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Food Habits of Roosevelt Elk

Kurt J. Jenkins and Edward E. Starkey

Knowledge of forage used by Roosevelt elk *(Cervus elaphus roosevelti)* is fundamental to understanding habitat relationships and planning habitat improvement programs in the Pacific Northwest. Foods available to Roosevelt elk in the Pacific Northwest are influenced largely by forest management practices that include clearcut logging and, in many cases, the subsequent seeding of clearcuts with grasses and legumes to improve big game and livestock forages and control shrubs (Ramsey and Krueger 1986). It is commonly assumed that Roosevelt elk, like Rocky Mountain elk *(C.e. nelsoni)*, are grazers primarily and that they benefit from management that favors grasses over shrubs (Kufeld 1973). Many early studies of food habits of Roosevelt elk, however, suggest that Roosevelt elk are primarily browsers (Skinner 1936). Following is a summary of results from several recent studies of food habits that identify important seasonal and geographical patterns of food habits of Roosevelt elk.

Methods

Food habits were reviewed for elk populations inhabiting the historic range of Roosevelt elk, including the western slope of the Cascade Mountains in Oregon and Washington, Vancouver Island, British Columbia, and northwestern California, as well as an introduced population inhabiting Afognak Island, Alaska (Fig. 1). Although native populations of Roosevelt elk have been supplemented with transplanted Rocky Mountain elk throughout Oregon and in the Cascade Range of Washington, we included several of these populations in our review. Studies were included in the review if they satisfied the following criteria: (1) percentages of all forage species or taxonomic groups in the diet were quantified (this excludes early qualitative studies of browsing pressure that may have overestimated importance of shrubs), (2) forage selection was determined seasonally, and (3) food habits were determined for free-ranging elk. Three methods of data collection were represented in the resulting sample of food habits studies, including analyses of stomach contents (2 studies), analyses of fecal samples (7 studies), and feeding observations of free-ranging elk (2 studies).

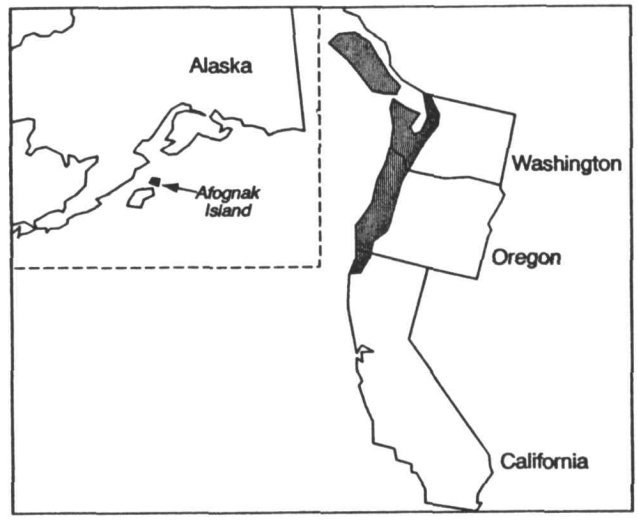

Fig. 1. *Historic range of Roosevelt elk and area covered in this review.*

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Previous reviews of food habits of elk assigned an importance value to each forage species based on the degree of use and qualitative considerations of forage abundance (Nelson and Leege 1982); species were assigned high importance values if they were rare and actively sought by elk or if they made up a large percentage of the diet. Such ratings failed to distinguish true forage preference from opportunism. In this summary, we report the mean percent contribution of each forage in the reported diets of elk. Means were determined from all studies in which a species was reportedly eaten. We leave interpretations of forage preference to those familiar with individual study areas, or those with specific estimates of forage availability.

Data were separated and analyzed by the following seasons of use: Winter (Dec.–Feb.), Spring (March–May), Summer (June–Aug.) and Fall (Sept.–Nov.). For studies that reported monthly food habits or that reported separate food habits for different herds within the same geographic area, data were averaged within seasons.

