

Status of Thinhorn Sheep in British Columbia

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SUMMARY

I. GENERAL BIOLOGY

Two subspecies of Thinhorn Sheep are extant in British Columbia: Dall's Sheep (*Ovis dalli dalli*) of the St. Elias Mountains of extreme northwestern British Columbia; and Stone's Sheep (*Ovis dalli stonei*) of the northern mountains and plateaus. Basic biology and ecology are similar for both subspecies. The two subspecies interbreed commonly where their ranges overlap, producing pelage colour patterns that intergrade from pure white through shades of grey to brownish black. Both sexes bear horns. Thinhorn Sheep inhabit open mountain slopes, mainly in the subalpine and alpine zones, and forage on grasses, forbs and shrubs. Rutting begins in mid-November and extends into mid-December. Gestation is approximately 175 days, with single young being born mostly between mid-May and mid-June.

II. CONSERVATION BIOLOGY

Thinhorn Sheep in British Columbia can be thought of as being part of one large metapopulation inhabiting B.C., the Yukon, the Northwest Territories and southern Alaska. Six subpopulations are recognized in British Columbia, based on subspecies designation, pelage colour and geographical isolation. The actual number of herds present in these subpopulations is unknown. Problems of founder effect and genetic drift believed to be common among Bighorn Sheep (*O. canadensis*) populations are not likely to be present among Thinhorn Sheep, because their distribution remains largely intact in the province.

III. DISTRIBUTION AND ABUNDANCE

Thinhorn Sheep are found in the northern third of British Columbia, in the Mackenzie and Richardson mountains of western and northwestern Northwest Territories, throughout much of the Yukon Territory (southwestern, northern, eastern and central mountains) and in interior Alaska. From all accounts, the distribution of Thinhorn Sheep has not changed appreciably from historic times. Their habitat remains mostly

intact relative to that encountered by early European explorers. In North America, the population estimate of Thinhorn Sheep has varied from approximately 84 500 in 1975 to 129 000 in 1999. For the same time period, the estimates in Canada have varied from 34 500 to 59 000, and in British Columbia from 12 300 to 15 000.

This report analyzed herd classified count data from 14 surveys conducted from 1972 to 1998. A comparison of the results of two extensive surveys over the majority of the range of Dall's Sheep in the province indicated that between 1985 and 1996 (the most recent survey for this area), all components of this subpopulation increased or were stable. For Stone's Sheep, trends varied by Game Management Zone (GMZ). In the Atlin GMZ, the proportion of lambs increased between 1985 and 1998, while the proportion of rams declined and then recovered; the proportion of class IV rams declined slightly. In the Stikine GMZ, between 1972 and 1996 (the most recent survey of record), all components of this subpopulation, including lambs and all classes of rams, declined markedly, except for the 1998 Cry Lake survey. In the Upper Finlay GMZ, between 1985 and 1993 (the most recent survey of record), all components of this subpopulation, including lambs and all classes of rams, declined markedly. Between 1990 and 1994 in the Northeast Rockies GMZ, both the ram:ewe ratio and the lamb:ewe ratio increased. The class II ram component increased, while the class III and IV rams were stable. Surveys conducted in 2001-02 and 2003-04 in the Cypress-Prophet area of the Peace-Liard (MUs 7-42 and 7-57) indicate Stone's Sheep may be declining in some areas with a lower than average ram component recorded.

IV. HABITAT

Thinhorn Sheep live on open mountain slopes from valley bottoms up to mountaintops. They are found on steep, rugged cliffs and rocky outcrops (predator escape terrain) and on nearby open grass and sedge meadows, where they feed in the summer. The diet of Thinhorn Sheep largely depends on plant availability. They are

primarily grazers on grasses and sedges — more grasses in winter and more sedges in summer.

Dall's Sheep mainly live in the alpine. In winter they select areas with light snowfall and strong winds, where they can move easily and find forage. In the northern part of their range, Dall's Sheep winter range has relatively shallow and soft snow and the climate is cold and dry. Near the southern limits of their range, Dall's Sheep winter range has more precipitation and warmer temperatures, with occasional thaws and subsequent crusting and deeper snow.

Stone's Sheep use alpine areas and cliffs, but also inhabit lower-elevation sub-alpine brushlands and lower forested areas. The highest concentrations of Stone's Sheep are found on lower mountain areas to the northeast of high-elevation mountains, where the high precipitation and winds result in good graminoid production, winter snow removal and summer drying.

V. LEGAL

Thinhorn Sheep in British Columbia are defined as "big game" under the British Columbia *Wildlife Act*. The B.C. Conservation Data Centre of the Ministry of Sustainable Resource Management classifies Dall's Sheep as a blue-listed or Vulnerable species. Although the Blue List identifies conservation concern, it does not provide legal protection. Stone's Sheep are on the Yellow List and are not considered to be at risk. Thinhorn sheep are not protected by legislation other than the general provisions to regulate the use and transport of all wildlife and the prohibition of domestication under the *Wildlife Act*. Thinhorn sheep are not listed in the Convention on International Trade in Endangered Species (CITES), but an export permit or equivalent must be issued. COSEWIC (Committee on the Status of Endangered Species in Canada) has not assessed the status of this species in Canada.

VI. LIMITING FACTORS

At the 2000 North American Wild Sheep and Goat Conference, representatives from British Columbia identified the most significant factors that limit Stone's Sheep survival are predation;

severe winter weather; access management, including access associated with mining and oil and gas exploration; fire suppression and forest encroachment, resulting in reduction of range quality; and disease introduction from domestic animals. Dall's Sheep occur in an ecological zone where forest encroachment is not a factor and at least 75% of them occur within Tatshenshini-Alsek Provincial Park. Therefore, the main limiting factors for Dall's Sheep are predation and severe winter weather.

VII. SIGNIFICANCE

Traditionally, First Nations' people in British Columbia placed a high value on mountain sheep (*Ovis* spp.) and utilized the entire animal, including the meat, hide, sinews, bones and horns. There is considerable interest in Thinhorn Sheep among hunting and wildlife conservation organizations. Thinhorn Sheep are a high-profile, valuable big game species and as a member of the mountain sheep genus are appreciated by many British Columbians for a variety of reasons, including food, culture, art, photography and trophy value. In terms of hunters' willingness to pay, mountain sheep, including Thinhorn Sheep, were rated the highest of the seven provincial ungulate species surveyed in 1995.

VIII. HARVEST MANAGEMENT

Traditionally, since the inception of laws regulating the harvest of wildlife in North America, beginning around the late 1800s and early 1900s, hunting of Thinhorn Sheep was limited to males under an "any ram" regulation. This was followed by a three-quarter-curl horn restriction and, since 1976, a full-curl horn restriction, which was modified to the current definition in 1982. The Provincial Wildlife Harvest Strategy set out the principles and guidelines for Thinhorn Sheep harvest management for the province in 1996. The total annual Stone's Sheep harvest by residents and non-residents between 1976 and 2001 has fluctuated, declining slightly from the beginning to the end of the period. The harvest increased from 1976 to 1989, except for a decline from 1982 to 1984, and then decreased from 1989 to 2003. It is recommended that

Thinhorn Sheep continue to be managed with conservative horn curl regulations. Ewe harvests are not considered to be biologically sustainable at this time.

The total annual Stone's Sheep harvest by residents and non-residents between 1976 and 2001 fluctuated between 250 and 500, declining slightly from the beginning to the end of the period. The annual Dall's Sheep harvest ranged from a high of 14 in 1980 to a low of zero in 2000 and averaged approximately eight rams per year. Both resident hunter numbers and resident hunter effort, measured as hunter days, approximately doubled during the 20-year period from 1981 to 2000, while catch per unit effort (CPUE), measured as rams per hunter day, was reduced approximately by half. An examination of the data based on GMZs indicates that this trend has been universal. This suggests that mature ram numbers are declining

IX. CONSERVATION MEASURES

A metapopulation approach should be used to develop a strategic plan for managing Thinhorn Sheep in British Columbia, the Yukon, Northwest Territories and southern Alaska. The effective management of wilderness areas and the establishment of protective designations, particularly Wildlife Management Areas (WMAs), and the maintenance of connective movement corridors are essential for the long-term viability of Thinhorn Sheep. A coordinated program of prescribed burning and improved livestock grazing practices, particularly for horses, should be instituted to enhance and maintain Thinhorn Sheep winter range. Access management planning must be initiated for controlling off-road vehicle and helicopter access. Commercial backcountry recreational developments must be sited so as to prevent adverse effects on Thinhorn Sheep populations. Lastly, but perhaps of greatest importance, it is recommended that no grazing of domestic sheep (*O. aries*) must be permitted on Crown lands within 16 km of areas

known to be frequented by Thinhorn Sheep. A program should be developed to educate the public about the lethal effects of exposing Thinhorn Sheep to domestic sheep and domestic goats (*Capra hircus*), even "healthy" domestic animals.

X. RESEARCH NEEDS

More studies of predator–Thinhorn Sheep dynamics, including systems with multiple prey species, are recommended. Standardized population inventories should be conducted periodically (every three to five years) based on approved Resources Inventory Standards Committee (RISC) inventory standards, within each Game Management Zone (GMZ) to assess conservation status. Baseline research on diseases in Thinhorn Sheep should receive high priority. Capability/suitability mapping of Thinhorn Sheep ranges, particularly winter ranges, should be completed. Research should also address issues raised by land use activities such as oil and gas exploration and development, fire suppression and subsequent forest encroachment, recreational, urban and access developments and land alienation. The cumulative effects of various types of disturbance on Thinhorn Sheep viability including aircraft disturbance, ground-based human disturbance and motorized access associated with industrial development needs to be investigated.

XI. STATUS EVALUATION

Currently Dall's Sheep is on the Blue List of species and subspecies of special concern (formerly described as "vulnerable"). While both Dall's and Stone's sheep can be negatively affected by human disturbance and domestic livestock, neither is in danger of being affected at this time, due to the protected status of Dall's Sheep habitat and the large size of the Stone's Sheep populations and the relative lack of adverse effects on their habitats. This review found no reason to change the provincial status.

TABLE OF CONTENTS

1.0 GENERAL BIOLOGY	1
1.1 Origin and Taxonomy	1
1.2 Physical Description	2
1.3 Breeding Age and Frequency	3
1.4 Timing of Reproductive Events	3
1.5 Productivity	4
1.6 Mortality and Survival	5
1.7 Population Structure	6
1.8 Population Dynamics	7
1.9 Characteristics of Movements and Seasonal Home Ranges	7
1.9.1 Movement characteristics	7
1.9.2 Sexual segregation of home ranges	8
1.9.3 Home range	8
1.9.4 Size of home range and distance between seasonal ranges	10
1.9.5 Home range fidelity	10
1.9.6 Origin of routes	10
2.0 CONSERVATION BIOLOGY	10
2.1 Metapopulation	11
2.1.1 Subpopulation, herd and band	12
2.2 Demographics	15
2.3 Genetics	16
2.3.1 Inbreeding	16
2.3.2 Random genetic drift	16
3.0 SUBSPECIES DISTRIBUTION AND ABUNDANCE	17
3.1 North America	17
3.1.1 Historic and current distribution	17
3.1.2 North American abundance	17
3.2 Canada: British Columbia, Northwest Territories and Yukon	19
3.2.1 Historic and current distribution	19
3.2.2 Historic and current abundance	20
3.2.3 Population trends	22
3.2.4 Thinhorn Sheep transplants	26
4.0 HABITAT	28
4.1 Habitat Distribution	28
4.1.1 North America	28
4.1.2 Canada	28
4.1.3 British Columbia	30
4.2 Habitat Trend	30
4.3 Habitat Status	32
4.4 Habitat Characteristics	33
4.5 Ungulate Winter Range	35
4.6 Diet	35
4.7 Mineral Licks	37
5.0 LEGAL PROTECTION AND STATUS	37
5.1 North America	37
5.2 British Columbia	38
6.0 LIMITING FACTORS AND RISKS	40
6.1 Habitat Alienation	40

6.2 Disease, Epizootics and Parasites	41
6.2.1 Pasteurellosis	42
6.2.2 Camelids.....	43
6.2.2 Internal parasites	43
6.2.3 External parasites	44
6.2.4 Complex of factors	44
6.3 Forage Competition.....	45
6.3.1 Domestic livestock	45
6.3.2 Native ungulates and other wildlife.....	46
6.4 Forest Encroachment, Fire Suppression and Prescribed Burning	47
6.5 Access and Other Forms of Human Disturbance	48
6.6 Predation	50
6.6.1 The role of predation.....	50
6.6.2 Predator control.....	52
6.6.3 The history of predator control.....	53
6.7 Invasive Alien Plants.....	54
6.8 Winter Severity	54
7.0 SPECIAL SIGNIFICANCE.....	55
7.1 Use and Value.....	55
7.1.1 First Nations' people	55
7.1.2 Early European explorers, prospectors and hunters	56
7.2 Public Interest	58
8.0 Harvest Management	59
8.1 Management History.....	59
8.2 Response to Hunting	60
8.3 Thinhorn Sheep Management Guidelines	61
8.3.1 Provincial management principles and goals	61
8.3.2 Hunting policies	62
8.3.3 Regulating harvest.....	62
8.4 Analysis of Current Harvest	63
8.4.1 Monitoring the harvest	63
8.4.2 Trends in the harvest	63
8.4.3 Hunters and hunter effort	64
8.4.4 Population model.....	68
9.0 CONSERVATION AND MANAGEMENT MEASURES	68
9.1 Strategic Planning	69
9.1.1 Land use planning	70
9.2 Habitat Management and Conservation	71
9.2.1 Livestock grazing strategies	71
9.2.2 Wilderness management.....	71
9.2.3 Forest and range planning	72
9.2.4 Human disturbance and access management.....	72
9.2.5 Adaptive management: habitat enhancement and stewardship programs.....	74
9.3 Population Management and Conservation.....	74
9.3.1 Population inventory and monitoring.....	74
9.3.2 Disease prevention and mitigation	75
9.3.3 Translocations	76
9.3.4 Predation	77
10.0 RESEARCH NEEDS.....	77
10.1 Population Dynamics	77
10.2 Biophysical Inventory	78
10.3 Health.....	78

10.4 Habitat Use and Enhancement	78
10.5 Limiting Factors.....	78
10.6 Fragmentation and Dispersal Rates.....	79
10.7 Genetics and Taxonomy.....	79
11.0 STATUS EVALUATION	79
11.1 Dall’s Sheep	79
11.2 Stone’s Sheep	79
12.0 REFERENCES	80
13.0 APPENDICES	94
13.1 Appendix 1: Population Trend Data.....	94

LIST OF TABLES

Table 1. Classification of Thinhorn Sheep	1
Table 2. Range requirements of wild sheep at landscape and local levels of resolution	9
Table 3. Population divisions of mountain sheep based on a metapopulation conceptual model using a Thinhorn Sheep example with population estimates for each division.....	12
Table 4. Proposed subdivisions of Thinhorn Sheep subpopulations in British Columbia based on pelage colour patterns, isolation and management units.....	13
Table 5. Population estimates for Thinhorn Sheep in North America	19
Table 6. Population estimates for Dall’s and Stone’s sheep in Canada.....	21
Table 7. Population estimates for Stone’s (and Dall’s) Sheep in British Columbia, 1987-2003.....	22
Table 8. Population estimates of Thinhorn Sheep in British Columbia in 1994.....	23
Table 9. Population structure of Dall’s and Stone’s sheep in five Game Management Zones in northern British Columbia from 14 inventory reports, 1972-1998.....	24
Table 10. Age and sex ratios of Dall’s Sheep in the Tatshenshini watershed of British Columbia, 1980-1996.....	26
Table 11. Inventory summary of Stone Sheep for Prophet River/Cypress Creek survey area (MUs 742, 7-51).....	26
Table 12. Thinhorn Sheep transplant history for British Columbia.....	27
Table 13. Ecoregions in Alaska containing Dall’s Sheep, with equivalent terminology from Canada in brackets.....	29
Table 14. Ecozones, ecoprovinces and ecoregions in British Columbia, Yukon and Northwest Territories that contain either Dall’s Sheep (D), Stone’s Sheep (S) or zone of overlapping range.....	29
Table 15. Distribution of Thinhorn Sheep habitat in British Columbia in relation to ecoregions and ecosections and biogeoclimatic zones	31
Table 16. Biogeoclimatic zones and broad ecosystem units inhabited by Thinhorn Sheep in British Columbia	32
Table 17. Coarse feature requirements used for habitat mapping of Bighorn Sheep and applicable to Thinhorn Sheep	34
Table 18. Parks and protected areas in British Columbia that contain Thinhorn Sheep habitat, by management zone	38

Table 19. Three categories of responses of wild sheep to human activities in their habitats, and expected population effects	48
Table 20. Respective hunting management regimes (2001-2002) and degree of interchange between British Columbia and Yukon Thinhorn Sheep populations.....	60
Table 21. Ten-year average number of Thinhorn Sheep hunters, hunter days and harvest between 1992 and 2001	63
Table 22. Dall's and Stone's sheep classified count data from 14 inventory reports from northern British Columbia, 1972-1998	94
Table 23. Revised Dall's and Stone's sheep classified count data from 14 inventory reports from northern British Columbia, 1972-1998.....	96

LIST OF FIGURES

Figure 1. Distribution of Thinhorn Sheep in North America including British Columbia, Yukon, Northwest Territories and Alaska, defined by ecoprovince	18
Figure 2. Thinhorn Sheep distribution in British Columbia and adjacent portions of the Yukon and Northwest Territories, defined by ecoprovince, ecoregion and ecosection.....	20
Figure 3. Resident and non-resident harvest of Stone's Sheep rams in British Columbia, 1976-200	64
Figure 4. Resident and non-resident harvest of Dall's Sheep rams in British Columbia, 1976-2003	65
Figure 5. Resident and non-resident Stone's Sheep hunters in British Columbia, 1981 to 2003	65
Figure 6. Resident and non-resident Dall's Sheep hunters in British Columbia, 1981 to 2003	66
Figure 7. Stone's Sheep rams per hunter day (resident and non-resident) in British Columbia, 1981-2003	67
Figure 8. Dall's Sheep rams per hunter day (resident and non-resident) in British Columbia, 1981-2003	67

1.0 GENERAL BIOLOGY

1.1 Origin and Taxonomy

Thinhorn Sheep (*Ovis dalli*) belong to the Order Artiodactyla (even-toed ungulates), Suborder Ruminantia (ruminating or cud-chewing mammals), Family Bovidae (horned ungulates)

and Tribe Caprini (Table 1). Caprini is sometimes called the goat antelope subfamily and includes such species as Ibex (*Capra ibex*), Musk Ox (*Ovibos moschatus*), Mouflon (*Ovis musimon*) and Mountain Goat (*Oreamnos americanus*).

Table 1. Classification of Thinhorn Sheep (Valdez and Krausman 1999).

Upper Taxa	Class Mammalia; Order Artiodactyla (even-toed ungulates); Family Bovidae (sheep, goats, bovines, antelopes); Tribe Caprini (sheep, goats); Genus <i>Ovis</i> (true sheep).
Species Thinhorn Sheep	<i>Ovis dalli</i>
<i>Ovis dalli dalli</i>	Nelson, 1884 (Dall's Sheep)
Type locality	Mountains south of Fort Yukon on west bank of Yukon River, Alaska, probably Tanana Hills.
Synonym	<i>Ovis dalli kenaiensis</i> J.A. Allen, 1902. Type from head of Sheep Creek, Kenai Peninsula, Alaska.
<i>Ovis dalli stonoi</i>	J.A. Allen, 1897 (Stone's Sheep)
Type locality	Headwaters of Stikine River, British Columbia.
Synonym	<i>Ovis dalli fannini</i> Hornaday, 1901. Type from Dawson City, Yukon.

Large wild sheep evolved in Asia during the early Pleistocene from about 2 to 2.5 million years BP. During the late Pleistocene, ancestors of today's North American sheep evolved their distinctive characteristics while isolated in the ice-free Beringian glacial period (Cowan 1940; Korobitsyna et al. 1974). During this period, ice covered most of North America north of an imaginary line extending from what is now Washington State to New Jersey. When the continental and cordilleran glaciers blocking this route melted, ancestors of Bighorn Sheep (*O. canadensis*) migrated southward into western Canada and the United States, while ancestors of Thinhorn Sheep remained in the region or migrated back across the land bridge to recolonize northeastern Asia. These latter sheep evolved into the present-day Snow Sheep (*O. nivicola*), while the isolation of ancestors of Thinhorn Sheep in northern North America during the

Wisconsin glaciation resulted in the differentiation of Dall's and Stone's sheep (*O.d. dalli* and *O.d. stonoi*) (Korobitsyna et al. 1974).

Formerly, taxonomists relied almost exclusively on morphological skull measurements to separate species and subspecies of large mammals (e.g., Cowan 1940). However, cranial differences are often a reflection of age and environmental conditions affecting growth under natural conditions. Without the benefit of controls, cranial measurements are probably not statistically reliable indices upon which to base species or subspecies differences (Ramey 1999). Also, subspecies or geographic races are usually based on subjective criteria, often making their differentiation more controversial. For example, Hornaday (1901) and Sheldon (1911) attempted unsuccessfully to establish a separate subspecies (*O.d. fannini*) based on pelage colouration alone.

In the past decade, DNA testing has been employed to study speciation in Bighorn Sheep (Ramey 1993, 1999). More recently, this technology has been applied to Thinhorn Sheep populations in the Yukon, although at the time of writing the results have not been finalized (J. Carey, pers. comm.)

1.2 Physical Description

Thinhorn Sheep are the smallest of the New World species of the genus *Ovis*. They are a medium-sized, stockily built, slim-legged, short-eared and short-tailed ungulate (Shackleton 1999). Mature Thinhorn Sheep possess powerful, muscular front and hind quarters, sturdy necks, legs and backs, and robust, concave hooves with rough, flexible under-pads, all of which are adaptations to travel in steep, rugged, rocky terrain.

Dall's Sheep are all white, while Stone's Sheep vary in colour. All Stone's Sheep possess a short, black tail, a white muzzle and ivory white rump and ventral patches. Pelage colour on the head, neck and dorsal body of Stone's Sheep varies greatly from very light grey to medium rich brown to almost black. The winter coat of Dall's Sheep is composed of dense, hollow, crinkly guard hairs and grows thicker than 5.1 cm on their backs, with a thinner layer of fine wool close to the skin. Dall's Sheep and Arctic Foxes (*Alopex lagopus*) are the best insulated northern mammals, better than Caribou (*Rangifer tarandus*) or Polar Bears (*Ursus maritimus*) (Scholander et al. 1950 in Nichols and Bunnell 1999).

Both sexes support horns, which normally stop and start growing during the nutritional stress period during winter, resulting in visible external growth rings or annuli. The horns of female Thinhorn Sheep are goat-like and similar in size to those of female Bighorn Sheep, averaging approximately 15 to 20 cm, and occasionally reaching 30 cm. The curved and often circular horns of male Thinhorn Sheep may reach 130 cm in length, but most mature rams produce horns that are between 90 and 110 cm in length. Horns of Dall's Sheep are not as massive as those of Bighorn Sheep and are slightly smaller

than those of Stone's Sheep. An average Dall's Sheep ram produces horns with a basal circumference of between 30 and 36 cm, while male Stone's Sheep horns may reach 41 cm in basal circumference. These are in comparison to a maximum of 43 cm in Bighorn Sheep (Geist 1971; Boone and Crockett Club 1988; Trophy Records Club of B.C. 1988).

The horns of rams form the concussive weapons used during highly ritualized head butting contests between males for access to females, and are displayed in threatening postures to establish rank order among males (Geist 1971). Mountain sheep males develop a frontally strengthened skull plate and an expanded sinus structure designed to create space (pneumation) that acts to cushion the effects of blows.

Considerable attention has been paid to studying horn growth, particularly in rams (Hoefs and Nette 1982), although horn growth in ewes has been studied as well (Bunnell 1978; Nichols and Bunnell 1999). Bunnell (1978) concluded that measures of horn growth in Dall's Sheep were not correlated with body size in either ewes or rams. He found that horn growth is a function of precipitation, implicating primary production, and shows marked differences. Rams that exhibited rapid early horn growth subsequently showed slower growth. He also found that horn growth of rams is more strongly affected by differences in environmental conditions than is horn growth of ewes. In good years, growth is enhanced uniformly over all ram age-classes. Interestingly, the physical condition of a ram's dam during pregnancy and lactation can affect the growth of his horns for at least his first five years. Bunnell (1978) suggested the use of horn growth patterns to develop indices of herd quality and emphasized the importance of range quality in the production of large-horned rams.

Adult rams (>4 years old) weigh an average of 80 kg (to a maximum of ~135 kg) and adult ewes (>2 years old) weigh an average of 57 kg (to a maximum of ~80 kg) (Valdez and Krausman 1999). Bunnell and Olsen (1976) calculated that in Kluane National Park, mature Dall's Sheep ewes older than six years of age had a mean weight of 48.7 kg (n = 8). Hoefs and

Nowlan (1993) found that captive Dall's Sheep female lambs, shortly after birth, had a mean weight of 3.5 kg ($n = 6$). Bunnell (1980*b*) correlated body weight, body length, chest girth and horn length in Dall's Sheep and found that body length and chest girth provided the most accurate estimates of weight.

1.3 Breeding Age and Frequency

Nichols and Bunnell (1999) concluded that Thinhorn ewes usually become reproductive when reaching their adult weight, rather than at a specific age, and that ewes and rams on nutritious ranges may mature earlier than those on poor ranges. The average minimum breeding age of ewes varies by herd and can be 18 months under good nutritional conditions, 30 months with less favourable conditions and four to five years in some herds, depending upon growth rates (Nichols and Bunnell 1999). Free-ranging Dall's Sheep ($n = 63$) had their first lamb at three, four or five years of age (Bunnell and Olsen 1982), while 95% of captive Dall's Sheep gave birth at two years old ($n = 25$) (Hoefs and Nowlan 1994). In Dall's Sheep, as in other mountain sheep, there have been exceptions when yearlings or long-yearlings were found to be pregnant (Bunnell and Olsen 1982; Hoefs and Nowlan 1993). Delayed puberty has also been found in Dall's Sheep, with some ewes being five years of age before primiparity (first birth) (Bunnell and Olsen 1982).

Under natural conditions, where older rams are present, rams begin active participation in the rut at approximately six years. Rams with horns larger than three-quarter curl (five to seven years in Dall's Sheep and younger in Stone's Sheep on good range) generally dominate the breeding. Younger rams of 1.5 to 5.5 years are sexually mature, but most are inhibited though not totally prevented from breeding by the dominance hierarchy of the older rams. Social interactions between males (i.e., displays of antagonistic dominance behaviour) occur well before the rut. The importance of this behaviour is realized through the establishment and reinforcement of a dominance hierarchy, which presumably results in the successful courtship and insemination of estrous females by the most dominant

males (i.e., the largest, healthiest and fittest), although immature sheep are known to copulate with ewes (Blood 1963; Geist 1971).

For Dall's Sheep studied over two seasons in the Klauane area of the Yukon, 80% reproductive success (the birth of a viable lamb) was achieved only by five-year-old ewes (Bunnell and Olsen 1982). The authors concluded that the birth rate did not exceed 50% until ewes reached five years of age. Rams and ewes can reproduce throughout their adult lives. Some of the few Dall's Sheep ewes surviving to 13 to 16 years have been found to be pregnant or to have lambs at heel (Nichols and Bunnell 1999).

In Dall's Sheep in Alaska, the rate of initial lamb production was found to be sacrificed as an adaptation favouring enhanced survival of lambs (Heimer 1978). Ewes extended the lactation period, which led to reproduction in alternate years in a declining population. The reasons for low, alternate-year reproduction were unclear and may have been related to weather or poor range condition. At northern latitudes, where the period for rearing young is limited, ewes vary weaning time to compensate for environmental conditions and the timing of births (Rachlow and Boyer 1994). By varying the weaning time, ewes can consecutively raise young each year rather than alternating reproduction years or terminating pregnancies.

1.4 Timing of Reproductive Events

Bunnell (1980*a*) concluded that timing and duration of lambing in Dall's Sheep are influenced primarily by vegetative growth mediated through energy requirements and that photoperiod is the proximate factor governing the breeding period. Rachlow and Boyer (1991) found that climatic variability probably contributes more than predation in constraining timing and synchrony of parturition in Dall's Sheep, even in a predator-rich environment. As with most northern ungulates, the mating period or rut is timed to optimize the availability of abundant nutritious forage at parturition due to the energetic and nutritional requirements of lactation (Hebert 1973; Bunnell 1982; Thompson and Turner 1982). Estrous cycles are approximately

12 to 14 days in Dall's Sheep (Bunnell 1980a). Estrus (i.e., heat, mating receptivity) in ewes lasts about three days and induces rutting activity in rams. Rutting in Dall's Sheep in the Kenai Mountains, Alaska, begins in mid-November and ends in mid-December, peaking on November 20 (Nichols 1978). Stone's Sheep rut peaks and extends later than Dall's Sheep (Nichols and Bunnell 1999).

The gestation period is about 171 days. Thin-horn Sheep populations in harsh environments have shorter lambing periods and terminate lambing earlier (Nichols and Bunnell 1999). There were no significant correlations between latitude and onset, termination or duration of lambing. The mean lambing period of 18 populations of North American mountain sheep was 29.8 ± 2.4 days (almost precisely two inter-estrous periods in length) (Bunnell 1982). Most Dall's ewes conceive during the first two estrous cycles, but sometimes during the third cycle (Bunnell 1980a, 1982). The lambing period for Stone's Sheep is from May 23 to June 16 and from May 17 to May 24 for Dall's Sheep (Nichols and Bunnell 1999). The duration of lambing is restricted by the need for lambs to grow large enough to survive winter.

1.5 Productivity

Productivity is the measure of the vigour of a sheep population and varies both between years, for a given herd, and between herds. Recruitment, the number of sheep of breeding age added to a herd each year, is one measure of a herd's productivity. Because recruitment is not always measured, it is necessary to use other factors for assessing productivity, such as pregnancy, birth and mortality rates and the observed ratios of classes of sheep.

In a wild population of Dall's Sheep studied for 23 years, the productivity per adult female was 0.32 young per year. In comparison, among captive Dall's Sheep under artificial conditions the average was 0.85 young per adult female (Hoefs and Nowlan 1994). The mean recruitment rate for a Dall's Sheep population in southwest Yukon was 0.15 yearlings per adult (2+ years

old) in a population characterized by low productivity, high lamb survival and short life expectancy (Hoefs and Bayer 1983).

Hoefs and Bayer (1983) also found that 78% of Dall's Sheep ewes older than two years were pregnant after the rut. Pregnancy rates of 75 to 100% are probably typical (Nichols and Bunnell 1999).

The birth rate is defined as the number of viable lambs observed immediately after parturition and expressed as the ratio of lambs to 100 ewes over two years of age (Nichols and Bunnell 1999). Ratios have been observed from zero lambs per 100 ewes to greater than 80:100 (Nichols and Bunnell 1999). Birth rates can vary depending on habitat conditions. Fetus mortality rates also affect birth rates. A birth rate of 75.2% was estimated for Dall's Sheep in the Mackenzie Mountains (Simmons et al. 1984).

Lamb:ewe ratios measured at various times after parturition are commonly used as indicators of mountain sheep population vigour (i.e., productivity). High proportions of lambs are assumed to imply healthy, expanding herds of high quality, while the reverse is implied for herds with low ratios (Geist 1971). Generally, 30 to 40 lambs per 100 ewes and yearlings in mid- to late summer is considered adequate to maintain a stable population in years with normal or less severe winters (Whitten 1997). Midsummer Dall's lamb:ewe ratios ranged from 8:100 to 81:100 in Alaska, with an average of 37:100 (Nichols 1978).

J.P. Elliott (B.C. Wildlife Branch, unpubl. data in Nichols and Bunnell 1999) reported a lamb:ewe ratio of 47:100 in a summer survey of 521 Stone's Sheep ewes and juveniles. Winter surveys by the same source documented a lamb:ewe ratio of 35:100 for nine-month-old lambs. Simmons et al. (1984), reporting on the results of a seven-year study of immature and female Dall's Sheep in the Mackenzie Mountains, Northwest Territories, estimated a 75.2% birth rate, 80% early lamb survival and 49% survival to one year of age. They estimated that the average annual mortality for ewes older than one year was 14.8%. Average life expectancy for

yearling ewes was 6+ years, with both sexes living as long as 14 years, similar to life spans in other mountain sheep populations.

Heimer and Watson (1986b) described a population of Dall's Sheep over a period when weather conditions, hunting seasons and Grey Wolf (*Canis lupus*) control may have been factors affecting lamb production. They hypothesized that high lamb abundance correlates not only with favourable weather conditions, but also with high ram abundance and older ram age structure. Presumably, older rams have more experience with predator avoidance and stimulate higher frequency of estrus in ewes. When there are fewer older rams in a population, there are fewer individuals to watch for predators. In addition, young rams may be compromised by being in poorer shape for their premature participation in the rut. This could lead to greater mortality levels for young rams and consequently less mating and poorer lamb production (Heimer and Watson 1986b).

In a comparison of two separate herds of Dall's Sheep in Alaska, one heavily hunted and one lightly hunted, Heimer and Watson (1982) hypothesized that alternate-year lamb production by the heavily hunted herd may have been due to breeding of younger ewes by younger rams in the absence of older rams. The less heavily hunted herd, with similar nutritional and body condition components, had annual lamb production and an older age of primiparity by ewes. The benefits of managing for annual lamb production are evident when measured over a 10-year life span: with primiparity at three years of age, production is eight lambs per ewe. If primiparity is at two years old and there is alternate-year lambing, the lifetime production over 10 years would be only five lambs per ewe (Heimer and Watson 1982).

1.6 Mortality and Survival

Mortality rates are variable, depending on the cohort examined and the conditions or stocking rates of those cohorts. An average annual mortality rate of 20% was calculated for adult Dall's ewes in Kluane National Park and 15% for ewes older than one year in the Mackenzie Mountains

and in McKinley National Park (Simmons et al. 1994; Nichols and Bunnell 1999). For an un-hunted Dall's Sheep population in southwest Yukon, the mortality rate of rams from birth was 24% (Hoefs and Bayer 1983).

Mountain sheep are most vulnerable to death during their first year of life and the average mortality rate for Dall's Sheep at or just after birth is generally about 50 to 60% (Nichols and Bunnell 1999). Lamb mortality is not uniform; it appears to be concentrated into two distinct time periods: during the first weeks following parturition; and during winter. Lambs are particularly vulnerable during the first few days after birth, when predation and/or disease (e.g., pneumonia) are major mortality factors, while death can occur in later weeks due to malnutrition (Festa-Bianchet 1988a). However, predation risk is reduced because Thinhorn Sheep lambs are born in precipitous terrain relatively safe from predators (Murie 1944; Geist 1971; Nichols and Bunnell 1999). Heimer (1978) estimated that in Dall's Sheep, lamb mortality associated with parturition may range from 40 to 60% when unfavourable weather conditions occur, while under favourable weather conditions it may range from zero to 40%. In Kluane, Dall's Sheep lamb mortality was 24 to 28% in the first two weeks and 10 to 17% in the next two weeks (Nichols and Bunnell 1999). In the Mackenzie Mountains of the Northwest Territories, about 20% of lambs died between birth and midsummer (Simmons et al. 1984).

Survival of lambs to one year of age has been observed to range from 7% in a declining population to 100% in a rapidly expanding population (Nichols and Bunnell 1999). The variation can depend on factors such as winter conditions, nutrition and predation. Average survival of lambs to the age of 11 to 14 months was approximately 60% in Dall's Sheep herds (Nichols and Bunnell 1999).

Unlike in many Bighorn Sheep populations, few large die-offs have been recorded for Dall's Sheep and those that have occurred were attributed mainly to adverse weather, including summer droughts and severe winters (Heimer 1988b). A search of the literature failed to

uncover any recorded die-offs of Stone's Sheep. Burles and Hoefs (1984) documented a 25.3% decline of Dall's Sheep in Kluane National Park, from 241 in June 1981 to 180 in June 1982. Declines of 30 and 40% were also recorded during the same period in other areas in the park, as well as other areas of the Yukon, indicating the influence of a universal factor, probably weather. Older animals (7+ years) and lambs were the cohorts primarily affected. The factors involved included: a high density of sheep on winter ranges with below average forage production; a severe, calm winter with long cold periods and deep snow taxing the energy reserves of the sheep; delayed green-up, slowing the recovery of the sheep; and unusually high predator pressure because of lack of alternate prey species. This incident occurred during the most severe winter on record for the 15 years that sheep populations have been monitored in the Yukon.

