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E. E. Starkey
Oregon State University

D. S. deCalesta
Oregon State University

G. W. Witmer
Oregon State University, gary.w.witmer@usda.gov

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E. E. Starkey
USDI National Park Service
Oregon Cooperative Park Studies Unit
Oregon State University, Corvallis

D. S. deCalesta
Department of Fisheries and Wildlife
Oregon State University, Corvallis

G. W. Witmer
Department of Forest Science
Oregon State University, Corvallis

Introduction

Historically, Roosevelt elk (*Cervus elaphus roosevelti*) were distributed from northern California to southern British Columbia in the coastal Pacific Northwest. During the Pleistocene, the subspecies was isolated reproductively from the Rocky Mountain elk (*C. e. nelsoni*) to the east by the Cascade Mountain Range and by glaciation (Guthrie 1966). Thus Roosevelt elk have adapted to relatively moist forest habitats with maritime climates, while Rocky Mountain elk evolved under the continental climate of the interior.

Unfortunately, less is known of Roosevelt elk biology than of the closely related Rocky Mountain elk east of the Cascades. This has frequently resulted in generalization of Rocky Mountain elk research findings to management of Roosevelt elk. However, differing evolutionary histories may have resulted in significant differences in the two subspecies' behavior, physiology, and habitat requirements. It may be improper to manage Roosevelt elk as if they are Rocky Mountain elk.

Wood products production is one of the most important industries within the range of the Roosevelt elk; opportunities for conflict between elk and forest management are numerous. Our objectives are to postulate probable primeval Roosevelt elk-habitat relationships, to describe contemporary elk habitats and impacts of forest management on elk, and to discuss areas of compromise and cooperation between wildlife and forest managers.

Primeval Habitat

Prior to human settlement, Roosevelt elk inhabited forests of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) 200 to 750 years old, commonly referred to as old-growth. However, in spite of the relatively great ages of many of these forests, they were not structurally uniform. Rather, there was considerable variation in tree size and age, and understories were relatively diverse. Numerous small openings, with early seral communities were scattered throughout the forests. Grasses, forbs and deciduous shrubs provided forage in these areas, as well as in the understory of the mature forest. Wind storms, insects, diseases, and landslides created openings that resulted in a high degree of patchiness (Franklin et al. 1981).

Infrequent fires occurred at intervals of several hundred years. Such fires were often extremely large and catastrophic. This fire regime is distinctly different from that typical of much Rocky Mountain elk habitat where fires are smaller, more frequent, and burn with relatively less intensity because of less fuel.

There were also alluvial areas dominated by grasses and deciduous forest. Some were relatively large, such as the Willamette Valley, but many were associated with smaller streams and rivers. Periodic flooding maintained these areas in early seral stages.

Except for large and rare wildfires, most disturbances were relatively small scale, and habitats were generally stable. For large areas, many generations of elk probably were not displaced nor affected by major forest perturbations. Subsequent to the retreat of glaciers, the climate of the coastal northwest has been characterized by mild temperatures and by a consistent pattern of high winter precipitation, and warm, dry summers. Thus, Roosevelt elk evolved within an environment characterized by stable habitat and mild climate.

Historic Abundance and Distribution

Although historic abundance is difficult to determine, Roosevelt elk were found by Lewis and Clark to be plentiful along the lower Columbia River in 1805. During settlement, elk were reported from nearly all areas of western Oregon and Washington. They were particularly abundant on the Olympic Peninsula; Skinner (1936) suggested that 25–40,000 elk were present in the 1850s.

Roosevelt elk mainly occurred in lowland areas that contained a mixture of open and forested communities. These habitats provided many sources of both forage and cover, including old-growth forests containing a diversity of understory communities. Ecotones were probably preferred by elk as today (Witmer 1982). Use patterns undoubtedly changed seasonally as elk matched physiological and behavioral needs to availability of forage and cover.

Apparently, these elk populations coexisted primevally with various predators, including wolves (*Canis lupus*), cougars (*Felis concolor*), grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), and man. Human predation may have influenced population structures somewhat, but had relatively little effect on distribution or density (Raedeke and Taber, in press).

