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MOUNTAIN GOATS AND MOUNTAIN SHEEP OF WASHINGTON

by
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WASHINGTON
DEPARTMENT OF GAME

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PREFACE

Washington State has the largest native population of mountain goats in the contiguous United States. A pioneer study of mountain goats was initiated here more than four decades ago (Anderson, 1940). The two-year study was the first comprehensive life history work done on mountain goats in North America. The need for more data and for refined management resulted in the initiation of a new goat study in 1959 (Wadkins, 1965). This eight-year goat study evaluated population numbers and environmental factors responsible for observed goat declines. During the 1970's, goat and bighorn sheep populations in some areas of the state suffered losses dictating a need for further research on both species to solve management problems. Better survey information in particular was needed for mountain goat management.

Field work on the current sheep and goat study was initiated in 1976 as Federal Aid Project W 88 R. The study's principal objective was to determine current population status of mountain goats and mountain sheep throughout the state. This bulletin summarizes current and previous information on both montane bovids in Washington.

TERMINOLOGY

A definition of terms used in this bulletin may avoid ambiguity. I have used the terms "goat" and "mountain goat" interchangeably. In the same way, "sheep" and "mountain sheep" are used interchangeably. Where I refer to domestic goats (*Capra hircus*) or domestic sheep (*Ovis aries*), I include the word "domestic." "Nanny" refers to all adult female mountain goats and "ewe" refers to all adult female mountain sheep. Similarly, "billy" refers to an adult male mountain goat and "ram" refers to an adult male mountain sheep.

A "band" of either sheep or goats is a family-sized association interacting within a herd. A "herd" refers to sheep or goats that share specific seasonal ranges. A herd may consist of several bands of either sheep or goats. "Population" refers to all animals of the same species within a geographic area. With rare exceptions, populations are genetically isolated from one another.

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MOUNTAIN GOATS

INTRODUCTION

The mountain goat (*Oreamnos americanus*) is not a true goat but a mountain-dwelling antelope. Mountain goats are the only living member of the genus *Oreamnos*, and they have no close relatives living or extinct in North America. Their nearest living relative is the mountain-dwelling antelope of the Alps, the chamois (*Rupricapra rupricapra*). Other related species are found in the mountains of Asia. The mountain goat is most often differentiated from other mammals by its short, black horns and white hair giving rise to the characteristic beard, "baggy pants" and a prominent crest along neck, back and rump. While the thick hair and wooly underfur keep the mountain goat warm in winter, this animal has other unique functional adaptations. Mountain goats have extremely powerful front shoulders and broad hooves which make them premier climbers. These features enable the mountain goat to negotiate deep snow and rocky, precipitous terrain, and survive cold climates.

Although four subspecies (*Oreanmos americanus americanus, O. a. columbiae, O. a. kennedy*, and *O. a. missoulae*) were recognized at one time, Cowan and McCrory (1970) found no valid reason for recognizing subspecies within *Oreamnos americanus*.

HISTORICAL DISTRIBUTION

Ancestors of our mountain goat apparently evolved in Asia and colonized North America via the Bering land bridge about 2.5 million years ago. While extinct species of *Oreamnos* may have ranged from Yukon Territory to California, the current distribution of mountain goats is similar to historical occurrence (Johnson, 1977). A fossil mountain goat recovered from Lake Washtucna in eastern Washington indicates the environmental conditions or habitat requirements of mountain goats have changed considerably since their invasion during the Pleistocene era. This area is currently flatland and far from mountainous and forested goat range.

Native mountain goats are found in many of the mountainous areas of North America, from southeastern Alaska to south-central Washington in the coastal range and as far south as central Idaho in the Rocky Mountains. The present distribution of mountain goats is depicted in Figure 1.

Fig. 1. Distribution of mountain goats in North America.

Fig. 2. Distribution of Mountain Goats in Washington State.

Mountain goats are native to the Cascade and Selkirk Mountains in Washington (Figure 2) and range over most of the same areas occupied when the first white men arrived. Reports of native mountain goats in the Cascades were documented as early as 1805 and 1806 by Lewis and Clark (Burroughs, 1961), who saw skins and blankets woven from mountain goat wool by Indians. Unfortunately Lewis and Clark used the term "goat" to refer to pronghorn antelope while "sheep" referred to mountain goats along the Columbia River. The type locality for *O. americanus* (Bailey, 1936) is described as "Cascade Range near the Columbia River in Oregon or Washington." Almost certainly these goats were taken in Washington, since Bailey (1936) indicated that there was no authentic record of mountain goat occurrence south of the Columbia River in Oregon. Dalquest (1948) believed the type locality was near Mount Adams. Historic records and other references to distribution since the turn of the century indicate that the native range of mountain goats extended throughout the Cascade Mountains from the Canadian border to Mount St. Helens and Mount Adams. Mount Chopaka, located on the eastern edge of the Cascades near the Canadian border, was historically bighorn sheep range. While a large herd of bighorns was found on Chopaka during the late 1800's, bighorn numbers declined after the turn of the century. Game Department reports indicate the sheep gradually disappeared from Chopaka about 1910-1915. No mountain goats were present when large numbers of sheep occupied Mount Chopaka. Mountain goats immigrated to Chopaka about 1910 from a resident population north of the border in British Columbia.

Goats have been reported as "seemingly a rare wanderer from outside the state" in the Selkirks of northeastern Washington (Dalquest, 1948). Taylor and Shaw (1929:31) [in Hall and Kelson (1959)] and Dice (1919:21) report the historic occurrence of mountain goats in the Blue Mountains of southeastern Washington. Dalquest (1948), however, believed that the reports of goats in the Blue Mountains by Dice (op. cit.) were erroneous. Native mountain goat populations do not currently inhabit either the Blue Mountains or Selkirk Mountains of Washington.

Harvest of mountain goats has changed considerably from their initial exploitation by Indians. Indians killed goats not only for their meat, but also for their hair and hides. Early explorers in the state found that Indians valued the wool of mountain goats for making blankets (Bailey, 1936). Salish Indians from along the Fraser River sometimes hunted goats and traded hides to tribes on the coast. Indians of the Cascades, including Skagits and Wenatchees, gathered goat wool from hillsides during the spring and summer when goats were shedding (Underhill, 1945; Collins, 1974; Thompson, 1970). Lewis and Clark discovered that Indians along the Columbia River made the skin of a goat head (with horns remaining) into a cap and valued it as an ornament (Burroughs, 1961). Indians of the Mount Baker district of Washington made a determined effort to take mountain goats; entire tribes took part in organized goat drives (Brooks, 1930). Early settlers undoubtedly also took mountain goats for their meat and hides, but the rugged terrain occupied by goats probably precluded high utilization except in accessible areas.

CURRENT DISTRIBUTION IN WASHINGTON

Cascade Mountains

Current distribution is nearly identical to historic occurrence (also shown in Figure 2). The only exception is probably on Mount St. Helens where native populations were extirpated.

Population estimates of mountain goats in the Cascade Mountains were made for the first time in 1961 (Table 1). During the recent study, trends in goat numbers have been evaluated and population estimates calculated for some units (see section entitled Population Trends).

In addition to goat populations managed by the state of Washington, four areas of the state have goat populations managed by federal agencies in the Department of Interior (Table 2). No hunting is permitted within any of the national parks but a few are probably taken on the Yakima Indian Reservation.

The North Cascades National Park was established in 1968 and consists of north and south units of the Park as well as the Ross Lake and Lake Chelan National Recreation Areas. Mountain goat hunting is permitted in the two recreation areas but closed in the park interior. Harvest statistics revealed that prior to 1968, slightly over 20 percent of the goat harvest in the state occurred within the current boundaries

Table 1. Mountain goat population Estimates in 1961 (from Wadkins 1962).*

Area No.	Area Name	Number Goats	Closed Area Name	Number Coats	Total
1	Skagit River	400			400
2	North Methow	300			300
3	Okanogan River	300			300
4	Nooksack River	250	Mt. Baker Area	650	900
5	South Methow	200			200
6	North Lake Chelan	300			300
7	South Lake Chelan	250			250
8	Chiwawa River	450	Nason Ridge Area	250	700
9	Glacier Peak	300	Whitechuck and Sauk	250	550
10	Stillaguamish River	250	Long, Dickerman and Whitehorse Mtns.	50	300
11	West Stevens Pass	400	Baring and Groto Mtns.	100	500
12	Snoqualmie	400	Mt. Si and Denny Creek	50	450
13	North Wenatchee Mtns.	225			225
14	South Wenatchee Mtns.	500	Cle Elum River Area	125	625
15	Naches Pass	750	Castle Mountain	50	800
16	Bumping River	475	Timber Wolf Mountain	80	555
17	Packwood	450			450
18	Tieton River	300			300
19	East Ross Lake	150			150
20	West Ross Lake	150			150
21	Stehekin River	150			150
State totals		6,950		1,605	8,555

* The above populations do not include any estimate of the goats on the Yakima Indian Reservation or in Mount Rainier and Olympic National Parks.

Table 2. Goat populations in Washington managed by U.S. Department of Interior.

Area	Jurisdiction	Square Miles	Estimated Population	Source
North Cascades National Park	N.P.S.	1,053	600	Population estimates solicited from each federal agency and published in Johnson (1977).
Olympic National Park	N.P.S.	1,401	700	
Mt. Rainier National Park	N.P.S.	368	400	
Yakima Indian Reservation	B.I.A.	1,643	100	
NPS & BIA TOTALS		4,465	1,800	

of the park. Since 1968, only the two national recreation areas have been open to goat hunting. Mountain goat populations within both parts of North Cascades National Park have declined in some areas (Bruce Smith, National Park Service, pers. comm.).

Mountain goats are native to Mount Rainier and have been plentiful since records of the park's wildlife have been monitored. Current distribution appears to be similar to historic range. Mountain goats within Mount Rainier National Park have been protected since the park was established in 1899. Mount Rainier National Park records (Stan Schlegal, pers. comm.) indicate the mountain goat population has been relatively stable.

Mountain goats are found in only a small area of the Yakima Indian Reservation bordering the Goat Rocks Wilderness. Reports by Bradley (pers. comm.) indicate goats may be expanding their range and increasing in number.

Olympic Mountains

Mountain goats are not native to the Olympic Peninsula but were introduced from three transplants in the vicinity of Lake Crescent between 1925 and 1929. These introductions came from Alberta in 1925 and Alaska in 1927 and 1929. The transplants were made prior to creation of the State Game Department and Olympic National Park. Sportsmen from the Klahhane Club in Port Angeles made the introduction with assistance from the U.S. Forest Service and state of Washington. Ironically, 13 years after initial introduction by sportsmen, Olympic National Park was created in 1938. At that time, the goat population was distributed sparsely throughout the northern half of the Olympic Mountains (Moorehead, 1976).

About 70 to 80 percent of the goat range on the Olympic Peninsula lies within Olympic National Park. During the first four decades after introduction, goats received complete protection. Mountain goats increased in number and dispersed to the east and south (Moorhead, unpub. report). As the population increased, goats colonized ranges outside the park in Olympic National Forest. The increase in goat

numbers in many areas of the forest became significant during the late 1960's and 1970's. By 1981, the goat population had increased to about 700 within Olympic National Park (Hutchins and Stevens, 1981) and 150 outside the park.

Selkirk Mountains

Mountain goats probably inhabited isolated mountains in the Selkirks at various times in recorded history, but they were never numerous or widespread. Dalquest (1948) referred to the sighting of a mountain goat in the Selkirks as a rare wanderer from outside the state.

In the 1960's the Washington Game Department began stocking mountain goats in the Selkirks with three releases of goats from the Cascades. All of these transplants are discussed later in the management section.

GOAT HABITAT

CHARACTERISTICS

Mountain goats occupy diverse habitats but nearly all "goat country" is appropriately described by physiographic rather than elevation or vegetation criteria. These features include steep, rocky cliffs, projecting pinnacles, ledges and an occasional talus slide. Although goat range in Washington is extensive, some areas are much more desirable than others and support much larger populations. Goats also tend to spend much of their life in rather small, localized, highly preferred niches within these habitats. Highly preferred areas are utilized every year, while less desirable areas are frequented only sporadically. Migration patterns and distances vary considerably; some migrations are very short, while in other areas, goats may migrate from 10 to 15 miles or more to find suitable summer and winter habitat.

Mountain goats occupy very wet forested areas in western Washington and some very dry open areas on the eastern side of the state. Each band of goats adapts to very diverse local conditions which vary from region to region.

Throughout North America, mountain goats have adapted to extensive differences in elevation. In some areas goats spend much of the summer above tree-line, while in other areas of Washington goats live in mountains that do not reach tree-line. Mountain goats seem to prefer that narrow band of habitat near tree-line in most of Washington. Throughout mountain goat range tree-line elevations are quite different. Tree-line occurs at about 1,800 meters (6,000 feet) in Washington but ranges to 3,600 meters (12,000 feet) in Colorado. In Alaska, goats have been known to winter at sea level; yet summer range for some goats in Colorado is over 4,000 meters (13,100 feet).

