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# HOW MUCH DIFFERENCE DO DIFFERENT TECHNIQUES MAKE IN ASSESSING BIGHORN POPULATION TRENDS?

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Abstract: Using data collected during 1981-87 on the Cinnabar bighorn sheep winter range in southcentral Montana, we compared 5 estimators of numerical trend and 4 age/sex ratio estimators to determine: 1) the relative consistency of values derived using each estimator, 2) sampling intensity necessary to achieve consistency, and 3) the degree to which use of different techniques would have influenced our interpretation of population trend. None of the 5 numerical trend estimators would have produced satisfactory results from 1 survey. Two of the 4 ratio estimators would have performed well with a single survey if a high proportion of the herd were classified. All numerical and ratio estimators performed reasonably well (90% chance of being within 20% of yearly values obtained using all the available data) when derived from 6 surveys. Correlation coefficients, used as an index of agreement in rate/direction of change over time, were generally high ($\underline{r}$ = 0.69-0.99) for numerical trend estimators, lamb:ewe ratio estimators ($\underline{r}$ = 0.89-0.99), and ram:ewe ratio estimators ($\underline{r}$ = 0.87-0.97). Changes in the ratios of legally harvestable (3/4-curl or greater horns) rams to ewes varied ($\underline{r}$ = 0.55-0.93) among techniques. Most of the techniques would have led us to the same conclusions regarding the status of the Cinnabar herd. The analysis process we followed could be beneficial for biologists working with other herds, but no one should blindly adopt "off the shelf" sampling schemes without assessing the suitability of the techniques for the herds with which they are working.

Mountain sheep (*Ovis canadensis*) management relies heavily on winter surveys to assess population status and trends (Trefethen 1975). Sheep use open terrain, tend to concentrate on traditional winter/rutting grounds, and may be classified by horn characteristics to obtain population age structure (Geist 1966, 1971). Consequently, more detailed assessments of sheep populations are possible than for most other ungulates.

In conversations among ourselves and with other biologists, we

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discovered differences in the way "standard" population parameters were collected, analyzed, and reported that frequently are not obvious in methods sections of agency reports or published papers. While many of the differences are subtle, they could bias comparisons among herds studied by different biologists.

To determine the magnitudes of these differences, we examined results obtained from 5 techniques for assessing numerical trends and 4 for assessing ratios of lambs, rams, and legally huntable rams to ewes in a habituated herd in southcentral Montana. In our evaluation, we looked at similarity (Would different techniques produce similar values?), trend comparability (Were direction and relative magnitude of changes over time similar among techniques?), and efficiency (Did techniques differ in precision or in the sampling effort required to obtain a given level of precision?).

Data were collected from Rocky Mountain bighorn sheep (O. c. canadensis) wintering on the Cinnabar winter range (CWR) in the upper Yellowstone River valley 10 km northwest of Gardiner, Montana. The core winter range, approximately 5 $km^2$, was easily accessible via a county road, and sheep were habituated to humans. Vehicles could often approach within 5 m without causing sheep to move away from the road. The herd was hunted (Irby et al. 1986), and the Montana Department of Fish, Wildlife, and Parks (MDFWP) has monitored the population for >10 years.

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METHODS

During 1981-87, 118 ground surveys of the CWR were completed. Surveys were conducted 1-4 times per month during October - April along a county road through the winter range. About 50% of the core winter range, including most sheep concentration areas, was visible from the road. Because a plot of the number of sheep seen on individual surveys against time indicated that sheep numbers were highest on the survey route during November - January, we used only surveys from this period in our evaluations. Surveys in which <20 sheep were counted were deleted from most analyses as inadequate samples.

Numbers of individuals in recognizable age/sex classes were recorded during each survey. Rams were classified by horn shape (<1/2-curl, 1/2 - 3/4-curl, >3/4-curl) and, whenever possible, aged by horn annuli counts (Geist 1966). Ages were not assigned to ewes. Individually recognizable animals (collars or distinctively broken horns) seen during each survey were noted. Throughout the paper, we refer to annual periods by the year in which survey sets were initiated (i.e. 1981 = November 1981 - January 1982).

