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Author(s): Louis C. Bender and Patrick J. Miller

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Effects of elk harvest strategy on bull demographics and herd composition

Louis C. Bender and Patrick J. Miller

Abstract The impacts of differing bull harvest strategies on elk (*Cervus elaphus*) population demographics have been widely speculated but poorly documented. We documented bull:cow ratios, bull age structure, and annual bull mortality rates under 4 differing bull harvest strategies (open-entry any-bull, open-entry ≥ 3 -point, and 2 levels of limited-entry bull harvest) in southwest Washington. Mean annual bull:cow ratios increased from 22 to 54/100 from any-bull harvesting to the most restrictive limited-entry strategy, reflecting a decrease in mean annual bull mortality rates from 0.70 to 0.36. Limited-entry harvesting allowed significantly greater ($P < 0.001$) bull survivorship into prime age classes (22–26%) than did open entry harvesting (10%). The magnitude of population response to limited-entry harvesting was dependent on degree of hunter-access restriction. Among open-entry strategies, 3-point strategies allowed greater yearling survivorship and consequently slightly increased bull:cow ratios compared to the any-bull strategy, but did not increase survivorship into older age classes. Herd productivity did not differ among strategies.

Key words age structure, bull:cow ratios, *Cervus elaphus*, elk, harvest strategy, mortality rates

Increasing bull survivorship is a management objective in many exploited elk (*Cervus elaphus*) populations (Weigand and Mackie 1987, DeSimone et al. 1993, Washington Department of Fish and Wildlife 1996). Potential benefits of increased bull survivorship include enhanced productivity, recruitment, hunter satisfaction, and esthetics (Bubenik 1982; Geist 1982, 1991; Squibb et al. 1991; DeSimone et al. 1993; Noyes et al. 1996). Varying bull harvest restrictions is the most common tool managers use to influence bull demographics, including total numbers and age structure (Boyd and Lipscomb 1976, Weigand and Mackie 1987, DeSimone et al. 1993, Matthews and Coggins 1993). Numerous harvest strategies have been used to increase bull proportions. These include some variation of limiting overall bull harvests through permit-only bull hunting or some type of antler restrictions (Carpenter and Gill 1987, Weigand and Mackie 1987). The effects of harvesting strategy alone on increasing the proportion of bulls in gen-

eral, and older bulls in particular, have been mixed (Carpenter and Gill 1987, Weigand and Mackie 1987).

Bull harvest rates are the primary determinant of bull:cow ratios and bull age structure in the state of Washington (L. C. Bender, Washington Department of Fish and Wildlife, unpublished data; Smith et al. 1994). Management goals in Washington are to maintain existing population levels, with a minimum post-hunting season ratio of 12–15 bulls/100 cows in open-entry game management units (GMUs) and >20 bulls/100 cows in limited-entry units (Washington Department of Fish and Wildlife 1996). Various population management strategies are used to achieve these goals, including manipulation of season lengths, bull harvest restrictions, and cow harvest level (Washington Department of Fish and Wildlife 1996). The most common of these is to manipulate the bull harvest strategy. Impacts of differing bull harvest strategies on herd composition, productivity, and bull mortality and age structure have been widely speculated but poorly

Address for Louis C. Bender: Washington Department of Fish and Wildlife, 2950 Ley Road, Cle Elum, WA 98922, USA. Address for Patrick J. Miller: Washington Department of Fish and Wildlife, 2108 Grand Blvd., Vancouver, WA 98661, USA.

documented (Carpenter and Gill 1987, Weigand and Mackie 1987). Previous empirical work has looked primarily at "before-and-after" results of changing a single harvest strategy or long-term demographics associated with a single strategy (Carpenter 1991, Vore and DeSimone 1991, Hughbanks and Irby 1993, Matthews and Coggins 1993). This is the only study to our knowledge that has compared effects of multiple harvest strategies used concurrently on populations that are close geographically on bull demographics.

We investigated the effects of varying bull harvest restrictions in southwest Washington on elk population parameters. Our objectives were to document bull:cow ratios, annual bull mortality rates, bull survivorship into mature (4.5-yr and older) age classes, and herd productivity under each harvest strategy.