Characteristic mountain goat winter ranges are steep rocky sites with slopes of 40 degrees or more close to diverse forage and cover. The best sites do not usually accumulate more than two feet of snow because of steep slopes or low elevation. While south aspects absorb the most winter sunlight and heat, many goats winter on east or southwest slopes. The elevation of winter ranges is quite variable, depending on local snow accumulation. Mountain goats seek the thermal cover of conifer stands or caves during periods of inclement weather. Mosses and lichens found in the timber can provide forage during extended storm periods.

Mountain goats in Washington frequently occupy a large summer range that is usually not a limiting factor. Summer ranges are large enough that goats can be selective and feed only on the highest quality forages. Deep snow depth forces mountain goats to migrate to lower winter ranges. In most areas, resources in shortest supply occur on winter ranges.

ESCAPE TERRAIN

Mountain goats are more closely associated with rock-cliff habitats known as escape terrain than any other ungulate. Schoen (1979) found that goats frequented broken terrain during all seasons and suggested a year-round preference for escape terrain. Taber and Stevens (1980) also noted that mountain goats rarely stray far from rocky areas unless leaving a range. During the present study we found goats seldom travel more than one-half mile from this habitat. Mountain sheep, on the other hand, frequently forage on rolling grasslands up to two miles from escape terrain. Geist (1971) believes that goats select precipitous terrain to minimize interspecific competition from mountain sheep rather than an avoidance of predators. Klein (1953), however, noted that mountain goats were indifferent to the presence of sheep, but sheep avoided goats. Observations in Washington indicate mountain sheep are far less tolerant than goats of the presence of other species. Mountain goats are the premier rock climbers and tend to remain in the rock cliff habitat even though more nutritious forages are often found in adjacent, less precipitous terrain. During the late spring when goat kids are born, nannies occupy the most precipitous terrain on their range. Since kids are more vulnerable to predation than adults, one would expect greater use of this terrain if escape from predators were a habitat consideration. Also, as Anderson (1940) and others have noted, goats found a long way from escape terrain are invariably mature billies less vulnerable to predation. Escape from predators is believed to be a major reason goats have a strong preference for cliffs and bluffs.

VEGETATION

Vegetation found in goat habitat throughout North America is extremely diverse. Mountain goats in the xeric Pahsimeroi of Idaho utilize curl-leaf mountain mahogany (*Cercocarpus ledifolius*)(Kuck, 1975) while goats in southeast Alaska forage in old-growth conifer forests (Schoen, 1980). These extremes point out the ability of mountain goats to adapt to vegetation that grows in a variety of climates. As mentioned earlier, the vegetation on goat range in wet western Washington is far different from plants found in the eastern part of the state. Furthermore, the vertical migration of individual bands of mountain goats passes through a variety of vegetation zones. In addition, natural events such as avalanches and wildfires create even greater diversity in plant species composition. Most goats in the western Cascades winter in one of the forested vegetation zones; a few in eastern Washington winter on bunchgrass communities. The diversity of plant species found in wintering areas in Washington is described by Olmsted (1978). During the spring, summer and fall, many goats move up to parkland, meadow and alpine zones. Some goats, however, have little if any alpine habitat in their range.

FIRE

Wildfires are natural phenomena that have occurred periodically throughout most goat range in North America. The impact and occurrence of fire, however, varies considerably from alpine to forest

habitats. Goat range in the Rockies, for example, is characterized by large, treeless alpine areas. Mountain goat habitat in the Cascades, however, has few alpine communities (Franklin and Dyrness, 1969). Most of the alpine zone on the Pacific Coast is occupied by glaciers, snow fields, bare rocks, and talus slopes (Douglas and Ballard, 1971). The sparse plant communities found in these areas obviously would not carry a fire.

In the western Cascades, mountain goat winter range is characterized by Douglas fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*). Wildfires have been a frequent occurrence in forests dating back far into prehistory (Loope and Gruell, 1973). Mountain goats obviously evolved with periodic fires and seem to have benefited from their occurrence.

Research shows that following fires, minerals contained in ash from burned organic matter are taken up rather quickly by herbaceous plants, and resprouting shrubs are more nutritious and productive (Lyon and Pengelly, 1970). In addition, the elimination of tall plants allows new growth to be more available as forage than pre-fire plants.

In Idaho (Brandborg, 1955), fires during the 1930's were responsible for increased production of shrubs and prevention of forest encroachment. Brandborg (1955) noted that lack of fire would cause mountain goats to adjust their feeding habits to available forage dominated by conifer overstory or undergo a natural reduction in population numbers. Forage found beneath a conifer overstory is far less nutritious than that found in the open.

During the last 40 years, biologists in Washington State have observed the beneficial impact of wildfires on mountain goat populations. Mountain goats seemed to respond to favorable habitat conditions after a fire with increased productivity. The most dramatic example occurred on Mount Chopaka in north-central Washington. Mountain goats apparently immigrated to Chopaka from native population to the north in British Columbia. From 1910 until 1929, the goat population was very small. This area was apparently marginal range. In 1929, however, a wildfire on Chopaka burned most of the precipitous "goat country." The mountain goat population irrupted following this fire and reached a high of nearly 250 animals in 1941 (Anderson, N. and Crouse, C., pers. comm.). During the following years, goat numbers gradually declined and reached a low of about 60 goats in 1970 (J. King, pers. comm.). Since then mountain goat numbers have been increasing again. A similar mountain goat population irruption occurred on Mount Wardle in Kootenay National Park in British Columbia (DeBock, 1970). Studies in Washington by Douglas and Ballard (1971) and Olmsted (1979) indicate that fire causes substantial and persistent diversity in plant communities. Mountain goat forage studies indicate diversity can be very desirable, especially on winter ranges. Fire suppression has caused range deterioration and loss of quality habitat.

POPULATION CHARACTERISTICS

The primary social unit for mountain goats is a band consisting of one or more nannie(s) and their kid(s), as well as the previous year's offspring. The band is usually small, but sometimes an old nanny is followed by female offspring from previous years with kids of their own. Nannies and kids, along with yearlings and two-year-olds of both sexes, join together in bands of 3 to 50 animals. Adult males, on the other hand, are usually solitary in the summer or are found in small groups of one to five (Brandborg, 1955; Casebeer, 1950; and others). Band sizes also vary with population density and time of year. Mature billies tend to be solitary or form loose associations with other billies. Billies and nannies usually do not form close associations, although they are frequently found on the same range. Mature nannies with kids are the dominant individuals in mountain goat society. Kids, yearlings and two-year-olds of both sexes tend to remain with their mother. Female offspring tend to remain with their mother and retain the band social unit from generation to generation. Nannie-kid bands under the leadership of the dominant nanny select the optimum winter range (Kuck, 1976), while billies and subordinate females tend to occupy secondary ranges. Brandborg (1955) found that 89 percent of the goat populations in Idaho consisted of 50 or fewer animals. This small group size of mountain goats is also found in Washington.

Goat numbers appear to be declining slowly in western Washington, while many populations in eastern Washington have declined precipitously. A variety of factors influences the status of each population. In some cases, a major mortality factor in one population is insignificant in another population. Intensive study of only one population can often lead one to make generalizations not valid in other populations. Since the growth of a population is limited to the requirement in shortest supply, each population has unique forces acting upon it.

POPULATION DYNAMICS

Animal population analysis determines the structure (i.e., age and sex composition) of a population and the forces controlling its past and future (Eberhardt, 1969). Mountain goats have a relatively low biotic potential since they often first breed at a relatively old age and since nannies usually have only one kid per year. In addition, mortality rates are high during the first two years of life. Once past two years of age, however, mountain goats have high survival rates and reproduce until relatively old age. The ratio of young to adults may be a useful indicator of population vigor, but more detailed sex and age classifications are difficult to obtain.

In Washington, Anderson (1940) found no increases in the statewide mountain goat populations after 15 years of hunting closure. Nevertheless, local declines may be directly related to hunter harvest. Goat declines in Idaho have been attributed to excessive hunter harvest (Kuck, 1977), but factors influencing population dynamics are interrelated and often only partially identified or understood.

Age and Sex Classification

The basis of analysis of population dynamics is accurate identification of age and sex as well as population estimates. Sex identification in goats is based on subtle differences in morphology, behavior and urination posture. While mountain goats are sexually dimorphic, the differences are usually identified only by the experienced observer. The horns of male goats have a larger basal diameter, curve more gently backward from base to tip of horn and are somewhat more parallel when viewed from the front. Female goats have horns which are smaller at the base, relatively slender and have less symmetrical curvature. Nannies' horns are straighter than billies for approximately the lower two-thirds of their length and then have a pronounced rearward curve. This "hook" in the nannies' horns is probably the best morphological feature to identify female goats. Urination posture is the most reliable method of sex determination (Hibbs et al., 1969), but requires long observation periods for confirmation. Females urinate in a squatting position with the tail at least partially raised. Males assume a stretch posture with the rear legs extended backwards and slightly splayed (Chadwick, 1973). In addition, females exhibit black vulval patches when the tail is raised which males lack (Nichols, 1978). Many mountain goat surveys are made from aircraft, however, and these require identification based mainly on morphological characteristics. A number of clues are useful in classification of mountain goats. Body shape and size can be quickly evaluated, even from a fast-moving airplane. Adult billies are generally larger and have more massive shoulder muscles than nannies. These distinctions are subtle, however, and unless several animals can be viewed for comparison, classification is difficult. One of the more practical clues of sex identification is group size and presence of kids. Billies occasionally join one of the nanny-dominated bands but stay with them only a short time (Nichols, 1978). During the rut in November and early December, however, billies tend to mingle with the bands, courting estrous nannies. Young males usually remain with nanny-dominated bands until they are 2-1/2 years of age (Chadwick, 1973; Hibbs, 1965). Male mountain goats over two years old are classified as adults (billies) and are frequently solitary animals.

Sex identification is useful but perhaps not as valuable in management as age classification. Kid production and survival of the yearlings are used as indicators of population quality and health. Kids are usually recognized by their small size during their first summer and winter. Yearlings, however, are much more difficult to identify. Male and female yearlings are larger than kids but much smaller than adults. While kids have horns less than four inches long, yearlings have horns over five inches long (about ear-length) by fall. In late winter and early spring yearling goats are difficult to distinguish from two-year-olds and adults. While some investigators (Nichols, 1978; Chadwick, 1973; and others) have attempted to distinguish two-year-old goats from adults, all age identification is subjective and probably subject to errors. The size of goats in some populations is considerably larger than others, and these differences influence age estimation. Mountain goats captured and

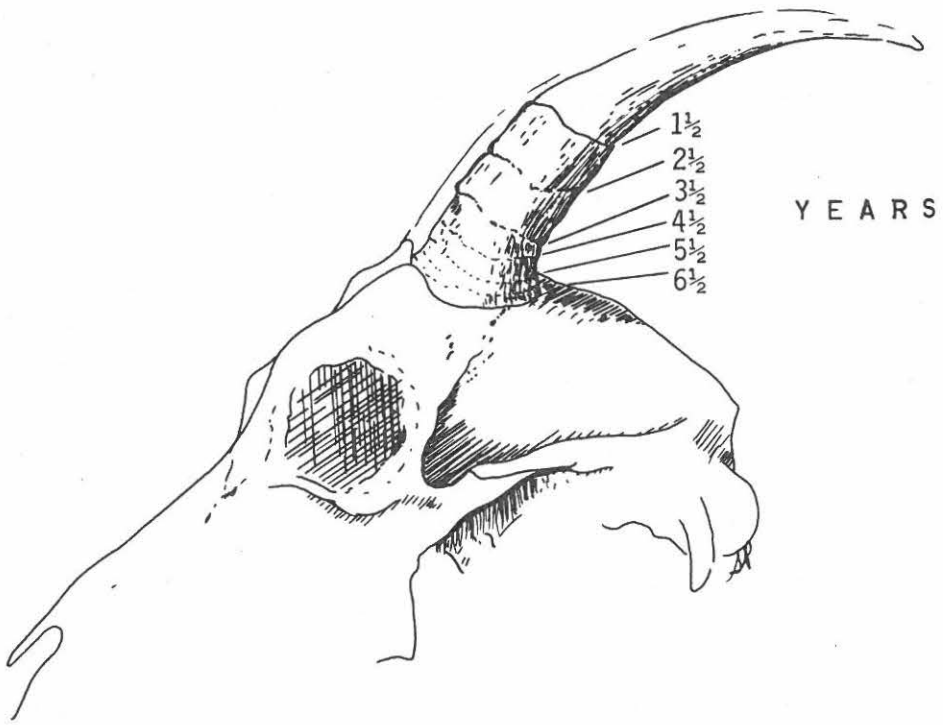

Fig. 3. Horn rings of a mountain goat are used to estimate age.

examined closely enable more accurate age identification. Horn "rings" are formed annually after the first winter and these rings can be used to determine age (Figure 3). Annual rings are formed on the horns as a result of cessation of growth during winter. No ring or sulcus is formed during a goat's first winter as a kid, but one forms after the second summer's growth. A single ring is formed each following year. Horn rings are sometimes indistinct and difficult to interpret. Nevertheless, horn ring counts in conjunction with tooth eruption patterns are invaluable in determining age. Growth between annual rings is also a fairly good indication of a goat's physical condition during any year. Good physical condition and ample forage result in excellent growth between annual rings on horns.

