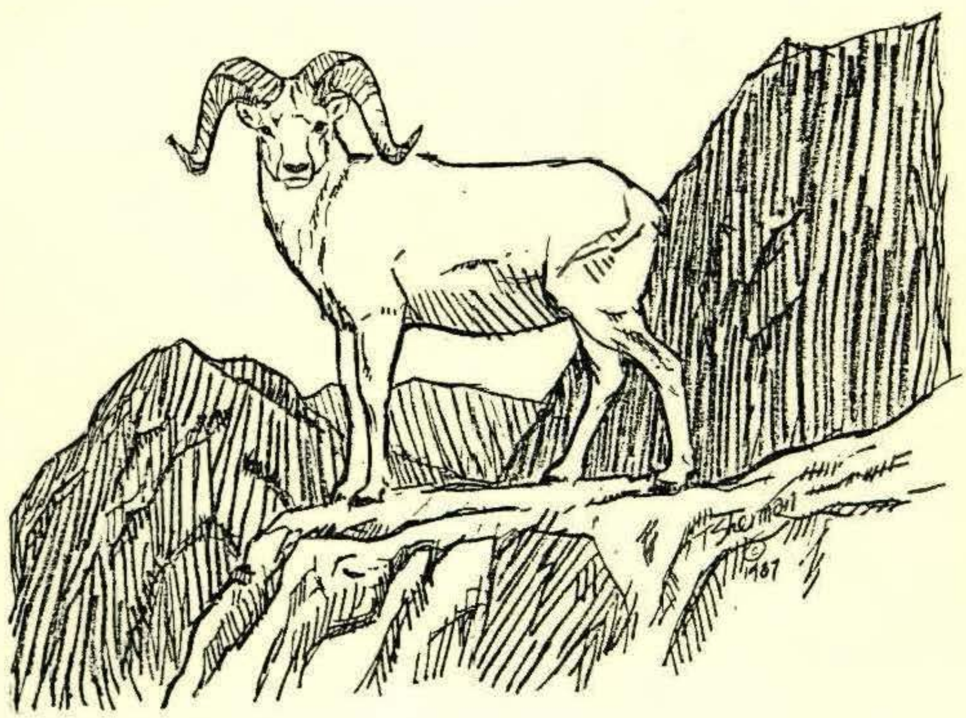
Alaska Department of Fish and Game
Division of Game
Federal Aid in Wildlife Restoration
Research Final Report

PUBLICATION OF DALL SHEEP FINDINGS AND DEVELOPMENT OF FUTURE RESEARCH DIRECTION



by
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Project W-22-5
Job 6.10R
February 1987

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SUMMARY

Following the completion of a major project segment, a comprehensive analysis and interpretation of the data base relevant to Dall sheep (*Ovis dalli*) ecology and management was conducted and published by the Alaska Department of Fish and Game to meet departmental needs and reporting obligations established by the funding agency. In addition, 2 papers were prepared, presented, and published in the Proceedings of the Northern Wild Sheep and Goat Council to help disseminate information to wild sheep managers. Abstracts of these papers are included in this report. Also, a research planning study was conducted to determine areas where future Dall sheep research is most needed. This was done by presenting a working hypothesis of Dall sheep ecology and management, in the form of a questionnaire, for response by Game Division staff members. Concurrence on possible information needs was assessed. This was not a particularly successful enterprise. Possible reasons are discussed, and recommendations for improving the technique are offered. Field studies were continued at the Dry Creek lick. Data gathered during the unusually dry summer indicated that mineral lick use may be more nutritionally motivated than has previously been appreciated. Alkaline earth cation concentrations in emerging forage appear to vary with soil moisture and produce varying physiological states that determine mineral lick use. Mitigation measures are considered and recommendations offered.

Key Words: Dall sheep, mineral lick, mitigation, nutrition.

CONTENTS

BACKGROUND

The Dall sheep (*Ovis dalli dalli*) populations in Dry Creek, Interior Alaska, were continuously studied from 1968 through 1986. Changes in population size and composition were correlated with weather severity, wolf (*Canis lupus*) predation, Dall sheep density, and differing levels of ram harvest by hunters. Similar data were collected from a population near the Robertson River with a different harvest scheme; comparison was made between populations. A final report (Heimer and Watson 1986) identified ram abundance and ram population age structure as important, controllable influences on Dall sheep population dynamics and performance. Although theoretical arguments predicted similar results years ago (Geist 1971), mountain sheep managers are generally unaware of the management implications of ram abundance and age structure. Consequently, a 1-year project was undertaken to publish these data and to plan further work while continuing to gather field data.

In planning further work, Sarah Watson and I (Heimer and Watson 1986) synthesized an integrated model (working hypothesis) from diverse data sets relating to Dall sheep ecology and management. This working hypothesis summarizes current knowledge regarding Dall sheep.

Future research on Dall sheep could be directed toward further testing the working hypothesis or meeting other information needs. A survey of wildlife managers, research biologists, and administrators within Game Division was conducted to obtain input on research direction. Planning for future work was not accomplished before a decision about field activities during summer 1986 was required, but to preserve future research options, data were collected at the Dry Creek lick in June 1986.

OBJECTIVES

1. Prepare for refereed publication a manuscript containing data collected on the sheep project during the past 16 years and presenting a hypothesis regarding the influence of ram age structure in Dall sheep population dynamics.

2. Obtain input from wildlife managers and senior staff within Game Division regarding future research direction in the Dall sheep program.

3. Preserve continuity of the Dry Creek data base by gathering data on lamb production, survival, age at 1st reproduction, and adult survival, from the population using the Dry Creek lick.

PROCEDURES

Objective 1: Publication

Additional data on weather influences were gathered from published sources. These data consisted of precipitation and temperature records published by the Department of Agriculture, the Soil Conservation Service, and the United States Weather Bureau climatological survey. These data were included in a manuscript dealing with variations in lamb production, and submitted to the editors of the Proceedings of the Northern Wild Sheep and Goat Council for review and publication. A 2nd manuscript was prepared on the relevance of ram abundance to ram harvest.

Objective 2: Evaluation of Working Hypothesis

A questionnaire summarizing the current model (working hypothesis) of Dall sheep ecology and management was developed. The questionnaire (Appendix A) consisted of summary statements with brief supporting paragraphs about Dall sheep population biology, range limitation, habitat components, predation, weather influences, disease, disturbance, and hunting. It was sent to area biologists, research and management coordinators, and senior staff in Game Division. The questionnaire was accompanied by a summary interpreting recent research findings as well as referenced, published material and conclusions upon which the working hypothesis was based.

Agreement or disagreement with various aspects of the working hypothesis was assessed by tallying the number of individuals who agreed or disagreed on each aspect of sheep ecology. Qualifying statements were analyzed. Components of the working hypothesis which revealed significant disagreement or uncertainty among respondents were considered to be of high priority for future work.

Objective 3: Field Activities

We continued to gather data as detailed in Heimer and Watson (1986).

RESULTS AND DISCUSSION

Objective 1: Publication

Two manuscripts, one on factors affecting lamb production and one on how to maximize ram harvest, were presented at the Northern Wild Sheep and Goat Council. These papers will be published in the Conference Proceedings; abstracts are presented in Appendices B and C.