In sharp contrast to patterns of primeval coexistence with humans, Roosevelt elk were impacted significantly by both hunting and habitat modification following settlement by European man. Elk were a source of meat and hides for settlers, and they were heavily hunted throughout the Northwest. Market hunting was especially damaging to elk populations and many animals were slaughtered for their canine teeth or "tusks." Roosevelt elk populations were greatly reduced, and actually extirpated, in many areas by the early 1900s. As few as 2,000 elk remained on the Olympic Peninsula by 1905 (Morganroth 1909). This population apparently declined by over 90 percent in approximately 50 years.

Such dramatic decreases stimulated considerable public outcry, and soon after the turn of the century protective legislation was enacted by states and provinces. In addition, Mt. Olympus National Monument was established in 1909 (later to become Olympic National Park) with a primary objective of protecting Roosevelt elk. Intensive predator control also began at this time.

Subsequently, Roosevelt elk populations have recovered in many areas and have even become locally abundant. Approximately 60,000 Roosevelt elk presently inhabit western Washington (with 15,000 on the Olympic Peninsula) and 40,000 in western Oregon (Thomas and Toweill 1982). Presently, Roosevelt elk provide abundant and increasing sport-hunting recreation in these states. In addition, many elk herds have become local "tourist attractions," providing considerable non-consumptive recreation.

Key Biological Characteristics

The stability of primeval Roosevelt elk habitat likely resulted in stable elk populations that were characterized by low reproductive rates. For example, Trainer (1971) found that about 50 percent of female Roosevelt elk became pregnant annually while nearly 90 percent of female Rocky Mountain elk conceived each year. In addition, recruitment rates of 30–40 percent have been reported for Roosevelt elk calves (Witmer 1982, Schwartz and Mitchell 1945), whereas 70–90 percent recruitment rates were reported for Rocky Mountain elk calves (Kimball and Wolfe 1979, Knight 1970).

A potential cause of the low reproductive rate in Roosevelt elk populations is forage quality (Trainer 1971, Mereszczak et al. 1981). Apparently, lactating Roosevelt elk cows may not be able to regain a level of physical condition that would permit ovulation in the same year. Reduced milk production associated with a low plane of nutrition could also be significantly related to calf mortality.

Deficiencies of micronutrients such as selenium could be involved in lowered reproductive performance. The entire coastal Pacific Northwest is deficient in selenium, and domestic livestock require selenium supplementation. Symptoms of selenium deficiency include high mortality of young and reduced fertility of adults (Church and Pond 1978).

Whether density independent factors such as forage quality limited primeval Roosevelt elk populations is impossible to determine. If habitats preferred primevally contained higher quality forage resources, populations may have been regulated by density dependent factors such as forage quantity (Caughley 1979). However, recent displacement from preferred habitats could have forced elk to areas that are nutritionally inferior and therefore cause reduced fecundity.

Franklin and Lieb (1979) suggested that stable habitats favor long-term social bonding and cohesiveness of elk. Unhunted Roosevelt elk in unmanaged forests of Prairie Creek Redwoods State Park, California, and Olympic National Park, Washington, form stable and long-lasting associations (Franklin and Lieb 1979, Jenkins and Starkey 1982). On the other hand, hunted populations of Roosevelt elk inhabiting silviculturally managed forests in southwestern Oregon form relatively smaller bands with greater interchange of individuals (Harper 1964, Witmer 1982). The tendency to form stable social groups is apparently not shared by Rocky Mountain elk (Knight 1970, Shoesmith 1979). This difference in social organization could be a result of differing evolutionary histories, with Roosevelt elk occupying relatively more stable habitats.

The two subspecies may also have different cover requirements, with Roosevelt elk requiring more cover than Rocky Mountain elk (Peek et al. 1982). In southwestern Oregon, Roosevelt elk spent as much as 80 percent of their time in cover in some seasons (Witmer 1982). Consequently, the 60 percent forage/40 percent cover recommendation for Rocky Mountain elk habitat in the Blue Mountains of Oregon (Thomas 1979) may not be appropriate.

Managed Forest Habitat

Although protection and regulation of hunting resulted in partial recovery of many elk populations, impacts of habitat modifications remained. By the mid-1800s pioneers had settled in many areas of the Pacific Northwest. Their pattern of settlement was not random and the most productive Roosevelt elk habitats were the first occupied by settlers. These were the valleys and floodplains of the larger river systems. Areas such as the Willamette Valley contained rich soils for agricultural use, and the associated rivers provided water, fish, and a transportation system. Many of these valleys were maintained as grasslands by Indians who burned the areas to enhance game habitat. These same areas supported abundant Roosevelt elk populations. With settlement, elk were forced into densely forested areas at higher elevations (Bailey 1936). A similar pattern occurred with the closely related red deer (*C. elaphus*) in Eurasia (Flerov 1952).

