nelson 1984). We have developed 12 generalizations from the studies of interactions between elk and cattle.

1. The potential for competition between elk and cattle is highest on winter and spring-fall ranges where either forage quantity or quality is limited and where both ungulates commonly share "ecologically compressed habitats" on low-elevation bottomlands or foothills. Elk typically use these ranges during late fall, winter, and early spring. Cattle usually graze these areas during late spring or early summer after elk have migrated upslope, or during fall before elk arrive.

On winter ranges, elk can reduce forage availability for cattle or vice versa. Forage quality is lowest during winter (Fig. 5) (Cook 1972, Hobbs et al. 1979), further compounding limitations in availability. If such areas are grazed heavily by cattle in the fall, insufficient forage may remain for elk during winter (Nagle and Harris 1966). On the other hand, heavy grazing by elk during winter may reduce the forage available to cattle during spring and early summer (Hobbs et al. In Press *b*) and reduce cattle production (Hobbs et al. In Press *a*). Inadequate winter range for elk, a problem common to all western rangelands, further magnifies the potential for competition.

Similar negative interactions can occur between elk and cattle on seasonal rangelands where common grazing occurs during spring and fall; dietary overlap is consistently high during these seasons as elk and cattle feed heavily on grasses (Nelson and Leege 1982). On the other hand, Sheehy (1988) and Hart et al. (1991) found that elk and cattle used habitats on seasonal rangelands that were spatially and temporally separate, thereby reducing the competitive effect of diet similarity.

2. Competition between elk and cattle is usually low on high elevation summer ranges where forage of moderate to high quality is readily available during late spring and summer and where animals have a more expansive land base from which to make optimal grazing choices. This is the period in which forage quality is highest (Fig. 5) (Cook 1972, Hobbs et al. 1979) and grasses are readily available. Furthermore, these ranges are composed largely of public lands that

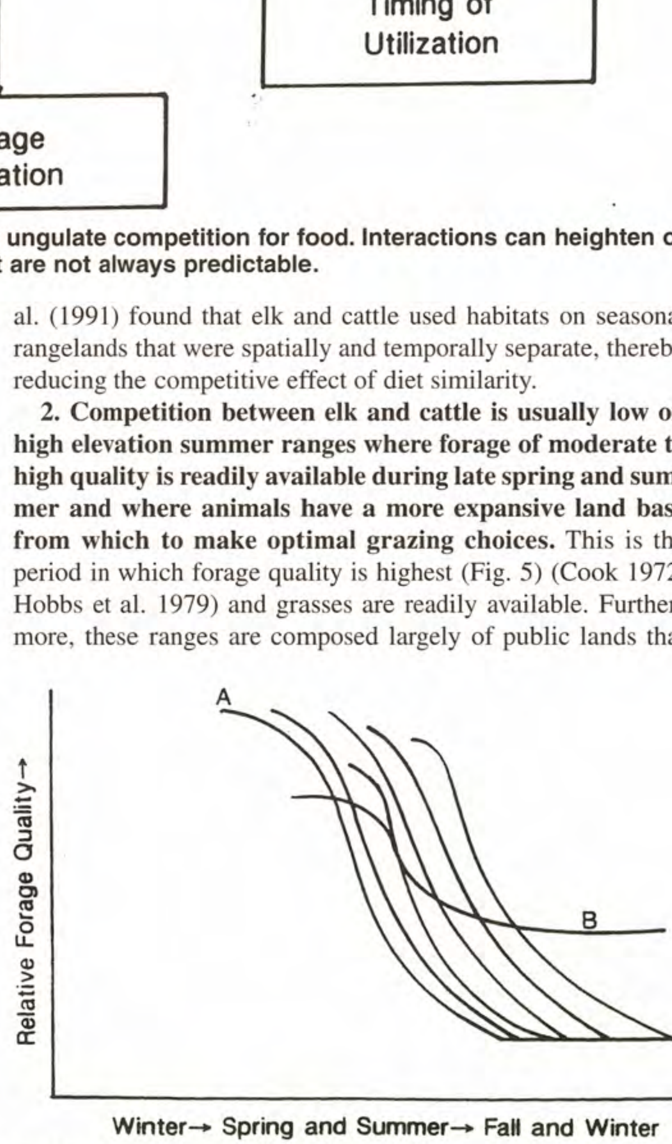


FIGURE 5. Generalized seasonal changes in forage quality of herbaceous and woody forages that are phenologically different (Nelson and Leege 1982:360). A = seasonal changes for various grasses and forbs. B = seasonal changes for a typical deciduous shrub.

encompass expansive areas in which elk can make optimal foraging choices. Elk usually arrive first to such ranges in spring and use many grasses in early stages of growth (Nelson and Leege 1982). Early defoliation of bunchgrasses can stimulate regrowth and extend forage quality into the summer and fall (Pitt 1986), with potential benefits to cattle and elk.

This response is not always predictable, however (Allayne-Chan 1986, Bryant 1993). Westenskow-Wall et al. (1994) found that spring clipping of bluebunch wheatgrass (*Agropyron spicatum*) did not increase forage quality later in the fall. Bryant (1993) found similar results, except during 1 year when sufficient rain occurred in summer and early fall to facilitate regrowth.

Another problem with spring grazing is increased mortality of bunchgrasses (Bryant 1993). If grazing is repeated and prolonged, bunchgrass mortality can be high and production reduced later in the year (Mueggler 1967, 1975; McClean and Wikeem 1985). This could negatively affect the nutritional plane of elk and cattle during late summer and fall, with carryover effects into winter and spring (Bryant 1993).

3. The potential for competition between elk and cattle increases during late summer and fall on high elevation summer ranges following the onset of prolonged seasonal drought and the subsequent decline in forage quality. This is a period in which elk often shift their diet from forbs to grasses (Nelson and Leege 1982), resulting in higher dietary overlap with cattle. It also is a time in which forage quality declines significantly (Fig. 5) (Skovlin 1967, Cook 1972, Hobbs et al. 1979, Baker and Hobbs 1982), sometimes resulting in a shortage of protein for lactating cow elk (Nelson and Leege 1982).

Continued intake of nutritious forage allows elk to put on nutrient reserves essential for proper body functions during winter and early spring, enhancing their ability to minimize depletion of fat and muscle, ensure survival of calves to the yearling age class, and carry fetal development to full-term. Late summer-early fall is a critical period for elk nutrition (Hobbs et al. 1979, Nelson and Leege 1982) and for meat production in cattle (Skovlin 1962, Holechek and Vavra 1983).

4. Elk and cattle often distribute themselves spatially in a manner that minimizes competition. Cattle typically select gentle slopes and areas near water (Holechek et al. 1989, Pinchak et al. 1991, Hart et al. 1993). In contrast to cattle, elk venture farther from water (Nagle and Harris 1966, Nelson and Burnell 1975, Hart et al. 1991), use steeper slopes (Julander and Jefferey 1964, Mackie 1970, Nelson and Burnell 1975, Hart et al. 1991, Yeo et al. 1993) and different aspects (Reynolds 1964, Sheehy 1988), eat a wider variety of foods (Nelson 1982, Nelson and Leege 1982), stay closer to forage-cover edges (Reynolds 1966, Sheehy 1988), and avoid areas near roads (Lyon 1983). Elk also prefer areas where cattle are absent (Skovlin et al. 1968, Komberec 1976, Lonner and Mackie 1983, Wallace and Krausman 1987, Frisina 1992, Yeo et al. 1993).

Not all these factors operate independently. Their combined effect, however, can minimize spatial overlap between elk and cattle; such data can be used to adjust animal unit equivalencies to reflect more realistic, complementary use of rangelands between both ungulates (Nelson 1984).

5. Elk and cattle can be distributed temporally in a manner that minimizes or heightens competition. Elk seek low elevations and foothills during winter while cattle usually graze these areas during spring, early summer, or fall (Nelson 1982, Sheehy 1988, Hart et al. 1991). Separation of ungulates by grazing season may reduce overall grazing pressure (Sheehy 1988). Forage quality may also be extended over multiple seasons from the continued regrowth of defoliated grasses (Allayne-Chan 1986, Pitt 1986). Anderson and Scherzinger (1975) and Alt et al. (1992) presumably observed such a response on elk winter ranges in Oregon and Montana, respectively. Elk use increased during winter following implementation of summer grazing by cattle.

On less productive rangelands, temporal separation of cattle and elk may not reduce competition for forage. On sagebrush grasslands of western Colorado, winter use by elk was manipulated experimentally by varying the density of animals among a replicated set of 32-ha pens; at higher densities of elk, quality of forage available to cattle during spring and early summer increased slightly; the quantity of forage available to cattle, however, was reduced (Hobbs et al. In Press *b*), with a subsequent reduction in cattle production when forage biomass fell below 45 g/m^2 (Hobbs et al. In Press *a*).

6. On ranges where spatial or temporal distributions overlap, differences in the diets of elk and cattle can sometimes minimize competition. When cattle arrive to high elevation ranges in early summer, elk often switch from a spring diet of grasses to a summer diet of forbs, thereby reducing dietary overlap (Nelson and Leege 1982). On many winter ranges, elk feed on browse (Nelson and Leege 1982) or a combination of browse and grasses (Hobbs et al. 1979), when available, in contrast to a cattle diet often dominated by grasses (Holechek et al. 1989). Competition for grasses, however, may be high on commonly grazed winter ranges where browse is not available to elk. The same is true on summer ranges during late summer and fall; elk and cattle feed heavily on grasses during this period.

