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USE OF AGE RATIOS TO PREDICT BIGHORN SHEEP POPULATION DYNAMICS

MARCO FESTA-BIANCHET, Département de biologie, Université de Sherbrooke, Sherbrooke, PQ J1K 2R1, Canada

Abstract: Age ratios are used as an index of the well-being of wild sheep populations under the assumption that high ratios indicate a growing and healthy population. I tested whether age ratios in June and in January predicted recruitment (number of yearlings) to the population or changes in total and nursery herd size. Lamb:ewe ratios in June did not predict either recruitment or population changes. Lamb:ewe ratios in January were good predictors of yearling recruitment only if yearlings were not classified as ewes. Lamb:ewe ratios, however, were not good predictors of population changes, regardless of whether or not the year of a pneumonia epizootic was included in the analysis. Lamb survival from June to January, calculated by the change in lamb:ewe ratio, was not correlated with change in population size. Yearling:ewe ratios in January were a poor predictor of changes in population size. These results suggest that age ratios in June are not useful for predicting population changes, and age ratios in January have limited usefulness. The inability to distinguish adult ewes from yearlings of both sexes during aerial surveys further limits the usefulness of age ratios. The results question the relevance of yearly variations in lamb survival with respect to changes in population density.

Wildlife managers are often interested in predicting changes in population size of wild animals. For bighorn sheep (*Ovis canadensis*), population size is usually estimated from winter counts. Bighorns inhabit open habitat, are gregarious, very traditional in their use of winter ranges, and easier to see than most other ungulates, particularly if surveys are flown after fresh snowfalls. Similar techniques are used for Dall sheep (*Ovis dalli*), except tha summer counts are preferred (Nichols 1978), because a white sheep is easier to spot against a brown-green background than on snow. There are few published estimates of potential errors in aerial or ground censuses of bighorn sheep (Irby et al. 1988), and there is little information on potential biases. For example, lambs may not be distributed randomly among nursery groups; moreover, that differences in snow condition, weather, sheep distribution and observer experience can bias the probability of finding and correctly classifying sheep.

Aerial mountain sheep censuses are expensive and can cause harassment (Bleich et al. 1990). Therefore, replicate censuses are rarely undertaken and managers have to rely on single surveys to estimate population size and trends in population dynamics. As an alternative to accurate complete counts, age ratios are often used to attempt to predict changes in population size, or to assess the "health" of a sheep population (Leslie and Douglas 1980, Burles and Hoefs 1984, Douglas and Leslie 1986, Wehausen et al. 1987, Coggins 1988, Jorgenson 1988, Hebert and Harrison 1988). The use of age ratios relies upon the assumption that high lamb:ewe or yearling:ewe ratios are indicative of a healthy, growing sheep population. There have been, however, no attempts to actually compare age ratios to changes in recruitment or in population size, nor is there any information on how any usefulness of these ratios may change according to the time of year when censuses are undertaken. For example, Hoefs and Bayer (1983) reported wide fluctuations in lamb:ewe ratios (0.10 - 0.64) during a 12-year study of Dall sheep characterized by only 10% variation between the minimum and the maximum number of ewes observed. On the other hand, Smith (1988) found that a decline in kid:adult ratios in mountain goats (Oreamnos americanus) accompanied a decline in overall population size over a wide area in west-central Alberta.

Here I compare several types of age ratios with changes in recruitment and population size in a marked bighorn population monitored for 11 years. I test the null hypothesis that age ratios are not correlated with either recruitment (number of yearlings present the following May) or changes in population size.

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STUDY AREA AND METHODS

The study population in southwestern Alberta overwinters in the Sheep River Wildlife Sanctuary and areas to the east (Festa-Bianchet 1986a,b). The study began in March 1981 and since 1982 over 85% ($\bar{x}$ = 94%) of the ewes present each year have been individually marked with colored ear tags. The high proportion of marked ewes and the ease of finding them in the winter range (an average of 97% were seen during each census in winter) allowed exact counts of nursery herds (ewes, lambs, and yearlings of both sexes). The proportion of rams marked was smaller (51 - 74%, $\bar{x}$ = 61%). Estimate of ram numbers were made more difficult by the seasonal presence of non-resident rams, and by their use of areas east of the

Sanctuary in winter, where they were difficult to find (Festa-Bianchet 1986b).

Rams in this population are hunted outside the Wildlife Sanctuary (Festa-Bianchet 1986c). Ewe permits are also issued, but ewe harvest averages less than 1 ewe/year. A minimum of 6 rams, 3 ewes and 1 lamb were poached during the study.