Descriptions and acronyms used to identify the techniques we evaluated are given in Table 1. Of the 5 numerical trend techniques, MEAN

Table 1. Approaches used for estimating numerical trends and age/sex ratios (lambs: rams: and legally harvestable rams:100).

| Technique | Definition |
|---|---|
| POPULATION INDICES | |
| MEANC (Mean Count) | - Mean of all counts during Nov.-Jan. |
| MAX (Maximum count) | - Maximum total count for all surveys during Nov.-Jan. |
| MAX/C1 (Maximum count/class 1) | - Maximum count for all recognizable age/sex classes including male year classes (horn annuli counts). Individually recognizable animals not seen on days of maximum counts for their class were added to class total. Animals known to have died during Nov.-Jan. were subtracted from total. Includes all surveys during Nov.-Jan. |
| MAX/C2 (Maximum count/class 2) | - Similar to MAX/C1 except males were classified only by horn shape (<1/2 curl, 1/2-3/4 curl, 3/4+ curl), recognizable animals were not added to class totals, and known mortalities were not subtracted from totals. |
| LINC (Chapman - corrected Lincoln estimator) | - Estimates for individual surveys based on proportion of total individually recognizable animals (physical anomalies or collars) seen in counts >19 during Nov - Jan.<br>a) Estimated number for individual surveys = $\frac{(\text{N marked} + 1)\ (\text{N observed} + 1)}{(\text{Marked animals observed} + 1)} - 1$<br>b) Estimated number for multiple surveys = mean of estimates for individual surveys. |
| CUMR (Cumulative ratio) | - Ratios based on cumulative counts of all animals sighted (including duplicated sightings) during Nov - Jan. |
| MEANR (Mean ratio) | - Mean ratio derived from ratios calculated for individual surveys with counts >19 during Nov - Jan. |

(Table 1. cont'd.)

| Technique | Definition |
|---|---|
| RATIO ESTIMATORS | |
| MAX R1 (Maximum/class ratio 1) | - Ratios calculated from maximum counts per distinguishable age/sex class recorded during all surveys from Nov - Jan. Males were classified by year classes, recognizable animals were added to totals when not seen in maximum counts, and known mortalities were subtracted from class totals. |
| MAXR2 (Maximum/class ratio 2) | - Similar to MAXR1 except males were classified by horn shape, marked animals were not added to totals, and known mortalities were not subtracted. |

and MAX involved the smallest investment of time and money. These techniques required counts of sheep on winter range 1 or more times during winter but no marking or age/sex classification of animals.

MAX/C1 and MAX/C2 required more than 1 survey per winter and sufficient effort to classify animals by age and sex, but the presence of individually recognizable animals was not essential. MAX/C1 approximated conditions for an accessible, intensively studied population in which some individually recognizable animals are available and biologists could approach sheep closely enough to obtain horn annuli counts for rams. MAX/C2 approximated conditions in an inaccessible or unhabituated herd in which classification of rams by horn annuli counts is unfeasible and individually recognizable animals are not present.

The fifth technique, LINC, required marked animals. Population estimates were based on the lease complex mark-resight model (no heterogeneity in resighting probability, no avoidance of resighting by marked animals, and no variation in resighting probabilities over time) presented by Otis et al. (1978:21-24). Estimates from multiple surveys utilized the bias-corrected hypogeometric estimator (Chapman 1951) and methodology outlined by Rice and Harder (1977) and Bartmann et al. (1987).

During 1980-84, 11 females (1/2 - 4+ yrs) and 7 males (1 1/2 - 4 1/2 yrs) were captured (Keating 1982, Andryk et al. 1983) and fitted with individually marked radio collars (n = 16) or neckbands (n = 2). Seven additional individuals (5 females and 2 males) with distinctive broken horns were identified during 1981-86. Numbers of individually recognizable animals available as marked samples for individual surveys were determined based on total recognizable animals observed through April of each year. Radiocollared animals were not located using radio receivers during surveys.

Population estimates made using LINC were based on 5-15 recognizable sheep per survey. Estimates were calculated only for surveys during 1982-86 in which >19 animals, about 10-20% of the presumed population size, were counted and at least one marked animal was seen. Because we used an unrealistically simple model and a biased estimate of marked animals (Except for radiocollared animals with functioning radios, we could never be certain that an animal marked in an earlier year but not seen in the current year was not in the population), we refer to LINC as a population index in this paper.

Four techniques were evaluated for estimating age/sex ratios in the CWR population (Table 1). Lamb:ewe, ram:ewe, and legal ram (males with 3/4 or greater horn curl, regardless of age, that could legally be killed by hunters): ewe ratios were calculated using each technique. CUMR ratios were based on a simple summation of all animals classified during November - January. MEANR values represented the means of ratios derived from individual surveys. MAXR1 and MAXR2 values were calculated from maximum counts in each age/sex class from several winter range surveys. Ratios obtained using MAXR1 approximated conditions expected in a habituated herd in which rams could be aged by horn annuli counts. Ratios obtained using MAXR2 approximated conditions in an unhabituated herd.