7. The potential for competition between elk and cattle is high on unproductive rangelands, especially in arid ecosystems. Potential for competition also is high on rangelands grazed to full or maximum use by elk or cattle, and on rangelands experiencing a declining trend. Management for "proper use" (Archer and Smeins 1991) will reduce or minimize competition between elk and cattle. What constitutes "proper use" for dual grazing by elk and cattle, however, is not clear. Holechek et al. (1989:190-191) estimated acceptable levels of grazing use for most major range types in North America. These estimates were based on the premise that moderate livestock use of key forage species would retain sufficient vegetation residues for long-term maintenance of plant vigor, species composition, and site productivity (Smith 1965). Acceptable use of key forage species varied from 40 to 60% of annual biomass on more productive rangelands and from 20 to 40% on more arid rangelands.

We believe these estimates are useful as benchmarks for assessing the potential for competition between elk and cattle. Accordingly, on arid rangelands, we assume that elk or cattle use of perennial grasses at levels >25-30% will heighten forage competition with the other ungulate. On more productive rangelands, use of grasses at levels > 50-60% will likely induce this effect. Use of perennial grasses by elk or cattle at levels > 60-70% will likely bring about forage competition on nearly all sites, unless alternative, woody sources of nutritious forage are available.

Relatively unproductive rangelands, such as those at low elevation in the Great Basin and Desert Southwest, often are in poor condition due to past overgrazing by livestock (Holechek et al. 1989). These ranges cannot support high stocking rates by cattle and maintain low use of key grasses. Many of these ranges were likely ungrazed or grazed lightly by large ungulates before the arrival of livestock, and many key forages are not well-adapted to herbivory (Mack and Thompson 1982). High use of grasses by elk or cattle on these ranges during winter and/or spring and fall likely heightens potential competition between the 2 ungulates.

8. High densities of elk may induce negative effects on forage conditions similar to that caused by high stocking rates of cattle, resulting in lower animal performance. Intraspecific competition among elk, and resultant negative effects on forage, likely are density-dependent and manifested at high population densities. Intraspecific competition can occur within cervid populations that persist at high densities (Klein 1968, McCulloch 1986, Clutton-Brock et al. 1987, Irwin et al. 1994). Intensive herbivory resulting from competition among elk may alter the composition and vigor of key forages (Houston 1982, Edgerton 1987), reduce soil productivity (Tiedemann and Berndt 1972), and lower calf recruitment (Irwin et al. 1994). Similar effects on vegetation and soil have resulted from high stocking rates of livestock (Hart and Norton 1988). High densities of elk, combined with high stocking rates of cattle, can magnify competition between the 2 ungulates and alter plant composition and succession (Krueger and Winward 1974, DeByle 1979, Irwin et al. 1994). These effects are manifested in areas of high dual use such as riparian habitat, where conflicts between ungulate grazing and other resource objectives often are unresolved and intense.

9. Elk show an aversion to the presence of cattle that may or may not restrict their grazing choices. Many studies have shown that elk avoid or decrease their use of areas grazed concurrently by cattle (Nelson and Burnell 1975, Komberec 1976, Sauer 1980, Knowles and Campbell 1982, Lonner and Mackie 1983, Wallace and Krausman 1987, Frisina 1992, Yeo et al. 1993). Avoidance is not total, however. Ward et al. (1973) found no difference in patterns of elk use with or without cattle. They concluded that elk and cattle were socially compatible; both ungulates were observed grazing near each other on numerous occasions. Jeffrey (1963), Burbridge and Neff (1976), Stark (1973), Wallace and Krausman (1987), and Yeo et al. (1993) also observed elk close to cattle.

Such results may seem contradictory to the studies that show elk aversion to livestock (Nelson 1982), but we do not agree. As Sauer (1980:7) explained, "The introduction of cattle coincided with a significant decrease in elk use of the area, but elk that stayed in the area did not seem to change their habits in response to the cattle." Wallace and Krausman (1987) and Frisina (1992) found similar results: after cattle were introduced, most elk moved to adjacent areas without cattle; the elk that remained, however, were observed grazing near cattle.

Frisina (1992) believed that elk in his study area moved away in response to changes in vegetation in the grazed pasture rather than from a social intolerance of cattle; no supporting evidence was presented. However. Yeo et al. (1993) noted that elk avoidance of areas grazed by cattle might have been in response to increased human activities associated with cattle, rather than cattle themselves.

Regardless, the trend seems evident: with the onset of cattle grazing (and a likely increase in associated human activities), elk use shifts to areas unoccupied by cattle. Potential effects of these shifts on the population performance of elk are unknown and likely confounded with effects of elk harvest strategies (Yeo et al. 1993).

10. On productive rangelands that were grazed historically by native herbivores, systems of cattle grazing can be designed to enhance forage or foraging conditions for elk. Likewise, grazing by elk can enhance conditions for cattle.

Grazing systems are being used by state wildlife agencies to manage forage for elk and control elk distribution. Notable examples are those in Oregon (Anderson and Sherzinger 1975; Anderson et al. 1990*a*,*b*) and Montana (Frisina and Morin 1991, Alt et al. 1992, Frisina 1992). Rest-rotation grazing by cattle is used during late spring and summer to "condition" grasses (i.e., improve forage quality or foraging access) for later use by elk.

The reverse (i.e., elk "conditioning" grasses for later grazing by cattle) also is plausible. Pitt (1986) found that clipping bluebunch wheatgrass during spring extended forage quality into the fall compared to unclipped plots, although this response may not be predictable (Bryant 1993). Moreover, Dragt and Havstad (1987) found no increase in quality of Idaho fescue (*Festuca idahoensis*) and rough fescue (*Festuca scabrella*) during fall after spring grazing by elk and summer grazing by cattle.

Systems of rest-rotation grazing designed specifically for elk appear to work best on relatively productive rangelands such as those of the Pacific Northwest and northern Rocky Mountains. We do not believe these systems would be effective on rangelands in arid ecosystems of the Great Basin and Desert Southwest, due to inherent limitations in site productivity. In these areas, we believe that both the retention of vegetation residue and the regrowth of desirable forage would be *inadequate* to provide the desired benefits to elk and to maintain the desired composition, quantity, and vigor of forages.

11. Competition can be high at a given time and place during 1 year and low or nonexistent in the same place and time in subsequent years. Annual and seasonal variations in weather can dramatically alter forage availability and quality (Holechek et al. 1989). Periods of prolonged drought may induce competition between elk and cattle by reducing the quality or the availability of forage. Moreover, overgrazing during drought years can have lasting negative effects on range health, and thus on animal condition, which cannot be overcome during years of increased precipitation (Heady 1975, Holechek et al. 1989, Frank and McNaughton 1992). Stocking rates of elk and livestock, therefore, must be adjusted to match the carrying capacity of rangelands under drought conditions rather than for periods of average or optimum precipitation.

12. Perception is rarely reality when judging competitive interactions between elk and cattle. All too often, the mere presence of 1 ungulate on the other's range inspires heated debate and calls for reductions in stocking rates of the "culprit" species (Lonner and Mackie 1983). Casual observations of elk-cattle interactions often lead to wild speculation about the effects on vegetation and animal condition, most of which cannot be substantiated by the existing literature or by credible data from the area.

Professional expertise, valid research, and long-term monitoring data are needed to provide objectivity. Mechanisms for conflict resolution among divergent interest groups (Gerrans 1992, Brocci 1993) are also essential.

Elk and Domestic Sheep

Interactions between elk and domestic sheep are often restricted to relatively small areas of high elevation summer range. This is when forage of high quality exists in sufficient quantities over expansive areas. Consequently, the potential for competition between elk and sheep typically is not as pronounced nor as prolonged as that between elk and cattle. Rhodes and Sharrow (1990) found that summer grazing by sheep in western Oregon extended the high quality of grasses well into late summer and fall, with elk as the apparent beneficiaries, much like the effect of summer grazing by cattle claimed by Anderson and Sherzinger (1975), Anderson et al. (1990*a*), Frisina and Morin (1991), Alt et al. (1992), and Frisina (1992).

Situations exist, however, that increase the potential for competition. Sheep often feed heavily on forbs during summer, as do elk (Leege et al. 1977, Nelson 1982). Another is the aversion that elk apparently show to the presence of sheep (Stevens 1966, Ward 1973), much like their aversion to cattle. Finally, where elk and sheep share winter ranges containing browse as the dominant food source, competition can be direct and intense (Nelson 1982). These instances are relatively uncommon, however; options usually exist to reduce winter conflicts by moving sheep to alternate ranges or by supplementing the forage of elk.

Elk and Other Livestock

Little is known about the rangeland relationships of elk with other domestic or feral ungulates. Distributions of elk and ungulates such as goats, horses, burros, and pigs rarely overlap; feral varieties of these animals typically inhabit the driest portions of western rangelands where elk either are not present or are not common. That is changing, however, as elk colonize new areas or reestablish populations in drier areas of the Great Basin and Desert Southwest (Bunnell and Hancock 1985, Hess 1985).

As elk become more common in desert areas, it is likely that questions of competition will arise, especially between elk and feral horses. Horse and cattle diets are highly similar on desert rangelands in southeastern Oregon (McInnis and Vavra 1987); the added interaction of elk may heighten competition. Olsen and Hansen (1977) found high seasonal overlap of diets among elk, horses, and cattle on shared range in Wyoming, as did Hansen and Clark (1977) in Colorado and Salter and Hudson (1980) in Alberta. The dearth of forage and water and the poor condition of many desert rangelands could magnify competitive interactions.

Elk and Other Native Ungulates

Most western rangelands inhabited by elk also are occupied by mule deer (*Odocoileus hemionus*). Distributional overlap can also occur with white-tailed deer (*O. virginianus*), bison (*Bison bison*), moose (*Alces alces*), pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), and caribou (*Rangifer tarandus*). In eastern North America, overlap occurs with white-tailed deer and sometimes with moose and caribou.