The most reliable method of determining age of mountain goats is dental eruption patterns. Mountain goats do not have a full set of teeth until four years of age. This long eruption period enables fairly accurate identification of age classes during the first four years (Table 3). While premolars and molars are difficult to see on a live animal, the eruption pattern of incisors is a quick and easy age indicator. We have captured many goats during June, July and August in Washington and have assigned ages based on number of permanent incisors. Goats in good condition add one permanent tooth in the dental formula $PI_{123}C_{1}$ for each year of life. While C_{1} is frequently called the fourth incisor, this tooth is technically a canine. Recent studies in Olympic National Park (Johnson and Moorhead, 1982) indicate many younger goats in poor condition have a delayed tooth eruption schedule. For

example, most known-age yearlings did not have their first permanent incisor by mid-July, and most two-year-olds had only one permanent incisor. Both the three- and four-year-old known-age goats had three permanent incisors but five-year-olds had all permanent incisors and canines.

It is evident from this study that poor physical condition can delay tooth eruption schedules and make precise age determination difficult. Complementary use of horn ring counts and tooth eruption sequence, however, can be reliably used to determine age. Since all five-year-old goats have a full set of permanent dentition, this is a key to age determination.

The incisor eruption sequence can be used only for goats up to four years of age, but in most cases the majority of the population is less than four years old. The age of older goats can be estimated from horn ring counts which may suffice for management needs.

Reproduction

Mating

Mountain goats are polygamous, and billies fight to determine dominance. The older dominant billies attempt to breed as many nannies as possible. Breeding occurs during November and early December. Nannies, however, may be receptive for only 72 hours at a time (Chadwick, 1973). Billies may spend a great deal of energy moving from band to band to breed all receptive nannies during the critical period. Occasionally, snowstorms may isolate nannies during this period, which could affect breeding.

Table 3. Tooth eruption pattern in the mountain goat (From Brandborg, 1955). Milk or deciduous tooth-D; permanent tooth-P; parentheses indicates that the tooth is in process of eruption.

	Incisors			Canine	Premolars			Molars		
Age	1	2	3	1	2	3	4	1	2	3
1 week	(D)	(D)	(D)		(D)	(D)	(D)			
6 months	D	D	D	D	D	D	D	(P)		
10 months	D	D	D	D	D	D	D	(P)	(P)	
15-16 months	(P)	D	D	D	D	D	D	P	(P)	(P)
	P									
23 months	P	D	D	D	D	D	D	P	P	(P)
						(P)	(P)			
26-29 months	P	(P)	D	D	(P)	(P)	(P)	P	P	(P)
38-40 months	P	P	(P)	D	P	P	P	P	P	P
48 months	P	P	P	(P)	P	P	P	P	P	P

Nannies as well as billies possess dagger-like horns with which they are capable of killing. Nannies that are not in heat do not tolerate billies' courting and may be aggressive. Geist (1964) and Chadwick (1973) both saw non-amorous nannies strike billies with horn thrusts. Because of offensive weapons both sexes possess, the breeding period can be very hazardous to careless billies, although we saw no goats killed this way.

Breeding Age

The first breeding period for nannies is variable within and between populations. Mountain goats on native ranges sometimes breed for the first time at 2-1/2 years, but often nannies may not breed until 3-1/2 or 4-1/2 years of age (Chadwick, 1973; Foss, 1962; and others). The breeding age of introduced goats may be somewhat lower, since Taber and Stevens (1980) report breeding by yearling nannies in Olympic National Park. Even here, however, most nannies first breed at two or three years of age. In the Olympic Mountains, Taber and Stevens (1980) have found that just under half of the three-year-old nannies have young, but fecundity rates increase to a peak at seven or eight years.

Most billies are apparently capable of breeding at 2-1/2 years of age, but because of dominance in a herd few get the opportunity.

Kid Production

Kids are born from the second week in May to the end of June, with the peak about the first of June. Many investigators describe reproduction in terms of kids per 100 adult females; others express productivity in terms of kids per 100 older goats. In Washington, most classification information for management purposes is obtained from sportsmen and management biologists who have limited time to devote to mountain goats. While there are hazards in interpreting reproductive success from ratios of kids per 100 adults, this information allows detection of large differences in reproduction.

The fecundity of mountain goats appears to be related to availability of quality forage, with native goats having consistently lower reproductive rates than introduced populations. Recently introduced goat populations average 59 kids per 100 older animals, while native populations average only 28 kids per 100 older goats (Bailey and Johnson, 1977). Studies of introduced goats in Colorado (Bailey and Johnson, op. cit.) and in Washington (Taber and Stevens, 1980) indicate reproduction is influenced by density and therefore forage availability. In both cases, increasing demands on forage resulted in declining productivity after initial high levels. Mountain goats respond to forage availability and ultimately reach ecological carrying capacity with their resources.

The incidence of twinning is also variable and seems to be related to habitat quality. Native populations frequently have a lower incidence of twinning than recently introduced goats. In Idaho and Montana, Brandborg (1955) found no twins in over 140 kids observed on native ranges. In Washington, Anderson (1940) found 13 percent incidence of twinning in the Okanogan, and Wadkins (1965) found over 25 percent of the tagged goats on Nason Ridge had twins. Lentfer (1955), however,

reported 3 percent triplets and 30 percent twins for goats introduced in the Crazy Mountains of Montana.

Without individual identification, investigators must be careful in calculating multiple births, however, because one nanny may "babysit" several kids. On June 21, 1977, I saw an old nanny with five kids come to a salt lick on Mount Chopaka. While all of these kids were obviously not hers, she herded all of them away when alarmed. No other goats were visible at the time and she apparently felt responsible for each kid.

Wadkins (1965) tagged 59 goats over four years on Nason Ridge in the Washington Cascades. Reproduction information on one tagged nanny revealed she had three sets of twins and one single kid in four years. Other nannies were less productive, however, and two had no kids at heel. The average kid production during Wadkins' study was less than one kid (0.9) per adult nanny.

Studies by Kuck (1975) indicate excessive hunting pressure on dominant nannies results in decreased reproductive potential. The dominant nannies typically select the steep (over 40-degree slopes), rocky winter ranges, which are sometimes more vulnerable to hunter harvest. New roads being built in mountain goat range provide hunters with easy access to primary winter ranges occupied by dominant nannies. In Idaho, Kuck (1975) found that when hunters overharvested goats, dominant nannies were replaced on primary winter ranges by subordinate individuals from adjacent ranges. Subordinate goats are usually younger with a lower reproductive potential. Since nannies do not normally have their first kid until three or four years of age, many subordinate goats are under reproductive age. Over a period of years, the selective harvest of dominant nannies results in loss of productivity and a declining population.

Population Structure

Age Distribution

The age and sex distribution of a mountain goat population reflects its history. Ages of animals in a population indicate mortality as well as reproductive success. Consistent wide differences between the number of yearlings and kids is indicative of poor kid survival and may be cause for concern. When the age structure of a population is dominated by older animals, the population may be at carrying capacity and have poor recruitment as a result of a series of heavy snowfall winters, or may be declining from excessive hunting pressure, causing low recruitment (Klein, 1970). Inadequate forage may also delay reproduction. When forage quantity was limited for captive and wild deer, Wood et al. (1962) and Klein (1964) reported delayed growth and reproductive maturation. Although there is no scientific documentation showing that limited forage can delay physiological development in mountain goats, introduced populations reproduce at younger ages and have a younger age structure than native populations (Taber and Stevens, 1980; Hibbs, 1965; Hansen, 1950). Intensive studies by Stevens (Taber

and Stevens, 1980) in Olympic National Park revealed that colonizing subpopulations had higher reproduction than interior populations that had reached ecological carrying capacity. Forage availability, therefore, is an important factor influencing reproduction. This productivity is reflected in the percent of kids and yearlings in native and introduced populations (Tables 4 and 5).

Most mountain goat studies have depended upon field classification. While these studies have been very useful in identifying kids and yearlings, the accuracy of these surveys in constructing detailed

Table 4. Population structure of selected mountain goat populations.
Sp = spring S = summer F = fall W = winter

Area and Source	Period	Number Per 100 Adult Females			Number Classified
		Kids	Yearlings	Adult Males	
IDAHO					
Selkirk Range	1950 F	33	—	—	36
Selkirk Range	1951 S	72	24	—	90
Selway River (Brandborg, 1955)	1952 S	56	29	72	97
COLORADO					
Collegiate Range[1] (Hibbs, 1965)	1963, 1964 S	100	84	100	83
MONTANA					
Swan Mountains (Chadwick, 1973)	1973 S	89	78	56	31
Glacier National Park (Chadwick, 1974)	1974 S	58	22	61	517
Glacier National Park (Rideout, 1974)	1969 S	71	14	114	23
Saphire Mountains (Rideout, Op. cit.)	1972 S	77	23	23	69[2]
Bitterroot Mountains (Smith, 1976)	1975 W.Sp.	39	32	87	110
OREGON					
Wallowa Mountains[3] (Vaughan, 1975)	1972 W	30	30	80	24

[1]Goats first introduced in 1948 (Hibbs, 1965)

[2]Schnabel population estimate

[3]Goats introduced from Washington in 1950 (Vaughan, 1975)

population structure must be viewed with skepticism. The distinction between two- and three-year-old females, for example, is nearly impossible, even for the experienced observer. If the number of subadults (two-year-olds included) cannot be identified in the field, then the number of breeding age females cannot be determined. Annual kid production can be assessed accurately only if the proportion of young to breeding-age females can be determined. Another major variable in comparing kid production and survival is time of year when the population is classified. Late spring counts conducted in this study would naturally be higher than summer and winter surveys. During this study, we based our assessment of population structure only on captured animals. Deficiencies of this technique include limited sample size and capture bias. Three areas of the state were sampled to examine goat population structure. Native populations such as those on Mount Chopaka (Figure 4), which were not hunted for nine years, are composed of goats that are relatively old (mean age 3.7 years). Although this population experienced declines during the 1950's and 1960's, mountain goat numbers stabilized in the 1970's and have been slowly increasing in recent years. Seventeen goats (nearly 20 percent) were captured between 1977 and 1980. The mean age of males was 3.3 years and the mean age of females 4.2 years. Kid production

Table 5. Population structure of mountain goats in Washington.
Sp = spring S = summer F = fall W = winter

Area and Source	Period	Number Per 100 Adult Females			
		Kids	Yearlings	Adult Males	Number Classified
Pasayten Wilderness (Anderson, 1940)	1939-1940 S,F,W	75	18	77	151
Chopaka Mountain (Anderson, 1940)	1939-1940 S,F,W	71	4	98	142
Mt. Chopaka (Author)	1977-1980 Sp	60	20	100	17
Lake Chelan (Anderson, 1940[1])	1939-1940 S,F,W	58	11	83	161
Olympic National Park[2] (Moorhead, 1976)	1976 F	80	22	17	113
Barometer Mtn./Mt. Baker (Wright, 1977)	1976 S,F,W	40	17	46	29
Nason Ridge (Author)	1978-1981 Sp	100	86	114	32
Olympic National Forest (Author)	1979-1980 Sp	80	120	20	22

[1]Anderson and many other biologists classified 2 year old goats as adults.

[2]A total of 11 goats were introduced from Alaska and Alberta between 1925 and 1929.

