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THE EFFECTS OF PROGRESSIVELY MORE RESTRICTIVE REGULATIONS ON RAM HARVESTS IN THE EASTERN ALASKA RANGE

WAYNE E. HEIMER, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

SARAH M. WATSON, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

Abstract: Behavioral and energetic theory, as well as empirical observations, suggest that young ram survival will be compromised in Dall sheep populations when few dominant rams are present, and that maximum sustainable harvests of Dall rams will be greater if full-curl rather than 3/4- or 7/8-curl rams are harvested. Consequently, an experimental full-curl regulation was established in a heavily hunted portion of the Alaska Range as a field test of this hypothesis. Results after 6 years of full-curl ram harvest regulations show a significant increase of 49% in mean ram harvest over previously sustained levels. Increased survival of young rams is the most viable explanation.

The purposes of this paper are to present an analysis of the full-curl Dall sheep (Ovis dalli dalli) harvest reported from a heavily harvested portion of the Alaska Range, and to relate it to the specific predictions of Heimer and Watson's (1986a,b) hypotheses regarding intensively harvested populations under full-curl regulation.

Ram harvest from the Alaska Range has been restricted under 3 regulatory schemes defining the minimum age/size limit for legal rams. From 1951 through 1978, minimal legal size was 3/4-curl. The 3/4-curl regulation was adapted to Dall rams from bighorn sheep (Ovis candensis) management (Dimarchi 1978). From 1979 through 1983, harvest was limited to 7/8-curl or greater rams. The 7/8-curl regulation was a response to economic, aesthetic, and biological concerns raised by the specter of a harvest consisting predominantly of 3/4-curl rams after approximately 40% of Dall sheep habitat in Alaska was closed to sheep hunting pending passage of the Alaska National Interest Lands Conservation Act (Heimer 1980). Since 1984, harvest has been limited to rams with at least full-curl horns or with both horns broken. The full-curl regulation was experimentally established in the Alaska Range east of Mt. McKinley to assess its effect on harvests in an area managed for the maximum opportunity to participate in Dall ram hunting (Heimer 1985).

If mortality resulting from ram hunting is limited exclusively to those rams which are shot, it follows that ram harvests should decline as the minimum age at harvest increases (such as with regulatory changes in legal bag limit from 3/4- to 7/8- and eventually full-curl). However, several studies suggest this is not what happens. Using behavioral observations and energetic theory, Geist (1971) postulated that involvement of young rams in breeding would increase their mortality rate. Heimer (1980) related Geist's postulation of the costs of social dominance specifically to intense harvest of 3/4-curl rams and lowered sustainable harvest rates. Later, Heimer et al. (1984) documented compromised survival among young, marked rams in populations which were heavily cropped at 3/4-curl age/size.

When compared with survival of like-aged Dall rams from the unhunted sample reported by Murie (1944) and Deevey (1947), the hunted populations showed notably higher mortality among immature rams. This high mortality was interpreted as suggestive of an age-independent mortality cost associated with social dominance because dominant behaviors are exhibited by young rams when mature rams are scarce or absent (Nichols 1972). The low survivorship of immature marked rams (Heimer et al. 1984) was consistent with Geist's (1971) prediction. Similar patterns of increased immature ram mortality have been identified in other heavily exploited bighorn sheep populations (Stewart 1980, Festa-Bianchet 1986, Jorgensen and Wishart 1986, Barichello et al., 1987).

Finally, Heimer and Watson (1986a) hypothesized that restoring ram abundance in populations where few old rams were present would result in increased maximum sustainable ram harvests. They suggested this would result from a combination of increased survival of young rams and increased ewe fecundity (Heimer and Watson 1986b). Heimer and Watson (1986a) also suggested the most practical management approach to increasing ram abundance in heavily cropped areas was establishment of a full-curl regulation for ram hunting.

On the basis of this body of work, the Alaska Department of Fish and Game established regulation of legal horn size at full-curl (or with both horns broken) in the Alaska Range east of Mt. McKinley beginning in 1984. The intent was to test the prediction of Heimer and Watson (1986a) that a greater ram harvest could be sustained under full-curl regulation than under 3/4- or 7/8-curl regulations. Sheep populations of the Alaska Range east of Mt. McKinley were selected because their population history was well known and intense harvest pressure had been documented there for many years.