It is difficult to generalize about the competitive relationships of elk with these ungulates. Information is either lacking or inconclusive in documenting any measurable degree of competition (Mackie 1981). What is known is summarized below.

Elk, mule deer, bison, bighorn sheep, moose, and pronghorn apparently partition forage and habitat resources to minimize competition in areas of overlapping distribution such as Yellowstone National Park (Houston 1982). Often, patterns of foraging and habitat use are complementary. For example, grazing by elk and bison can enhance forage conditions for pronghorn and mule deer (Houston 1982).

Similar patterns of effective partitioning have been inferred from interaction studies of elk, mule deer, and other native ungulates across many western rangelands (Julander and Jeffrey 1964, Mackie 1970, Edgerton and Smith 1971, Constan 1972, Hudson et al. 1976, Skovlin and Vavra 1979, Hobbs et al. 1983, Sheehy 1988). Results appear to agree with partitioning observed among native ungulates in Africa (Bell 1971, Owen-Smith 1989, McNaughton 1991, Seagle and McNaughton 1992).

Regardless, competition does occur in some situations (Mackie 1981). In contrast to mule deer and bighorn sheep, elk generally are more opportunistic and catholic in their diet selection, more easily digest forage of low quality, are more mobile and wide-ranging, and form larger herds, all of which may result in a competitive edge when resources are limited (du Toit and Owen-Smith 1989). Accordingly, Cliff (1939), Mackie (1981) and Nelson (1982) presumed that elk out-compete mule deer on winter ranges that are limited in size and available forage. Nelson (1982) also believed that mule deer may leave or avoid areas of heavy use by elk, even if forage is available and dietary overlap with elk is low.

Ecologically incomplete habitats may cause similar problems between elk and bighorn sheep. Competition may occur on relatively unproductive alpine and subalpine ranges during summer, and on some bighorn wintering areas (Lyon and Ward 1982). Elk have sometimes overgrazed key forage plants and reduced their availability to bighorn sheep (Nelson 1982). Due to sheer numbers, elk may have a competitive advantage over bighorn sheep when vying for use of limited summer and winter ranges.

Elk are a potential host for meningeal worm (*Parelaphostrongylus tenuis*), a nematode parasite that is fatal to many cervids, including moose, caribou, mule deer, and black-tailed deer (*O. h. columbianus*). Meningeal worm is also fatal to elk, but animals exposed to lower densities of larvae can survive and transmit the disease to other cervids in the same manner as white-tailed deer (Samuel et al. 1992). Although meningeal worm is currently restricted to eastern North America, translocations of infected elk from eastern states and provinces could spread the disease westward. The result could have catastrophic effects on populations of cervids in the West, particularly caribou and moose. The likelihood of infected elk being translocated from eastern to western North America is increasing: hundreds of game-ranched elk are routinely moved across the continent each year (Williams 1992), and no reliable test exists to certify that such animals are not infected (Samuel et al. 1992).

GRAZING MANAGEMENT TRADE-OFFS BETWEEN ELK AND LIVESTOCK

Type of Grazing System

Few data exist about elk response to various systems of livestock grazing. Most research has focused on the effect of livestock grazing per se, with few tests of elk response to different grazing systems under experimental replication. The scant information that is available appears inconclusive regarding elk preference for or aversion to any particular grazing system.

Moreover, no studies have rigorously examined elk performance under various grazing systems. Furthermore, few data from controlled experiments are available regarding the effects of different grazing systems on vegetation parameters considered important to the nutritional needs of elk.

Skovlin et al. (1968) examined elk response to season-long, deferred-rotation, and ungrazed replicates in northeastern Oregon. Elk preferred ungrazed areas and showed no difference in their use of season-long versus deferred-rotation pastures.

Skovlin and Harris (1970), working in the same area, found higher elk use under season-long versus deferred-rotation grazing when cattle stocking was light. They found the opposite preference when stocking was high.

Knowles (1975) monitored elk response to cattle grazing under rest-rotation in Montana in the same area where Mackie (1970) had studied elk and cattle interactions under season-long grazing. Elk preferred pastures in rest and avoided pastures actively grazed by cattle. Knowles (1975) concluded, however, that overall use by elk was not significantly different under rotation grazing than that observed by Mackie (1970) under season-long grazing.

Yeo et al. (1993) found no changes in population trends of elk following a change from season-long to rest-rotation grazing in east-central Idaho. Like Knowles (1975), Yeo et al. (1993) concluded that elk preferred pastures in rest and avoided those actively grazed by cattle.

Effect of Stocking Rate

Stocking rate of livestock, more than any other grazing variable, directly influences the composition, quantity, and nutritive value of forage available to ungulates (Heady 1975, Van Poollen and Lacey 1979, Heitschmidt and Taylor 1991). This premise, combined with the potential for forage competition between elk and cattle, provide a framework for describing the effect of stocking rate on forage conditions for elk.

1. Regardless of the grazing system used, the composition, quantity, and quality of forage available to elk is determined largely by the stocking rate of cattle, interacting with the density of elk, the inherent characteristics of the site, and weather. Effect of stocking rate of domestic sheep, goats, or other livestock on forage conditions for elk is little known.

2. Light stocking rates of cattle can be neutral or positive in their influence on the composition and nutritive value of forage for elk. On more productive rangelands of the Pacific Northwest and Rocky Mountains, light grazing may "condition" grasses, presumably causing regrowth of high nutritive value or improving animal access to nutritious plant parts. In general, cattle use of key forage species at season-end levels of < 40%, using systems described like those of Alt et al. (1992) and Frisina (1992), may induce this effect while maintaining a desirable composition of forage for elk.

3. Moderate stocking rates of cattle, with allowable use of key species between 25 and 60%, can be positive, neutral, or negative in their effect on forage conditions for elk. Much depends on the timing of grazing, the physiological response of key forage plants to grazing, and the inherent productivity of the range and its condition. On relatively unproductive rangelands of the Great Basin and Desert Southwest, it is likely that cattle use > 25% will negatively affect forage conditions for elk, and vice-versa. Intensive monitoring of forage use, composition, quantity, and quality is required to determine specific effects.

4. High stocking rates of cattle invariably heighten the potential for competition with elk for limited forage. Similarly, high densities of elk may induce intraspecific competition for forage (Houston 1982, Irwin et al. 1993), magnifying potential competition with cattle. Regardless, cattle use of key species at levels > 60% may significantly reduce or eliminate key forage plants for elk and cattle on nearly all range types in North America (Holechek 1988, Holechek et al. 1989). The remaining forage will likely be abundant but of low nutritive value, or scarce but of high nutritive value, resulting in reduced animal performance or lower carrying capacity, respectively (Klein 1968, Hobbs and Swift 1985). On desert rangelands, both low quantity and quality of vegetation may result from overgrazing (Huston and Pinchak 1991), lowering both animal performance and carrying capacity.

These effects on elk forages may explain the inverse relationship between stocking rates of cattle and habitat use by elk (Fig. 6), documented by Skovlin et al. (1968) in northeastern Oregon. This relationship generally held true for all types of grazing systems that were studied.

By contrast, Anderson et al. (1990*a*), working in a similar area in northeastern Oregon, documented a long-term increase in stocking rates of elk and cattle with the use of a specially designed system of rest-rotation grazing during summer. However, close inspection of these data (Anderson et al. 1990*a*:106) indicate that elk numbers declined during the last 8 years of this 27-year study, commensurate with the highest stocking rates of cattle.

Methods of Stocking Allocation

Without question, the most confounding and frustrating process facing public range managers today is that of stocking allocation among wild and domestic ungulates. Much of the controversy centers on allocation between elk and cattle.

The allocation procedures we suggest here are generalized; their purpose is to demonstrate how trade-offs in allocation of forage between elk and cattle can be evaluated on a landscape scale such as a range allotment on public land. These procedures are not designed to estimate absolute carrying capacity of elk, nor to estimate the actual number of elk that may be present. Rather, they are designed to estimate realistic stocking rates of cattle within an allotment, given a potential carrying capacity of elk within the area, the expected patterns of distribution overlap between the 2 ungulates, and the potential for forage competition.

Additional fine-tuning is possible by incorporating more variables and by including site-specific data about potential carrying capacities, distribution patterns, and dietary preferences. That would allow range managers to use sophisticated allocation models such as those described by Nelson (1984), Cooperrider and Bailey (1984), Van Dyne et al. (1984), Ranching Systems Group (1992), and Johnson et al. (In Press). Use of our procedures involves the following steps:

1. Calculation of the stocking rate for cattle, based on the biomass of key forage species available, the allowable use of such forage, the forage demand of animals, the length of grazing period, and the spatial distribution of animals within the planning area.
2. Calculation of the stocking rate for elk, based on these same parameters.
3. Judgment of stocking allocation between the 2 species, based on the stocking rates calculated above, the potential overlap in spatial distributions, and the potential for forage competition. This process includes the following assumptions.

Stocking rates of elk and cattle can be estimated based on the biomass of key forage species. Note that biomass of key forage species is *not* equivalent to the total biomass of forage or vegetation that may be present (Smith 1965). Rather, key forage species are those plants that are abundant, productive, and palatable (Smith 1965). Such plants are the most valid indicators on which to base estimates of proper use and stocking (Holechek and Pieper 1992, Holechek et al. 1992). They represent the quantity of plants most likely to be consumed that provide high nutritional value to the consumer; such forages typically are "decreaser" species (Holechek et al. 1989).