Publication of these papers in the Proceedings of the Northern Wild Sheep and Goat Council will assure their availability to wild sheep managers in North America and meet the need for the information outside Alaska. However, distribution of these proceedings is limited, being best known among wild sheep research and management specialists. Distribution of the information to other wildlife managers will require additional publications. To meet this need, we are investigating the suitability of publishing the material as a Wildlife Monograph.

In the past year, we worked with National Wildlife magazine to produce a feature article on Dall sheep; the article emphasizes the implications of ram abundance and age structure (Mauck 1986). Current plans call for this article, with some additional interpretive information, to be reprinted in the Department magazine, Alaska Fish and Game.

Objective 2: Evaluation of Working Hypothesis

Questionnaires were sent to 36 individuals within the Game Division; 18 responded after 1 reminder letter was mailed. Of the respondents, 3 essentially disqualified themselves, but 2 of these stated that publication of past findings through the peer review process in accepted journals was, in their opinion, more important than continuing to refine the hypothesis at this time. This feeling was expressed by 2 other respondents who made significant comments on the working hypothesis.

When the responses of individuals agreeing and disagreeing with each component of the working hypothesis were summed, the following results emerged:

Population Biology Statement:	10 respondents-- 7 agreed, 3 disagreed (70% agreement)
Range Limitation Statement:	9 respondents-- 4 agreed, 5 disagreed (44% agreement)
Habitat Components Statement:	11 respondents-- all agreed (100% agreement)
Predator Statement:	8 respondents-- 6 agreed, 2 disagreed (75% agreement)
Weather Influences Statement:	9 respondents-- 8 agreed, 1 disagreed (89% agreement)
Disease Statement:	9 respondents-- all agreed (100% agreement)
Hunting Statement:	16 respondents-- 8 agreed, 8 disagreed (50% agreement) (everyone took a stand on this statement)
Disturbance Statement:	9 respondents-- 9 agreed, 1 disagreed (89% agreement)

Those components of the working hypothesis which were agreeable to 75% of the respondents were arbitrarily considered "well understood" and assigned low priority for future work. These areas of Dall sheep ecology included: habitat components, predation, weather influences, disease effects, and disturbance. The fact that substantial agreement existed on these statements does not necessarily show that our understanding in these areas is correct. It just shows that most respondents agreed with the statements.

The areas where disagreement was apparent were hunting effects (50% disagreement) and range limitation (56% disagreement). The statement on range limitation was apparently confusing to several respondents because they commented at length about the terms "limitation" and "quality and quantity" relating to forage. From these data, it appears that the research program should pursue an evaluation of differing hunting schemes for Dall sheep. This is something we can do (for minimal cost) to benefit sheep populations. It would be very difficult (i.e., expensive) to manupulate range conditions for the benefit of Dall sheep.

While our efforts with the questionnaire were not particularly useful, I think the concept of a working hypothesis for Dall sheep should be considered on its own merits. I attempted to summarize our working knowledge and the management options consistent with this knowledge of Dall sheep. I also suggested potential research projects designed to further enhance the validity of the working hypothesis and meet existing, specific management needs through the questionnaire. (Appendix A).

The questionnaire approach has some utility, but it also has many drawbacks, because of the time requirement and effort necessary to respond to the questions. A workshop where working hypotheses could be presented with their supporting data bases would probably be more productive.

Objective 3: Field Activities

A total of 1,450 ewes, lambs, and yearlings was classified from 16 through 30 June 1986. This period of time was selected because Heimer (1973) showed lamb percentage in incoming sheep at the Dry Creek lick stabilized by mid-June. These data give a relative lamb production rate of 33 lambs:100 ewes. This ratio is lower than the mean production and recruitment for the last 8 years of the study (Heimer and Watson 1986) in which mean lamb production averaged 54 lambs:100 ewes.

Classification of ewes and yearlings indicated 22 yearlings:100 ewes. Since 1978, the average yearling recruitment has been 27 yearlings:100 ewes. This mean includes the poor recruitment (7 yearlings:100 ewes) following heavy snow during winter 1981-82. If that recruitment, the poorest ever recorded in Dry Creek, is deleted, the mean is 30 yearlings:100 ewes. By both comparisons, 22 yearlings:100 ewes was a poor recruitment.

Snow accumulation and weather summaries for winter and spring 1985-86 are not yet available, so weather indices (Heimer and Watson 1986) cannot be calculated. However, subjective observations indicate that snow accumulation was low during winter 1985-86. Also, at the Dry Creek lick in early June we experienced atypically cool temperatures with green-up later than usual. Flowers of *Dryas octapetala* were scarce on 10 June; usually by this date *Dryas* flowers are abundant. We estimated green-up was a week to 10 days later than normal. Also, observers reported the area seemed generally drier than normal throughout the month of June. Factors contributing to low production of lambs remain speculative, but may include a late green-up and unfavorable lambing weather. They do not include low ram abundance.

Lactating ewes captured for marking in both June 1985 and June 1986 were in unusually poor condition. Spring green-up, as signaled by the emergence of blossoms on Richardson's anenome (*Anemone richardsoni*) and *Dryas* was delayed in both 1985 and 1986. In 1985, late green-up was probably a major contributor to poor lamb survival. A helicopter survey in July 1985 indicated significant mortality (approximately 10%) had occurred between the end of June and late July when the survey was conducted. We had no opportunity to determine if this effect was operative in 1986.

The cool, dry period of early summer 1986 in Dry Creek ended about 10 June. Record high temperatures were recorded in Interior Alaska during the remainder of the summer. Mineral lick activity was minimal during this extremely hot weather, and the Dry Creek drainage was more arid than I have seen it in 15 summers. This unusually hot and dry weather apparently affected mineral lick use by the sheep population.

Only 65 of the possible 95 marked ewes (68%) visited the mineral lick during June 1986. This represents either an unprecedented failure (32%) to return to the mineral lick, or a major mortality. I do not think it is the latter, as most marked ewes were adults; with no noticeably heavy snowfall, a large die-off of adults is quite unlikely. Also, 20 of 32 (63%) old ewes (>9 years) were observed. The presence of these older ewes is not only inconsistent with a high adult mortality but indicative of a mild winter (Watson and Heimer 1984). The actual occurrence remains speculative, but we hypothesize that the unusually dry summer of 1986 may have resulted in a decreased mineral lick drive among the Dry Creek sheep.

The reason sheep use mineral licks has interested wildlife observers for many years, and preservation of mineral licks has been a high priority among wildlife biologists. Animal physiology has always been assumed to play a major role in mineral lick use. Still, the understanding of mineral physiology is a specialized field that is not widely understood. I think a brief review of the relevant literature may be useful to biologists and land-use planners concerned with justifying mineral lick preservation. Hence, I include the following brief review.

Jones and Hanson (1985), in their extensive book on mineral licks in North America, proposed a nutritional/physiological model which explains decreased mineral lick use through a reduced lick drive. Based on soil samples from 276 ungulate mineral licks throughout North America, characterization of soil types within the regions surrounding these mineral licks, and review of the physiology of mammalian ion regulation, they deduced that the common physio-nutritional lick drive among North American ungulates is acquisition of the alkaline earth cations, magnesium and calcium. This may be considered a new finding because naturalists and writers from Ernest Thompson Seton in his 1901 classic, Lives of the Hunted, to Nancy Ferrell in the July-August 1986 issue of Alaska Fish and Game have concluded that "salt licks" supply common salt, sodium chloride, required by the animals that use them. Because of the association of sodium chloride with many licks, particularly in the eastern United States, most biologists have also held this opinion.