Study area and methods

Study site

Our study area was located in Region 5 (southwest Washington) of the Washington Department of Fish and Wildlife (WDFW; approximately 46°10'N, 122°40'W) and included portions of Cowlitz, Lewis, Skamania, and Wahkiakum counties (Figure 1). Bull harvest strategies included: 1) open-

entry any-bull harvesting (any-bull), 2) open-entry 3-point-or-better bull harvesting (3-point), and 3) 2 limited-entry bull harvest strategies, one designed to moderately restrict bull harvest [Moderate Limited Entry (MLE), defined as an overall annual bull mortality rate <50%] and one designed to greatly restrict bull harvest [Light Limited Entry (LLE), defined as annual bull mortality <40%]. We selected Game Management Units (GMUs) according to harvest strategy and included: 1) any-bull GMUs, including Winston (520) and Coweeman (550); 2) 3-point GMUs, including Willapa Hills (506), Ryderwood (530), and Marble (558); 3) MLE, which included Toutle (556); and 4) LLE, which included Margaret (524). Any-bull and 3-point units had been managed under that harvest strategy since at least 1989; MLE and LLE had been managed under their respective strategies since 1983.

The any-bull GMUs were located in the Western Hemlock (*Tsuga heterophylla*) zone of the Southern Washington Cascade Province (Franklin and Dyrness 1973). Topography in the Coweeman (1,170 km²) and Winston (725 km²) units consisted of rolling foothills, with steep, high-elevation terrain present only in the extreme eastern portion of the Winston unit. Both GMUs were >80% forested and dominated by private industrial tree farms of Douglas-fir (*Pseudotsuga menziesii*), with lesser amounts of western hemlock. In riparian areas, characteristic species included red alder (*Alnus rubra*) and big-leaf maple (*Acer macrophyllum*). Significant snowfall occurred only in the extreme eastern portion of the Winston unit. Elk were sedentary except for the eastern portion of the Winston unit, where they migrated to winter ranges along the northern or southwestern boundaries of the unit. Migrations occurred after hunting seasons closed.

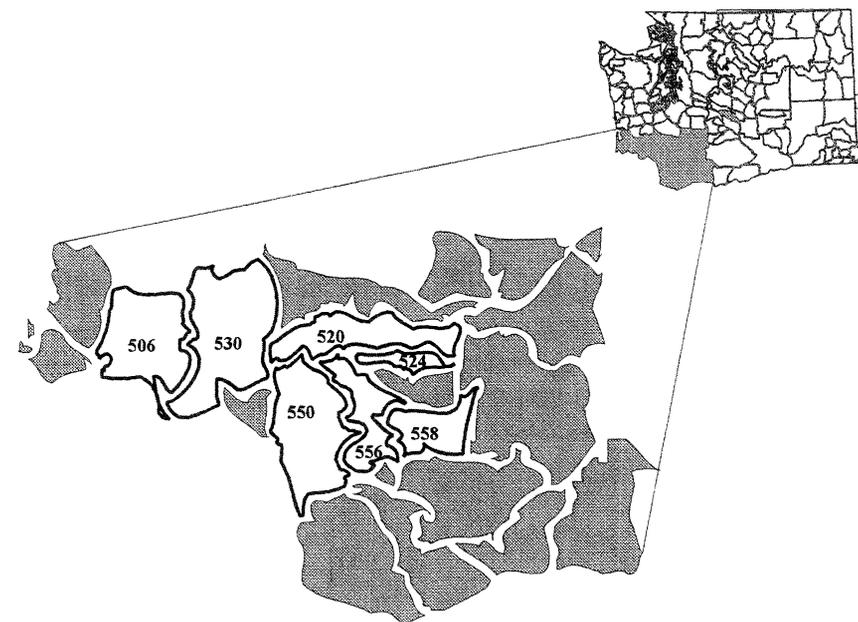


Figure 1. Location of the study's game management units in southwest Washington. Units by harvest strategy were: any-bull, Winston (520) and Coweeman (550); 3-point, Willapa Hills (506), Ryderwood (530), and Marble (558); Moderate Limited Entry, Toutle (556); and Light Limited Entry, Margaret (524).

The 3-point GMUs occurred in the Coast Range Physiographic Province (Willapa Hills, Ryderwood) and the Southern

Washington Cascade Province (Marble); all 3 units were primarily within the Western Hemlock zone (Franklin and Dyrness 1973). Topography consisted of rolling to steep hills in the Willapa Hills (998 km²) and Ryderwood (1,422 km²) units and rolling to extremely steep terrain in the Marble (403 km²) unit. The extreme northern portion of the Marble unit included unvegetated habitats associated with Mount St. Helens. Land ownership was primarily industrial tree farms in the Willapa Hills and Ryderwood units and United States Department of Agriculture Forest Service land in Marble. Forest coverage was similar to the any-bull units. Snowfall was significant throughout the central and northern portion of the Marble unit only. Elk were generally sedentary, except for individuals that summered at high elevation in the Marble unit on or near Mount St. Helens and migrated to lower-elevation winter ranges, generally within the Marble unit, after hunting seasons were completed.