Accuracy of stocking estimates will be improved if the nutritive supply of forage is considered (Hobbs et al. 1982, Hobbs and Swift 1985, Schwartz and Hobbs 1985, Johnson et al. In press). Estimates based on nutrition, however, require intensive, site-specific data about energy and protein levels in forages consumed by ungulates. These data often are not available, and their collection can be time- and cost-prohibitive. Moreover, Klein (1968:363) stated that "With regard to ungulate range, it can perhaps be stated that forage quantity acts primarily to govern population size while quality determines the size of the individual." Schwartz and Hobbs (1985:35) further concluded that "Although the quality of food items has profound influence on the condition of individual herbivores, the quantity of forage ultimately determines how many animals can exist within a habitat." Also, both elk and cattle have similar digestive systems (Janis 1976, Hanley 1982), and in contrast to many smaller ungulates, are better-adapted to foraging in areas where food is high in quantity but low in quality (Wickstrom et al. 1984, Vavra et al. 1989). Biomass of key forage species therefore provides a reasonable basis for calculating a basic stocking rate for elk and cattle.

Stocking rates must be adjusted to reflect the spatial distribution of animals. For example, cattle avoid areas with increasing slope and distance from water (Tables 1, 2). Elk use declines significantly with increasing density of roads open to motorized traffic (Fig. 7). Both ungulates likely avoid forage

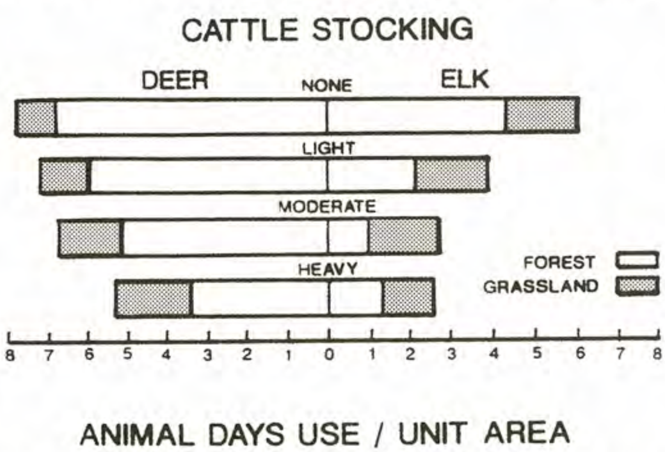


FIGURE 6. Cattle stocking in relation to deer and elk use in northeastern Oregon (Skovlin et al. 1968).

TABLE 1. Cattle use of landscapes in relation to topography (Holechek et al. 1989:194).

% slope	% use	% reduction in grazing capacity
0-10	100	None
11-30	70	30
31-60	40	60
> 60	0	100 (consider these slopes ungrazable)

TABLE 2. Cattle use of landscapes in relation to distance from water (Holechek et al. 1989:193).

Distance from water (km)	% use	% reduction in grazing capacity
0-1.6	100	None
1.6-3.2	50	50
> 3.2	0	100 (consider this area ungrazable)

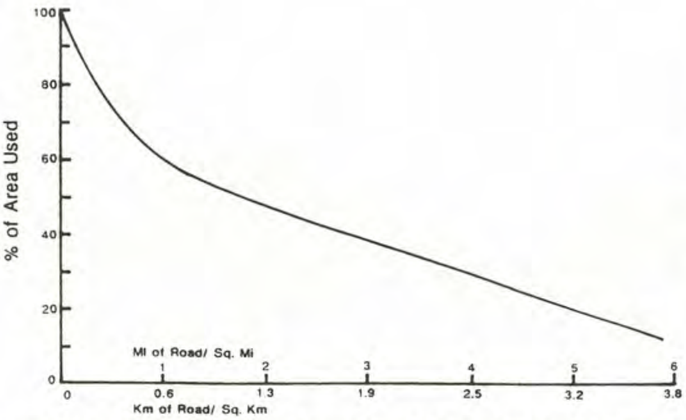


FIGURE 7. Elk use of habitat in relation to the density of roads open to motorized vehicles (Lyon 1983).

patches of low quality, and instead distribute themselves commensurate with the distribution of nutritious forage, as described for ungulates in general (Westoby 1974, Seagle and McNaughton 1992). Deep snow on winter range also can reduce the area available for foraging and alter animal distributions (Lyon and Ward 1982). In addition, elk use declines with increasing distance from cover-forage edges and in certain cover types (Wisdom et al. 1986, Thomas et al. 1988), and with increasing stocking rate of cattle (Skovlin et al. 1968, Painter 1980).

All such variables that induce a nonuniform distribution of ungulates at a specific time and place should be used to adjust stocking rates. One note of caution, however: determination of multi-variable effects on the spatial distribution of ungulates requires knowledge of the interactions among spatial variables. These are largely unknown. Geographic Information Systems (GIS) and Decision Support Systems (DSS) like that used by Ranching Systems Group (1992) and Johnson et al. (In Press) are required to analyze spatial interactions. Our procedures include single variables for purposes of illustration. We assume that a GIS and DSS will be used to analyze spatial variables over extensive areas, especially when analyzing multi-variable effects on animal distribution (Stuth et al. 1990).

Stocking rate, unadjusted for spatial distribution, is calculated as follows:

$$SR_u = \frac{(bf)(as)(au)}{(mw)(dfi)(dg)}$$

where SR_u is the stocking rate (no.) of either cattle or elk, unadjusted for spatial distribution, and where

- bf = biomass of key forage species (kg/ha),
- as = area size (ha),
- au = allowable use of key forages (% of plant wt),
- mw = mean weight of animals (kg),
- dfi = daily forage intake of animals (kg of forage/kg animal/day, expressed as forage consumed daily as a % of body wt), and
- dg = days of grazing (no.).

Stocking rate, adjusted for spatial distribution of animals is then calculated as:

$$SR_a = SR_u \sum_{i=1}^{n} (\text{\% area in category})\ (\text{\% use in category})$$

where SR_a = the stocking rate (no.) of cattle or elk, adjusted for spatial distribution, and where n = number of mapped categories for each spatial variable used, i = each mapped category in which the variable is applied, % area = proportion of area in each category relative to the total area, and % use = % of area or % of time that animals use a category relative to 100% or full use of that category.

Cattle use is that expected in each mapped category due to the effect of slope (Table 1) or distance to water (Table 2). Elk use is that expected in each category based on the density of roads open to motorized vehicles (Fig. 7). Effects of other spatial variables, like those mentioned earlier, can also be included here.

These stocking rates can then be used to judge stocking allocation between elk and cattle. This process includes the following additional assumptions.

If spatial distributions of elk and cattle do not overlap, owing to factors other than the social intolerance of elk for cattle, stocking allocation is additive (complementary) rather than either/or (competitive). If spatial distributions do overlap, stocking allocation is still additive unless forage competition occurs. **Regardless of distributional overlap, stocking allocation between elk and cattle is additive rather than either/or whenever forage is not limiting.**

In areas where elk-cattle distributions overlap, the potential for forage competition must be assessed. If site-specific research or monitoring data are unavailable, we recommend using a decision tree to assess the potential for forage competition, based on range condition and trend (Fig. 8). A better method is to collect site-specific data about elk and cattle use of key forages over time. If results indicate that elk and cattle are using the same key forages, and if total use exceeds that allowed, assume that potential competition for forage is high. If different forages are being used or if total use is at or below that allowed, assume that potential competition is low.

Following is an example of how these procedures can be applied. The example was developed originally by Holechek et

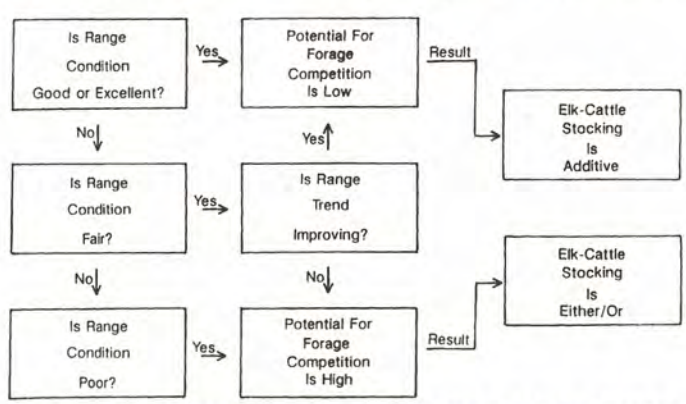


FIGURE 8. Decision tree for assessing the potential for forage competition between elk and cattle in areas where spatial distributions overlap, and where site-specific research or monitoring data about forage availability and dietary overlap are not available.

al. (1989:189-203) to demonstrate the effect of spatial distribution on the calculation of stocking rates for cattle. We extended this process to calculate stocking rates for elk in the same manner. We then estimated a stocking allocation from the 2 stocking rates, based on the overlap in spatial distributions between the 2 ungulates and the assumed potential for forage competition. The assumptions made for calculation of cattle stocking are described by Holechek (1988) and Holechek et al. (1989:189-203).

***Example*: *Elk Summer Range in Northeastern Oregon*.** Cattle graze this hypothetical 1,000-ha allotment for 4 months during summer. Elk use the area for 7 months from late spring through fall. Approximately 200 kg/ha of key forages are available, with allowable use of these forages set at 25% because range condition is poor.

The area is characterized by diverse topography and a high density of roads open to motorized vehicles (Fig. 9A). Thus, the distributions of cattle and elk are clumped (Fig. 9B) due to the effect of slope on cattle use (Table 1) and open road density on elk use (Fig. 7).

No other spatial variables are assumed to affect animal distribution, including social intolerance of elk for cattle. Competition for forage is assumed to be high (i.e., 100% dietary overlap) in areas where cattle-elk distributions overlap because range condition is poor (Fig. 8). Daily forage intake is assumed to be 2% of body weight for both elk and cattle due to the poor condition of range, in contrast to a daily intake of 2.5% or higher that would be expected during summer when forage quality is normally high (Nelson and Leege 1982).