However, Jones and Hanson (1985:4) stated that,

> "...Some biologists...have discounted the importance of sodium. French (1945), working in west Africa, found difficulty in ascribing importance to sodium. Cowan and Brink (1949), in a survey of 29 lick sites in the Rocky Mountains of British Columbia and Alberta, also discounted sodium chloride as the major attractant for the wide variety of native ruminants using these ranges. Their opinion was 'that trace elements may well be the critical constituents' (p.387). In his monograph on North American elk, Murie (1951:237, 309-313) reviewed and discounted the importance of common salt both as a constituent of lick earths and as a nutrient to be supplied to free-ranging elk. Heimer (1973:63) speculated that Dall sheep countervailed high phosphorus loads from winter and spring alpine vegetation by geophagy of calcium- and magnesium-rich earths that provided cations for excretion of the phosphorus."

Jones and Hanson (1985) present strong arguments which support their working hypothesis that North American ungulates preclude tetany caused by low serum magnesium levels by obtaining magnesium at mineral licks. Low serum magnesium levels occur because of dietary deficiencies and the absence of significant body reserves of this ion. Magnesium occurs primarily inside cells and functions most notably as an enzyme activator and/or a cofactor in metabolic processes. There is no known storage area, in the body, for magnesium.

Effects of the generally limited abundance of magnesium in sheep diets are amplified by its low concentration relative to potassium in forage. High levels of potassium relative to magnesium (and calcium) in emerging spring vegetation cause ionic imbalance in mineral-lick-using species such as Dall sheep. Normally, potassium and sodium are kept in balance in the mammalian body by chemoreceptors which monitor the ratio of these 2 ions in cerebrospinal fluid. When this balance is tipped in favor of potassium by sodium loss or potassium ingestion, a hormone called aldosterone is secreted by the adrenal cortex. This hormone acts on the kidney to limit loss of sodium from the body. The mechanism of this action results in increased excretion of the excess potassium (Ruch and Patton 1965). Both sodium and potassium are normally abundant in Dall sheep diets, but the mammalian system is adapted to conservation of sodium through the aldosterone mechanism. Mechanisms for potassium homeostasis apart from sodium have not been found. Unfortunately for northern ungulates, aldosterone also increases fecal loss of magnesium (Levin 1976). This loss is probably compounded by high concentrations of phosphorus in the emerging alpine plants as Heimer (1973) hypothesized.

Jones and Hanson (1985) also cite work by Grunes et al. (1970) which demonstrates that forages with high amounts of potassium relative to magnesium and calcium lead to net calcium and magnesium loss because the potassium load tips the sodium/ potassium balance in cerebrospinal fluid toward potassium. This triggers aldosterone secretion with the unfavorable side effect of compromising absorption of magnesium from the gut. Consequently, lowered serum magnesium levels follow with the danger of metabolic dysfunction (which produces tetany) due to lowered enzyme activity resulting from insufficient quantities of intracellular magnesium. To forestall these potentially fatal symptoms, many North American ungulates, including Dall sheep, use mineral licks as sources of magnesium and calcium which are most critical at the time of plant emergence, lambing, and lactation. Calcium is lost from bone to maintain serum levels over winter, and is also required for milk production and skeletal reconstruction (see Heimer 1983 for data on changes in Dall sheep skeletal mass).

What does all this have to do with apparently lower than expected mineral lick use in Dry Creek? The amount of magnesium found in emerging plants may vary even though soil concentrations are constant. Jones and Hanson (1985) cite empirical evidence (Thomas and Hipp 1968) that the amount of potassium relative to magnesium and calcium in plant tissue decreases with declining soil moisture. When soil moisture is high the relative chemical activity or chemically active concentration of monovalent cations (such as potassium with an oxidation state of plus 1) increases. Consequently, plants absorb more potassium. In drier circumstances, the chemical activity of the divalent cations (magnesium and calcium with oxidation states of plus 2) is relatively greater and plants absorb more of these cations even though measurable concentrations in soil samples are unchanged. This is due to a factor called the dilution effect which occurs in the outer layers of the soil colloidal system (Wicklander 1964).

Other hypotheses involving low soil temperatures and subsequently elevated concentrations of ammonium ions in the soil during early growth have also been suggested as causative factors in lowering magnesium plus calcium concentrations in plant tissue (Wilcox and Hoff 1974). These mechanisms are consistent with low Alaskan soil temperatures and the general paucity of nitrogen-fixing bacteria in Alaskan alpine soils. They probably contribute to hypomagnesemia as well.

Winter 1985-86 produced low snowfall which probably led to relatively dry spring soils and increased magnesium and calcium concentrations in plant tissue. In addition to these conditions, the high ambient temperatures which followed during the 2nd half of June probably enhanced dessication of the soils. Finally, the lamb:100 ewe ratio was low in spring 1986; lactating ewes have the highest documented frequency and duration of mineral lick use (Heimer 1973).

These circumstances, if the model proposed by Jones and Hanson (1985) is relevant, may have acted to produce generally lower metabolic stresses on the Dry Creek Dall sheep than we have normally observed. As a result, I think it highly probable that a lower level of mineral lick use resulted.

Heimer and Watson (1986) developed a model for population estimation which worked well under the weather conditions extant from 1980 through 1984. These conditions were typical of those prevailing in Alaska. Still, spring 1986 was unusually dry and ewe fidelity to the Dry Creek lick was low. This apparent change in use requires discussion of at least 2 points.

First, the model of Heimer and Watson (1986) may not be universally applicable. It requires consistently high fidelity to mineral licks. In my experience this has occurred with "normal" precipitation and temperature conditions. These variables influence soil moisture and plant nutritive composition. The frequency of occurrence of unusually hot and dry weather following light winter snow and a late plant emergence is not known but those conditions are apparently rare. Still, the basic requirement of the monitoring scheme proposed by Heimer and Watson (1986) is a continuing field presence. In the event of an unusual occurrence such as the one documented here, confirmation of the status (presence or absence) of most marked individuals could be determined later in summer by helicopter survey. Alternatively, application of the modeling procedure could be skipped for a year (providing, of course, that weather conditions return to "normal") by lumping 2 years together as a single mortality period. A good population estimate could still be obtained once mortality is determined.

The more important aspect of these findings (low mineral lick fidelity associated with dry weather conditions which probably increased the magnesium plus calcium to potassium ratio in forage) may be that this is the 1st demonstrable instance of nutritional necessity for Dall sheep mineral licks. If mineral lick use is determined by lick drive, and if Dall sheep had sufficient range resources during spring 1986 to reduce lick drive, it follows that use of mineral licks is probably nutritionally motivated. Therefore, mineral licks could be a nutritional necessity under conditions of "normal" snowfall and wet spring soils.

The Alaska Department of Fish and Game has taken the position that mineral licks must be important to Dall sheep populations because of the highly visible, intense use they receive. Further, Heimer (1973) proposed that mineral licks function to maintain genetic homogeneity among populations that used them. Still, there has been a lack of data indicating actual dependence on these licks. With the advent of Jones and Hanson's (1985) exhaustive review of literature and synthesis of an acceptable physiological hypothesis explaining mineral lick use, and our observations that intensity of lick use correlates with weather conditions, it is apparent that we can justify protection of mineral licks. Whenever mineral licks or access to them may be destroyed by human activity, wildlife managers must consider actions to mitigate or minimize these impacts. It is important that wildlife managers realize there is a considerable data base which suggests a physiological need for replacement of mineral components in affected ungulate populations. If it becomes necessary to mitigate due to the loss of a lick, nutritional supplements emphasizing magnesium and calcium should be supplied.