Foods of Elk

Roosevelt elk consumed a wide variety of forage species across their range, demonstrating a high degree of dietary plasticity and generalist foraging strategies. One hundred and eleven taxa were reported in the diets of Roosevelt elk (Table 1), but only 80 taxa made up greater than 1% of an average seasonal diet.

Table 1. Average percent contribution of major elk forages in diets of Roosevelt elk[1]. Sample size (i.e., number of studies in which forage species was reported in diet of elk) is included in parentheses.

Forage species	Mean percent of diets				References[2]
	Winter	Spring	Summer	Fall	
Forbs					
Anaphalis margaritacea		0.9(1)	2.3(2)	0.2(1)	2,5,7
Caltha biflora			2.2(1)		2
Dicentra formosa			1.8(1)	0.1(1)	7
Epilobium angustifolium	4.7(1)	1.7(1)	10.6(3)	11.7(4)	2,3,7,10
Epilobium spp.		1.0(3)	1.4(3)	0.1(2)	2,5,7,11,12
Fragaria spp.	0.4(2)	1.4(2)	0.3(1)	1.4(2)	6,11,12
Galium spp.		0.2(2)	0.6(2)	0.2(2)	11,12
Hypochaeris radicata	3.1(3)	3.0(4)	6.7(4)	4.6(4)	3,4,7,10,12
Lactuca muralis	0.5(2)		7.4(1)	5.4(1)	5,10
Lotus spp.	0.2(2)	1.1(2)	0.6(1)	0.5(3)	7,11,12
Lysichitum americanum	0.2(2)	0.6(4)	2.2(4)	1.2(2)	2,5,7,10
Mimulus guttatus			1.2(2)		2,7
Denanthe sarmentosa	0.8(2)	1.2(2)		1.1(2)	11,12
Oxalis oregana	0.1(1)	10.1(2)	9.5(3)	4.4(3)	4,6,7,9
Plantago spp.	0.2(1)	0.6(3)	2.8(2)	1.8(4)	4,7,11,12
Prunella vulgaris	0.2(3)	0.2(2)	2.0(1)	1.9(2)	4,11,12
Ranunculus spp.	0.6(1)	0.7(1)	0.8(2)	1.1(2)	4,7,12
Stachys cooleyae	0.2(2)	0.6(2)	1.6(2)	0.3(4)	2,6,7,11,12
Tiarella trifoliata	0.7(4)	0.4(2)	2.4(2)	2.6(2)	5,6,9,10,11
Trifolium spp.	0.5(2)	1.6(3)	1.5(2)	1.6(4)	4,7,11,12
Veretrum viride		1.0(1)	1.2(2)		5,10
Whipplea modesta	2.3(1)	1.2(1)	0.3(1)	7.0(1)	3
Unknown Forbs	2.5(5)	3.2(6)	20.6(4)	5.2(6)	1,2,3,5,7,8,10,11,12
FORBS SUBTOTAL	4.5(9)	9.8(8)	28.3(8)	14.0(11)	
Ferns					
Athyrium filix-femina	0.8(4)	1.0(3)	2.1(4)	1.0(5)	2,5,6,9,10,11,12
Blechnum spicant	5.5(6)	4.8(5)	0.3(4)	8.2(7)	2,5,6,7,9.10,11,12
Equisetum spp.	0.9(3)	0.7(2)	4.2(3)	2.6(3)	2,7,10,11,12
Polystichum munitum	7.6(7)	9.1(7)	4.4(5)	2.1(7)	3,4,5,6,7,9,10,11,12
Pteridium aquilinum	1.0(3)	2.5(1)	1.6(5)	1.0(4)	2,3,5,6,7,9,10
Unknown ferns	11.2(2)	12.7(2)	2.2(2)	5.0(2)	5,8,10
FERNS SUBTOTAL	12.9(9)	14.7(8)	6.3(8)	8.9(11)	
Grasses and Grass-like Plants					
Agrostis spp.	6.0(4)	3.6(4)	5.3(3)	5.0(5)	4,6,7,11,12
Anthoxanthum odoratum	7.2(1)	16.6(1)	11.3(1)	20.8(1)	4
Bromus marginatus			2.5(1)		4
Bromus mollis	3.5(1)	0.2(1)	2.0(1)	0.8(1)	4
Bromus spp.			0.1(1)	1.3(1)	7
Calamagrostis canadensis			7.1(1)		2
Carex spp.	10.3(7)	10.8(6)	5.1(7)	2.7(7)	2,4,5,6,7,8,9,10,11,12
Dactylis glomerata	4.9(3)	8.7(3)	7.7(2)	21.9(4)	4,7,11,12
Danthonia californica	17.5(1)	7.4(1)		3.1(1)	4
Elymus glaucus	0.7(2)	0.5(2)	1.1(1)	1.8(4)	6,7,11,12
Festuca arundinaceae	1.2(2)	1.4(2)	0.5(1)	3.0(3)	7,11,12
Festuca spp.	1.9(3)	1.3(2)		4.5(4)	4,7,11,12
Holcus lanatus	0.9(3)	0.6(2)	2.0(2)	2.0(4)	4,7,11,12
Juncus spp.	4.1(2)	7.2(2)	1.8(2)	2.5(3)	2,7,11,12