Similarities of values produced by numerical and age/sex ratio techniques were tested using blocked analyses of variance and Newman-Keuls means tests (Steel and Torrie:110-111, 132-146). An unbiased estimate of the missing 1981 value for the LINC method was calculated as suggested in Steel and Torrie (1960:139). Similarities in trends among the 5 population and 4 age/sex structure techniques were determined using Pearson correlations (Steel and Torrie 1960:183-187). Statistical analyses were conducted using the MSUSTAT statistical package (Lund 1983).

Because the estimates obtained using each technique were based on the same transect data and were sometimes derived from subtle variations of the same approach, the requirement for sample independence in analysis of variance and correlation analysis was violated. We elected to use these tests despite this violation of assumptions because the tests provided a conventionally recognizable manner of displaying differences.

We evaluated efficiency in terms of precision and, for techniques used to estimate trends in population size, the time costs of aging and sexing sheep versus merely counting them. Standard deviations, conventional measures of precision (Otis et al. 1978), were calculated for the MEANC, LINC, and MEANR techniques, but we were unable to locate suitable methods for calculating standard deviations for techniques relying on maximum or cumulative values from a series of counts. As an alternative, precision was assessed empirically by determining the number of surveys necessary to achieve results within a specific range using a variant of the "species-area curve" method (Oosting 1956). We calculated the percentage of individual surveys and of subsets of 3 and 6 randomly selected surveys that fell within 20% of values derived from all surveys within a single year. Surveys in which <20 sheep were counted were excluded from calculations to avoid variation due to obviously inadequate sample sizes. Six sets of 3 and 3 sets of six surveys were selected for each year for 1982-86. Twenty percent was selected as the acceptable level of deviation to avoid excluding values that differed from annual values by only 1-2 animals (i.e. with a 10% acceptance range, a lamb:100 ewe ratio of 12 would have been outside the "acceptable" range in a year in which the mean ratio was 10).

The additional field time required for classifying, rather than simply counting, animals was estimated from 2 segments of the survey route. One segment crossed the most heavily used portion of the winter range and included three 5-min scanning stops and 11 km of driving. The second segment crossed a portion of the winter range used by fewer sheep and included four 2-min scanning stops and 4 km of driving. At each stop, 7x35 binoculars and a 20-60x telescope were used to locate sheep. Counts (without age/sex classification) could be made in <2 min at stops on both segments.

## RESULTS

### Numerical Trend Indices

The numerical trend techniques produced 3 statistically different ($\underline{P} < 0.05$) sets of estimates (Table 2). In order of increasing estimated numbers, the sets were: 1) MEANC, 2) estimates based on maximum counts (MAX, MAX/C1, and MAX/C2), and 3) LINC (AOV F = 66.25).

Table 2. Summary of the results of 5 techniques for estimating population trend on the CWR ($\underline{N}$ = number of surveys). Standard deviations are given in parentheses.

| Technique | 1981 | | 1982 | | 1983 | | 1984 | | 1985 | | 1986 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Est. | N | Est. | N | Est. | N | Est. | N | Est. | N | Est. |
| MEANC[a] | 7 | 46(25) | 16 | 62(28) | 15 | 64(23) | 11 | 46(17) | 12 | 52(19) | 12 | 54(22) |
| MAX | 7 | 90 | 16 | 117 | 15 | 93 | 11 | 64 | 12 | 73 | 12 | 82 |
| MAX/C1 | 7[b] | 91 | 15 | 127 | 15 | 101 | 11 | 71 | 11 | 83 | 12 | 93 |
| MAX/C2 | 7 | 91 | 16 | 117 | 15 | 95 | 11 | 68 | 12 | 77 | 12 | 88 |
| LINC[c] | | | 13 | 150(66) | 12 | 135(35) | 9 | 113(44) | 10 | 96(29) | 8 | 117(41) |

[a] Definitions of acronyms are given in Table 1.
[b] Only yearling males were aged in 5 counts.
[c] Median numbers of recognizable individuals available were: 1982 = 8, 1983 = 10, 1984 = 9, 1985 = 8, 1986 = 8.