The number of lambs produced each year was estimated by the number of ewes that had extended udders or were seen nursing a lamb. Lamb:ewe ratios in June were obtained by dividing the total number of lambs seen (therefore not including those that presumably died at or soon after birth) by the number of ewes alive in June. Lamb:ewe ratios in January were obtained by dividing the number of lambs alive in January by the number of ewes alive in January. An average of 69% of the lambs were marked by January. January yearling:ewe ratios were obtained from total counts of yearlings and ewes. Beginning in 1982, an average of 83% of yearling females and 65% of yearling males were ear-tagged each year. To approximate aerial surveys, some of the lamb:ewe ratios were recalculated including yearlings of both sexes as "ewes".

Lamb survival was calculated in two ways: actual survival (the number of lambs that survived to May 1 divided by the number born the previous year) and survival calculated dividing the January lamb:ewe ratio by the June lamb:ewe ratio. The data are complete counts, not estimates based upon a sample. Although it is likely that some small errors were involved (not all sheep were marked, especially in the first few years of the study), the data are more accurate than censuses of unmarked populations.

RESULTS

Population Changes

Table 1 summarizes the changes in population size and in age ratios during the study. The drop in numbers after 1985 was caused by pneumonia (Festa-Bianchet 1988a). Because of the die-off, the number of sheep in March varied considerably during the study, from a low of 99 to a high of 153 (55% difference). The nursery herd varied from 65 to 106 animals, a difference of 63%. Age ratios also varied during the study; in most cases the highest ratio was twice or more the lowest ratio.

Relationships of Age Ratios to Recruitment

Most attempts to find correlations between age ratios and recruitment failed (Table 2). The only exception was the significant correlation between the January lamb:ewe ratio and the number of yearlings recruited the following May. The June lamb:ewe ratio had no relationship to the number of yearlings recruited the following May, and when yearlings of both sexes were included as "ewes" I even obtained a near-significant negative correlation.

Table 1. March population size and age ratios for the Sheep River bighorn sheep herd, southwestern Alberta, between 1982 and 1991. Ratios in June refer to the same year, while January ratios refer to the following year. The category "ewe" includes yearlings of both sexes.

	Year									
	82	83	84	85	86	87	88	89	90	91
Numbers										
Adult females	49	48	50	53	49	46	44	48	50	54
Yearling females	6	15	12	18	8	3	7	5	9	5
Yearling males	6	11	9	8	7	3	3	8	7	8
Total Nursery herd	97	103	100	106	71	65	68	80	88	89
Adult males	43	41	47	47	36	34	31	29	30	29
Total population	140	144	147	153	107	99	99	109	118	118
Ratios										
Lamb:ewe (Jun)	0.88	0.76	0.85	0.81	0.69	0.87	0.80	0.67	0.77	0.68
Lamb:"ewe" (Jun)	n/a	0.52	0.58	0.59	0.62	0.70	0.62	0.50	0.56	0.50
Lamb:ewe (Jan)	0.54	0.64	0.54	0.31	0.42	0.35	0.41	0.53	0.43	
Lamb:"ewe" (Jan)	0.33	0.46	0.35	0.24	0.36	0.29	0.32	0.40	0.35	
Yearling:ewe (Jan)	n/a	0.47	0.37	0.13	0.21	0.28	0.33	0.34	0.36	

Relationships of Age Ratios to Population Changes

Lamb:ewe ratios in either June or January were very poor predictors of population changes. The January yearling:ewe ratio was correlated with change in total herd size only because of the inclusion of data from 1985-86, a year of very poor yearling survival followed by a drastic decline in herd size caused by pneumonia. When 1985-86 was excluded, the correlation was no longer significant (Fig. 1). A similar situation was found for the correlation between January lamb:ewe or yearling:ewe ratio and the change in nursery herd size excluding lambs, the most variable component of the population (Hoefs and Bayer 1983) (Table 3).

Lamb survival from birth to 1 year was correlated with changes in population size (Table 3), but only because of the pneumonia die-off. The correlation disappeared when that year was eliminated, suggesting that the

Table 2. Pearson correlation coefficients (r) between recruitment of yearlings (number of yearlings the following May) and age ratios or population characteristics for the Sheep River herd, 1981 to 1991. The category "ewe" includes yearlings of both sexes. P values: NS, not significant; * <0.05, **<0.01. For each comparaison, the first line indicates the results from all years, the second line indicates the results of the same analysis excluding 1985, the year of a pneumonia die-off.