METHODS

Ram harvest data reported from the Nenana River to the eastern limit of Delta Creek (Fig. 1) were summarized for the periods with each regulation (3/4-curl, 7/8-curl, and full-curl) in effect (Table 1). This portion of the eastern Alaska Range was selected for harvest comparisons because it receives intense pressure by ram hunters and is free of complications attending emigration and immigration. The marshy lowlands to the north, the glacial continental divide to the south, and the Nenana River to the west are barriers to sheep movement. Additionally, sheep are absent between Delta Creek and McGinnis Creek on the eastern border. This gap in distribution was first noted in 1973 (Alaska Department of Fish and Game, unpubl. data) and later confirmed using radio-marked sheep (Spiers and Heimer 1990).

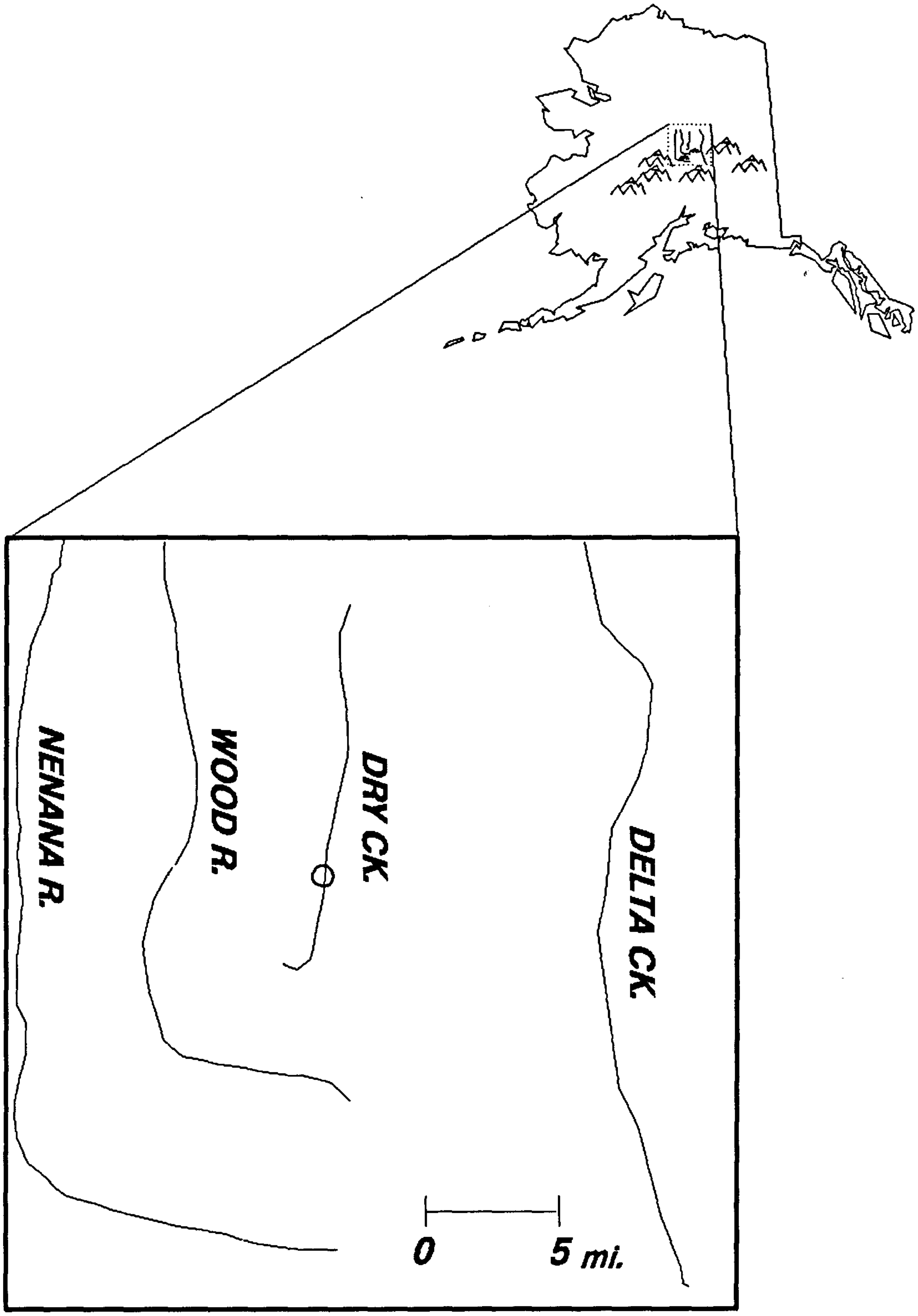

FIG 1. HARVEST COMPARISON AREA, EASTERN ALASKA RANGE

Table 1. Legal horn size, harvest, hunter numbers, percent success, relative cohort size, ewe population size, and horn size by year for the eastern Alaska Range, 1968-90.

Legal horn size/ year	Harvest	Hunter numbers	Percent success	Yearling: 100 ewe ratio (year recruited)	Ewe population size in production year	Ram horn size (in)
3/4-curl						
1968	107	224	48	--	--[a]	33.1
1969	82	217	38	--	--[a]	32.9
1970	97	228	43	--	--[a]	33.6
1971	121	309	39	--	--[a]	33.8
1972	104	302	34	--	--	32.5
1973	74	224	33	13 (1968)	--	31.3
1974	95	199	48	31 (1969)	--	31.8
1975	97	217	45	31 (1970)	734[b]	32.3
1976	114	250	46	51 (1971)	724[d]	32.3
1977[c]	103	244	42	16 (1972)	714[d]	32.3
1978	98	248	40	11 (1973)	704[d]	31.8
7/8-curl						
1979	86	226	38	11 (1973)	704[d]	33.4
1980	88	220	40	25 (1974)	694[d]	34.9
1981	117	253	46	23 (1975)	685[b]	34.9