The oldest Dall's Sheep recorded is a ewe of 19 years 10 months in Kluane National Park in the winter of 1988-89 (Hoefs 1991). The loss of functional teeth appears to determine longevity, with the oldest Thinhorn rams living 12 to 14 years and ewes living on average one to two years longer (Nichols and Bunnell 1999). Hoefs and Nowlan (1994) recorded a mean life expectancy of 8.8 years for wild male Dall's Sheep ($n = 184$) and 5.7 years for captive males ($n = 10$). Female life expectancy is longer at 10.5 years for wild Dall's Sheep ($n = 42$) and 9.2 years for captive females ($n = 5$). The condition of the population, however, can determine the length of life and the reproductive potential. Comparable data do not exist for Stone's Sheep, but longevity is expected to be similar.

1.7 Population Structure

Population structure can be understood as an analysis of the sex ratio and age-class structure of a population. Monitoring sex and age structure is essential for management purposes. The sex ratio at birth is probably equal, although distorted sex ratios favouring females have been documented in captive Dall's Sheep that have high-quality supplementary feed (Hoefs and Nowlan 1994). These same authors postulated that males are favoured when range conditions

are poor, possibly as a form of population regulation.

Sex ratios change temporarily and spatially due to a variety of factors, such as survival of cohorts and hunting removals. In un hunted Dall's Sheep populations the observed ram:ewe ratio averaged from 60 to 67:100 in Mount McKinley and Gates of the Arctic national parks in Alaska, 93:100 in Kluane National Park in the Yukon and 56:100 in the Copper Landing closed area from Alaska (Nichols and Bunnell 1999).

In Management Unit (MU) 6-20 in the southern Stikine watershed of British Columbia, where hunting occurs, Harper (1972) classified 804 Stone's Sheep, with a ram:ewe ratio of 52:100. In the same area 13 years later, 401 sheep were classified and the observed ram:ewe ratio was 46:100 (Steventon and Marshall 1985) and in 1992, of 717 sheep classified, the ram:ewe ratio was 38:100 (Schultze 1992). In one accessible, overhunted area (Todagin Mountain), Harper (1972) classified 109 sheep and found a ram:ewe ratio of 20:100, with mainly class I and II rams.

The long-term, average yearling:ewe ratio over many Dall's Sheep herds and under varying conditions was 21:100 ($n = 59$) (Nichols and Bunnell 1999). For Stone's Sheep, the long-term average ratio of yearlings at 21 months old to ewes was 15:100 (J.P. Elliott, unpubl. data in Nichols and Bunnell 1999). In the Todagin Stone's Sheep population, the observed lamb:ewe ratio was 48:100 in 1985 and 27:100 in 1992 (Schultze 1992). The 1996 survey of 233 Dall's Sheep in Tatshenshini-Alsek Provincial Park found that lamb production was higher, at 45 lambs:100 ewes and yearlings, than in 1985 at 35:100 (Cichowski 1996).

Herd classified counts (HCC) generally include these classes: lambs; ewes and yearlings; and class I to IV rams (Geist 1971). Survey data can be compared with previous counts to assess changes in the population structure. For example, in the Todagin sheep population, the number of class IV rams per 100 ewes was 4 in 1972 (Harper 1972), 8 in 1985 (Steventon and Marshall 1985) and 6 in 1992 (Schultze 1992). In Tatshenshini-Alsek Provincial Park in 1996, the

number of class IV rams per 100 ewes and yearlings was 14, among the highest recorded over a comparable area (Cichowski 1996).

McCullough et al. (1994) cautioned wildlife managers that herd classified counts by themselves do not estimate population size changes nor do they allow for interpretation of population dynamics. They recommend that HCC be used together with management experiments to maximize usefulness of the method. The difficulty in distinguishing yearling ewes from lambs and yearling rams from ewes (Geist 1971) further limits the usefulness of such data when obtained by aerial census. Festa-Bianchet (1992) states: "...it appears that there is no substitute for complete counts to assess changes in Bighorn population size. Age ratios cannot reliably forecast such changes."

1.8 Population Dynamics

Population dynamics are manifested and expressed in terms of births, deaths, immigration and emigration. Whether the size and structure of a population is stable, increasing or declining depends on the net effect of those factors. Most Thinhorn Sheep herds experience great fluctuations, often caused indirectly by winter weather, which affects the herd's foraging opportunities and/or predator vulnerability. Dall's Sheep herds on Alaska's Kenai Peninsula and in McKinley National Park have been documented as having the classic ungulate pattern of population irruption after a major decline (Nichols and Bunnell 1999). During their sigmoidal period of increase, the herds grew at an annual mean of 11 to 14%, a rapid increase. As the maximum population number was reached, their growth rate dropped to zero and the herds either stabilized or decreased. Geist (1971) characterized sheep in expanding populations as having rapid body and horn growth, early sexual maturity, high lambing rates, high juvenile survival to adulthood and short life expectancy. Conversely, nonexpanding or stable populations have slower body and horn growth, delayed sexual maturity, lower lambing rates, higher juvenile mortality and long life expectancy.

On ranges of expanding sheep populations, winter forage could be expected to be abundant, but over utilized and stressed where stable sheep populations occur (Nichols and Bunnell 1999). The density of expanding sheep populations would be low for abundant available forage and competition would be light. For stable sheep populations, the density of sheep would be high in relation to available forage and competition would be severe.

Such characteristics of expanding and stable populations have been confirmed in Thinhorn Sheep, demonstrating that as populations reach range carrying capacity, lowered nutrition affects the animals' growth rates, survival and ability to reproduce. Thinhorn Sheep can be considered density-dependent because the pattern of irruption oscillates with the food supply, but catastrophic winters, disease outbreaks or excessive predation can disrupt this pattern, causing a decline regardless of forage availability (Nichols and Bunnell 1999).

At Sheep Mountain in southwest Yukon, the sheep population has remained at carrying capacity, annually consuming less than 50% of the forage, which is a safe range use practice (Hoefs and Brink 1978). Forage production seems to correlate with lamb production and overwintering lamb survival. Thus, Hoefs and Brink (1978) speculate that a Thinhorn Sheep population is regulated by those factors in relation to forage production. This is different than Bighorn Sheep populations, which have periodic die-offs after population build-ups (Stelfox 1971).

1.9 Characteristics of Movements and Seasonal Home Ranges

1.9.1 Movement characteristics

Complex spatial and temporal range use patterns are characteristic of subpopulations of mountain sheep. These natural patterns of migration and socialization have serious implications for some aspects of genetics, disease transmission and conservation efforts. In addition to frequent movements by individual rams and infrequent movements by small bands of ewes, mountain sheep have three kinds of major movements:

1) local shifts within home ranges; 2) seasonal migrations between home ranges; and 3) rare mass emigrations (Geist 1971). Local shifts are usually due to environmental factors such as a crust forming on snow or abnormally low snowfall in the winter (allowing a more dispersed distribution) or sprouting vegetation in the spring. Seasonal migration is not simply a response to weather, forage or pests, but a more complex, internally motivated movement, which is synchronized by external environmental factors, most likely light regime (Geist 1971) and by forage development and maturation (Hebert 1973). Seip and Bunnell (1985c) showed that herbage production in subalpine areas started four to five weeks before production in the alpine areas. This would affect seasonal migrations. Mass emigration is a deviation in movement patterns usually due to sudden deterioration of habitat (Geist 1971).

Movements are not rigid, nor are they the same for all individuals within a group. The tempo of movements also varies. Ram movement to and from wintering areas is a slow drift, with smaller groups gradually arriving at or departing from the wintering grounds (Geist 1971). Conversely, the trip to rutting grounds is rapid and determined (Geist 1971). The migration of rams is probably internally motivated, but synchronized by the changing light regime (Geist 1971). For both sexes, these migrations are initiated by hormonal changes stimulated by day length. The rutting season and the gestation period could synchronize movements for females (Geist 1971). Other events are less accurately timed.

1.9.2 Sexual segregation of home ranges

Mountain sheep are gregarious, but live in sexually segregated groups (Geist 1971). This social system has a role in influencing their home ranges. Group living improves feeding efficiency and predator detection and avoidance. During the lambing season, ewes seek solitude in rocky bluffs near their winter range to protect lambs from inclement weather (Geist 1971) and to avoid predation on lambs (Shackleton and Bunnell 1987; Festa-Bianchet 1988b). Ewes and lambs are highly vulnerable for several days following birth. Shackleton et al. (1999) state:

“...the only consistently effective anti-predator strategy at this stage seems to be the female’s selection of an isolated and precipitous area to give birth.” Indeed, it is such rugged “escape terrain” which often defines or limits the suitability of otherwise productive range to sustain mountain sheep. After the ewe-lamb bond is formed and lambs are fully mobile, they join other maternal groups and move up-slope to summer range. Rams over 1.5 years old normally form all-male groups and only occasionally frequent ewe-juvenile groups during the summer. Sexual segregation outside the rut has been hypothesized to reduce intraspecific competition and disturbance of ewes and lambs by males (Geist and Petocz 1977; Shank 1982).

In the fall, both sexes migrate towards the ewe-juvenile wintering areas. Rutting normally occurs on the ewe-juvenile winter ranges. After the rut, most of the males over 1.5 years old separate from the ewe-juvenile groups, moving to separate winter ranges while ewe-juvenile groups either remain on or move to winter ranges until spring.

1.9.3 Home range

Geist (1971) defined seasonal home range as “an area to which an animal confines itself between two seasonal migrations and which it occupies at the same time in successive years.” Male mountain sheep use as few as two and as many as six separate seasonal home ranges during a year (Table 2). For major ram bands, ranges can include pre-rut, rutting, mid-winter, later-winter/spring, salt lick and summer ranges, as was found for Stone’s Sheep on Sanctuary Mountain (Geist 1971). Ewes can use as many as four ranges, including winter, spring, lambing and summer ranges (Geist 1971). Generally ewes use two to three seasonal ranges (Geist 1971; Shackleton 1973). When two ranges are used, they are a summer and winter range. An example of the average length of time that Stone’s Sheep rams spent on their seasonal home ranges (based on two to twelve rams) was 25 days on the pre-rut range, 50 days on the rutting range, 154 to 191 days on the rut and mid-winter home range (Geist 1971).

Table 2. Range requirements of wild sheep at landscape and local levels of resolution (after Bailey 1999).

Landscape Requirements	Herd Component^a	Habitat Requirements
Pre-rut range	Rams	Security factors
Rutting range	Rams, ewes	Visibility, escape terrain
Winter range	Rams, ewes	Forage
Spring range	Rams, ewes	quantity
Lambing range	Ewes	continuity, dispersion
Salt-lick range	Rams and ewes	quality, composition
Summer range	Rams, ewes	reliability, diversity
Migration corridors	Between ranges	Water
Metapopulation corridors	Between herds	Minerals
		Juxtaposition of factors

^a Covariables: sex, age, number of sheep; predator types and abundance; human disturbance; biotic disturbance (e.g., fire) and succession; proximity to domestic sheep (*O. aries*); season; weather.

Most rams are scattered in small groups in rugged habitat through the summer and many do not return to the wintering grounds until just prior to the rut (Nichols and Bunnell 1999). In late September or early October, large bands of rams move to a fall concentration area, where they generally stay for two to five weeks. They disperse from that pre-rut range to rutting grounds from the last week of October or the first week in November until the end of December (Geist 1971). At that time, some rams will return to pre-rut home ranges, while others move to midwinter home ranges, where they spend 271 to 303 days (Geist 1971). Ewes arrive later at the wintering areas and depart earlier, spending 240 to 268 days on wintering grounds (Geist 1971).

The fall concentration area will usually be where the ewes remain in the winter (Geist 1971). By mid-March, most of the rams return to these fall concentration areas for a massive spring concentration, which is often twice as large as in the fall. When moving from winter to summer range, sheep will visit mineral licks and this is the period of maximum use. Even when their winter and summer ranges were not geographically separated, Dall's Sheep in Alaska traveled to visit a lick at that time (Heimer 1973). Rams were found to travel up to 16 km out of their way to spend time at the mineral lick, increasing their traverse to summer ranges to as much as 20 km. Peak lick use was in early summer (June) over three years in Dry Creek, Alaska (Heimer

1973). Dall's Sheep in Alaska have winter ranges that appear to lie within summer ranges, and separate winter ranges are uncommon in the Alaska Range (Spiers and Heimer 1990). Rutting and lambing areas in the Alaska Range are usually small areas within winter ranges and this is probably true for British Columbia as well.

In late March or April, separate winter/spring range may be used once the snow hardens or is reduced enough to allow movement. For Stone's Sheep north of the Peace Arm of the Williston Reservoir, spring movements occurred between mid-May and the first week of June (Backmeyer 2000). In spring, Thinhorn Sheep frequently move down to lower elevations to feed on emergent vegetation and then follow the new vegetation up as it appears through the summer at higher elevations. Females move upward to lambing areas in late May, June or the beginning of July. Lambing may take place on the winter range or in a separate lambing range. In late June or early July, barren females, juveniles and rams move to summer ranges. En route to summer ranges, sheep may spend time at intermediate ranges or mineral licks. Throughout their range, Dall's Sheep ewes leave winter/spring ranges in mid- to late June after lambing and move to summer habitat, following or preceding the rams by a week or two, depending on the weather (Nichols and Bunnell 1999). Stone's Sheep normally leave their winter ranges prior to parturition, and lambing occurs on early summer ranges (Nichols and Bunnell 1999).

1.9.4 Size of home range and distance between seasonal ranges

Seasonal home ranges vary considerably in size and in the distance to other seasonal home ranges. Generally, home ranges encompass part or all of a mountain. Geist (1971) calculated minimum diameter of a mountain sheep home range to be about 0.8 km in mid-winter and the maximum to be about 5.9 km in spring and fall. During the winter when the snow is soft, Thinhorn Sheep may confine themselves to rather small areas, such as the steep rugged west slope of Sanctuary Mountain, which is 0.8 km across (Geist 1971). The home range size for four Stone's Sheep ewes north of the Peace Arm of Williston Reservoir ranged from 43 to 132 km² with a mean of 75 km² over 12 months (Backmeyer 2000). Seven newly transplanted sheep south of the Williston Reservoir had extremely variable home ranges, ranging from 5 to 154 km² with a mean of 59 km².

The area separating one Dall's Sheep seasonal range from another can be as little as one steep gorge or as much as a trek of 16 to 64 km (Jones 1963 in Geist 1971). Distances between summer and winter ranges varied from 6.2 to 15 km for Stone's Sheep north of the Peace Arm of the Williston Reservoir, and the longest movement for the one radio-collared ram was 20 km between spring and summer ranges (Backmeyer 2000).

Thinhorn Sheep are generally more sparsely distributed in areas where they occur, and thus have lower densities than Bighorn Sheep. Geist (1971) found a maximum of two sheep per 10 km² for Stone's Sheep in the southern Eagle Nest Range and about 20 sheep per 10 km² for Bighorn Sheep in the Palliser Range.

1.9.5 Home range fidelity

Generally, female Stone's Sheep show philopatric (fidelity to home range) tendencies (Geist 1971). Stone's Sheep ewes returned to the same range 90% of the time, while rams returned 75% of the time (Geist 1971). Both sexes have a strong home range fidelity to a particular mountain, but generally the return rate of ewes to a specific range is higher than that of males.

Deviations in that pattern include sheep whose movements are more unpredictable, such as rams less than four years of age or older sheep that may skip migrations (e.g., an older barren ewe) (Geist 1971). Six out of 18 unexpected appearances by Stone's Sheep rams in 1962 were by rams 2.5 and 3.5 years old (Geist 1971). Deviation from their traditional movement patterns has been noticed in older mountain sheep and can be due to a number of factors, including social effects of other sheep with differing migration patterns and disturbance by humans.

Fidelity to a mineral lick was calculated to be 100% for adult ewes and 80% for adult rams in Dry Creek, Alaska (Heimer 1973). Such predictable fidelity and the concentration of sheep at mineral licks after lambing offer excellent opportunities to obtain representative population structure data.

1.9.6 Origin of routes

Migration patterns are not simply part of maternal home ranges learned from mothers by both sexes of lambs. Both rams and ewes may join several different home range groups, but the movements are generally orderly and predictable (Geist 1971). Young rams develop migration routes by following older rams and may patch together migration routes from several older rams. This often inefficient movement usually involves routes which pass by several bands of females, but probably reduces inbreeding, removes the rams from critical ewe winter range and reduces competition (Geist 1971). Pre-rut dispersal and long movements during rutting season may have been selected for, since males increase their opportunity to breed more females and reproductive success has been shown to be higher for ewes that breed with more mobile rams (less barrenness, less loss of lambs at birth and higher birth weight) (Geist 1971). This is probably due to "hybrid" vigour from greater genetic distance of parents.

2.0 CONSERVATION BIOLOGY

Conservation biology is a discipline which seeks to prevent loss of the variety and variability of organisms and their ecological complexes based

on the assumption that natural systems have functional, historical and evolutionary limits which anthropogenic changes often cross (Primack 1993). Theoretical models and testable hypotheses from the perspective of this discipline are useful for managing over broad ecosystems using landscape ecology and metapopulation management. Three categories of events (which are frequently stochastic) threaten small populations with extinction: environmental; demographic; and genetic. Bleich et al. (1996) detailed four possible causes of metapopulation extinction in Bighorn Sheep: distribution; adaptation; demographic; and genetic. The environmental and demographic (including distribution and adaptation) categories are often of greater importance than the genetic category for the long-term persistence of a species. Genetic issues continue to be studied and discussed, not only because they can be the source of viability problems, but also because genetic techniques can give insight into such factors as evolution, dispersal rates and habitat fragmentation.

2.1 Metapopulation

The naturally fragmented distribution of mountain sheep appears to fit a metapopulation model. There are also physiographic features and habitat discontinuities that distinguish metapopulations and subpopulations. This model has largely replaced island biogeography as the theoretical framework for fragmentation issues (Wiens 1996). A metapopulation is a group of populations or local subpopulations with dynamic patterns of local extinctions and recolonizations (Fiedler and Jain 1992). The metapopulation model has important implications for maintaining evolutionary processes, since a subdivided population may preserve variation (minimizing genetic drift) better than a single larger population of equal size (Simberloff 1988). Armentrout and Boyd (1994) provided information on the least fragmented of all the sheep subspecies, Dall's Sheep, and the extensive fragmentation of all subspecies of Bighorn Sheep. They suggest that metapopulation management is necessary to avoid fragmen-

tation and loss of populations and habitats. Due to this and other work (e.g., Ramey 1993), the U.S. Bureau of Land Management and other agencies have begun to manage over broad ecosystems, resulting in a focus on landscape ecology and metapopulation management (Armentrout and Boyd 1994). Unless subgroups are identified, management programs could fail to recognize subgroups that are experiencing problems. Stevens and Goodson (1993) warn about the need to pay attention to substructures within a sheep population, since the overall population could be increasing while a segment could be heading for extirpation.

Using mitochondrial (mt) DNA analysis, Bleich et al. (1996) demonstrated that sheep inhabiting ranges in southern California <15 km apart are part of the same metapopulation. Although sheep can traverse intermountain distances >20 km (Schwartz et al. 1986), the philopatry of females is evident in the differences in mtDNA between herds (Bleich et al. 1996).

Bailey (1992) proposed an arbitrary size or potential size for a metapopulation of at least 1000 for practical and theoretical reasons, particularly for coordinating management. To facilitate management, Bailey (1992) identified three types of metapopulation structure: 1) megapopulation of ≥ 1000 individuals, without barriers to dispersal; 2) core-satellite metapopulation of ≥ 1000 , with at least one core herd of ≥ 150 sheep and several smaller satellite herds that depend on core herds; and 3) patchy metapopulations of ≥ 1000 , distributed in interdependent herds of ≤ 100 sheep. Understanding the structure can be crucial for managing sheep, particularly for issues such as disease transmission. Thinhorn Sheep in British Columbia, the Yukon and Northwest Territories may fit as a core-satellite metapopulation. There are probably several metapopulations in Alaska that may be metapopulations or core-satellite metapopulations. One of these in the south is probably part of the B.C.-Yukon-Northwest Territories metapopulation.

Table 3. Population divisions of mountain sheep based on a metapopulation conceptual model using a Thinhorn Sheep example with population estimates for each division.

Population Divisions	Definition	Citation	Example for Thinhorn Sheep	Estimate of Sheep Numbers
Metapopulation	Two or more subpopulations which have no barriers to dispersal and/or are <15 km apart.	Bleich et al. 1996	BC, Yukon, NWT, southern Alaska populations	88 000
Subpopulation (a.k.a. contiguous herds)	Two or more wintering herds which share a common summer range.	After Luikart and Allendorf 1996	Atlin, BC MU 6-27, 6-25 West, 6-26 North	1000
Herd	A self-sustaining group of ewes and their progeny using a particular area and named by their discrete winter range.	Festa-Bianchet 1986; R. Forbes, pers. comm.	Snowden Range MU 6-25D	100
Band	A cohesive, home-range group which is a subgroup of a herd.	Geist 1971	(not well documented)	

2.1.1 Subpopulation, herd and band

A subpopulation can be defined as two or more wintering herds that share a common summer range. A metapopulation is made up of two or more subpopulations (Table 3). “Herd” commonly refers to one group of ewes and their progeny using a particular area and is normally named by their winter range (Festa-Bianchet 1986). The herd is a logical unit since mountain sheep generally breed and winter in discrete, identifiable groups. As the unit for research and management, the herd and its definition have implications for conservation and management. Festa-Bianchet (1986) has shown that a herd using a winter range may actually be made up of distinct subgroups that use different portions of the range. Ewes form stable bands or “home range groups” — a definition of subgroups found among herds of domestic sheep (Geist 1971).

Luikart and Allendorf (1996) defined “regions” as groups of contiguous herds separated by substantial geographic distance or potential barriers to gene flow. While they did not use metapopulation terminology, a region can probably be considered a metapopulation. Contiguous herds or subpopulations were defined as being sepa-

rated by <15 km and having limited interchange of individuals (Luikart and Allendorf 1996).

Bleich et al. (1996) maintain that habitat fragmentation is the most significant threat to mountain sheep. Unoccupied habitat patches, suboptimal habitats and peripheral populations are important for evolutionary processes and to maintain interconnectivity and therefore must not be eliminated. Unsuitable habitat can be extremely important as stepping stones for sheep for historic, existing or potential migratory or exploratory corridors. Intermountain movement is necessary for gene flow, but has negative potential as a route for disease transmission.

Generally, other than the subspecies distinction between Dall’s and Stone’s sheep, there has been a perception that Thinhorn Sheep are a contiguous population from British Columbia to Alaska. Thinhorn herds are more contiguous than Bighorn populations, largely because of the more contiguous nature of the high-capability habitat and the relative low level of anthropogenic changes within their range. There is not sufficient study of vital rates, dispersal distances, intra-herd movement or genetic differences to definitively subdivide Thinhorn Sheep into subpopulations based on scientific data (Hanski and

Gilpin 1991; Doak and Mills 1994). The delineation of local populations is often subjective, but the metapopulation concept naturally applies to populations that are divided into discrete habitat patches (Hanski and Gilpin 1991). Despite the absence of proof about population parameter differences between subpopulations, Thinhorn Sheep do have some discrete habitat patches and range groups, which are important for management and conservation, particularly for assessing their status. For instance, there are distinct breaks in the distribution between and within some of the Alaskan metapopulations and there are discontinuities in the metapopulation that includes British Columbia's thinhorns. While the more continuous nature of the distribution is positive for the species, there are some good reasons to try to develop an appreciation for logical subdivisions for Thinhorn Sheep based on a metapopulation model.

In the British Columbia thinhorn population, it is possible to recognize some logical subpopulation divisions for management purposes using factors such as subspecies designation, pelage colour and geographical isolation. The division of the larger Thinhorn Sheep metapopulation into subpopulations can proceed through a series of logical steps in the hopes that there will be more data in the future that will adjust these divisions.

First, there is the well-recognized division of *Ovis dalli* into two subspecies, Dall's Sheep and Stone's Sheep. Second, there are colour differences in Stone's Sheep that were well described by Sheldon (1911). He provided detailed descriptions of pelage colour patterns, including the anatomically accurate drawings of wildlife artist Carl Rungius and remarkably accurate maps, considering the period. Sheldon's (1911) map of pelage colour differences divided into distinct groupings can serve as a basis for division into subpopulations. Comparing these with the pelage colour patterns of harvested rams today, it is possible to divide the province's

Stone's Sheep into three main subpopulations (Table 4).

While subdivision based on pelage colour may be considered arbitrary, this morphological attribute has been maintained over at least centuries and is probably indicative of the degree of isolation of subpopulations. Further subdivision into subpopulations is proposed based on physiographic barriers, ecosection boundaries, land use patterns (including major roads, settlements and reservoirs) and Thinhorn Sheep management considerations.

British Columbia's Thinhorn Sheep population connects with the range of Thinhorn Sheep in the Yukon Territory in several areas. It is useful for conservation purposes to consider how these transboundary subpopulations are connected with Thinhorn Sheep in the Yukon. Because the herds are <15 km apart, these subpopulations can be considered part of the same metapopulation (Luikart and Allendorf 1996). Dall's Sheep are only weakly connected to herds in the Yukon in MU 6-29 (west of the Haines Highway in Tatshenshini-Atsek Provincial Park), but are strongly connected to herds in the Yukon in MU 6-28 (east of the Haines Highway). In the latter locality, there are only a few small, scattered areas capable of serving as winter range. Most of the sheep observed during the summer in British Columbia in MU 6-28 move northward into the Yukon during the winter.

Stone's Sheep in the vicinity of Atlin in MU 6-25 west of Teslin Lake and River, and in MU 6-27, are contiguous with small numbers of sheep that are relatively restricted in their distribution and movements by several large transboundary lakes, including Bennett, Tagish, Atlin and Teslin lakes. Some of the sheep in this vicinity range short distances into the Yukon during the summer, but are generally discrete and are not connected directly to the main Yukon population. Stone's Sheep across the remainder of the Yukon-British Columbia boundary vary in their

Table 4. Proposed subdivisions of Thinhorn Sheep subpopulations in British Columbia based on pelage colour patterns, isolation and management units.

	Subpopulation	Pelage Colour Pattern	MU ^a	Ecosections	Yukon Connection
1.	Tatshenshini-Alsek	Pure white (MU 6-29); white with some black tails (MU 6-28)	6-29	Tatshenshini Basin	Very weak
			6-28	Tagish Highlands	Strong
2.	Atlin	Very light grey with black tails (MU 6-27); light to medium grey with some darker individuals, all with black tails (MU 6-25 & 26)	6-27 6-25 West 6-26 North	Teslin Plateau	Weak
3.	Rancheria	Some light individuals but mainly dark, brownish black	6-24		Moderate
			6-25 East	Tuya Range	Weak
4.	Stikine	Mainly dark, brownish black	6-17 6-18 6-19 6-20 6-21 6-22 6-23	Stikine Plateau, Southern Boreal Plateau	None
5.	Upper Finlay		7-38 7-39 7-40	Cassiar Ranges (southern half)	None
6.	Liard		7-51 7-52 7-54	Kechika Mountains, Cassiar Ranges (northern half)	None
7.	NE Rockies		7-36 7-37 7-41 7-42 7-43 7-50 7-57	Eastern and western Muskwa Ranges (7-31 isolated by the Williston Reservoir)	None

^a Management unit boundaries are listed in Provincial Hunting and Fishing Regulation Synopsis.

degree of interchange, ranging from moderate immediately east of Teslin Lake in MU 6-25, to weak north of the Rancheria watershed in MU 6-24, to very light or nil in MU 6-23.

The size of documented Dall's Sheep subgroups ranges from one to as large as the 106 ewes and juveniles seen by Geist (1971) on Sheep Mountain in Kluane National Park. The largest ram group that Geist (1971) observed in this area had 51 members. Ram bands are smaller on average

than ewe bands, and rams occur as singles more frequently than females. At Gladys Lake in rutting season, the number of individuals in Stone's Sheep bands averaged four with a maximum of 21; there were 108 bands sighted in 1962 and 58 in 1965 (Geist 1971). In mid-winter, just after the rutting season, sheep were usually found in smaller bands than in other seasons. In late spring, bands tend to be larger than in winter and as large as or even larger than in the fall. These subgroups or bands may sometimes intermix with other bands on a seasonal range, but maintain distinct migration patterns and separate population dynamics, physical characters, and relation between range quality and population characteristics (Festa-Bianchet 1986).

Bleich et al. (1996) suggest that the maternal lineage may be the real operational metapopulation unit since females (possibly lone females) may be the founders of subpopulations, while the males are responsible for nuclear gene flow.

2.2 Demographics

Minimum viable population (MVP) is often a controversial concept because of calculation difficulties. It can be defined as the minimum number of organisms that constitute a viable population for a particular species over a long period of time, such as 100 years. For mountain sheep, MVP has been estimated to be greater than 100 or 125 (Berger 1990). Viability is a state in which the species maintains its vigour and potential for evolutionary adaptation (Soule 1987). Berger (1990) studied 122 populations of three Bighorn Sheep subspecies (Rocky Mountain [*O.c. canadensis*], California [*O.c. californiana*] and Desert [*O.c. nelsoni*]) and found that 100% of the populations with <50 individuals went extinct within 50 years. The rapid loss of populations was found not likely to be caused by food shortage, severe weather, predation or interspecific competition; therefore, 50 is apparently not a minimum Bighorn population that is viable over the long-term. Populations with >100 individuals persisted for up to 70 years. Berger (1990) concludes that genetic and etiological factors influence mountain sheep reproduction and survival and thus their persistence. Wehausen (1995) has raised doubts about the

likelihood of extinction for the populations that Berger (1990) identified.

MVP models have mainly focused on genetic issues, but it is widely recognized that demographic and environmental factors are usually of greater significance in the occurrence of extinction. Bleich et al. (1996) stated that demographic processes are more important than genetics for mountain sheep. Only careful population monitoring over a long period of time will determine who is correct (Armentrout and Boyd 1994). Effective population size (N_e ; the size of an idealized population which can counteract the effects of genetic problems) for Bighorn Sheep has been estimated to be $N_e \geq 50$ to manage for genetic variability (Franklin 1980 *in* Fitzsimmons and Buskirk 1992), which would keep the inbreeding rate at <1% to prevent loss of variability over generational time. This means a total population size of $N \geq 150$ would be required to avoid short-term loss of genetic variability (Fitzsimmons and Buskirk 1992).

While striving to manage for larger populations is not ill-advised, the importance of small populations should not be undervalued. Small populations can be critical for connecting larger habitats as stepping stones (Bleich et al. 1996) or for augmenting population size as one subpopulation of a larger metapopulation. Factors such as MVP are critical for establishing translocation protocols, maintaining corridors and minimizing fragmentation. Fitzsimmons and Buskirk (1992) caution that the "objective of genetic management of Bighorn Sheep populations should be to minimize the loss of naturally occurring genetic variability, rather than to maximize genetic variability through out-crossing to distant herds." Thus, Franklin (1980 *in* Fitzsimmons and Buskirk 1992) suggests that $N_e > 500$ (which means a total population of >1530) would be necessary over the long-term to reduce genetic loss, but this assumes little or no exchange of individuals between herds. Most herds are not that big, but by maintaining exchange between subpopulations and herds by reducing fragmentation and restoring habitat corridors, it is possible to maintain or increase the size of the effective population. Fitzsimmons and Buskirk (1992) suggest that managers use a range of one

to five immigrants per generation to retain 90% of the long-term genetic variability in planning supplemental transplants. Before such a program is instituted, however, studies should establish existing natural immigration rates and the implications of such a program.

2.3 Genetics

Genetic concerns in the extinction of species centre around two main factors: inbreeding depression (lowered fecundity and viability); and genetic drift (the loss of rate of variance in alleles).

2.3.1 Inbreeding

Thinhorn Sheep are currently believed to be at less risk of inbreeding than Bighorn Sheep. Concern about inbreeding in Bighorn Sheep has been based primarily on four main factors: 1) the popular but unsubstantiated assumption that Bighorn Sheep have declined to approximately 2% of the historic population level in North America; 2) the distribution of Bighorn Sheep in isolated mountain habitats; 3) the polygamous mating system of Bighorn Sheep; and 4) the development of human cultural features which prevent dispersal of sheep (Schwartz et al. 1986). Thinhorn Sheep have not experienced the severe population declines or the adverse effect of extensive human cultural features to the extent that bighorns have. Like bighorns, however, thinhorns have isolated mountain habitats and a polygamous mating system. A future concern for thinhorns could be the slow recovery and recruitment rates common to populations trying to recover from catastrophic die-offs (Demarchi 1972).

Inbreeding has not been well documented in natural populations, even in very small populations. Past concerns about inbreeding have been based mostly on closed population models, which have a greater likelihood of inbreeding, and have not been verified for free-ranging sheep populations. It is also possible that only low levels of new gene flow may be necessary to prevent loss of genetic diversity in small populations (Schwartz et al. 1986).

A number of mechanisms exist which may prevent or reduce inbreeding in free-ranging mountain sheep. The vagility (freedom to move) of female sheep and the migration capabilities of both males and females have probably been underestimated. Philopatry in mountain sheep is not complete, since a young ram will combine migration patterns from several different older rams, and females have also been shown to have variation in their migration patterns. There is potential for much undetected intermountain movement. The ability of mountain sheep to cross artificial obstacles such as highways has been underestimated (Schwartz et al. 1986).

2.3.2 Random genetic drift

Random genetic drift is the change in allele (forms of a gene) frequency in a population from one generation to another due to chance fluctuations. Genetic drift is a concern for smaller populations because of the potential for loss of alleles. The particular combination of alleles of four genes on a chromosome is called the haplotype, and the haplotype frequency can be compared among groups of sheep to detect possible genetic drift and loss of alleles. Mountain sheep would be expected to have substantial genetic drift due to overlapping generations, few breeding females in most populations ($f = <100$), dramatic population size changes over time and the sometimes high variation in reproductive success of females (Luikart and Allendorf 1996). Heimer (1974*b*) has suggested that mineral licks may be important in preventing genetic drift. Young rams are exposed by chance to the opportunity to join any ram band depending on the coincidence of their arrival at the lick. Thus, genetic stability may be preserved by preventing genetic drift among the otherwise isolated populations of ewes and rams.

Of 50 Bighorn Sheep tested from native herds in British Columbia and Alberta, 48 individuals had the same mitochondrial DNA AAA haplotype (Luikart and Allendorf 1996). There is low allozymic variation in Bighorn Sheep in Canada compared to sheep from Montana, Wyoming and Colorado (Luikart and Allendorf 1996). This indicates that there has probably been genetic drift in the populations of Bighorn Sheep in

Canada. Luikart and Allendorf (1996) attribute the lower level of genetic variation to probable founder effects and genetic drift during recolonization following the Wisconsin Ice Age, 10 000 000 to 20 000 years ago. No similar work has been completed for Thinhorn Sheep.

If genetic drift is suspected to be problematic in the future, the introduction of some genetic material with more variability, perhaps from herds with more variation, could be explored. While gene flow from herds with more variability can reduce random genetic drift problems, it can also facilitate disease transmission and actually reduce variability over the long-term. Thus, it is important that metapopulation structure be maintained by using transplanting judiciously and not creating a new problem through too much interbreeding.

The metapopulation structure is a useful model for conceptualizing environmental, demographic and genetic issues for sheep, and can be used to develop testable hypotheses and subsequent management programs, along with a means to evaluate the status of Thinhorn Sheep in British Columbia.