Table 1. (Continued)

Forage species	Mean percent of diets				References[2]
	Winter	Spring	Summer	Fall	
Lolium spp.	0.7(3)	0.6(3)	6.3(2)	2.9(4)	4,7,11,12
Luzula spp.	0.2(2)	0.4(2)	1.6(2)	0.4(3)	2,7,11,12
Phleum pratense	1.8(2)	1.0(3)	0.3(1)	3.0(3)	6,7,11,12
Poa spp.	1.8(4)	2.6(3)	0.8(4)	2.2(5)	2,4,6,7,11,12
Scirpus microcarpus			1.9(1)		2
Typha latifolia			1.0(1)		7
Unknown grasses	6.3(8)	13.8(7)	11.4(7)	8.2(10)	1,3,5,6,7,8,9,10,11,12
GRASSES SUBTOTAL	24.2(9)	32.0(8)	23.1(8)	23.6(11)	
Conifers					
Abies amabilis	4.0(2)	3.8(2)	1.6(1)	11.6(2)	5,10
Picea sitchensis	7.3(1)	0.2(7)		1.0(1)	4,9
Pseudotsuga menziesii	2.0(7)	2.0(5)	0.4(3)	0.5(5)	2,3,5,7,8,9,10,11,12
Taxus brevifolia	3.9(5)	3.8(3)	2.0(2)	5.2(3)	2,5,8,10,11,12
Thuja plicata	7.6(8)	3.8(6)	2.5(3)	4.6(7)	2,3,5,6,8,9,10,11,12
Tsuga heterophylla	14.1(8)	3.6(7)	2.4(6)	5.2(8)	2,3,5,6,7,8,9,10,11,12
Unknown conifers	2.3(3)	1.0(3)	1.1(1)	2.5(2)	5,11,12
CONIFERS SUBTOTAL	25.2(9)	9.6(8)	3.3(8)	11.0(11)	
Shrubs					
Acer circinatum	5.2(5)	3.1(6)	4.1(5)	2.2(7)	2,3,5,6,7,8,9,11,12
Alnus rubra	2.0(4)	2.1(5)	2.6(5)	6.0(8)	2,4,5,6,7,9,10,11,11,12
Amelanchier alnifolia	4.7(1)	10.7(1)	3.5(1)	4.6(1)	8
Arctostaphylos uva-ursi	0.4(3)	0.2(2)		1.5(2)	10,11,12
Berberis nervosa	3.3(7)	1.6(3)	0.6(1)	1.1(5)	3,5,7,8,9,10,11,12
Chimophila umbellata	0.7(2)	0.2(2)		1.1(2)	11,12