MANAGEMENT RECOMMENDATIONS

This project was designed to define future work and goals, and to publish present data. I think our collective experiences during the past year merit consideration of the following recommendations:

1. Working hypotheses for Dall sheep should be formulated into working documents. These should identify research needs and help generate new information. Major components of Dall sheep ecology should be summarized in brief statements supported by data. Data need not be unequivocal but should be the most complete available.

2. Protection of mineral licks should be a high Department priority. A research project that investigates lick use as a function of forage potassium to magnesium plus calcium ratios, should produce relevant data.

3. When considering mitigation, managers should look beyond common salt as a nutritional component in mineral licks, and consider providing alkaline earth cations in a suitable matrix.

ACKNOWLEDGMENTS

Sarah Watson coauthored the papers we published, and participated fully in articulating the working hypothesis. She also made a major contribution to gathering mineral lick use data in Dry Creek and understanding the weighty writings of Jones and Hanson. Sarah also deserves credit for clarifying our hypothesis regarding the importance of social status in ram survival, for writer Bob Mauck.

I would like to thank those individuals in Game Division who thoughtfully reviewed the working hypothesis. In addition, I should acknowledge the contributions of our colleagues from Canada, Manfred Hoefs, John Eliott, and Kevin Lloyd. Wayne Regelin suggested I seek input from others about the future direction of our sheep research program.

Roy Osborn, Steve Youngs, Phil Garrett, Jane Schied, and Junior Kerns also helped with mineral lick observations during the hot, dry June of 1986. I would also like to gratefully acknowledge the support the 222nd Brigade provided during their helicopter training missions. Junior Kerns organized this support, and I thank him for that also. Harry Reynolds developed this support relationship in recent years for grizzly bear work. I am grateful to Harry.

During a previous report, the contributions of Marguerite Paine Matthews were inadvertently overlooked. Margo has helped many times in the past and was willing to help this season also.

I am pleased to acknowledge the participation of the Alaska Chapter of the Foundation for North American Wild Sheep which funded the summer's nonpersonnel costs in 1986. I think the willingness of this group of concerned sheep users to participate constructively in Dall sheep programs should serve as a model for other Alaskan groups interested in improved management of particular species.

I would also like to thank Dick Bishop for the support he showed in authorizing our field work this summer. The year's effort was particularly valuable in terms of what it may mean to further habitat protection efforts. Surely the stimulus to investigate the nutritional aspect of mineral lick use would have been less effective if we had not become aware of the variability in lick use. I hope Dick feels his decision and support were correct and worthwhile. I am hopeful that we, as a department, will always opt for putting biologists in the field whenever it is possible.

Finally, I thank Wayne Regelin, Steve Peterson, and Barbara Townsend for editing this report.

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Appendix A. Questionnaire requesting input on future direction of Dall sheep work.

See Distribution

November 6, 1985

Through: Wayne L. Regelin
Research Coordinator

456-5156

Wayne E. Heimer
Sheep Biologist
Division of Game
Department of Fish and Game
Fairbanks

Sheep Research/
Management Program
Direction

We would like your opinion on future Dall sheep research and management. There are 2 reasons for asking. First, we are attempting to define future direction of the Dall sheep program in Region III. You influence our program, and you may have some feelings about what we should be doing. If you have specific questions or problems relating to sheep management in your area, we are also interested in those. If possible, we would like to address your concerns in our program. Second, I have been invited to participate in a study group to identify research needs for Stone and Dall sheep. The organizers of this effort suggested that participants bring a statewide or provincial perspective with them. For these reasons, I am requesting your assistance.

So that you will be up to date on the status of our knowledge and our working model of Dall sheep biology, we are enclosing some informational material with this memo. It includes a brief discussion about the nature of research, what is known about Dall sheep from past work, and the Synthesis and Summary section from our most recently completed (as yet unpublished) job on population dynamics. We have some specific questions we would like you to answer. They are distributed throughout this material.

The thinhorn sheep study group will meet during the first week in December. Consequently, I hope you will be able to respond to this inquiry before Thanksgiving.

Distribution:

Headquarters		Region I	Region V	
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Holderman	Tobey-Lieb	Nowlin	Whitten
Schneider	Westlund		

Attachment

RESEARCH IN WILDLIFE MANAGEMENT

We do at least 2 types of research. I will call one fundamental research and the other applied. Neither should be considered abstract or esoteric. I believe we should conduct research which is related to our responsibility to maintain, protect, enhance, and manage the Dall sheep resource in the best interests of the resource, the people, and the economy of the State as mandated by the Alaska statutes.

Fundamental research is research designed to develop or refine the working hypothesis (or model) of Dall sheep biology and management. This hypothesis should integrate everything we know about the ability of Dall sheep to respond to today's common human uses and those anticipated in the future. The nature of this research is to answer fundamental questions about the capacity of Dall sheep to tolerate a variety of hunting regimes, habitat disturbances, and other related population stressors. We shall detail the components of this working hypothesis as it presently exists, later.

Applied research is research designed to obtain information needed to deal with a specific problem. All management actions and challenges require specific information. For example, let us suppose domestic sheep grazing is proposed on Dall sheep ranges, and the possibility of disease transmission is one of our concerns.

To address this concern, we need to know what diseases are likely to be carried by domestic sheep, whether Dall sheep have the diseases already, whether the diseases are likely to present a threat to Dall sheep, and if mitigation is possible. Applied research should answer these specific questions and provide acceptable assurance that our conclusions are correct. It is centered on specific problems which require immediate answers.

Much of the research currently being conducted by the Division may be classified as applied. In addition to providing information for a specific problem, the results of applied research also expand the data base that supports our working hypotheses. Refining the working model of species biology is seldom the primary objective of applied research, but it should always be understood as part of the purpose for the work. The working model should be reassessed after each piece of research, applied or fundamental, is completed.

Synthesis of a data-based, working model of species biology which is relevant to possible species uses or abuses is essential to our function. Such a model (or hypothesis) should determine our management policy, management planning, and eventually, through feedback from managers, our applied research. This should occur as the management planning process or unexpected crises define specific information needs. An understanding of species biology is a basic prerequisite to successful wildlife management. If we don't understand species biology, our management programs are likely to be ineffective because our actions will have slightly better than random chances of congruence with species requirements and capabilities. Once we have defined a working model of species biology which is sufficient for our needs, we can logically pursue the applied research suggested by managers in the field.

IN THE PAST OUR FUNDAMENTAL RESEARCH HAS:

1. Estimated how many sheep are present on most Alaskan Dall sheep ranges (Heimer 1984).

2. Determined horn growth capabilities (trophy production potential) for most sheep populations in the state (Heimer and Smith 1975).

3. Defined what a sheep population is, and established ewe population loyalty to seasonal ranges (Heimer 1973, 1974; Heimer and Watson 1982a, as well as NPS/ADF&G movement study in Noatak, and BLM/ADF&G radiotelemetry studies in Tanana/Yukon uplands).

4. Determined the probable effects of adverse weather on continental sheep ranges (Burles and Hoefs 1984, Watson and Heimer 1984).