3.0 SUBSPECIES DISTRIBUTION AND ABUNDANCE

3.1 North America

3.1.1 Historic and current distribution

Thinhorn Sheep are found in northern British Columbia, western Northwest Territories and throughout much of the Yukon and Alaska (Figure 1). From all accounts, the distribution of Thinhorn Sheep has not changed appreciably since historic times. Their habitat remains mostly intact relative to that encountered by early European explorers. In Canada, Thinhorn Sheep are found in the western and northwestern part of the Northwest Territories in the Mackenzie and Richardson mountains, in the mountains of southwestern, northern, eastern and central Yukon, and in the northern third of British Columbia. Dall's Sheep is the only wild sheep occurring in the Northwest Territories and Alaska. It occupies suitable alpine and subalpine

habitats in Alaska's mountains, from the northernmost reaches of the Brooks Range south to approximately 60° north latitude in the Kenai Mountains and Alaska Range (Nichols 1975).

The range of Thinhorn Sheep is more or less continuous throughout the drier mountain ranges of northwestern North America. One excellent record of the historic distribution of Thinhorn Sheep is a map produced by Sheldon (1911). Sheldon utilized extensive personal observations, as well as records obtained from sheep specimens taken in the late 1800s to 1905 from what is now northwestern British Columbia, the Northwest Territories, the Yukon and Alaska. It is noteworthy that Sheldon's map was produced prior to the advent of airplane travel or aerial photography and some 50 years prior to the construction of the Alaska Highway through the northern Rocky Mountains. He omitted, however, to record the occurrence of Stone's Sheep in that area.

Thinhorn Sheep habitat has remained relatively unaltered historically. This is unlike Bighorn Sheep range, which has been significantly reduced to smaller patches of suitable, occupied habitat, due to displacement by domestic sheep, settlements, access corridors, intensive agriculture and industrialization (Buechner 1960; D.A. Demarchi et al. 2000).

3.1.2 North American abundance

There are no reliable early historic numerical estimates of Thinhorn Sheep abundance. The estimates of Seton (1927) of two million mountain sheep in Canada and Alaska combined have no basis in fact and have been refuted by several mountain sheep biologists (Demarchi 1977; Valdez and Krausman 1999; Demarchi and Demarchi 2000). His overestimation resulted from a failure to recognize the specific habitat requirements of mountain sheep and that they are not evenly distributed across their range. Inaccurate mapping and a failure to apply ecological criteria has resulted in an erroneous depiction of historic and current North American mountain sheep distribution and, by inference, their abundance. (Demarchi and Demarchi 2000).

The populations and ranges of Thinhorn Sheep remain mostly unchanged from those encountered by early explorers and have been relatively unaffected by humans. Heimer (1998) cites indirect evidence of localized over-harvesting of Dall's Sheep for sustenance and commercial purposes by aboriginal people in the Brooks Range of Alaska in the early 20th century. During the late 19th and early 20th century gold rushes in British Columbia, Northwest Territories and Alaska, meat-seeking prospectors locally reduced Thinhorn Sheep herds, particularly in

areas where placer mining was concentrated, such as in the vicinity of Atlin (R. Marshall, pers. comm.). It is commonly accepted that, except for local, unrecovered extirpations that resulted from sustenance hunting by aboriginal hunters and prospectors, current Thinhorn Sheep numbers are not significantly different from those present during the period of early contact with European explorers (Heimer 1998).

Population estimates for Thinhorn Sheep in North America vary somewhat from the 1970s to

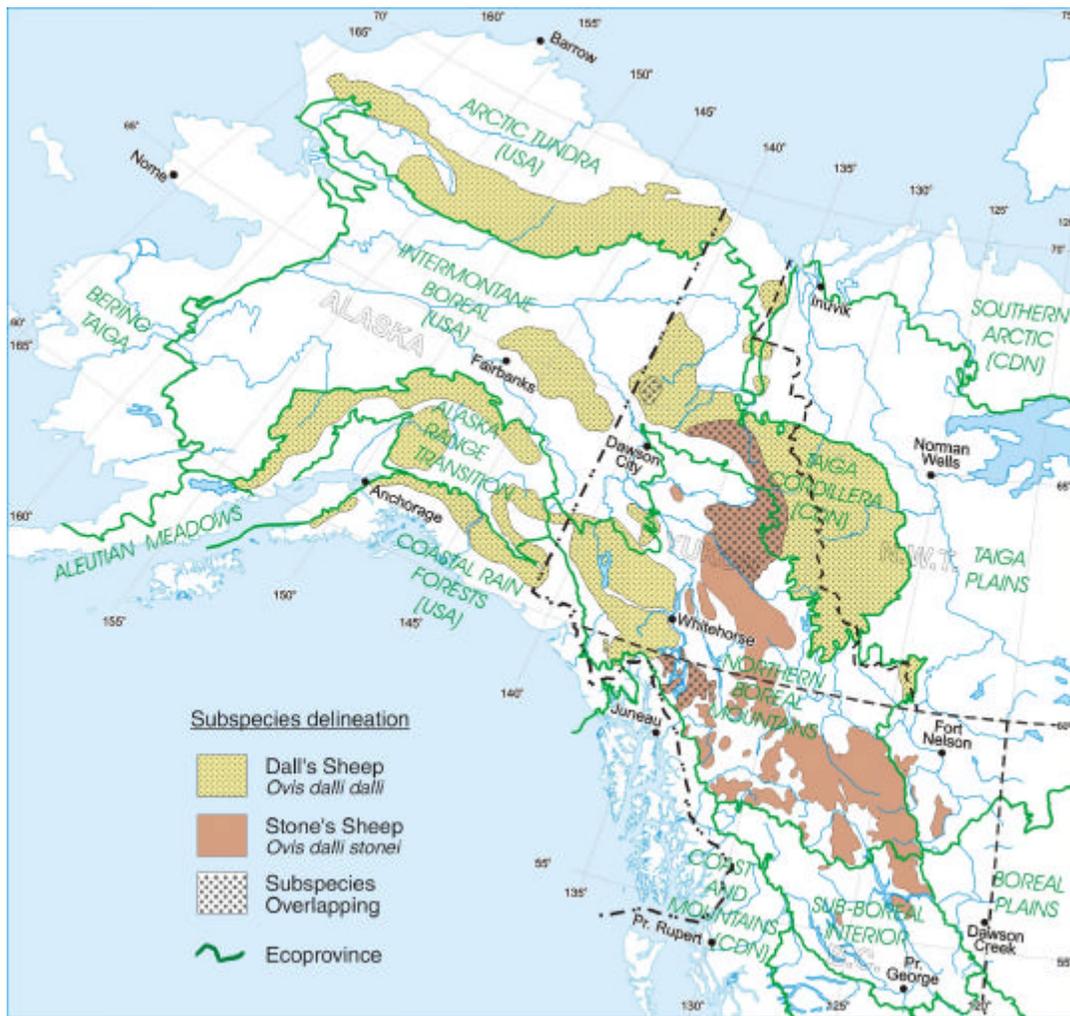


Figure 1. Distribution of Thinhorn Sheep in North America, including British Columbia, Yukon, Northwest Territories and Alaska, defined by ecoprovince (Demarchi 1995; Towell and Geist 1999).

Table 5. Population estimates for Thinhorn Sheep in North America.

Location	1975 ^a		1991 ^b		1999 ^c	
	Stone's	Dall's	Stone's	Dall's	Stone's	Dall's
Canada	13 500 – 16 500	21 000 – 26 000	14 000	26 000	18 500	40 500
United States (Alaska)	Nil	50 000 – 55 000 ^d	Nil	73 250	Nil	50 400 – 64 300
North America Subspecies Totals	13 500 – 16 500	71 000 – 81 000	14 500	99 750	18 500	96 900 – 110 800
Canadian thinhorn Totals	34 500 – 42 500		41 000		59 000	
North America thinhorn Totals	84 500 – 97 500		114 250		109 400-123 300	

^a After Trefethen 1975

^b Valdez and Krausman 1999

^c Toweill and Geist 1999

^d Heimer 1974a

1999, but this may be more a reflection of different estimation techniques than of actual numbers, which have been relatively stable (Table 5). Both subspecies have higher estimates in 1999 than in the 1970s, although the greatest increase occurred for Dall's Sheep in Canada from 1991 to 1999. In North America, the population estimate for Thinhorn Sheep were previously estimated at a mean population of 91 000 in 1975 and more recently at a mean of 116 350 in 1999. Over the same period, in Canada the population estimate ranged from 38 500 to 59 000. During the mid- to late 1990s, declines were detected in Dall's Sheep populations throughout much of Alaska and Yukon, possibly due to inclement weather exacerbated by wolf predation (Heimer 1999; Hoefs 1999).

3.2 Canada: British Columbia, Northwest Territories and Yukon

3.2.1 Historic and current distribution

In British Columbia, Dall's Sheep are found in the extreme northwest corner of the province from Bennett Lake to the St. Elias Mountains (Figure 2). There is considerable interchange with herds in southwestern Yukon. Stone's Sheep distribution in British Columbia runs northwest to southeast, from the east side of Bennett Lake on the British Columbia–Yukon

border along the eastern side of the northern Coast Mountains to the northern end of the Skeena Mountains, through the Cassiar and Omineca mountains and the northern Rocky Mountains to just south of the Peace Arm of the Williston Reservoir (Shackleton 1999). There is also a report of an isolated sighting further southwest in the Omineca Range, on the east side of Takla Lake in the vicinity of Leo Creek (G. Hazelwood, pers. comm.), plus an unconfirmed report by a helicopter pilot of “a couple of young rams” on Mount Horetsky north of the Babine River (D. Hatler, pers. comm.).

In the Northwest Territories, Dall's Sheep are distributed throughout the Mackenzie Mountains west of the Mackenzie River and almost as far north as the Mackenzie Delta on the Arctic Coast in the Richardson Mountains. They are present on almost all usable ranges (Nichols 1975).

In the Yukon Territory, Dall's Sheep are distributed in two broad regions in the southwest corner and in the northern and eastern regions. In the south, the Yukon River separates the Dall's and Stone's sheep subspecies; Dall's Sheep are found in all ranges between the Yukon River and the Alaska border to the west and the British Columbia border to the south. In the northern Yukon, sheep are found in the British

Mountains, Richardson Mountains, the ranges along the Northwest Territories boundary and the Warnecke and Ogilvie mountains. In the latter, Dall's Sheep integrate with Stone's Sheep that occupy the small mountain ranges in the central Yukon (Nichols 1975). In the Yukon Territory, Stone's Sheep are found in bands of relic herds in the Cassiar, Pelly, Selwyn and Salmon mountains. Some Stone's Sheep intergrade with Dall's Sheep in the Ogilvie Mountains (Nichols 1975).

3.2.2 Historic and current abundance

Canada's Thinhorn Sheep population was estimated at 59 000 in 1999 (Table 6). The Northwest Territories has the largest number of Dall's Sheep at 22 000 while British Columbia at 14 500 has the greatest number of Stone's Sheep with the Yukon intermediate in population size for both subspecies. Stone's Sheep numbers did not vary significantly between 1975 and 1999. There was a marked increase in the Dall's Sheep estimates from the Northwest Territories over

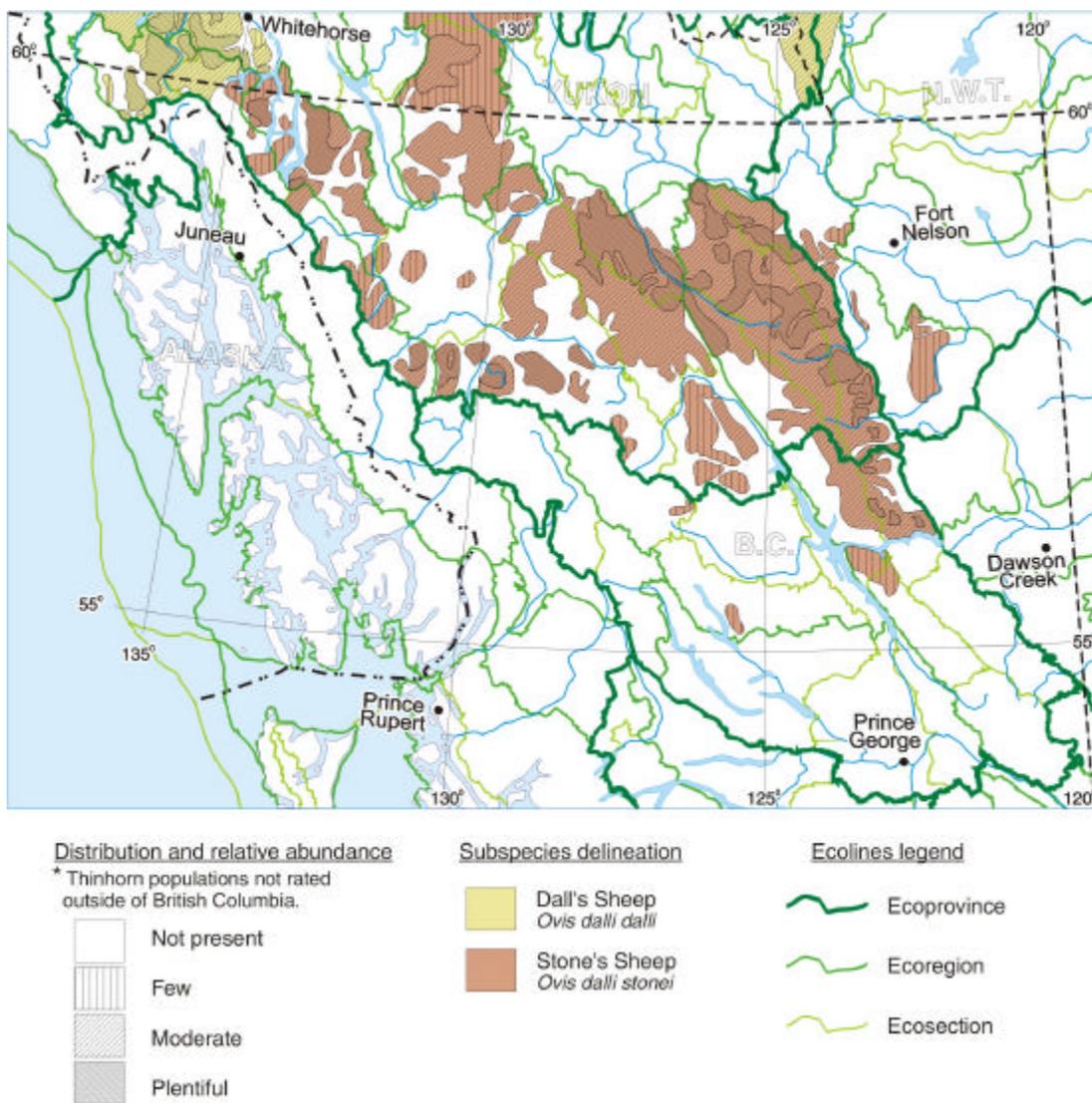


Figure 2. Thinhorn Sheep distribution in British Columbia and adjacent portions of the Yukon and Northwest Territories, defined by ecoprovince, ecoregion and ecosection (Blower 1988; Demarchi 2002).

Table 6. Population estimates for Dall's and Stone's sheep in Canada, 1975 and 1999.

Province or Territory	1975 ^a			1999 ^b		
	Stone's	Dall's	Total	Stone's	Dall's	Total
British Columbia	12 000	300	12 300	14 000	500	15 000
Northwest Territories	Nil	12 000	12 000	Nil	22 000 ^c	22 000
Yukon Territory	4500	18 000	22 500	4000	18 000	22 000
Subspecies Totals	16 500	30 300	46 800	18 500	40 500	59 000

^a Trefethen 1975

^b Toweill and Geist 1999

^c The Northwest Territories' Wildlife and Fisheries Division counted 1510 Dall's Sheep in the Richardson Mountains in 1991 and recently estimated 14 000- 26 000 in the Mackenzie Mountains based on surveys conducted 1984-1994 (www.nwtwildlife.rwed.gov.nt.ca); Toweill and Geist (1999) estimated 2000 and 26 000, respectively.

the same time period. All jurisdictions, consider Thinhorn Sheep populations to have been stable and attribute differences in population estimates primarily to variations in estimation methods.

The earliest official Thinhorn Sheep population estimate for British Columbia, was made in 1961 and published in 1964 in the British Columbia Natural Resource Conference (1964). An extensive "Northern Wildlife Inventory" was conducted in the early 1960s by the British Columbia Wildlife Branch (R. Ritcey, pers. comm.), which presumably produced the published estimate of 15 500 Thinhorn Sheep. Considering the extensive nature of the survey this was a reasonably accurate estimate for the period since subsequent inventories and population modeling have produced estimates within this range.

While Dall's Sheep estimates have varied little or not at all between years, Stone's Sheep numbers fluctuated from 11 950 in 1987 to a peak of 14 210 in 1994 to 10 550 in 2003 (Table 7). Most of the change has occurred in the Region 7B-Peace-Liard where Stone's Sheep numbers were estimated to have declined from a peak of 8860 in 1994 to 5000 or fewer in 2003. Wolf numbers and thus wolf predation appears to have rebounded from government sanctioned wolf reductions of the 1980s and is believed to be the primary factor currently limiting Stone's

Sheep numbers in the Peace-Liard Region by many resident northern hunters, guide outfitters and Ministry of Water, Land and Air Protection (MWLAP) staff.

1986-88 Regional Wildlife Plans: The following was excerpted from the 1986-1988 Regional Wildlife Management Plans, the most recent plans available (B.C. Wildlife Branch 1986-1998).

Skeena Region: In 1986-1988 in the Skeena Region, the estimated population of Thinhorn Sheep was about 4450, of which about 500 were Dall's Sheep (Table 8). Thinhorn Sheep occurred then, much as they do today.

Region 7A-Omineca: There was an estimated minimum of 600 Thinhorn Sheep in the Omineca on several ranges in 1986-1988. The populations, especially those surveyed, were in good condition. Thinhorn Sheep in the area are characteristically found in areas of folded and faulted sedimentary rocks in the Omineca Mountains of the Finlay-Omineca Planning Unit. More southern populations inhabit the Mitchell Ranges in MU 7-27 in the Takla-Nechako Planning Unit and on the east side of Williston Reservoir, south of the Peace Arm on Mount Selwyn in MU 7-30. Sightings on various other ranges in both planning units have also been reported.

Table 7. Population estimates for Stone’s (and Dall’s) Sheep in British Columbia, 1987-2003.

Region	1987 ^a	1990 ^b	1994 ^b	1997 ^b	2000 ^b	2003 ^b
Region 6-Skeena	4550	4500	4550	4900	4750	4750
Reg. 7A-Omineca	750	750	800	800	750	750
7B-Peace-Liard	6750	6750	8860	6750	6750	5000
Total Stone’s	12 050	12 000	14 210	12 450	12 250	10 500
Region 6 (Dall’s)	(500)	(500)	(500)	(500)	(500)	(500)
Provincial Total	12 550	12 500	14 710	13 000	12 750	11 000

^a British Columbia Natural Resources Conference 1964

^b Standardized B.C. Ungulate Species Regional Population Estimates – Preseason , MWLAP records.

Region 7B-Peace-Liard: There is little historic information about Thinhorn Sheep abundance in the past. Long-time residents of Fort St. John and Hudson Hope report that in the 1930s and 1940s, many guide-outfitters guided non-resident hunters in MUs 7-35 and 7-36 and took very good rams in the Schooler Creek and Nabesche River drainages. Reportedly, Stone’s Sheep were much more abundant than in 1986-1988. Above-average snowfalls in the 1960s through the mid 1970s may have reduced Stone’s Sheep by as much as 50%. By 1986-1988, an estimated 250 sheep occurred in MUs 7-35, 7-36, 7-43 and, occasionally, in 7-47.

Except for a small Stone’s Sheep herd intermittently reported on the Sikanni River in MU 7-47, all sheep in the Peace Zone winter in the Hart Foothills Biophysical Area. Wolves (*Canis lupus*) are common in all sheep areas, and given the small size of herds and the restrictiveness of the winter ranges in this particular area, wolf predation likely limits population growth.

3.2.3 Population trends

As part of this status evaluation, herd classified count data for B.C. was compiled and analyzed by date and by Game Management Zone

(GMZ)¹. This analysis of the available classified count data in the province is shown in Table 9. (The original data used to compile Table 9 are summarized in Appendix 1.) Only those surveys where at least 100 adult ewes were classified and recorded were included. Recording and reporting of results varied between observers and between regions, requiring the amalgamation of population classes (e.g., all adult ewes, yearling ewes, yearling rams and Class I rams were grouped as “ewe-like sheep” [ELS]). This group became the benchmark for all ram:ewe and lamb:ewe calculations and comparisons.

The overall provincial ratio of lambs per 100 ELS was 29, while the ratio of rams per 100 ELS was 32, for the entire period from 1972 to 1998. A study from the Northeast Rockies and Liard GMZs, which also used additional data from Sheep Mountain, Yukon, indicated that lamb recruitment (lambs:100 ewes) could be used to estimate sheep population trends. The recruitment rate (at nine months of age) that balanced adult mortality and provided a finite rate of increase of 1.00 was approximately 24

¹ GMZs are amalgamations of Wildlife Management Units (WMUs) in B.C., which share similar ecological characteristics and hunter harvest patterns and thus provide a suitable geographical framework for implementing management strategies.

Table 8. Population estimates of Thinhorn Sheep in British Columbia in 1994 (B.C. Wildlife Branch Records 1994).

Region	Subpopulation Name and Estimated Size	Management Unit	Stone's Sheep	Dall's Sheep	
Skeena Region	Tatshenshini-Alsek	6-28		125	
		6-29		375	
	Atlin	6-25 West	400		
		6-26	400		
	Rancheria	6-27	300		
		6-24	400		
	600	6-25 East	200		
		6-17	25		
	Stikine	6-18	75		
		6-19	250		
	2850	6-20	1750		
		6-21	300		
		6-22	50		
			6-23	400	
Skeena Region Total			4550	500	
<hr/>					
7A-Omineca Region					
		7-38	40		
	Upper Finlay	7-39	90		
		610	7-40	480	
	Northeastern Rockies (see below)	7-37	90		
		7-41	90		
	Isolated by reservoir 10	7-30	10		
Omineca Total			800		
<hr/>					
7-B-Peace-Liard Region					
	Isolated by reservoir 10	7-31	10		
		Northeastern Rockies	7-35	50	
	4230	7-36	150		
		(including two MUs above)	7-42	1500	
		7-43	50		
		7-48	50		
		7-49	50		
		7-50	2000		
		7-57	200		
	Liard	7-51	1200		
		4800	7-52	3000	
		7-54	600		
Peace-Liard Total			8860		
<hr/>					
Provincial Totals	14 710		14 210	500	

Table 9. Population structure of Dall's and Stone's sheep in five GMZs in northern British Columbia from 14 inventory reports, 1972-1998.

Date	GMZ	Rams: 100 Ewes	Lambs:1 00 Ewes	% Rams	% Lambs	% Ewes	Class II	Class III	Class IV	n	
Jul 85	Atlin-Tat	19	35	0.12	0.23	0.65	0.19	0.45	0.35	256	
Jul 96	Atlin-Tat	42	42	0.23	0.23	0.55	0.09	0.58	0.32	233	
	GMZ mean	29	38	0.17	0.23	0.60	0.13	0.54	0.33	489	GMZ Total
Jul 85	Atlin	37	23	0.23	0.14	0.63	0.45	0.40	0.14	182	
Jul 90	Atlin	13	26	0.09	0.18	0.72	0.21	0.58	0.21	203	
Nov 97	Atlin	27	36	0.17	0.22	0.61	0.44	0.34	0.22	230	
Mar 98	Atlin	35	30	0.21	0.18	0.61	0.46	0.48	0.06	318	
	GMZ mean	28	29	0.18	0.18	0.64	0.43	0.44	0.13	933	GMZ Total
Feb 72	Stikine	42	46	0.22	0.25	0.53	0.31	0.31	0.39	804	
Mar 85	Stikine	45	48	0.23	0.25	0.52	0.59	0.23	0.18	401	
Mar 92	Stikine	37	27	0.23	0.17	0.61	0.40	0.42	0.17	717	
Mar 93	Stikine	38	25	0.23	0.15	0.61	0.44	0.43	0.13	479	
Jun 96	Stikine	14	19	0.11	0.14	0.75	0.43	0.24	0.33	197	
Sep 96	Stikine	26	24	0.17	0.16	0.67	0.26	0.44	0.29	199	
Dec 96	Stikine	29	19	0.20	0.13	0.67	0.26	0.38	0.36	199	
Mar- 98	Stikine	50	42	0.26	0.22	.52	0.24	0.49	0.27	335	
	GMZ mean	35	31	0.21	0.18	0.61	0.37	0.37	0.26	3331	GMZ Total
Jul 85	Upper Finlay	54	34	0.29	0.18	0.53	0.44	0.30	0.26	406	
Mar 93	Upper Finlay	25	21	0.17	0.15	0.69	0.54	0.37	0.08	350	
	GMZ mean	38	27	0.23	0.17	0.60	0.48	0.33	0.20	756	GMZ Total
Feb 90	Northeast Rockies	24	13	0.17	0.10	0.73	0.21	0.56	0.23	1167	
Feb 94	Northeast Rockies	26	22	0.18	0.15	0.68	0.21	0.54	0.24	1016	

Date	GMZ	Rams: 100 Ewes	Lambs:1 00 Ewes	% Rams	% Lambs	% Ewes	Class II	Class III	Class IV	n
	GMZ mean	25	17	0.18	0.12	0.71	0.21	0.55	0.24	2183
	Provincial mean	32	29	0.20	0.18	0.62	0.36	0.41	0.23	7692
										GMZ Total
										Prov total

lambs:100 ewes. The most extensive set of actual survey data on Stone's Sheep was collected during the 1980s in the Muskwa and Kechika as part of a larger study on the effect of wolf predation on ungulates in northern B.C. (Bergerud and Elliott 1998).

Atlin-Tatshenshini GMZ: A comparison of the results of two extensive surveys over the majority of the range of Dall's Sheep in the province indicated that between 1985 and 1996, all components of this subpopulation increased or were stable (Table 9). The proportion of rams in the subpopulation increased between the two periods and exceeded the provincial average, while the proportion of lambs remained stable at a level above the provincial average (i.e., between 35 and 42 lambs:100 ELS). The proportion of class IV rams also increased slightly.

A more detailed examination of the survey information confirmed a stable to increasing trend from 1980 to 1996 for both lamb and ram per 100 ewes ratios (Table 10). Hatler (1990) stated that the results of the 1980 to 1990 surveys suggested a baseline population for the general study area of 350 to 400 sheep, slightly lower than the official regional estimate of 500.

Atlin GMZ: The proportion of lambs increased between 1985 and 1998, while the proportion of rams declined and then recovered. The proportion of class IV rams exhibited a slight decline.

Stikine GMZ: Between 1972 and 1996, the most recent survey of record, all components of this subpopulation, including lambs and all classes of rams, declined markedly except for the 1998 Cry Lake survey.

Upper Finlay GMZ: Between 1985 and 1993, the most recent survey of record, all components of this subpopulation, including lambs and all classes of rams, declined markedly.

Liard GMZ: Based on aerial inventories of some local populations, anecdotal evidence from others (including experienced guide outfitters operating in the area), and evidence compiled by MWLAP's Region 7B-Peace-Liard staff, it appears that declines of Stone's Sheep numbers occurred in much of this GMZ since reaching a peak in the mid-1990s (J. Elliot, pers. comm.). The decline in numbers may not have been universal throughout this GMZ, however as other long time guide outfitters and resident hunters did not report significant changes in population numbers in the areas where they guide and/or hunt. Also, a concomitant decrease in harvest did not occur in the adjacent Stikine GMZ. The authors infer that where a wolf predation minimization program was in place, Thinhorn Sheep numbers were maintained while in other areas where wolves were uncontrolled, sheep numbers, particularly the mature ram component, declined from their highs of the mid-1990s.

North East Rockies GMZ: Between 1990 and 1994 both the ram:ewe ratio and the lamb:ewe ratio increased. The class II ram component increased, while the class III and IV rams remained stable over the same time period. More recently, sheep numbers, including the mature ram component, declined. The most complete series of repeat sheep counts are from the Cypress River - Prophet area (MUs 7-42 and 7-57) (Table 11). These counts indicate a 13 % decline between 1990 and 1994, a 39% decline between 1994 and 2002, for an overall decline of 47%

Table 10. Age and sex ratios of Dall's Sheep in the Tatshenshini watershed of British Columbia, 1980-1996 (calculated from data in Hatler 1990; Cichowski 1996).

Area/Ratio	Survey Date					
	Jun 1980	Jul 1985	Jun+Sep 1988 ^b	Feb+Apr 1989 ^b	Jun 1990	Jul 1996
Core Area ^a	0.27	0.24	0.63	0.42	0.41	0.43
Ram:100 Ewes						
Lamb:100 Ewes	0.32	0.36	0.31	0.42	0.42	0.35
n	170	197	341	259	266	173
Tkope and Mansfield						
Ram:100 Ewes	–	0.02	–	1.10	0.17	0.37
Lamb:100 Ewes	0.42	0.35	–	0.44	0.37	0.63
n	71	59	74	88	80	60
All						
Ram:100 Ewes	0.18	0.19	0.56	0.55	0.35	0.42
Lamb:100 Ewes	0.35	0.36	0.43	0.42	0.41	0.42
n	241	256	415	347	346	233

^a Tatshenshini-Alsek Provincial Park north of the Tatshenshini and O'Connor rivers.

^b Results of two surveys combined.

between 1990 and 2002. The counts also show a substantial reduction in legal (full curl) rams, with a legal ram to 2+ year-old ewe ratio of 7.7%. A recent survey in 7-54 indicated that the

legal ram to 2+ ewe ratio was only 2.4%, compared to a previous normal value of about 12% for this area (J. Elliott, pers. comm).

Table 11. Inventory summary of Stone Sheep for Prophet River/Cypress Creek survey area (MUs 7-42, 7-57).

Year	ELS ¹	Lamb	Yrlg Ewe	2 Year Ram	3 Year Ram	4 Year to < FCR ²	Full Curl Ram	Total
1990	744	112	37	71	42	114	47	1167
1994	591	148	61	36	38	98	44	1016
2002	350	104	52	16	29	46	23	620

¹ Ewe-like sheep (ELS). Includes yearling (Yrlg) rams and 2+-year-old ewes

² Includes rams 4 years of age or older, but less than full curl ram (FCR)

3.2.4 Thinhorn Sheep transplants

There have been three locations for transplants of Thinhorn Sheep in North America and all were of Stone's Sheep in British Columbia. The first transplant consisted of three separate efforts over three years (Table 12). During the winters of 1990 and 1991, 25 Stone's Sheep were captured for transport from the north side of the Peace Arm to the Mount Frank Roy/Mount

Monteith area on the south side of the Peace Arm (Wood and Hengeveld 1998). Three of the sheep died in transport. The reason for the transplant was that the creation of the Williston Reservoir had flooded the Peace River, creating a barrier between bands of sheep to the north and the south of the Peace Arm of the reservoir. The majority of the sheep were found on the north side during inventories in 1991, with only 11 Stone's Sheep sighted south of the Peace Arm.

Table 12. Thinhorn Sheep transplant history for British Columbia (Hatter and Blower 1996).

No.	Year	Source	Region	Transplant Location	Region	Number of Sheep Transplanted
1	1990	N. of Peace	7B	Mt. Frank Roy	7B	8
	1991	N. of Peace	7B	Mt. Monteith	7B	14
	1993	N. of Peace	7B	Mt. Monteith	7B	6
2	1994-95	E. of Atlin	6	W. of Atlin Lake	6	24
3	1996	Toad River	7B	Toad River, 25 km east of source	7B	8

In March 1993, an attempt was made to transplant eight more sheep (six ewes and two lambs) to supplement the previous transplants (Wood 1995a). Of these eight sheep, two younger ewes died. By 1996, nine of the total 28 transplanted sheep had died (four of which were rams) and only three sheep were confirmed to still be alive (Wood and Hengeveld 1998). There is no further information on the remaining 16 sheep (Wood and Hengeveld 1998) and the original 11 sheep have not been accounted for.

Between 1992 and 1994, there were reports of Stone's Sheep along Highway 97 in the Pine River Valley and several reports from ranchers in the same area of Stone's Sheep interacting with domestic sheep. A persistent wild ram that was attempting to breed with domestic ewes 10 km west of Chetwynd was captured and transplanted to Callazon Creek, 25 km southwest of Mount Monteith in May 1994.

Three possible reasons for the low rate of survival of the transplanted sheep are hypothesized: 1) severe winter snow conditions in 1990, 1991 and 1992; 2) dispersal to areas to the north and west, where there have not been surveys; and 3) fatal respiratory disease as a result of contact with domestic sheep (Wood and Hengeveld 1998). In addition, a comparative analysis of habitat use and movements of the transplanted and source herds concluded that in future transplant attempts, emphasis should be placed on capturing sheep adapted to the transplant site habitat, not merely those individuals readily captured (Backmeyer 2000). The report also recommended that future transplant projects move sheep in early to mid-winter, while they are still in sound physical condition and while

there is sufficient time for them to become familiar with the new winter range.

Two other aspects of proposed transplants should be examined: the capability of the habitat; and the proximity of domestic sheep to both donor sheep herds and the transplant site. Habitat on the edges of Thinhorn Sheep range should be carefully evaluated, because marginal habitat may have a poor probability of success for a transplant. The proximity of domestic sheep to the transplant site must be especially carefully examined, as transplanted sheep are often prone to dispersal as they look for suitable habitats or attempt to return to their original range. The wanderings of the transplanted sheep and their return to existing herds in the transplant area could expose existing herds to disease from domestic sheep and cause die-offs.

A second transplant of Stone's Sheep, in the Atlin area, was more successful. A feasibility study found that from 1979 to 1991, no sheep had been found in the area from west of Atlin Lake to Tagish Lake and from Graham Inlet north to the Yukon border (Marshall 1991). There were historic accounts of the presence of sheep in this area and there was substantial moderate-capability winter range. In 1994 and 1995, 24 sheep from the east side of Atlin Lake (Surprise Lake area) were released on the west side of Atlin Lake (Table Mountain) (Hatter and Blower 1996). In the winter of 1997-98, 45 to 50 sheep were found in the area (Shackleton 1999).

In 1996, in the third and most recent Stone's Sheep transplant to date, eight sheep were moved from Toad River to a site 25 km to the east (Hatter and Blower 1996). The outcome of this transplant is unknown at the time of writing.

4.0 HABITAT

4.1 Habitat Distribution

Thinhorn habitat is distributed across four jurisdictions that have differing methods of classifying land (British Columbia, Yukon, Northwest Territories and Alaska) (Figures 1 and 2). The regional ecosystem classification system used in British Columbia is based on climatic processes rather than vegetation communities (Demarchi 1995). In the following tables that give details of thinhorn distribution, the ecoregion level has been standardized among Alaska, Yukon and British Columbia, meaning that all units and names along any border are identical (except between the Brooks Range and British and Richardson mountains). British Columbia uses a hierarchy that has five levels (Bailey et al. 1994), while Alaska has dropped this methodology in favour of a classification that has three levels of ecoregions and two levels of sections (Nowacki et al. 2001). The Canadian National Standard uses only ecozones (roughly the same as British Columbia's ecoprovinces) and ecoregions, below which they use ecodistricts (Ecological Stratification Working Group 1995), which are the equivalent of British Columbia's biogeoclimatic subzones.

There is a close correlation between the distribution of Thinhorn Sheep and the boundary lines for ecoprovinces and ecozones (Figure 1). Ecoprovinces are areas with consistent climate or oceanography, relief and regional landforms. Ecozones are areas of the earth's surface representative of large and very generalized units characterized by macroscale climate, human activity, vegetation, soils, geological and physiographic features (Ecological Stratification Working Group 1995). There are 15 ecozones in Canada. Figure 2 is a further subdivision of ecological units to the ecoregion and ecoregion level and demonstrates a high correlation between these units and the distribution of Thinhorn Sheep in British Columbia. This correlation of ecoregion classification boundaries with the distribution of Thinhorn Sheep is not coincidental, demonstrating that Thinhorn Sheep occur within certain thresholds of habitat variables that are captured within the limits of the ecoregion

classification boundaries and, therefore, their characteristics.