1982	112	216	52	16 (1976)	690[d]	34.0
1983	100	206	49	17 (1977)	695[d]	33.7
Full-curl						
1984	108	300	36	17 (1977)	695[d]	34.0
1985	102	293	35	25 (1978)	700[d]	34.0
1986	138	362	38	19 (1979)	705[d]	34.2
1987	142	354	40	36 (1980)	707[b]	35.0
1988	151	415	36	43 (1981)	810[d]	35.2
1989	161	405	40	25 (1982)	787[d]	34.3
1990[e]	119	--	--	7 (1983)	743[d]	--

[a] No population estimate, however other ungulate populations in immediate area were high.

[b] Estimated from aerial censuses.

[c] Minimum harvest estimate.

[d] Linear interpolation between aerial censuses.

[e] Preliminary minimum harvest, hunter numbers, and horn size not known; this year not included in statistical tests.

This portion of the eastern Alaska Range includes the Dry Creek study area populations described by Heimer (1974), Smith (1978), and Heimer and Watson (1986a,b). The Dry Creek study area contains 20-25% of the 5,000 sheep in the eastern Alaska Range study area. Ewe population sizes from the Dry Creek area were used as indices of population size and trend in the eastern Alaska Range from 1968 to 1989. Ewe population sizes (Tables 1 and 2) were estimated using resightings of marked sheep on comparable high effort fixed-wing aircraft censuses (Heimer and Watson 1986b). Horn size (Table 1) was calculated from hunter reports.

Ratios of yearlings:100 ewes observed at the mineral lick on Dry Creek each year (Heimer and Watson 1986b) were used as indices of relative cohort sizes within the study area (Table 1). On-ground classifications of sheep throughout the eastern Alaska Range from 1972 through 1978 showed production and recruitment ratios gathered at the Dry Creek mineral lick accurately reflected those of sheep populations from other portions of the study area (Smith 1978).