Age ratio or population character	N	r	P
Jun lamb:ewe	8	0.03	NS
	7	0.18	NS
Jun lamb:"ewe"	8	-0.54	NS
	7	-0.65	NS
Jan lamb:ewe	8	0.89	**
	7	0.85	*
Jan lamb:"ewe"	8	0.75	*
	7	0.60	NS
% lactation	8	0.64	NS
	7	0.72	NS
% lactation, 2-3-yr-olds	8	0.16	NS
	7	0.41	NS

significance was spurious and due mostly to point-cluster correlations like the one illustrated in Fig. 1. Lamb survival from June to January, calculated by the change in lamb:ewe ratio, was not correlated with changes in population size (Table 3), particularly if the die-off year was excluded from the analysis.

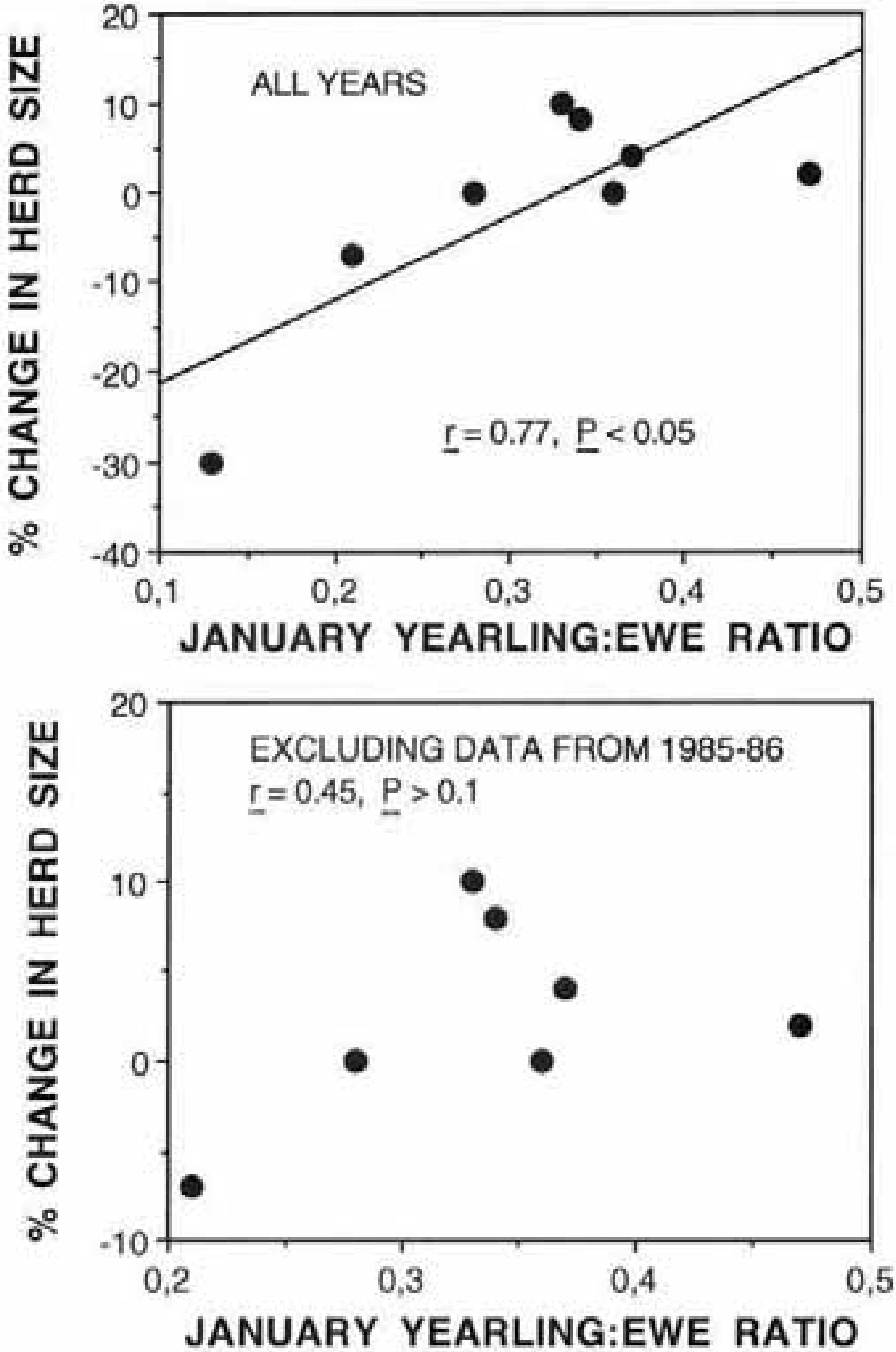

Fig. 1. Correlation between January yearling:ewe ratio and percent change in total herd size for bighorn sheep at Sheep River, Alberta, 1982 - 91.

