FEDERAL AID
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ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
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Title: Ewe Dall's sheep survival, pregnancy and parturition rates, and lamb recruitment in GMU 14C, Chugach Mountains, AK

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I. PROBLEM AND NEED THAT PROMPTED THIS RESEARCH

Dall's sheep (Ovis dalli dalli) populations fluctuate. Periodic die-offs and rebounds are well documented (Murie 1944; Murphy and Whitten 1976; Whitten 1997). 28-35% increases and decreases in sheep numbers have been reported over 1-3 year periods in some areas in the Alaska Range (Arthur 2003) and in Canada (Hoefs and Bayer 1983). However, aerial trend surveys as well as anecdotal evidence suggest that sheep populations in Southcentral Alaska appear to have been experiencing a continual decline since approximately 1990 (ADF&G, 2007 sheep management reports).

Several causes for recent declines have been hypothesized (Kellyhouse and Tobey 2007). Indeed, declines are most likely driven by different factors in different locations. However, definitive cause and effect relationships have not been documented. Without the ability to track individual animals over time, and assess demographic parameters, it is impossible to quantify the impact and magnitude of suspected influences on sheep populations.

Unfortunately, our ability to obtain precise population estimates and identify changes in population status has been limited. Comprehensive census counts are rare, and aerial trend counts have been flown only at irregular intervals because of poor weather, limited personnel availability, and reduced budgets. Even when accomplished regularly and consistently, these trend counts only provide a snapshot of a population at a moment in time, and do not provide insight into processes that shape populations. Focused research is necessary to assess population status and to understand what factors determine that status.

II. STATEMENT AND BACKGROUND

Dall Sheep are highly valued by sport and subsistence hunters as well as nonconsumptive users, yet very little research has been conducted on sheep in Southcentral Alaska during the last 20 years.

Monitoring and research on Alaskan Dall sheep has been compromised by the attitude among many biologists that the 'full curl' hunting regulation allowed a self- sustaining, hands-off management approach. This view, combined with limited agency wide funding, focused research on other big game species. As a result, there is little current information on sheep upon which to base management actions or frame research hypotheses.

The lack of recent study, coupled with the fact that much of the initial sheep research was conducted prior to the advent of reliable, inexpensive VHF radio collar technology, and used data obtained during observations of sheep at mineral licks (e.g. Heimer and Watson 1986), or through multiple survey flights and ground observations without benefit of marked individuals (e.g. Nichols 1978, Murphy et al. 1990), makes it difficult to form meaningful hypotheses upon which to base research on specific factors that may be influencing sheep numbers. As noted before, aerial observations are only a snapshot, and further, cannot differentiate ewes from subadult rams that remain in nursery groups, nor can yearlings be consistently classified from the air. These errors add potential bias to birth rates or recruitment calculations. Furthermore, survey methods and intensity are often inconsistent over time and there is no ability to quantify the proportion of animals missed during aerial surveys. Lick observations provide opportunity for long-term monitoring but population-level conclusions drawn from these observations must be interpreted with caution (Heimer and Watson 1986 p.29). Poor weather can hinder overall sightability of sheep at licks, and neonate mortality between birth and appearance at the observation site may affect conclusions about reproductive rates. Arthur (2003) calculated minimum observed parturition rates from daily monitoring of radio collared ewes before and during the lambing season. During years when weather allowed daily flights during lambing, reported rates ranged from 68-76%. However, when poor weather conditions precluded daily flights and delayed observation of neonates by only a few days, observed parturition rates decreased substantially, to 44-55%. It follows that even slight delays can greatly alter an investigators' ability to determine parturition rates by observation, so in a case where a ewe's appearance at a lick might be as much as several weeks postpartum—mid-June in the case of the Dry Creek lick (Heimer and Watson 1986, p. 9)—there is a large window of vulnerability during which lamb mortality could potentially be unrecorded. Finally, different age and sex classes of sheep appear to use licks at different seasons and with differing frequencies (Tankersly 1984) and so might not be observed at the lick in proportion to their presence in the population.