Soon after settlement, harvest of timber began in the lowlands and progressively moved to higher elevations. Because logging residues were not treated or disposed of, fire was frequently associated with logging. Many sites were repeatedly burned, resulting in an increased abundance of herbaceous species. Today, forest fires are controlled and slash is usually managed to reduce fire hazard.

Most historic Roosevelt elk habitat has been altered by clearcut logging and only federal lands contain significant areas of primeval forest. At forest harvest rates typical of the last decade, even these lands will be logged in the next 20–40 years (Franklin et al. 1981, Meslow et al. 1981). Roosevelt elk will be required to exist in a managed landscape dominated by second-growth forest and clearcuts.

Early forestry was different from that practiced today. Individual areas logged and burned were of greater acreage. Reforestation efforts were minimal. Areas remained brushy or hardwood-dominated, often for decades. These areas provided good elk habitat, but only after adequate cover became re-established. Accessibility of these lands to the public was generally limited.

A rapid rate of harvest occurred on private lands in the early days of logging and still occurs in areas of public lands dominated by large acreages of old-growth forest. With "progressive clearcutting," large, adjacent tracts were clearcut one after the other. On private lands, size of clearcuts was often determined by property lines so that whole sections or half-sections were clearcut. These practices led to large acreages devoid of cover other than occasional residual patches. Only edges provided Roosevelt elk with foraging places close to thermal and escape cover. Clearcuts then became brushy and provided good elk habitat until the canopy closed with subsequent decline in forage levels. The vast area of dense, young conifers was then poor elk habitat until the canopy opened either naturally or through human activities.

During the last half of this century intensive forest management became the dominant practice on forestlands. Silvicultural prescriptions common to intensive forest management are: clearcut logging of relatively smaller-sized parcels followed by burning; planting nursery-grown seedlings; controlling competing brush with herbicides or mechanical means; using fertilizers and thinning stands; protecting young trees from damaging mammals and insects; and suppressing, to a high degree, post-planting fire. The potential for conflicts between wood fiber production and elk production increased as these practices significantly altered elk habitat.

Managed second-growth stands are much different in structure and composition than old-growth forest (Edmonds 1979). The former are of less value to elk populations during periodic severe winters because they have less forage and, in some cases, a lower ability to intercept snow than old-growth stands. Recent studies also suggest that old-growth stands provide better summer thermal cover than younger stands (M. Zahn, pers. comm.). Because old-growth forests provide all cover needs of elk as well as forage and because Roosevelt elk evolved in an old-growth dominated setting, it is not surprising that elk prefer old-growth over younger stands throughout much of the year (Janz 1980, Witmer 1982).

The liquidation of old-growth forest, followed by rapid regeneration, thinning, and shortened rotations truncates natural succession, thus reducing the diversity of age and structure of forest stands. This also introduces instability in the pattern and duration of the forest openings. The acreage of old-growth forest in western Oregon and Washington has declined from about 75 percent of forestlands in the mid-1800s to less than 30 percent currently (Meslow et al. 1981).

Diversity is further reduced when hardwood stands (of low commercial value) are converted to vigorous conifer stands—a common practice in the intensively managed forest. The mature mixed forests bordering perennial streams are important to Roosevelt elk for foraging, loafing, and travel (Jenkins 1980, Witmer 1982). These areas are being harvested completely, or more commonly, only a narrow band of 1–2 tree widths is left on each side of the stream. Such a band may protect water temperature and quality, but does not provide a corridor for elk use.

Conifer stocking densities and thinning regimes often resulted in a reduced quality of forest cover for elk. In the past, clearcut areas were densely planted with seedlings, resulting in stands difficult to traverse and containing little forage. Pre-commercial thinning results in more elk forage, but the slash generated may be a travel barrier. Commercial thinning increases forage for elk, but decreases thermal cover and a stand's ability to intercept snow.

Forest practices can have dramatic impacts on the quantity and quality of forage available to elk. These may be direct, as with actual changes in forage production, or indirect with behavioral and physiological characteristics of Roosevelt elk greatly restricting their use of forage beyond a relatively short distance from cover.