Both the MLE and LLE units were greatly impacted by the eruption of Mount St. Helens in 1980. Both units lie in the Southern Washington Cascade Province, primarily in the Western Hemlock zone (Franklin and Dyrness 1973). The Margaret unit (234 km²) was north and west of Mount St. Helens and consisted primarily of private industrial tree farms of Douglas-fir to the west and shrub- and herbaceous-dominated habitats intermixed with large unvegetated areas on Forest Service ownership to the east. Snowfall was significant throughout the eastern half of Margaret. Elk were generally migratory in the eastern half of the unit, wintering along the Toutle River to the southwest, in either the Margaret unit or the Loo-Wit (GMU 522) unit. Migrations occurred following the hunting seasons.

The Toutle unit (712 km²) was west and southwest of Mount St. Helens. It also was primarily industrial tree farms of Douglas-fir. Snowfall was significant throughout the eastern portion of the unit. Topography was steep in the east and rolling elsewhere. Elk were migratory in the eastern portion of the unit and wintered primarily in the Toutle unit or the Loo-Wit unit. Migrations occurred after hunting seasons closed.

During our study, hunting pressure was similar among open-entry GMUs; any-bull units averaged 7.9 (SE=0.3) hunters and 38.5 (SE=2.0) hunter-days/2.6 km², whereas 3-point units averaged 7.9 (SE=0.2) hunters and 36.5 (SE=1.7) hunter-days. Limited-entry units had significantly less hunter

effort, with 1.0 hunters (SE=0.1) and 6.7 (SE=1.2) hunter-days/2.6 km² for the MLE unit, and 0.7 (SE=0.02) hunters and 4.6 (SE=0.6) hunter-days/2.6 km² for LLE, respectively. Bull harvest was similar among units: 0.43 (SE=0.03), 0.48 (SE=0.07), 0.44 (SE=0.06), and 0.41 (SE=0.04) bulls/km² for the any-bull, 3-point, MLE, and LLE units, respectively (L. C. Bender, Washington Department of Fish and Wildlife, unpublished data).

Herd composition

We determined bull:cow ratios by helicopter counts in the last 2 weeks of September and the first week of October, 1993-1997. Counts were timed so as to be conducted outside of any elk hunting seasons, yet still within the rut or immediate post-rut aggregations to allow unbiased composition (Geist 1982). Counts were generally made prior to any hunting season; however, a portion of a 15-day archery elk season may have occurred prior to or concurrent with composition counts in certain units in some years. The maximum level of elk harvest in the early archery seasons was <8% of the total harvest and proportional to herd composition (L. C. Bender, Washington Department of Fish and Wildlife, unpublished data). Therefore, we felt that this did not bias composition data.

We surveyed units from 3 hours prior to sunset until dark and from sunrise until 3 hours after sunrise, with each GMU flown in its entirety. To minimize double counts, adjacent areas were separated by ≥ 8 km from their common border unless we surveyed these units on the same day.

This separation distance corresponded to twice the diameter of the average home range of elk in southwest Washington (Michaelis et al. 1995). Composition counts were completed in ≤ 10 days.

We recorded sizes and composition of all elk social groups; we categorized elk as calf, cow, or bull. We further categorized bulls by number of antler points and subjectively placed them into 1 of 3 age categories based on antler development: yearling (spikes), immature (lightly beamed antlers with 2-6 points, equating to 2.5- to 3.5-yr-old bulls), and mature (heavily beamed antlers with ≥ 5 points, e.g., age 4.5 and older bulls).

Estimating elk mortality

We estimated bull mortality rates from the percentage of yearling bulls present during pre-season herd composition counts (Burgoyne 1981, Bender and Spencer 1999). In an age-stable or stationary

population where recruitment is defined as occurring at age 1.5, percentage of yearling bulls (Y) in preseason counts is equal to the annual adult (age ≥ 1.5) bull mortality rate (Burgoyne 1981, Roseberry and Woolf 1991). Because this assumes a stationary population, Y will overestimate the true mortality rate if a population is increasing and underestimate the true rate if a population is declining (Roseberry and Woolf 1991). Therefore, we corrected the mortality rate estimate annually for increasing or declining population trends using the observed finite rate of population increase (λ), e.g., trend-corrected mortality rate = $1 - [(1 - Y) * \lambda]$ (Eberhardt 1988, Bender and Spencer 1999). We used harvest per unit effort (HPUE, where $HPUE = \text{bull elk harvest} / \text{number of hunter-days spent hunting bull elk}$) as an index of population trend to determine annual λ 's for each experimental unit (e.g., GMU or grouping of GMUs), i.e., $\lambda = HPUE_t / HPUE_{t-1}$. In western Washington, mean annual bull mortality rates estimated in this manner accounted for 78–90% of the variation seen in bull:cow ratios and did not differ from telemetry-based mortality rates (Bender and Spencer 1999).

