A POPULATION ASSESSMENT OF ROCKY MOUNTAIN ELK IN THE EAST KOOTENAY TRENCH, 1980-93

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INTRODUCTION

In 1981, the East Kootenay Sub-Region (MU's 401-405, 420-426, 434-437, 440) adopted an elk management strategy which emphasized the hunting of branch-antlered bulls through general open seasons (GOS), and cow/calf and calf only with limited entry hunting (LEH) seasons. The intent of this strategy was to increase recreational hunting opportunities, and to reduce and stabilize elk numbers within the East Kootenay Trench in response to elk depredation conflicts on crown range (Simpson 1988). An assessment of this strategy on the elk population was undertaken in 1990 by Demarchi and Wolterson (1991). They used a POP II simulation model (Bartholow 1990) to determine elk numbers and trends in the subregion. The driving variables in their model were: numbers of elk harvested, age structures of bull and cow harvested, fecundity rates and late winter calf/cow ratios. Their modelling suggested that prehunt elk numbers had been reduced from approximately 28,300 elk in 1983 to 25,800 in 1988.

In 1992, a comprehensive absolute abundance survey estimated 8,941 ± 714 elk (90% CI) on select winter ranges within the Kootenay Trench (Simpson 1992). Although the POP II estimate (prehunt estimates for all of Kootenay Sub-Region including National Parks) could not be directly compared to the census estimate (mid-winter population estimate on select winter ranges in the East Kootenay Trench), the census estimate was substantially less than expected. The present report seeks to assess elk population numbers and trends within the East Kootenay Trench from 1980-93 based in part upon the 1992 winter survey, to evaluate the effectiveness of calf harvesting for reducing elk numbers, and to investigate various harvest strategies for manipulating future population levels.

STUDY AREA AND METHODS

The study area (~20,562 km^2) includes the East Kootenay Trench and portions of the Rocky and Purcell Mountains from the Canada/US border north to Radium Hot Springs. The area includes all of Wildlife Management Units (MU's) 402-405, 420-422, and 424-426 and is referred to in this report as the East Kootenay Trench (EKT). Biogeoclimatic zones utilized by elk include the Alpine Tundra and Engelmann Spruce-Subalpine Fir zones in the spring, summer and fall (May through October) and the Montane Spruce, Interior Douglas Fir and Ponderosa Pine zones during winter (November through April) (Simpson 1989). Although most elk are seasonal migrators, a small component resides year round on the winter ranges (Simpson 1988). The study area was considered large enough to assume population closure, ie. few elk were believed to move into and out of the study area.

Approach

The approach taken was to reconstruct elk numbers and trends using cohort analysis (Fryxell et al. 1988, Hilborn and Walters 1992). Cohort analysis (also called virtual population analysis) calculates past population abundance based on past harvests. It relies on a simple relationship when harvests occur over a very short hunting season and it can be assumed that natural mortality during this period is negligible, i.e.:

[1]

$$N_{a+1,t+1} = (N_{a,t} - H_{a,t})Sn_a$$

where $N_{a,t}$ is the number of age a individuals present prior to the hunt (prehunt) in year t, $H_{a,t}$ is the number of animals killed in the hunt, and Sn_a is the age-specific nonhunting survival rate. By rearranging Eq. 1, the basic equation is:

[2]

$$N_{a,t} = (N_{a+1,t+1} / Sn_a) + H_{a,t}$$

Eq. 2 is all that is required to reconstruct cohorts that have passed completely through the population. In order to estimate recent populations with cohort analysis, the terminal instantaneous harvest mortality rate (h) must also be calculated (Hilborn and Walters 1991). Typically h is estimated from hunter days of effort (E_t) and an age-specific harvest vulnerability coefficient (q_a), where $h_{a,t} = q_a E_t$. This provides an estimate of the prehunt population, i.e.