4.1.1 North America

Populations of Thinhorn Sheep have been managed in isolation by provinces and states in the past. However, many populations and their habitats cross jurisdictional boundaries. British Columbia shares its Thinhorn Sheep populations with the Yukon, Northwest Territories and Alaska. Table 13 identifies ecoregions in Alaska that contain Dall's Sheep habitat, using both the Alaskan classification levels and the equivalent terminology from Canada.

In preparing these tables and the figures, it was necessary to harmonize the differing systems of classification, particularly between the U.S. and Canada (D. Demarchi, pers. comm.). Figure 1 shows ecoprovince classes for the four jurisdictions that support Thinhorn Sheep. The Southern Arctic Ecozone (Canadian) is flat, treeless Arctic Tundra; whereas the Arctic Tundra (U.S.) includes both flat, treeless Arctic Tundra and treeless Cordillera. Because the U.S. is using a new standard, it was not appropriate to include the Brooks Range Ecoregion with the Taiga Cordillera Ecozone (Canadian). No boundary is shown on the map between the Taiga Cordillera Ecozone (Canadian) and the Intermontane Boreal (U.S.). They are probably the same; therefore, the map shows both names, each in their respective jurisdictions. The Northern Boreal Mountains Ecoprovince extends from British Columbia through southern Yukon to south-central Alaska. The Canadian national ecozone system calls this the Boreal Cordillera, while the U.S. system calls this portion of Alaska, the Alaska Range Transition. The map designates it all as the Northern Boreal Mountains, the British Columbia name.

4.1.2 Canada

The British Columbia portion of the Thinhorn Sheep population is integrated with the Yukon populations of Thinhorn Sheep for both Dall's and Stone's subspecies. Populations that winter in one jurisdiction are likely to migrate into summer range that straddles both jurisdictions.

Table 13. Ecoregions in Alaska containing Dall's Sheep, with equivalent terminology from Canada in brackets (Nowacki et al. 2001).

LEVEL I (Ecodomain)	LEVEL II (Ecoprovince)	LEVEL III (Ecoregion)
Polar	Arctic Tundra	Brooks Range
Boreal	Inter Montane Boreal	Yukon – Tanana Uplands
	Pacific Mountains Taiga	North Ogilvie Mountains
		Alaska Range
		Kluane Range
		Wrangell Mountains
Maritime	Cold Hypermaritime	Chugach Mountains and Icefields

Table 14 indicates the distribution of Thinhorn Sheep habitat in Canada using the appropriate ecological units. Ecoregions are areas with major physiographic, minor microclimatic or oceanographic differences within each ecoprovince (Resources Inventory Committee 1995). Ecoregions can be used to group biogeo-

climatic or marine zones for the determination of historical and potential distribution of vegetation and wildlife. Ecosections are areas with minor physiographic, climatic and oceanographic differences. Each ecosection has a unique sequence of biogeoclimatic subzones and marine zones.

Table 14. Ecozones, ecoprovinces and ecoregions in British Columbia, Yukon and Northwest Territories that contain either Dall's Sheep (D), Stone's Sheep (S) or zone of overlapping range (X) (Ecological Stratification Working Group 1995; Yukon Government 1998; D.A. Demarchi et al. 2000).

ECOZONES	ECOPROVINCES	ECOREGIONS	Subspecies
Montane Cordillera	Sub-Boreal Interior	Central Canadian Rocky Mountains	S
		Omineca Mountains	S
		Fraser Basin	S
Boreal Cordillera	Northern Boreal Mountains	St. Elias Mountains	D
		Ruby Ranges	D
		Yukon Plateau – Central	D
		Yukon Plateau – North	S + X
		Pelly Mountains	S
		Yukon – Stikine Highlands	D + S
		Boreal Mountains and Plateaus	S + X
		Hyland Highland	D
		Northern Canadian Rocky Mountains	S
Taiga Cordillera		British – Richardson Mountains	D
		North Ogilvie Mountains	D + X
		Mackenzie Mountains	D, S + X
		Selwyn Mountains	D, S + X
Taiga Plains	Taiga Plains	Muskwa Plateau	S

4.1.3 British Columbia

Table 15 lists the ecoregion, ecosection and biogeoclimatic zones inhabited by Thinhorn Sheep in British Columbia. Table 16 lists the biogeoclimatic zones and ecosystem units used by Thinhorn Sheep. These habitats are widespread throughout the thinhorn's range. Biogeoclimatic zones are geographical areas having similar patterns of energy flow, vegetation and soils as a result of a broadly homogeneous macroclimate (B.C. Ministry of Forests 1995). A broad ecosystem unit is a permanent area of the landscape that supports a distinct kind of dominant vegetative cover or distinct non-vegetated cover (such as lakes or rock outcrops) (Resources Inventory Committee 1995).

4.2 Habitat Trend

In the Omineca Region, Stone's Sheep habitat is stable and mainly in an unaltered state. In the Skeena Region, habitats for sheep are secure, but mining exploration is one exception (e.g., Red Chris Mine at Todagin Mountain). In the Peace Sub-region, habitat for Stone's Sheep is limited by suitable terrain. Habitat was lost through the creation of Williston Reservoir, but that downward trend was localized and has probably been arrested. A perceived decline in sheep numbers in the Liard Sub-region in the northeast Rockies may be due to predation and not loss of habitat. While habitat losses have been minor, there must be vigilance concerning human developments and potential for disease transmission from domestic livestock. Oil and gas development and exploration is a potential concern that may affect future habitat trend in the Peace and Liard.

The 1978 preliminary mountain sheep management plan for British Columbia (B.C. Fish and Wildlife Branch 1978) noted that while many of the province's larger mountain sheep ranges had been examined for their capacity to support wintering herds, there had been little study of summer ranges and their components (i.e., lambing areas, rutting grounds, mineral licks, etc.). There had also been little inventory of the ranges of smaller herds and alpine wintering herds in terms of habitat requirements. The management

plan recommended that these habitat studies or inventories be completed, along with land use planning or the establishment of land reserves to protect habitat against damaging forms of land use by humans and domestic animals. Some progress has been made since 1978 (see section 9.0).

4.3 Habitat Status

The following are summaries of habitat status from the most recent management plans from the regions with Thinhorn Sheep habitat (B.C. Wildlife Branch 1986-1988) and current advice from MWLAP staff.

Peace Sub-region: Small herds of Stone's Sheep are found throughout MU 7-36, on Butler Ridge in MU 7-35 and in the Horn Creek and Upper Chowade River drainages of MU 7-43. Most of these sheep winter in windswept alpine tundra habitats, but about 75 sheep winter in the shrub-grassland habitat on the north side of Williston Lake between Scholler Creek and Dunlevy Creek. The creation of Williston Lake inundated much good sheep winter range. Existing winter range currently limits the distribution of Stone's Sheep in the sub-region. The relatively high mean annual snowfall for the area restricts sheep to microclimate habitats of lower snow accumulation. Prescribed fire enhancement of the Williston Lake winter ranges is ongoing, and a 50% increase in this sheep herd is expected. The shrub-grassland habitat on the south-facing escarpment of Graham River may provide some good sheep winter range, although no sheep presently winter there. The ongoing prescribed fire treatment of this escarpment to enhance Elk (*Cervus elaphus*) and Moose (*Alces alces*) habitat may attract some sheep to this range. No other habitat enhancement opportunities are identified at this time. Habitat capability mapping may identify some Stone's Sheep winter ranges in MU 7-31, in which case a transplant may establish a sustainable population in that MU.

Northeast Region: A large drop in Thinhorn Sheep numbers has increased the relative food

Table 15. Distribution of Thinhorn Sheep habitat in British Columbia in relation to ecoregions and ecosections (D.A. Demarchi et al. 2000) and biogeoclimatic zones (B.C. Ministry of Forests 1992).

Ecoregion	Ecosection and Biogeoclimatic Zones ^a
Central Canadian Rocky Mountains	Misinchinka Ranges (AT, SWB, BWBS, SBS, ESSF) Peace Foothills (BWBS, SBS, ESSF)
Omineca Mountains	Manson Plateau (AT) Eastern Skeena Mountains (AT, ESSF)
Fraser Basin	Babine Upland (AT, ESSF)
Northern Canadian Rocky Mountains	Muskwa Foothills (AT, SWB, BWBS) Eastern Muskwa Ranges (AT, SWB) Western Muskwa Ranges (AT, SWB, BWBS)
Northern Mountains and Plateaus	Cassiar Ranges (AT, SWB, BWBS) Kechika Mountains (AT, SWB, BWBS) Southern Boreal Plateau (AT, SWB, BWBS) Stikine Plateau (AT, SWB, BWBS) Teslin Plateau (AT, SWB, BWBS)
Pelly Mountains	Tuya Range (AT, SWB, BWBS)
Yukon-Stikine Highlands	Tagish Highland (AT, SWB, SBS, ESSF) Tatshenshini Basin (AT, SWB)
Muskwa Plateau	Muskwa Plateau (SWB, BWBS)

^a Biogeoclimatic zones: AT (Alpine Tundra); BWBS (Boreal White and Black Spruce); ESSF (Engelmann Spruce–Subalpine Fir); SBS (Sub-Boreal Spruce); SWB (Spruce–Willow–Birch)

Table 16. Biogeoclimatic zones (B.C. Ministry of Forests 1992) and broad ecosystem units (Resources Inventory Committee 1995) inhabited by Thinhorn Sheep in British Columbia.

Biogeoclimatic Zone	Broad Ecosystem Unit
	Alpine Grassland (AG)
	Alpine Heath (AH)
	Alpine Meadow (AM)
	Alpine Sparsely Vegetated (AN)
	Alpine Shrubland (AS)
	Alpine Tundra (AT)
	Alpine Unvegetated (AU)
	Subalpine Grassland (AG)
	Subalpine Meadow (SM)
	Subalpine Shrub / Grassland (SU)
	Boreal White Spruce – Trembling Aspen (BA)
	Black Spruce – Lodgepole Pine (BL)
	Boreal White Spruce – Lodgepole Pine (BP)
	Subalpine fir – Mountain Hemlock Wet Forest (EW)
	Subalpine Fir – Scrub Birch Forest (FB)
Alpine Tundra (AT)	Lodgepole Pine (LP)
Spruce–Willow–Birch (SWB)	Subboreal White Spruce – Trembling Aspen (SA)
Boreal White and Black Spruce (BWBS)	White Spruce – Paper Birch (SB)
Sub-Boreal Spruce (SBS)	White Spruce – Subalpine Fir (SF)
Engelmann Spruce–Subalpine Fir (ESSF)	Subboreal White Spruce – Lodgepole Pine (SL)
	Trembling Aspen – Balsam Poplar (TB)
	Subalpine Fir – Scrub Birch Krummholz (BK)
	Engelmann Spruce–Subalpine Fir Dry Parkland (FP)
	Avalanche Track (AV)
	Bunchgrass Grassland (BS)
	Cliff (CL)
	Gravel Bar (GB)
	Glacier (GL)
	Lodgepole Pine Outcrop (PO)
	Rock (RO)
	Talus (TA)
	Unvegetated (UV)
	Mine (MI)
	Transmission Corridor (TR)

supply, but there can still be benefits from enhancing low-elevation ranges to improve growth rates. A substantial area was improved through burning of low-elevation range, which can now support 20% more sheep.

The MWLAP advice for habitat management is to modify mining programs to protect key forage

sites, modify access development to facilitate multiple resource use, avoid direct destruction of key habitat, enhance the range through fire and oppose the introduction of domestic bovinds to sheep range to avoid disease transmission.

Omineca Region: The MWLAP policy is that largely inaccessible sheep ranges should remain

intact. There is no conflict at the present time with cow (*Bos taurus*) or horse (*Equus caballus*) grazing in any part on the region. No potential competition for the same range use is apparent at this time. In general, sheep habitat is limited and irreplaceable, and it must therefore be identified and protected. Because sheep are reluctant to colonize non-traditional habitat, populations must be maintained on each available range.

Due to a lack of good information on sheep habitats, it is difficult to assess the influence of human activities. The most far-reaching effect relates to a forest fire suppression policy that has allowed woody species to encroach onto former fire-stimulated seral grassland areas. This results in reduced range sizes and, consequently, smaller herd sizes.

Some mining developments may have affected sheep populations. The Baker Mine in MU 7-39 was opened in the late 1970s and was closed in the early 1980s but is occasionally opened up to mill some ore from other mineral prospects. Although the Cyprus Anvil Mine on Paul River was never put into production, a road from the Finlay River to the alpine was built in the mid 1980s and a substantial amount of exploration activity occurs during some years. Currently, logging has been proposed within the Finlay and Pelly river valleys. Hunting closures or limited entry hunting seasons have been enacted because of the potential for effects on local herds. Disruption of migration routes via new roads is more difficult to control and usually results in either a change in migration pattern or a population reduction. If access improves, poaching of sheep by hunters in the Ingenika–Fort Ware area could become a significant problem.

Skeena Region: Habitats for sheep are mostly secure due to the lack of competing land use. The exception is mining exploration and development in selected key ranges, particularly in the Tatshenshini and Atlin areas. Increased encroachment of shrubs into subalpine ranges may also be slowly reducing the quality of sheep range. More effective wild fire suppression has reduced the frequency of natural fires in much of the north.

4.4 Habitat Characteristics

The habitat and forage requirements of Thinhorn Sheep are paraphrased from Nichols and Bunnell (1999) as follows: Thinhorn Sheep are found on steep, rugged cliffs and rocky outcrops, which provide good escape terrain from predators; on nearby open grass and sedge meadows; and on mountain slopes up to the alpine zone, where they feed in the summer. Windswept alpine slopes provide much of their critical winter range.

Dall's Sheep mainly live in the alpine. In winter they select areas with light snowfall and strong winds, where they can move easily and find forage. In the northern part of their range, Dall's Sheep winter range is characterized by relatively shallow, soft snow and cold, dry weather conditions. Near the southern limits of their range, Dall's Sheep winter range has more precipitation and warmer temperatures, with occasional thaws and subsequent crusting, and deeper snow. These conditions may cause movement to be restricted to small areas where forage is available. In summer, the climate is generally cool and moist in the south and warm and dry in the north. High winds are common in both locales in fall and winter.

During lambing, Dall's Sheep ewes make trade-offs between foraging in habitats with abundant food and the risk of predation. In Alaska, ewes seemed to select areas with forage when food was less abundant, and terrain to avoid predators when forage was more plentiful (Rachlow and Bowyer 1998).

Stone's Sheep use alpine areas and cliffs, but they also inhabit subalpine brushlands and forested areas at lower elevations. The highest concentrations of Stone's Sheep are usually found in lower mountainous ranges to the northeast of tall mountain chains where the high precipitation and winds result in good graminoid production, winter snow removal and summer drying (Nichols and Bunnell 1999). Warm winter winds or chinooks occur in these areas and wind speeds can exceed 160 km/hr (Luckhurst 1973). Near Toad River, Thinhorn Sheep did not dig into snow when it reached depths of 32 cm, even if

Table 17. Coarse feature requirements used for habitat mapping of Bighorn Sheep (after Sweanor et al. 1996) and applicable to Thinhorn Sheep.

Habitat Requirement	Definition
Escape Terrain	Areas with slope $>27^\circ$ and $<85^\circ$.
Escape Terrain Buffer	Areas within 300 m of escape terrain and areas ≤ 1000 m wide that are bound on ≥ 2 sides by escape terrain.
Vegetation Density	Areas must have visibility $>55\%$, as defined by the mean percent of squares visible on a 1-m ² target, divided into 36 equal squares, 14 m from an observer viewing N, E, W, S from a height of 90 cm along a 10-pt, 280-m transect.
Water Sources	Areas must be within 3.2 km of water sources.
Natural Barriers	Areas that Bighorn Sheep cannot access are excluded (e.g., rivers >200 cubic feet per second, areas with visibility $<30\%$ that are 100 m wide, cliffs with $>85^\circ$ slope).
Human Use Areas	Areas covered by human development are excluded.
Manmade Barriers	Areas that cannot be accessed due to manmade barriers are excluded (e.g., major highways, wildlife-proof fencing, aqueducts, and major canals).
Domestic Livestock	Areas within 16 km of domestic sheep are excluded.

abundant food was beneath (Seip and Bunnell 1985a). Many Stone's Sheep ranges in the Stikine and the Tatshenshini occur on west-facing slopes.

Table 17 provides a summary of coarse habitat requirements used for Bighorn Sheep habitat mapping within the known range (Sweanor et al. 1996). Thinhorn Sheep probably have similar habitat requirements. Desforges and Carey (1992) have developed a model to predict spring lamb locations by using slope, aspect and distance from escape terrain and winter range.

Common vegetation on Dall's Sheep ranges include sedges (*Carex* spp.), rushes (*Juncus* spp.), bunchgrasses such as fescues (*Festuca* spp.) and bluegrasses (*Poa* spp.), species of forbs, low shrubs including dwarf willows (*Salix* spp.) and huckleberry (*Vaccinium* spp.), mountain-avens (*Dryas* spp.), crowberry (*Empetrum* spp.), four-angled mountain-heather (*Cassiope tetragona*), lichens and mosses (Nichols and Bunnell 1999). Lower winter ranges may have dwarf birch (*Betula* spp.), alder (*Alnus* spp.), mountain hemlock (*Tsuga mertensiana*), larger

willows, balsam poplar/black cottonwood (*Populus balsamifera*), trembling aspen (*Populus tremuloides*) and, occasionally, white spruce (*Picea glauca*).

Stone's Sheep are mainly dependent on herbaceous vegetation in the relatively stable alpine habitats for protein and carbohydrate needs (Luckhurst 1973). Productive sites on steep south and west exposures appear to be the result of insolation (radiation received per unit area), temperature and soil moisture that favours the development of fertile, chernozemic soils (Lord and Luckhurst 1974). Seral grasslands are less suitable because they tend to be short lived and largely unsuitable for wintering sheep because they are rapidly invaded by shrubs that cause drifting snow to accumulate (Luckhurst 1973). Thus, the vegetation composition of ranges for Dall's and Stone's sheep do not differ significantly (Nichols and Bunnell 1999).

On many of the alpine and subalpine Stone's Sheep winter ranges there are graminoids, usually wheatgrasses (*Agropyron* spp.), bluejoint reedgrass (*Calamagrostis canadensis*), sedges,

wildrye (*Elymus* spp.), fescues and bluegrasses. Many forbs are present. Shrubs include kinnikinnick (*Arctostaphylos uva-ursi*), common juniper (*Juniperus communis*), soopolallie (*Shepherdia canadensis*) and prickly rose (*Rosa acicularis*) on drier sites, and willows, scrub birch (*Betula nana*), bog blueberry (*Vaccinium uliginosum*) and lingonberry (*V. vitis-idaea*) on moist sites (Nichols and Bunnell 1999). Subalpine forests that have not been disturbed are dominated by white spruce, black spruce (*Picea mariana*), subalpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta*). These forests have less forage than ones that have been disturbed by fire or other disturbances that encourage the growth of deciduous species such as cottonwood, aspen and willows. In the southern portion of the Stone's Sheep range, the brush zone of willow and birch is at the transition between forest and alpine. Unless these are disturbed, they are too dense for sheep movement or for graminoid production.

4.5 Ungulate Winter Range

Winter range is the most critical habitat for Thinhorn Sheep (i.e., population limiting) and at present the majority of winter range is in government ownership (Crown land).

An Ungulate Winter Range (UWR) is defined as an area that contains habitat that is necessary to meet the winter habitat requirements of an ungulate species. Specific management objectives are applied within the UWR boundary. Thinhorn Sheep have been designated as an ungulate species for which an ungulate winter range may be required for their winter survival (http://wlapwww.gov.bc.ca/wld/documents/uwr/UWR_order.pdf).

In August of 2003, a Memorandum of Understanding (MOU) on the Establishment of Ungulate Winter Ranges and Related Objectives was developed between MWLAP, the Ministry of Forests (MOF) and the Ministry of Sustainable Resource Management (MSRM) (see http://wlapwww.gov.bc.ca/wld/uwr/ungulate_doc.html). The purpose of the Memorandum of Understanding (MOU) was to expedite and facilitate the orderly confirmation and establish-

ment of ungulate winter ranges (UWR) and related objectives across the province, in order to support the Forest Practices Code and the new *Forest and Range Practices Act* (FRPA).

As of May 2004, an UWR for Stone's Sheep was established along the Peace Arm within the Mackenzie Forest District. The specific management objectives that were applied to this UWR included no commercial forest harvesting within winter range units, manage forest health to reduce conflicts between Stone's Sheep and bark beetle management, and maintain a mature forested buffer (200 m no harvest zone) adjacent to escape terrain/thermal cover or forested movement rails and licks. Further details of this UWR that pertain to range management, fire management and access management are available at

http://wlapwww.gov.bc.ca/wld/documents/uwr/uwr_u7_006.pdf. Additional UWR that will address winter range habitat for Stone's Sheep are currently proposed for the Peace Region in the Fort St. John Timber Supply Area, Fort Nelson Timber Supply Area, Dawson Creek Timber Supply Area and Tree Farm License 48. There are no UWRs anticipated for Dall's Sheep.

4.6 Diet

The diet of Thinhorn Sheep largely depends on plant availability. Thinhorn Sheep are primarily grazers that use grasses and sedges — more grasses in winter and more sedges in summer. Their diet can include 50 to 120 species, although only 10 to 15 are eaten throughout the year (Nichols and Bunnell 1999). Stone's Sheep near Toad River fed mainly on sedges and bluegrass in winter, in the alpine, whereas sheep in the subalpine fed primarily on ryegrass and bluegrass (Seip and Bunnell 1985a). Luckhurst (1973) found that contents from five rumens collected in winter averaged 88% graminoids, 3% forbs and 9% shrubs. The grass content can be much less in summer. A study of winter diets of Stone's Sheep in the Peace Arm and Ospika River drainages found that at the lower-elevation site dominated by graminoids, sheep pellet fragments contained an average of 77% grasses, 14% shrubs and 6% forbs (Corbould 1998). In contrast, a site dominated by forbs had 50%

forbs, 25% mosses and 12% grasses in the pellets, and a site with mainly lichens had 43% lichens and 18% grasses in the pellets.

Because lichens are more digestible, their contribution to the diet is probably underestimated, while mosses are probably overestimated because they are highly indigestible. Terrestrial lichens (mostly *Cladonia spp.*) and mosses form a larger part of the diet of Thinhorn Sheep than of other mountain sheep (Nichols and Bunnell 1999). Near Toad River, lichens became a high-percentage item (36%) in the diet when sheep were restricted to windswept alpine areas during high snowfall years (Seip and Bunnell 1985a). In the Brooks Range, terrestrial lichens made up 74 to 80% of the Dall's Sheep diet in the fall (Ayers 1986 in Nichols and Bunnell 1999). In lower snowfall years, lichens composed less than 10%.

The *Elymus-Agropyron* plant community was particularly significant to Stone's Sheep wintering within the Nevis Creek drainage of the northern Rocky Mountain foothills (Luckhurst 1973). Although this plant community occupied less than 20% of the winter range and 4% of the total productive habitat, it provided almost 60% of the forage for wintering sheep. In Alaska, rumen contents of ewes in winter contained 95% grasses and sedges, 4% willow parts and 1% other material. *Dryas* was absent. In summer, the ewes' rumens contained 82% grasses and sedges, 6% willow parts and 12% *Dryas* leaves. Winter weight loss for five- and six-year-old ewes was 15% (W. Heimer, pers. comm.). Even with abundant food, mountain sheep lose weight over the winter because the quality of forage is inadequate for maintenance.

In June near Toad River, forbs, particularly locoweed (*Oxytropis spp.*), and willow were important (Seip and Bunnell 1985a). Poplar (*Populus spp.*) was also used early in June until the sheep migrated above the altitudinal limit of these trees. Conifers were rarely used, even when they were available. Early in the growing season, Stone's Sheep selected substantial amounts of forbs and willow while avoiding them in the latter part of the growing season to avoid ingesting tannins and phenolics (Seip and

Bunnell 1985a). Because grasses are free of tannins and low in phenolics, they formed the main part of the diet in spite of being lower in nutrients. Sedges and other graminoids were the most important food items on alpine summer range, although a wide variety of forbs and browse species were eaten. Bluegrass was the one species that was intensively selected for on subalpine and alpine ranges, even though it was sparsely distributed (Seip and Bunnell 1985a).

In Alaska, forage species used by Dall's Sheep on native ranges in the summer included broad-leaved willowherb (*Epilobium latifolium*), mountain sagewort (*Artemisia norvegica ssp. saxitilus*), northern anemone (*Anemone parviflora*), alpine bluegrass (*Poa alpina*), yarrow (*Achillea borealis*), spike trisetum (*Trisetum spicatum*), Altai fescue (*Festuca altaica*), Bellard's kobresia (*Kobresia myosuroides*), net-veined willow (*Salix reticulata*), grey-leaved willow (*S. glauca*), arctic willow (*S. arctica*), (*S. planifolia*), (*Boykinia richardsonii*), alpine arnica (*Arnica angustifolia*), Alaskan sagebrush (*Artemisia alaskana*), northern shootingstar (*Dodecatheon frigidum*), Ratzshivin's saxifrage (*Saxifraga razshivini*) and mountain sorrel (*Oxyria digyna*) (Viereck 1963; Whitten 1975 in Elliott and McKendrick 1984). A detailed study of Dall's Sheep diets within Alaska found that sedges, alpine fescue (*Festuca brachyphylla*) and other grasses made up most of the summer diet in all areas, while the use of sedges decreased markedly by mid-winter and the use of alpine fescue increased (Nichols and Heimer). The consumption of other grasses, including red fescue (*Festuca rubra*), alpine sweetgrass (*Hierochloë alpina*) and bluegrasses, was constant throughout the year.

Seeding of reclaimed mine sites can contribute to forage production for Thinhorn Sheep. On the reclaimed Usibelli Mine site in south-central Alaska, two seeded native grasses, red fescue and bluejoint, comprised 49% and 10% of the summer diet and 40% and 15% of the winter diet, respectively. While these grasses were the most consumed of the revegetated grasses, desirable habitat characteristics such as escape terrain, benches and windblown areas may be

greater factors governing Dall's Sheep use of reclaimed mine spoils.

4.7 Mineral Licks

Mineral licks are an important source of essential minerals for most mountain ungulates (Cowan and Brink 1949; Hebert 1967). Sheep will lick or eat soil during their time at the mineral lick, possibly to obtain sodium, which is deficient in much of their forage. Seip (1983) found that sodium was the only element higher in mineral lick samples than in other soil samples found at Toad River. At the Watana Creek Hills in Alaska, soil samples from well-used mineral licks contained significantly higher amounts of sodium than soil samples collected away from lick sites (Tankersley 1984). One lick had higher total sodium, magnesium and calcium levels than a second lick, but sheep endured the danger of travel to the second lick, which had greater amounts of water-soluble elements or possibly some other foraging access benefits. The macroelements sodium, magnesium and calcium and the water-soluble element sulfate were the dominant components in the licks, along with the microelement copper. Copper deficiency in Moose has been reported (Flynn et al. 1977 in Tankersley 1984).

Heimer (1988a) proposed a magnesium-driven hypothesis for why Dall's Sheep use mineral licks. He suggested that during the spring, when potassium is high in forage, an imbalance occurs in the potassium-sodium body chemistry. This leads to a hormone, renal aldosterone, being secreted to return sodium from body fluids, which in turn limits magnesium absorption from the gut. Sheep may rectify this imbalance by ingesting sodium- and magnesium-rich soils at mineral licks and may use licks more frequently in wet years, when there is a high potassium-to-magnesium ratio in forage.

In Alaska, the average amount of time spent licking minerals was 70 minutes during two visits per day. Ewes nursing lambs appeared to spend more time licking and 1.6 times as much time involved with the lick. Both rams and ewes made an average of four visits per season to the mineral lick and thus spent four days per season at or near the lick (Heimer 1973b). The

predictability of the use of licks demonstrates their critical nature, particularly as foci immediately following lambing. At Toad River during June and July, sheep used licks once every two to three days on average, and the frequency of use ranged from one to six days out of a ten-day period (Seip 1983). Individual sheep spent from one to four hours licking. Their feces in that location contained up to 88% mineral material and averaged up to 45%.

Unfortunately, the distribution and locations of mineral licks used by sheep are not well known. Demarchi and Demarchi (1994) mapped known mineral licks for Bighorn Sheep in the Kootenay region using information from local residents and guide-outfitters. This was not a comprehensive catalogue of all mineral licks in the region. Nothing similar exists for Thinhorn Sheep, but it should be done.

Water requirements for thinhorns are not known and even for bighorns are not clearly established. However, it has been postulated that water is not a limiting factor (McCann 1956) and it appears that mountain sheep can go long periods without drinking free-standing water. In describing Bighorn Sheep habitat requirements, however, Sweanor et al. (1996) indicated that habitats must be within 3.2 km of water sources.

5.0 LEGAL PROTECTION AND STATUS

5.1 North America

COSEWIC (Committee on the Status of Endangered Species in Canada) has not assessed the status of this species nationally and they have not been given any special status in Canada or in the United States. The species is rated by each province, territory and state individually. All three Canadian jurisdictions classify Thinhorn Sheep as "big game" under their respective *Wildlife Acts*, while in Alaska, sheep are classified under applicable *Game Acts* as a "game species." While CITES (Convention on the International Trade of Endangered Species) does not require a Convention Export Permit for Thinhorn Sheep, an export permit is required from the province. The compulsory inspection

Table 18. Parks and protected areas in British Columbia that contain Thinhorn Sheep habitat, by management zone.

Management Zone	Park/Protected Area Name	Size (ha)
Atlin	Atlin Recreation Area	38 445
	Atlin Provincial Park	232 695
	Tatshenshini-Alsek Provincial Park	947 026
	Management Zone Total	1 218 166
Stikine	Todagin South Slope Provincial Park	3557
	Mount Edziza Recreation Area	4000
	Pitman River Protected Area	16 316
	Tuya Mountains Provincial Park	18 001
	Chukachida Protected Area	19 637
	Gladys Lake Ecological Reserve	44 098
	Tatlatui Provincial Park	105 829
	Stikine River Provincial Park	257 177
	Mount Edziza Provincial Park	266 095
	Spatsizi Plateau Wilderness Park	696 091
Management Zone Total	1 386 703	
Omineca	Finlay-Russel Protected Area	13 566
	Finlay-Russel Provincial Park	109 205
	Management Zone Total	122 771
Northeast Rockies	Northern Rocky Mountains Provincial Park	665 709
	Butler Ridge Provincial Park	6024
	Kwadacha Recreation Area	44 031
	Redfern-Kelly Provincial Park	80 712
	Graham-Laurier Provincial Park	99 904
	Kwadacha Wilderness Park	126 995
	Management Zone Total	1 023 375
Liard	Denetiah Corridor Protected Area	7441
	Dune Za Keyih Protected Area	16 059
	Stone Mountain Provincial Park	25 690
	Muncho Lake Provincial Park	88 420
	Denetiah Provincial Park	90 379
	Dune Za Keyih (Frog-Gataga) Provincial Park	330 254
	Management Zone Total	558 243
	Provincial Total	4 353 356

data sheet may serve as an export permit (see section 8.3.3). Federally, Thinhorn Sheep found in national parks are protected by the *National Parks Act*.

5.2 British Columbia

British Columbia was granted jurisdiction over all wildlife, including Thinhorn Sheep, under the

British-North America Act. The B.C. Conservation Data Centre of the Ministry of Sustainable Resource Management (MSRM) classifies Dall's Sheep as a blue-listed or Vulnerable species. Stone's Sheep are on the Yellow List of species and subspecies recommended to be actively monitored and studied. Neither subspecies is protected by legislation other than the general provisions for all vertebrate wildlife under the

provincial *Wildlife Act*, which empowers the Directors of the Biodiversity Branch and Fish and Wildlife Recreation and Allocation Branch to regulate the use and movement of all wildlife in the province. Domestication of nearly all species of native wildlife, including Thinhorn Sheep, is prohibited under the provisions of the *Wildlife Act*. Also FRPA (Forest and Range Practices Act) has designated Thinhorn Sheep as an ungulate species for which an UWR (ungulate winter range) may be required (see Section 4.5). Other provisions such as wildlife habitat features may protect habitat elements such as mineral licks (see Section 4.7).

Specific areas of habitat are designated as National Parks or Provincial Parks and Protected Areas and, as such, are under the jurisdiction of the *National Parks Act* and the *British Columbia Parks Act*, respectively. Both subspecies of Thinhorn Sheep have benefited at least as much as any other wildlife from the expansion of protected areas and special management areas. Between 1991 and 2001, the British Columbia government doubled the amount of provincial parks and protected areas from 6% of the provincial land base to 12%. Many of the additional areas were established within the northern third of the province and included much Thinhorn Sheep habitat (Table 18). Parks and protected areas of importance to Thinhorn Sheep occupy more than 4.3 million ha.

Tatshenshini-Elsek Provincial Park has the largest population of Dall's Sheep in the province. There are no national parks in British Columbia that protect Thinhorn Sheep; however, Kluane National Park (2 201 500 ha) in the southwest corner of the Yukon immediately north of the British Columbia boundary, protects a large population of Dall's Sheep, the park's most abundant large mammal. Kluane National Park, Tatshenshini-Elsek Provincial Park and Alaska's Wrangell-St. Elias and Glacier Bay national parks form the largest international UNESCO World Heritage Site in the world. This offers additional protective land status to Dall's Sheep habitat in British Columbia and in adjacent jurisdictions.

Protected areas and parks of significance for Stone's Sheep shown in Table 18 include Atlin, Mount Edziza, Spatsizi Plateau Wilderness, Tatlatui, Finlay-Russel, Redfern-Kelly, Northern Rocky Mountains, Dune Za Keyih (Frog-Gataga), Denetiah Corridor, Stone Mountain, Todagin South Slope and Muncho Lake. The 44 000-ha Gladys Lake Ecological Reserve in Spatsizi Plateau Wilderness Park also includes important Stone's Sheep habitat. Ecological reserves are places of special ecological importance that are designated for scientific research and educational purposes. Scientific research and study into values contained in protected areas is part of the BC Parks' ongoing commitment to knowledge and information gathering.

In 1997, the B.C. government established the Muskwa-Kechika Management Area (M-KMA) over 4.4 million hectares of the northern Rockies (The Muskwa-Kechika Wildlife Management Area includes all or part of MUs 7-36,7-42,7-43,7-50, 7-51, 7-52, 7-54 and 7-57.). In March 2001, 1.1 million hectares of parks and another 3.3 million hectares of legislated special management zones were added as an extension to the M-KMA after the government legislated the recommendations of the Mackenzie Land Use Planning Table. The area is now over six million hectares in size, or twice the size of Vancouver Island. The M-KMA was British Columbia's largest-ever land-use decision and is North America's largest example of a conservation biology model. The area includes a significant proportion of the province's Stone Sheep population. A management plan is currently being prepared for this area, which will include recommendations for the conservation and management of Stone's Sheep.

Through the establishment of parks, ecological reserves and protected areas, an important first step has been undertaken to ensure that Thinhorn Sheep and their habitat are afforded legal protection. The legal framework for protecting these important areas includes the following acts: *Parks and Protected Areas of British Columbia Act*; *Park Act*; *Ecological Reserve Act*; and *Environment and Land Use Act*. As noted previously, ungulate winter ranges may be established for Thinhorn Sheep under the *Forest and Range*

Practices Act (see 4.5). The protection of wildlife habitat features, such as mineral licks, may also be identified under FRPA.

6.0 LIMITING FACTORS AND RISKS

At the 2000 North American Wild Sheep and Goat Conference, representatives from British Columbia identified what they considered to be the most significant limiting factors for Stone's Sheep. These were: predation and severe winters; access management, including access associated with mining and oil and gas exploration and development; fire suppression and forest encroachment, resulting in reduction of range quality; and disease introduction from domestic animals (Bailey and Hurley 2000). For Dall's Sheep the three most significant limiting factors were predation and severe weather, increased access and human activities (mining, forestry, etc.) and unregulated First Nations harvest.