Cornus canadensis	0.5(2)	1.4(4)	5.4(2)	3.9(3)	5,6,10,11,12
Gaultheria shallon	5.6(6)	1.8(5)	1.8(3)	3.2(7)	3,5,7,9,10,11,12
Ledum spp.			2.2(1)		5
Linnaea borealis	9.7(4)	4.7(4)	0.5(1)	2.5(3)	2,5,9,11,12
Lonicera involucrata		0.7(1)	1.1(1)	0.9(1)	5,10
Menziesia ferruginea			1.5(1)		2
Myrica gale	0.1(1)		5.0(1)	0.4(1)	5,10
Oplopanax horridum	1.0(3)	1.9(1)	3.4(2)	2.1(3)	2,5,11,12
Physocarpus malvaceus	3.2(1)	2.4(2)	5.3(1)		5,10
Populus trichocarpa	2.9(4)	1.0(3)	3.4(2)	6.4(5)	5,7,9,11,12
Ribes spp.	0.2(2)	0.8(1)	1.6(2)	1.0(1)	5,10
Rosa spp.	2.6(4)	0.8(5)	3.6(3)	1.5(4)	4,7,8,11,12
Rubus spectabilis	1.9(6)	5.8(8)	10.6(8)	3.5(10)	2,3,4,5,6,7,8,9,10,11,12
Rubus spp.	2.0(3)	9.5(3)	5.0(4)	1.6(6)	3,4,5,7,9,11,12
Rubus ursinus	7.0(4)	5.6(5)	7.1(3)	4.4(6)	3,4,6,7,11,12
Salix spp.	2.1(7)	1.7(7)	4.8(7)	6.7(8)	1,2,3,5,6,7,8,10,11,12
Sambucus racemosa	2.0(2)	1.1(5)	3.8(5)	16.0(3)	1,2,3,5,7,10
Sorbus sitchensis			2.2(1)		2
Spiraea spp.	0.4(2)	1.1(3)		2.0(1)	5,11,12
Vaccinium spp.	3.7(7)	3.8(6)	2.8(8)	2.7(8)	1-12
Viburnum edule		0.6(1)	2.1(1)	5.0(1)	1,5
Unknown shrubs	4.6(5)	4.0(5)	8.9(3)	6.5(5)	5,7,8,10,11,12
SHRUBS SUBTOTAL	28.9(9)	31.7(8)	37.1(8)	36.7(11)	
MOSSES SUBTOTAL	0.0(4)	1.6(2)	0.7(2)	0.5(2)	6,8,9,10
FUNGI SUBTOTAL		0.2(1)		0.1(1)	4
UNKNOWN SUBTOTAL	4.3(3)	0.8(1)	1.0(2)	4.8(1)	6,9,10
GRAND TOTAL	100.0	100.4	99.8	100.1	