Managers could benefit from accurate estimates of demographic parameters. The first priority is to further our understanding of baseline demographics including survival, pregnancy, natality, and recruitment rates. At the same time, the influences shaping sheep population trends need to be elucidated. These influences include but are not limited to weather, predation, disease, habitat and nutrition, and human action. Finally, a research program must be designed to develop techniques and compile baseline data sets that will facilitate future research to advance the scientific knowledge base on Alaskan Dall Sheep while simultaneously providing the best possible information with which to manage sheep populations.

It is also critical that any investigation examine as many potential population influences as possible with sufficient depth to be able to determine the effect on the population, and the magnitude of that effect. It is initially tempting to compare broad measures of demographic

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parameters or indices across as many sheep ranges or populations as possible. However, given the limitations of our current knowledge base, it would be efficacious to quantify variables driving current population trends in one geographic region rather than diluting research efforts across multiple sheep ranges.

Some factors that affect thinhorn sheep populations have been identified. While it is possible to make inferences from research on other Ovidae as well as other ungulates, all that can be gleaned are potential mechanisms, not their individual contributions in our proposed study population.

Limiting factors.--Changes in sheep numbers have been linked to weather patterns (Nichols 1978; Heimer and Watson 1986; Whitten 1975). Disease, predation, nutritional limitation, and density also have pronounced population –level effects (review, Bunch et al. 1999; Scotton 1997; Arthur 2003; Festa-Bianchet et al. 2003; Portier et al. 1998). In addition, genetic effects, human influence/ hunting, and population age structure (Coltman et al. 2002; Murphy and Whitten 1976; Festa-Bianchet et al. 2003) may also influence population trends in some areas. Annual mortality rates measured in prime-aged adult female thinhorn sheep range from 3-24% (Heimer and Watson 1986, Arthur 2003). And, Nichols (1984) summarized results from a number of investigations and reported that between 14-43% of rams die prior to attaining full curl. Mortality rates increase substantially in aged sheep, reaching as high as 50-67% in ewes older than eight with very few animals living past 12 or 13 (Heimer and Watson 1986). Overall, sheep appear to follow a similar trajectory as other northern ungulates, as mortality is high in juveniles, decreases during prime age (Murie 1944; Whitten and Murphy 1976; Heimer and Watson 1986), and increases again with senescence. While we assume that these trends are conserved in sheep populations in Southcentral Alaska, again, we have no empirical evidence that this is the case.

Despite relatively high adult survival and pregnancy rates ranging between 74-91% (Arthur 2003) to 100% (Nichols 1978), potential exists for recruitment not to meet mortality. Twinning is extremely rare (Nichols 1978), and lambs appear to be extremely vulnerable to a number of influences. Predation (Arthur, 2003, Scotton, 1997), weather (Whitten 1997; Portier et al. 1998 and multiple anecdotal reports), disease (review, Bunch et al 1999), and nutritional limitation (Portier et al. 1998) can exert substantial effects on lamb survival. As a result, even a few consecutive years in which ewes evidence low parturition rates, coincident with high lamb mortality, could lead to population decreases. In fact, Scotton (1997) noted that the extreme variability observed in lamb:ewe ratios was much greater than that noted in caribou and moose populations, and Arthur (2003) reported that lamb survival rates of 12-36%, combined with adult ewe survival rates of 86% were not sufficient to sustain population numbers. Several factors shape sheep populations, and at this point, all are unexplored in Southcentral Alaskan sheep populations.

Weather.--Weather has the potential to affect sheep populations in several ways. Maritime influences may alter snow depth and/or hardness (review, Nichols and Bunnel 1999). The effects of ocean-influenced weather patterns may be accentuated by recent warming trends that appear to diverge from long term weather patterns with an increased number of freeze-thaw 'chinook' events that could lead to increased snow hardness or ice formation. Kellyhouse and Tobey (2007) noted that in the five winters between 1993-1994 and 1998-1999, there were, on average, 10.7 days per winter when the daily maximum temperature recorded at the Gulkana airport rose above freezing, but in the five winters immediately following that period, 1999-2000 to 2004-2005, the number of days above freezing almost doubled, increasing to an average of 19.7/winter. Despite the fact that these temperatures were recorded on the valley floor and not on sheep winter range, the broader warming trend is certainly of interest, given that foraging behavior, as well as the amount of forage available to sheep on winter range, depends on snow depth and hardness (Nichols 1976; Nichols 1988). It follows that harder snow surfaces and formation of ice due to freeze-thaw cycles could alter winter range carrying capacity. Changes in summer weather patterns may also alter forage phenology and/or nutritional content (review, Nichols and Bunnell 1999), though a survey of the available literature shows that researchers have reached different conclusions about thinhorn sheep responses to summer weather and its effects on forage production and quality. Hoefs (1984) reports increased lambing rates with increased precipitation during the previous summer, while Heimer and Watson (1986) report that warm and dry weather during summer correlated with increased lamb numbers the following spring, though they note differences between Hoefs et al and their results may only reflect climatic variation across sheep ranges.