6.1 Habitat Alienation

Thinhorn Sheep have escaped many of the detrimental effects that decimated many Bighorn Sheep populations and their habitats in the U.S. and Canada during the 19th and 20th centuries. As development and settlement proceed, however, they face many threats to their long-term survival. Bighorn Sheep are perhaps the best example of what could potentially limit Thinhorn Sheep, and the greatest threat is contact with domestic livestock, particularly domestic sheep and domestic goats (*Capra hircus*).

The effects of human activities on most mountain-dwelling native wildlife species are usually negative. Although hunting decimated many wildlife populations following Euro-Asian settlement of North America, hunting is now regulated. After a full century of successful wildlife management and enforcement, today's declines more often are the result of habitat alienation or human developments. Generally, potential effects threatening thinhorn habitat within the species' range are:

- Access developments: highways, logging roads and rights-of way.

- Industrial developments: oil and gas exploration and development, prospecting and mining, hydroelectric dams and reservoirs, and forestry, including domestic sheep silvicultural treatments.
- Recreational developments and activities: motorized commercial backcountry recreation, all terrain vehicle (ATV) use, etc. (see Section 6.5).
- Agricultural developments: croplands and livestock grazing on private and leased lands.

In British Columbia, there are few private land holdings within the boundaries of Stone's Sheep range and virtually none within Dall's Sheep range. Except for fee simple lands at several locations in Stone's Sheep habitat in the northern Rockies along the Alaska Highway (Highway 97) and in the Iskut-Stikine region along the Stewart-Cassiar Highway (Highway 37), private lands are restricted to small, scattered home sites and agricultural in-holdings, often associated with big game guide-outfitting businesses.

Hydroelectric developments can affect Thinhorn Sheep populations. In British Columbia, the creation of the Williston Reservoir in the late 1960s isolated sheep habitat south of the Peace Arm (Backmayer 1994) and formed a barrier to east-west movement between the Rocky Mountains and the Omineca Mountains for some smaller sheep herds south of the settlement of Tsay Keh. In Alaska, in the Watana Creek Hills, Tankersley (1984) identified a number of direct and indirect effects of a proposed hydroelectric impoundment that she felt would hinder the use of mineral licks by sheep. These included erosion, flooding, mudslides, ice shelving, disturbance from timber removal in the impoundment, and increased recreational use.

Prior to 1950, the development of productive agricultural land occurred in valley bottoms and plateaus away from the mountains, and therefore well removed from Stone's Sheep habitat. It wasn't until the 1960s that a major initiative to develop agricultural land resulted in the establishment of farms near Stone's Sheep habitat in the Peace River region and the foothills of the northern Rocky Mountains (Demarchi and Demarchi 1987). These were scattered and isolated,

and many such homesteads have been abandoned or never fully developed. However, the potential remains for conflict with livestock, especially domestic sheep, an animal common to many marginal farms. New initiatives such as the Extensive Agriculture Program of Land and Water BC, which converts crown land to private land to benefit agriculture, need to consider the potential risks of disease transmission between wild and domestic sheep.

Placer mining operations, particularly in the Atlin district, became common in the latter half of the 1800s and continue today. Damage to sheep habitat has been often severe, but localized in extent.

Major seismic work has occurred throughout the northern Rocky Mountain foothills and the northeastern corner of B.C. (Taiga Plains and Boreal Plains ecoprovinces), beginning in the 1950s and continuing to date. Helicopter activity associated with seismic work can dislocate sheep. In Montana, this caused Bighorn Sheep to be displaced from more productive forage, leaving them vulnerable to major die-offs (Hook 1986).

Oil and gas extraction is a top priority for economic development on the east slope of the Rocky Mountains. There are requirements for planning prior to road construction in the Muskwa-Kechika Management Area. Road building will commence across the east slope, potentially extending into the Racing River drainage on the north slope of the Rockies. There is likely to be a road constructed to every well site for safety reasons, in accordance with Worker's Compensation Board regulations (J.P. Elliott, pers. comm.).

A study from Alberta documented the concentration of Bighorn Sheep near gas well sites, where salty deposits attracted the sheep (Morgantini and Bruns 1988). This is problematic for a number of reasons, including crowding and range depletion, altered distribution, tameness, possible exposure to toxic chemicals, industrial accidents and vulnerability to hunting (Morgantini and Bruns 1988, Morgantini and Worbets 1988). Road, well site and pipeline construction can

displace Thinhorn Sheep. This may be temporary since mountain sheep may re-establish themselves, particularly if mitigation reclaims critical elements of habitat. Other measures can be taken, such as avoiding drilling during critical periods, controlling access and properly disposing of drilling wastes (Mead and Morgantini 1988).

The Cassiar Iskut-Stikine Land and Resource Management Plan (LRMP) states: "There are substantial resources of high grade metallurgical coal in the Klappan watershed adjacent to Spatsizi Park, estimated at 640 million tonnes. Lower grade coal deposits have also been identified in the Tuya River area north of Telegraph Creek. There is moderate to high oil and gas potential in the Telegraph Creek and Klappan areas" (Land Use Coordination Office 2000a). Future plans to develop that coal must keep in mind the needs of Stone's Sheep through a proper environmental assessment and possibly through development of reclamation plans.

Transportation and utility corridors for highways, resource extraction roads, railroads, power transmission lines and pipelines have had a negative effect on Bighorn Sheep habitat in the province and there is similar potential for effects on Thinhorn Sheep habitat. Transportation and utility corridors remove habitat from use, dissect migration routes and lead to sheep being killed in collisions with vehicles. These developments can also affect seasonal movements of sheep along established, secure corridors, increasing their exposure to predation and hunting.

6.2 Disease, Epizootics and Parasites

Stone's and Dall's sheep do not exhibit the exaggerated population cycles of Rocky Mountain Bighorn Sheep, such as those in the East Kootenay region during the 20th century. This is probably because Thinhorn Sheep populations have not had contact with domestic sheep and their pathogens and have not been exposed to anthropogenic stressors such as habitat loss, decreased suitability of available habitat, translocations and loss of chase predators, such as wolves (Jenkins et al. 2000).

6.2.1 Pasteurellosis

Pasteurella spp. infections causing pasteurellosis in wild sheep are one of the most common causes of mortality in North American wild sheep. Certain *Pasteurella* spp. bacteria commonly present in domestic sheep and occasionally in other domestic species, such as biotype A serotype 2 (Martin et al. 1996), can cause fatal pneumonia in otherwise healthy Bighorn Sheep within days to weeks of nose-to-nose contact or inoculation with bacterial culture (Foreyt and Jessup 1982; Onderka 1986; Onderka and Wishart 1988; Foreyt et al. 1994).

In Bighorn Sheep, pneumonia most commonly involves the bacterial species *Mannheimia* (*Pasteurella*) *haemolytica* (various biotypes) or *Pasteurella multocida*, often in combination with *Arcanobacterium* (*Actinomyces* or *Corynebacterium*) *pyogenes* (Schwantje 1988a). *Pasteurella/Mannheimia* spp. and *A. pyogenes* are commensals of the upper respiratory tract, tonsils and skin (the latter, *A. pyogenes* only) of healthy domestic and Bighorn Sheep. These bacteria are opportunistic pathogens in the lungs when stressors or other pathogens compromise natural defenses, but can act as primary pathogens, for example, when naïve bighorns are exposed to a foreign *Mannheimia* species from domestic sheep or biotypes from other Bighorn Sheep (Foreyt and Jessup 1982; Foreyt et al. 1994).

Since no method currently exists to prevent mountain sheep from contracting pneumonia after contact with virulent strains of *Pasteurella*, “wildlife professionals have concluded that mountain sheep and domestic sheep should not occupy the same ranges or be managed in close proximity” (Martin et al. 1996).

A recent experiment with a vaccine to protect Bighorn Sheep from fatal pneumonia that predictably occurs after exposure to domestic sheep failed and all Bighorn Sheep died (Foreyt 1998). Therefore, vaccination against pneumonia is not reliable.

The first documented cases of pneumonia in wild Dall’s Sheep was discovered in two ewes in

the Mackenzie Mountains, Northwest Territories (Jenkins et al. 2000). *M. haemolytica* and *A. pyogenes*, as well as lungworms (*Protostrongylus* sp.) and other lung parasites, were found in the sheep (Jenkins et al. 2000). The *Mannheimia* species is thought to be distinct from that found in Bighorn or domestic sheep. While both ewes were in poor body condition, there was no evidence of anthropogenic stressors and there was no opportunity for transmission of domestic sheep or cattle pathogens.

Lungworms may have played a predisposing role in the pneumonia, but the proximate cause of death was the bacterial bronchopneumonia and septicemia. The authors concluded that sporadic mortality is typical for Thinhorn Sheep at the present time and may reflect the situation for Bighorn Sheep when anthropogenic stressors are introduced (Jenkins et al. 2000). They warn, however, that while Thinhorn Sheep managers must work to keep populations free of these stressors and introduced pathogens, natural stressors and global climate change may shift the equilibrium of host-pathogen relationships in the north.

Experimental infections of Dall’s Sheep have illustrated that they are as susceptible to domestic animal bacteria as bighorns. In fact, Dall’s Sheep neutrophils may be more sensitive to cytotoxins of *M. haemolytica* biotype A serotype 2 than neutrophils of bighorns (Foreyt et al. 1996). In the Metropolitan Toronto Zoo in 1986, *Mycoplasma ovipneumoniae* was isolated from 10 Dall’s Sheep that were sick with pneumonias and from three that had died from pneumonia (Black et al. 1988).

A serosurvey of Dall’s Sheep in Alaska found antibodies to *Campylobacter fetus*, *Brucella* spp. and contagious ecthyma virus. Lumpy jaw, or mandibular osteomyelitis, a bacterial infection of jaw bones, was found in two populations studied in the Yukon and occasionally in B.C. None of these were considered significant (Heimer et al. 1982). Serum from 251 Dall’s Sheep from interior Alaska collected from 1979 to 1987 showed no evidence of exposure to significant pathogens (Zarnke and Røsendal 1989). The authors caution that the health of free-

ranging Dall's Sheep is dependent on strict enforcement of domestic animal health regulations and prudent land use practices.

Pasteurella haemolytica biotypes, *P. trehalosi* and *Arcanobacterium pyogenes* were isolated from pharyngeal swabs taken from Stone's Sheep on the north shore of the Peace Arm of the Williston Reservoir in 1999 (Wood and Schwantje in press). Their presence was considered normal in a healthy wild sheep population (B. Foreyt, pers. comm. in Wood and Schwantje in press). Serum antibodies to common sheep respiratory viruses were not detected. Antibodies to these viruses are commonly present in many wild Bighorn Sheep populations and may be the result of exposure to domestic animals or disease outbreaks. The absence of antibodies suggests that the sheep examined have not been exposed to diseased wild or domestic sheep. This study and further Stone's Sheep health monitoring is ongoing in northern B.C.

6.2.2 Camelids

Llamas (*Lama glama*) are part of the Family Camelidae, which includes Alpacas (*L. pacos*), and camels (*Camelus* spp.). Llamas are increasingly used for access to the backcountry. Camelids, as well as ungulates other than domestic sheep, may carry diseases infectious to mountain sheep. Foreyt (1994) exposed healthy Rocky Mountain Bighorn Sheep to Llamas, domestic goats, Mountain Goats, cattle, domestic sheep and Mouflon Sheep. All were carriers of strains of *P. haemolytica*. The experimental Bighorn Sheep remained clinically healthy during and after contact with the Llamas, cattle, Mountain Goats and domestic goats, but all of the Bighorn Sheep died from acute bronchopneumonia after contact with the domestic sheep and the Mouflon Sheep.

In the spring of 1998, near Toad River, British Columbia, an otherwise healthy six-year-old ram and two emaciated rams were reported to be wheezing; they were not seen again and were believed to have died. (J.P. Elliott, pers. comm.).

British Columbia's provincial wildlife veterinarian has commented that the use of camelids in wilderness areas in Canada and the U.S. has

been a source of controversy for years. The fact that the camelids cause less damage to soils and trails, and are more easily controlled, is one advantage of using camelids instead of pack-horses in sensitive areas. Camelids may, however, potentially carry some diseases and parasites that can be transmitted to wildlife. There does not seem to be any documented evidence of this happening in the wild, but some of these diseases and parasites are impossible to detect in live animals. In many cases, there is little to no information on the organisms normally present in Thinhorn Sheep, therefore it would be difficult to ascertain whether there is a new disease or parasite that has been transmitted via the camelids. There is reason for caution, however, because control of disease is virtually impossible once introduced (H. Schwantje, pers. comm.).

Other jurisdictions vary in their flexibility regarding camelid use. For example, the U.S. National Park Service determines use of camelids on a park by park basis, depending on specific regional conditions, particularly the status of the wild species present. Schwantje and Stephen (2003) cautions that the use of camelids in Thinhorn Sheep range in B.C. is not worth the risk, because the sheep have had no exposure to domestic animals and no opportunity to develop immunity to their pathogens.

6.2.2 Internal parasites

Pneumonia outbreaks in bighorns may be associated with additional environmental stressors, such as heavy burdens of lungworms (*Protostrongylus stilesi*).

P. stilesi has been identified in Dall's Sheep in Alaska (Neiland 1977) and in the Yukon and Northwest Territories; in Stone's Sheep near Atlin (in the winter of 1994) and in winter and spring fecal samples from Stone's Sheep at Toad River (Seip 1983); and in all Stone's Sheep herds sampled in the Muskwa-Kechika area in 2000-2002 (Kutz et al. 2001; H. Schwantje, pers. comm.). The prevalence of lungworms varied from 60 to 90% in some of the herds examined.

Intensive parasite evaluations of Stone's Sheep in the Peace Arm area identified *Protostrongylus* sp., *Eimeria* sp., *Trichuris* sp., *Nematodirus* sp. and dorsal-spined protostrongylid-like larvae in 2000 (Wood and Schwantje in prep). In 1998, *Protostrongylus stilesi* and a *Parelaphostrongylus odocoilei*-like nematode were found in Dall's Sheep feces in the Mackenzie Mountains (Kutz et al. 2001). Further research is underway on the dorsal-spined protostrongylid-like larvae found in both Stone's and Dall's sheep to determine whether it affects the general health of the sheep.

Low-intensity infections of sarcocystis were found in cardiac tissue of about half of the Dall's Sheep examined in a study in Alaska (Neiland 1977). This same study of Dall's Sheep failed to find the presence of hydatid cysts, which are otherwise common in Moose and Caribou in Alaska.

6.2.3 External parasites

Other than lungworms (particularly *Protostrongylus stilesi*), both external and internal endemic parasites are considered to be of minor consequence to the health of mountain sheep in British Columbia (Blood 1963). The psoroptic scabies mite (*Psoroptes* spp.), believed to have been introduced by domestic sheep, was blamed for the decimation of Bighorn Sheep in the U.S. in the mid- to late 1800s and early 1900s (Buechner 1960; Goodson 1982). A recent die-off of bighorns from scabies was reported in Oregon and Washington (Foreyt et al. 1990). However, neither species of scabies mites (*Psoroptes equi-ovis* or *Sarcoptes ovis*) has been identified in Thinhorn Sheep or Bighorn Sheep in B.C. A Stone's Sheep in captivity in Washington State contracted psoroptic mange from captive Rocky Mountain Bighorn Sheep in 1996, the first time this had occurred in Thinhorn Sheep (Foreyt 1997). It died of bronchopneumonia caused by *Pasteurella haemolytica* and *P. multocida*.

Winter ticks (*Dermacentor albipictus*) were identified as causing moderate hair loss on Stone's Sheep on the Peace Arm (Wood and Schwantje in press). The Stone's Sheep in this area are conspecific with other ungulate tick

hosts, primarily Elk, but also Moose, on low-elevation winter range. While hair loss and breakage on the sheep's coats was easily visible, the significance is unclear, because the sheep appeared in good general health. Of the animals examined, 67% in 1999 and 18% in 2000 were considered moderately affected by the ticks. No winter ticks were found on Stone's Sheep wintering on adjacent alpine ranges in 2000. These sheep did not descend to lower-elevation ranges during spring and fall and thus did not pick up winter ticks. There is potential for reduced survival of individuals due to severe winter tick infestations, but this has not yet been documented and likely depends on winter conditions. The average body condition of the Stone's Sheep in 1999 scored 1.75 on a scale of 0 to 5, compared to 2.7 in 2000 and 2.75 for alpine-dwelling sheep in 2000 (Wood and Schwantje in press).

6.2.4 Complex of factors

Animals experiencing environmental pressures (stressors) requiring physiological compensation are said to be "stressed" (Selye 1956). The mechanisms causing stress are complex, but can be outlined simply. Exposure to stressors stimulates endocrine responses, which allow the animal to cope. However, if the stressors are chronic they can be detrimental to animal health. Under chronic stress, an animal's immune system is compromised. Immuno-compromised mountain sheep are more vulnerable to infectious diseases and parasitism, including lungworms and subsequent pneumonia-causing respiratory infections (H. Schwantje, pers. comm.).

Stressors implicated in Bighorn Sheep die-offs include: poor nutrition; trace mineral deficiencies; high animal density; interspecific competition; weather; harassment by humans or dogs (*Canis familiaris*); and high parasite levels (Schwantje 1988b; Davidson 1992). Some of these same stressors may affect Thinhorn Sheep in the future as human development increases in areas adjacent to or within their habitats. Global climate change is an additional factor that may affect Thinhorn Sheep, as global warming effects are accentuated at more northerly latitudes.

Schwantje (1988*b*) found differences between low- and high-elevation wintering bighorn herds in the East Kootenay region, which predisposed bighorns at low elevations to all-age die-offs in 1981. Factors involved included high animal density, poor nutrition, parasites and trace mineral deficiencies. Similarly, for Thinhorn Sheep, low-elevation ranges may have more potential for stress factors, including transmission of diseases and parasites, as demonstrated by the high tick loads of low-elevation sheep on the Peace Arm of the Williston Reservoir in comparison to the tick-free alpine-dwelling sheep.

An informal Thinhorn Health Investigation Network (THIN) has been established with the goals of determining the baseline microbiological fauna (parasites, bacteria and viruses) of Thinhorn Sheep and monitoring and diagnosing Thinhorn Sheep mortalities due to disease (Jenkins et al. 2001). A common methodology involves systematic fecal surveys, necropsies of healthy wild sheep and sampling from legally harvested animals. The impetus for establishment of the network is the fact that northern ecosystems may be particularly sensitive to disruptions such as global climate change, habitat loss and new pathogen introduction (Kutz et al. 2000), and the need to survey pristine sheep populations before more anthropogenic changes occur (H. Schwantje, pers. comm.). A recent report by the B.C. Ministry of Water, Land and Air Protection (2002) states that mean temperatures in the Boreal Mountains ecoprovince increased 1.7°C between 1895 and 1985, with the spring seasonal temperature rising 3.8°C over this same period. Under conditions of climate change, parasite development may begin earlier in the spring and extend later into the fall, and development rates may increase.

6.3 Forage Competition

Competition occurs when resources cannot meet the combined demands of users or when one organism interferes with another, such that resource acquisition by one or the other of them is hindered. Competition can be between species (interspecific competition) or within a species (intraspecific competition). The degree of resource competition (e.g., space and forage

competition) and whether it is among or between species varies depending on the resource and the competitors.

6.3.1 Domestic livestock

With the exception of horses owned by guide-outfitters, and a few scattered cattle herds kept on private or leased land, there is very little presence of domestic livestock on Stone's or Dall's sheep range in any jurisdiction. There is considerable concern, however, that the risk of contact between domestic sheep and Thinhorn Sheep has increased since the B.C. Ministry of Forests began authorizing the use of domestic sheep for silviculture treatments in provincial forests. The use of domestic sheep is restricted at a minimum distance of 15 km from peripheral Thinhorn Sheep summer range at the southern end of their range. However, there is presently nothing that prevents any person from transporting domestic sheep or goats into their private holdings within Thinhorn Sheep range.

Protection of Thinhorn Sheep ranges from domestic sheep is a critical issue. Since domestic goats may share some pathogens with domestic sheep they are also included in this concern. The recommendation of the Northern Wild Sheep and Goat Council is to provide a buffer of at least 4 km, while others recommend 16 km (Sweanor et al. 1996). The provincial government has vegetation management guidelines for Crown land, but, to date, has not taken any action to protect wild sheep from domestic sheep on private land. J.P. Elliott (pers. comm.) reported that there are concerns about domestic goats in areas with small land-holdings, such as the Toad River area.

Within the Mackenzie Land and Resource Management Planning area there are 14 grazing tenures, which provide approximately 1300 animal-unit months (AUMs) per year, predominately on Crown range during the summer months (Land Use Coordination Office 2000*b*). As of 1994, in the Fort Nelson Forest District there were 21 Crown land grazing tenures providing 7370 AUMs of forage or 1850 animal units per month (Land Use Coordination Office 1997*a*). Guide-outfitters' horses utilize about 80% of these

AUMs, 12 months of the year. As of 2002, the year of the latest available figures, there were 26 grazing licences and permits in the Fort Nelson District. In the Mackenzie district, there were 10 grazing licences and permits and 1 hay-cutting licence or permit. It is also important to ensure that Crown land that is made into fee simple land through BC's Extensive Agriculture program is monitored to determine what effects this might have, if any, on Stone's Sheep habitat and populations.

In British Columbia, horses are often the most common source of competition in Thinhorn Sheep habitats. At Sheep Mountain in southwest Yukon, the introduction of horses to Dall's Sheep range resulted in an over-utilization of ranges, which eventually led to a decrease in sheep populations (Hoefs and Brink 1978; Hoefs and Bayer 1983). One horse is estimated to consume as much as six sheep consume on average, and the addition of six horses for 180 days on the sheep range increased the rate of forage use from 40% by sheep alone to 58% by sheep and horses combined (>50% utilization is considered overgrazed). Similar overgrazing of winter ranges by domestic horses in Canada's Rocky Mountain national parks has contributed to population die-offs of Bighorn Sheep through lungworm-pneumonia infections (Stelfox 1971). The decline of Desert Bighorn Sheep can also be partly explained by competition with feral burros (Summer 1959 in Hoefs and Brink 1978).

Horses are obligatory grazers and will use the same wintering range forage plants as sheep. They also physically displace sheep because of their large size and tendency to move in groups (Hoefs and Bayer 1983). Effects of trampling can exceed forage removal by grazing. Big game and livestock need not occupy the same habitat simultaneously to be in competition (Smith and Julander 1953). For example, when livestock use sheep winter range in spring, summer or fall, they may reduce forage availability for sheep during the critical winter season. In the spring, sheep follow the band of green-up vegetation, feeding on the new growth of grasses and forbs. This is a critical period for the plants, because if they are repeatedly grazed at this time, production later in the year may be reduced (Mueggler

1967). Therefore, these plants may not support a second grazing by livestock if they are to support sheep the following winter and spring.

6.3.2 Native ungulates and other wildlife

Competition between Thinhorn Sheep and other wildlife species is considered minimal, mainly because there is little interspecific competition on winter ranges (Nichols and Bunnell 1999). Wild species tend to select different habitats specifically to reduce competition (Hudson et al. 1975; Nelson and Burnell 1975). The opportunity for habitat partitioning is implicit. Mountain Goat, Elk and Mule Deer (*Odocoileus hemionus*) ranges substantially overlap mountain sheep range in B.C. and competition for forage is assumed, but has rarely been quantified. Winter range availability is often cited as one of the major factors limiting ungulate populations.

Mountain Goats and Thinhorn Sheep share summer and winter ranges; however, the overlap in habitats is not extensive and it is not clear whether they directly share the same portions of these ranges (Nichols and Bunnell 1999). Both species depend on graminoids, although abundant forage on summer ranges probably means that competition is minimal at that time. Elk occur on about 25% of the province's Stone's Sheep range and these species have considerable overlap in diet (Nichols and Bunnell 1999). Different habitat preferences, however, lead to little mutual use of the critical ranges. Elk prefer timber cover, while sheep tend to select areas with escape terrain. Caribou prefer lush vegetation in summer and forests in winter. Caribou only occasionally occupy sheep habitat and, although competition has not yet been documented, interaction between them has been observed (Nichols and Bunnell 1999). Mule Deer and White-tailed Deer (*Odocoileus virginianus*) occur in Thinhorn Sheep range in low numbers and only on the low-elevation portion, so they are unlikely to compete for winter forage. Bison (*Bison bison*) and sheep have similar diets, but Bison tend to occur on shallower slopes and flats without the escape terrain that sheep prefer. Competition between Moose and Thinhorn Sheep is also minimal (Nichols and Bunnell 1999).

Hoary Marmots (*Marmota caligata*) in British Columbia and Arctic Ground Squirrels (*Spermophilus parryii*) feed on grasses and sedges in Thinhorn Sheep habitat, but both rodents hibernate during winter and thus are not considered to be significant competitors (Nichols and Bunnell 1999).

6.4 Forest Encroachment, Fire Suppression and Prescribed Burning

Thinhorn Sheep, particularly Stone's Sheep, can benefit from forage produced in early successional forest stages. Northern ecosystems in natural disturbance types (NDT) 3 and 4, particularly in the Northern Boreal Mountains ecoregion and the Northern Canadian Rocky Mountains ecoregion, historically experienced large, frequent fires, which maintained some Thinhorn Sheep habitats in early successional stages. Areas in NDT 1 and 2 have rare and infrequent stand-initiating events. NDT 5 comprises alpine tundra and subalpine parkland ecosystems.

Broadcast burning of forest and range has been used in Stone's Sheep habitat in northern British Columbia for many years. In the Muskwa-Kechika Management Area, broadcast burning began in 1948 (L. Rudledge, pers. comm.); since then, more than two million hectares have been burned by guide-outfitters to enhance grasslands for horses, as well as for Elk and, peripherally, Stone's Sheep. The size of burned areas on individual Stone's Sheep ranges has varied from a few hundred hectares to well over 100 000 ha. Burning to enhance habitat for ungulates can also affect predators by increasing the prey base and increase the mobility of wolves by removing dense forest cover and coarse woody debris.

Seip (1983) and Seip and Bunnell (1984, 1985b) compared two ranges, one burned every nine years for 80 years (and 20 to 30% reburned each spring) and one unburned for 120 years. The quality of the forage on the burned range was not nutritionally superior to the unburned range, but the quantity was greater on the burned range. Range burning may have reversed a decline in one herd by increasing the lamb production and lowering spring lungworm loads in sheep that

wintered in burned areas (Elliott 1978; Elliott 1985c; Seip and Bunnell 1985b; Nichols and Bunnell 1999). This they attributed to earlier spring forage growth in the burned area and additional winter forage. Sheep wintering on alpine ranges apparently were in poorer condition, reflected by higher lungworm counts and lower lamb crops, than those wintering in the subalpine burn.

Seip and Bunnell (1984, 1985b) maintain that the benefits of burning sheep range may be limited because burned ranges are often in subalpine areas with deep snow accumulations and thus are unavailable when most needed. Burned spring ranges increased grass production, but it was not nutritionally superior to the forage produced on natural sites and the intake rate did not differ between the sites. In summer, Stone's Sheep used high alpine ranges, so burned subalpine sites were of no consequence.

Elliott (1978, 1985c) reported that horn growth in rams was greater on burned ranges than on unburned ranges, while Seip (1983) and Seip and Bunnell (1985b) found that horn growth of yearling rams was greater on burned ranges, but total horn length was not different at age of harvest by hunting. In the Kenai Peninsula, Alaska, Dall's Sheep used burned ranges twice as much after a wildfire changed the dominant vegetation from shrubs to forbs and mosses, but slightly lowered the production of grasses and sedges (Culbertson et al. 1980 in Nichols and Bunnell 1999).

Nichols and Bunnell (1999) describe the effect of fire on vegetation composition and the benefits for Stone's Sheep: "Unaltered subalpine forests are dominated by white spruce (*Picea glauca*), black spruce (*Picea mariana*), alpine fir (*Abies lasiocarpa*), and lodgepole pine (*Pinus contorta*). Unless altered by fire or other disturbance, which encourages growth of deciduous species such as cottonwood (*Populus balsamifera*) or aspen (*Populus tremuloides*) and willows (*Salix* spp.), these forests provide much less forage than alpine communities. In southern portions of their range, similar conditions hold for the brush zone (i.e., willow and birch [*Betula*

Table 19. Three categories of responses of wild sheep to human activities in their habitats, and expected population effects (Bailey 1999).

Sheep Responses ^a	Population Effects
Tolerance, adaptation	None ^b
Endurance	Negative, including stress
Avoidance, movement	From limiting range: negative From non-limiting range: none

^a Covariables: sex, age of sheep, season, weather.

^b Human presence may displace predators and have a positive population effect.

spp.]), which provides the transition between alpine and forest. Unless opened by disturbance, these areas may be too dense to permit access to sheep or to allow significant graminoid growth.”

Burned sites have been found to experience higher rates of grazing and increased forb production compared to unburned sites (Easterly and Jenkins 1991). However, the benefits of spring burning to enhance winter forage for Bighorn Sheep are reduced on ranges that experience summer-long grazing by sympatric populations of Elk and deer (Easterly and Jenkins 1991) and this may hold true for Stone’s Sheep as well.

Fertilizer enhancement of Dall’s Sheep winter range by the U.S. Forest Service has been shown to increase biomass of preferred forage (Nichols and Bunnell 1999). The application of fertilizer at rates of 17 to 35 kg N/ha did not seem to increase production, but other studies have found increased production and nutrient content of herbage on tundra ranges at application rates of 100 kg N/ha (Seip and Bunnell 1985c).

6.5 Access and Other Forms of Human Disturbance

Mountain sheep are, by necessity, a highly vigilant species. They are constantly aware of their surroundings and are alert for potential hazards. Human activities such as wildlife viewing, being accompanied by domestic dogs, aerial censuses and use of snowmobiles, helicopters or other vehicles, can cause stress (MacArthur et al. 1982; Krausman and Hervert 1983; Stemp 1983). While the effects of occasional disturbance are likely minimal, repeated harassment

may have detrimental effects, including reduced foraging efficiency (Stockwell et al. 1991; Bleich et al. 1994). Such an effect can lead to poor health, reduced growth and reduced reproductive fitness (Geist 1979). Chronic disturbance of immuno-compromised individuals and/or populations may have been a factor in past epizootic die-offs in Bighorn Sheep, and there is no reason to not expect the same for Thinhorn Sheep. The unpredictability of an activity can make it more difficult for adaptation and some activities are negative enough that they displace sheep from their habitat. The responses of sheep to human activities and the population effects have been categorized by Bailey (1999) as outlined in Table 19.

For sheep that endure and suffer a disturbance, but do not move to avoid it, there may be measurable effects or “stress.” An avoidance response might be interpreted as either bad or good for sheep. If the animals move to a range of equal or better quality, there would likely be no negative effects, whereas if they are forced to move to an inferior range, effects may be severe. Other factors that influence these responses include the sexes and ages of the animals involved.

Specific research on the effects of stress on Thinhorn Sheep is incomplete. Paquet and Demarchi (1999) reviewed the pertinent literature regarding the effects of increased human access on Stone’s Sheep. They concluded that while Thinhorn Sheep have escaped the dramatic die-offs suffered by their southern Bighorn counterparts, they nonetheless are vulnerable to human-induced stress, including mechanical noise. The authors concluded that more research is required

to determine the net effects of human disturbance on Thinhorn Sheep.

Habituation to vehicle traffic has been observed in Dall's Sheep in Denali National Park, Alaska and Stone's Sheep near Toad River, B.C. (Dalle-Molle and Van Horn 1991). Sheep occupying ranges distant from these roads, however, must cross them during seasonal migrations and have not habituated to traffic, even though both roads have existed for more than 50 years. Thus, animals that occupy areas distant from human activities are less likely to habituate. This disturbance may potentially cause delayed or abandoned spring migrations, increased grazing pressure on winter ranges, poorer condition of the sheep and loss of migration patterns over time. Additionally, movement delays and repeated crossing attempts expose sheep to increased probability of mortality from vehicle collisions and predation, as well as increased energetic costs (Geist 1971).

Bighorn Sheep had higher mean heart rates when they were disturbed on flat terrain or when they were <200 m from a road (MacArthur et al. 1979). A study of the reaction of Dall's Sheep to wildlife viewing from the Denali National Park road found that sheep were very responsive within 400 m of the road (alert 80%, flight 38%), when they were removed from security habitat and when crossing the road (Singer and Beattie 1986). Running retreats by sheep of 0.4 to 2.0 km were observed. One group of sheep remained near the road for three hours attempting to cross it. When distant sheep sightings were included, however, sheep were the least responsive species (14% reacted, 7% fled). The percentage of extreme responses (running, excitation, alarm) was 5% for sheep compared to 18% for Caribou. Visitors leaving vehicles or people on foot appear to cause increased wildlife disturbance (MacArthur et al. 1979; Singer and Beattie 1986).

A part or all of a local population may become habituated to chronic disturbance. This is particularly a problem around small towns and major highways. Mountain sheep exposed to such influences often lose their wariness. Successive generations may change their natural habits and

sometimes become dependent on artificial sources of forage, such as golf greens, alfalfa fields and lawns. They are then susceptible to increased highway mortality, harassment by people and domestic dogs, exposure to chemical contaminants (pesticides and herbicides), and exposure to diseases carried by domestic livestock.

The issue of the effect of helicopter disturbance on mountain sheep is complex and the total effect is not yet clearly understood. Stemp (1983) measured heart rate responses of Bighorn Sheep to helicopter disturbance and hypothesized that when disturbed, either temporarily or for prolonged periods, sheep experienced higher levels of stress, which could predispose them to increased predation. Multi-year research in one study found that Bighorn Sheep did not habituate substantially to long-term helicopter disturbance by overflights (Bleich et al. 1994) and this was confirmed in Dall's Sheep by a one-year study in the Yukon (Frid 2000a). The latter study confirmed that sheep behaviour toward helicopters suggests a trade-off between energetics and predation risk. The probability of sheep fleeing was inversely related to the helicopter's angle of approach and directly related to distance from rocky slopes; the effect of the two factors is multiplicative. Thus, fleeing probability decreased at a faster rate for sheep on rocky slopes than for sheep 5 to 20 m from these slopes, and sheep >20 m from rocky slopes always fled, even if the helicopter approached very indirectly. Fixed-wing aircraft appear to cause substantially less disturbance to Dall's Sheep than helicopters (Frid 2000b). Models proposed could be used to predict minimum distances from a trajectory that would result in an acceptably low disturbance rate for helicopters (Frid 2000a) and for fixed-wing aircraft (Frid 2000b). Krausman and Hervert (1983) found that sheep moved >100 m during 19% of observations when an airplane flew directly towards sheep and circled them up to 10 times.

Spiers and Hiemer (1990) studied the mortality of radio-collared Dall's Sheep adjacent to the Fort Greely, Alaska, military base, an area frequented by military helicopters. They reported much higher than expected mortality in their

sample of eight radio-collared ewes. They state, however, that even though army pilots normally fly at least 150 m above ground, the sheep in their study area were less likely to run when approached by small helicopters, such as those used in capture operations, than are sheep in other areas. This observation appears to contradict other findings that mountain sheep tend not to habituate to helicopters. Further clouding the issue, some human harassment studies have failed to account for differential behaviour of groups that include radio-collared individuals that have been sensitized after being caught by researchers using helicopters (D. Hatler, pers. comm.).

Scotton and Pletscher (1998) maintain that disturbance of mountain sheep by researchers is often not quantified and should be minimized. They have found that maternal behaviour can vary depending on the research technique and that the use of a small (e.g., Robinson R-22) helicopter can be less disturbing to ewe-lamb pairs than a larger turbine helicopter. In their study, none of the lambs died immediately as a result of capture and handling, but two lambs were killed by a Golden Eagle (*Aquila chrysaetos*) less than four hours after capture with a Hughes 500 (turbine engine) helicopter, before their mothers returned to them.

British Columbia's draft backcountry guidelines for Thinhorn Sheep (B.C. Wildlife Branch 2001) state: "Chronic stress can also compromise the immune system in wild sheep, increasing their vulnerability to diseases." Frid (1998) suggests a preliminary setback distance of 3.5 km to reduce helicopter disturbance of Dall's Sheep in the Yukon. A five-year research program in the Churn Creek area suggests Bighorn Sheep may be as sensitive as Mountain Goats to helicopter disturbance. Bighorn Sheep have been observed to flee from helicopters that are one to two km away (J. Youds, pers. comm.). Helicopter activities associated with wildlife viewing could have an even greater effect, since there would be more of a tendency for operators to fly in for a "closer look."