Table 3. Pearson correlations between age ratios, population characteristics and relative change in population size for the Sheep River herd, 1981 - 91. The category "ewe" includes yearlings of both sexes. The Jan:Jun lamb:ewe ratio is the survival of lambs from June to January according to the change in lamb:ewe ratio. P values: NS, not significant; * <0.05, **<0.01. For each comparaison, the first line indicates the results from all years, the second line indicates the results of the same analysis excluding 1985, the year of a pneumonia die-off.

Correlation between	and	N	r	P
Jun lamb:ewe	Jun lamb:"ewe"	9	0.67	*
		8	0.68	NS
Jun lamb:ewe	% total change	9	0.06	NS
		8	0.09	NS
Jun lamb:ewe	% nursery herd change	9	0.06	NS
		8	0.29	NS
Jan lamb:ewe	% total change	9	0.57	NS
		8	0.22	NS
Jan lamb:ewe	% nursery herd change	9	0.40	NS
		8	0.16	NS
Jan lamb:ewe	% nursery herd change[a]	9	0.66	*
		8	0.46	NS
Jan yearling:ewe	% total change	9	0.77	*
		8	0.45	NS
Jan yearling:ewe	% nursery herd change	9	0.64	NS
		8	0.11	NS
Jan yearling:ewe	% nursery herd change[a]	9	0.84	* *
		8	0.68	NS
Lamb survival from birth to 1 year	% nursery herd change	9	0.71	*
		8	0.18	NS
Lamb survival from birth to 1 year	% total change	9	0.78	*
		8	0.35	NS
Jan:Jun lamb:ewe	% total change	9	0.52	NS
		8	0.16	NS
Jan:Jun lamb:ewe	% nursery herd change	9	0.33	NS
		8	0.24	NS

[a] Nursery herd excluding lambs

Data from the die-off year strongly affected most correlations between age ratios and changes in population (Table 3), but had little effect upon the correlations between age ratios and recruitment of yearlings (Table 2).

DISCUSSION

Age ratios appear to be poor predictors of either recruitment or changes in population size in bighorn sheep. The only age ratio that may have some use is the winter yearling:ewe ratio, that is almost impossible to obtain from aerial surveys. By their second winter, "yearlings" are almost 2 years old and difficult to distinguish from adult ewes. An experienced observer, however, could classify most yearlings correctly in a ground count. Overall, it seems that information on the number of yearlings is more useful than information on the number of lambs.

Lamb:ewe ratios (or, even worse, lamb:"ewe" ratios) in June appear to be useless to predict either recruitment or population changes. This result is not surprising in view of the very high fecundity rates of northern populations of bighorn sheep (Festa-Bianchet 1988b, Jorgenson and Wishart 1986). It appears that since almost all adult ewes produce lambs, year-to-year fluctuations in yearling recruitment or in population size are due mostly to variations in survival, not in production. The number of lambs produced, either in absolute terms or in relation to the number of ewes, is not by itself a useful parameter to predict population changes. The survival of lambs and older sheep is likely to be of greater interest, although my analysis suggests that lamb survival calculated simply by the change in lamb:ewe ratio is not very useful to predict recruitment or population changes.

Lamb:ewe ratios in January (when most aerial censuses are done) were a slightly more useful indicator of recruitment than lamb:ewe ratios in June, but were not a reliable predictor of population changes. Nevertheless, the number of yearlings that may recruit in a bighorn population remains a parameter of interest to managers, especially in populations where ewes are harvested. Therefore, it would appear that lamb:ewe ratios in January could be used to forecast changes in recruitment, but any such forecast would likely include a wide margin of error.

In conclusion, it appears that there is no substitute for complete counts to assess changes in bighorn population size. Age ratios cannot reliably forecast such changes. Nevertheless, drastic changes in age ratios (Wehausen et al. 1987, Festa-Bianchet 1988a), could be detected by aerial counts. These changes would provide clues to the possible occurrence of disease or to changes in other factors, such as predation, that may affect lamb survival (Wehausen et al. 1987). It remains to be seen, however, whether changes in lamb survival affect population size in bighorn sheep. The data presented here and in other studies (Hoefs and Bayer 1983, Jorgenson 1992) suggest that yearly variations in lamb survival may not have very strong effects upon bighorn sheep populations. Lamb production varies little between years, and changes in survival of yearlings and adults may play a key role in determining population size. That pattern is to be expected in populations of long-lived animals.

It would be interesting to compare these data with other long-term studies. In my study, the population suffered a pneumonia epizootic. It is possible that results obtained from populations not affected by disease would be different. It remains to be seen whether age ratios are a more reliable predictor of changes in population size in populations whose density changes over a wider range than that available during my study. Results from the Ram Mountain study (Jorgenson 1992) suggest that the usefulness of age ratios may indeed be universally limited.

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