Data analysis

To include geographic (e.g., GMU) variability within a harvest strategy, we pooled sampled GMUs based on their harvest strategy for any-bull and 3-point units. We analyzed MLE and LLE individually. Data were used to generate calf:cow and bull:cow ratios, expressed as number of calves or bulls/100 cows. We used nested ANOVAs (year nested within harvest strategy, Zar 1996) to test for differences among study areas in bull:cow ratio, bull mortality rate, and proportions of bull elk in each age category (yearling, immature, mature) for each harvest strategy, 1993–1997. We converted percentage data to ranks (Conover and Iman 1981) prior to conducting the ANOVA. We followed each significant ANOVA with Fisher's Least Significant Difference test. Statistical significance for all tests was set at $\alpha=0.05$.

Results and discussion

Bull:cow ratios ($P<0.001$), bull mortality rates ($P<0.001$), and proportions of bulls in each age class [yearling ($P<0.001$), immature ($P<0.001$), and mature ($P<0.001$)] differed by bull harvest strategy (Table 1). Harvest strategy accounted for 97, 93, 92, 83, and 82% of the variability among treatments for bull:cow ratios, bull mortality rates, and yearling, immature, and mature bull proportions in preseason composition, respectively. Cow:calf ratios did not differ based on harvest strategy ($P=0.075$), and harvest strategy explained only 37% of the variation in calf:cow ratios among treatments through time. As bull harvest strategy became more restrictive, bull:cow ratios increased from 22 bulls/100 cows (any-bull units, Table 1) to >50 bulls/100 cows (LLE unit, Table 1). Moreover, proportion of mature bulls increased from 0.10 (any-bull and 3-point units, Table 1) to >0.20 (MLE and LLE units, Table 1). These results were consistent with decreasing mean annual bull mortality rates, which declined from 0.704 in any-bull units to 0.338 in the LLE unit.

Various antler regulations have been used to increase total numbers of bulls or numbers of older age class bulls (Weigand and Mackie 1987). Most schemes limit either number of yearling or number of adult animals taken. Regulations designed to save young bulls (i.e., harvests of only ≥ 3 - to 4-point bulls) without simultaneous measures to decrease hunting pressure have not resulted in greater numbers of mature bulls in populations (Weigand and Mackie 1987, Carpenter 1991, Vore and DeSmone

Table 1. Mean annual bull:cow ratios, bull mortality rates, bull proportions by age category in the late September–early October population, calf:cow ratios and sample sizes for fall composition surveys under 4 differing bull harvest strategies, southwest Washington, 1993–1997.

Strategy ^a	Demographic ^b \pm SE						n
	Bull:cow	Mortality	Yearling	Immature	Mature	Calf:cow	
Any bull	22.0 \pm 1.1 ^A	0.70 \pm 0.03 ^A	0.70 \pm 0.04 ^A	0.20 \pm 0.02 ^A	0.10 \pm 0.02 ^A	44.0 \pm 2.8	258 \pm 43
3-point	27.4 \pm 0.7 ^A	0.54 \pm 0.01 ^B	0.54 \pm 0.01 ^B	0.35 \pm 0.02 ^B	0.10 \pm 0.02 ^A	40.8 \pm 2.1	270 \pm 40
MLE	42.8 \pm 1.6 ^B	0.41 \pm 0.02 ^C	0.42 \pm 0.02 ^C	0.37 \pm 0.02 ^B	0.22 \pm 0.01 ^B	48.0 \pm 2.7	160 \pm 13
LLE	53.5 \pm 1.9 ^C	0.34 \pm 0.01 ^D	0.36 \pm 0.01 ^D	0.38 \pm 0.03 ^B	0.26 \pm 0.05 ^B	47.8 \pm 2.9	237 \pm 26

^a 3-point = any-bull with 3 or more antler points on any one side; MLE = bull hunting by limited-entry permit; permit numbers designed to limit annual adult bull mortality to $<50\%$; LLE = bull hunting by limited-entry permit only; permit numbers designed to limit annual adult bull mortality to $<40\%$.