6.6 Predation

6.6.1 The role of predation

Predation is a demonstrated limiting factor for Thinhorn Sheep populations and is one of the principal factors influencing their evolution. As noted by Geist (1999): "An anti-predator strategy of placing obstacles in the path of pursuing predators has profound consequences for the adaptations of American mountain sheep. This strategy ties sheep to escape terrain, thereby fixing their grazing to narrow bands around such terrain. The use of narrow grazing bands should make the annual reproductive output of mountain sheep a function of the annual fluctuations in available food supply."

Seven carnivore and one raptor species are known to prey on Thinhorn Sheep: Grizzly Bear (*Ursus arctos*), Black Bear (*U. americanus*), Grey Wolf, Coyote (*Canis latrans*), Lynx (*Lynx canadensis*), Wolverine (*Gulo gulo*) and Golden Eagle (Heimer 1982; Paquet and Demarchi 1999). It should be noted that one of the most efficient and significant predators on Bighorn Sheep, the Cougar (*Puma concolor*), is scarce to absent throughout Thinhorn Sheep range and, therefore, is not a significant predator of thinhorns. In the Peace-Liard region, however, there has been an increase in sightings of Cougars over the past few decades (J.P. Elliott, pers. comm.), probably related to a northward expansion in their distribution. The reasons are not documented, but may be a result of global climate change, which is also resulting in a northward expansion of Mule Deer.

One of the first pertinent studies of Thinhorn Sheep predation was Adolph Murie's investigation of Grey Wolf-Dall's Sheep interactions in Mount McKinley National Park, Alaska, between 1939 and 1941 (Murie 1944). He concluded that, at the time of his study, the sheep and the wolves appeared to be in equilibrium. He suggested that the wolves tended to "restrict the sheep to the rougher country," but added that "[w]olf predation probably has a salutary effect on the sheep as a species."

The effect of predation on thinhorn populations varies over space and time. Wolves, particularly, and Grizzly Bears are known to take a considerable portion of the annual production, the amount depending upon a number of variables, including the extent and quality of escape terrain, presence or absence of alternative prey species and prevailing weather conditions (Murie 1944; Heimer 1982; Geist 1999).

Mountain sheep have three basic adaptations to predation: great agility on rocks; a high degree of alertness; and keen enough vision to detect predators at sufficient distances to make escape probable.

Perhaps of greater significance than direct losses to predators are the evolutionary effects and consequences of predation. Festa-Bianchet (1991) suggests that the social systems of Bighorn Sheep have been shaped by anti-predator and foraging strategies that rely on learned traditions. Range abandonment, partitioning of sexes and forcing of ewe-lamb groups into suboptimal habitats have all been demonstrated in recent radio-telemetry studies (Huggard 1993; Wehausen 1996; Bleich et al. 1997). Bleich et al. (1997) found evidence to support the hypothesis that because of their smaller body size, their potentially greater vulnerability to predation and the need to minimize the risk to their offspring, female ungulates and their young use habitats with fewer predators and greater opportunities to evade predators than do mature males. He also found that during the growing season males are able to, and do, exploit nutritionally superior areas. They concluded that sexual segregation among sexually dimorphic ungulates likely results from differing reproductive strategies of males and females.

Males may enhance their fitness by exploiting habitats with superior forage during the growing season, while simultaneously incurring greater risk of predation. In contrast, females appear to enhance their fitness by minimizing risks to their offspring, albeit at the expense of nutritional quality. How food and risk of predation are arrayed in the environment, however, affect whether males or females inhabit better quality

ranges, as well as which sex moves to produce spatial separation.

Following the rut in late fall and early winter, the body-fat stores in rutting males are often depleted and stamina is reduced. Thus, during the post-rut period, which may last the duration of the winter, rams tend to occupy habitats that favour protection from predators over provision of nutrients (Huggard 1993; Wehausen 1995; Bleich et al. 1997).

A further complication regarding predator-prey relationships is the supply of alternate prey sources. Bergerud and Elliott (1998) studied the relationship between wolves and ungulates in the Muskwa-Kechika area. One of their findings was that as ungulate diversity and biomass increase, the ungulate-wolf interaction might become unstable. They also indicated that during a period of wolf control in their study area, recruitment of lambs increased about twofold. They attributed the decline in recruitment of sheep aged nine to 21 months to wolf numbers, not winter severity. They also concluded that where there are other species of prey in the ecosystem, especially Moose, wolf densities are higher and sheep populations will be regulated at lower densities by predation. They concluded that in simpler predator-prey systems, with fewer alternate prey, wolf densities will be lower and sheep will reach higher densities, with forage and snow interactions becoming important in regulating sheep numbers.

Scotton (1998) investigated the mortality of Dall's Sheep lambs in an essentially single prey-multiple predator system in central Alaska. He found that despite a threefold increase in the wolf population during his study, there was no increase in wolf predation on lambs. He determined that 43% of kills were by Coyotes, 22% by eagles, 4% by wolves, 9% by other large predators (e.g., Grizzly Bears) and 17% by unknown canids (i.e., either wolves or Coyotes); one lamb (representing 4% of the mortalities) died in a rock fall. J.P. Elliott (pers. comm.) also confirmed that on a few sheep ranges in north-eastern British Columbia there have been attacks on both ewes and lambs by Coyotes. Scotton (1998) states that the effects of predation on

Dall's Sheep are not well documented. His study seemed to contradict earlier research on the role of wolf predation on lambs, and highlighted the need to conduct further research on an ecosystem basis in order to better understand and manage predator-prey systems.

Heimer (1982) conducted a study of the responses of Dall's Sheep populations to wolf control in the interior of Alaska following a period of severe winters, high wolf numbers and an overharvest of Moose by hunters. After wolf control, the Dall's Sheep population stabilized and subsequently increased. In summary, Heimer (1982) stated that their calculations "clearly showed that relatively small increases or decreases in wolf predation can significantly influence sheep population dynamics." While Heimer (1982) stated wolf predation might have been largely responsible for the decline in the number of sheep, he believes it was a proximate factor in lamb mortality and that winter severity was probably a primary factor.

Barichello and Carey (1988*b*) compared the demography of two Dall's Sheep herds in the Yukon, one in an area where wolf removals had occurred and another that was isolated from wolf reductions. Ram numbers in the wolf-removal area remained lower than in the non-removal area, a factor that appeared to be linked to ram harvests by hunters. The number of sheep in nursery groups appeared to be linked to the rate of lamb production and, on an area-specific basis, to the previous year's production of lambs. Lamb production varied strongly between years and consistently between areas and appeared to be influenced by general weather patterns. Barichello and Carey (1988*b*) suggest that general differences in sheep demography between the wolf removal and non-removal areas were associated with sheep densities; areas supporting higher densities of sheep produced fewer lambs, but appeared to experience higher rates of survival. Variable densities of wolves, in time and between areas, produced no predictable response in sheep demography. Rather, demographic trends appeared largely as an expression of lamb production, resulting in cohort gaps and pulses transferred over all sex and age segments as a result of winter snow conditions.

In 1978, biologists in northeastern British Columbia began a series of operational field trials to test the effectiveness of wolf control as a means of increasing Thinhorn Sheep and Moose in the Kechika watershed, sheep, Elk, Caribou and Moose in the Muskwa Valley, and Caribou in the Horseranch and Level Mountain areas (Hancock 1987; Bergerud and Elliott 1998). Studying the effects of Wildlife Branch-sponsored wolf reductions in the Muskwa-Kechika area, Elliott and Bergerud (1998) reported a significant relationship between lamb:ewe ratios and wolf densities. In the absence of wolves, they predicted that there would be about 57 lambs:100 ewes in early winter, while a density of around 15 wolves per 1000 km² would result in about 25 lambs:100 ewes.

Hatter (1994) modeled the population status and trend of rams five years old and older using compulsory harvest, survey and kill per unit effort data. His modeling suggested that the abundance of mature rams in the Muskwa-Kechika area increased following the Wildlife Branch's wolf reduction program of the late 1970s and 1980s.

6.6.2 Predator control

The role of predator control has been debated ever since the first sheep hunters' campfire was lit. There are two schools of thought among wildlife managers, hunters and the interested public, including naturalist and animal rights groups. One is that predation, mainly wolf predation, limits Thinhorn Sheep numbers by confining sheep to only those habitats that provide protection from predation, thus reducing overall sheep numbers and hunting opportunities. The other is that predation is not a significant factor affecting sheep, has little effect on hunting opportunities and, with some exceptions, is beneficial to the species. The adherents to this belief often cite the "balance of nature" and promote an evolutionary concept of wildlife management - one of "hands-off" or "let it be".

Searching the literature or entering into discussions with long-time sheep hunters and guide-outfitters about the role of wolves does not clarify the situation, as one can find arguments on

both sides of the debate. There is an emerging wisdom, however, that wolves can be either beneficial or harmful, depending upon the local circumstances. The emerging position of most wildlife management agencies is that predator-prey systems should be naturally regulated where possible. This is partly based on science which recognizes that predation imposes selective pressures on prey, which are an important component of natural selection and long-term evolutionary adaptation, and partly on animal rights-formed public opinion.

Bowyer et al. (2000) in their review of the ecology and management of Dall's and Stone's sheep in North America state: "Currently there is no reason to attempt to manage populations of Dall's Sheep using predator control or by intervening in disease processes; predators or diseases do not regulate populations of this mountain ungulate often enough to be of consequence. Effective management, then, is restricted largely to regulating sport and subsistence harvest or providing viewing opportunities for aesthetic and other non-consumptive uses."

Seip (1983) questioned the validity of utilizing predator control to increase sheep numbers and stated: "The sheep encounter severe nutritional problems related to high densities on restricted winter ranges. Therefore, any improvement in survival rates caused by predator control would only increase the negative effects of high densities on winter ranges." Within his study area, Seip (1983) concluded that it was unlikely that the winter ranges could support any more sheep.

6.6.3 The history of predator control

The history of predator control in northern British Columbia dates to the early 20th century, when the government introduced a bounty to "rid the province of pests and noxious animals." That quote, from Hancock (1987) is part of a paper describing the history of the province's attempts to eliminate, control and, finally, to legally recognize predators as wildlife. Official wolf control was sanctioned at first by the imposition of a bounty. After several decades of debate, the bounty system was terminated in 1954,

after it proved both ineffective and subject to fraud. The bounty was replaced by extensive poisoning, with government agents using strychnine and cyanide-guns and dispensing the poisons to stock growers, trappers and guide-outfitters upon demand. Paraphrasing and quoting from the annual report of the head of the Predator Control Branch, Hancock (1987) notes that, "...in 1958 'every wild sheep range in the province' was baited with poison to protect the sheep from 'outside elements' such as predators."

The use of Compound 1080 (sodium fluoroacetate) by the province's animal control officers was widespread in the late 1950s and early 1960s. It had been chosen over strychnine and cyanide for several reasons, including canid specificity and relative safety for human use. It was distributed to the Fish and Game Branch's district offices in powder form in 45-gallon drums, mixed with water, injected into quartered horse carcasses and distributed by commercial airplanes onto all major wildlife ranges in the province (C.G. Ellis, pers. comm.). In some instances, baits were dropped in the Yukon by British Columbia government agents, while baits were also dropped in British Columbia by Yukon staff on a quid pro quo basis (C.G. Ellis, pers. comm.).

Broadcast baiting in non-agricultural areas was terminated in 1961 and the Predator Control Branch was disbanded in 1963 (Hancock 1987). The effect of the extensive broadcast poison bait program, although seemingly potentially devastating, was apparently limited and short lived. Evidence gathered in an extensive wildlife inventory of the northern third of the province in the late 1960s and early 1970s revealed "expected numbers of wolves" (K. Sumanik, pers. comm., and B.C. Wildlife Branch records).

In 1979, the use of poisons by unlicensed persons was made illegal within British Columbia. At that time, baits were injected with a solution that contained up to 500 g or more of Compound 1080 in solution. During the 1980s and 1990s, baits were restricted to capsules (up to 20 mg of 1080). Since 1998, Compound 1080 has not been used by licensed professionals employed

by the provincial government to protect livestock.

6.7 Invasive Alien Plants

Invasive alien plants are of moderate concern in Thinhorn Sheep habitats. In addition to the threat of forest encroachment, invasive alien plants are beginning to invade Thinhorn Sheep range. Noxious weeds are specifically mentioned in the Cassiar Iskut-Stikine LRMP.

The Cassiar Iskut-Stikine LRMP (section 2.3.8 – Settlement/Agriculture/Range) includes these provisions concerning noxious weeds:

- Objective 9: Reduce and, where possible, eradicate invasive weed species that pose a risk to wildlife habitat and range lands.
- Strategy 9.1: Undertake measures in the short term and long to control existing alien plants and to monitor and prevent the introduction of other alien species, as presented in the Weed Control Plan for the LRMP area.
- Strategy 9.2: Manage noxious weeds through the use of methods other than herbicides except in cases where risk of outbreak or spread is high.

Invasive alien plants are of greater concern for sheep where domestic livestock and human disturbance increase opportunities for their spread. The primary use of range in the Cassiar Iskut-Stikine LRMP area is for horse grazing for guide-outfitting, although there are also a few cattle.

The B.C. Ministry of Forests has an active program of weed control in some areas of the province. Herbicides are presently used extensively, but the use of bio-control agents is being researched and will hopefully provide lasting protection in the future.

6.8 Winter Severity

Dall's Sheep seem to be unaffected by cold or wind alone, but they do respond to the combination of these factors by seeking protected areas out of the wind (Nichols and Bunnell 1999). Although Thinhorn Sheep are tolerant of low

temperatures, severe winter conditions in the form of deep snowpack levels affect their ability to dig for forage, particularly at snow depths greater than 30 cm. This results in decreased forage acquisition and, consequently, reduced health (Nichols and Bunnell 1999). During warm, wet winters in areas affected by maritime weather conditions, heavy snowfalls can partially melt and then refreeze, producing hard crusts through which sheep are unable to dig. Over a 12-year period with several such winters in the Kenai Mountains, herds totalling 900 sheep at their peak declined 66% (Nichols and Bunnell 1999). Such population fluctuations are common in the southern Alaskan mountains, where winter weather conditions vary from mild (cold temperatures, light snowfall and strong winds that remove the snow) to severe (warm temperatures and heavy snowfalls that form a deep, hard-crusting snowpack).

Interior Dall's Sheep herds have also experienced winter-related reductions; for example, 20 to 25% in 1981-1982 and 40% in 1982-1983 in the Yukon; 67% in McKinley Park in the early 1960s; and 60% in the Brooks Ranges and the Wrangell Mountains during 1991, 1992 and 1993 (Nichols and Bunnell 1999).

A 40% decline of Stone's Sheep was reported in the Glenlyon Range of the Pelly Mountains in the Yukon after the winter of 1982-83, which was characterized by deeper than average snow conditions during all but one month (Barichello and Carey 1988a). Animals lost included the 1982 cohort and older animals during the winter, compounded by the reproductive failure of the 1983 lamb crop and poor lamb production in 1981 and 1982. Sheep in the area were widely distributed in snow-free winters and concentrated during average winter weather, suggesting that winter snow conditions may play an important role in the population dynamics in this area.

Snow depth has been inversely correlated with lambing success the following spring, suggesting that poorer nutrition affects the ewes' ability to produce viable lambs (Burlles and Hoefs 1984; Burlles et al. 1984). Winter temperature and snow have been correlated with lamb production in the Yukon. Winter temperature and snow

(total precipitation) were combined into an index of winter severity by expressing their deviation from the long-term mean value as a percentage, positive or negative. This index was significantly correlated with lamb production the following spring ($r = -0.796$) (Burles and Hoefs 1984; Burles et al. 1984). Another factor, wind, was not evaluated.

While winter severity may affect thinhorn populations, they are able to overwinter in better condition and to produce viable lambs when their nutritional requirements are being met. High population numbers, good lamb winter survival and good lamb production have been correlated with wet summers and good growing conditions the previous summer (Burl and Hoefs 1984; Nichols and Bunnell 1999).

Bowyer et al. (2000) provide a useful conceptual model showing the relationships between population density, winter severity and rate of mortality (interactions between density-dependent and density-independent effects).

Attempts are underway in the Yukon to determine the possible correlation between the Pacific Decadal Oscillation (PDO) and winter severity and, therefore, the correlation between the PDO and Thinhorn Sheep lamb recruitment (J. Carey, pers. comm.). The PDO is often described as a long-lived, El Niño-like pattern of Pacific climate variability (Mantua 2002). The PDO is characterized by seasonally changing patterns of wind, air temperature and precipitation. Each pattern also has a typical lifetime for any given "event" and this contributes to skilful climate forecasts for North America. The persistence time for PDO eras have been shown to be 20 to 30 years and the extreme phases of the PDO are classified as either warm or cool, as defined by ocean temperature anomalies in the northeastern and tropical Pacific Ocean (Mantua 2002).

7.0 SPECIAL SIGNIFICANCE

7.1 Use and Value

7.1.1 First Nations' people

First Nations' people in British Columbia utilized the meat, hides, sinews, bones and horns of mountain sheep. Sheep were easily ambushed at mineral licks (D. Wedge, pers. comm.). Thinhorn Sheep were likely hunted as long as 7000 years ago, shortly after the withdrawal of glaciers in the Pleistocene Ice Age. Drill handles, combs and knives were made from bones. Large ceremonial spoons and handles for utensils were made from the horns (Banfield 1974). The horns of adult males were fashioned into ladles and bowls, after heating them in hot water and allowing them to dry to a durability greater than clay or wood (Davidson 1992). In some cases, either the artifact or the raw horn was traded with west coast First Nations (Shackleton et al. 1999).

Although sheep are taken when convenient or when other species are scarce, Moose and Caribou, being more accessible and providing more meat, are preferred food sources for northern First Nations. Kaska-Dene people sometimes hunt sheep for a change of diet (Paquet and Demarchi 1999). First Nations' people of the southern Yukon Territory made annual hunting trips for Moose, Caribou and Dall's Sheep in southern Yukon and northern British Columbia early in this century (J. Johns [retired Guide outfitter and First Nations elder, deceased, formerly of Carcross, Yukon], D. Wedge and S. Van Bibber, pers. comm.). Heimer (1999) states that in Alaska, certain sheep populations were exploited to the point of near extirpation by early aboriginal hunting.

Currently, a number of First Nations' bands and individuals are involved in the tourism and guide-outfitting industries, where Stone's Sheep play a major role in both non-resident hunting and wildlife viewing expeditions.

7.1.2 Early European explorers, prospectors and hunters

The first written record of Stone's Sheep is probably Samuel Black's observations of 1824 (Rich and Johnson 1955). None of the early European explorers, including Daniel Harmon, Simon Fraser and Alexander Mackenzie, mention seeing Stone's Sheep on their passages through the Rocky Mountains along the Peace River (Lamb 1957, 1960, 1970). In fact, Harmon wrote a chapter called "A Concise Account of the Principal Animals Which Are Found in the North Western Part of North America" (Lamb 1957) and, while he listed many species, he made no mention of mountain sheep.

Black (1824 *in* Rich and Johnson 1955) wrote: "June the 6th. [On the upper Finlay River at Cascade Canyon, west of Fox Pass between the Sifton and Cornier Ranges.] ...In the evening the Old Slave arrived with the carcass of an animal on his back, he names Sason or little Bear but we would name a little deer when deprived of its horns as in the present case being too weighty to carry in deed they weigh some time 30 lb[.] This animal is, without its horns in every respect a small deer with rather clumsy Legs for its size, the Flesh is bad at this season being very lean but towards the fall when fat its very good[.] This Animal is the Mountain sheep & the first animal of this or any other of the larger kind he has killed since leaving Rocky Mountain Portage.

July the 31st. [On the upper Stikine, between Park Creek and Pitman River.] This morning Perreault came up with a Lamb on his Load he says he killed 2 young sheep besides but the old escaped; erected a Scaffold to dry our Meat, sent Cournoyer & Tarrangeau for the Old Slave's sheep & Le Guard & Perreault are too for the hunt – passing a high peaked mountain last evening which we shall name Sheep Mountain....

August the 26th. [On the upper Stikine, between Park Creek and Pitman River.] Early this morning, saw 3 sheep coming down the mountain to their accustomed Track, our best hunter Perreault went after them practicing all the arts to get a shot at them but without effect, they have

taken flight before us over the mountain[.] These mountain sheep look like Roes [deer] at a distance[.]... in the evening arrived at the foot of Sheep Mountain[.] I went up the 31st Ultó & here again we luckily discovered near the Top, a Flock (7-8) of mountain sheep, & Perreault again took the start & get[t]ing in a proper situation & after firing a good many shots secured two Rams of two years old. One of them rolled down, the sloping side of the mountain of its own accord & the Hunter rolled down the other before him this is a Thecannie method of Conveyance... This mutton proves excellent Beef & scarcely any peculiar taste perceptible, it carries ½ Inch thick of fat on the Rump, but an old Ram would be fat[t]er at this Season. These Animals Horns made y so, do not weigh more than 15-20 lb. But some of the old Rams much more[.] I saw on in these mountains as big as a mans Thigh above the knee & would have made a famous Bugle horn... I cannot imagine what nature intended in furnishing so small Animals with such enormous Horns, except to humour their propensity for Boxing for the Ewes...."

An influx of trappers, prospectors and miners began shortly after Black's visit. The early history of northern B.C. is one of boom and bust cycles related to mining, and these continue to today. The Cassiar gold rush from 1874 to 1876 resulted in large numbers of prospectors, miners and support workers traveling up the Stikine River en route to the Dease Lake area. At one point, the region's mining population was estimated at 5000 men. In 1897, the Klondike gold rush produced another influx of wealth seekers to the same area as they sought out an alternate route to the Yukon Territory's gold riches (Land Use Coordination Office 2000a). Moose and Caribou were most commonly sought to supply meat for the resident and transient population, but they were often locally scarce and Thinhorn Sheep became the next best alternative.

The development of land and river access played an important role in the early European exploitation of the province's Thinhorn Sheep and in the evolution of the guide-outfitting industry. Early European travel through northeastern B.C.'s Rocky Mountain passes was via the Liard and Peace rivers and through the Yellowhead Pass

near Mount Robson and the headwaters of the Fraser River. By the beginning of the 20th century there were paddle wheelers plying the upper Fraser River from Tete Jaune Cache to Prince George (then Fort George). Then came the Grand Trunk Pacific Railway, later renamed the Canadian National Railway, which brought non-resident sheep hunters to the northeast (Rutledge 1989).

In the northwest, access for visiting sheep hunters was via steamer to Haines, Alaska, and then by the White Pass and Yukon Railway to Whitehorse. This was followed by the construction of the Alaska Highway (Highway 97) in the early 1940s. Prior to the completion of the Stewart-Cassiar Highway (Highway 37) in 1972, road access to the Stikine watershed was limited to a tote road off the Alaska Highway into the asbestos deposit on McDame Mountain. This deposit was developed into an open pit mine, the Cassiar Asbestos Mine, with the attendant town of Cassiar, which existed from 1953 until the early 1990s, following the mine's closure in 1989.

Paquet and Demarchi (1999) briefly describe the history of the Stone's Sheep range in the northeast Rockies as follows: "Prospectors and trappers came to the region looking for wealth. Mountaineers and tourists followed the miners and explorers; they came to experience the grandeur and remoteness of B.C.'s Northern Rockies. Wildlife was more abundant than most of these people imagined. By the end of the [early gold] exploration and fur trade era, people from all over the world came to hear about the outstanding big game range in northern British Columbia. By the 1920s, the entire Cassiar-Liard region, from Telegraph Creek on the Stikine to the eastern foothills of the Rockies near Fort St. John, Dawson Creek, and Fort Nelson was seeing trophy hunters. Stone's Sheep were a major draw for these non-resident hunters. Because of the terrain and remoteness, it was imperative that guides be used. Trappers and ranchers knew the region and its trails and passes, and many became the earliest guide outfitters."

Today, guide-outfitting remains an important economic activity, as well as a major land use,

throughout all of the Thinhorn Sheep range in the province. Rutledge (1989) offers a detailed and colourful presentation of the history of guide-outfitting in this and other regions in the province; in it he writes: "Ross Peck (pers. comm. licensed guide outfitter) said that before the Alaska Highway (Highway 97) was constructed in the early 1940s, the only way into Stone's Sheep country was by 30-day horseback trips. The Alaska Highway made sheep range that much closer and ran right through it northwest of Fort Nelson in the Tetsa, Racing, and Toad rivers and Muncho Lake areas. With improved transportation technology, all Stone's Sheep populations are now accessible to some degree either by road, ATV, float plane, inflatable raft or riverboat."

Demarchi (1999) reviewed the historical literature on Thinhorn Sheep over a 130-year period. Her findings supported the view that, except for a few localized reductions, there is no evidence that Dall's Sheep numbers have deviated significantly since 1870 from their current estimated population of 500. Demarchi (1999) states: "Access into Dall's Sheep habitat was limited until well into the 20th century. The isolated location of the Tatshenshini Basin was adequate protection from human impact until prospecting claims arose in the area shortly after the turn of the [20th] century and continued for many years. As prospectors moved into the area, unregulated Dall's Sheep harvesting for food took place, and likely became a negative effect. As mineral exploration was furthered in the 1970s and 1980s, the destruction of Dall's Sheep habitat began to occur. Furthermore, the Haines Highway into Alaska was constructed directly through B.C.'s Dall's Sheep range, increasing access including mountain roads for hunting. The establishment of the Tatshenshini-Elsek Protected Area in 1993 provides security for Dall's Sheep west of the Haines Highway which represents about two thirds of their B.C. range."

In referring to Stone's Sheep, Demarchi (1999) states: "Although there was some hunting by First Nations peoples, commercial and sustenance hunting by prospectors and miners, who were attracted by the Klondike Gold Rush and smaller gold discoveries in northern B.C., was

likely the first negative effect on Stone's Sheep populations. This hunting, however caused only localized depletions, and was unlikely a serious impact on the entire population. The Annual Game Warden and Game Commission reports from 1905 to the 1940's note "good" to "plentiful" numbers with few exceptions, implying a stable population overall."

7.2 Public Interest

North American's oldest and largest big game trophy record keeping organization, the Boone and Crockett Club, recognizes both Stone's and Dall's sheep in British Columbia, using Tagish Lake, rather than Bennett Lake, as the demarcation line between the subspecies. The Trophy Wildlife Records Club of B.C. maintains separate records for both species and all four subspecies of mountain sheep in the province (Trophy Records Club of B.C. 1988).

Society places a high value on all races of mountain sheep, including Thinhorn Sheep, as exemplified by the use of the species image in a great variety of forms. Sheep and their natural habitats are extensively used in artworks, and the male sheep, with its large curved horns, has wide appeal and is extensively utilized in product marketing.

There is considerable interest in Thinhorn Sheep among hunting and wildlife conservation organizations, such as rod and gun clubs and fish and game associations, some of which have been in existence for more than 100 years in B.C. Numerous non-government organizations have been developed to conserve big game species in general and mountain sheep specifically. A number of national and international organizations, such as the Boone and Crockett Club, Safari Club International, Shikar-Safari-Club, the Wildlife Management Institute and the Foundation for North America Big Game, are concerned with the conservation of all hunted wildlife, including wild sheep, while the Foundation for North American Wild Sheep (FNAWS) and the Wild Sheep Society of B.C. focus almost entirely on mountain sheep and their habitats. These organizations contribute substantial funds and volunteer labour for research and

management programs (Stelfox 1992). Other provincial conservation organizations with a varying degree of interest in conservation of Thinhorn Sheep include the B.C. Wildlife Federation, the Guide and Outfitters Association of B.C., the Federation of B.C. Naturalists, the British Columbia Conservation Foundation, the B.C. Environmental Network, the Grasslands Conservation Council of B.C. and the Canadian Parks and Wilderness Society.

In addition to the outdoor experience, each year hunters kill and take home rams, mainly as trophies to display on the walls of their homes. The meat is also used, although it is usually of secondary value, as many sheep hunters look askance at those who would pursue sheep merely for the meat rather than for the trophy. Mountain sheep were valued by resident hunters at \$83.20 per day of hunting in 1995 and were rated the highest of all seven provincial ungulate species surveyed and second only to Grizzly Bear in hunters' "willingness-to-pay" (Reid 1997a, 1997b). Non-resident hunters pay considerably more, with an average Thinhorn Sheep hunter paying upwards of \$2000 per day for a 10-day trip.

Sheep capes (head to shoulder portion of the hide) are valued by sheep hunters whose original capes are lost or destroyed, while horns have both aesthetic value and value for art and crafts, including those created by First Nations' artisans. Undersized and other illegal sheep horns and capes are annually auctioned in British Columbia for these purposes.

In Alberta, British Columbia and several U.S. states, special hunting opportunities (e.g., "Governor's Permits") are both auctioned to the highest bidder and raffled as part of a government program to raise funds for wild sheep research and management. The first such auction and raffle for a sheep hunt in British Columbia took place in 2000. In the 20-year history of auctioning special wild sheep conservation permits, FNAWS has raised more than \$11 million for wild sheep enhancement projects. The B.C. Habitat Conservation Trust Fund (HCTF) annually supports fish and wildlife conservation projects throughout the province. Funded almost

exclusively from surcharges on resident and non-resident fishing, hunting and trapping licences, the HCTF has supported some major thinhorn research and enhancement projects since its inception in 1981.

8.0 HARVEST MANAGEMENT

8.1 Management History

Traditionally, since the inception of laws regulating the harvest of wildlife in North America beginning around the late 1800s and early 1900s, hunting of mountain sheep has been restricted to the harvest of males only. Because of the impressiveness of the horns and the difficulties of hunting in sheep habitat, sheep hunting was considered a challenge and recreational hunting quickly evolved into hunting for large “trophy” males.

At the turn of the 19th century, hunting mountain sheep, particularly mature rams, was a popular recreational pursuit. As a result of extensive and uncontrolled hunting by visiting European and American hunters, British Columbia’s first closed seasons were instituted by Order of the Executive Council in 1906. Subsequent open seasons allowed hunting of males only.

Robinson (1987) provides a comprehensive review of the 200-year history of wildlife conservation law in the province, starting from the early fur trading and exploration era in the late 18th century. The following is a brief summary of hunting regulations for mountain sheep (Demarchi 1978; Robinson 1987; Hatter 1994 and annual B.C. Wildlife Branch Hunting Regulations synopses):

- 1859: First wildlife protection laws passed, but did not include mountain sheep.
- 1890: \$50 licence fee and a bag limit of eight sheep for non-residents.
- 1905: Bag limits of three rams for non-residents and five for residents.
- 1906: Regulated mountain sheep open and closed seasons.
- 1909: Specific area hunting closures established.

- 1913: First resident hunting licence requirement.
- 1964: Sheep tag-licence introduced.
- 1969: Three-quarter-curl ram regulation.
- 1973: Seven-eighths-curl ram regulation.
- 1974: Seven-eighths-curl or eight-year-old ram regulation.
- 1975: Compulsory inspection of harvested rams for all mountain sheep, including Stone’s and Dall’s sheep.
- 1976: New full-curl ram regulation replaced seven-eighths-curl regulation. Full curl was defined as a ram of eight years determined by horn annuli or whose horn tip extended upwards beyond a straight line drawn between the centre of the nostril and the lowest hindmost portion of the base of the horn.
- 1977: Initiation of non-resident harvest quotas for Thinhorn Sheep, allocated by guide-outfitter territory.
- 1977: Limited entry hunts (LEH) in selected areas.
- 1982: Definition for full curl changed to “any male Thinhorn Sheep of eight years of age or whose horn tip extends upwards beyond the forehead-nose bridge” (Hatter 1994).
- 1993: Bag limit in Peace-Liard and Omineca regions reduced from one per year to one in three years (Hatter 1994).
- 1996: Bag limit in Peace-Liard and Omineca regions (one sheep every three years) is changed to allow hunters to harvest a second sheep within the 3 year period provided the first sheep taken is eight years old or older.
- 2004: Bag limit in Peace-Liard and Omineca is changed back to one sheep in three years. A hunter who harvests a Thinhorn Sheep cannot hunt or kill another Thinhorn Sheep until the calendar year of the kill and two subsequent years have expired.

Thinhorn Sheep subpopulations that are adjacent to the Yukon are managed with a variety of systems, including general open season, limited entry season and closed seasons. All Thinhorn Sheep in the Yukon are managed under a full-curl regulation (horn tip must extend beyond the imaginary eye-nostril line), which is less

Table 20. Respective hunting management regimes (2001-2002) and degree of interchange between British Columbia and Yukon Thinhorn Sheep populations (Ministry of Water, Land and Air Protection 2001; Yukon Ministry of Renewable Resources 2001).

Location and Management Unit	Connection with Yukon	B.C. Hunting Management ^a	Yukon Hunting Management
Tatshenshini 6-29	Weak	LEH	NOS ^a
East of Haines Hwy 6-28	Strong (mainly summer in B.C.)	LEH	GOS ^a (residents only)
Bennett-Atlin Lake 6-27	Weak	LEH	NOS
Atlin-Teslin Lake 6-25 West	Weak	LEH	NOS
East of Teslin Lake 6-25 East	Moderate	GOS	GOS
Rancheria 6-24	Weak	GOS	GOS
6-23	Weak	GOS	GOS

^a LEH = limited entry hunt; GOS = general open season; NOS = no open season.

restrictive than British Columbia's thinhorn regulation (horn tip must extend beyond the forehead-nose bridge). Table 20 gives details about the management of these subpopulations by both British Columbia and the Yukon.

8.2 Response to Hunting

The systematic removal of older rams has been hypothesized to affect the social and biological performance of populations in a number of negative ways, including reduced productivity (Geist 1971, 1975; Morgan 1974). Rutting by young, growing males is hypothesized to cause them stress, which increases vulnerability to mortality. Less time is spent feeding and resting and more time is spent sparring, running and rutting, diverting energy from somatic growth and fat deposition prior to the onset of winter. Festa-Bianchet (1989) argued that whether or not young rams participate in breeding, they nonetheless become involved in rutting activities and expend considerable energy. He hypothesized that the differential higher mortality rate of young males may be independent of hunting removals of older rams, and is likely common to most sheep populations due to the greater forage requirements of immature males and their greater vulnerability to disease.

Hoefs and Barichello (1984) found that, over a decade, the annual removal of up to 80% of the mature rams in a hunted herd resulted in no lowered life expectancy when compared to an unhunted herd. Conversely, Heimer and Watson (1982, 1986a, 1990) identified a number of potential undesirable population and behavioural consequences from large-scale removal of mature rams from a study population of Thinhorn Sheep. They provided data supporting the hypothesis that excessive removal of mature rams adversely affects the survival of younger rams.

The adult ram:ewe ratio in the hunted portion of Gates of the Arctic National Park was 59:100, and other hunted populations had ram:ewe ratios of 87:100 and 54:100 in the Brooks Range, 33:100 over 23 years at Surprise Mountain in the Kenai Mountains, and 69:100 in nearby Crescent Mountain (near the Copper Landing herd) (Nichols and Bunnell 1999). A survey of 2036 Stone's Sheep in areas open to hunting in British Columbia found a ram:ewe ratio of 35:100 over two years (Nichols and Bunnell 1999).

Selecting for a rutting strategy, rather than allowing it to occur by default, has been found to be more reliable for achieving management goals. Heimer (1990) explained three rutting strategies: alpha ram; normal; and immature

ram. Each of these is suitable for different circumstances. The alpha ram strategy avoids the harvesting of alpha rams and is impractical except in aggressive attempts to increase ram horn size or for non-consumptive management goals. The normal strategy, which is to manage for class IV rams, is the most cost-effective for maximizing ram harvests. The immature ram strategy is the removal of all mature rams and should be used only for reducing populations.

Heimer (1992) proposed that, in spite of the fact that Dall's Sheep often exist at constant population sizes over extended periods, it may not be appropriate to manage them as though they are at carrying capacity. He suggests that cropping Dall's Sheep in northern climates with abundant predators may be additive and not compensatory.