[1]Major species were defined as those making up >1% of a mean seasonal diet. Minor species, not reported here included: *Achillea millefolium, Achlys triphylla, Circium* spp., *Clintonia uniflora, Habenaria saccata, Hieracium albiflorum, Hydrophyllum fendleri, Lupinus* spp., *Maianthemum dilatatum, Montia* spp., *Rumex acetosella, Senecio triangularis, Smilacina stellata, Streptopus* spp., *Taraxacum officinale, Tolmiea menziesii, Veronica* spp., *Gymnocarpium dryopteris, Lycopodium sitchense, Deschampsia elongata, Abies grandis, Sequoia sempervirens, Acer macrophyllum, Baccharis pilularis, Cornus stolonifera, Corylus cornuta, Holodiscus discolor, Malus* spp., *Rhamnus purshiana, Ribes bracteosum, Symphoricarpos* spp.

[2]References and Geographic locations:

1. Batchelor (1965): Afognak Island, Alaska
2. Hanley (1980): Cascade Mountains, Washington
3. Harper (1985): Coast Range, Southwestern Oregon
4. Harper et al. (1967): Northwestern California
5. Janz (1983): Vancouver Island, British Columbia
6. Leslie et al. (1984): Olympic Peninsula, Washington
7. Merrill (1987): Cascade Mountains, Washington (Mount Saint Helens)
8. Schoen (1977): Cascade Mountains, Washington
9. Schwartz and Mitchell (1945); Olympic Peninsula, Washington
10. Brunt et al. (1989): Vancouver Island, British Columbia
11. Jenkins and Starkey (1990); Cascade Mountains (Mount Rainier National Park)
12. Jenkins and Starkey (1990): Cascade Mountains (managed forests adjacent to Mount Rainier National Park)

Although 39 species of forbs have been reported in diets, only a few dominated seasonal diets, particularly during summer and fall (Table 1). Fireweeds (*Epilobium* spp.) and wooly catsear *(Hypochaeris radicata)* were abundant in summer and fall diets of elk on silviculturally managed ranges (Hanley 1980, Harper et al. 1985, Merrill 1987, Brunt et al. 1989), whereas wood sorrell *(Oxalis oregana)* and foamflower trefoil *Tiarella trifoliata)* were abundantly eaten in unmanaged old-growth forests of the Olympic Peninsula (Schwartz and Mitchell 1945, Leslie et al. 1984).

Sedges contributed large proportions to the winter and spring diets of Roosevelt elk throughout their range (Table 1). A variety of other graminoids, notably bentgrass (*Agrostis* spp.), sweet vernal grass (*Anthoxanthum* spp.), and orchard grass *(Dactylis glomerata)* were also locally important.

Several shrubs dominated seasonal diets of elk (Table 1). Salal *(Gaultheria shallon)*, huckleberry (*Vaccinium* spp.), and trailing blackberry *(Rubus ursinus)* were especially abundant in winter diets. Salmonberry *(Rubus spectabilis)* and huckleberry were abundant in summer diets, whereas alder *(Alnus rubra)*, cottonwood *(Populus trichocarpa)* and a variety of other shrubs were abundant during autumn (Table 1). Western hemlock *(Tsuga heterophylla)*, western red cedar *(Thuja plicata)* and the ferns swordfern *(Polystichum munitum)* and deer fern *(Blechnum spicant)* were consumed abundantly during winter.

Seasonal differences in diet selection of Roosevelt elk reflected seasonal differences in forage availability and phenology. Averaged across the geographical range, shrubs made up the greatest proportion of the annual diet of Roosevelt elk (Fig. 1). Consumption of shrubs peaked during summer when leaves and succulent shoots were most available. Grasses comprised the second largest part of the annual diet, especially during spring when

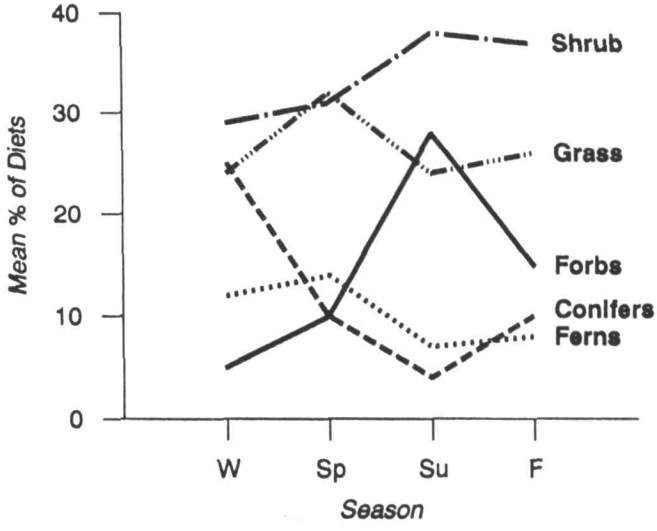

Fig. 2. *Mean percentages of major forage classes in the diets of Roosevelt elk as determined from 12 studies of food habits from throughout the range of Roosevelt elk (Table 1).*

grass is most productive and nutritious. Forbs made up a very small percentage of the mid-winter diets of elk, but together with shrubs and grasses they were important summer forages. Conifers were winter staples of Roosevelt elk, but proportions of conifers in the diets diminished appreciably during spring and summer. Ferns were eaten abundantly by Roosevelt elk during winter and spring.

