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REPRODUCTIVE RESPONSE OF THE ABSAROKA MOUNTAIN GOAT POPULATION TO AN EXPERIMENTAL REDUCTION

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Abstract: Previously published data from the introduced mountain goat (*Oreamnos americanus*) population in the Absaroka Mountains in southwestern Montana indicated a compensatory reproductive response to changes in population size. This led to the prediction that maximum kid production would occur if the number of older goats was reduced by about 25% from the 1983 level. One of the methods used may have been inappropriate to infer density dependence, so the data are reanalyzed here. The reanalysis supported the original conclusion of density-dependent reproduction and predicted maximum kid production at about 28% fewer older goats than the 1983 level. The only conclusion that changed in the reanalysis was that density of older goats and winter severity appeared to be equally important in determining the number of kids observed in the surveys, rather than density being more important. In 1984, permits were increased to reduce goat numbers towards the predicted optimum for maximum kid production. The 1985 survey showed 11% fewer older goats than in 1983, and the observed number of kids (21) was close to the predicted number (23). The increase in kids with a reduction in older goats further supported the conclusion of compensatory reproduction to hunter induced population reduction in this mountain goat population.

Published studies of compensatory responses in reproduction by mountain goats to changes in population size have yielded conflicting results. No compensation was found by Kuck (1977) or Hebert and Turnbull (1977) in native populations, but Adams and Bailey (1982) and Swenson (1985) reported compensatory reproduction in introduced populations. The differences among these studies may be due to the relative position of the populations in the ungulate irruptive sequence (Caughley 1970), with introduced populations in the "initial increase phase" best able to respond reproductively to reductions in numbers (Swenson 1985).

An analysis of past population fluctuations and reproductive rates of an introduced mountain goat population in the Absaroka Mountains of southwestern Montana, which was judged to still be in the "initial increase phase," suggested compensatory reproduction to hunter induced reductions in the number of older goats (Swenson 1985). Swenson (1985) predicted that maximum production of young would occur after the number of older goats was reduced by 25% from the 1983 level. However, one of the analytical methods used may have been inappropriate to test for density dependence. The purpose of this paper is to present a reanalysis of the question of density-dependent reproduction and to discuss the first-year results of an experimental reduction in the population through hunter harvest.

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STUDY AREA AND METHODS

The study area, located in the southern portion of the Absaroka Mountains in southwestern Montana, has been described previously (Swenson 1985). The mountain goat population resulted from the introduction of 23 goats during 1956-58 and has been hunted with a limited permit system since 1964.

Data on population trends and age ratios were collected during intensive aerial surveys with a pilot and observer in a 150 hp Piper Super Cub on calm, clear days (Swenson 1985). The 1985 survey was conducted on 24 and 25 August. The study area is relatively easy to survey, compared with most goat areas (Swenson 1985), due to open slopes above and below the cliffs.

Snow depth data are from the Soil Conservation Service snow course at Monument Peak (2,682 m), 3 km from the study area boundary; the 1 May readings were used as an index to winter severity. Harvest estimates are from the Montana Department of Fish, Wildlife and Parks telephone hunter survey. An attempt was made to contact all hunters, and the results were corrected for those not contacted, assuming that their responses would have been similar to those of the contacted hunters.

Statistical methods for testing curvilinear regressions using an $\underline{F}$ test follow Snedecor and Cochran (1967:453-456). Multiple regressions were calculated using a computer package (Lund 1983).

RESULTS

Reanalysis of Density-dependent Reproduction

In my first analysis of the data (Swenson 1985), I used a multiple regression with kids:100 older goats as the dependent variable and older goats observed and snow depth as independent variables to test for density-dependent reproduction. The resulting regression was statistically significant ($\underline{R} = 0.942$, $P < 0.005$, Swenson 1985). However, regressing a ratio on an independent variable can lead to autocorrelation when the independent variable is the denominator of the ratio (Eberhardt 1970). Plotting the number of young against the number of older goats from such an equation yields a hyperbolic curve (Eberhardt 1970), which is what I did to determine the number of observed older goats that would result in the greatest number of observed young (Swenson 1985).

I reanalyzed the data in Swenson (1985) to determine if the multiple regression of number of kids observed on number of older goats and snow depth was curvilinear. The hypothesis of linear regression was abandoned (F = 7.93, 1,5 df, $P < 0.05$), indicating significant curvilinearity in the regression, which was consistent with my original conclusion.

The multiple regression using a quadratic equation for number of older goats observed and a linear equation for snow depth explained 69% of the variation in the number of kids observed (R = 0.832, $P < 0.05$). Using this equation, and assuming average spring snow depths, the maximum production of young would be expected when 57 older goats were observed in the study area. This compares with 60 older goats calculated using the multiple linear regression reported in Swenson (1985). The new analysis did reveal one difference from the previous analysis, however. Swenson (1985) reported that the number of older goats (density) was more important than snow depth in determining kid:100 older goat ratios. The present analysis showed these two factors to be similar in imporance in determining the number of kids observed (R partial for number of older goats = 0.789, R partial for snow depth = -0.744; both $P < 0.05$). The higher correlation coefficient for number of older goats found in the first analysis may have been the result of autocorrelation.

Experimental Reduction

In 1984, 30 permits were issued for the Absaroka Mountains, an increase from the 1977-83 level of 15-18, in an effort to reduce the number of goats towards the optimum number for maximum kid production, as suggested in Swenson (1985). The hypothesis for this experiment, based on the previous analysis, was that reducing the number of older goats would result in an increased number of kids and that the increase in kids would be predictable from the multiple regression.