[3]

$$N_{a,t} = \frac{H_{a,t}}{(1 - e^{-h_{a,t}})}$$

The primary problem with using Eq. 3 is that q_a can only be estimated for completed cohorts. It is therefore necessary to assume that harvest vulnerability has not changed for the more recent cohorts which still have some surviving members. This assumption, when tested, has almost always been found to be false, particularly in declining populations (Hilborn and Walters 1991). For elk, this is because most hunters will attempt to improve their efficiency (e.g. learn to call for bull elk during the rut, use ATV's to improve access, etc.) as a population declines in order to maintain their success rates. One solution to this problem, that is explored in this report, was to incorporate a recent survey estimate ($N_{a,t}$), in lieu of $h_{a,t}$. This estimate was then used with estimates of Sn_a to initiate the cohort analysis and reconstruct population numbers and trends (Eq. 2 and 3).

The 1992 Elk Mid-Winter Population Estimate

The 1991/92 mid-winter survey was analyzed using the program *Aerial Survey - Version 3.20* (Unsworth et al. 1991). We reanalysed the original survey data with the revised program *Aerial Survey - Version 4.0*. This newer version, which also considers the influence of snow cover on elk sightability, was not available when the survey was conducted.

The 1991/92 mid-winter survey did not include all of the EKT. For example, Simpson (1992) noted there were significant concentrations of elk in the upper Kootenay River (MU 425) and St. Mary's River (MU 420), that were outside of the survey area. In order to estimate all of the elk wintering within the EKT (referred to as the EKT survey estimate) we: (1) calculated the area (km^2), by biophysical capability rating, of elk winter range not surveyed within the East Kootenay Trench; (2) applied the 1992 survey low stratum density to Class 3 & 4 winter ranges, and the moderate stratum density to Class 2 winter ranges; (3) partitioned these additional elk by sex and age according to the stratum sex/age composition; and (4) added these elk to the census estimate.

Estimation of Harvest and Age Composition

Harvest statistics, including total harvest, sex-age composition, hunter numbers and hunter days, were estimated annually from a mail-out harvest data questionnaire sent to a random sample of hunters, with a follow-up second questionnaire sent to nonrespondents. In addition, hunters received a Voluntary Tooth Return Program (VTRP) card when they purchased a elk licence. Elk teeth obtained through the VTRP were aged by cementum annuli analysis. Because selectivity for elk varied between hunter groups (residents and nonresidents), we estimated the harvest age composition for each hunter group (proportion harvested by age x estimated harvest by hunter group) and then combined the estimates for the cohort analysis. Age-specific harvests were adjusted for a 20% wounding loss (Freddy 1987, Unsworth et. al. 1993).

Estimation of Birth and Natural Survival Rates

Age-specific pregnancy rates were determined from reproductive tracts from adult cows which were voluntarily submitted by hunters annually at least one month post rut. As annual twinning rates were very low (0.0-2.5%), age-specific fecundity rates (F_a) were considered to equal age-specific pregnancy rates. Annual birth rates (births/100 1+ year-old cows) were estimated from the fecundity rates and reconstructed cow age structures, i.e.

$$B_t = \sum(F_a \times N_{a,t,f})$$

where B_t is the birth rate in year t and $N_{a,t,f}$ is the number of prehunt females in each age class. Annual summer calf survival rates (*Sjs*) were estimated from calf births and prehunt calves, i.e.

$$Sjs = \frac{N_{0.5,t}}{B_t \times N_{t,f}}$$

Adult and overwinter calf natural survival rates were unknown for the EKT elk population. Thus, we selected age-specific natural mortality rates ($Mn_a = 1 - Sn_a$) similar to those used to model the White River elk herd in Colorado (Freddy 1987).