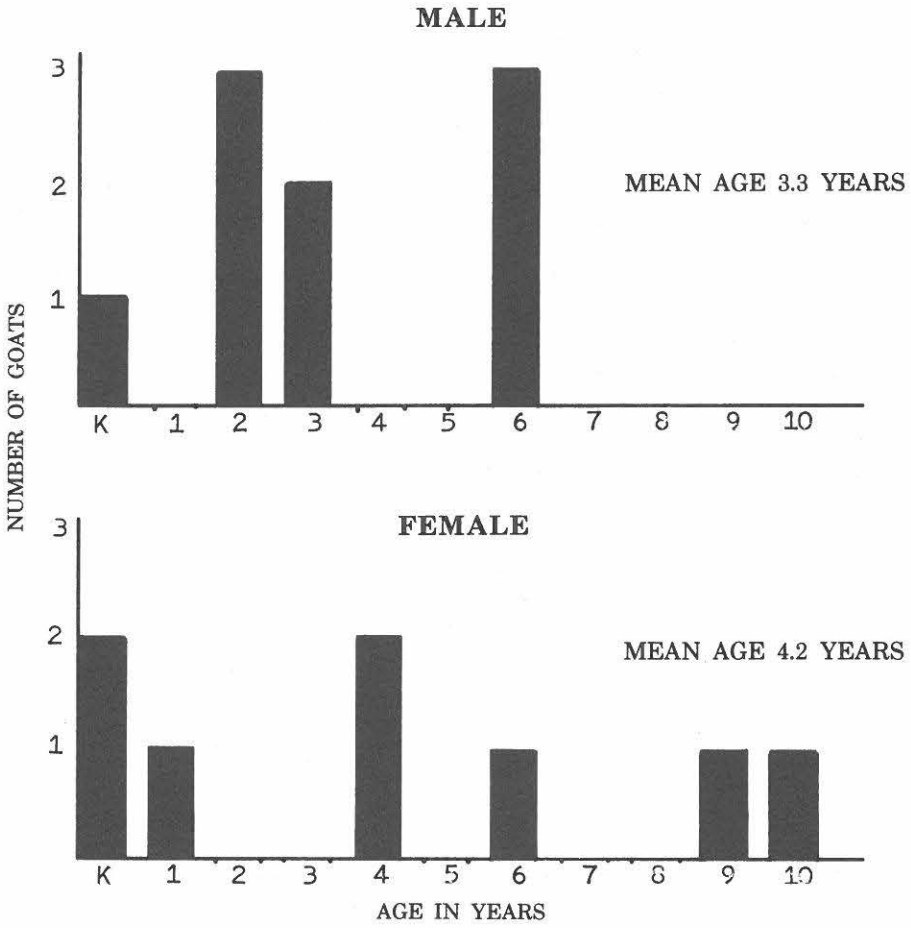

Fig. 4. Population structure of goats captured on Mount Chopaka.

during these three years averaged 60 kids:100 adult nannies (three or more years old). Survival of kids to yearlings has been poor; only 20 yearlings were captured per 100 adult females. In addition, over 62 percent of the females were three years of age or older. Compared to other populations studied, this population has the most older nannies but the poorest kid production and survival.

Gaps in the age distribution reflect years of high mortality or poor reproductive performance. The mortality factors responsible are discussed later, but gaps in age structure appear to follow severe winters (Wadkins, 1967; Chadwick, 1973; Rideout, 1974; Smith, 1976).

The mountain goats on Nason Ridge are also native but have a higher percentage of younger animals. In this case, conservative hunting for several years has probably contributed to a younger age distribution by keeping the population below carrying capacity. Thirty-two goats were captured between 1978 and 1981, and the mean age for both males and females was 2.6 years. Kid production was good, with one associated with every adult nanny captured. Kid survival was good, as indicated by the fact that we counted 86 yearlings per 100 adult

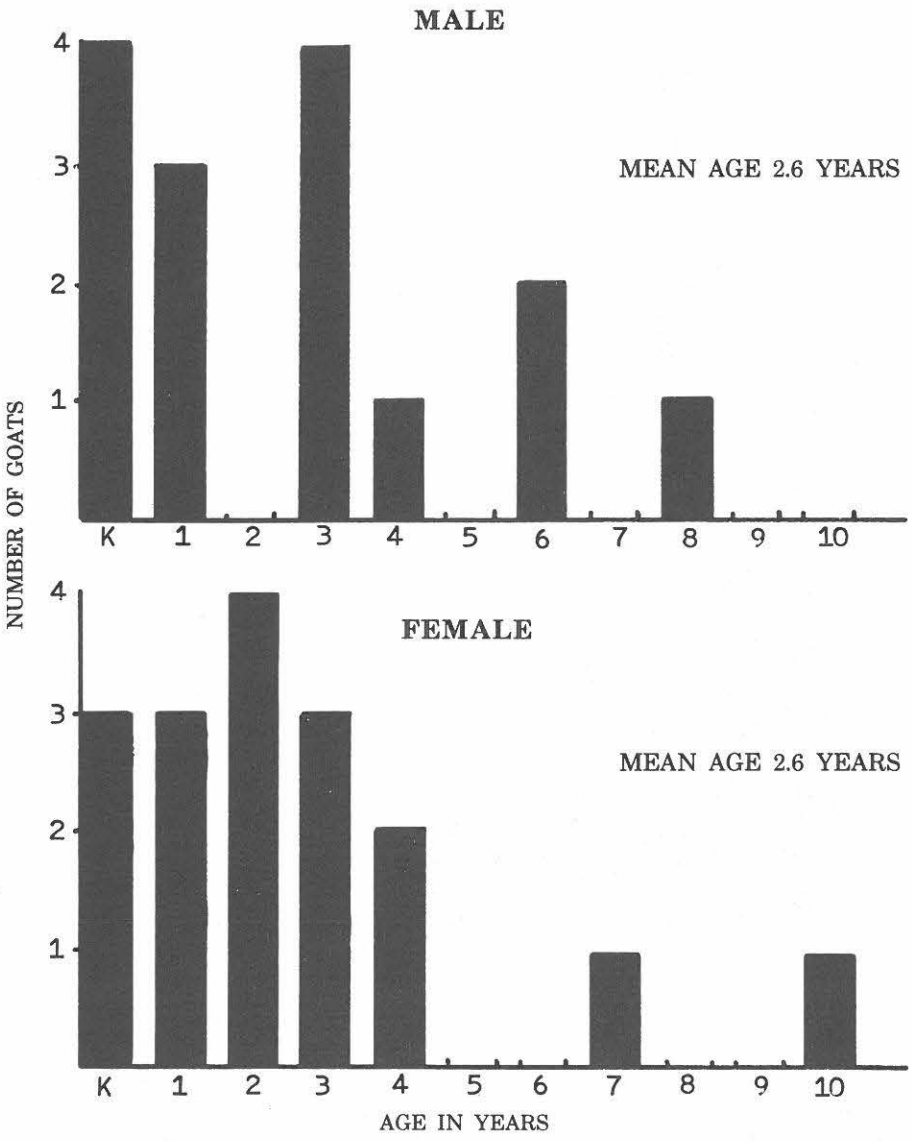

Fig. 5. Population structure of goats captured on Nason Ridge.

nannies in the population. The percent of adult nannies three or more years old was only 41 percent of the female sample, reflecting good subadult survival. The sample size was 32, or about 26 percent of the population.

In the Olympic Mountains, goats were captured during 1979 and 1980 at two sites on the periphery of the major goat population in Olympic National Park. This population of introduced goats has been dispersing from the major population center in the park interior. A few wandering billies have frequented the capture sites on Iron and Charlia Mountain for several years, but an increasing number of nannies and kids now occupy this range. The mean age of 22 goats captured in

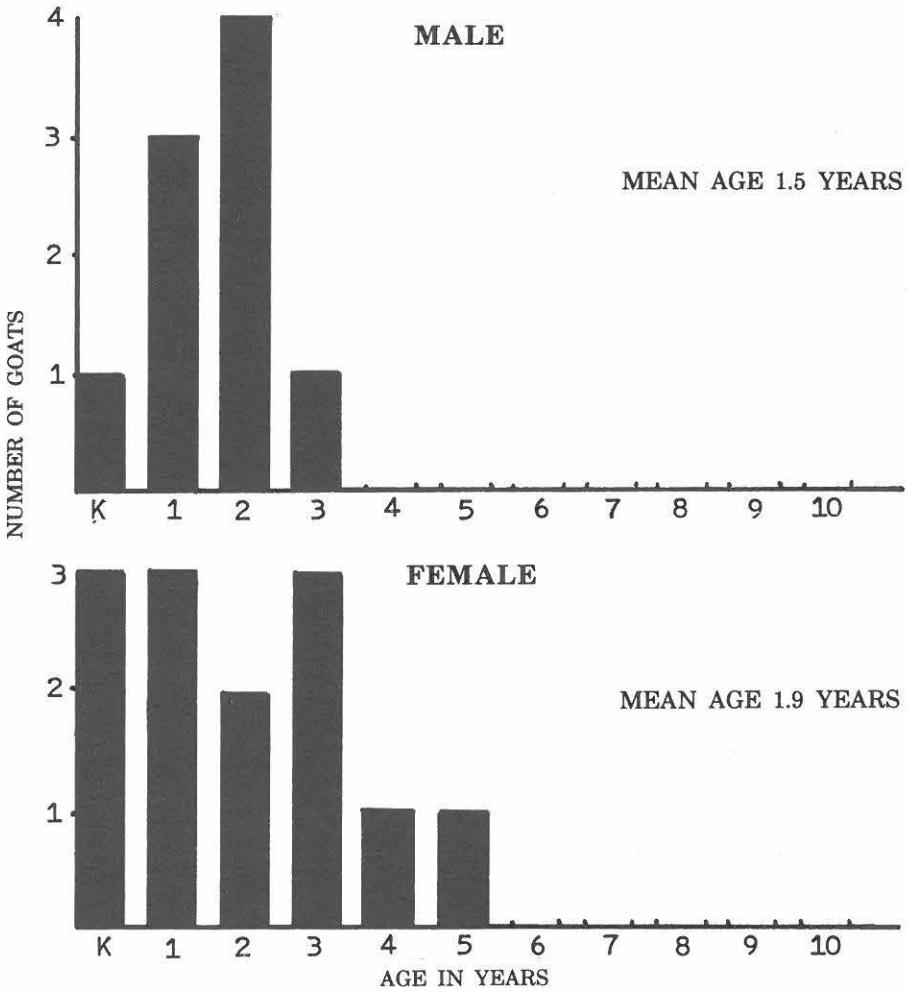

Fig. 6. Population structure of goats captured in Olympic National Forest.

these areas was only 1.7 years (Figure 6). Population dynamics are undoubtedly influenced by these colonizing subpopulations which have emigrated from Olympic National Park. Males averaged only 1.5 years, while females averaged 1.9 years. Although only 38 percent of the female goats were three or more years of age, kid production averaged 80 per 100 adult females, with a ratio of 120 yearlings per 100 females. This age structure is certainly an indicator of high survival of younger animals.

The average life span of mountain goats appears to be quite variable. Seton (1927) reported one goat in captivity lived to be 20 years old. In Olympic National Park, Taber and Stevens (1980) reported the oldest goat lived to be 12 years old, but the average age was seven or eight years. Many goats do not reach this "average age"; Taber and Stevens (op. cit.) calculated that the average age of death among females was 6.1 years, while that among males was 3.5 years.

The average age of hunter-harvested goats is not the same as average life span but this figure can be useful for population management.

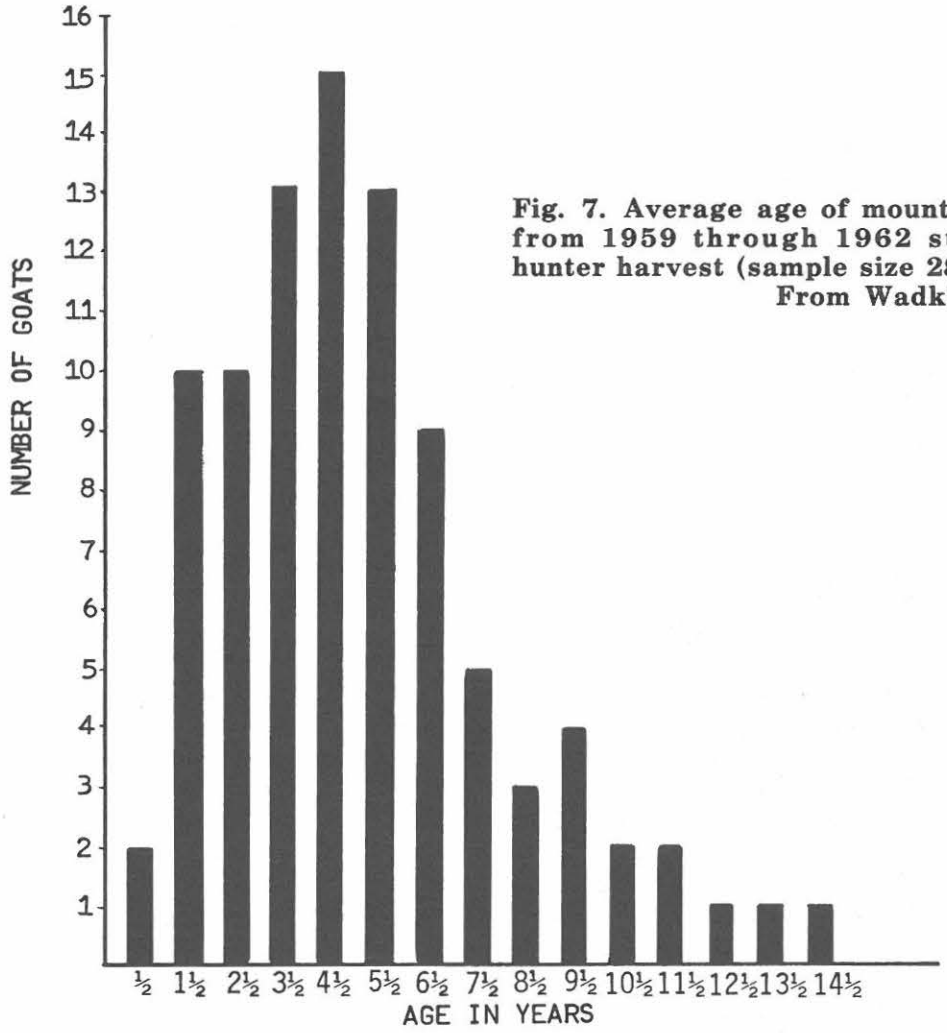

Fig. 7. Average age of mountain goats from 1959 through 1962 statewide hunter harvest (sample size 289 goats). From Wadkins, 1963.