Mean harvest, hunter numbers, and hunting success were compared among the 3 regulatory periods. Means for hunter numbers and hunting success from the periods of differing regulations were compared using a 2-tailed Student's $\underline{t}$-test ($\underline{P} < 0.05$). The 2-tailed test was selected because the directions of change were not specified in the hypothesis. Student's 1-tailed test was used to test for significance ($\underline{P} < 0.05$) of change in mean harvest because it was predicted to increase. Linear regression analysis was used to test the relationship between harvest and hunter effort plotting harvest as a function of hunter effort.

RESULTS

Harvest

Mean harvest (Table 1) under the full-curl regulation (harvest = 134 rams/year, S = 24, N = 6 years) was significantly greater ($\underline{t}$ = 2.7249, P < 0.05) than under 3/4- (harvest = 99 rams/year, S = 13, N = 11 years) or 7/8-curl (mean = 101 rams/year, S = 14, N = 5 years) regulations ($\underline{t}$ = 4.4035, $\underline{P} < 0.001$). There was no significant difference ($\underline{t}$ = 0.2783, $\underline{P} > 0.05$) in mean harvest between the 3/4-curl regulation period and the 7/8-curl regulation period. When data from the 3/4- and 7/8-curl harvest periods were pooled, their mean (100 rams/year, S = 13, N = 16 years) was significantly less ($\underline{t}$ = 4.3149, $\underline{P}$ < 0.001) than the mean full-curl harvest.

Hunter Numbers

There was no significant difference ($\underline{t}$ = 1.0612, $\underline{P} > 0.05$) between the mean number of hunters using the area under the 3/4-curl (mean = 242 hunters, S = 35, N = 11 years) and 7/8-curl regulations (mean = 224 hunters, S = 18, N = 5 years). However, testing the mean for these periods pooled (mean = 236 hunters, S = 31, N = 16 years) revealed a significant ($\underline{t}$ = 2.9925, $\underline{P} < 0.01$) increase in hunter numbers during the full-curl regulation period (mean = 309 hunters, S = 91, N = 6 years).

Hunter Success

Percent hunter success was variable between regulatory periods. There was no significant difference (t = 0.3075, P > 0.05) between the mean percent success during the 3/4-curl (mean = 41%, S = 5, N = 11 years) and the 7/8-curl periods (mean = 45%, S = 6, N = 5 years). When these periods were pooled (mean = 42%, S = 5, N = 16 years) and compared with hunter success during the full-curl period (mean = 38%, S = 2, N = 6 years), a statistically significant decrease was identified (t = 2.148, P < 0.05).

Effect of Hunter Numbers on Harvest

Harvest was not closely linked to the number of hunters participating when harvest was tested as an independent variable. Regression of harvest as a function of hunter numbers (Table 1) during the 16 years of 3/4- and 7/8-curl regulations, when there was no significant difference in harvest or success, but a large variation in the number of hunters, (range = 199-309 hunters, mean = 236 hunters) did not suggest a strong, linear relationship (harvest = 0.22 hunters + 47, r = 0.53).

Horn Size

Horn size decreased significantly (t = 3.742, P < 0.01) from a mean of 33.2 inches (S = 0.5263, N = 5 years) before 1973 to a mean of 31.9 inches (S = 0.4761, N = 6 years) from 1973 through the end of the 3/4-curl regulation period. Subsequently, horn sizes increased with the 7/8- and full-curl regulations.

Ram harvests from 1971 and 1972 were produced by 309 and 302 hunters, respectively. These levels of participation by hunters were higher than in the years between 1968 and 1983 (all of which had 253 or fewer hunters afield). The mean number of hunters for 1971 and 1972 was 306 hunters, 37% above the mean of the previous 3 years and 44% above the mean of the following 3 years. Changes in horn size, harvest, and the transiently high hunter numbers of 1971 and 1972 (Table 2) indicate standing stocks of rams were depleted during those years.

Table 2. Mean indicator ewe population size, harvest, hunter numbers, and percent success for the eastern Alaska Range, 1968-89.