Population Reconstruction and Projection

We used cohort analysis to reconstruct both prehunt (N_t) and posthunt (S_t) elk numbers and trends from 1980 to 1993 based upon the 1992 EKT survey estimate, Mn_a, and $H_{a,t}$. Population trends were expressed as the average finite population growth rate calculated as

$$\lambda = \left(\frac{N_t}{N_0} \right)^{(1/t)}$$

where N_0 (or S_0) is the number of elk in the initial year and N_t (or S_t) is the number of elk present t years later. Preliminary analyses indicated that both bull and cow elk population trends were very sensitive to the initial starting population (N_{91}) and that cow elk trends were also very sensitive to estimates of Mn_a. We therefore considered 3 scenarios for adult bulls (1.5+ years-of-age) with different estimates of $N_{a,91}$. Adult cow numbers were then 'tuned' to the 'most likely' bull scenario by assuming there were ~87 male yearlings/100 female yearlings. We based this on ~87 male calves per 100 females (range 65-100), observed from the harvest age composition data.

Scenario #1

The first scenario assumed that the EKT survey estimate provided an unbiased estimate for yearlings and 2.5-year-olds, but underestimated 3.5+ year-olds (Simpson 1993). We estimated yearlings and 2.5 year-old bulls from antler point/age class tables for the East Kootenay Sub-Region. To convert the 1992 EKT survey estimate of yearlings and 2.5 year-olds to 1991 prehunt estimates, we applied approximately one-half of the assumed annual natural mortality between the end of the hunting season and the start of the census period (i.e $S_{1.5,91}$ = yearling mid-winter estimate/$Sn_{1.5}^{.5}$), and then added the harvest removal (i.e. $N_{1.5,91} = S_{1.5,91} + H_{1.5,91}$). For older bulls, we estimated each age class from the harvest estimate and the harvested and estimated number of 2.5 year-olds [e.g. $N_{3.5,91} = H_{3.5,91} (N_{2.5,91}/H_{2.5,91})$]. The extrapolated prehunt age distribution was then smoothed with a second degree log-polynomial equation (Caughley 1977:96) to produce a predicted prehunt population age structure. We assumed that the smoothed age structure provided an estimate of the actual number of bulls in the prehunt population.

Scenario #2

The second scenario assumed that the EKT survey estimate was an unbiased estimate of the wintering population. We followed the same procedure outlined in scenario #1. The prehunt age structure was then adjusted for harvest removals and natural mortality to produce a mid-winter estimate. The number of 3.5 - 15.5 year-olds were adjusted to match the winter survey estimate, and then back-calculated to a prehunt age distribution.

Scenario #3

The third scenario considered that the EKT survey estimate may also have underestimated yearling and 2.5 year-old bulls. We increased the estimate for these age classes by 7.7%, which was the upper 90% CI of the elk population estimate, and then followed the same procedures as outlined in scenario #1.

We projected both the prehunt and posthunt elk population forward for 1992 and 1993 based upon the 1991 posthunt age structure, demographic rates, and hunter harvest data. Future population trends (1993-98) were simulated under several different harvest scenarios. We also investigated the impact of stochastic summer calf survival on population trends under various harvest scenarios using Monte Carlo methods (Spain 1982).

RESULTS AND DISCUSSION

The 1992 EKT Mid-Winter Elk Survey Estimate

The survey estimate (based on *Aerial Survey - Version 3.20*) on select winter ranges within the East Kootenay Trench was 8941 ± 714 (90% CI's) elk and included 1451 bulls, 5982 cows, and 1518 calves. *Version 4.0* indicated an overall sightability correction of 17%, almost twice as high as the original 9% correction (Tables 1 and 2). The revised survey estimate was 9694 ± 746 and included 1530 bulls, 6433 cows and 1707 calves (Table 3). Sampled elk densities were 9.5 elk/km^2 in the high stratum, 3.7 elk/km^2 in the moderate stratum and 1.8 elk/km^2 in the low stratum. The EKT survey estimate (including all elk wintering within Class 1, 2, 3 and 4 winter ranges of the EKT) was 11,038 elk and included 1852 bulls, 7269 cows and 1918 calves (Table 4). We estimated 1123 yearling bulls, 515 2.5 year-old bulls and 216 3.5+ year-old bulls (Appendix 1).