Wadkins (1963) examined 289 goat horns from the 1959 through 1962 hunter harvest and found the indicated mean age to be 5.5 years. The oldest goat was 14.5 years (Figure 7). These data are skewed because kids of the year may not be legally taken, and many hunters select the biggest and oldest goat available. In addition age determinations from horn rings are imprecise.

The age structure of goats in Washington today has been influenced by years of hunter harvest designed to stabilize goats below carrying capacity. In 1941, after hunting closures throughout the state for 16 years, Anderson indicated the population was stable. Kid production (Anderson, op. cit.) remained fairly good, but survival of yearlings was poor in both Okanogan and Chelan Counties. At present, yearling survival is good in two of the three study areas.

The average age of goats in the primary study areas today is much younger than Anderson (op. cit.) found 40 years ago. More "youthful" age structures may reflect the effects of conservative hunting

that reduced populations below carrying capacity, but standing age distributions are difficult to interpret (Caughley, 1977).

Sex Ratio

Mountain goats are polygamous, and the observed sex ratios do not seem to influence productivity. Extensive tagging studies in Washington and elsewhere indicate the sex ratio among newborn kids is nearly fifty-fifty, although this ratio varies from year to year. In Washington, tagging studies indicate an abundance of adult billies on Chopaka and Nason Ridge, but few adult billies in Olympic National Forest. Classification counts of other populations have reflected far fewer billies than nannies (Tables 4 and 5). These surveys, however, are influenced by seasonal variations in billy association with bands of nannies and kids. Billies are more solitary, and their transient lifestyle leads to underrepresentation in classification counts. Males accompany females only in November and December when goats are difficult to classify. Frequently billies occupy more remote habitat and weather conditions preclude accurate classification surveys.

Despite this bias in classification, billies obviously have a lower survival rate than nannies in many populations. In Olympic National Park, Taber and Stevens (1980) found a ratio of 0.5 adult billies to each adult nanny, while outside the park we found 0.2 billies per adult nanny. On Barometer Mountain, Wright (1977) found an adult sex ratio of 0.46 billies to each nanny. Two factors discussed by Wright (op. cit.) are probably responsible for higher natural billy mortality. Males have a lower nutritional state at the onset of winter, following high energy expenditures during the rut, and subordinate status of males relegates them to suboptimal habitat during winter and at other times when food may be limiting.

Despite the low adult billy ratio in the Olympics, this area has high productivity. Mountain goats, especially billies, in the Olympics readily travel between adjacent herds. High billy ratios are apparently not necessary where males from other herds are close to small, nanny-dominated herds.

Mortality

As noted earlier, the greatest mortality in a mountain goat population occurs in the kid and yearling age classes. These animals have neither the experience nor the fat reserves to carry them through stressful periods. While the immediate causes of mortality are often difficult to detect, several important factors have been identified.

Weather

The greatest natural losses occur when adverse weather intensifies susceptibility to starvation, predators, parasites, disease and accidents. Although mountain goat winter range is usually on snow-shedding slopes, deep snow makes forage more difficult to obtain. Mountain goats with access to adequate forage cope with environmental stresses better than malnourished animals. Thorne (1971), working with Rocky Mountain elk, found that if a pregnant female loses more than 10 percent of her body weight, the fetus is likely to die. Other investigators have found that quality of forage during pregnancy determines viability

of the newborn (Arnold and Verme, 1963; Murphy and Coates, 1966; and others). Wadkins (1967) correlated mortality rates with snowpack on Nason Ridge. Above-normal snowpack in the 1964 winter was correlated with a 40 percent loss of kids and a complete loss of yearling goats. Other investigators (Chadwick, 1973; Rideout, 1974; Smith, 1976) have found a similar relationship between deep snowpack and high mortality.

Another mortality factor is weather during the kidding period. Domestic lambs experience high losses when cold rains occur during lambing periods. Brandborg (1955) suggested that cold, wet weather may adversely affect survival of kids during the first weeks of their lives. Art Ryals (pers. comm.) has found prolonged periods of cold, wet weather during June in the Darrington area to be a major mortality factor for kids. While the adult mountain goat is well adapted to survive during adverse weather periods, the young do not have this resiliency, and high losses occur during all periods of stress.

Natural Hazards

Mountain goats are well adapted to their niche, but natural hazards in this habitat result in accidental losses. Avalanche chutes, for example, have greater forage availability than adjacent areas and goats frequently forage there, exposing themselves to periodic avalanches. Brandborg (1955) found snow-slides in the late winter and early spring responsible for more accidental deaths than any other natural cause.

Although mountain goats are sure-footed, they occasionally suffer accidental falls. In several areas of Washington, biologists (Anderson, 1940; Wadkins, 1965; Wright, 1977; Driver and Stevens, 1978) have found goat carcasses at the bases of cliffs. In 1980 a photographer attempted to take a picture of a goat on Coal Creek Bluff near Packwood. The goat spooked, fell and broke its neck on the road below.

Mountain goats exhibit a variety of aggressive displays to communicate and to establish dominance. Occasionally, intraspecies aggression results in injury, but rarely in death. The only time when aggression has been known to result in mortality is when similar-sized billies fight for dominance during the rut and when more than one goat is confined in a trap. Seton (1927) cited a fight between two billies in which one of the animals was killed. Lentfer (1955) cited an example where a nanny killed a yearling in a trap. Geist (1967) described a fight in a trap where an old nanny stabbed a three-year-old billy 33 times, until he became unconscious. One of the goats transplanted to Mount Pilchuck in Washington immediately attacked a hiker–apparently in response to nearly 12 hours of confinement. Numerous goats, particularly billies, have scars reflecting aggressive encounters, but it has not been documented that the injuries from these encounters result in death.

Predation

Cougars (*Felis concolor*), golden (*Aquila chrysaetas*) and bald eagles (*Haliaeetus leucocephalus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*) and black bears (*Ursus americanus*) are potential predators in Washington. Rideout and Hoffman (1975) found the cougar to be the most important predator of mountain goats in Montana. In Alberta

(Holroyd, 1967), a hunter watched a cougar spring upon and kill a goat. The cougar was on a cliff above the goat, blocking its way to escape terrain. Holroyd (op. cit.) reported that the goat kept trying to make its way up into the cliffs until, coming too close to the cougar, it was sprung upon and killed. Since the cougar is particularly adapted to ambush prey from cliffs, and since goats nearly always run uphill to escape from predators (including man), the cougar is potentially the most efficient goat predator in Washington. Cougar populations have increased in Washington since repeal of the bounty law in 1960 and adoption of conservative cougar hunting seasons. Cougar populations have increased on many goat ranges. During the 1976 hunting season, goat hunters found four goat carcasses on Cougar Divide near Mount Baker that they believed were killed by a cougar. Tracks of an adult cougar and two kittens were found at each carcass. Whether the cougar scavenged the goats or made the kills was not determined, but circumstances indicated probable predation. Incidents of cougar predation on mountain goats have also been reported by Cowan (1944), Young and Goldman (1946), Cowan and Brink (1949), and Hornocker (1970). Brandborg (1955) speculated that a cougar could make serious depredations on a small, isolated band of goats. Considering their hunting technique and their population increases on some goat ranges, cougars could be a serious mortality factor on isolated populations.

Both golden and bald eagle predation on juvenile mountain goats is well documented in the literature. Anderson (1940) saw a golden eagle knock a yearling goat off a cliff on Mount Chopaka. The yearling regained its footing on a ledge only 10 feet below, however, and escaped. Anderson also saw an eagle attack a mature billy on Mount Chopaka. The billy saw the eagle in time and jumped back so it received only a light blow. Brandborg (1955) saw a bald eagle carry away a kid, and Smith (1976) reported successful golden eagle attacks on kids. Many observers have noted that goats assume a squatting position or lean tightly against a cliff when eagles circle or harass them. Eagles obviously attack goats and undoubtedly are occasionally successful. The impact of this predation varies by area in response to local circumstances. Most successful eagle attacks appear to be on kids shortly after birth. Although eagles attack older goats occasionally, the incidence of mortality resulting from these attacks is probably low.

Coyotes occur on most mountain goat ranges in North America, but steep, rocky, mountain goat terrain is not easily negotiated by coyotes. Smith (1976) and Rideout (1973) have reported single coyotes harassing nannies and kids in Montana. Brandborg (1955) examined 960 coyote scats in Idaho and Montana and found 19 percent contained goat hair. In Washington, Anderson (op. cit.) found goat hair in 17 coyote scats but could not determine if coyotes actually killed goats or merely fed upon some that died from other causes. Residents along east Stevens Pass report packs of dogs (*Canis familiaris*) take goats in deep snow in mid-winter. Mountain goats would be vulnerable to coyotes or dogs if they were in deep snow away from escape terrain. As previously noted, however, goats seldom leave the security of rocky cliffs. Coyotes are opportunistic, and have been seen chasing goats in many areas.

Very likely, coyotes "test" the goat to determine if it is weak or ill or if other conditions exist that would make it an easy victim. In general, I believe the incidence of coyote predation on goats is low.

Holroyd (1967) cites an unsuccessful attack by a grizzly bear (*Ursus horribilis*) on a goat in Banff Park, Canada, but Brandborg (1955) and Smith (1976) did not consider bears to be serious predators on goats. No cases of bobcat or lynx predation have been documented on goats, although occasional incidents probably occur. Many biologists believe bobcat, lynx and bear take few healthy mountain goats.

Parasitism

The incidence of mortality resulting from parasitism or disease of mountain goats has never been evaluated. Brandborg (1955) and Cowan (1951) documented the presence of several internal and external parasites. Brandborg thought parasites and disease could contribute to mortality during critical winter periods when goats suffer from malnutrition. Recent studies and observations in Washington indicate parasitism and disease may be more important than previously realized.

Art Ryals of Darrington, long-time goat authority, related an example of mortality resulting from parasitism in the early 1970's. Ryals took a hunter into the Goodman Creek area in 1971, and the hunter took a billy heavily infected with roundworms. The next year Ryals began placing phenothiazine (deworming) salt blocks in the Goodman goat range. The following year 80 percent of the nannies in the treated area produced kids which survived, while a goat herd in an adjacent area (Clear Creek) experienced 100 percent kid mortality. The goats in the non-treated area had high roundworm levels, which apparently caused the high mortality of kids (Art Ryals, pers. comm.). In 1978, goat hunters in the Darrington area complained that goats were heavily parasitized. A goat from this area that was road-killed in August 1979 was taken to Dr. Bill Foreyt of Washington State University's School of Veterinary Medicine for necropsy. Foreyt found extremely heavy parasite loads and suggested that if similar burdens were widespread, high mortality would be experienced. In April 1980, two goats were collected on White Chuck Mountain and were also found to be heavily parasitized (see section entitled Disease and Parasites for species and abundance.)

The contribution of internal parasitism to mortality of mountain goats is difficult to evaluate on a statewide level. It is apparent that some populations carry high parasite loads and, during stressful periods, experience high mortality. Mountain goat kids have little, if any, fat reserves or ability to withstand high parasite infections. The eight-month-old kid collected on White Chuck Mountain in February had high parasite loads and weighed only 48 pounds. High internal parasite levels undoubtedly exacerbate declines in animal condition during stressful periods and contribute to mortality. Young of the year are most susceptible to parasite infections.

External parasites are not believed to be a major mortality factor, but many goats harbor high tick (*Dermacentor andersoni*) infections during the early summer shedding period. During this period, however, forage is usually of high quality and most goats manage to tolerate

ticks. Goats with high tick infections (over 20 ticks) lose a substantial amount of blood, severely draining the hosts' energy reserves.

Harvest

In the last few years goat hunting has become much more restrictive in nearly all states and provinces (Johnson, 1977). The history of over-exploitation in the Kootenays (Foster, 1978) is typical of many goat ranges in North America. In most cases, uncontrolled access has allowed overharvest of local populations. A policy limiting the kill to less than 5 percent of the population has been established in Washington, British Columbia (Bone, 1978), and Alberta (Hall, 1978).

While mountain goats ultimately depend on available food supply, their primary ranges are dictated by physical characteristics of the range. Adult nannies select those winter ranges known as primary winter range, characterized by steep, rocky cliffs which shed snow (Smith, 1976; Chadwick, 1974; Peck, 1972; Brandborg, 1955). Because older nannies are aggressive and dominate goat society (Thompson and Guenzel, 1980; Chadwick, 1977; Kuck, 1977), they are able to force subordinate goats, including billies, to winter on adjacent, less desirable range.