Positive Pearson correlations (*r* = 0.69-0.99) indicated that changes in values during 1981-86 were generally similar in direction among the 5 techniques. Significant correlations (*r* > 0.86: *P* < 0.05), indicating similarities in relative magnitude as well as direction of change, were identified among MAX, MAX/C1, and MAX/C2 (*r* = 0.98-0.99) and between LINC and MAX and MAX/C2 (*r* = 0.88-0.89). All techniques indicated a population decline between 1982 and 1984 and an increase between 1984 and 1986 (Table 2). Estimates of the magnitude of the 1982-84 decline varied from 25-45% with 2 distinct groupings: 1) MAX, MAX/C1, and MAXC/2 (42-45%), and 2) MEANC and LINC (25-26%). The 1984-86 increase followed a similar pattern with highest percentage increases obtained with MAX, MAX/C1, and MAX/C2 (28-31%) and smaller increases with MEANC (17%) and LINC (4%).

The proportion of individual surveys falling within 20% of average annual values for the 5 techniques varied from 0.20 to 0.54 (Table 3). Three surveys were judged inadequate (<90% chance of obtaining a value within 20% of the value calculated from complete sets of 11-16 surveys) for all techniques. Six surveys were apparently adequate for all techniques.

Table 3. Percentages of winter range surveys, sets of 3 surveys, and sets of 6 surveys that were within 20% of annual values for numerical estimators. Percentages were calculated from sets drawn from 61 surveys in which >19 sheep were counted during November-January, 1982-86.

| Numerical estimator | 1 survey (*N* = 61)[a] | 3 surveys (*N* = 30) | 6 surveys (*N* = 15) |
|---|---|---|---|
| MEANC[b] | 54 | 83 | 93 |
| MAX | 34 | 73 | 93 |
| MAX/C1 | 20 | 67 | 93 |
| MAX/C2 | 33 | 83 | 93 |
| LINC | 48[c] | 53 | 100 |

[a] *N* = number of values used to compute percentages.
[b] Acronyms are defined in Table 1.
[c] Based on 52 of the 61 surveys in which 1 or more marked animals were seen.

Age/Sex Ratios

The 4 methods used to determine lamb:ewe ratios (Table 4) gave comparable results (AOV *F* = 0.49, *P* = 0.70). Over a 6-year period, all techniques produced values within 20% of annual estimates in >50% of individual surveys and in >90% of sets of 6 surveys (Table 5).

Table 4. Lamb:ewe, ram:ewe, and legal ram:ewe ratios in the CWR population during 1981-86 calculated using 4 techniques.

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|
| Total surveys | 7 | 16 | 15 | 11 | 12 | 12 |
| (Counts >19) | (6) | (15) | (14) | (10) | (11) | (11) |
| Total animals classified | 322 | 972 | 950 | 516 | 666 | 633 |
| TECHNIQUES | | | | | | |
| Lambs:100 ewes | | | | | | |
| CUMR[a] | 35 | 34 | 11 | 16 | 40 | 24 |
| MEANR (SD) | 37(7) | 36(16) | 11(3) | 17(5) | 39(10) | 23(6) |
| MAXR1 | 34 | 31 | 10 | 20 | 41 | 33 |
| MAXR2 | 34 | 32 | 10 | 20 | 41 | 33 |
| Rams:100 ewes | | | | | | |
| CUMR | 49 | 47 | 47 | 46 | 31 | 50 |
| MEANR (SD) | 45(16) | 47(12) | 47(10) | 48(15) | 33(14) | 50(8) |
| MAXR1 | 60 | 64 | 59 | 58 | 48 | 70 |
| MAXR2 | 60 | 56 | 53 | 50 | 34 | 63 |
| Legal rams:100 ewes | | | | | | |
| CUMR | 25 | 17 | 13 | 21 | 17 | 18 |
| MEANR(SD) | 22(18) | 16(7) | 13(5) | 22(12) | 18(5) | 18(6) |
| MAXR1 | 38 | 33 | 24 | 32 | 27 | 30 |
| MAXR2 | 36 | 24 | 19 | 22 | 16 | 22 |

[a] Definitions for acronyms are given in Table 1.