Geographical differences in diets of Roosevelt elk reflected broad differences in forage availability as influenced by prevailing land-uses and vegetation. In northern California, for example, Roosevelt elk fed extensively in coastal prairies where grasses made up the majority of the annual diet, and conifers and ferns were eaten only rarely (Table 2). In contrast, in forested regions of the Olympic Peninsula and Vancouver Island, conifers and ferns made up the bulk of the winter diet, and grasses,

Table 2. Geographic variation in forage-class composition of Roosevelt elk diets.

			% of Diet				
Geographic region	Reference	Seasons[1]	Forbs	Ferns	Grass	Conifers	Shrubs
Afognak Island, Alaska	Batchelor (1965)	F	43	0	3	0	54
Vancouver Island, British Columbia	Janz (1983)	Y	4	20	19	22	35
Olympia Peninsula, Washington	Schwartz and Mitchell (1945)	F,W	4	11	7	16	25
	Leslie et al. (1984)	Y	16	20	16	17	21
Cascade Mountains, Washington	Jenkins and Starkey[2] (1990)	F,W,Sp	9	1	11	35	43
	Jenkins and Starkey (1990)[3]	F,W,Sp	16	5	30	13	36
	Hanley (1980)	Su	31	6	27	14	23
	Merrill (1987)	Su,F	35	7	30	T	27
	Schoen (1977)	Y	13	11	33	9	33
Coast Range, Oregon	Harper (1985)	Y	17	6	15	6	56
Northwestern California	Harper et al. (1967)	Y	10	T	63	T	26

[1]Seasons of study include Fall (F), Winter (W), Spring (S), Summer (Su), and Year-long (Y).
[2]Diets from old-growth forest ecosystems in Mountain Rainier National Park.
[3]Diets from cutover, regenerating forests adjacent to Mount Rainier.

Photo by Patricia Happe

being comparatively rare, made up a relatively small part of the annual diet. Graminoids and forbs were seasonally important to elk in coniferous forests of the Olympic Peninsula and Vancouver Island, but never to the extent that they were in managed forests of the western Cascades or in prairie habitats of northwestern California. Deciduous shrubs were key forages of Roosevelt elk across their range (Table 2).

Discussion and Conclusions

Mean percentages of forages reported in the diets of Roosevelt elk are subject to bias and must be interpreted with caution. Ten of the twelve diets of elk reported in this study were determined from stomach and fecal analyses, which can misrepresent actual consumption of some forages (Gill et al. 1983). Conifers and evergreen shrubs, for example, often are overrepresented in fecal or stomach samples (Leslie et al. 1983); whereas forbs and stems of deciduous shrubs may be underrepresented (Gill et al. 1983, Holechek and Valdez 1985). Only Leslie et al. (1984) attempted to correct for such biases. We suggest, therefore, that forbs and deciduous shrubs may actually be more important during some seasons than is suggested by this review; conifers and evergreen shrubs may be less important than reported.

Secondly, one must be cautious not to equate relative abundance of forages in the diet with forage preference. Dietary percentages are influenced by availability of forages as well as by forage preference. Few of the studies reviewed obtained reliable estimates of forage availability for use in determining forage preference. Studies that compared forage selection to forage availability, however, ranked forbs and grasses as the most preferred forages, and evergreen or coniferous browse at the least preferred forages (Merrill 1987, Jenkins and Starkey 1990). Even non-preferred forages, however, such as evergreen browse, may be functionally important to elk during periods of seasonal food shortage.

Our results confirmed the dietary plasticity of Roosevelt elk, and the importance of maintaining a variety of forages on elk ranges in the Pacific Northwest. Current management efforts to seed cutover forests with grasses and forbs are laudable; however, habitat managers should not underestimate the importance of deciduous browse for Roosevelt elk especially during summer and winter when many herbaceous forages are unpalatable or unavailable due to deep snow. Recent studies of nutrient qualities of browse in clearcuts and old-growth forests revealed that high concentrations of astringent tannins often eliminated the protein available to browsers in open-grown shrubs (Happe et al. 1990). Consequently, we believe that optimum management of forage resources for Roosevelt elk in commercial forests would include seeding grasses and legumes in clearcuts and retaining old-growth patches that contain abundant shrubs.