Kuck (1980) found that when exposed to exploitation, harvested dominant nannies were replaced on their winter ranges by subordinate goats from adjacent ranges. Remaining goats did not benefit from better forage availability on winter ranges because they continued to use the same primary winter ranges. Kuck (op. cit.) concluded that harvest mortality in Idaho was largely additive and not a form of compensatory mortality. In British Columbia and Alberta (Hebert and Turnbull, 1977; Youds et al., 1980) biologists concluded that mountain goat harvests are additive to other mortality. As an example, Kuck (1977) found a population decline resulted from a harvest rate of 12 to 13 percent of the adult population. Youds et al. (1980) assumed that hunter take as additive and, coupled with natural mortality, would result in a total mortality of 20 percent of the adults. Given their reproductive potential and the normal survival rate of kids, mountain goat populations cannot compensate for this level of mortality.

The sex composition of the harvest also influences population structure. In Washington, the harvest has averaged 49 percent billies since goat hunting was initiated in 1948 (Table 6). As Brandborg (1955) observed, the harvest of a nanny with kid frequently results in the loss of the kid. No studies have adequately documented this relationship, but the loss of a nanny during the autumn undoubtedly reduces her kid's chances to survive the upcoming winter. In 1977, the Washington Game Department urged hunters to refrain from shooting nannies with kids. Since then, the sex ratio of harvest has favored billies every year (Table 6). Classification counts in the Olympics indicates one billy can successfully breed several nannies. The harvest of billies, within limits, should not be detrimental to productivity, but must be monitored carefully.

The Washington mountain goat harvest has remained fairly consistent on a statewide basis for several years, but fluctuations occur annually from unit to unit.

The extent of unlawful take of mountain goats is difficult to document. Goat hunters in Washington are allowed to kill only one goat and cautioned to shoot a goat only where it can be retrieved. Brandborg (1955) assumed that 30 percent of the legal harvest could be added to the kill in the form of crippling loss and illegal kill. Obviously, crippling loss and poaching must be considered when setting harvest quotas.

Table 6. History of Mountain Goat Harvest by Sex

Year	Billy	Nanny	Sex Unknown	Percent Billy	Total Goats
1948	27	26	2	51%	55
1949	25	56	1	31%	82
1950	45	53	1	46%	99
1951	17	37	2	31%	56
1952	31	39	1	44%	71
1953	21	23	1	48%	45
1954	17	28	9	38%	54
1955	39	62	2	39%	103
1956	36	40	1	47%	77
1957	99	106	1	48%	206
1958	88	110	1	44%	199
1959	91	100	0	48%	191
1960	134	136	0	50%	270
1961	132	134	4	50%	270
1962	129	134	2	49%	265
1963	161	127	1	56%	289
1964	151	190	3	44%	344
1965	186	200	5	48%	391
1966	179	161	7	53%	347
1967	142	163	4	47%	309
1968	164	172	3	49%	339
1969	148	177	1	46%	326
1970	153	186	1	45%	340
1971	148	166	2	47%	316
1972	110	141	2	43%	253
1973	131	135	0	49%	266
1974	136	132	4	51%	272
1975	121	116	1	51%	238
1976	144	143	1	50%	288
1977**	143	143	1	52%	276
1978	164	118	0	58%	282
1979	114	108	0	51%	222
1980	153	112	4	57%	269
1981	145	128	1	53%	274
TOTAL	3724	3891	69		7684
AVERAGE	110	114	2	49%	226

**Starting in the 1977 Mountain Goat, Sheep, and Moose Hunting Seasons Pamphlet the Game Department has urged hunters to refrain from shooting nannies with kids.

PHYSICAL CONDITION

Many wild animals, and mountain goats in particular, exist for several months of the year under extremely adverse conditions. The mountain goat remains on the icy and desolate crags during the harshest winters when forage is scarce. The physical condition of most big game animals fluctuates annually with forage quality and availability. Excellent forage is available in the spring and summer, and most animals are in good condition. During the winter, however, forage quality and availability are poor and many animals use fat reserves accumulated during the summer. Consequently, mountain goats gradually lose weight during the winter. Body weight is a dependable indicator of physical condition. If goats fail to build up adequate fat reserves by summer or if they cannot find sufficient forage during winter, they become malnourished and more vulnerable to mortality.

Anderson (1940) captured a newborn kid on Island Mountain in the Pasayten Wilderness that weighed only 6.5 pounds. Large billies, on the other hand, weigh as much as 242 pounds (Table 7). Sixteen mountain goats were weighed on Mount Chopaka (Table 7) during

Table 7. Weight of mountain goats captured on Mount Chopaka June and July, 1977-1980.

Age	Tag No.	Date	Weight (lbs.)	Mean For Age Class
		MALE		
3 wks.	173	6/25/79	30	30
2 yrs.	408	6/23/77	125	
2 yrs.	144	6/26/79	170	145
2 yrs.	145	6/27/79	140	
3 yrs.	411	6/24/77	171	183
3 yrs.	413	7/17/77	194	
6 yrs.	412	7/17/77	242	206
6 yrs.	419	7/8/80	170	
		FEMALE		
3 wks.	142	6/21/77	14	37
6 wks.	440	7/15/79	59	
1 yr.	410	6/23/77	77	77
4 yrs.	177	6/25/79	150	157
4 yrs.	146	7/15/79	163	
6 yrs.	143	6/26/79	148	148
9 yrs.	407	6/21/77	161	161
10 yrs.	406	6/21/77	167	167

June and July. Mountain goats usually gain weight from May through September, so the weights are intermediate between high and low for the year. Average weights were similar to goats weighed at the same time of year in Montana (Lentfer, 1955). Chopaka goats in the one- to three-year age classes are slightly heavier, but older goats weigh much the same. The weights are useful for comparison to goat weights obtained during he winter.

Brandborg (1955) picked up a seven-month-old kid that had starved to death; it weighed only 25 pounds. He also reported examining in late winter a three-year-old billy that weighed 60 pounds and a four-year-old nanny that weighed 67 pounds. On White Chuck Mountain, Washington, two nannies and a kid were collected during winter (February). The 3-1/2-year-old nanny weighed 83 pounds; the 6-1/2-year-old, 98 pounds. These weights suggest a weight loss of approximately 30 percent, compared to goats on Chopaka during June and July. The ten-month-old kid weighed only 48 pounds.

The emaciated goats collected on White Chuck were heavily parasitized, which probably contributed to their low weights. Bone marrow analysis also revealed poor bone marrow fat reserves. Hunters in the White Chuck unit report taking heavily parasitized and "stunted" goats, so year-round weights of nannies may also be comparatively low in this area.

The physical condition of goats removed from Klahhane Ridge in Olympic National Park during 1981 indicates the goats have been affected by recent habitat deterioration. Mountain goats are overcrowded on Klahhane Ridge and are affecting the vegetation on summer range. Tory Stevens (pers. comm.) has found that goats from this herd weigh less than goats from other areas of the park. Subadult goats in particular weighed much less than goats weighed on Chopaka during the same time of year. Subadults weighed 20 to 30 percent less than Chopaka goats, but weights of adult goats appear to be similar.

FOOD HABITS

Anderson (1940), studying goats in the Pasayten Wilderness of Washington, and Casebeer (1948), in western Montana, both found mountain goats prefer grasses in the winter and shrubs in the summer. Saunders (1955) found grasses, sedges (*Carex* spp.) and rushes (*Juncus* spp.) were preferred forage species during all seasons in the Crazy Mountains of Montana. In the Black Hills of South Dakota, Harmon (1944) found goats subsisting primarily on mosses and lichens (*Usnea* spp.) during the winter and spring. Brandborg (1955) found bunchgrasses (*Agropyron* spp.) and mountain mahogany (*Cercocarpus ledifolius*) were the key forage items in the Salmon River area of Idaho. In the Pahsimeroi of Idaho, Kuck (1970) found mountain mahogany and big sagebrush (*Artemisia tridentata*) were the key winter forage items. Hibbs (1967) found grasses and grass-like plants composed the greater part of a mountain goat's diet throughout the year in Colorado.

These studies indicate that goats have generalized food habits. Also, each particular goat population may depend upon certain key forage items or a combination of forage species that varies with phenological succession or snowpack. In recent years, microhistological analysis of forage items in goat fecal pellets has made food habit studies easier to conduct and more quantifiable. During the last four years, a food habit study was conducted on Chopaka Mountain in cooperation with the Bureau of Land Management. Although every goat herd in the state appears to have somewhat different food habits, we identified some of the more important factors that influence forage preference.

Chopaka Mountain Study

Study Areas and Methods

Chopaka Mountain is located in north-central Washington, approximately 24 kilometers west of Oroville. Nearly 71 percent of the Chopaka goat range is administered by the Bureau of Land Management, with the Washington Department of Natural Resources administering 25 percent, and private lands totaling less than 4 percent. The goat range is about 2,400 hectares in size, and elevations range from 360 meters in the Similkameen Valley to 2,388 meters on the top of Chopaka Mountain. Annual precipitation totals vary from 65 centimeters at the crest to 38 centimeters at the lower elevations. Snowpack averages 2 to 3 meters at the top, but only 0.5 meters on the lower range. The topography on the east face, the principal goat range, is characterized by steep cliffs interlaced with sharp, steep draws and hogback ridges. Geologically, Chopaka Mountain is part of the eastern Cascade slopes, although it borders the Okanogan Highlands and shares similar rock formations.

The last major fire on Chopaka occurred in 1919, when much of the mountain burned. The area did not burn evenly, however, resulting in a diversity of unburned and successional plant communities. The lower elevations are dominated by an open forest of ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and

bunchgrass (*Agropyron* spp.) communities. Subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), and whitebark pine (*Pinus albicaulis*) grow at high elevations. Bunchgrass communities dominate the developed soil sites, while shrubs are found near rock slides on poorer soils. The diversity of plant species occurring in the study area is described by Olmsted (1978). Common grasses include bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), pinegrass (*Calamagrostis rubescens*), Sandberg's bluegrass (*Poa sandbergii*), and cheatgrass (*Bromus tectorum*). Some of the more common shrubs are buffaloberry (*Shepherdia canadensis*), currant (*Ribes* spp.), sagebrush (*Artemisia* spp.), serviceberry (*Amelanchier alnifolia*), Oregon grape (*Berberis nervosa*), ninebark (*Physocarpus malvaceous*), and snowbrush ceanothus (*Ceanothus velutinus*).

Food habits of mountain goats were determined from fecal pellet analysis. We collected fecal samples from sites where mountain goats were seen during winter (January-March), spring (April-June), summer (July-September), and fall (October-December). All fecal samples were gathered in the Anderson Creek drainage after observing goats at a specific site. During winter and spring, fecal samples were collected at elevations of 450 meters to 1,200 meters, while summer and fall collections were made in the area from 1,800 meters to 2,300 meters. Those fresh fecal pellets conforming to the shape and size of mountain goats (Murie, 1954) were collected quarterly from the winter of 1977 to the fall of 1980.

Plant voucher microscope slides and fecal microscope slides were prepared according to Davitt and Nelson (1980) at the Wildlife Habitat Laboratory, Washington State University, Pullman, Washington. Food habits were determined utilizing cover rather than frequency as the sampling criterion as described by Davitt (1979). Diets were also summarized by season and year for analyzing sources of variation. Similarity of seasonal food habits was calculated using Kulcyznski's (Oosting, 1956) similarity index.

Forage Consumed

Fifty-four major plant species were identified as forage items in the diets of mountain goats on Chopaka Mountain. Table 8 lists the major forage species. Throughout the four-year study, grasses were the most commonly consumed forage. Shrubs were second, with conifers and forbs a distant third and fourth, respectively.

Seasonal forage items are summarized in Table 9. On the average, grasses were the most preferred forage in the spring, summer and fall, while almost equal amounts of grass, shrubs, and conifers were present in the diet during the winter. Although 10 grasses were identified in diet analysis, the most common grasses year-round were bluebunch wheatgrass, Idaho fescue, bluegrasses, pine grass, and sedges, in that order.

Twenty-three different shrubs were identified. The most common shrubs included buffaloberry, currant, sagebrush, serviceberry, snowbrush ceanothus, Oregon grape, and mallow ninebark, in that order.

Conifers were not differentiated in the diet, except for common juniper (*Juniperus communis*), which was only a minor forage item. The

major conifers in the area are Douglas fir, ponderosa pine, subalpine fir, western larch (*Larix occidentalis*), lodgepole pine, and whitebark pine. Conifer use was high during some winter periods, but the volume of conifers consumed could not be directly related to snow-pack or moisture.

Although forbs were the fourth most abundant forage class, no one species was highly preferred over the others. Seventeen different forb species were identified; preferred species included bigleaf sandwort

Table 8. Major forages in the diet of mountain goats on Chopaka Mountain, Washington in 1977, 1978, 1979 and 1980.