Table 5. Percentages of individual winter range surveys ($N$ = 61), sets of 3 surveys ($N$ = 30), and sets of 6 surveys ($N$ = 15) in which lamb:ewe, ram:ewe, and legal ram:ewe ratios fell within 20% of annual values using 4 techniques. Percentages were calculated from 61 surveys conducted during November-January 1982-86 and include only surveys in which >19 sheep were counted.

| Technique | Lamb:ewe | | | Ram:ewe | | | Legal ram:ewe | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of surveys in set | | | | | | | | |
| | 1 | 3 | 6 | 1 | 3 | 6 | 1 | 3 | 6 |
| CUMR[a] | 59 | 83 | 100 | 67 | 90 | 100 | 39 | 87 | 9 |
| MEANR | 67 | 80 | 100 | 67 | 90 | 100 | 39 | 77 | 93 |
| MAXR1 | 52 | 83 | 93 | 36 | 67 | 100 | 21 | 67 | 100 |
| MAXR2 | 51 | 80 | 93 | 56 | 83 | 100 | 43 | 97 | 100 |

[a] Definitions for acronyms are given in Table 1.

Ram:ewe ratios (Table 4) varied significantly among techniques (AOV $F$ = 36.75). CUMR and MEANR produced the lowest ratios, MAXR2 significantly higher ratios, and MAXR1 the highest ratios. More than 50% of individual surveys fell within 20% of annual values in all techniques except MAXR1 (Table 5). All randomly selected sets of 6 surveys produced values within 20% of annual values.

Ratios of legal rams to ewes (Table 4) also varied among techniques (AOV $F$ = 30.22). MAXR1 produced estimates 32% higher than those of the next highest technique, MAXR2. There was no significant difference between MEANR and CUMR. The probability of deriving a ratio within 20% of annual values on a single survey was low, but >90% of randomly selected sets of 6 surveys produced values within 20% of annual values for all techniques (Table 5).

Correlations here high ($r$ > 0.87) among techniques used to derive lamb:ewe and ram:ewe ratios. Correlations of legal ram:ewe ratios among techniques were high ($r$ > 0.80) except for MEANR with MAXR1 ($r$ = 0.74) and MAXR2 ($r$ = 0.55).

Time Costs of Classifying Sheep

The survey segment that passed through areas of high sheep density required 30 min to complete if no sheep were counted. In 10 replicates of this segment in which scanning stops were completed in the same order and times were noted, 4 to 56 sheep were classified (including aging rams by horn annuli counts). Mean time for completion of this segment was 66 min (range = 30-150 min, SD = 39), a 122% mean increase over the minimum time requirement.

The survey segment that passed through areas with low sheep density required a minimum of 15 minutes to complete. In 10 replicates in which no sheep were counted, the mean time for completion was 19 min (range = 15-25 min, SD = 5). In 13 replicates, 1-21 sheep were classified in a mean time of 30 min (range = 20 - 55 min, SD = 10). Replicates in which sheep were classified required an average of 58% more time than replicates in which no sheep were counted.

DISCUSSION

The 5 techniques for estimating numbers were generally in agreement on trends in population size for the CWR sheep herd during 1981-86, but the magnitudes of changes between years varied among techniques. Techniques based on maximum counts (MAX, MAX/C1, and MAXC/2) indicated that year-to-year changes in population size were proportionately greater than did the MEANC and LINC techniques.

None of the 5 numerical trend techniques we evaluated performed well when based on a single survey. The percentages of surveys that fell within 20% of annual values were higher for MEANC and LINC than for MAX, MAX/C1, and MAX/C2, but these differences were artifacts of methodology rather than differences in efficiency. Values within 20% of annual values could occur above or below the annual values for MEANC and LINC but only below for techniques based on maximum counts.

All techniques gave reasonably consistent results when based on 6 surveys. If we had been forced by logistical or financial constraints to conduct a single survey, we would have covered a larger proportion of the winter range in hopes of increasing the proportion of the population seen and scheduled a series of brief preliminary surveys of the CWR to insure that the intensive survey was conducted when sheep numbers in accessible parts of the winter range were high.

Sexing and aging individuals added >50% to survey time in 2 segments of the survey route. This additional investment in time increased population estimates over simple maximum counts <20%. Trends for maximum counts agreed closely with trends from techniques relying on aging and sexing individuals.

Values derived from the Lincoln Index (LINC) were consistently higher than maximum or mean counts, as expected. The high variability in values from single surveys (48-223% of those derived from respective annual multiple survey calculations) indicated that reliance on a mark-resighting model that requires only a single survey to make a population estimate would be unwise, at least for our sampling conditions (5-10% marked animals in a population of <200). Based on the formula given by Overton and Davis (1969:448) and a probability of resighting marked animals of 0.45 (Irby, unpubl. data), we would have had to mark 80% of the population to obtain narrow confidence limits (±10% at the 95% confidence level).