Removal of the forest canopy allows light penetration to the understory, leading to increased forage production. Burning and fertilization further improve the quality of the forage. These benefits are short-lived because other common practices, such as the planting of large conifer seedlings and the use of herbicides to reduce brush competition, hasten succession. The result is less forage and shorter periods of availability.

Roads facilitate implementation of silvicultural practices as well as make forestland accessible to the public for recreational purposes or travel. Some intensively managed forests have 6 miles of roads per square mile (9.7 km per 260 ha) of forestland. This density of roads is often associated with moderate to high levels of harassment of elk. Roosevelt elk, like Rocky Mountain elk, have shown a sensitivity to human harassment by significantly lowered levels of use of areas near roads (Witmer 1982).

High road densities also lead to higher elk harvest rates, both legal and illegal. This is especially important for Roosevelt elk, which have a significantly lower reproductive rate than Rocky Mountain elk. Roosevelt elk are faithful to traditional home range areas and do not readily colonize new habitat. They generally have a smaller home range size and are less prone to migrate than Rocky Mountain elk. Locally extirpated Roosevelt elk bands are not soon replaced by animals from surrounding areas.

The ability to maintain adequate amounts of forage and cover with appropriate juxtaposition as well as old-growth stands may be lessened in other ways. For example, portions of the forested acreage in management units are withdrawn from harvest for various reasons without a forest district's allowable cut volume being reduced. Thus, forest harvest must be concentrated in other basins or diverted to areas that had been set aside earlier for retention as elk habitat. Within the next few decades, large areas of public and private forestlands in western Oregon and Washington will consist of 15–40 year old second-growth Douglas-fir. Forage for elk would be severely limited in these areas.

Thus, forest management has greatly changed primeval Roosevelt elk habitat, and its stability has inadvertently exposed elk to much higher than normal mortality (legal and illegal harvest via roads). What have been the consequences, and what does the future hold for Roosevelt elk in the coastal Pacific Northwest?

Roosevelt Elk Management—Past, Present, Future

With the removal of vast stands of old-growth from the coastal forests, areas were created that initially were of high value to elk—openings with associated forage, surrounded by uncut forest that provided thermal and escape cover. It is probable that more habitat suitable for Roosevelt elk was created than previously existed in the absence of logging. With increased numbers of elk came increased demand from sportsmen to again harvest elk.

Hunting for Roosevelt elk resumed in the 1930s; harvests were restricted to bulls during fairly short hunting seasons. Harvest of elk grew quickly. Oregon records indicate that, in 1940, 198 Roosevelt elk were harvested by 1,343 hunters. The counts soared to 1,955 elk harvested by 14,765 hunters in 1960 and, in 1970, the levels reached 3,340 elk killed by 21,370 hunters.

By 1977, low bull escapement from hunting and the resultant public comment prompted wildlife commissioners to restrict bull harvest in Oregon to 3-point-or-better bulls in management units exhibiting low escapement. This restriction on bull harvest was designed to prevent suboptimal reproduction by cows that were bred primarily by yearling bulls (Hines and Lemos 1979). This tactic had little effect on overall harvest of Roosevelt elk in Oregon, however, as more liberal cow seasons compensated for reduced bull harvests and hunter numbers grew: 4,482 elk were harvested by 37,550 hunters in 1975, and 5,692 were harvested by 34,083 hunters in 1980 (Oregon Department Fish and Wildlife 1980).

Harvest of Roosevelt elk in Oregon increased by 292 percent from 1950 to 1980, and the number of elk hunters increased by 561 percent. Success rate dropped from a high of 32 percent in 1950 to 19 percent in 1980. From 1976–80 in Washington, harvest of Roosevelt elk increased by only 2 percent while number of hunters increased by 23 percent; success rate declined from 12.5 to 10.4 percent (Washington Game Department 1980). Number of elk counted per mile of census route in Oregon increased from 2.8 (1.7 per km) elk in 1950 to a high of 4.8 elk (3.0 per km) in 1960 and then declined continuously to 2.1 elk per mile (1.3 per km) in 1980. The continuing high number of elk harvested may relate to increased hunter pressure and access to the elk. National forest road mileage in the Pacific Northwest increased from approximately 20,000 miles (32,200 km) in 1953 to 85,000 miles (136,850 km) in 1981 (J. Hughes, pers. comm.). The trend over the last 30 years was for more hunters, with greater access, to collectively shoot more and more elk. The decline in success rates and census trend counts over this period suggests that elk populations may be declining, or at least will not be able to meet the increasing demand placed on them for a sustained yield.