Under these assumptions, the independent stocking rates of each ungulate, unadjusted for effect of spatial variables (SR_u), are 60 elk and 52 cattle within the allotment (Table 3). These stocking rates are then discounted (SR_a, Table 3) to reflect portions of the allotment not used or used less than 100% (Fig. 9B).

As a result of differences in elk-cattle distributions, potential competition is reduced significantly; 40% of the area theoretically is grazed exclusively by cattle, and another 10% is grazed only by elk (categories A and D, Table 3, Figs. 9,10). Hence, stocking allocation is partially additive; that is, cattle and elk can be stocked partially independent of each other to account for 50% of the area where their modeled distributions are mutually exclusive (Fig. 10).

Use of these procedures results in mixed species stocking that is highly complementary and flexible, regardless of which ungulate is emphasized in management (Table 4). By contrast, the traditional method of allocation (Stoddart and Smith 1955) overestimates the number of elk or cattle that can stocked independent of one another (Table 4). This is because the traditional method does not account for clumped distribution of a given

TABLE 3. Independent stocking rates of elk and cattle before (SR_u)[a] and after (SR_a)[b] adjustment for effects of spatial variables on animal distribution within a 1,000-ha allotment in northeastern Oregon.

	Cattle		Elk	
Mapped category[c]	SR_u	SR_a	SR_u	SR_a
A	5	0	6	6
B	16	6	18	18
C	10	7	12	12
D	21	21	24	0
Total	52[d]	34[e]	60[f]	36[g]

[a] $SR_u = \dfrac{bf\,(\text{biomass of forage, kg/ha}) \times as\,(\text{area size, ha}) \times au\,(\text{allowable use, \% of plant weight consumed})}{mw\,(\bar{x}\text{ wt of animals, kg}) \times dfi\,(\text{daily forage intake, kg forage/kg animal/day}) \times dg\,(\text{days of grazing})}$

[b] $SR_a = SR_u \sum_{i=1}^{n} (\text{\% area in category } i)(\text{\% animal use in category } i)$

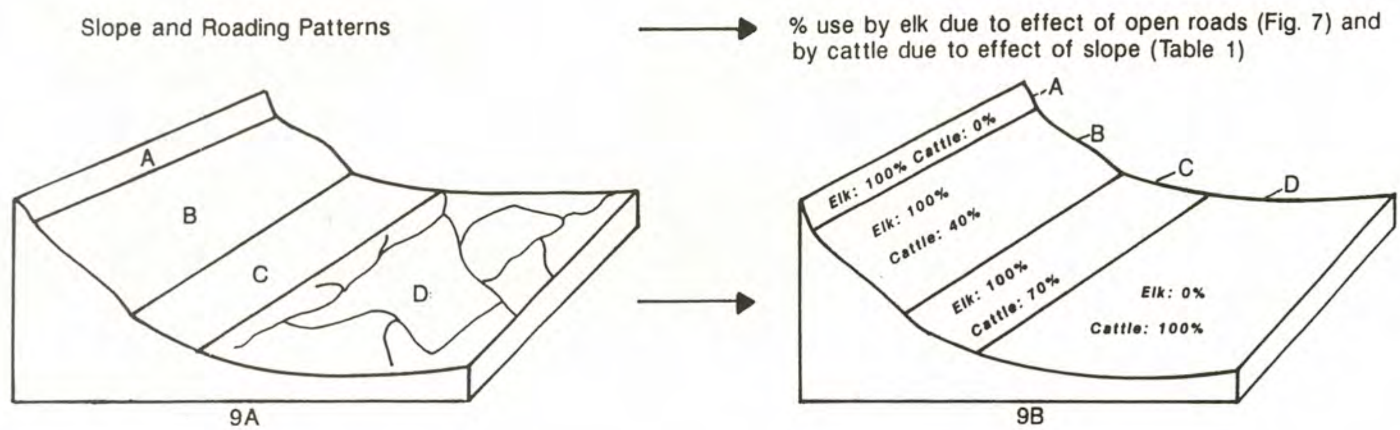
[c] See Fig. 9

[d] $SR_u = \dfrac{(200)(1000)(0.25)}{(400)(0.02)(120)} =$ 52 cattle (from Holechek et al. 1989:197); no. animals for mapped categories are based on proportion of the biomass of key forages available in each category

[e] SR_a = (52)(0.1)(0.0) + (52)(0.3)(0.4) + (52)(0.2)(0.7) + (52)(0.4)(1.0)
= 0 cattle, category A + 6 cattle, category B + 7 cattle, category C + 21 cattle, category D = 34 cattle
(adjusted for slope, Table 1, Fig. 9)

[f] $SR_u = \dfrac{(200)(1000)(0.25)}{(200)(0.02)(210)} =$ 60 elk; no. animals for mapped categories are based on proportion of the biomass of key forages available in each category

[g] SR_a = (60)(0.1)(1.0) + (60)(0.3)(1.0) + (60)(0.2)(1.0) + (60)(0.4)(0.0)
= 6 elk, category A + 18 elk, category B + 12 elk, category C + 0 elk, category D = 36 elk
(adjusted for roads, Figs. 7, 9)



Mapped Categories

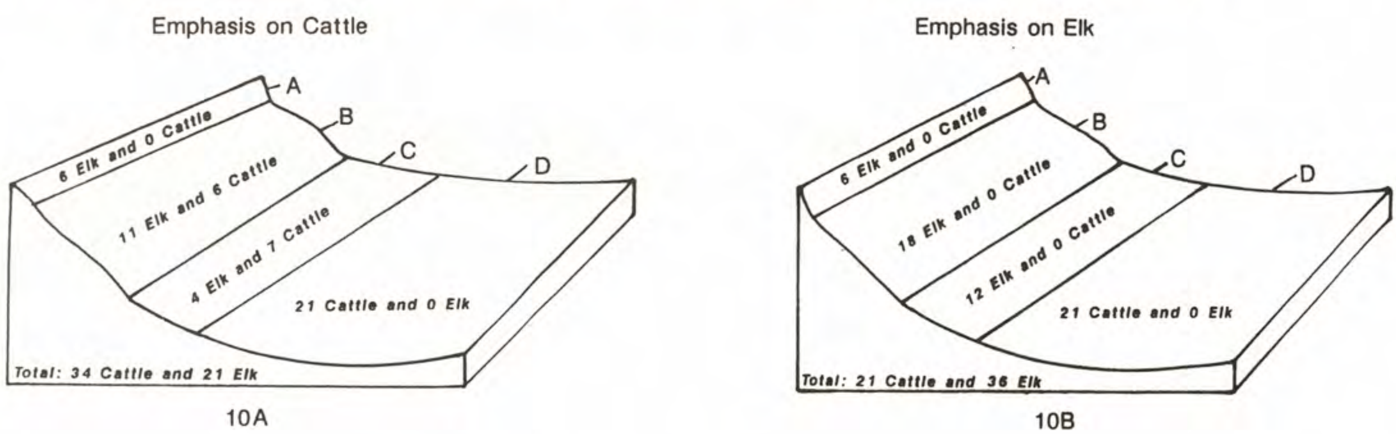
A= 10% of area with slopes >60% and road density of 0 Km/sq. Km

B= 30% of area with slopes 31-60% and road density of 0 Km/sq. Km

C= 20% of area with slopes 11-30% and road density of 0 Km/sq. Km.

D= 40% of area with slopes ≤ 10% and road density > 4Km/sq. Km

FIGURE 9. Effect of spatial variables on elk and cattle use of a 1,000-ha allotment in northeastern Oregon.



Mapped Categories

A and D = Forage competition low due to little or no overlap of elk and cattle distributions.

B and C = Forage competition high due to high distribution overlap and poor range condition.

FIGURE 10. Stocking allocation with emphasis on cattle (10A) or elk (10B), based on adjusted stocking rates (SRa, Table 3) of each ungulate and the combined effect of distribution overlap and potential competition for key forages in each mapped category of a 1,000-ha allotment in northeastern Oregon. No. elk in 10A is calculated from the biomass of key forage available in mapped categories A, B, and C that is not used by cattle due to effect of slope (Table 3, forage for 18 cattle (SRu – SRa) is available for elk in A, B, and C; no. elk = 1.15 x no. cattle). No. cattle in 10B is the adjusted stocking rate for cattle (SRa, Table 3) in category D, where elk do not occur due to high density of open roads (Table 3).

species, and in essence, overestimates stocking potential whenever a species' distribution is nonuniform (Fig. 9).

The traditional method also calculates stocking of elk as a simple weight ratio, or animal equivalence, of the number of cattle (Table 4), thus not accounting for areas of minimal or no overlap in elk-cattle distributions such as in categories A and D, Fig. 10. Moreover, differences in length of grazing period between elk and cattle in the estimates of animal equivalence are ignored, resulting in highly inaccurate stocking estimates of elk (Table 4). Finally, the traditional method does not account for the biomass of key forages available to 1 species when use of a category by the other ungulate is high but < 100%, such as the forage available to elk with < 100% cattle use of categories B and C, Figs. 9 and 10.

For these same reasons, our procedures allow a higher number of total animals to be stocked in contrast to single species stocking (Table 4). This corroborates conclusions by Nelson (1984:491), who stated that "common use grazing generally results in more efficient use of the forage resources because different herbivores have different habitat and forage preferences."

TABLE 4. Stocking of elk and cattle using different methods of allocation and management objectives for a 1,000-ha allotment in northeastern Oregon.