Regulation (years)	Mean indicator ewe population in Dry Creek	Mean annual harvest	Mean number hunters	Mean harvest success
3/4-curl (1968-78)	724 ewes	99 rams	242	41%
7/8-curl (1979-83)	700 ewes	101 rams	224	45%
Full-curl (1984-89)	713 ewes	134 rams	354	38%

Ram Survival

Yearling cohort sizes, as indicated by yearlings:100 ewes ratios, and their relationship to harvests when these cohorts reached legal age/size suggest increased survival of sublegal rams. Yearlings:100 ewes ratios produced in 1968-71 (before ram depletion by heavy hunting and the winter of 1971-72) averaged 31 yearlings:100 ewes (N = 4, S = 15.5). These cohorts eventually produced mean harvests of 99 3/4-curl rams per year. The mean yearlings:100 ewes ratio for cohorts which produced rams harvested during the 7/8-curl period (1973-77) was significantly less (t = 3.4758, P < 0.02), averaging only 18 yearlings:100 ewes (N = 5, S = 5.6). However, harvests from these smaller cohorts still produced a mean of 101 7/8-curl rams per year which is almost identical to the 99 rams per year harvested from the significantly larger cohorts. These data suggest that survival to harvestable age was greater for these smaller cohorts.

DISCUSSION

The significant increase in mean ram harvest under full-curl regulation is consistent with Heimer and Watson's (1986a,b) prediction that increased ewe fecundity, natality, and young ram survival expected to result from minimally distorted ram age structures would lead to increased ram harvests where maximum hunting participation is allowed. The credibility of this result should be enhanced because use of all harvest data following the full-curl regulation minimizes the negative effect of including the harvests from the first 2 years following the period of maximal 7/8-curl ram harvest. Results suggest harvest did not respond to regulatory change until the third year following implementation of the regulatory change (Table 1). During 1986-1989, the third through sixth years of full-curl regulations, mean ram harvests (149 rams/year) exceeded harvests during 3/4-curl hunting (99 rams/year) by 50%.

The statistically significant 58% increase in hunter participation during the full-curl regulation period suggests the increased harvest could have been due to increased numbers of hunters aside from any effects of ram social structure on production or survival of young rams. We do not think the data support this explanation.

For this hypothesis to be acceptable, it must follow that harvest of rams was low enough under 3/4- and 7/8-curl regulations that standing stocks of full-curl rams were accumulating to be harvested later. There are no data which suggest this occurred. Aerial survey data from 1974 and 1975 (Heimer and Watson 1986b) showed rams greater than 3/4-curl were scarce, amounting to only 3% of the total population, while Heimer and Smith (1975) reported other hunted populations in Alaska were averaging 15% rams greater than 3/4-curl.

Furthermore, the decrease to significantly smaller mean horn sizes after 1972, the unusually severe winter of 1971-72 (Watson and Heimer 1984), the transiently high hunter numbers of 1971 and 1972, and the weak regression coefficient of harvest as a function of hunter numbers during the 3/4- and 7/8-curl regulatory periods argue against this hypothesis. The eastern Alaska Range has been heavily hunted since the early 1970s. All these findings consistently argue against the possibility that the primary cause of increased ram harvests was increased hunting pressure.

If the increasing harvest of full-curl rams did not result from increased hunter effort, alternate explanations must be considered. One population response associated with increased ram abundance in the Dry Creek study area was increased ewe fecundity and resulting lamb production (Heimer and Watson 1986c). Another possibility, also postulated by Geist (1971) and Heimer and Watson (1986a,b), is lowered mortality among young rams.

The sustained harvest of about 100 rams under the 7/8-curl regulation, even though this harvest came from smaller yearling recruitments, suggests increased survival. Class III and IV rams were scarce during the aerial survey of 1975. Still, the unusually large cohort of 51 yearlings:100 ewes recruited in 1971 (Heimer and Watson 1986b) would have been 3 years old (Class II) when the yearling cohort of 1973 was recruited. Surviving members of the large 1971 cohort would have been in Classes III and IV when the 1977 cohort was recruited. It is possible that the rams from the 1971 cohort could have limited social activity by the ram cohorts harvested during the 7/8-curl period by dominating these younger rams even though these dominating rams were not fully mature themselves. The 49% higher harvests recorded under the full-curl regulation suggest survival increased further with the increasing presence of Class III and IV rams. V. Geist (pers. commun.) predicted further increase in harvest would follow change from 7/8- to full-curl based on the radical increase in rutting activity he reported among rams of approximately 7/8-curl size (Geist 1971).