	Percent forage species by year				
	1977	1978	1979	1980	4-yr. Avg.
Grasses and grasslike	44	34	40	50	42
Bluebunch wheatgrass	10	16	20	16	16
Idaho fescue	20	8	2	6	9
Bluegrass	9	5	5	10	7
Pinegrass	0	1	4	8	3
Sedges	5	1	3	4	3
Other grasses	0	3	6	6	4
Shrubs	44	40	25	19	32
Buffaloberry	3	5	10	6	6
Currant	4	8	4	1	4
Sagebrush	4	5	3	0	3
Serviceberry	5	3	0	2	2
Snowbrush ceanothus	5	3	1	2	3
Oregon grape	3	1	2	1	2
Other shrubs	20	15	5	7	12
Conifers	3	13	22	19	14
Forbs	5	12	13	11	10
Bigleaf sandwort	0	1	3	1	1
Yarrow	0	1	2	1	1
Penstemon	0	1	1	1	1
Moss campion	1	1	0	1	1
Stonecrop	1	1	0	0	0
Mullein	0	1	1	0	0
Wild strawberry	0	1	0	0	0
Other forbs	4	5	6	7	6
Lichen	1	1	0	1	1
Unknown	3	0	0	0	1
Total	100	100	100	100	100

(*Arenaria macrophylla*), yarrow (*Achillea millefolium*), penstemon (*Penstemon* spp.), moss campion (*Silene acaulis*), stonecrop (*Sedum* spp.), mullein (*Verbascum thapsus*), and wild strawberry (*Fragaria* spp.). A variety of others were found in very small amounts. Lichens occurred in most of the samples, but never in substantial amounts.

Mountain goat food habits varied considerably between 1977 and 1980, even though winter weather was relatively mild all four years. Snowfall at the nearest recording station (Toats Coulee) was highest

Table 9. Seasonal forages in the diet of mountain goats on Chopaka Mountain, Washington. (1977-80)

	Percent Forage by Season				
	Winter	Spring	Summer	Fall	Year-round
Grasses and grasslike	31	47	44	47	43
Bluebunch wheatgrass	13	16	18	17	16
Idaho fescue	7	11	4	9	8
Bluegrass	7	8	5	8	7
Pinegrass	2	4	4	5	4
Sedges	1	3	6	4	4
Other grasses	1	5	7	4	4
Shrubs	37	29	29	30	31
Buffaloberry	5	4	9	6	6
Currant	5	7	1	4	4
Sagebrush	3	1	7	1	3
Serviceberry	4	2	0	4	3
Snowbrush ceanothus	6	2	1	1	2
Oregon grape	2	2	0	1	1
Other shrubs	12	11	11	13	12
Conifers	28	14	6	9	14
Forbs	3	8	20	14	11
Bigleaf sandwort	0	0	4	2	2
Yarrow	0	0	3	2	1
Penstemon	0	1	2	1	1
Moss campion	1	1	0	1	1
Stone crop	1	1	0	1	1
Mullein	0	0	1	0	0
Wild strawberry	0	0	0	1	0
Other forbs	1	5	10	6	5
Lichen	1	1	1	0	1
Unknown	0	1	0	0	0
Total	100	100	100	100	100

in 1978 and lowest in 1977, but during all four years snow-pack was below average.

We noted substantial inter- and intraseasonal variability in mountain goat forage preferences. Table 10 summarizes intraseasonal variation in mountain goat diets between 1977 and 1980. Intraseasonal diet similarity indices during the years 1977, 1978, 1979, and 1980 ranged from 22 to 67 percent. The fall diet of mountain goats had the least (39 percent) overlap, while winter, spring, and summer diet similarities were all close to 50 percent. Thus, plant species in mountain goat diets have about 50 percent diet overlap within each season.

A comparison of mountain goat diets between seasons shows similar

Table 10. Intraseasonal variation of seasonal Mt. Goat diets between 1977-1980, Mt. Chopaka, Washington.

Source	Kulcyznski's Similarity Index
Winter	
1977 vs. 1978	52.4
1977 vs. 1979	22.9
1977 vs. 1980	39.2
1978 vs. 1979	43.1
1978 vs. 1980	62.4
1979 vs. 1980	67.0
mean ($\bar{x}$)	**47.8**
Spring	
1977 vs. 1978	51.7
1977 vs. 1979	39.6
1979 vs. 1980	45.7
1978 vs. 1979	44.3
1978 vs. 1980	54.1
1979 vs. 1980	60.9
mean ($\bar{x}$)	**49.4**
Summer	
1978 vs. 1979	54.0
1978 vs. 1980	46.2
1979 vs. 1980	54.8
mean ($\bar{x}$)	**51.7**
Fall	
1977 vs. 1978	38.4
1977 vs. 1979	28.3
1977 vs. 1980	36.7
1978 vs. 1979	41.2
1978 vs. 1980	45.0
1979 vs. 1980	43.8
mean ($\bar{x}$)	**38.9**

overlap (Table 11). Winter and spring diets were most similar (38.1 percent overlap). These results show that diet overlap is close to 50 percent both within and between seasons.

Forage Variability

The most predictable feature of mountain goat diets is their variability. Kulcyznski's similarity index of mountain goat diets in this study documents considerable inter- and intraseasonal variability. The diet overlap of Rocky Mountain bighorns in Colorado (Cooperider et al., 1980) is similar, but mountain goats appear to have a more diverse diet. Food habit observations by Forest Service biologists in Washington (Bartleme, 1981; Ball, 1981) indicate that forage items differ substantially from population to population. While grasses and shrubs were the primary forage items throughout the year on Chopaka Mountain, diet preferences differed markedly between sampling periods. Mountain goats consume a generalized diet, and forage preferences seem to change within the season almost as much as from season to season. Mountain goat selection of foraging areas appears to be largely based on topographical features rather than forage species actually present.

Mountain goats occupy diverse habitats subjected seasonally to extended periods of harsh environmental conditions. Several factors appear to influence the forage items consumed, but the most important of these appears to be the microhabitats within goat range topography. A few highly preferred sites are extensively used, while adjacent, less desirable sites receive little, if any, use. There appears to be some plant selectivity within these preferred sites, but plant presence appears to generally dictate the forages consumed.

Mountain goat movement and migration patterns are influenced by storms, snow pack, and even minor weather disturbances. Vertical migrations for goats are most common, with upper parts of the range being summer range and lower elevations winter range. These designations, although generally appropriate, do not account for occasional vertical movements of goats to favorable foraging areas. For example, goats may climb to higher elevations during midwinter if high, wind-swept ridges are blown free of snow, while heavy snow in typical wintering areas makes foraging difficult. Mountain goats seek shelter from harsh weather, and frequently the sheltered areas dictate the forages they consume. A natural shelter, such as a cave or old-growth conifer stand, may be used during periods of inclement

Table 11. Kulcyznski's indices of similarity for seasonal variation of mountain goat diets, Mt. Chopaka, 1977-1980

	Winter	Spring	Summer	Fall
Winter	47.8	50.1	38.1	42.9
Spring	....	49.4	46.7	48.6
Summer	....	....	51.7	45.7
Fall	....	....	....	38.9

weather. Forages in and adjacent to these shelter areas are consumed more than those in other areas regardless of forages present.

Geist (1962) found that subalpine fir was a major rumen "filler" and was important as a food source on winter ranges in northern British Columbia. During one midwinter collection period of this study, over 45 percent of the diet consisted of conifer needles. Mountain goats obviously cannot always be selective, and some forages have low nutritive value. The highest conifer intake occurred during the heaviest snow-pack, although there was no overall relationship between snow-pack and conifer consumption.

Mountain goats also take advantage of phenological succession. As noted by Schoen et al. (1980) in Alaska, goats descend to the lowest elevations of their range with the onset of spring green-up. As the green-up belt rises in elevation, the goats follow the new growth up the mountain. During the growing season, forages found in the high alpine meadows are more nutritious than plants found at lower elevations (Hebert, 1973).

The preferred kidding areas are usually in the most precipitous and inaccessible terrain of goat range. Nannies select these areas during May and June and consume forages found in these areas. Later in the year, mountain goat foraging areas are influenced by insect disturbances and hot weather. Goats seek wind-blown ridges or heavily timbered north slopes during the heat of summer to escape biting insects and hot weather.

Brandborg (1955) noted a strong attachment between goats and their historic ranges. In some cases, goats consume most of the available forage in one area while adjacent similar forage species receive little use. Mountain goats tend to concentrate and overbrowse some parts of their range, despite abundant forage nearby. Forage productivity inevitably drops in these high-use areas as a result of depleted forage. If the overused range is critical to the goat population and no control of the population or habitat improvement program is implemented, the goat population must eventually decline.

Summary

Mountain goat food habits are extremely variable and appear to depend more on which forages are found in preferred topographical features than a purposeful selection for plant species. While nutritive value of forage items was not evaluated, conifer species in particular seemed to be eaten primarily as a "filler" during severe winter weather. The relationship between forage availability and mountain goat populations has been documented with wildfire on Chopaka Mountain. As is generally the case with other big game animals, the mountain goat population irrupted after fire created early plant succession communities, which included abundant forage.

An evaluation of the mountain goat diet showed approximately 50 percent diet overlap both within and between seasons. This high variability makes it difficult to identify key forage species. Management decisions based on forage availability must consider a variety of factors, including habitat preferences, survival mechanisms, snowfall, phenology, range condition and behavioral habits which influence mountain goat use of a range, as well as nutritive value of preferred forage species.

Minerals

Mineral or salt licks are an obvious attraction to mountain goats in Washington, particularly during June and July. Studies by Hebert and Cowan (1971) indicate that the salts from licks fill an important physiological need. Mountain goats use the licks shortly after shifting to a diet of newly emergent green vegetation. This dietary transition causes fecal pellets to change from hard and dry to soft, amorphous masses or to diarrhea, with consequent high sodium loss (Frens, 1958; Hebert and Turnbull, 1977). During this period goats lose sodium in milk and hair (Franzmann and Arneson, 1974), as well as in urine (Weeks and Kirkpatrick, 1976). These studies suggest sodium is a key element that cannot be counter-balanced by available sodium in vegetation (Hebert and Turnbull, 1977).

This situation is more complex than suggested because chemical analysis of some mineral licks indicates sodium levels are extremely low or absent (Singer, 1975). On Mount Baker, for example, Wright (1977) found low sodium levels in a lick used by mountain goats. Recent studies reported by Hutchins and Stevens (1981) indicate sodium is relatively rare and that goats are actually seeking sulfur in the form of sulfates. Sulfur compounds are converted in the ruminant's digestive system into amino acids which are essential for many physiological functions.

Mountain goats obviously have a special need for some mineral during the spring, and Brandborg (1955) reported goats could be drawn to natural licks from as far away as 15 miles. Lentfer (1955) described a salting project in Montana where goats were drawn into an adjacent range by salt. Salt was placed further away from existing ranges each year, and goats expanded their range accordingly.

Salt has been used as a bait for trapping goats in Washington since the early 1960's. During the current study, salt was packed into several potential trapping sites. On the western side of the Cascades, goats found and consumed salt at only half of the salting sites in a three-year period. Two salt licks in eastern Washington (Chopaka Mountain and Nason Ridge) have been established and maintained for over 20 years, and goats use these sites each year. Mountain goats in the Olympics have a much greater craving for salt and usually found each artificial salt lick within two weeks.

Water

Throughout most of the year water is found in ample supply. Mountain goats eat snow to get water, and for much of the year snow is readily available. In most areas of the state, snow and run-off from snow make water available throughout the year.

In some warm and dry summer ranges, however, water availability influences seasonal distribution of goats. In the Pasayten Wilderness, for example, Anderson (1940) found that goats go to water at least once a day throughout spring and summer. When water holes and streams dried up on Island Mountain in the latter part of July, the goats migrated off the mountain into an area where water was abundant. In the Olympics, mountain goats leave preferred areas on Iron Mountain

when snow fields melt and water becomes scarce. Throughout most of the state, summer ranges have lakes and streams which provide ample water, but some areas dry up and cause goats to migrate to water sources.

Competition

Mountain goats occupy a niche rarely preferred by other ungulates, particularly on critical winter ranges. Potential competitors in Washington are deer, elk, mountain sheep and cattle (*Bos taurus*). Competition can occur when interspecies aggression causes one species to abandon a range, as well as when both species compete for the same forage.

Interspecies Aggression

Deer are seldom present on critical goat ranges in sufficient numbers to cause habitat deterioration. Also, mountain goats dominate deer at salt licks. Bighorn sheep are reported to exhibit an avoidance for goats (Klein, 1953), but mountain goats seem unconcerned about the presence of both deer and sheep. The presence of goats and elk on the same range, however, could result in competition. Chadwick (1973) reported that goats could be dominated by elk, but elk in Montana shared the same range with goats for only a short time in the fall. In some forests of Washington, timber harvest programs result in elk encroachment onto mountain goat range. Clear-cut units are spreading up the mountains in an elevation continuum and elk are taking advantage of favorable forage conditions created by logging. No studies in Washington have evaluated elk-goat competition, but casual observations indicate goats may be retreating to other ranges.