Use of the multiple survey approach yielded better results, but coefficients of variability (standard deviation / mean x 100, Steel and Torrie 1960:20) were greater than the 20% or less considered acceptable by White et al. (1982:50). More precise estimates may have been produced by increasing the number of marked animals (25% of the population should have been marked given the probabilities of resighting, survey numbers, and population size associated with the CWR (Rice and Harder 1977)) or utilizing more sophisticated models for analysis of data (Otis et al. 1978, Bartmann et al. 1987).

The 4 techniques used for estimating age/sex ratios produced similar lamb:ewe ratios. Trends in lamb:ewe ratios over time were also similar (decreases between 1981 and 1983; increases between 1983 and 1985; decreases between 1985 and 1986).

MAXR1 and MAXR2 generally produced higher ram:ewe and legal ram:ewe ratios than CUMR and MEANR. These differences were either related to differences in the proportion of the winter sampling period spent in accessible areas by ram and ewe bands (most individual collared ewes were sighted on a higher proportion of surveys than individual collared rams) or were an artifact of having more subclasses for identifying males than for identifying females. Year to year changes in ram and legal ram:ewe ratios were not as consistent among approaches as those indicated for lamb:ewe ratios.

A single survey would likely be adequate for obtaining lamb:ewe and ram:ewe ratios if a large proportion of the population (>50% of the estimates obtained using the LINC method for the CWR) could be classified during the period in which all age/sex classes were concentrated in the same area. The cumulative results of a series of partial counts would also give adequate results.

Estimates of the minimum number of legal rams surviving hunting season obtained by aging rams via horn annuli counts were higher than those obtained by classification of rams based on 3 horn shape classes (6-year mean = 15 vs. 12). This difference is important in the intensive management regime established in the CWR (Irby et al. 1986). Conducting horn annuli counts in larger, more remote, or less intensively managed herds may not be cost-effective.

## MANAGEMENT RECOMMENDATIONS

Of the techniques we tested, those judged optimal for the CWR (an easily accessible, intensively managed herd with individuals habituated to close human approaches) were:

1) Trend - maximum count (MAXC) from 6 surveys during mid November - January. Although its usefulness is limited by lack of a means of calculating variance (Calculation may be feasible, but we were unable to find a statistician that knew of a suitable formula), MAXC (with 6 or more replicates) produced values that were relatively stable within a year, changed between years in directions that were consistent with changes in lamb production and herd health, did not require marked animals, and was not sensitive to errors in classification by age and sex. A multiple

survey, mark-resighting approach such as the multiple Lincoln Index (Bartmann et al. 1987) would give a better population estimate if adequate numbers of individually recognizable individuals could be maintained in the population. We do not have sufficient funds to mark a large proportion of the population, and, if we did, many of the non-consumptive users of the Cinnabar herd would be upset at marked animals spoiling their photographs of "wild" sheep.

2) Lamb:ewe and ram:ewe ratios - mean ratios (MEANR) derived from 6 surveys. This technique produced relatively precise results, and allowed us to calculate variances with which to assess year to year changes statistically. This technique may underestimate the actual proportion of rams in the population, but the direction of bias is known. Additional factors that should be considered in designing and analyzing sampling plans for age/sex ratios are given by Bowden et al. (1984).

3) Harvest quota - utilize maximum counts of males in individual age classes from at least 6 winter range surveys in which males are aged by horn annuli counts. The Cinnabar herd is utilized for 2 purposes (hunting and sheep viewing) that could easily conflict. Because we can get detailed information on ram ages, we believe it is worth the extra effort to determine numbers and ages of rams surviving to winter. This enables MDFWP to set quotas for the next year's hunt that will provide the greatest opportunity to harvest rams consistent with maintenance of ram numbers, age structure, and behavior patterns that will allow non-consumptive users ample opportunity to see and photograph mature rams.

Applications of this set of techniques to other herds may be inappropriate. Sheep occupying a winter range may belong to several bands with different seasonal range use patterns (Geist 1971, Festa-Bianchet 1986, Irby unpubl. data). Timing of movements on and off the winter range, movements within the winter range, and extent of movement among adjacent winter ranges could vary with different bands. If intensive management is a desirable option, winter range complexes should be observed for 3-5 years prior to initiating a routine sampling scheme. During this period, movement patterns, observability, seasonality of use, and variability among surveys should be determined. Settling on techniques without this information is likely to yield poor results.

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