Other weather effects that could affect sheep include recent warming trends driving elevational shifts in vegetation communities, potentially leading to a decrease in the amount of habitat available to alpine ungulates (Klein et al 2005; Dial et al 2007). Weather may have indirect effects as well. Changes in snowpack depth, density, or hardness alter sheep vulnerability to predation (Burles and Hoefs 1984). With the exception of Nichols' work, the great majority of research on Alaskan Dall sheep has been conducted in the Alaska and Brooks ranges. However, conclusions drawn from research in these locales are not necessarily applicable to the Chugach, Wrangell, Talkeetna, and Kenai mountains, and on the south side of the Alaska Range that comprise sheep habitat in southcentral Alaska. Weather, snowpack, and temperature regimes differ between coastal mountains and higher latitude, interior sheep habitats.

Predation.--Predation has also been shown to have substantial effects on Dall sheep populations, though recent studies suggest most predation focuses on juveniles (Arthur 2003, Scotton 1997). These investigators measured lamb survival rates to one year ranging between .12 and .36 (Arthur) and .68 (Scotton) with 90% (Arthur), and 95% (Scotton) of lamb deaths due to predation. Most of the predation was attributed to coyotes (approximately 40% in both studies) and golden eagles (likewise, ~20%). Other predators included wolves, bears, and wolverines. Adult sheep are also subject to predation (Arthur 2003; Geist 1971; Murie 1944), though population-level effects are variable and may depend on terrain type or population size, and could be compounded by weather, habitat quality, and other factors. Overall adult mortality due to predation is usually assumed to be relatively low, as the mean adult ewe annual survival rate of .86 reported by Arthur (2003) parallels rates reported by other investigators. Yet, during the first four years of Arthur's study, all (n=14) deaths of radio-collared adult animals were caused by predation, with most (57%) caused by wolves. Predator abundance, distribution, and their resulting effects on sheep populations in southcentral Alaska are unknown and may be different than what has been documented in interior ranges.

Nutrition and reproduction.-- Nutritional condition in other ungulates varies as a function of habitat quality, forage availability, weather, and density, all of which are uninvestigated in sheep in this region. Murphy and Whitten's (1976) observation that birth rate is inversely correlated with snowfall during the winter preceding birth, and also inversely correlated with population density, strongly suggests that whether a ewe carries a pregnancy to term, and more importantly, her lifetime reproductive output, is determined by her nutritional status. Heimer (198X) investigated the nutritional content of summer and winter sheep forages on multiple ranges in interior Alaska. No differences were found between ranges or years in a number of nutritional parameters. However, no information has been collected from sheep ranges in Southcentral AK. Remote sensing utilizing NDVI (Normailzed difference vegetation index) and fecal nitrogen content have been used as indices of forage quality for other wild ungulates. It is possible that these technologies, properly validated by field browse collection, combined with an assessment of body condition at capture, could provide insight into the nutritional condition of sheep in this study.

In short, no information exists about what drives female reproductive output nor how many offspring are typically recruited into the population by one adult Dall sheep ewe in Southcentral Alaska.

Disease.--Disease presence and prevalence, and more importantly, disease effects on populations, are unknown. While the presence of lungworm, which can predispose wild sheep to respiratory disease, as well as the species of *Pasturella* bacteria that cause pneumonia, have been documented in sheep in southcentral Alaska (Beckmen pers. comm.), no systematic assessment has been conducted. At a minimum, baseline screenings need to be conducted in every animal handled.