^b Bull:cow = bulls/100 cows; Mortality = mean annual bull mortality rate; Yearling = proportion of yearling bulls; Immature = proportion of immature (2.5- to 3.5-yr-old) bulls; Mature = proportion of mature (age 4.5 and older) bulls; Calf:cow = calves/100 cows.

ABCD Means within a column sharing a superscript do not differ ($P>0.05$).

1991). Hernbrode (1987) similarly found that protecting spikes would not increase numbers of older bulls. Thus, Colorado's quality hunting areas do not have point restrictions; they simply limit total number of bull permits. This practice allows hunters the opportunity to harvest a spike if they choose, which allows more bulls to reach older age classes (Hernbrode 1987).

Our results support these arguments. The 3-point harvest strategy decreased overall bull mortality and marginally increased bull:cow ratios relative to any-bull harvesting, but did not increase bull survivorship into mature age classes. The effect of 3-point harvesting was to concentrate the harvest pressure on branched bulls (Firebaugh 1988, Vore and DeSimone 1991, Carpenter 1991). Thus, while overall bull mortality decreased due to protection of spike bulls, harvest mortality remained comparable or increased on the ≥ 2.5 -year-old age classes. If a management objective is to increase numbers of older bulls, antler point regulations must be accompanied with restrictions in hunter numbers or access (Carpenter 1991, Unsworth et al. 1993). Additionally, increased survival of yearling bulls (spikes) with point restrictions could result in an effective increase in numbers of cows (as yearling males are more closely associated with cows and calves than adult bulls), thereby increasing adult male mortality if sexes are competing for limited resources (Carpenter and Gill 1987).

Limited-entry bull harvesting increased bull:cow ratios and proportions of mature bulls substantially over open-entry (Table 1). The magnitude of response was related to the degree of access limitation. As access became increasingly restricted (e.g., moved from MLE to LLE), bull mortality decreased, bull:cow ratios increased, and proportions of mature bulls increased. In the LLE unit, ratios exceeded 50 bulls/100 cows, survivorship into mature age classes was $>25\%$, and mean annual bull mortality dropped to 0.338. This decrease in bull mortality represented a decrease of over 50% as compared to the rate in any-bull units (0.704). Similar results were seen in Colorado's specified (limited-entry) permit units relative to open-entry units, where proportions of mature bulls increased to $>25\%$ compared to 13% in unlimited harvest areas (Carpenter 1991). Thus, hunter numbers must be limited (e.g., limited-entry strategies) if bull escapement into older age classes or substantial increases in bull proportions are desired in a population. Alternatively, increased survival of bulls in

general and branched bulls in particular also may be accomplished through antler regulations that place the bulk of the harvest pressure on the younger age classes, such as open-entry spike bull with branched bull by permit strategies (Vore and DeSimone 1991; Hughbanks and Irby 1993; P. Fowler, Washington Department of Fish and Wildlife, unpublished data).

Finally, managers must precisely define bull management goals before selecting a harvest strategy. In western Washington, 3-point strategies may be able to meet escapement objectives of 12 bulls/100 cows postseason. Alternatively, if predominant breeding by mature bulls is a management goal, then mature bull:cow ratios of 18-25/100 in the fall population may be necessary (Bubenik 1985; Noyes et al. 1996; L. C. Bender, Washington Department of Fish and Wildlife, unpublished data). In western Washington, these ratios can be achieved only through very restrictive limited-entry harvest strategies. However, the tradeoff for enhanced bull demographics is loss of recreation. Hunter numbers and hunter days in the LLE unit were approximately 91% and 88% less, respectively, than in any-bull or 3-point units in southwest Washington.

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Louis C. (Lou) Bender is elk and deer specialist with the Washington Department of Fish and Wildlife. He was previously deer research biologist with the Indiana Department of Natural Resources. Lou received his B.S. in wildlife biology from the University of Montana and his M.S. and Ph.D. in wildlife management from Michigan State University. His interests include all aspects of ungulate ecology and management, particularly as they influence population dynamics and behavior. **Patrick J. (Pat) Miller** is a district wildlife biologist with the Washington Department of Fish and Wildlife. His management interests include the recolonization of wildlife into the Mount St. Helens area and management of the dusky Canada goose. He has a B.S. in wildlife management from Oregon State University and has been with the department over 20 years.



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