Singer and Nichols (1992) reported on the results of a study of heavily hunted and unhunted Dall's Sheep populations over a 15-year period in Alaska. No statistical evidence was obtained that removal of all or nearly all rams equal to or greater than three-quarter curl (i.e., approximately five years old and older) for the first 11 years and seven-eighths curl (i.e., approximately six years old and older) for the last four years of their study influenced productivity, recruitment or survival. Behavioural changes were observed in the heavily hunted population; however, including aggressive courtship behaviour and increased use of ewe-lamb winter ranges by young rams, suggesting that overexploitation of mature rams could have long-term negative consequences. The authors recommended further research. Since their study, however, Alaska has adopted more conservative horn curl regulations and it is unlikely that such conditions will reoccur to provide another study population with a depleted mature ram component. Indeed, all Thinhorn Sheep are now managed conservatively, and overexploiting all age-classes of mature Thinhorn Sheep males is not known to occur in any jurisdiction.

Heimer and Watson (1986a) examined the effects of heavy Dall's Sheep ram harvests under a three-quarter-curl regulation in Alaska based on theoretical, experimental and empirical approaches. They concluded that, not only was the

health of individual rams and the population improved, but also it was possible to harvest more rams by taking them after they had fully matured as class IV rams than by harvesting them at a younger age. Their findings contributed to the replacement of the three-quarter-curl regulation with a full-curl regulation for Dall's Sheep throughout Alaska.

Based on 25 years of intensive research and monitoring of the Dall's Sheep population in the eastern Alaska Range, Heimer (1998) concluded: "The biology of Dall's Sheep and common management practices coupled with recorded and anecdotal histories of ewe harvests strongly suggest the harvest of ewes should not be considered biologically sustainable under normal conditions in Alaska." Heimer (1998) maintains that any experimental design required to test such a hypothesis would, for all practical purposes, be impossible to establish. His conclusions were similar to those reached by the British Columbia Wildlife Branch, that under fully natural conditions only Thinhorn Sheep rams are surplus to the biological needs of the population and, therefore, only rams should be harvested. M. Festa-Bianchet (pers. comm.) warned that removal of Bighorn ewes for transplanting purposes must be based on accurate, up-to-date inventory information, because of the additive effects of mortality caused by predation and severe winter weather. This advice would apply to Thinhorn Sheep as well.

8.3 Thinhorn Sheep Management Guidelines

In British Columbia, the principles and conditions for managing Thinhorn Sheep are set out in the Provincial Wildlife Harvest Strategy (Halladay and Demarchi 1996). The following guidelines are set out under the Bighorn Mountain Sheep Harvest Management Standards.

8.3.1 Provincial management principles and goals

In general, Thinhorn Sheep are managed to optimize population sustainability within ecosystems, while allowing for options and opportunities associated with viewing and hunting. Hunting has been restricted for the past 20

years, primarily to the harvest of full curl or eight-year-old rams. Because Dall's Sheep are a blue-listed species in British Columbia they are managed more conservatively than the yellow-listed Stone's Sheep.

8.3.2 Hunting policies

The B.C. Wildlife Harvest Strategy (Halladay and Demarchi 1996) states: "Where Thinhorn Sheep hunting seasons are compatible with population objectives, the level of harvest will be adjusted to meet hunter demand within the constraints of conservation and allowance for non-hunting uses of Thinhorn Sheep. Wherever possible, sheep hunting regulations will be kept simple, uniform within ecosystem units, and consistent over time. Ewe and lamb hunting will not normally be allowed because most Thinhorn Sheep populations appear to be below habitat carrying capacity. Regulation will require that hunters remove the edible portions of the carcass to a place of consumption and submit specified parts for compulsory inspection."

8.3.3 Regulating harvest

"Where hunting seasons are prescribed, Thinhorn Sheep will normally be harvested under a general open season 'full curl' regulation (i.e., any male thinhorn mountain sheep which has attained the age of eight years, or whose horn tip extends upwards beyond the forehead-nose bridge). Thinhorn Sheep may also be managed under LEH regulations in some provincial parks and highly accessible areas. Quotas and/or administrative guidelines will be employed to regulate the guided non-resident harvest. The general open season for rams will normally start on August 1 and close by October 15." (Halladay and Demarchi 1996).

Harvest monitoring: "Compulsory inspection of all harvested mountain sheep will continue. The Annual Hunter Sample and Guide-Outfitter returns will also continue so that data from successful and unsuccessful sheep hunters can be consolidated. Annual estimates by Management Unit (MU) of the number of hunters, number of days spent hunting, and number of sheep harvested will continue to be used to monitor trends

in hunter demand and the harvest." (Halladay and Demarchi 1996).

Population monitoring: "Wherever possible, absolute abundance and sex/age composition will be monitored within established provincial Bighorn Sheep survey units (discrete mountain blocks) every three to five years. Selection of survey units will be based upon their representativeness within provincial Ecoregions and logistic considerations. Where feasible, and where required to verify sightability, a sample of mountain sheep will be marked and mark-recapture methods used to estimate total numbers. Additional site-specific surveys will be conducted where required. Population modeling will be used to monitor population trends at the ecosystem level, and may utilize indices of habitat condition as reflected by growth performance from horn increments and recruitment (e.g., lamb-ewe counts)." (Halladay and Demarchi 1996).

Provincial hunting regulations: Hunting regulations under the *Wildlife Act* set out the periods and conditions under which Thinhorn Sheep may be hunted and exported from the province. The main provisions are as follows:

- While special limited entry hunting seasons are applied in the Spatsizi, Mount Edziza, Atlin and Tatshenshini areas, all other Thinhorn Sheep hunting seasons in the province are under a general open season. A full horn curl or eight-year-old age regulation is in effect for all Thinhorn Sheep ram hunting seasons in the province.
- Thinhorn Sheep are not listed in the Convention on International Trade in Endangered Species (CITES), but an export permit must be issued if export takes place more than 30 days after the date of the kill. If exported less than 30 days after the date of the kill, either the species licence or the compulsory inspection data sheet may serve as an export permit.

Thinhorn Sheep are included in the list of compulsorily inspected species and must be submitted to a Compulsory Inspection Centre

Table 21. Ten-year average number of Thinhorn Sheep hunters, hunter days and harvest between 1992 and 2001 (B.C. Wildlife Branch records).

Game Management Zone	Management Units	Resident Hunters (RH)		Non-resident Hunters (NRH)		No. of Rams Harvested		Percent of Rams ≥ 8 years old in Harvest	TOTAL RH & NRH
		No.	Days	No.	Days	RH	NRH		
Tatshenshini-Alsek	6-28 to 6-29	33	301	5	30	5	2	88%	7
Atlin	6-25 to 6-27	69	523	33	214	11	22	72%	33
Stikine	6-19 to 6-24	160	1118	54	351	24	43	75%	67
Upper Finlay	7-37, 7-39 to 7-41	30	220	18	139	3	9	76%	12
Liard	7-51 to 7-54	356	2502	102	716	73	76	74%	149
Northeast Rockies	7-36, 7-42 to 7-43, 7-50, 7-57 to 7-58	325	2467	69	494	59	51	76%	109
Total		973	7131	280	1945	175	203	77%	378

- for the purpose of taking measurements within 30 days of the kill.
-
- British Columbia is part of a North American system of recording wild sheep identification and hence all mountain sheep horns that are taken in the province must have a numbered metal plug inserted in one of the horns by a compulsory inspector.

8.4 Analysis of Current Harvest

In the context of a sustainably managed wildlife population, the basic question for Thinhorn Sheep harvest management boils down to, “Is the harvest sustainable?” One proposed definition of sustainable harvest for Thinhorn Sheep is to maintain a ram harvest age structure of at least 75% animals greater than eight years old (I.W. Hatter, pers. comm.). This recognizes that sheep populations are dynamic and that a constant annual harvest is neither possible nor desirable. It also recognizes that ewes should not be harvested and that hunting should focus on a small segment of the mature ram population (Geist 1999). Under this type of management regime, much of the harvest analysis need only focus on monitoring ram age structure, with actions (e.g., imposing access restrictions, reducing season length, adjusting bag limits) taken as needed to ensure that three-quarters of the

mature ram harvest is at or above eight years of age.

8.4.1 Monitoring the harvest

Harvest monitoring allows managers to evaluate performance over five, 10 or more years. Information is collected from hunters each year and summarized by the Fish and Wildlife Recreation and Allocation Branch, MWLAP, (previously a Wildlife Branch function) in Victoria (Table 21).

While some have questioned the usefulness of harvest data to determine population trends (Carey and Dehn 1998), monitoring the harvest is extremely important and should not be abandoned. Harvest data, when combined with periodic survey data and/or cautious use of CPUE (catch or kill per unit of hunting effort), provides a powerful platform to reconstruct populations and assess population trends using statistical catch-at-age models (see Section 6.4.5).

8.4.2 Trends in the harvest

This review examined the following variables: resident and non-resident hunter numbers; hunter days; number of rams harvested; hunting season lengths; and sex and age restrictions. Compulsory inspection data for harvested rams were available for 1976 to 2003. Hunter effort data, however, were available only for 1981 to

2000. Although the methods for determining resident and non-resident hunter effort differ slightly, comparisons are nonetheless useful. Non-residents are guided and their trips are recorded as ending on the day a sheep was harvested, while resident hunters are not guided and normally record the entire length of their hunt, regardless of when a sheep may have been harvested.

Stone's Sheep harvest: The total annual Stone's Sheep harvest by residents and non-residents between 1976 and 2003 fluctuated and exhibited a slight decline from the beginning to the end of the period (Figure 3). The harvest increased from 1976 to 1989, except for a decline from 1982 to 1984, and then decreased from 1989 to 2003.

The resident sheep harvest increased from 1976 to 1981, declined between 1981 and 1984, increased from 1985 to 1993, when it reached its peak, and then declined from 1994 to 2003. The

non-resident harvest of Stone's Sheep declined from 1976 to 1983, increased from 1983 to a peak in 1989, then decreased to 2003.

Dall's Sheep harvest: The annual Dall's Sheep harvest fluctuated relatively widely, but consisted of small numbers ranging from a high of 14 in 1980 to a low of zero in 2000 and averaging approximately eight rams per year (Figure 4).

8.4.3 Hunters and hunter effort

Number of hunters: The number of resident Stone's Sheep hunters shows an increasing trend from 1984 to 1988 then a stabilizing trend with an upturn in 1998, followed by a steady decline to 2003, the most recent year of record. (Figure 5). The number of resident Dall's Sheep hunters shows an increasing trend from 1981 to 2003 (Figure 6). The number of non-resident hunters was remarkably stable over this same period for both subspecies.

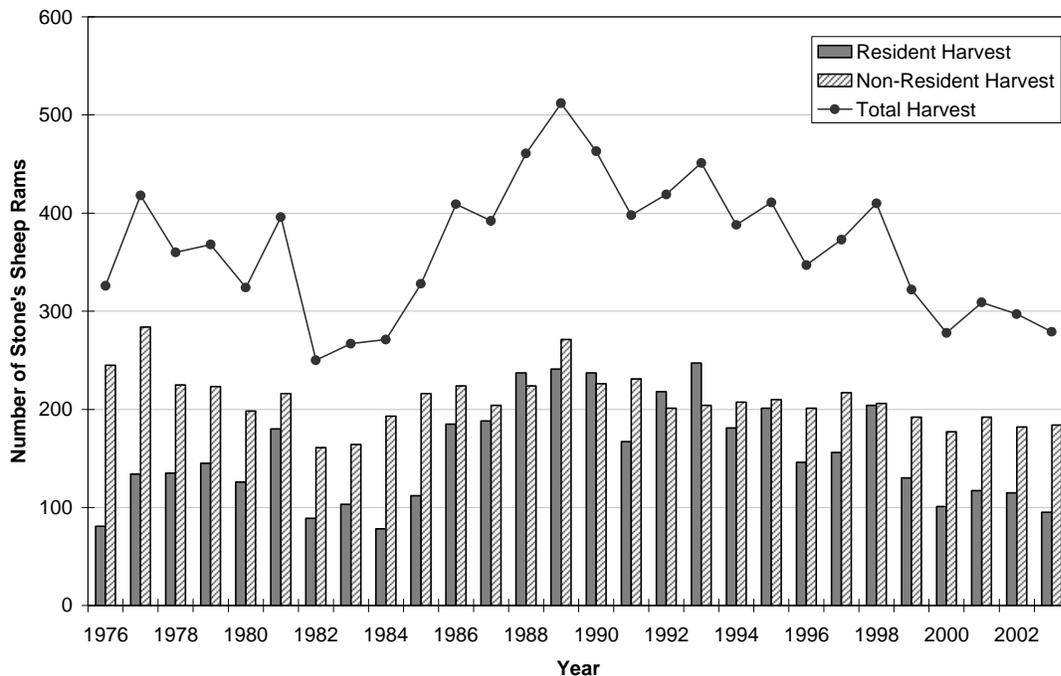


Figure 3. Resident and non-resident harvest of Stone's Sheep rams in British Columbia, 1976-2003 (unpubl. data).

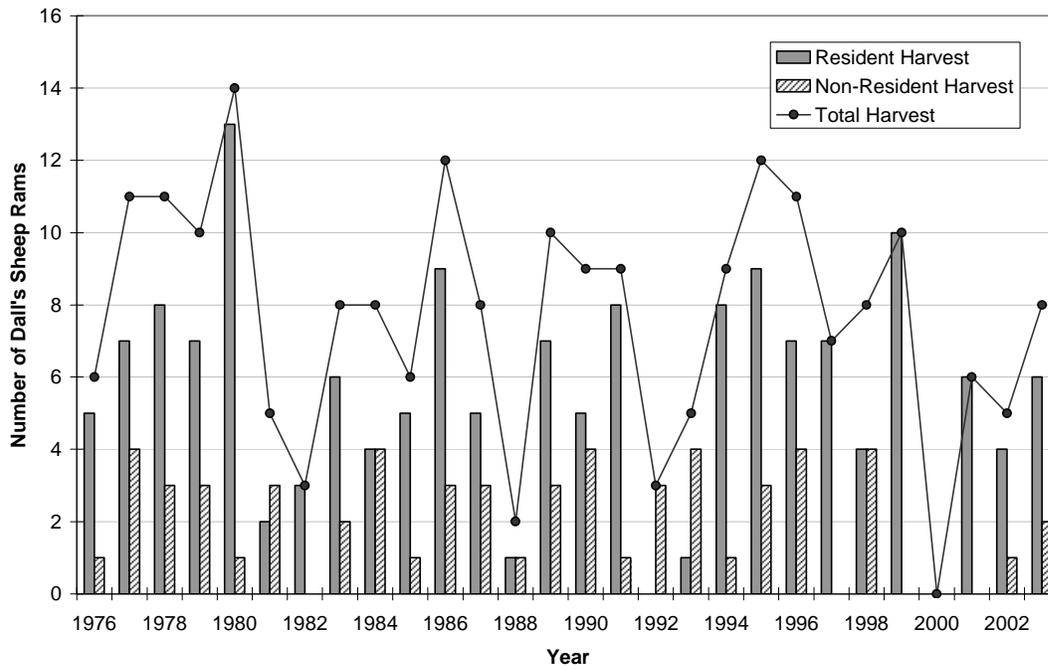


Figure 4. Resident and non-resident harvest of Dall's Sheep rams in British Columbia, 1976-2003 (unpubl. data).

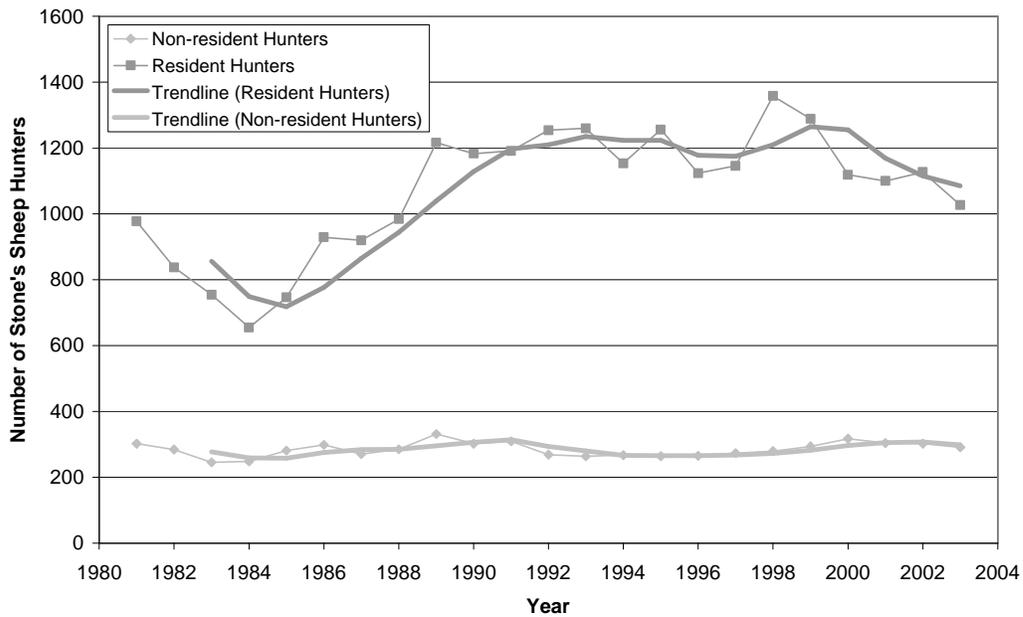


Figure 5. Resident and non-resident Stone's Sheep hunters in British Columbia, 1981 to 2003 (unpubl. data).

Hunter success: The most common statistics used to assess population trends are hunter success (also called catch or kill per unit effort) and harvest age structure. Of the two, catch per unit effort is probably the most reliable. CPUE is commonly measured as the number of rams harvested per hunter day. Some managers attempt to use CPUE as an index to monitor the abundance of harvestable rams, although other variables such as weather and hunter effort are also important. Typically, it is assumed that there is a straight-line relationship between CPUE and abundance and that the regression slope (log-normal scale) indicates the observed exponential rate of change (Caughley 1977). However, other relationships are possible (Hilborn and Walters 1992). Hyperstability is probably the most serious concern with ungulate CPUE. This occurs when CPUE fails to decline (or only slightly declines) until the harvested component has severely declined (Hatter 2001). Two reasons why this may occur with mountain sheep are that hunters concentrate within those areas where rams are most abundant and that rams remain vulnerable as their abundance declines.

Managers should be aware that a statistically significant decline in CPUE may, in fact, represent a much greater level of decline than that indicated by the regression slope.

There has been a marked decline in $\log(\text{CPUE})$ for Stone's Sheep, particularly for resident hunters, but also for non-residents (Figure 7). There was an average 5.5% decline in resident hunter CPUE from 1988 to 2003 ($R^2 = 0.82$, $p < 0.001$), and a 4.8 % decline for non-resident hunters from 1994 to 2003 ($R^2 = 0.59$, $p < 0.01$). Although there is much more variability in CPUE for the Dall's Sheep harvest, a similar trend was noted (Figure 8).

Both resident hunter numbers and resident hunter effort, measured as hunter days, approximately doubled during the 20-year period from 1981 to 2003, while CPUE, measured as rams per hunter day, was reduced by approximately half. An examination of the data based on GMZs indicates that this trend has been universal. The number of days hunted per resident

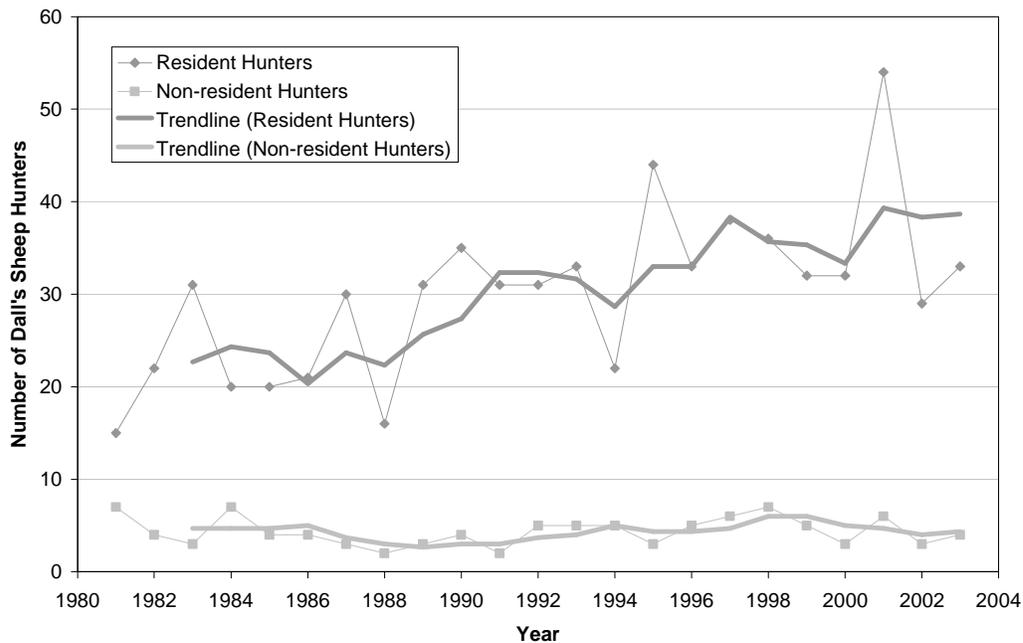


Figure 6. Resident and non-resident Dall's Sheep hunters in British Columbia, 1981 to 2003 (unpubl. data).

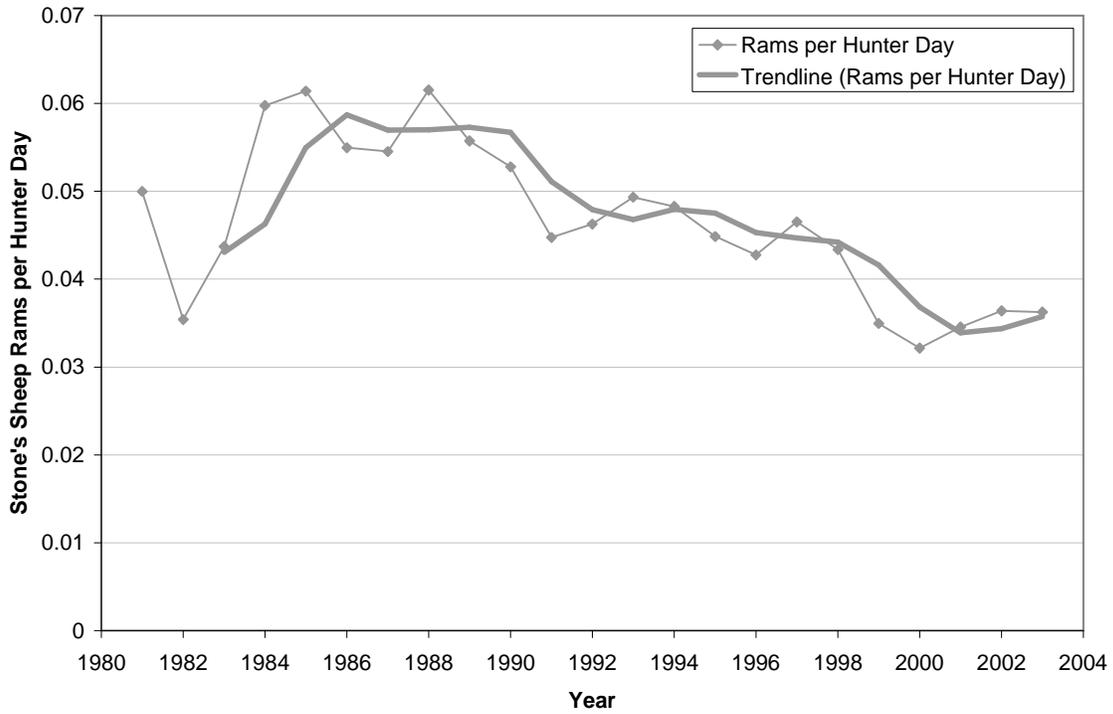


Figure 7. Stone's Sheep rams per hunter day (resident and non-resident) in British Columbia, 1981-2003 (Fish and Wildlife Recreation and Allocation Branch Data).

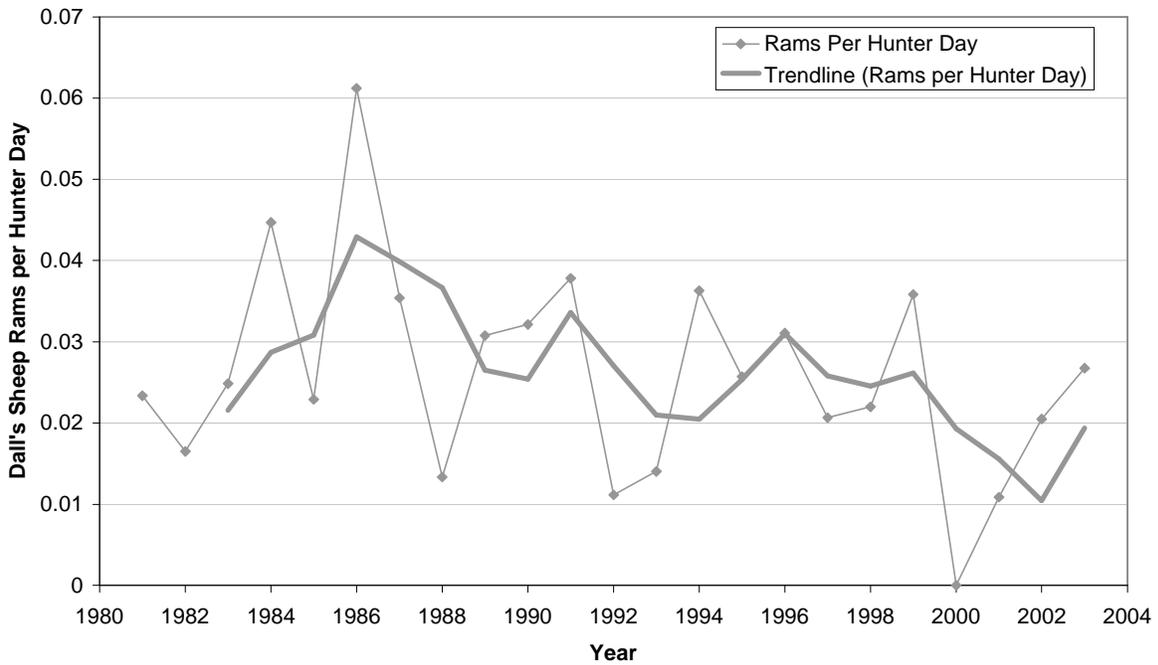


Figure 8. Dall's Sheep rams per hunter day (resident and non-resident) in British Columbia, 1981-2003 (Fish and Wildlife Recreation and Allocation Branch Data).

hunter has remained remarkably consistent throughout the 20-year period, while the number of days per non-resident hunter increased by one full day near the end of the period. Possible explanations for declining CPUE include: 1) increasing number of hunters; 2) declining ram recruitment; and 3) a combination of the two. Of the several variables examined, the near doubling of the number of resident hunters appears to be the most important factor causing the decline in hunter success rates overall. Hunting season lengths and horn curl restrictions remained virtually unchanged during the period. The introduction of a limit of one ram per hunter per three-year period in the Omineca-Peace Wildlife Region was intended to reduce effort and increase CPUE, but it does not appear to have done that or to have stopped the decline (D. Heard, pers. comm.).

There is one exception to the increasing trend in hunter numbers and effort. In the Cypress-Prophet area (MUs 7-42 and 7-57), hunter numbers have been relatively stable since 1990, while the harvest of mature rams has declined. The decline in CPUE for resident hunters from 1993 to 2001 in MUs 742 and 757 is similar ($\lambda = 0.89$) to the survey results for mature rams ($\lambda = 0.92$) and adult ewes ($\lambda = 0.93$). Thus, for this area at least, CPUE appears to correlate with population trend (I.W. Hatter, pers. comm.).

8.4.4 Population model

The Provincial Wildlife Harvest Strategy recommends that population models of game species be developed from periodic inventory (surveys) and annual harvest data (Halladay and Demarchi 1996). This type of analysis is ideally performed every three to five years and can then be compared with CPUE trends determined from harvest analysis. One modeling approach for Thinhorn Sheep used CAGEAN (Catch at AGE Analysis) to assess population status and trend of the five-year-old and older ram component in the Peace-Liard Subregion from 1978 to 1993 (Hatter 1994). The CAGEAN modeling suggested that legal ram numbers decreased from 1978 to 1982, increased from 1982 to 1988 (during the period of government sanctioned wolf

reductions in the Muskwa and Kechika planning units), and then decreased following the termination of wolf control. Population trends from 1991 to 1993 were much less certain (Hatter 1994). A decline was recorded for rams eight years old and older from 76% in 1988 to 50% in 1993 for resident hunters. It was hypothesized, but not tested, that this may have been an influence of the strong cohorts produced during the wolf control period, rather than reflecting a population decline (Hatter 1994). Population modelling using a more advanced statistical catch-at-age model such as Coleraine (Hilborn et al. 2001) should be used to update the previous work.

9.0 CONSERVATION AND MANAGEMENT MEASURES

Conservation and management measures for Thinhorn Sheep must include a variety of land use processes and management techniques in order to adequately address population and habitat issues (Hurley 2000). Managers should identify steps to be taken to protect the species. These would include:

- land use designations under FRPA including UWR and WHF (wildlife habitat features) and the *Land Act*, habitat acquisition, strategic (higher level) land use planning processes (protected areas, wildlife management areas, buffer zones, wildlife corridors, Land and Resource Use Management Plans, Sustainable Resource Management Plans, property covenants);
- disease prevention;
- operational land use planning, prescriptions for forestry, grazing, agriculture, mining and oil and gas development, stewardship programs, public education programs;
- access management;
- habitat enhancement; and
- population and harvest management.

General principles that should guide conservation and management for Thinhorn Sheep were discussed at the North American Wild Sheep Conference (Hurley 2000) and these are presented as bullets at the beginning of each of the three main sections (9.1, 9.2 and 9.3) below.

9.1 Strategic Planning

Hurley (2000) recommends:

- View Thinhorn Sheep as subspecies, not jurisdictional groups.
- Do not let thinhorn populations become endangered.

A metapopulation approach should be used to develop a strategic plan with goals and objectives for managing Thinhorn Sheep over a large scale, as was suggested for Bighorn Sheep (R.A. Demarchi et al. 2000a, 2000b). Armentrout and Boyd (1994) suggest erasing jurisdictional boundaries and creating an interagency group to oversee this strategic planning. For Thinhorn Sheep this would mean involving the Alaska, Yukon, Northwest Territory, the Canadian Wildlife Service and Parks Canada agencies (e.g., Kluane National Park). Information about the relevant populations must be collected and a set of goals developed along with management objectives based on sound techniques.

Strategic land use plans in British Columbia: LRMP planning in regional venues has the potential to identify important habitats for Thinhorn Sheep and to prescribe strategies to manage and protect habitats, particularly critical winter habitats. An important issue for planning is the official designation of Crown land for various resource management purposes, including parks, forestry, livestock grazing, oil and gas exploration and development, prospecting and mining. Land and Resource Management Planning was a sub-regional integrated resource planning process including the public and interagency coordination and technical support. LRMPs have been completed in the areas supporting Stone's Sheep in the following forest districts: Fort St. John; Mackenzie; Cassiar Iskut-Stikine; and Fort Nelson. There are no plans in Atlin-Taku and Dease Liard, where there are Stone's and Dall's sheep populations. LRMPs developed zonation for land in a sub-region and then prescribe objectives and strategies for those particular zones. Zones range from high levels of protection to high levels of resource use, and include these designations: protected areas; special management areas; general resource zones; and enhanced resource zones.

The Mackenzie LRMP does not address Stone's Sheep specifically (Land Use Coordination Office 2000b). In Section 6.8 of the LRMP (Wildlife and Wildlife Habitat), there are objectives that may pertain to Stone's Sheep (i.e., to maintain and enhance habitats and to manage wildlife populations at sustainable levels). This involves such activities as identifying important habitat features, allowing for judicious use of prescribed fire, encouraging research about habitats, managing game species populations to provide sustainable harvest levels, and preventing declines of populations resulting from other mortality factors.

The Fort Nelson LRMP anticipated that Stone's Sheep would remain stable in the short and possibly long-term (Land Use Coordination Office 1997a). The final plan allocated 100% of the Stone's Sheep habitat (34 302 ha) to special management areas and protected areas by establishing the Muskwa-Kechika Management Area. The Muskwa-Kechika Management Area includes many provincial parks and ecological reserves. Because of these protective land zones, Stone's Sheep in that sub-region are considered at low risk. Threats to the species have not been eliminated, however, because of the continued strong demand for access to natural gas reserves. The draft (2004) Muskwa-Kechika wildlife management plan provides guidance for managing access and activities to minimize negative effects on Stone's Sheep and their habitat.

The Cassiar Iskut-Stikine LRMP concluded that implementation of the plan would pose moderate risks to Stone's Sheep populations, but that risks may be higher in the short term near the Todagin Plateau and Mount Edziza areas due, respectively, to the Red Chris and Spectrum mine development and the attendant increased access (Land Use Coordination Office 2000a). Those risks will decline once the tenures lapse and the Red Chris property is incorporated into the Wildlife Management Area (WMA) and the Mount Edziza Resource Management Zone becomes part of the existing Mount Edziza Provincial Park. The Todagin South Slope Protected Area captures high suitability winter and lambing habitat and there are access restrictions for the Todagin Plateau Zone. Section 2.3.5

(Hunting, Trapping, Guide Outfitting, Fishing) of the Cassiar Iskut-Stikine LRMP has very specific strategies for Stone's Sheep. To achieve the objective of managing game wildlife populations as a sustainable renewable resource, there are specific strategies to survey and monitor game populations, to manage predators and to promote effective wildlife management. To ensure that sex ratios and population numbers reflect natural population structures, two examples are presented for Stone's Sheep, (i.e., that a full-curl harvesting regulation applies and that a near natural herd structure is maintained).

The Fort St. John LRMP directs that management strategies to identify critical wildlife habitat areas provide for greater consideration of ungulate winter ranges during landscape-level planning and the development of stand-level prescriptions (Land Use Coordination Office 1997b). In areas important for Stone's Sheep, such as the Lower Sikanni-Fontas Zone, the LRMP stipulates the objective of maintaining high-capability ungulate winter habitat. Techniques used to address that objective include: 1) identifying and mapping ungulate wintering areas; 2) incorporating maintenance of high-capability ungulate wintering habitat into landscape level plans; 3) considering establishing wildlife habitat areas for wintering habitat; 4) developing new access routes to avoid disturbance of winter habitats; and 5) developing and implementing strategies to maintain site-specific habitats.

9.1.1 Land use planning

Hurley (2000) recommends:

- Recognize Thinhorn Sheep habitat needs when issuing tenures or otherwise disposing of Crown land and resources.
- Encourage Thinhorn Sheep stakeholders, including wildlife agencies, First Nations, guide-outfitters, hunters and naturalists, to enthusiastically participate in land management planning and review.
- Anticipate problems and proactively plan for specific Thinhorn Sheep management.
- Firmly educate involved public concerning probable negative effects on Thinhorn Sheep.

Thinhorn Sheep habitat can be protected through a variety of land use designations and planning processes, including the protection and management of wilderness. The current system of provincial parks and protected areas, provincial wildlife management areas and national parks offers a significant amount of protection for important thinhorn ranges. This should be examined in more detail to identify and protect important thinhorn range on Crown lands before they are sold or otherwise tenured through forestry, mining, oil and gas development, agricultural or commercial back country recreational permits and leases. A complete assessment on the impacts of these activities should be considered within the context of a cumulative effects analysis. Actual seasonal ranges should also receive protection. Protection of movement corridors may also be critical as a conservation tool that can improve the viability of populations (Beier and Noss 1998). The designation of key wildlife habitats as wildlife management areas can secure corridor habitat to ensure its long-term viability.

Local land use planning processes, which allow community sectoral representation, should establish management objectives and prescriptions that allow for recognition and protection of Thinhorn Sheep, their seasonal ranges and corridors. The Muskwa-Kechika Management Board is one example of such sectoral representation. Stewardship programs that take the requirements of Thinhorn Sheep into account should be considered for the small amounts of private lands and leases within and immediately adjacent to Thinhorn Sheep range. These could include landowner programs, property covenants, operational planning such as forest stewardship plans, grazing prescriptions and agricultural and urban planning, where appropriate. Public education programs can be useful for informing private landowners about how they can protect Thinhorn Sheep range.