5. Generally defined limits of disturbance which are tolerable by Dall sheep (Heimer 1979, Heimer et al. 1980, pipeline work, observations at Usibelli coal mine, Cooper Landing and Sheep Mountain closed areas, Seward Highway near Girdwood, and Denali Park, etc.).

6. Shown that moderate harvest of mature (full-curl) rams has little effect on the viability of Dall sheep populations (Heimer and Watson 1986, summary attached).

7. Established that removal of virtually all Class III and Class IV rams (all rams above 3/4 curl) causes increased mortality among remaining young rams (Heimer and Watson 1986, see attached summary).

8. Learned that some low level of ewe harvest can be tolerated by Dall sheep populations (Heimer and Watson 1986, see attached summary).

9. Gathered information which strongly suggests excessive ram hunting (of rams at immature ages) seriously compromises lamb production (Heimer and Watson 1982b, 1986, see attached summary; also see Nichols 1978).

10. Established that most Dall sheep populations are relatively stable over time at densities which vary from range to range (Heimer 1979, Heimer and Watson 1986, see attached summary).

11. Shown that great differences in population quality and performance are not likely to be a function of nutrition (Heimer 1980, 1983).

12. Established to a large degree the endemic diseases present in sheep populations of the eastern Alaska Range (Heimer et al. 1982, Foreyt et al. 1983).

13. Determined that wolves can control and depress sheep populations (Murie 1944, Heimer and Stephenson 1982).

14. Developed accurate Survey and Inventory methods (Heimer and Watson 1986, see attached summary).

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We have just come to the end of a work segment in the sheep research program. Hence, now seems an appropriate time to review the status of our working hypothesis. If we all agree our fundamental understanding is adequate, our research direction may profitably address several applied information needs. If there are serious reservations about some aspects of our fundamental model of species biology, our model needs further work.

THE BASIC TENETS OF OUR WORKING MODEL OF DALL SHEEP BIOLOGY ARE DETAILED BELOW. Please read each section and mark whether you agree or disagree in the box provided. If you disagree, please highlight or circle the statements which trouble you. We have left space for brief comments. Please comment.

1. POPULATION BIOLOGY: Dall sheep are a climax habitat species adapted to relatively stable environments throughout most of their range. As such, we do not expect them to show explosive population growth, and we anticipate (in presence of normal predation) population stability OVER THE LONG HAUL.

Population size may vary considerably from year to year depending on a variety of factors; our experience indicates abrupt, weather-related changes of plus or minus 20% in ewe population size may occur from 1 year to the next. Favorable weather occasionally causes transiently high numbers of ewes when given cohorts of ewes survive a year or so longer than expected due to mild winters. When weather "catches up" with these populations, the old ewes usually die, but few prime age ewes succumb. Temporary accumulation (or removal of) entire cohorts of old ewes does not materially affect lamb production except in a positive way--the ewes may produce 1 or 2 "extra" lambs in their lifetime given an extra season or 2 of mild winter weather. These changes do not affect production by prime age ewes.

Slow population growth is expected. Population growth may occur under favorable conditions (mild winters and depressed predator populations), but these conditions are usually transient, and increasing populations will be stabilized by difficult weather or increased predation before habitat quality declines enough to cause reductions in the population.

__________ Agree   __________ Disagree

Comments:

2. RANGE LIMITATION: There is no doubt that winter range limits Dall sheep population performance. However, the limitation is typically one resulting from poor food quality rather than insufficient quantity of forage.

We do not expect sheep populations to reach sufficiently high densities that concern about density-related nutritional stress is warranted. Nutritional stress may occur in unusual circumstances, but normal circumstances do not lead to this problem. Comparisons of nutrient quality of winter range plants selected by sheep, the summer nutrient quality of these food plants, and the body condition of ewes during rut and in late winter revealed no caloric advantage for a low-density population when compared with a high-density population. Still, population performance was strikingly different between the 2; the low-density population had better performance. Nutritional stress or run-away population growth should not be primary management concerns.

__________ Agree __________ Disagree

Comments:

3. HABITAT COMPONENTS: All components of Dall sheep habitat are considered critical to population welfare.

Dall sheep habitat consists, most simply, of winter and summer ranges. Specific life functions such as rutting, lambing, geophagy (mineral licking), and migration may involve specific habitats. However, our present understanding is inadequate to define whether any given habitat-centered activity is essential to population survival. Certainly, mineral licks are the most clearly identifiable of the habitat components. We cannot say whether this makes them the most important or critical. A major concern of management should be habitat preservation; at this point, we should not relinquish any Dall sheep habitat components in the belief that little or no harm will result.

__________ Agree __________ Disagree

Comments:

4. PREDATORS: Predators can limit and depress Dall sheep populations.

Predators, particularly wolves, and possibly eagles, can depress sheep populations. Our data suggest wolves have little if any effect on lamb survival. Also, our data indicate wolves generally use sheep as alternate prey, perhaps relying on them most during summer months when larger animals like moose and caribou are difficult to capture. We found little evidence of sheep in the diets of wolves killed adjacent to sheep habitat in the GMU 20A wolf reduction program. Still, sheep population trajectory changed from decline to stability with wolf removal. Data from

British Columbia suggest wolves there may be preferentially killing lambs. Coyote predation may be important in some areas. In recent years, the observed incidence of eagle predation on lambs has increased dramatically. Eagles may be a significant predator on Dall sheep, particularly in areas where eagles are abundant and sheep population sizes are small.

__________ Agree __________ Disagree

Comments:

5. WEATHER INFLUENCES: Dall sheep distribution is determined by climate. Wind action, snow depth, and hardness appear to be limiting factors in determination of suitable habitat. Prevailing winds are required to reliably remove snow from winter food.

The effects of severe winter weather act selectively to remove older animals from sheep populations. The time course of this removal is not understood. Weather severity also influences survival of lambs to yearling age and the production of lambs. Severe weather may reduce lamb production if it is operative during gestation or parturition. It may also lower lamb survival to yearling age while not depressing lamb production. We have never documented an all-age winter die-off. Such die-offs are alleged to have occurred historically, but data have always been gathered long enough after the fact that such die-off explanations are suspect. In modern times, the only well-documented all-age die-offs have been caused by disease.

__________ Agree __________ Disagree

Comments:

6. DISEASE: Dall sheep are not expected to tolerate introduction of exotic diseases. Bulk losses will probably result from introduction of virulent, new diseases to Alaska's sheep ranges.

While Dall sheep, at least in the Alaska Range, apparently live with contagious ecthyma, lumpy jaw, and a fairly spectacular array of parasites, they are free from other diseases known to have lethal effects on other species of wild mountain sheep. Most investigators think the major cause of bighorn sheep decimation in the western United States was introduction of diseases common to domestic grazers, most notably domestic sheep. We have done little experimental work, but suspect Dall sheep will be unable to adjust to new diseases without extensive selection through mortality of susceptible individuals.

__________ Agree __________ Disagree

Comments:

7. HUNTING: Hunting of Dall sheep can produce marked depressive effects on populations. Ewe hunting at less than 2% per year can limit growth in a vigorous population with nominal wolf and eagle predation. Ram hunting has less impact on population performance, but the effects are significant. Maximum harvest of rams at 3/4 curl is associated with breeding by younger rams and immature ewes, extended lactation, and lowered rates of ovulation and lambing. It is also associated with reduced survival of young rams. Hunting 7/8-curl rams seems to fix the problems associated with lamb production, but the effect on survival of young rams is unknown. It is probable that the sustainable harvest of rams is higher when the social structure is not disrupted by removal of most or all of the socially mature rams.