Genetics.--Genetic effects—whether created through founder effects, population bottlenecks, or via selective harvest regimes – have been suggested to affect Dall sheep populations, these remain untested. Currently, the USGS (G. Roffler, PI) is conducting a project assessing genetic variability within one sheep range in Southcentral Alaska. At a minimum, tissue and blood samples need to be collected and archived, certainly from study animals but possibly from harvested sheep as well, in order to allow the opportunity to assess genetic variability between and across this and other sheep ranges in Southcentral Alaska.

Summary.--Due to the high variability in pregnancy, parturition, and recruitment rates, and lamb: ewe ratios reported in other sheep populations, and the number of potential influences, it is unlikely that we will be able to definitively identify the factors influencing sheep populations in a single year. I suggest we design the project such that we collect data on the above parameters for an initial two year period to better evaluate weather and predation effects, as well as initiate assessments of disease and tissue archiving. After that initial period, project needs and goals can be reevaluated relative to the information already gathered.

Objectives and Approach

Objective 1. Determine pregnancy, natality, and recruitment rates.

1a. Pregnancy rates: 35 ewes were captured in March and April 2012 and fitted with VHF radio collars. All except one of these animals was four years of age or older. 15/34 (44%) were pregnant according to serum progesterone levels measured by BioTracking LLC.

During the 2013 reporting period, 32/35 survived until March and April 2013, when we recaptured 22 of the surviving 32. 20/22 (91%) were pregnant during the 2013 reporting period.

During the 2014 reporting period, we recaptured 22 of the surviving 25 ewes from previous years, plus an additional 10 animals to add to the sample size. Of these 32 animals, 30 were pregnant for a 94% pregnancy rate. After spring captures, 35 total animals were on the air, and no animals died between April 2014 and March 2015.

During the 2015 reporting period, 23/35 of the surviving ewes were recaptured. 22/23 were pregnant, for a 96% pregnancy rate.

During the 2016 reporting period, 32/35 animals survived. We recaptured 22 of the 35, and 16/22 were pregnant for a 73% pregnancy rate.

During the 2016 reporting period, 29/32 animals survived. We recaptured 22 of the 29, and 21/22 were pregnant for a 95% pregnancy rate.

1b. Parturition rate. In 2012, 12 of the 15 pregnant ewes were observed with a neonate lamb, for an 80% parturition rate.

During the 2013 reporting period, a large storm covered the study area with up to 18" of snow during the first few days of our fieldwork (16-18 May, 2013). We suspect that a number of lambs were delivered during the storm and perished before we could observe them,, as we only saw 15/21 (71%) of ewes that were known to be pregnant with lambs. The final ewe known to be pregnant died giving birth to a lamb on 5/19/2013.

During the 2014 reporting period, we observed 26/30 ewes that were known to be pregnant with a neonate lamb, for an 86% observed parturition rate.

During the 2015, 2016, and 2017 reporting periods, we did not attempt to capture neonate lambs; as a result, we did not observe parturient ewes and cannot calculate a parturition rate.

1c. Lamb Recruitment and adult survival:
Lambs: 27 lambs were captured and radiocollared between May 15 and June 15 2012. 16/27 (59%) survived to one year of age. Six were killed by golden eagles in May and June 2012, one was killed by a coyote in June of 2012, and one drowned, also in June. One lamb was killed by a predator, also in June, but a definitive diagnosis could not be

determined. Two lambs died during winter 2012-2013, one killed by a wolverine in February 2013, the other to an avalanche in March.

We captured and radiocollared 11 lambs during May-June 2013. Capture operations were difficult this year due to the large number of lambs born early in the lambing period; we captured 9/11 lambs between 20 -31 May, and only two after that date. At the time of this writing, 7/11 are alive. Two were killed by eagles, and one by a wolverine in May and June. The final animal slid into a moat between a rock and an icefield and was recorded as a mortality on May 22, 2013. No further mortalities occurred during the project year, giving an annual survival rate of 64%.

24 lambs were captured and radiocollared in spring 2014. Four collars were dropped, leaving 20 animals in the sample for the 2014 project year. 9/20 survived for a 45% annual survival rate. 3 were killed by eagles, two by brown bears, and one each by a wolverine and coyote. One lamb was killed when a rockslide carried it into a rock crevice, and one additional lamb died of pneumonia due to heavy lungworm load. A final lamb mortality could not be reached for analysis.