Literature Cited

Batchelor, R.F. 1965. The Roosevelt elk in Alaska—its ecology and management. Alaska Dep. Fish and Game, Juneau.

Brunt, K.R., D.Q. Becker, and J.A. Youds. 1989. Vancouver Island Roosevelt elk/intensive forestry interactions. Phase 1 (1981–1986) Job Completion Report. Research, B.C. Ministries of Environment and Forests. IWIFR-33. Victoria, B.C.

Gill, R.B., L.H. Carpenter, R.M. Bartmann, D.L. Baker, and G.G. Schoonveld. 1983. Fecal analysis to estimate mule deer diets. J. Wildl. Manage. 47:902–915.

Hanley, T.A. 1980. Nutritional constraints on food and habitat selection by sympatric ungulates. Ph.D. Thesis, Univ. Washington, Seattle.

Happe, P.J., K.J. Jenkins, E.E. Starkey, and S.H. Sharrow. 1990. Nutritional quality and tannin astringency of browse in clear-cuts and old-growth forests. J. Wildl. Manage. 54:557-566.

Harper, J.A. 1985. Ecology and management of Roosevelt elk in Oregon. Oregon Dep. Fish and Wildlife, Portland.

Harper, J.A., J.H. Harn, W.W. Bentley, and C.F. Yocum. 1967. The status and ecology of Roosevelt elk in California. Wildl. Monogr. 16:1–49.

Holechek, J.L., and R. Valdez. 1985. Magnification and shrub stemmy material influences on fecal analysis accuracy. J. Range Manage. 38:350–352.

Janz, D.W. 1983. Seasonal composition and quality of Roosevelt elk diets on Vancouver Island. M.S. Thesis, Univ. British Columbia, Vancouver.

Jenkins, K.J., and E.E. Starkey. 1990. Influences of adjacent forest management activities on migratory elk of Mount Rainier National Park. College of Forestry, Oregon State University, Oregon Cooperative Park Studies Unit Report 90-3.

Kufeld, R.C. 1973. Foods eaten by the Rocky Mountain elk. J. Range Manage. 26:106–113.

Leslie, D.M., Jr., E.E. Starkey, and M. Vavra. 1984. Elk and deer diets in old-growth forests in western Washington. J. Wildl. Manage. 48:762–775.

Leslie, D.M., Jr., M. Vavra, E.E. Starkey, and R.C. Slater. 1983. Correcting for differential digestibility in microhistological analysis involving common coastal forages in the Pacific Northwest. J. Range Manage. 36:730–732.

Merrill, E.H. 1987. Population dynamics and habitat ecology of elk in the Mount St. Helens blast zone. Ph.D. Thesis, Univ. Washington, Seattle.

Nelson, J.R., and T.A. Leege. 1982. Nutritional requirements and food habits, p. 323–369. *In:* J.W. Thomas and D.E. Toweill (eds.), Elk of North America: ecology and management. Stackpole Books, Harrisburg.

Ramsey, K.J., and W.C. Krueger. 1986. Grass-legume seeding to improve winter forage for Roosevelt elk: a literature review. Ore. Agr. Exp. Sta. Spec. Rep. 763.

Schoen, J.W. 1977. The ecological distribution and biology of wapiti *(Cervus elaphus nelsoni)* in the Cedar River watershed, Washington. Ph.D. Thesis, Univ. Washington, Seattle.

Schwartz, J.E., and G.E. Mitchell. 1945. The Roosevelt elk on the Olympic Peninsula. J. Wildl. Manage. 9:295–319.

Skinner, M.P. 1936. Browsing of the Olympic Peninsula elk in early winter. J. Mammal. 17:253–256.