See attached summary from final report.

__________ Agree __________ Disagree

Comments:

8. DISTURBANCE: Dall sheep may be considered a disturbance-tolerant species.

Dall sheep are so bound to their home ranges it is difficult to make them leave. This is reflected in a behavioral syndrome that may be construed as tolerant of disturbance. Whether they are stubbornly committed to home ranges or tolerant of disturbance doesn't really matter. The result is that they will put up with an amazing amount of disturbance in their environment (coal mining, pipeline construction, intense human contact by viewers, heavy hunting, heavy automobile and air traffic, scientific study, etc.) without leaving. They apparently require some time to habituate to "new" environmental components, but they do adapt with SEEMINGLY few problems as long as they are not killed and their range remains habitable.

__________ Agree __________ Disagree

Comments:

APPLIED RESEARCH

If there is basic agreement that our working model is sufficient, we can look toward some necessary applied research. The following applied studies have been identified as needs.

1. What are the effects of subsistence hunting in Gates of the Arctic National Park? We have a liberal season and bag limit there. The hunting patterns reported for residents of Anaktuvuk Pass indicate they are probably killing more sheep than can be sustained at current levels

of harvest. This work would be done in conjunction with the National Park Service and the appropriate area office. It should add to our knowledge of the effects and limits of ewe hunting.

2. Are we unnecessarily restricting hunting opportunity in restrictive lottery permit areas managed to provide aesthetic hunting opportunities? The Delta Management Area sheep population may be able to sustain greater harvest than we now allow. Population size and productivity should be assessed and a determination made of how much hunting pressure is tolerable before aesthetic hunting conditions are compromised. Should we be looking at a "GMU 14C type" of rotating season to provide more opportunity there? This research would be done in conjunction with the Delta area office.

3. Can we build substitute mineral licks? There is considerable economic interest in mineral extraction from some mineral licks. We think it may be feasible to build substitute mineral licks, but nothing like this has ever been systematically tested. This research should advance our knowledge of habitat components. This research would be done through the Fairbanks area office.

4. What, if anything, can be done to expand the possibilities for sheep hunting in the Tanana/Yukon uplands? Sheep populations there are disjunct, small, and essentially relict. Transplants have been considered in the past. Predators are thought to be the limiting factor, and forest succession in this area may have decreased sheep range to below historic levels. Fire suppression is a likely cause; burning could create sheep range in this situation. This research would add to our knowledge of predator effects and habitat components and would be done through the Fairbanks, Delta, and Tok area offices.

5. Are we ready to expand hunting opportunity by offering ewe hunting on a larger scale? At this time, there is little public interest in ewe hunting. However, as other hunting opportunities are restricted, interest in ewe hunting may develop, or we could develop it to increase hunting participation. Current knowledge dictates extreme conservatism in setting ewe harvest quotas. Should we be looking specifically at hunting more ewe sheep?

You may be able to think of other applied studies. What are they?

MANAGEMENT PROGRAMS

IN ADDITION TO THE RESEARCH PROGRAM, WE NEED TO MAKE SOME IMPROVEMENTS IN SHEEP MANAGEMENT. I think it is logical to state the goal of our sheep management program as: TO MAINTAIN, PROTECT, ENHANCE, AND MANAGE THE DALL SHEEP RESOURCE OF ALASKA IN THE BEST INTERESTS OF THE RESOURCE, THE PEOPLE, AND THE ECONOMY OF THE STATE.

Objectives which will facilitate achievement of this goal include:

1. Maintenance and enhancement of public interest in Dall sheep by providing as much hunting as possible.

This is clearly the place to start; we can achieve this objective. Hunters already have intense interest in sheep. This interest translates readily into actions which are in the best interests of the species. Habitat protection, monetary contribution, political support of associated Department programs, and willingness to help in many other ways are examples. I think this interest stems from interest in sheep hunting.

The first line of defense against restricting hunting in the face of pressures to appropriate sheep habitat for other uses is DOCUMENTING HUNTER USE. The harvest reporting and resource use system should be upgraded so hunter use is completely and accurately recorded. At the present time, we are putting minimum effort into maintenance and even less into improvement of the harvest/use reporting system. We have a system which is good, but has been deteriorating because of lack of effort for several years. It is in the best interests of maintaining hunting opportunity to improve this system.

SUCCESS MUST BE MAINTAINED AT THE HIGHEST POSSIBLE LEVEL because successful hunters are happy, supportive citizens. This objective can be met by educating new sheep hunters and managing for the maximum number of legal sheep on the ranges.

WE SHOULD PROVIDE THE BROADEST RANGE OF HUNTING EXPERIENCES POSSIBLE. Experience has shown that sheep hunters are interested in differing types of experience. Most would like to be alone in the mountains with their partner, see many sheep, and kill an enormous ram. They realize this is not possible for everyone. Sheep hunters are willing to set aside special areas so they have the opportunity, even at a fairly low probability of participation, for this special experience. The overwhelming support of sheep hunters for areas like the Tok and Delta Management Areas and the GMU 14C permit hunts demonstrates this prevailing ethic. If unable to participate in experiences like these, hunters prefer low to moderate densities of sheep hunters afield. At the extreme, they want some place they can go every year even though success might be low and numbers of hunters high. Areas like this function well for beginning sheep hunters whose aesthetic senses are less well developed than veteran hunters.

We can start to provide these types of experience by evaluating the potential given areas have for providing them. We should consider establishment of 2 more trophy areas--perhaps in the Brooks and Chugach Ranges. We might also consider reducing the areas committed to aesthetic hunting and correspondingly increase those dedicated to maximum opportunity to hunt. At this time, we have disproportionately few areas so designated in management plans. If changing management goals will provide more participation, it might be in the best interests of sheep and sheep hunters. Of course, we are currently making little effort to assure aesthetic conditions exist in most of the areas designated for that management goal.

WE SHOULD MAINTAIN AND ENHANCE THE ECONOMIC BENEFITS OF DALL SHEEP HUNTING TO THE CITIZENS OF THE STATE.

Sarah Watson's economic study shows that Dall sheep hunting as practiced in the past was of immense economic benefit to the State. Gross expenditures for sheep hunting by only 2,500 hunters in 1983 came to approximately 7.3 million dollars. Approximately 51% came from nonresident hunters. This means it is in the interest of the resource, the people, and the economy of the State to allow and encourage nonresident hunting and for us to work with the guiding industry.

We should bring the guiding industry more actively into the management and reporting systems. This will require some effort at persuading the guides this is in their best interests. This should not be difficult given the current pressure to eliminate nonresident hunting in the name of subsistence. Documenting value and use will prove beneficial to all concerned. We should also make greater use of the economic argument than we have in the past.

WE SHOULD UPGRADE THE QUALITY OF PROGRAMS WHICH MEET THE NEEDS OF NONCONSUMPTIVE AND EDUCATIONAL USERS. Nonconsumers have not contributed greatly to Dall sheep management in the past. We have not asked them to. We should seek their active support. I think we should provide more management-related materials for educational uses. In the past we have provided natural history-type programs. These programs show how wonderful sheep are, but do not really do anything for the resource! We have left sheep in the conceptualized "balance of nature." Changing this established norm will require production of material emphasizing Dall sheep uses, their values, population responses, and negative impacts on sheep populations. This should occur throughout the State, particularly in urban areas.