Before concluding increased production and increased ram survival are the primary causes of increased harvest, other possibilities must be considered. Wolf numbers were reduced in 1976 and 1977. This may have decreased ram mortality during 1976-78. Before 1976, sheep were presumably being used by wolves in the absence of abundant preferred prey (moose and caribou) (Heimer and Stephenson 1982). However, wolf numbers were reestablished at their previous abundance by the beginning of the 7/8-curl regulatory period. They currently persist at densities which are equal to or exceed those documented during 1968-75 (McNay 1986). Still, moose and caribou populations adjacent to sheep ranges have increased, and wolves may now be killing fewer sheep than before. However, yearling recruitment and survival rates of marked ewes in the Dry Creek population showed no changes in relation to wolf abundance from 1970 through 1986 (Heimer and Watson 1990).

Weather may also affect lamb production and young ram survival. To test this possibility, Heimer and Watson (1986c) investigated snow accumulation as an indicator of weather severity during gestation, assessed the severity of weather at lambing, and correlated growing conditions for food plants in summer with subsequent lamb production and yearling recruitment. Weather conditions likely to affect production and survival were not statistically different ($\underline{P} > 0.05$) during periods with 3/4-, 7/8-, and full-curl hunting (Heimer and Watson 1986c).

Furthermore, documented ewe survival has shown no significant variability ($P > 0.05$) (Heimer and Watson 1990) throughout the 3/4-, 7/8-, and full-curl periods. We think weather conditions should affect young rams and ewes equally. Consequently, we do not think the increased ram harvests can be attributed to unusually favorable weather conditions.

Lastly, increased harvests could have been due to ewe population growth in the study area. This did not occur. Evidence suggests the Dry Creek study population accurately represents the population trend for sheep throughout the study area (Smith 1978). The ewe population in the Dry Creek area has not increased sufficiently to account for the increases in harvest (Tables 1 and 2). The Dry Creek ewe population declined slightly but steadily from 1970 through 1975, and then slowly increased beginning in 1977 (Table 1). It is currently thought to be about as large as it was in 1970. Still, there is no significant difference ($P > 0.50$) between the average Dry Creek ewe population size (719 ewes) associated with the mean harvest of 99 rams per year at 3/4-curl and the mean ewe population size (734 ewes) linked to the mean harvest of 134 full-curl rams from 1984 to 1989. The 2% increase in the trend-indicating ewe population could not be responsible for the 32% to 49% increase in ram harvest.

In conclusion, we think the most likely causes of the observed increase in harvest were increased lamb production and increased ram survival. Both of these causes were probable and predictable results of a more ordered social environment. It is possible that decreased predation associated with wolf reductions and a subsequent shift away from sheep as a major prey item for wolves contributed somewhat to the increased ram survival. The other possible causes including increased hunter effort, increased population size, and favorable weather conditions appear to offer little in the way of explanation.

We emphasize the only consistently management-alterable variable among this list of possibilities is ram population composition. Managers may or may not be able to limit predation, and they certainly cannot control weather. Hunter numbers can be controlled by restrictive permit systems, but this method carries the risk of decreased public interest and is not typically a means for maximizing public benefits. This leaves control of the age structure of rams through hunting regulations as the manager's most promising tool for increasing public benefits associated with maximum-use management objectives involving hunting.

We have empirically demonstrated that full-curl regulations did not result in a reduced harvest. In contrast, harvest increased following full-curl regulations. The causes of this increase are not ambiguous. Hence there appears to be little risk and measurable gain associated with full-curl regulations or other means of assuring a minimally compromised ram age structure in populations managed to provide maximum hunting and harvest opportunities. In Alaska, hunters clearly favor an assured opportunity to take larger rams and have vocally supported increased full-curl ram regulations.

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