Fall ratios of calves per 100 cows recorded in Oregon do not indicate increased productivity in response to increasing harvest: 31 calves:100 cows in 1950 increased to 36 calves:100 cows in 1960, and remained unchanged through 1980 (Oregon Department of Fish and Wildlife 1950, 1960, 1980). Similarly, exploited elk populations adjacent to Olympic National Park did not have significantly higher calf:cow ratios than unexploited populations within the Park (Smith 1980). Rocky Mountain elk reproductive rates were substantially greater in exploited populations (Knight 1970, Houston 1982). Until the difference in reproductive performance between the subspecies is understood, harvest of Roosevelt elk should be more conservative than that of Rocky Mountain elk.

Efforts in Oregon to transplant Roosevelt elk into suitable habitat have increased. However, Roosevelt elk damage Douglas-fir seedlings as well as forage and crops intended for domestic use. Complaints of elk damage, primarily from small, private ranchers have increased. Elk were identified as the second most significant pest of reforestation efforts in coastal Oregon and Washington (Black et al. 1979). The very areas essential to elk for procuring forage are contested by man for timber and crop production. As forest management and agriculture replace the small forest openings and alluvial plains with clearcuts and cultivated lands, the potential for conflict will grow as elk are forced onto these areas for forage.

The future of Roosevelt elk populations in the coastal Pacific Northwest is clouded. There will be increased harassment and harvest pressures as more logging roads are built. Hunters from highly populated areas of western Oregon and Washington will increasingly favor hunting nearby Roosevelt elk as transportation costs increase. In Oregon, 27 percent of elk hunters hunted Roosevelt elk in 1950, but by 1980 the figure was 37 percent. For Washington, Roosevelt elk hunters comprised 41 percent of elk hunters in 1976; this figure increased to 50 percent in 1980. Demands to reduce damages by elk to forestry and agriculture will increase; already, special post-season hunts exist to reduce local populations of depredating elk. Habitat instability, habitat loss, overharvest of forest cover, and truncation of succession will result in acreages less optimum for elk production.

Essentially, the problem faced by elk managers consists of producing enough elk to satisfy hunter demand on habitats managed primarily for other purposes. Current and future forest management will, in all probability, continue to expose elk to harassment, including poaching and hunting via increased logging road construction, reduce thermal and escape cover with favorable juxtaposition to foraging areas, and reduce the period of forage availability on regeneration sites. This management will serve to depress rather than maintain or increase elk numbers.

Short-term solutions exist for some of these problems. Road construction and logging activity in an area are short-term. Elk may leave the area, but return after disturbance ceases. To minimize this disturbance, forest managers can condense roading and logging activities in time and space, especially during peak elk breeding and calving periods.

The long-term harassment of elk continues, and may even increase after roading and logging cease. Harassment and hunting pressures can be reduced by road closures. A road closure program may provide additional benefits because elk utilize old, non-paved, logging roads as travel lanes and forage on the abundant grass and forb growth along sides (Witmer 1982).

Numbers of hunters, and subsequent harvest, can be controlled by limiting number of hunters via a permit system. Such a system, which would deny the opportunity to hunt elk to some hunters, is a politically and economically sensitive issue and may not be implemented until state wildlife agencies are confident of damage to elk herds by overharvest and can replace funds that would be lost through reduced sales of elk tags.

Providing good forage areas for elk would not be so frustrating for the forest manager if elk did not damage conifer seedlings. Forest managers often resort to the physical protection of seedlings. Seeding and fertilizing preferred elk forage on clearcuts may provide a less expensive answer; elk obtain abundant and nutritious forage while damage is reduced. Additionally, enhanced forage quality may support better reproductive performance by elk (Mereszczak et al. 1981).

The real challenge to managers and agencies is to plan for managing the animal and its habitat cooperatively and concurrently. Management objectives related to elk numbers must be related to management of habitats needed to produce the elk and to management objectives related to other outputs (i.e. timber) from those habitats. Deliberations between elk managers and managers of public and private forestlands are necessary so that optimal outputs of sport hunting, nonconsumptive use, and wood products are achieved. Special interest groups must be prepared to compromise. If not, the day will soon come when supply of elk is outstripped by demand. It will be too late then to determine whether harvest levels are realistic or habitat adequate, for battle lines will be drawn, rigid positions taken, and management options foregone.

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