Allocation method and management objective	Stocking Allocation: Cattle (no.)	Stocking Allocation: Elk (no.)	Total no. animals
Traditional stocking			
Maximize cattle	52[a]	0	52
Maximize elk	0	104[b]	104
Single species stocking, adjusted[c]			
Maximize cattle	34	0	34
Maximize elk	0	36	36
Mixed species stocking, adjusted			
Maximize cattle	34	21[d]	55
Maximize elk	21[e]	36	57

[a] SR_u for cattle, Table 3 (unadjusted for effect of spatial variables), per Stoddart and Smith (1955).
[b] Animal equivalence of approximately 1 cow/2 elk (Stoddard and Smith 1955:192).
[c] Numbers for single species stocking are stocking rates adjusted for effects of spatial variables (SR_a, Table 3).
[d] Calculated from biomass of key forage available in mapped categories A, B, and C that is not used by cattle (see Table 3; forage for 18 cattle ($SR_u - SR_a$) is available for elk in A, B, and C; no. elk = 1.15 × no. cattle).
[e] Cattle can graze in category D, where no. elk is assumed to approximate 0 due to high density of roads open to motorized vehicles (see Table 3).

RANGELAND PRESCRIPTIONS FOR ELK

Managing Elk Distribution and Nutrition

By managing for nutritional needs, we can manipulate the spatial distribution of elk and improve animal condition. This is important to rangeland managers who seek to maintain productive elk herds on public land for hunting and viewing, and away from private land where the potential for damage to crops, fences, and livestock forage is high.

Crude protein (CP) and dry matter digestibility (DMD) are typically evaluated as indices of the nutritive value of forages consumed by ruminants (Dietz 1970, Mautz 1978). These values can be used with estimates of other nutritional parameters to derive digestible protein and digestible energy, which indicate the actual amount of protein and energy, respectively, that is available to ruminants for metabolic and other physiological functions (Mautz 1978, Huston and Pinchak 1991).

Nelson and Leege (1982) estimated crude protein requirements of cow elk by season (Fig. 11). These are perhaps the most practical and pertinent estimates of elk nutritional requirements that can be readily used to guide the design of effective land treatments. Note that at a minimum, elk requirements for maintenance are 5-6% CP year-round. This was corroborated by Hobbs et al. (1981), who concluded that "elk diets containing much less than 5% crude protein would fail to meet the animals' metabolic requirements." Hobbs et al. (1981) also cited McCullough (1969), who inferred that a diet of 7% crude protein met elk requirements during winter. Mould and Robbins (1981) found that diets containing < 3.5% CP resulted in negative protein digestibilities in tame elk; they concluded that levels of digestible nitrogen are inadequate for maintenance requirements if CP during winter is < 5% and biomass of forage is limited.

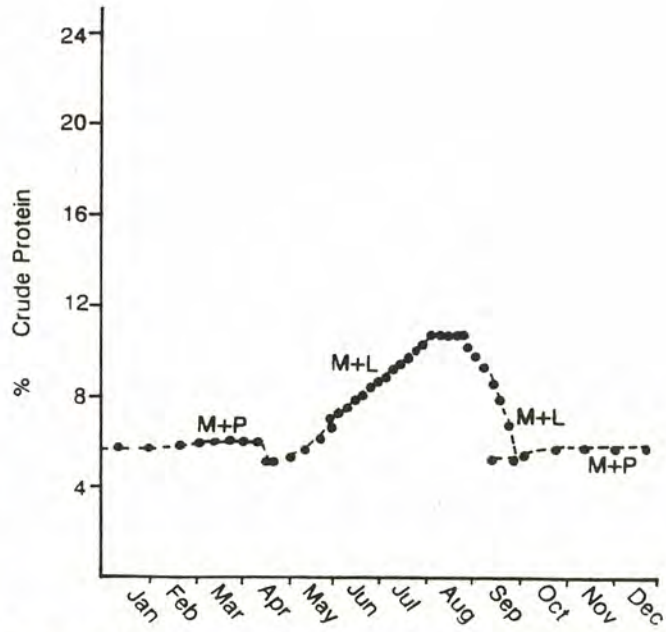


FIGURE 11. Crude protein requirements of cow elk by season, considering needs for maintenance (M), pregnancy (P), and lactation (L), as estimated by Nelson and Leege (1982:365).

Demand by cow elk for protein increases to 10-11% during lactation in spring and summer (Fig. 11). Quality of elk diets appears sufficient in spring and early summer to meet this demand (Baker and Hobbs 1982, Nelson and Leege 1982), but this may not be the case during late summer and fall. Nelson and Leege (1982:365-366) provided an excellent illustration of the importance of early calving in relation to protein availability. For calves born on or before 15 June, their demand for milk coincided with maximum availability of protein in spring and summer forages; these calves usually are weaned before protein content declines rapidly in late summer and early fall on ranges dominated by herbaceous forage. Calves born after June 15 placed protein demands on lactating cows that potentially could not be met in late summer and fall.

Elk requirements for digestible forage have not been studied extensively. Hobbs et al. (1981) found that digestibility of species consumed by elk during winter varied from 23 to 50%, similar to that found by Ward (1971) and Rowland et al. (1983). Hobbs et al. (1981) concluded that elk diets < 50% digestible were substantially submaintenance. They also cited Ammann et al. (1973:200), who concluded that "it is reasonable to assume that a ruminant could not maintain itself on a diet much below 50% digestible energy." This is in agreement with digestibility requirements for maintenance of adult beef cattle, estimated to be 51% (National Research Council 1984). We believe that 55% dry matter digestibility is adequate for maintenance of adult elk if dietary requirements for protein are met (Fig. 11) and daily intake is ≥ 2.5% of body weight.

Assessing the nutritional status of elk, and applying the appropriate mix of land treatments to overcome nutritional deficiencies, is a complex challenge. The following points should be considered:

1. Assessing the nutritional status of elk is most accurate when diet quality is evaluated in tandem with the quality of available forage. Inferring the nutritional status of elk based only on the quality of available forage can be misleading because elk and other ungulates select a diet higher in quality than that generally available (Hobbs et al. 1981, Baker and Hobbs 1982, Rowland et al. 1983, Hobbs and Spowart 1984).

2. Forage quantity and quality often are inversely related (Hobbs and Swift 1985, Hobbs et al. In Press *b*), except on desert rangelands where both quantity and quality can be low (Huston and Pinchak 1991). Management for maximum quality of forage is therefore a strategy to maintain fewer animals in better condition, whereas management for maximum biomass is a strategy to maintain more animals in relatively poor condition (Klein 1968, Hobbs and Swift 1985). Managers should set explicit objectives as to which strategy the range improvements are designed to support.

3. Many range improvements will increase forage quality but reduce quantity in the short-term, and increase forage quantity but reduce quality thereafter. For example, burning may improve the nutritive value of some forages immediately after treatment, but quality usually declines within 2 years (Nelson and Leege 1982, Skovlin et al. 1983, Van Dyke et al. 1991). Continued growth of post-treatment vegetation then results in increased biomass (Leege 1979, Peek et al. 1979, Van Dyke et al. 1991). Maintenance of a patchy mix of habitats, some high in forage biomass and some high in quality, therefore requires diverse temporal applications of range improvements that span multiple seasons and years.

Applying this mix of treatments in a "patchy" manner, temporally and spatially, throughout a seasonal herd range implies a strategy to maintain moderate densities of elk in moderate condition. Moreover, this approach is likely to maintain the desired spatial distribution of animals across public-private ownerships, commensurate with the distribution of range improvements.

4. It is difficult to specify the quantitative, interactive effects of various combinations of range treatments on elk nutrition, due to the lack of research on multi-variable effects. General, single-variable effects of the most common treatments are as follows.

Levels of Stocking

Stocking rates of elk, other wild ungulates, and livestock are rangeland treatments that dramatically affect the nutrition of elk. Proper levels of stocking of all ungulates are essential to maintain desired animal and population performance, and to sustain the range itself. Guidelines for proper stocking and procedures for stocking allocation were given earlier.

Grazing Systems

Livestock grazing can be designed to enhance forage for elk. Moreover, grazing systems can be used to manage the distribution of elk across land ownerships and habitats within a herd range. Rest-rotation grazing by cattle has been used effectively on rangelands dominated by bluebunch wheatgrass and Idaho fescue in Montana and Oregon, as follows.

Cattle graze the Mount Haggin Wildlife Area (8,100 ha) in southeastern Montana from mid-June through mid-October (Fig. 12) (Frisina 1992). Grazing level is 4,000 animal unit months across 3 pastures. During a given year, 1 pasture is grazed early, 1 is grazed late, and 1 is rested, with the order rotated over 3 years (Fig. 12). Grazing in the early pasture begins during the period of maximum growth of grasses (mid-Jun) and generally ends at seedripe (mid to late Aug); grazing in the late pasture is from seedripe to 15 October.