Assessment of Bull Elk Scenarios

For scenario #1, the 1991 prehunt bull estimate was 4268. Harvest mortality was 26% for 1.5+-year-old bulls, 34% for 2.5+-year-old bulls, and 43% for 6.5+-year-old bulls (Appendix 2). Prehunt bull numbers decreased from 6559 in 1982 to 3618 in 1993 (λ=0.947) (Fig. 1). When the bull population was projected forward with H_{92} and H_{93}, posthunt estimates in 1993 were negative for the 4.5 and 5.5 year-old age-classes (Fig. 2, Appendix 6).

For scenario #2, the 1991 prehunt bull estimate was 3016. Harvest mortality was 36% for 1.5+-year-old bulls, 59% for 2.5+-year-old bulls, and 86% for 6.5+-year-old bulls (Appendix 3). Prehunt bull numbers decreased from 6479 in 1982 to 2212 in 1993 (λ=0.907) (Fig. 1). When projected forward with H_{92} and H_{93}, posthunt estimates in 1993 were negative for all age-classes older than 3.5 years-of-age (Fig. 3, Appendix 6). This scenario strongly suggests that either the mid-winter survey estimate, or our extrapolation procedure resulted in a substantial underestimation of the bull segment of the EKT elk population.

For scenario #3, the 1991 prehunt bull estimate was 4513. Harvest mortality was 24% for 1.5+-year-old bulls, 32% for 2.5+-year-old bulls, and 46% for 6.5+-year-old bulls (Appendix 4). Prehunt bull numbers decreased from 6563 in 1982 to 4037 in 1993 (λ=0.957) (Fig. 1). When projected forward with H_{92} and H_{93}, posthunt estimates were still negative (-59) for the 5.5 year-old age class (Fig. 4. Appendix 6).

Of the 3 scenarios examined, scenario #2 appeared to be the least compatible and scenario #3 the most compatible with recent harvest data. Even scenario #3 failed to generate enough 5.5 year-olds to support the estimated harvest of this age-class. However, there was potential for considerable error associated with the calculation of age-specific harvests, particularly for the more recent years, as indicated by the low sample sizes (1989-92: <20%, 1993: <10%) from the VTRP (Figure 5). Given the likelihood of errors in the harvest age structure, and the need to adopt more conservative estimates when there is substantial uncertainty with population numbers (MELP 1994), we selected scenario #3 as the 'most likely' scenario for developing a complete population assessment.

Population Assessment - Scenario #3

The 1992 mid-winter population was estimated to be 14,667 or 33% higher than the EKT survey estimate (Appendices 3 and 4). The 1991 prehunt elk population included 4512 bulls, 12,366 cows and 3397 calves (Table 5). The elk population reconstruction indicated a 25% reduction in numbers from 24,365 posthunt in 1980 to 18,160 in 1993 (λ=0.978) (Table 6). Posthunt adult bull numbers increased from 1980 (5113) to 1982 (5521), but then declined by 46% between 1982 and 1992 (2976) (λ=0.945). Although the POP II estimates (Demarchi and Wolterson 1991) for 1983 and 1988 were about 10% higher than the estimates reported here (note: POP II estimates included the entire Kootenay Sub-Region) the estimated rate of decline (λ=0.982) was identical to that calculated from the cohort analysis. The greatest decline occurred within the 2.5+ year-old bull segment, with numbers ranging from 4077 in 1983 to 1650 in 1993 (-60%, λ=0.914). Cow numbers showed a progressive decline from 15,150 in 1980 to 11,768 in 1993 (λ=0.981). Posthunt bull/cow ratios increased from 34 bulls/100 cows in 1980 to 39 bulls/100 cows in 1983, and then declined to 25 bulls/100 cows in 1992. Posthunt calf/cow ratios showed little variation and averaged 27/100 from 1980 to 1991 (range 22-28), but then increased to ~30 calves/100 cows in 1992 and 1993. Adult bull and cow numbers increased in 1993 and calf numbers increased in 1992, in response to reduced harvests. Prehunt calf sex ratios averaged 83 males/100 females (range 74-92) and prehunt yearling sex ratios averaged 81 males/100 females (range 72-93).