WHAT DO YOU THINK WE SHOULD DO TO IMPROVE OUR MANAGEMENT PROGRAM?

It is with some trepidation I solicit your opinion. Given the turbulent history of the Dall sheep program, the fact that we appear to be managing conservatively, and that there are seemingly no present crises threatening Dall sheep, I fear there is a tendency to conclude that sheep will manage themselves and concentrate on other alligators. Please give this thoughtful consideration and send us an honest report of your thoughts.

SYNTHESIS AND SUMMARY OF RECENT WORK

#1. Our Finding: Ewes collected in the Robertson River study area showed greater ovarian activity than ewes collected in Dry Creek.

Other Relevant Data: Nutritional resources appear to be the same in both populations of sheep. The 2 populations differed in abundance and ages of rams. Most ewes in an unhunted population of Dall sheep were polyestrus. A highly significant positive correlation between numbers of rams present during rut and lamb:100 ewe ratios the following spring exists on the Kenai Peninsula in Alaska. Reduced ram numbers or perhaps insufficient numbers of mature rams occurred coincident with lowered reproduction on the Kenai Peninsula, and in this study it correlates with decreased ovarian activity.

Our Conclusion: Ovarian activity is reduced when few Class III and Class IV rams are present in Dall sheep populations.

Explanation: Ovulation in Dall ewes is influenced by numbers and perhaps maturation status of rams present in the rut. This sensitivity on the part of ewes to ram numbers (and possibly behavior) resulted in lower ovarian activity where fewer and younger rams were responsible for breeding.

Management Implication: Nearly total removal of mature rams will probably result in lowered lamb production. To assure maximum lamb production, managers should maintain the greatest number of rams possible on the ranges. Ages of rams may be important; a significant percentage of these rams should be mature, Class IV rams.

#2. Our Finding: Ewes in both populations first ovulated at 18 months.

#3. Our Finding: Ewes in the Robertson River population bore their 1st lamb on their 3rd birthday. Bearing lambs on the 2nd birthday was common in Dry Creek when few mature rams were present.

Other Relevant Data: Nutritional differences between the 2 populations were insufficient to explain these differences. The more crowded population showed frequent breeding at 18 months of age, but it was virtually absent in the less dense population which produces greater horn growth. This is contrary to what would be expected if nutritional differences existed. The only apparent difference between the study populations was the absence of Class IV and most Class III rams from the population which bore lambs earlier. Dall sheep in the wild normally have their 1st lambs on their 3rd birthday. Wild Dall ewes typically deliver lambs on their 2nd birthday in only 2 instances--this study and on the Kenai Peninsula. Both of these latter populations were subjected to intense ram harvests at 3/4 curl. Dall sheep in captivity routinely have lambs at age 2 years. These lambs are often sired by very young rams. In an open, captive breeding situation, mature Dall rams did not breed 18-month-old ewes, but juvenile rams did.

Our Conclusion: The absence of Class III and Class IV rams in the heavily hunted ram populations caused disruption of breeding activities which led to breeding of 18-month-old ewes. These ewes would not have been bred in a less disrupted rut.

Explanation: In the presence of mature rams, juvenile rams appear to be psychologically castrated. If mature rams are absent, the young rams court and breed the 18-month-old ewes which, while physiologically capable of reproduction, would not normally be inseminated by mature rams. Behavioral maturation at a slower rate than physical maturation among ewes would explain how this could occur.

Management Implication: Removal of mature rams from rutting ranges may cause early breeding. This may sound attractive, but it should be noted that early breeding has been associated with alternate-year reproductive success in Dall sheep. The relationship may not be linked, but caution should be exercised in viewing this as a means of increasing production. Typically, breeding in the 1st estrus results in stunted female development and production of disadvantaged, "runt type" offspring in domestic ewes. Early breeding is probably not advantageous unless it results from better nutrition. This seems unlikely in free-ranging Dall sheep.

#4. Our Finding: Reproductive frequency of Dry Creek ewes increased with the corresponding increases in ram numbers and ram age associated with the change in minimum legal horn size from 3/4 to 7/8 curl. Instances of consecutive-year lambing success increased from 6 to 40% in Dry Creek after the regulatory change in ram hunting. There were no differences in frequency of consecutive-year lambing success between Dry Creek and the Robertson River after the change.

Other Relevant Data: Nutritional changes did not account for the difference. Weather changes could not have accounted for the difference. Alternate-year lambing success was associated with extended lactation.

Our Conclusion: Changing the hunting regulation from 3/4 to 7/8 curl caused the increase in consecutive-year lambing success.

Explanation: Alternate-year lambing success was most likely mediated through a neuroendocrine reflex resulting from extended lactation. For some reason, presence of more and older rams on the range seems to have lowered the frequency of alternate-year lambing success. For these 2 events to be linked, the presence of many or more old rams on the range must somehow limit suckling on the part of lambs, or stimulate weaning on the part of the ewes.

Management Implication: Consecutive-year lambing success is much more desirable than alternate year success. Over the course of a ewe's lifetime, approximately 60% more lambs will be produced by a ewe that begins reproduction at age 3 and produces a lamb annually, than by a ewe that begins to reproduce at age 2 and then produces lambs in alternate years. Maximizing lamb production requires keeping as many mature rams on the range as is practical.

#5. Our Finding: Lamb production is extremely variable and is greatly influenced by weather. Countable lamb production is greatly influenced by number and possibly age composition of breeding rams.

Other Relevant Data: The lowest sustained levels of countable lamb production in this study were from Dry Creek when minimum numbers of Class III and Class IV rams were present in the population. From 1972 through 1978 countable lamb production averaged 35 lambs:100 ewes. Lamb production averaged 56 lambs:100 ewes when more mature rams were present. Lamb production averaged 50 lambs:100 ewes during the 11 years that full-curl hunting occurred in the Robertson River. On the Kenai Peninsula a heavily cropped (at 3/4 curl) population averaged 25 lambs:100 ewes while an unhunted population averaged 34 lambs:100 ewes.

Conclusion: Lamb production can be increased by increasing the number and age of breeding rams.

Management Implication: Weather cannot be controlled and will always influence lamb production. Managers can positively influence lamb production by regulating ram harvest to assure a reasonable presence of mature rams in the sheep populations. Ewe numbers must also be maximized to give the highest possible lamb production.

#6. Our Finding and Conclusion: Survival to yearling age is weather dependent and appears inversely related to size of lamb crop produced. Survival to yearling age is also independent of wolf predation influence on the overall population.

Explanation: We lack a good understanding of survival from lamb to yearling age. It seems to continue at approximately the same rate regardless of predation by wolves and population trend. The observation that populations could decline, grow, or remain stable with approximately the same mean survival rate from lamb to yearling age probably suggested other factors (notably wolf predation) were influencing the study populations. The vague relationship between size of lamb crop and survival as well as our limited knowledge of winter weather effects may be obscuring an important relationship.

Management Implication: Winter severity can be generally determined by the rate of lamb survival to yearling age. Of course, it is imperative to know production of lambs before assessing survival to yearling age. Low yearling:100 ewe ratios may result from poor survival of a large lamb production or from high survival of a poor lamb production. These data are probably the best available to managers in the field to assess winter severity on a relative scale.