An estimated 29 mountain goats were taken by hunters in the Absaroka Mountains in 1984. This was a record high harvest since hunting was initiated in 1964. Eighteen of these goats came from the study area, based on the harvest survey and goats checked by department personnel.

During the 1985 aerial survey, 70 older goats were observed, a reduction of 11% from the 1983 survey (Table 1). The number of kids and the kid:100 older goats ratio increased 24% and 36%, respectively, so the total number of goats observed declined only 5% (Table 1). Using the multiple regression formula based on the data from 1966-83, 23.2 $\pm$ 4.5 kids (95% C.I.) were expected to be observed on the study area in 1985. The 21 actually seen (Table 1) were within the predicted range.

Table 1. Results of aerial surveys for mountain goats and spring snow depths in the Absaroka Mountains, 1966-85.

		N goats				
Year	Date	Older goats	Kids	Total	Kids:100 older goats	Spring snow depth (cm)
1966	5 Aug	30	18	48	60	150
1967	3 Aug	--	--	56	--	---
1969	1 Sep	59	27	86[a]	46	180
1972	24, 25, 27 Jul	66	19	85	29	218
1974	27 Jul	50	17	67	34	234
1977	4 Aug	40	20	60	50	119
1978	5, 7 Aug	42	18	60	43	193
1981	8 Sep	64	26	90	41	135
1982	19 Aug	76	16	92	21	221
1983	6 Aug	79	17	96	22	163
1985	24, 25 Aug	70	21	91	30	145

[a]Adjusted total, see Swenson (1985).

DISCUSSION

Reanalysis of the data supported the original conclusion that reproduction in the Absaroka mountain goat population is density dependent. Although this is based on correlative analysis, it is further supported by the increased reproduction observed following the experimental population reduction in 1984. Also, the negative correlation found by Swenson (1985) between goat numbers and population trends independently supported the conclusion of density-dependent reproduction, because the goats were better able to increase from lower densities.

The management recommendation in the first paper appears to still be appropriate. This population should be reduced until about 57-60 older goats are observed during the surveys on the study area, or a further reduction of 14-19% from the 1985 level. Using the multiple regression based on all 10 data points (Table 1), the expected number of kids observed = -5.172 + (1.353)(number of older goats) - (0.01189)(number of older goats)^2 - (0.05974)(snow depth in cm); $\underline{R} = 0.818$, $\underline{P} < 0.025$. Assuming mean spring snow depths, the maximum calculated number of kids observed from this equation would result from 57 observed older goats. This population should be reduced further and the reduction should be viewed as an experiment to further test the hypothesis of density-dependent reproduction in this goat population.

I agree with Bailey and Johnson (1977) that introduced mountain goat populations should be managed at an intermediate level before they reach an irruptive peak and decline to lower numbers and productivity. The management objective of introducing goats into unoccupied habitat should be maximum harvest for sport hunters. Besides providing more goats for harvest, managing populations at this initial increase phase should result in less impact to the native vegetation than if the exotic ungulate were allowed to reach an irruptive peak.

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QUESTIONS AND ANSWERS

Leslie Chow, California: Did you say there was an actual increase in the number of kids seen?

Jon Swenson, Montana: On our surveys, yes, by about 25%.

Daryll Hebert, BC: John, are you recommending that the population be maintained in a high reproductive capability for any specific period of time?

Swenson: Yes, I am recommending that we keep it that level of 57-60 adults that we see on our survey. Try to always keep it below the eruptive peak in that initial increase phase.

Hebert: How much evidence do you have if you let it go to that eruptive peak its going to do any damage?

Swenson: Well, we have evidence from the Crazy Mountains which is the next mountain range north where that happened. The population peaked at about 350 goats and then it declines just the way Lonn Kuck's population declined. As the population numbers declined, the reproduction declined and it was significantly correlated. There was also high harvest at that time and the decline was also correlated with that. The Crazy Mountains goats haven't been hunted for 10 years, and there's about 1/7 the number of goats now that there was at the peak, and the reproduction is still very low - in the low 20's per 100 older goats.

Hebert: I don't know what kind of winters you get in that particular area you're talking about, but with some of the other information that's around in terms of density dependent vs. density independent, if you leave that population at a higher level of reproductive capacity, remembering that for the last 7-10 years in western North America we've had some pretty mild winters, I think you're leaving yourself wide open for a major density independent factor to knock that population way down.

Swenson: Well, that's true, we get our best regressions when we put snow depth in there.

Hebert: I don't think you've seen all the snow depths yet that you might see.

Swenson: That could be. We've got data that goes back to the mid 60's. I guess the alternative is that if you let it go too high and we could see it crash like we did in the Crazy's, then we have a population that acts a lot more like these native populations.

Hebert: I think you've probably got a lot of flexibility between the two levels, though.

Swenson: Its hard to measure to know where that is.

Jim Bailey, Colorado: I don't understand Daryll's point. It seems to me that if there is going to be a major density independent adverse effect, it should be, if anything, less adverse to this population if its held at the level you want to hold it as opposed to if it is allowed to grow further and impact its resources before that event.

Swenson: Yes, that's a good point. I would agree with that.

Hebert: The point being that it depends on what segment of the population that that effect is going to take place on, and its probably more likely to take place on the kid component which you're pushing up then it is on a slightly higher population with fewer kids and more adults.

Swenson: But the overall long term effects on the population would probably be less if you leave it at a lower level. You'd have percentage wise a less of a drop due to a density independent factor like that.