Bull/cow ratios were substantially higher and calf/cow ratios lower than those reported from annual mid-winter classification surveys (Demarchi et al. 1987, Demarchi and Wolterson 1991). Several elk biologists, however, have reported difficulty in obtaining unbiased bull/cow ratios from composition surveys due to differential winter range use and habitat associations by mature bulls during winter (Peek and Lovaas 1968, Cole 1983). Although observed calf/cow ratios from composition surveys within the East Kootenay Subregion ranged from 33-58 calves/100 cows (Demarchi and Wolterson 1991), the ratios reconstructed from the cohort analysis were similar to ratios obtained from recent stratified random block surveys (Simpson 1991). The prehunt calf/cow ratios (~31 calves/100 cows) were also not particularly low compared to other populations in the western United States (Taber et al. 1982, Boyce 1989).

Pregnancy rates averaged 24% for yearlings, 76% for 2.5-3.5 year olds, 87% for 4.5-10.5 year-olds and 72% for 11.5+ year-olds (Appendix 8). The birth rate averaged 66 calves/100 cows (range 64-73). Summer calf survival averaged 47.6% (range 40.6-55.3%). Other elk studies have reported similar pregnancy, birth and summer calf survival rates (Houston 1982, Taber et al. 1982, Sauer and Boyce 1983, Boyce 1989). Sauer and Boyce (1983) also provided evidence of density dependent calf survival and suggested that this may be the primary population regulatory mechanism in elk herds.

We were unable to discern any density dependence in summer calf survival, perhaps because population densities did not vary enough. Annual nonhunting mortality rates averaged 7.6% for bulls (range 7.5-7.9%) and 11.3% for cows (range 11.1-11.6%). The higher natural mortality rate for cows was primarily due to the older age structure, as age-specific survival rates were similar between bulls and cows until age 12 (Appendices 4, 5). Other studies have reported cow elk mortality rates of 9-12% (White 1985, Brunt et al. 1988, Bergerud and Elliott 1991, Unsworth et al. 1993).

Harvest rates averaged 21% for bulls (26% for 2+ year-old bulls), 2% for cows and 16% for calves (Table 7). Bull harvest rates, however, increased steadily from 14% in 1981 to 30% in 1992. The 1992 harvest rate on 2+-year-old bulls (40%) was substantially greater than previous years, and suggests fewer mature bulls were present. This was supported by a reduction in the proportion of bulls 6.5+ years-of-age between 1986 and 1993 (Figure 6). Cow harvest rates ranged from 1% in 1980 to 5% in 1984, but generally varied between 2-3%. Calf harvest rates ranged from 1% in 1980 to 27% in 1988, and was $\geq$ 20% for 7 of 9 years between 1983 and 1991. A simple population projection based on the 1980 prehunt population and estimated demographic parameters suggested that, in the absence of calf harvesting from 1980 to 1993, the elk population would have increased by 20% (Figure 7). This assumes that calf harvesting was additive to natural mortality, which was probably only partially true. Nonetheless, calf elk harvesting during the 1980's was likely an important factor in reducing the growth rate of the elk population.

Harvest Strategies, 1994-98

In the absence of hunting, the elk population was projected to increase from 18,160 posthunt in 1993 to 24,818 in 1998 (λ = 1.064). Harvesting the population at average rates (26% of 2+ year-old bulls, 2% of cows and 16% of calves) over this period resulted in a slowly declining population (λ = 0.991) with postseason ratios of 32 bulls/100 cows and 27 calves/100 cows. A predominate bull harvest strategy (35% of 2+ year-old bulls, 2% of cows and 0% calves), similar to the strategy imposed in 1994/95, resulted in postseason ratios of 29 bulls/100 cows, 31 calves/100 cows and population growth from 18,160 to 18,829 (λ=1.007). Harvest levels for bulls averaged 1039 (range 980-1088), which was similar to the 1993 harvest (1036). By reducing the 2.5+ year-old bull harvest rate to 25%, the bull/cow ratio improved to 36 bulls/100 cows, and the population increased from 18,160 to 19,651 animals (λ=1.016). Bull harvest levels, however, averaged 840 animals (range 700-947).