#7. Our Finding: A model of the ewe segment of each population was created by combining aerial survey data with collared sheep survival and relative lamb and yearling:100 ewe ratios gathered at mineral licks. This allowed accurate modeling of ewe populations from year to year. This model predicted the number of ewes seen in subsequent aerial surveys 4 years after the initial survey. Differences between predictions and aerial surveys were 3 to 8%. A similar method shows promise in understanding ram population dynamics.

Conclusion: Population modeling represents a cost-effective means of discerning actual population performance. It shows that point-in-time surveys give managers limited power to understand changes in sheep populations.

Explanation: Even if routine sheep surveys were repeatable, they are incapable of determining population changes with sufficient accuracy to allow meaningful management decisions without coordinated ground-based classification counts. Sheep populations are so dynamic that attempts to monitor changes on an intermittent basis with no ground-based information such as accurate ewe, yearling, and 1/4-curl ram data or confidence in survey efficiency are unlikely to ever decrease the uncertainty and contention associated with their interpretation.

Management Implication: Most routine sheep population assessments are of minimal value. Their primary value is to give the manager a minimum population size and a "feel for what is happening." Consequently, establishment of realistic harvest goals is guesswork. When, on a practical level, this may be necessary, managers should always err on the side of conservatism. This establishes the mandatory situation of always harvesting below maximum level. This method of population assessment and component modeling allows confident establishment of maximum harvest goals.

#8. Our Finding: Heavy harvest of 3/4-curl rams coincident with absence of Class IV rams due to the "killer" winter of 1971-72 lead to subsequent decreased survival of sublegal rams and low harvest by hunters. Realized harvest during the heavy 3/4-curl hunting period in Dry Creek was 16%. Under 7/8 curl it increased to 67%. Sublegal ram mortality in Dry Creek dropped from 17% to 5% when the 7/8-curl regulation was established.

Other Relevant Data: Tag returns from marked rams in the full-curl area already exceed returns from Dry Creek when the 3/4-curl limitation was in effect. These sheep are just entering the legal age classes, and many marked rams are not yet legal. The 5% mortality for sublegal rams in a heavily harvested, 7/8-curl population is twice that in unhunted populations.

Conclusion: Maximum harvest of rams at 3/4 curl is lower than at 7/8 curl. Maximum harvest at 7/8 curl is lower than at full curl.

Explanation: Removal of Class III and Class IV rams allows younger rams to participate in breeding and exposes them to the rigors of social dominance. This causes them to die at the same rate older rams experience, but at much earlier ages. The result is that fewer rams are harvestable. Weather events and human harvest occurred coincidentally to produce this situation in Dry Creek. Ram hunting, alone, could have caused the same effect.

Management Implications: If managers desire to maximize harvest, they should establish regulations which protect significant numbers of rams in the upper age/size/status classes. This will allow increased recruitment to these classes and subsequently higher harvests.

MANAGEMENT RECOMMENDATIONS

Establishment of harvest regulations which protect all Class III and some Class IV rams is the most effective tool available to managers for increasing Dall ram harvest potential and population health. The immediate yield to hunters from this approach will, in all likelihood, surpass even management of predators because of the very high mortality among sublegal rams promoted to dominance status when virtually all Class III and Class IV rams are removed. Establishment of protective regulations is inexpensive and generally supported by hunters and the general public. This management approach should not be seen as obviating wolf control in unusual circumstances, but will provide more immediate and measurable results. Ewe numbers must be maintained, and should predator pressure be depressing the population, control will be necessary. Still, this should be viewed by sheep managers as a secondary treatment when demand for human use exceeds the ability of sheep populations to meet it under existing conditions.

Establishment of a 7/8-curl regulation apparently benefitted the Dry Creek sheep population. These benefits are likely to be further enhanced by going to a full-curl regulation. A major question in the minds of managers centers on the effects this will have on harvest rate and success. Only further work will tell whether the current predictions of increased harvest are correct. At this time it is clear we recommend that managers not return to 3/4-curl regulations. Further work is required to determine the effect of full-curl regulations on harvest levels. Should this study reveal no serious lowering of harvest rate below present levels, we recommend establishment of full-curl harvest regulations for rams throughout Alaska.

We further recommend that area biologists reevaluate the effectiveness of their routine survey and inventory programs for sheep. Intermittent survey programs are probably incapable of producing accurate population trend data. Biologists managing populations where harvest is regulated by permit should be particularly attentive to dynamics of the populations they influence. We should certainly err on the side of conservatism if we must err, but reexamination of ram population dynamics may indicate we are unnecessarily curtailing the opportunity to participate in ram hunting in some of these areas.

Ideally, management biologists should identify a survey trend area, mark many sheep, determine population ranges, fly aerial surveys at 5-year intervals, and gather annual ground-based data on lamb production, marked sheep mortality, and yearling recruitment. These procedures are beyond those routinely in use at this time. However, conditions are changing rapidly in Alaska. Management practices which were thought adequate to meet yesterday's needs clearly were not. They are quite likely to be inadequate now or in the future.

Finally, the major body of data gathered in this study casts serious doubt on the assumptions under which sheep management has proceeded for the last 50 years. We recommend that biologists carefully examine the assumptions under which they work. We are hopeful the underlying assumptions of sheep management will receive the careful scrutiny this report is certain to receive.

Appendix B. Abstract of paper presented at Northern Wild Sheep and Goat Council Meeting in Missoula, Montana, April 1986.

HARVEST STRATEGY PANEL: MAXIMIZING RAM HARVESTS

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Author's Note: This report is a summary of ideas presented for discussion. It is not intended to represent the position of the Alaska Department of Fish and Game.

Abstract: Discussion of harvest strategy implies a management goal which the strategy is employed to achieve. However, the most common harvest regulation in the western United States, the 3/4-curl law, appears, upon historical review, to exist because of tradition instead of being selected to achieve maximum harvest goals. When maximum sustainable harvest is the management goal, ram mortality patterns, behavior, theoretical energetic considerations, and empirical data gathered in Alaska's Dall sheep (*Ovis dalli dalli*) management experiences indicate greater harvests of rams can be sustained by limiting harvest to Class IV rams. This strategy may not be the most effective if maximum sustained ram harvests are not the primary management goal.

Appendix C. Abstract of paper presented at Northern Wild Sheep and Goat Council Meeting in Missoula, Montana, April 1986.

TIME AND AREA SPECIFIC VARIATIONS IN DALL SHEEP LAMB PRODUCTION: AN EXPLANATORY HYPOTHESES

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Abstract: Lamb production as indicated by lamb:100 ewe ratios was studied in 2 differing Dall sheep (*Ovis dalli dalli*) populations. One population was affected by changes in hunting and predator management; the other population was subjected to little change in management. Lamb production was more variable in the population with variable management history. Lamb production correlated significantly ($P < 0.01$) with an aggregate weather index which included weather influencing breeding condition of ewes, weather during gestation, and weather during lambing. However, weather did not seem to be an important factor in other determinants of lamb production: ovarian activity, age at 1st reproductive success, and frequency of reproductive success. Decreased ram abundance and the concomitant skewing of ram age structure toward young rams were associated with maximum 3/4-curl harvest and maladaptive changes in lamb production. Reproductive frequency and age at 1st breeding appear to have been reestablished at levels found in unhunted populations following establishment of the 7/8-curl regulation in the heavily hunted Dall sheep population.