Lambs were not captured in 2015 or 2016.

Adults: One adult ewe was killed in an avalanche in April of 2012, and two were killed by unknown predators, likely a wolverine, in February 2012.

Several adult ewes perished between April and June 2013. Of the surviving 32 referenced above, a total of 7 died. Three were killed in separate avalanches, two in April, and one in May 2013. One was killed by a unknown predator, one by a wolverine, and one by a brown bear, in March, April, and May 2013, respectively. The final animal died giving birth to a breech born lamb that did not clear the birth canal, giving an annual survival rate for adult ewes for the reporting period of approximately 70% .

No adult ewes died between July 1 2013 and June 30 2014.

No adult ewes died between July 1 2014 and March 2015, however, five radiocollared ewes died between April 2015 and June 30, 2015: Two as a result of capture mortality, two more to avalanches, and one to an unknown predator.

Three adult ewes died between July 1 2015 and June 30 2016. Two were killed in avalanches, one in early December 2015, and one in late April 2016, while one was killed by a predator, likely a wolverine, in February 2015.

Two adult ewes died between July 1 2016 and June 30 2017. One was lost to an unknown event that was NOT related to predation in May 2017, while another was killed in an avalanche in late April 2017.

Objective 2. Animal health profile.

2a. Disease presence and prevalence. Blood sera and fecal samples were collected from 31/35 ewes and 17/19 rams that were captured for this project. These samples were analyzed by the Washington Animal Disease Diagnostic Laboratory at Washington State University. These samples were not collected during captures during the 2013, 2014, 2015 or 2016 reporting periods.

2b. Trace mineral levels and blood chemistry (CBC, CMP). At capture, 60-75 ml of blood was collected from adult ewes. These samples were collected in 2013, 2014, 2015, and 2016. Laboratory analysis is complete and data analysis is ongoing. Preliminary data suggests some animals may be selenium deficient relative to reference levels for Bighorn and/or domestic sheep.

2c. Qualitative BCS. A numerical BCS of 1-5 was assigned to each animal captured. Ewes in GMU 14C appeared, on average, larger and in better body condition than ewes in GMU 13D. This analysis was repeated during captures in March and April 2013, with animals appearing in slightly better condition in 2013 than in 2012. Adult ewes were captured in March 2014 were again in slightly better condition than in the previous year. Body condition scores recorded again showed a slight improvement in March and April 2015 compared to 2014. Body condition scores again decreased in 2016 compared to 2015. During the most recent reporting period, we used ultrasound to measure subcutaneous rump fat in our sample of sheep. All animals sampled were in poor condition with 0.0-0.77cm of subcutaneous rump fat.

Objective 3 Assess weather effects.

3a. Temperature and snow depth monitoring sites will be developed and placed at selected sites on sheep winter range prior to winter. Tidbit brand temperature loggers will be programmed and deployed during October 2012. Temperature loggers were deployed during fall 2012, and again in October 2013. Data collection is completed and analysis is ongoing.

Objective 3b. If funds are available, we will determine snow hardness at selected sites on sheep winter range using the powder ram technique (Rinaldi 2006) periodically during the winter. No action has taken place yet.

Objective 3c. In collaboration with Liz Solomon, ADF&G GIS specialist, we will attempt to determine the extent and type of snow coverage of winter range annually using remote sensing. This objective was modified after Ms Solomon left ADFG employ. We are currently working with Dr. Roman Dial at Alaska Pacific University to develop methodology to estimate snow cover, and changes in summer and winter habitat over time.

Objective 4.

Objective 4a.Data analysis and writing

We are developing a study plan for future research to better investigate the relationship between habitat quality, weather patterns, and sheep population performance, and to build a carrying capacity model for GMU 14C sheep.

III. EXPECTED RESULTS/BENEFITS/MANAGEMENT IMPLICATIONS

Management objectives and desired densities for Southcentral Alaska sheep populations are several decades old, and are probably not realistic given current long-term population declines. Demographic information is critical prior to establishing management direction and objectives. Additionally, much of the historical research on Dall sheep and hypothesized limiting factors are equivocal. This project will provide tools, techniques, and baseline demographic information with which research hypotheses can be developed to test previous conclusions.

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