Presumed benefits to elk are continuous availability of preferred grasses in varying stages of phenological development during spring, summer, and fall among the 3 pastures; sustained

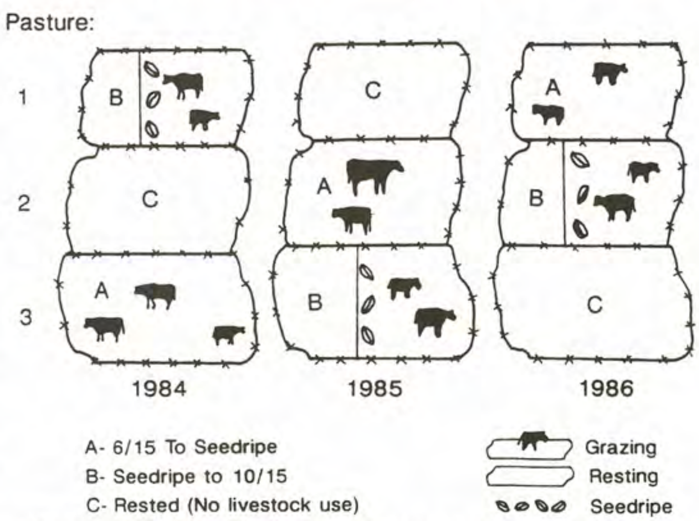


FIGURE 12. A rest-rotation grazing system used to manage forage on elk summer range at the Mount Haggin Wildlife Area in Montana (Frisina 1992:94).

maintenance of grasses of high nutritive value across the Wildlife Area as a whole; improved access to grasses of high quality due to the removal of surrounding litter; adequate periods of grazing rest, allowing preferred grasses to re-seed and/or restore food reserves in roots to maintain their abundance and vigor; and options for elk to graze in expansive areas with little or no interaction with cattle.

Benefits to livestock growers are increased animal unit months in contrast to no grazing or more restricted grazing practices of the past; improved quality of grasses available to cattle; and reduced damage by elk to adjacent, private rangelands (Frisina 1992).

Alt et al. (1992) described a similar system of rest-rotation grazing using cattle at the Wall Creek Wildlife Area in southwestern Montana; the area encompasses a combination of elk summer and winter range. Since its inception in 1984, the grazing system has apparently become increasingly effective in redistributing elk onto the Wildlife Area, and away from adjacent, private lands where damage by elk was significant and unacceptable. Today, the system has become so successful that Alt et al. (1992:15) stated that "The program has eliminated the need for a full-time manager to be housed at Wall Creek since hazing wintering elk off private lands is no longer a major factor." Frisina and Morin (1991), Anderson and Scherzinger (1975), and Anderson et al. (1990*a*) documented similar effective management of elk by using rest-rotation grazing.

These examples employ similar grazing strategies that are presumably responsible for their success: (1) cattle are removed from the early grazed pastures before or just after mid-growing season to allow for sufficient regrowth of grasses; this regrowth is unobstructed by litter and thus provides elk with efficient foraging access to higher quality plant parts during late summer, fall and/or winter; (2) cattle use of grasses is light to moderate, further allowing for regrowth of forage for elk and maintenance of healthy range condition; (3) sufficient grazing rest is provided to facilitate survival and recovery of preferred grasses; (4) ungrazed forage preferred by elk is maintained in the rested pastures; (5) cattle are used primarily to "condition" grasses for elk; beef production is more of a benefit than a goal in itself.

Adopting such grazing strategies demands flexibility from livestock operators in the timing, location, and rate of stocking by season and year. Most conventional systems of livestock grazing do not use such strategies in a similar, holistic manner. Therefore we cannot assume that elk derive similar nutritional benefits on other rangelands where more conventional grazing systems are employed. This is especially true of relatively unproductive rangelands in arid areas of the Great Basin and Desert Southwest. In these areas, it may be difficult to design systems of cattle grazing to achieve the desired forage response for elk, simply because regrowth of vegetation is slow, litter reserves are easily diminished, and precipitation is low and less predictable.

One additional caution: none of the presumed benefits from these examples were documented under a formal experimental design. Moreover, designed experiments have not always produced similar results in like environments (Bryant 1993, Westenskow-Wall et al. 1994). As a result, some of the claimed benefits have been questioned for specific examples (Weurthner 1992) and in general (Bryant 1993).

Prescribed Burning

Fire dramatically changes the composition, quantity, and quality of forage available to ungulates (Wright and Bailey 1982, Bailey 1988). It is 1 of the most common and popular tools used to manipulate forage for elk in the United States today. For example, the Rocky Mountain Elk Foundation, the largest private funder of habitat improvements for elk on public lands, matched >$500,000 with >$1,000,000 from other sources for prescribed burning of approximately 48,000 ha of western rangelands during 1986-1992 (C. Hastings, Rocky Mtn. Elk Found., pers. comm.).

Short-term effects of such broad-scale treatments appear beneficial to forage characteristics (Vallentine 1989) and to foraging conditions (Hobbs and Spowart 1984) for many ungulates, including elk (Lyon and Ward 1982). Burning removes accumulated plant litter, thereby making current, nutritious growth more accessible (Canon et al. 1987, Jourdonnais and Bedunah 1990). Consequently, the regrowth of vegetation up to 2 years after burning is usually desired by elk (Nelson and Leege 1982), presumably due to greater foraging efficiency (Canon et al. 1987). Similarly, burning sometimes improves forage quality immediately after treatment, but nutritive value usually declines within 2 years (Nelson and Leege, Skovlin et al. 1983, Van Dyke et al. 1991). Biomass of herbs and shrubs may increase thereafter (Leege 1979, Peek et al. 1979).

On the negative side, forage quality may not increase after burning, although diet quality may still be enhanced (Hobbs and Spowart 1984). Also, ungulate use usually declines quickly after burning (Wright and Bailey 1982). Moreover, long-term effects on the composition and productivity of forages are highly variable and often unpredictable and/or undesirable (Bailey 1988). For example, burning can significantly reduce nitrogen levels through volatilization, although grazing animals may partially mitigate the effect (Hobbs et al. 1991). Also, improper season of burning can produce unacceptable mortality of key forages. Much depends on the specific objectives and outcomes that are desired, the timing, frequency, and intensity of such fires, the scale of application, the plant communities burned, and the long-term effect on site productivity (Sanders and Durham 1985).

Forage Seeding and Planting

Key forage species are often seeded or planted immediately after a wildfire or prescribed burn to ensure the establishment of nutritious forage for elk. Like burning, such treatments are generally considered beneficial, but few studies have documented specific benefits to elk nutrition.

In general, the effects are likely beneficial if the seedings or plantings provide a more balanced mix of forage classes and species than would be present otherwise. In western Oregon, for example, seeding of grasses and legumes is considered beneficial to elk nutrition because these forage classes complement a naturally high composition of shrubs (Ramsey and Krueger 1986, Wisdom et al. 1986). In eastern Oregon, by contrast, grasses and forbs dominate the forage base (Irwin et al. 1993). Hence, shrubs of high nutritive value like curlleaf mountain-mahogany (*Cercocarpus ledifolius*) and antelope bitterbrush (*Purshia tridentata*) often are planted to provide more diverse phenological stages and composition of forages.

Fertilization with Nitrogen and Macro-minerals

Nitrogen is a critical element that yields microbial protein during fermentation of foods in the rumen. Most rangeland soils are moderately to severely deficient in nitrogen (Holechek et al. 1989, Vallentine 1989). Not surprisingly, nitrogen is the chemical element considered most critical in meeting the nutritional needs of elk (Hobbs et al. 1982, Nelson and Leege 1982). Phosphorus and sulfur also are deficient on many rangelands (Dietz 1970, Vallentine 1989), and both play important roles in physiological functions of ruminants (Mautz 1978, Robbins 1993).

Increasing the content of nitrogen, phosphorus, and/or sulfur in deficient soils can increase the protein content and digestible energy of herbage and its availability to ungulates (Vallentine 1989). Desired changes in elk distribution can be achieved with the application of such fertilizers in deficient areas (Gerrans 1992).

Beneficial effects of nitrogen fertilization, however, can be highly variable between vegetation communities (Mereszcak et al. 1981). Use by elk, and presumably the nutritional benefits to them, are usually limited to ≤2 years unless fertilization is repeated (Skovlin et al. 1983). Repeated applications of nitrogen also can change the species composition of grasses (Vallentine 1989), reduce or eliminate legumes (Duncan et al. 1985), and make some soils more acidic (Berg 1986).

Micro-mineral Supplementation

Trace elements, essential to protein and energy metabolism in ruminants (Huston and Pinchak 1991, Robbins 1993), are sometimes deficient in rangeland soils. For example, selenium is deficient throughout much of the Pacific Northwest and California (Robbins 1993). Masupu (1990) found lower blood levels of selenium in populations of elk, pronghorn, and bighorn sheep than that required by livestock.

Supplemental salting or fertilization with selenium on deficient rangelands is beneficial to livestock (Watkinson 1983, Holechek et al. 1989), and thought to benefit elk (Starkey et al. 1982). Selenium supplementation using metal boluses in female black-tailed deer increased preweaning fawn survival from 0.32 fawns/female to 0.83 fawns/female in a free-ranging population in northern California (Flueck 1994).

Mineral supplementation can improve performance of elk and other ungulates if deficient minerals are identified accurately, deficient minerals are administered at the proper time, rate, and mix, and other minerals not known to be deficient are not included in supplementation efforts.

Forage Supplementation

Winter damage by elk on privately owned farms and rangelands is often predictable and significant unless preventive steps are taken (Lyon and Ward 1982, de Calesta and Witmer 1994).

One approach is supplemental or replacement feeding with alfalfa hay or pellets. Although not as desirable as the acquisition or leasing of additional winter range, feeding is effective in keeping elk away from private land (Emerson 1988, McKeel 1988). This is especially true when feeding is combined with the removal of problem animals on private land, either through live-trapping and transplanting, hazing, or special hunts.

Feeding should meet the nutritional requirements of wintering elk; forage should contain ≥ 5-6% crude protein (Fig. 11) and be ≥ 50-55% digestible. The rate of supplementation depends on the availability and quality of natural forage. If natural forage is limited, alfalfa pellets fed at rates of 4.3 kg/elk/day, or alfalfa hay fed at rates of 5.4 kg/elk/day, appear sufficient (Thorne and Butler 1976). This assumes that alfalfa of high quality is used as the supplement (e.g., 15% crude protein and 66% digestibility of hay used by Thorne and Butler [1976]).