Stochastic summer calf survival did not mask these trends. For example, 10 Monte Carlo trials with harvest rates of 26% 2.5+ year-old bulls, 2% cows and 16% calves resulted in 1998 postseason ratios that varied from 31-34 bulls/100 cows, and 25-33 calves/100 cows. Average growth rates from 1993 to 1998 ranged from λ=0.982 to 1.005. A similar exercise for 35% 2.5+ year-old bulls, 2% cow harvests, and 0% calf harvests resulted in

1998 postseason ratios of 27-30 bulls/100 cows and 28-35 calves/100 cows, and growth rates ranging from λ=0.993 to 1.011.

RECOMMENDATIONS

While cohort analysis helped to define historical elk numbers and trends within the EKT, there was still uncertainty about current elk abundance, particularly with regard to the antlerless component of the population. The following recommendations should help to focus harvest management efforts, improve knowledge on the current population status of elk, and help to determine long-term sustainable harvest levels:

1. Develop population objectives for the EKT elk population. These should include target postseason elk numbers, adult sex ratios and recruitment (calf/cow ratios).

2. Implement a EKT elk population monitoring strategy, specifically:

    a. survey absolute abundance and sex/age composition on select winter ranges with the EKT every 3-5 years (as per the 1992 mid-winter survey, but refine procedures for extrapolating survey estimates);
    b. maintain annual elk productivity assessments through monitoring reproductive rates from cow elk harvested during late season antlerless hunts;
    c. increase the sample size of elk teeth submitted through the VTRP to a minimum of 20% (if this can not be achieved through voluntary returns, implement a mandatory tooth return program).
    d. maintain and monitor a 'pool' of 25 to 50 radio-collared elk (bulls and cows) for documenting harvest and non-hunting mortality rates, sightability bias (particularly bulls) and seasonal movement patterns within the EKT.
    e. conduct population modelling annually to assess and update elk numbers and harvest rates within the EKT. An age-structure population modelling approach, such as cohort analysis, should be used to integrate all of the above monitoring components.

3. Maintain the current bull harvest ($\leq$ 1000 animals including wounding losses) and the antlerless harvest strategy until the next elk survey collaborates population numbers, composition, and growth rates; and population objectives are established.

SUMMARY

Modelled posthunt elk numbers within the East Kootenay Trench declined from ~24,370 in 1980 to ~18,160 in 1993. Population numbers and trends over this period were considered to be most reliable for 2.5+ year-old bulls (60% decline), and least reliable for adult cows (22% decline). The 1993 posthunt population was estimated at ~2980 bulls, 11,770 cows and 3420 calves. The reduction in harvest rates in 1992 and 1993 may have been sufficient to halt the elk population decline. The midwinter 1992 EKT survey estimate likely underestimated the population. The rate of decline from 1983 to 1988 (λ=0.982) was consistent with the POP II model developed by Demarchi and Wolterson (1991). Posthunt population ratios did not correlate well with mid-winter elk composition surveys, but were in agreement with other recent absolute density surveys conducted within the Kootenay Subregion. The annual birth rate averaged 66 calves/100 cows, summer calf survival averaged 48%, natural mortality averaged 8% for adult bulls and 11% for adult cow elk. Calf elk harvesting during the 1980's was likely an important factor in reducing the growth rate of the population.

Harvest rates averaged 21% for bulls, 2% for cows and 16% for calves from 1980 to 1993. Bull harvest rates, however, increased steadily from 14% in 1981 to 30% in 1992. The harvest rate for 2.5 year-old bull elk was estimated at 40% in 1992 and 38% in 1993. Resident harvest age structures from 1986-93 showed a decline in the proportion of 6.5+ year-old bulls. The 1994/95 harvest strategy (~1000 bulls including wounding losses, 2% cows) should allow for some population recovery (λ=1.007) if the elk demographic parameters were estimated correctly. Stabilizing the elk population at desired population levels will likely require re-establishing a modest calf elk hunting season.

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