To protect thinhorn habitat further, it is important to ensure that Thinhorn Sheep ranges are not alienated or impaired through development and/or resource extraction. In addition, cooperative arrangements for the protection and man-

agement of important Thinhorn Sheep habitats within forestry tenures and petroleum leases should be increased. Commercial backcountry recreational developments should not proceed without due consideration of their impacts on sheep populations and their habitats.

9.2 Habitat Management and Conservation

Hurley (2000) recommends:

- Manage total predator-prey systems, not single species. Targeting management for one species often can be detrimental to other species.
- Management should be designed at the landscape scale.
- Maintain intact ecosystems.
- Maintain pristine ecosystems and let natural systems operate.

9.2.1 Livestock grazing strategies

The Mackenzie LRMP states that there may be potential for increasing the utilization of range resources while minimizing transfer of disease and parasites between domestic animals and wildlife. The LRMP also cautions about avoiding expansion or new tenures where the activity will have an unacceptable level of negative effect on areas of high use by wild ungulates. Finally, the plan advises that domestic livestock known to carry communicable diseases and/or parasites detrimental to wildlife be determined to be free of disease and/or parasites before introduction into the plan area. There is, however, no method for guaranteeing that any domestic sheep or goats are free of diseases and parasites pathogenic to wild sheep.

The Cassiar Iskut-Stikine LRMP includes a strategy to prohibit the agricultural or silvicultural grazing of domestic sheep and goats on Crown lands to avoid spread of disease from domestic livestock to wildlife. There is also a strategy in the LRMP to inform local landowners about the potential for disease transfer to wildlife from domestic livestock, including domestic sheep and goats, as well as other exotic species such as Llamas. The LRMP also includes provisions to provide for livestock grazing needs on Crown land subject to objectives for other resource values, including ungulate

winter range, and to avoid effects to ungulate winter range when allocating grazing opportunities.

In the Fort St. John LRMP, the ranching sector will have increased access to grazing opportunities, but there are provisions for the maintenance of high-capability ungulate wintering areas.

9.2.2 Wilderness management

Wilderness, while defined to a certain extent by its lack of active management and lack of human intrusion, requires designation under provincial legislation and requires certain types of management to ensure that the wilderness character is maintained. This includes preventing the intrusion of adjacent resource management activities, such as oil and gas exploration and development, and the management of certain human activities, such as livestock grazing, within wilderness areas. The following paragraph is excerpted from Hurley (2000).

“If Thinhorn Sheep are to contribute fully to wilderness values, wilderness management plans must recognize and provide for the natural processes expected in wild sheep populations and their habitat. Where wild sheep occur in wilderness areas, their populations should be designated as primary wilderness components (Bailey and Woolever 1992). Wild sheep should be reintroduced into all suitable, vacant historic ranges within wilderness areas. This latter action is well underway in restoring Stone’s Sheep to ranges depleted during the late 19th century gold rush in the Atlin area.”

Clear policies should be developed for management of habitats and wildlife populations in wilderness areas and wilderness study areas. Policies should be applied consistently in all areas and over the same time periods.

Based on input from provincial wildlife management agencies, wilderness management plans should identify times when wild sheep management activities, including survey flights, will cause minimal effects to other wilderness uses and values.

9.2.3 Forest and range planning

Recent changes in government protocols, policy, institutions and funding sources have affected how forest and range management and planning is done in B.C. The Forest Practices Code (FPC) has been changed to the *Forest and Range Practices Act* (FRPA) and Forest Renewal BC (FRBC) has been changed to the Forest Investment Account (FIA). Strategic land use planning including Land and Resource Management Plans (LRMPs) and Higher Level Plans (HLPs) are also changing with new initiatives such as Sustainable Resource Management Plans (SRMPs) and Sustainable Forest Management Plans (SFMPs). These changes will affect how forest and range plans conserve and protect Thinhorn Sheep habitats.

Ungulate Winter Range designation will continue to be the primary mechanism for managing winter range habitat under FRPA. Once UWRs have been established, forest licensees preparing forest stewardship plans must prepare results and strategies that are consistent with established objectives for UWR, such as the Stone's Sheep UWR in the Peace Arm. FRPA also provides interim protection for winter range habitat that has been identified, but not yet been established as UWR under FRPA. Forest licensees will be required to plan for winter range habitat for specified ungulate species when notified by the Ministry of Water, Land and Air Protection of the amount of area, distribution of area and attributes of area required for winter survival (see section 7 of the Forest Planning and Practices Regulation of FRPA). This tool is intended to be used to provide protection for the proposed UWR for Stone's Sheep in the Peace Region until they are formally established under FRPA.

In addition to their designation as an ungulate species for which a winter range may be required, Stone's Sheep may also be considered for inclusion in the category of Regionally Important Wildlife under FRPA. Regionally important wildlife are wildlife that are important to a region of British Columbia and may be adversely impacted by forest or range practices. The Ministry of Water, Land and Air Protection has not yet completed the review of species for inclusion in

this category of wildlife. Inclusion of species in the category of regionally important wildlife will allow fine filter habitat protection tools such as wildlife habitat areas and general wildlife measures to be used where required. Dall's Sheep are not considered to be negatively impacted by forest and range activities and therefore have not been considered for inclusion in the category of Species at Risk under FRPA.

9.2.4 Human disturbance and access management

Access management has long been a priority for the former B.C. Wildlife Branch and continues to be a concern for the Biodiversity Branch of MWLAP. Currently, the MSRM is responsible for managing access. Vehicular access has many detrimental effects on wildlife, including physical disturbance, soil erosion and increased legal and illegal hunting mortality. Motor vehicle access on the majority of Stone's Sheep range in the Peace Region is restricted under the current hunting and trapping regulations.

Demarchi and Demarchi (1994) made several recommendations regarding access management in the East Kootenays that could also apply to Stone's Sheep range because of the generally less rugged terrain. First, Thinhorn Sheep should be counted only once per year (on their winter ranges) by helicopter or fixed-wing aircraft to reduce harassment. Second, a policy concerning the off-road use of ATVs for hunting purposes should be developed. Third, habitat degradation due to ATV traffic should be mitigated through such a policy and through an active program of education, consultation and enforcement. Communication with the public is needed regarding the importance of access management.

The province has developed draft guidelines for commercial backcountry recreation (B.C. Wildlife Branch 2000, 2001) to regulate heli-skiing, heli-hiking and snowmobiling. Where threats cannot be mitigated or controlled through regulation, these activities should be prevented or, where they already occur, eliminated. The effects of these activities on mountain sheep and their habitats should be monitored and assessed on a regular basis and appropriate action taken.

This will allow strict control of the timing and location of access to reduce harassment of wildlife, particularly Stone's Sheep.

Under the draft commercial backcountry recreation policy (B.C. Wildlife Branch 2001), the following commercial recreation guidelines apply to all mountain sheep, including Thinhorn Sheep:

1. For major projects, identify and map sensitive sites, including escape terrain, lambing habitats, mineral licks and winter ranges. Assign ratings of high and moderate sensitivity.
2. Seasonally close highly sensitive habitats to snowmobiles and off-highway vehicles (OHVs).
3. Regulate snowmobile and OHV activity within moderate sensitivity areas as needed.
4. Limit helicopter and fixed-wing flight altitudes to a minimum of 500 m over designated sheep habitats and a minimum 1000 m horizontal distance from designated sheep habitats.
5. For sensitive sites (e.g., natal areas) maintain a 2000-m horizontal separation from helicopter and fixed-wing flights. Distance interval restrictions may be relaxed by ameliorating circumstance (e.g., safety concerns because of weather).
6. Select landing spots for all helicopter activities to avoid locations within 2000 m of designated mountain sheep habitats.
7. Prevent facility development on or near critical seasonal mountain sheep habitats.
8. All non-motorized access trails and mountain sheep viewing areas should be at least 300 m away from sensitive sites, such as mineral licks and natal areas.
9. Train staff and clients about responsible behaviour near mountain sheep and their habitats.
10. Apply ungulate winter range guidelines as follows:
 - a- For major projects, identify and map ungulate winter ranges and identify critical periods.
 - b- Prevent construction of facilities on designated ungulate winter ranges.

- c- Plan developments so there are buffer areas between humans and wintering ungulates, and create or maintain sight barriers, noise barriers and hiding cover between areas of human use and winter ranges.
- d- Locate transportation routes and snowmobile trails outside of critical winter ranges.
- e- Where existing snowmobile trails intersect critical winter ranges, restrict snowmobiles to designated roads and trails, and prevent their use during critical periods.
- f- Where proposed winter-use trails and roads are in close proximity (within 300 m) of important winter ranges, screen the routes behind ridgelines and vegetative cover.
- g- Establish, maintain and enforce low speed limits (e.g., 40 km/h) on roads and trails that are within 300 m of important winter ranges.
- h- Restrict off-road travel during critical winter periods.
- i- If ungulates are traveling on plowed roads, ensure frequent escape breaks are created in the bermed snow to allow animals to exit the road to avoid vehicular traffic.
- j- Regulate human activities so that they occur in a predictable fashion within defined areas to decrease flight responses. Where human activity occurs on winter ranges, keep it concentrated in established areas to limit disturbance effects.
- k- Plan human use of ungulate winter ranges, including viewing distances, to minimize flight responses as appropriate for different species in different locations.
- l- Restrict human use of certain critical winter ranges during critical periods when there are indications that ungulates are being displaced either spatially or temporally by human presence.
- m- Minimize and focus areas used for heliskiing. Helicopter over-flights should meet the species-specific avoidance criteria outlined above, unless these activities are separated from winter range

habitat by a physical barrier that would minimize disturbance levels (e.g., a mountain ridge or terrain block). Distance interval restrictions may be relaxed by ameliorating circumstance (e.g., safety concerns because of weather).

- n- Many hunters feel that mountain sheep hunting should provide a challenge that is not highly dependent on motorized vehicle use. Limiting vehicle access will impose limitations on some hunters. If most mountain sheep hunters continue to seek wilderness hunting experiences, access opportunities may need to be restricted. The use of ATVs should be restricted in an area before there is a long history of use.

9.2.5 Adaptive management: habitat enhancement and stewardship programs

Hurley (2000) states that habitat degradation of pristine habitats will be negative for Thinhorn Sheep, and recommends: protect basically pristine thinhorn habitats from degradation; managers should not rush to “improve” pristine habitats; monitor impacts and increase certainty of recommendations for future management of Thinhorn Sheep.

Prescribed burning in appropriate natural disturbance types is an efficient, economical and ecologically sound way to enhance Thinhorn Sheep ranges. To maintain or increase population levels, many northern guide-outfitters have cooperated with the Wildlife Branch (now Fish and Wildlife Recreation and Allocation Branch and Biodiversity Branch) and the Ministry of Forests in an active program of habitat enhancement dating back to at least 1950 (R. Peck, pers. comm.). The standard type of habitat enhancement in northern ecosystems is prescribed fire. The responses of the habitat to many of these prescribed burns are unknown except in a very general sense. Past habitat enhancement projects were rarely evaluated after treatment, due to lack of funding or staffing. Anecdotal information suggests that thinhorn population growth and increased lamb survival may have been stimulated by habitat enhancements.

Proper scientific evaluation of these enhancement projects has not been conducted. Intuitively it is argued that any increase in forage quality should be beneficial because offspring growth rates, conception rates, age at first reproduction and male mating activities are influenced by forage conditions (Shackleton and Bunnell 1987). On the other hand, Seip and Bunnell (1984, 1985*b*) have shown that an increase in forage quantity does not always benefit sheep. The lack of funding to properly assess the efficacy of past enhancements impairs the opportunity for wildlife managers to learn from their actions. Enhancement projects should be conducted as scientific experiments and monitored over time to develop an effective adaptive management program of habitat enhancement.

9.3 Population Management and Conservation

Hurley (2000) recommends:

- Thinhorn populations are not subject to density dependent effects. Rather they are held below carrying capacity by other factors, such as weather.
- Managers should take no management action that may reduce population size without clear and consistent data indicating a density-dependent limitation exists.

9.3.1 Population inventory and monitoring

Hurley (2000) recommends that reliable survey information be obtained, as a basis for allocating wild sheep harvest authorizations under limited entry hunting regimes. For large thinhorn populations with limited available access to them, conservative full-curl ram harvests can be sustained with minimum population monitoring. For other populations, at least monitor population trend, abundance, recruitment and ram age structure.

Hurley (2000) further recommends that forage conditions be monitored in important habitats, and states that additional data on sex- and age-specific mortality rates will enhance understanding of herd dynamics and enhance population monitoring efforts. Hurley (2000) recommends

the use of long-term data to assess the role of weather in determining herd performance.

As noted above, Thinhorn Sheep populations to which there is limited access and which are managed under a conservative full-curl regulation require only minimal population monitoring. In most cases, monitoring the harvest ram age structure meets the minimal requirements for maintaining hunting seasons. However, there is a need for more inventories to better document trends in Thinhorn Sheep and to detect major population changes.

As is evident from a review of the existing inventories, there is a need to ensure that the existing Resources Inventory Standards Committee (formerly RIC, now RISC) standards are applied to Thinhorn Sheep inventories. Even in recent inventories, there has been confusion over classes of animals, the invention of new classes and the reporting of ratios without the classification data. Inventory reports should follow RISC standards (i.e., use a standard format with descriptive titles and tables and include a small-scale and a large-scale map of the study area). Management unit and date should be in the title of all reports. In addition, there is a need to adopt standard procedures for incorporating inventory data into the official regional population estimates. Our review has shown that estimates have remained the same despite new inventory information that suggests there may have been population declines in some GMZs. Finally, there should be a formalized process for analyzing both inventory and harvest data over standard time periods.

9.3.2 Disease prevention and mitigation

Hurley (2000) recommends:

- Aggressively pursue legislation and regulations to assure that no domestic sheep, goats or cattle interact with Thinhorn Sheep.
- Establish baseline studies to examine health and disease status across Thinhorn Sheep range.

Coggins and Matthews (1996) state that domestic sheep must never use Bighorn range or contact wild sheep. This precaution is essential to

the health of both Bighorn and Thinhorn sheep. According to the habitat definition developed by Swenor et al. (1996), habitat within 16 km of domestic sheep is not suitable for wild sheep. Vegetation Management Guidelines (<http://www.for.gov.bc.ca/hfp/forsite/sheep/guidetoc.htm>) recommend that potential domestic sheep farms be located at least 15 km from wild sheep range or with a significant natural barrier. Any sheep farms that already exist within the range of wild sheep should be documented. All contact with domestic sheep or goats should be eliminated, either through enclosure fencing or removal of the domestic sheep. The presence of cattle can also significantly alter the behaviour and habitat use of wild sheep (Bissonette and Steinkamp 1996).

British Columbia and Alberta have developed a health protocol for domestic sheep used for silvicultural weed control on forest lands. Under this protocol, domestic sheep are examined and/or tested, prophylactically treated and monitored specifically for foot rot, pseudo-tuberculosis, contagious ecthyma and internal and external parasites before entry to sites and during grazing. The protocol is part of guidelines that include a review process to document the presence of wild sheep and goat herds within 15 km of the proposed vegetation management site. If these are present, the protocol recommends that the project be refused.

Given the rapid mortality of bighorns in a respiratory disease die-off and the lack of success of large-scale treatment trials in other jurisdictions, drug treatment of sick wild sheep is not yet an option. Vaccination trials of Bighorn Sheep have also not been successful. Presently, widespread, disease-induced die-offs of Thinhorn Sheep are not known to have occurred. Should they occur, management actions to lessen their effect should be taken. Recommendations for managing this situation are detailed in Demarchi et al. (2000a, 2000b) and could apply to Thinhorn Sheep should this situation arise.

The presence of cattle can also significantly alter the behaviour and habitat use of wild sheep (Bissonette and Steinkamp 1996). Therefore, where grazing allocations apply to Thinhorn

winter range, it is recommended that grazing rotations be adjusted to minimize the contact between cattle and wild sheep.

9.3.3 Translocations

Hurley (2000) recommends:

- Capture only as necessary. Use the best data available to select the most appropriate capture method.
- Minimize transplants in thinhorn ranges.

British Columbia has a long history of wildlife translocation (Janz 1988; Hatter and Blower 1996), but only three translocations of Thinhorn Sheep have occurred since 1990. The three translocations have had varying success and the problems experienced were of serious concern for managers. Founder effect and genetic drift can occur within small reintroduced herds of mountain sheep (Skiba and Schmidt 1982; Fitzsimmons et al. 1997). Therefore, management practices should minimize the loss of genetic variation from reintroduced populations of sheep by: 1) transplanting >75 sheep at a time; and/or 2) periodically augmenting small reintroduced herds with additional animals from the source herds. For the latter solution, it is not recommended that animals from other subpopulations be used. This will minimize disease transmission across large geographic areas and will also likely facilitate social integration (Roy and Irby 1994). Mixing of populations can introduce pathogens that may be well tolerated by unstressed sheep, but not tolerated by translocated sheep.

Assessment of the effects of removals on source herds is necessary, especially when the removals are large relative to the size of the source population and when maintenance of a viable source population is the management goal. The recovery time, or the time required to replace the removed animals, should be incorporated into the assessment of the population for future removals. Stevens and Goodson (1993) recommend that removals be based on the productivity of source herds, rather than on their assumed compensatory responses to removals.

Although the results of recovery programs using transplants can be significant, in many instances insufficient care has been taken to ensure they will be successful. British Columbia has not been immune from problems and the Wildlife Branch (function presently with the Biodiversity Branch) has established these criteria for transplants (Hatter and Blower 1996):

1. The proposed transplant site must provide sufficient and suitable habitat to support a viable population of mountain sheep, as determined by comprehensive study.
2. Prior study must establish that the introduction will not adversely affect the numbers, health or utilization of currently present wildlife species at either the transplant source or the transplant site.
3. The race of mountain sheep to be transplanted must be from a herd of "pure" strain and it must be transplanted in range of its own subspecies that is similar to the most accessible subspecies.
4. Prior study must establish that the introduction will not create intensive land use conflicts with other resource agencies or resource users.

The Montana Department of Fish, Wildlife and Parks follows a rigorous transplant protocol (Montana Department of Fish, Wildlife and Parks undated). Their protocol has some similarities, but with some modifications, several of these items could be used to augment British Columbia's protocol:

1. If translocation is proposed to a site where Thinhorn Sheep were historically present or a site with a depressed population, evaluate the habitat to determine the reason(s) for the lack of thinhorns and determine if the area can support more. The reasons for the initial extirpation or reduction must be determined to have been corrected. If predators are suppressing thinhorns on otherwise healthy range, transplants will likely only supplement predator diets.
2. Determine the health status of the herd to be transplanted and the herd, if applicable, to be augmented (e.g., fecal lungworm larvae trends, serological profile) to ensure that

sick thinhorns are not translocated to healthy populations and vice versa.

3. Keep genetic strains intact as much as possible by emphasizing transplants within continuous ranges.
4. Evaluate the potential for future consumptive and non-consumptive uses, including access. Recently transplanted sheep and/or augmented herds must not be hunted until they have stabilized and can withstand harvest (i.e., careful monitoring is needed to demonstrate that there is sufficient recruitment and good health).
5. Determine priority areas for translocations (i.e., sites with depressed populations, historic sites) by the fall before translocation is to take place.
6. Transplant young (e.g., <3 years old) animals to minimize losses from the knowledge-base of the donor herd and to minimize losses often caused when older animals attempt to return to their original range.
7. Release animals on quality winter range near escape terrain (i.e., within 300 m).

Considering the long-term consequences of transplants, provincial wildlife managers might consider whether it would be beneficial to include some representation from academia and the wildlife agencies of adjacent jurisdictions. The key to success is careful planning and monitoring. If the above criteria are not met, translocations could be futile or even dangerous to either the donor or the receiving herds, or both.

9.3.4 Predation

Hurley (2000) recommends:

- Predator management strategies should be flexible, adapting to local and temporal conditions and should be implemented in ways that allow reliable evaluations of their effects upon Thinhorn Sheep populations.
- Retain predator control as a management option, apply it with great care and identify why, how and what the thresholds should be for application.
- Additional research and documentation of situations where predation can have an effect are needed. If predator control/management is undertaken, the program

should be thoroughly documented and evaluated.

- Where consistent with applicable constitutional mandates and legal constraints, managers should support implementation of predator management to facilitate attainment of defined population size and human use objectives.
- Where a single predator (e.g., a specific wolf pack) targets a vulnerable population, it may be necessary to remove that predator to conserve the herd.

Extensive research in Alaska has shown that, compared to inclement winter weather, predation is seldom the most important limiting factor in Dall's Sheep populations. This may also be true for most Stone's Sheep populations, although predation was considered the primary limiting factor in northeastern B.C. (Bergerud and Elliott 1998). Predator control remains a valid option in some situations, however, especially for small or newly transplanted Thinhorn Sheep herds (Hurley 2000). In isolated cases, where predation may be a problem, the biology of the situation should be carefully documented and demonstrated, and then appropriate action taken.

10.0 RESEARCH NEEDS

The following research needs are rated for priority (high, moderate or low) and the highest priority needs are in bold.

10.1 Population Dynamics

- Develop and implement standardized population modeling for monitoring sheep populations by GMZ. **HIGH**
- Establish standardized population inventories within each GMZ. While the need for more inventories for harvest management is low, there is a need for reliable trend data on Thinhorn Sheep to assess conservation rankings. **MODERATE** for Stone's Sheep; **HIGH** for Dall's Sheep
- Research and document situations where predator control may be required. If predator control/management is undertaken, the pro-

gram should be thoroughly documented and evaluated. MODERATE

- More studies of predator–Thinhorn Sheep dynamics, including systems with multiple prey species, are needed. Wild sheep demographics, including lamb survival and recruitment, should be determined at various combinations of predator and prey population sizes. Experiments should be designed to manipulate predator population sizes in relation to prey sizes, and should include periods of both favourable and unfavourable weather for wild sheep (Bailey and Hurley 2000). LOW
- Identify the key predators of Thinhorn Sheep for each GMZ and estimate their effects on Thinhorn Sheep. Pertinent information will include the effects on a temporal and spatial scale and the effects on sex- and age-classes. LOW

10.2 Biophysical Inventory

- Complete habitat capability/suitability mapping over the entire Thinhorn Sheep range in B.C. at a scale of 1:250,000 and on all critical Thinhorn Sheep winter ranges at a scale of 1:50,000. Completion of these maps will facilitate management decisions regarding enhancement activities addressing specific concerns. HIGH
- Complete habitat capability/suitability mapping across the range of Thinhorn Sheep and for the adjacent populations in the Yukon that are important to the B.C. populations. HIGH

10.3 Health

- Consider legislation that would prohibit the introduction of exotic species, including domestic animals, into thinhorn habitat. HIGH
- Continue and expand baseline research on diseases and parasites in healthy and sick Thinhorn Sheep. This will establish the natural distribution of pathogens to compare with situations in the future. HIGH
- Participate with other jurisdictions in research on disease transmission and procedures for reducing or eliminating contact with vectors such as domestic sheep, goats, cattle and, possibly, camelids. HIGH

- Conduct research on competition and disease transmission between native ungulates. LOW

10.4 Habitat Use and Enhancement

- Review and synthesize information on fire frequencies needed to maintain open Thinhorn Sheep habitats. Develop standardized protocols between regions for conducting prescribed burning in Thinhorn Sheep habitats. HIGH
- Evaluate and assess broadcast burning, prescribed fire and conifer forest encroachment on Thinhorn Sheep winter ranges and potential movement corridors, as well as for other wildlife species using similar or adjacent areas. HIGH
- Conduct research on the occurrence of domestic livestock on Thinhorn Sheep ranges and the effect of the livestock, particularly horses. HIGH
- Assess the key components of habitat use patterns by radio tracking non-transplanted animals. This data can be used to determine the effects of habitat alteration and enhancement on habitat use and animal movement. MODERATE
- Study trace mineral use and requirements. Inventory distribution and location of mineral licks utilized by Thinhorn Sheep. MODERATE

10.5 Limiting Factors

- Review and synthesize information on effects of aircraft (fixed-wing airplanes, helicopters and hang gliders) upon wild sheep behaviour. Develop guidelines for management. HIGH
- Conduct research on the effects of oil and gas exploration. HIGH
- Conduct experimental and observational research on the effects of human disturbance upon wild sheep. Demographic, behavioural and physiological effects should be determined. There is a need for a review and synthesis of existing information on this topic. MODERATE
- Assess the cumulative effects of aircraft disturbance, ground-based human disturbance (hiking) and motorized access (summer and

winter) on Thinhorn Sheep viability.
MODERATE

10.6 Fragmentation and Dispersal Rates

- Conduct research on movements and seasonal home ranges to determine dispersal rates within and between metapopulations and sub-populations, and to determine fragmentation zones and viability of populations. MODERATE

10.7 Genetics and Taxonomy

- The issue of the Fannin race of Stone's and Dall's sheep is an academic concern, rather than a management concern. However, race, subspecies and other genetic issues can affect status decisions, translocations and other management activities (e.g. its designation as a regionally significant species under FRPA) and are deserving of analysis utilizing advanced genetic techniques. LOW

11.0 STATUS EVALUATION

11.1 Dall's Sheep

Dall's Sheep is currently on British Columbia's Blue List of species and subspecies of special concern maintained by the Conservation Data Center (<http://srmwww.gov.bc.ca/atrisk/>). Blue-listed taxa may not be threatened, but their habitat or other requirements are such that they are vulnerable to further disturbance.

The global rank indicator, the rank based on range-wide status for Dall's Sheep, is currently G5, which indicates that this subspecies is secure, common, typically widespread and abundant. The trinomial rank indicator, denoting range-wide status of infraspecific taxa, is currently T5: secure, common, widespread and abundant. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has not evaluated Dall's Sheep. The International Union for Conservation of Nature and Natural Resources Caprinae Specialist Group (IUCN/SSC) determined the status of Thinhorn Sheep within Canada to be "not threatened" (Shackleton et al. 1997).

The provincial or sub-national ranking for Dall's Sheep is currently S2S3 for the province of British Columbia (<http://srmwww.gov.bc.ca/atrisk/>). Although the British Columbia population of Dall's Sheep could fit the criteria for S1 in terms of population size or number of subpopulations (occurrences), other criteria are considered in the ranking process. The factors that could make this species vulnerable are absent or have largely been reversed (domestic livestock grazing, land alienation, industrial development), as most of their range is now within a provincial park where human disturbance can be regulated or restricted. If the protective status of the provincial park changes, if new population surveys demonstrate a decline or if there is unregulated human disturbance, then the status should be reviewed.

11.2 Stone's Sheep

Stone's Sheep is not red- or blue-listed in British Columbia. The provincial or sub-national ranking by the Conservation Data Centre for Stone's Sheep is currently S4: apparently secure, uncommon but not rare, and usually widespread with possible cause for long-term concern (Cannings et al. 1999). Stone's Sheep are on the Yellow List, a grab bag of species that are common, uncommon, declining and increasing (Fraser et al. 2001). These species are listed as S4, however, because they have experienced long-term threats or provincial declines. The Yellow List indicates species to be actively monitored and studied.

The global rank indicator, the rank based on range-wide status for Stone's Sheep, is currently G5, which indicates that this subspecies is secure, common, typically widespread and abundant. The trinomial rank indicator, denoting range-wide status of infraspecific taxa, is currently T5: secure, common, widespread and abundant. COSEWIC has not evaluated Stone's Sheep. The IUCN/SSC determined the status of Thinhorn Sheep within Canada to be "not threatened" (Shackleton 1997).

This status report suggests re-examining the S4 ranking for Stone's Sheep. Although Stone's

Sheep remain abundant, their historic range largely intact, and subpopulations are viable, there is evidence that some subpopulations have declined. Stone's Sheep are susceptible to contracting diseases from domestic sheep and goats and are also vulnerable to human development and disturbance. The effect of global climate change on Thinhorn Sheep and their habitat is unknown at this time, but, in addition to other unknown effects, some researchers warn that it may shift the equilibrium of host-pathogen relationships in the north.

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13.0 APPENDICES

13.1 Appendix 1: Population Trend Data

Table 22. Dall's and Stone's sheep classified count data from 14 inventory reports from northern British Columbia, 1972-1998.

Date	Source	GMZ	MU	Area	Ewes	Lambs	Yearling	Unclass E/L	Unclassified				Unclassi- fied Rams	Total Rams	Total Sheep	
									Ewe-like Sheep	Class I	Class II	Class III				Class IV
July 11-20, 1985	D. Steven- ton	Atlin-Tat	6-28, 6-29	Tatshenshini	120	58	30		0	17	6	14	11		48	256
July 25-27 1996	D. Cichowski	Atlin-Tat	6-29	Tat-Alsek Park	102	53	16	0	0	9	5	31	17		62	233
July 11-20, 1985	D. Steven- ton	Atlin	6-27	Tagish	92	26	13		1	8	19	17	6		50	182
July 6-8, 1990	G. Schultze	Atlin	6-27	Tagish	108	30	3	37		6	4	11	4		25	203
November 1997	R. Marshall	Atlin	6-27	Atlin	128	49		6		9	14	11	7	6	47	230
March 1998	R. Marshall	Atlin	6-27	Atlin	179	54		16		2	31	32	4		69	318
February 1972	F. Harper D. Steven- ton, R. Marshall	Stikine	6-20	Todagin	193	101		306		25	55	55	69		204	804
March 21, 1985	Marshall	Stikine	6-20	Todagin	203	98		6		0	55	22	17		94	401
March 16- 18, 1992	G. Schultze	Stikine	6-20	Todagin	434	118			2		66	69	28		163	717
March 11- 14 1993	D. Cichowski	Stikine	6-20	Spatsizi Park	271	74				23	49	48	14		134	479
June 28-29, 1996	D. Hatler	Stikine	6-20	Todagin	91	17			68		9	5	7		21	197
September 27, 1996	D. Hatler	Stikine	6-20	Todagin	112	27			26		9	15	10		34	199
December 2, 1996	D. Hatler	Stikine	6-20	Todagin	134	26			0		10	15	14		39	199
March 24- 26 1998	R. Marshall	Stikine	6-23	Cry Lake	159	69		13		7	19	38	21	9	94	335
July 11-12, 1985	G. Watts	Upper Finlay	7-40	Russell Range	42	74			161	13	50	34	29	3	129	406
March 9- 10, 1993	F. Corbould	Upper Finlay	7-40	Russell Range	172	51	47			21	32	22	5		80	350
February 1990	J. Elliott, I. Hatter	North- east	7-42, 7-57	Prophet River/Cypre	744	112	37			71	42	114	47		274	1167

Date	Source	GMZ	MU	Area	Ewes	Lambs	Yearling	Unclassified					Unclasi- fied Rams	Total Rams	Total Sheep	
								Unclass E/L	Ewe-like Sheep	Class I	Class II	Class III				Class IV
		Rockies		ss Creek												
February 1994	J. Elliott, I. Hatter	North- east Rockies	7-42, 7-57	Prophet River/Cypre ss Creek	591	148	61			36	38	98	44		216	1016
				Prov Total	3875	1185	207	384	258	247	513	651	354	18	1783	7692

Table 23. Revised Dall's and Stone's sheep classified count data from 14 inventory reports from northern British Columbia, 1972-1998.

Date	Source	GMZ	MU	Area	Rev* Ewes	Rev Lamb s	Rev Class II	Rev Class III	Rev Class IV	Total Rams	Total Sheep	Rams:10 0 Ewes	Lambs:10 0 Ewes
Jul 85	D. Steventon	Atlin-Tat	6-28, 6-29	Tatshenshini	167	58	6	14	11	31	256	19	35
Jul 96	D. Cichowski	Atlin-Tat	6-29	Tat-Elsek Park	127	53	5	31	17	53	233	42	42
				GMZ Total	294	111	11	45	28	84	489	29	38
Jul 85	D. Steventon	Atlin	6-27	Tagish	114	26	19	17	6	42	182	37	23
Jul 90	G. Schultze	Atlin	6-27	Tagish	146	38	4	11	4	19	203	13	26
Nov 97	R. Marshall	Atlin	6-27	Atlin	141	51	17	13	8	38	230	27	36
Mar 98	R. Marshall	Atlin	6-27	Atlin	193	58	31	32	4	67	318	35	30
				GMZ Total	595	172	71	73	22	166	933	28	29
Feb 72	F. Harper	Stikine	6-20	Klappan-Todagin	427	198	55	55	69	179	303	42	46
Mar 85	D. Steventon, R. Marshall	Stikine	6-20	Klappan-Todagin	207	100	55	22	17	94	133	45	48
Mar 92	G. Schultze	Stikine	6-20	Klappan-Todagin	436	118	66	69	28	163	260	37	27
Mar 93	D. Cichowski	Stikine	6-20	Spatsizi Park	294	74	49	48	14	111	173	38	25
Jun 96	D. Hatler	Stikine	6-20	Todagin	148	28	9	5	7	21	33	14	19
Sep 96	D. Hatler	Stikine	6-20	Todagin	133	32	9	15	10	34	59	26	24
Dec 96	D. Hatler	Stikine	6-20	Todagin	134	26	10	15	14	39	68	29	19
Mar 98	R. Marshall	Stikine	6-23	Cry Lake	175	73	21	42	23	87	153	50	42
				GMZ Total	1954	649	274	271	182	728	1182	37	33
Jul 85	G. Watts	Upper Finlay	7-40	Russell Range	216	74	51	35	30	116	406	54	34
Mar 93	F. Corbould	Upper Finlay	7-40	Russell Range	240	51	32	22	5	59	350	25	21

Date	Source	GMZ	MU	Area	Rev* Ewes	Rev Lamb s	Rev Class II	Rev Class III	Rev Class IV	Total Rams	Total Sheep	Rams:10 0 Ewes	Lambs:10 0 Ewes
				GMZ Total	456	125	83	57	35	175	756	38	27
											0		
Feb 1990	J. Elliott, I. Hatter	Northeast Rockies	7-42, 7-57	Prophet River/Cypress Creek	852	112	42	114	47	203	1167	24	13
Feb 1994	J. Elliott, I. Hatter	Northeast Rockies	7-42, 7-57	Prophet River/Cypress Creek	688	148	38	98	44	180	1016	26	22
				GMZ Total	1540	260	80	212	91	383	2183	25	17
				Provincial Total	4839	1317	519	658	359	1536	5543	32	27

* Revised by apportioning unclassified sheep, see explanation below.

Data collection:

Not all observers classified and recorded sheep similarly prior to the development of the Resources Inventory Committee ungulate inventory standards, and some observers still do not follow RISC inventory standards in all aspects, as detailed below.

1. The most common classification system is to lump all yearling females, yearling males, class I males and all adult ewes into one category that is sometimes referred to as “ewes and ewe-like sheep” or ELS.
2. Most observers classified sheep into at least class II, III and IV rams, ELS, lambs and unclassified ewe-lamb or nursery groups.
3. Most observers made every attempt to classify and record all rams seen. Seldom does a category of “unclassified sheep” appear. However, in some reports there may be two separate, undefined categories of unclassified sheep: “unclassified sheep” and “unclassified ewe-lamb or nursery group.” Because they are easy to identify, it is doubtful that these include any significant number of males over one or two years of age.

Analysis of the data:

In the absence of standardized, regular surveys, an attempt was made to extract as much information as possible out of the scarce data that were available, so they could be compared and compiled for the population trend analysis for this report (see Section 3.2.3).

1. All yearling ewes, yearling rams, class I rams and ewes, whether classified separately or individually, were amalgamated into a single category of “ewes and ewe-like sheep” (ELS) to standardize all surveys to date.
2. The class II, III and IV ram categories were retained where recorded. A total adult ram category was used to derive ram:100 ewes ratios.
3. Where it was apparent that the unclassified component was comprised almost exclusively of ELS and lambs (in other words, no rams over class I), the unclassified portion was divided into ELS and lambs based on the observed ratio, the derived number of ELS added to the observed number of ELS and the revised number used with the recorded ram component to estimate the overall ram:100 ELS ratio.