Elk are supplemented at lower rates where natural forage is available but inadequate by itself to meet nutritional requirements. For over 20 years, large numbers of elk have been maintained with a supplementation of 3.2-3.6 kg/animal/day at the National Elk Refuge (Smith and Wilbrecht 1988); here, natural forage is usually available until late January and again by early April.

Feeding is not a panacea for resolving winter range problems (Kimball and Wolfe 1985). Once initiated, it is difficult to reduce elk dependence on such rations. Numbers of elk residing in the area during the non-winter period may increase. Acquisition of additional winter ranges, improvements in the quality of natural forage on such ranges, and reductions in elk numbers to winter carrying capacity all are ecologically superior. Often, however, such approaches are politically unacceptable; supplemental feeding then becomes the likely and often-used alternative.

Water Developments

Water is considered limiting to elk on many arid and semi-arid rangelands (McCabe 1982). Elk may concentrate near water sources in extremely dry areas (McCorquodale et al. 1986). Moreover, some transplants of elk may have been ineffective in part from a shortage of free-standing water (Carpenter and Silvy 1991, Carpenter and Grant 1991). Increasing the distribution and availability of water on many of the driest rangelands will likely enhance elk use of such areas, especially during dry seasons or years.

Further development of water sources on most other elk ranges, however, can be a "double-edge sword" if livestock have access to the water. As discussed earlier, livestock use is usually highest within 1.6 km of water (Table 2); this is the zone of most direct competition between elk and livestock. Improving the distribution of water; i.e., making water more evenly and readily available throughout a pasture, will also result in a more even distribution of livestock (Holechek et al. 1989). This may increase the potential for competition with elk, or reduce elk use in favor of cattle use for 2 reasons.

1) Most water developments have roads associated with them; elk avoid areas near roads open to motorized traffic (Fig. 7). Elk are especially vulnerable to human harassment during hunting

seasons when roads facilitate harvest, and often the over-harvest, of targeted animals (Leptich and Zager 1991, Unsworth et al. 1993). Road densities and traffic will likely increase with an increase in number and distribution of water sources.

2) Elk avoid livestock but return to grazed areas after livestock have left. A more even distribution of livestock, resulting from a more even distribution of water, may hinder grazing choices by elk unless livestock-free areas also are available within a herd's seasonal home range.

Roads

Wherever elk occur, they consistently and dramatically avoid areas near roads that are open to motorized traffic (Marcum 1975, Perry and Overly 1977, Morgantini and Hudson 1979, Witmer 1981, Irwin and Peek 1983). This response was initially quantified by Thomas et al. (1979) and later verified by Lyon (1983) (Fig. 7). Implications of this relationship cannot be underestimated: the positive effects of land treatments like burning, seeding, and fertilization on elk nutrition may be partially or wholly offset by the negative effects of open roads. This is especially true in areas of open rangelands and gentle terrain; here, vegetation and topography provide limited hiding and security from human activities. Aggressive programs of road obliteration and closure are necessary to facilitate elk use of rangelands.

Managing Population Characteristics

Humans are the most effective, dominant, and pervasive predators of elk today. The population dynamics of elk are largely controlled and manipulated through hunting by humans, and less so through predation by other mammals. Moreover, anomalies of weather and disease likely play lesser roles in controlling elk numbers compared to the effects of human predation. Finally, although habitat largely determines carrying capacity, the actual number of elk present in a given area and time, and the sex and age composition of herds, are often more a reflection of hunting regimes than of habitat constraints.

Recognition of these relationships has resulted in a new term that addresses an old paradigm for managing elk demography: that of elk vulnerability to harvest. Lyon and Christensen (1992) define elk vulnerability as a "measure of elk susceptibility to being killed during the hunting season."

Susceptibility to harvest is affected by many variables (Thomas 1991) (Table 5). Those considered to most significantly increase the vulnerability of elk are high density of hunters (Vales et al. 1991), high density of roads (Hurley and Sargeant 1991, Leptich and Zager 1991, Unsworth et al. 1993), loss or absence of large cover blocks (Hillis et al. 1991), and gentle terrain (Edge and Marcum 1991, Unsworth et al. 1993).

Accordingly, elk are highly susceptible to harvest on open rangelands because cover usually is sparse and road densities often are moderate to high. Also, many rangelands are characterized by gentle topography, further increasing vulnerability. To ensure the presence of huntable populations in such areas, tight limits on hunter density, motorized access, and season length are necessary (Table 5). Prudent management of season timing and season type is required. Without such management, the presence and number of elk on open rangelands may be severely limited, during the hunting season and possibly other times of year.

TABLE 5. Management problems that increase elk vulnerability to harvest and the corresponding management remedies (Thomas 1991:319).

Management problems	Management remedies
1. Increasing density of roads.	1. Design roads to minimize impacts. Close roads permanently or temporarily. Enforce road closures.
2. Increasing density of hunters.	2. Restrict hunter numbers.
3. Decreasing amounts of cover.	3. Control stand configuration, juxtaposition, and size through modifications in timber management program.
4. Fragmentation of cover into smaller patches.	4. Retain adequate "escape cover" in the form of stands of several hundred or more acres.
5. No restriction on antler class in bull harvest.	5. Impose regulations on what can be taken—e.g. such as allowing the kill of spike-antlered bulls only.
6. Setting of open seasons that include the rutting period.	6. Insure that open seasons do not include the rutting period.
7. Improving technology.	7. Preclude "modern weapons."
8. Long open seasons.	8. Shorten the open season.
9. Relatively gentle terrain.	9. Decrease road density, maintain more cover, increase size of cover patches, decrease hunter numbers.
10. Increasing number of hunter days.	10. Related to both items 2 and 8 above. Reduce hunter numbers and/or reduce length of hunting season.

CONFLICT RESOLUTION OF ELK-LIVESTOCK PROBLEMS

New Partnerships and Paradigms

Even with the best biological information, conflicts between elk and livestock are rarely resolved without communication, coordination, and consensus among divergent interests. The need for such efforts has been recognized for quite sometime; often, however, the results have been more of frustration than solution (Peek et al. 1982). Nonetheless, more formal partnerships are being forged to resolve long-standing issues.

Two notable partnerships are underway in Colorado (Gerrans 1992) and Oregon (Blue Mountains Elk Initiative 1991, Brocci 1993). Both programs focus on reducing elk damage to livestock and crops on private land; this is accomplished by re-distributing animals away from problem areas through range improvements on nearby public land. Both programs have oversight committees and working groups who help plan, implement, and monitor the land treatments and assess the response of animals. Committees and working groups are composed of state, federal, private, and tribal interests who manage or are affected by the management of elk.

Ecosystem Management of Elk

Elk are mobile, adaptive, and opportunistic; they use a variety of habitats that span many jurisdictions and land ownerships. Their annual movements can encompass hundreds of square kilometers, bringing them into contact with a multitude of landowners and land uses.

At the same time, human development continues unabated on elk ranges. Traditional users of rangelands, such as farmers and livestock growers, are generally intolerant of high elk numbers. Fee hunting operators, hunters, wildlife viewers, and urban settlers on these same rangelands, however, desire more elk for hunting and watching. Given these conditions, elk-land use conflicts will continue to grow in area, frequency, and intensity. The loser, if history is the indicator, is likely to be the elk resource.

Is there hope? We believe so, but only if polarized interests adopt an ecosystem or landscape approach to elk management. Our geographic scale must change from that of an individual pasture, watershed, landowner, or allotment to that of an entire herd range, such as that encompassing ≥10,000 ha. Within each herd range, partnerships like those underway in Colorado (Gerrans 1992) and Oregon (Blue Mountains Elk Initiative 1991, Brocci 1993) must be forged. Such partnerships are politically effective and provide an ecological basis upon which all interests can plan and implement the proper combination of land treatments and hunting regimes necessary to achieve the desired demography and distribution of elk across all land ownerships in time and space.

The restoration of elk to rangelands of North America is likely to continue at a smart pace; with it will come an intense challenge to integrate the management of this special resource in a manner compatible with a myriad of other rangeland uses.

SUMMARY

Before European settlement, elk were among the most common and widely distributed of the wild ungulates in North America. Excessive hunting, overgrazing by livestock, and conversion of habitat to farms and cities in the seventeenth, eighteenth, and nineteenth centuries led to broad-scale population declines and extinctions. Today, population size is increasing and elk are recolonizing many rangelands they occupied historically.

Existing elk habitat is fragmented along property lines: summer ranges are publicly owned while most winter ranges are in private ownership. Winter ranges continue to be lost to recreation and urban developments. Elk damage on the remaining winter ranges is an increasing problem.

Potential competition between elk and cattle is an issue of intense controversy among rangeland users. On arid rangelands, competition is likely if either ungulate is present at moderate to high densities under common grazing. On more productive rangelands, common grazing by elk and cattle can be complementary. Specially designed systems of rest-rotation grazing are being used by state and federal agencies, in cooperation with private landowners, to improve elk nutrition and control elk distribution across multiple ownerships.

Methods of stocking allocation between elk and cattle must consider differences in the spatial distribution of animals and the potential for forage competition. Stocking of the 2 ungulates is additive (complementary) in areas where spatial distributions do not overlap. Where distributions do overlap, either spatially or temporally, stocking is still additive unless forage competition occurs.

A variety of rangeland prescriptions and practices can be used to effectively manage elk distribution and nutrition. Grazing systems and stocking rates of cattle, prescribed burning, fertilization, forage supplementation, and road management are key practices available to habitat managers.

New partnerships are needed to resolve on-going management problems. Because elk are highly mobile and opportunistic, a landscape-level approach that encompasses multiple ownerships and thousands of hectares is required to effectively manage this resource across rangelands of North America.

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