Forage Competition

Literature sources comparing food habits of mountain goats with other species are limited in scope and sample size. Recent studies on Chopaka Mountain in Washington (Campbell and Johnson, in press) compared food habits of mountain goats, mule deer and cattle from 1977 to 1980. Results of this study indicated that there was little competition between mountain goats and cattle because they occupied little common habitat. Cattle preferred the level top and base of the mountain, while goats used the steeper terrain.

Deer and mountain goats have greater dietrary overlap. The Chopaka study (Campbell and Johnson, op. cit.) indicated that mountain goats primarily ate grasses and shrubs, whereas mule deer consumed mainly shrubs and conifers. The period of greatest potential competition between mountain goats and mule deer occurred during the spring (44 percent overlap) and the period of least competition during the fall (29 percent overlap). Mountain goats have a strong affinity for niches in the habitat and seemed to consume mostly forage in those specific sites. Variability in forages consumed indicated little dietary preference. Mule deer, on the other hand, tend to wander over a large area and seldom frequent the preferred sites of mountain goats.

Mountain goats and bighorns occupy similar habitats, but preferred niches within these habitats differ. Goats appear to base their

preferences on the physical characteristics of their habitat, while sheep respond more to vegetation characteristics. Food habit studies in Washington indicate bighorns are more selective in their feeding habits. It seems likely, however, that if both species occupied the same range, severe competition could result.

MOVEMENTS

The daily movements of mountain goats are usually limited in the winter but highly variable in the summer. Most goat movements occur during the day, but goats have been known to forage on ridgetops and use salt licks on moonlit nights. Chadwick (1973) found goats moved an average of 101 feet per day during the winter but over 2,000 feet on an average summer day. Topographical features, weather, and snow depth obviously influence daily movement. Inclement weather, such as rain and snow storms, cause goats to remain relatively inactive.

Mountain goats take advantage of favorable foraging conditions at upper elevations whenever possible. During the winter, as snow-pack increases on lower ranges, goats have been observed climbing to upper elevations where snow is sloughed off steep slopes and winds clear the ridgetops and cliff faces. When these areas become snowbound again, goats descend to lower elevations.

During the summer, goats often spend several days within a mile radius, then travel several miles to a new ridge, where they may again remain for several days. In Mount Rainier National Park, Johnson and Morrow (1965) saw a band of goats travel 10 miles and climb several thousand feet in one day. Movements of goats, particularly males, is highly variable in the summer.

The home range of mountain goats in Washington is usually limited to four to six square miles (Bartleme, 1980; Hutchins and Stevens, 1981). Adult females exhibit a stronger affinity for particular home ranges than males and dominate the better winter ranges. Winter ranges are generally quite small and limited to cliffs on a particular hillside. In Idaho, Brandborg (1955) watched a band of 10 goats live for three months on a winter range of less than 200 acres. In most cases, summer ranges overlap winter ranges. Occasionally goats will leave their normal winter range and move up to high, wind-blown ridges that may offer better foraging conditions.

Most goats have well-established annual movement or migration patterns. A few goats, mainly billies, seem to wander and even leave goat range. Brandborg (op. cit.) reported goats wandering as far as 25 miles from known goat range. Taber and Stevens (1980) found most wandering goats in the Olympics were two- to three-year-old males. In 1979, however, a young nanny was seen two miles north of Tonasket, which is about 20 miles from the nearest goat range on Mount Chopaka.

MIGRATION

Migrations are typically altitudinal movements from summer to winter ranges. The extent of seasonal movements is influenced mainly by topographical characteristics. If suitable summer and winter ranges are close together, migrations may be limited to near-vertical changes in elevation. Hjeljord (1971) observed goats on the Kenai Peninsula in Alaska for which migration involved only a vertical drop in elevation on the same mountainside. Migrations on Mount Chopaka and Lake

Chelan cover only three to four miles and have the same near-vertical route. Bartleme (1981) reported that all goats in the Skykomish Ranger District of Mount Baker/Snoqualmie National Forest migrated from two to five miles. He described the winter range and migration routes for 13 herds of goats in the Skykomish Ranger District. Will Wright (1977) monitored the Barometer Mountain goat herd for two years and found a migration of nearly nine miles. The Barometer goats migrate in early spring to the west side of Mount Baker and in June, migrate to the east side of Mount Baker.

In the Hidden Lake area of the Pasayten Wilderness, goats migrate about 10 miles (Anderson, 1940). Studies in Alaska and Idaho (Nichols, 1979; Brandborg, 1955) have found migrations of up to 15 miles. In all areas, mountain goats tend to return to the same winter ranges each year. In addition, migration routes are learned and passed on to offspring (Hutchins and Stevens, 1981), as is the case with bighorns.

DISPERSAL

Klahhane Ridge in Olympic National Park appears to have the largest number of goats per square mile (36 goats/mi^2) of any area in North America (Driver, Stevens and Pike, 1978). In response to the overcrowding, goats have dispersed from Klahhane Ridge to other areas of the peninsula. Distance traveled varied from 10 to 58 miles (Taber and Stevens, 1980). By far the largest numbers of dispersers are two- to three-year-old males, although members of all age and sex classes have dispersed (Taber and Stevens, op. cit.). Since 1977, nearly 20 percent of the mountain goats on Klahhane Ridge have moved to other parts of the peninsula (Hutchins and Stevens, 1981). Goats dispersing from Klahhane Ridge occasionally return. A two-year-old male captured on Iron Mountain in the National Forest outside the park returned to Klahhane the next year. Several other goats dispersed to other areas of the park and returned to Klahhane Ridge (Taber and Stevens, 1980). The net effect, however, has been a massive dispersal from Klahhane Ridge.

The dispersal of goats from Olympic National Park is the most dramatic recent emigration documented in the state of Washington, and probably North America. In other areas of the state, goats occasionally emigrate from normal goat ranges but no widespread dispersal has been observed. Several goats dispersed southward from Chopaka Mountain to Bluegoat Mountain during high population years. When goat populations declined on Chopaka, however, goats disappeared from Bluegoat and other peripheral areas. Apparently, dispersal is one of the goats' major responses to overcrowding.

DISEASE AND PARASITES

Studies on the diseases and parasites of the mountain goat are extremely limited (Foster, 1977). Samuel et al. (1977) summarized previous parasite studies in mountain goats and compared parasites found in mountain goats to those found in bighorn sheep. Approximately 30 species of parasites have been reported from mountain goats and many of them are shared with bighorn sheep (Samuel et al., 1977).

Between 1977 and 1982, we examined 17 goat carcasses, 227 fecal samples and 35 serum samples from goats in Washington to obtain disease and parasite information.

Whole carcasses or selected organs were examined when available. Standard necropsy procedures were used. Fecal samples were collected randomly or collected from goats that were captured. A modified solution technique (sugar solution, specific gravity of 1.27) was used to isolate parasite eggs, larvae and oocysts. The Baermann apparatus was used to isolate larvae. Microscopic identification of parasites was done at Washington State University in Pullman, Washington. Blood samples were collected during trapping operations, and serum was evaluated by the Washington Animal Disease Diagnostic Laboratory in Pullman, Washington, for antibodies to parainfluenza 3 virus (PI-3), infectious bovine rhinotracheitis virus (IBR), bovine virus diarrahea virus (BVD), bluetongue virus (BT), and ovine progressive pneumonia virus (OPP).

DISEASES

Serologic results are summarized in Table 12 and indicated antibody to PI-3 virus in 6 of 35 (17 percent) with titers of 1:5 to 1:20. PI-3 viral infections are common in domestic sheep and domestic cattle and are associated with acute respiratory tract disease (Woods, 1981). Signs of infection include lacrimation, serous or mucopurulent discharge and dyspnea. Concurrent bacterial infections, such as *Pasteurella* spp. or parasites (lungworms) may exacerbate the respiratory syndrome and increase the mortality rate. Serologic data in mountain goats in Washington indicate virus infection in wild populations. The impact of the infection is not known, but it is possible that combined with bacterial infections or lungworms, the disease could decrease productivity, especially in areas where goat populations are concentrated.

Antibody to BVD virus was detected in 15 of 35 (43 percent) goats with titers of 1:10 to 1:640 (Table 12). BVD is an acute contagious disease of cattle, but can infect domestic sheep and domestic goats. Typical signs are fever, anorexia, nasal discharge, weight loss, laminitis, mucosal erosions and abortion (Reggiardo, 1981). It is obvious the BVD virus is present in goat populations in Washington, but the effects of these infections on the population dynamics are unknown.

No antibodies were detected against IBR virus, BT virus or OPP virus (Table 12).

Contagious ecthyma (sore mouth, orf, contagious pustular dermatitis), a virus disease causing dry, scabby lesions on mouth, face and udders of sheep and goats, was not observed in the mountain goats in Washington.

CE has been reported in mountain goats in British Columbia, in bighorns from Alberta (Samuel et al., 1975), and from Dall sheep (*Ovis dalli dalli*) in Alaska (Smith et al., 1982). Infections of contagious ecthyma, particularly in combination with other pathogens, may contribute to mortality.

Cowan (1951) reported three cases of actinomycosis in mountain goats in Canada. Two of these fungal infections involved tooth abscesses (lumpy jaw), and the other was a case of foot rot. Brandborg (1955) mentioned the occurrence of pasteurellosis in a billy, but gave no details of the disease. It is probable that in areas where lungworms are prevalent in goats, pneumonias associated with lungworms, bacteria (*Pasteurella*), or viruses (PI-3) may predispose to mortality.

Paratuberculosis (Johne's Disease) is a bacterial disease of ruminants caused by *Mycobacterium paratuberculosis* and has been diagnosed in one mountain goat in Colorado (Williams et al., 1979). The goat was emaciated with evidence of diarrhea. Acid-fast bacteria were present in intestinal cells, lymph nodes, and isolated in feces. The importance of this disease in goats is unknown. We have not diagnosed the disease in mountain goats in Washington.

Neoplasms or tumors are growths that are seen occasionally in wild

Table 12. Presence of Antibodies to Selected Diseases of Mountain Goats in Washington.

		DISEASE[a]				
Location	Date	PI-3	IBR	BVD	BT	OPP
Nason Ridge	June, 1979	1/7 (1:15)	0/7	6/7 (1:20-1:80)	0/7	ND
Chopaka Mtn	June-July, 1980	3/6 (1:5-1:10)	0/6	6/6 (1:10-1:640)	0/6	ND
Olympic Mtns[b]	July, 1980	0/5	0/5	1/5 (1:20)	0/5	ND
Chopaka Mtn	July, 1977	2/6 (1:10-1:20)	0/6	2/6 (1:160-1:320)	ND	0/6
Olympic Mtns[c]	July, 1981	0/11	0/11	0/11	0/11	ND
TOTAL		6/35 (17%)	0/35	15/35 (43%)	0/29	0/6

[a]PI-3 = Parainfluenza 3 virus, IBR = Infectious bovine rhinotracheitis virus, BVD = Bovine virus diarrhea virus, BT = Bluetongue virus,
OPP = Ovine progressive pneumonia virus.
Numbers indicate number positive/number examined.

[b]Transported to Montana

[c]Transported to Hooknose Mountain, Washington

ruminants, but the occurrence of tumors in mountain goats is unknown. On 25 February 1982, an adult male goat, six years of age, was submitted to Washington State University. The carcass was frozen, skinned and grossly emaciated. A large tumor measuring 4 by 18 by 4 centimeters was in the mouth attached to the broad base of the palate. The mass was covered by intact epithelium. Some distortion of cheek teeth (non-opposed) was present and was probably due to the tumorous mass. Histology of the tumor revealed a well-differentiated fibroma (a benign tumor). It was apparent that the goat had starved to death because the tumor filled the mouth and interfered with mastication and swallowing.

Capture myopathy (CM) is a stress-related disease and is usually associated with the capture of wildlife. The disease occurs from a few hours to several weeks after capture and is characterized by muscle stiffness, weakness, paralysis, myoglobinuria and death (Hadlow, 1973; Chalmers and Barrett, 1977).

Gross muscular lesions in affected animals are usually characterized by intramuscular edema and massive hemorrhage. Histological lesions of skeletal muscles consist of hemorrhage, fragmentation of muscle fibers, pyknosis, mineralization, necrosis, and rupture of muscles. Ruptured muscles may include the semimembranosus, semitendinosis, and gastrocnemius. Clinicopathologic findings associated with CM are elevated serum glutamic-oxalacetic transaminase (SGOT), serum glutamic-pyruvic transaminase (SGPT), serum creatine phosphokinase (SCPK), glucose, and creatinine. These elevations are probably the result of muscle fiber breakdown due to muscle damage and trauma.

Severe metabolic acidosis often occurs after pursuit and capture of ungulates. Increased lactic acid production as a result of capture may predispose to CM and death. It has also been indicated that deficiencies of selenium or vitamin E may predispose animals to CM (Hebert and Cowan, 1971).

In North America, CM has been reported from a variety of wild ungulates including mountain goats (Hebert and Cowan, 1971). In that report, three of six goats that were confined for study developed progressive paresis and died. Degeneration of muscle tissue of the hindquarters was demonstrated histologically.

In Washington, we have not observed CM in mountain goats in the wild, but two of four goat kids captured with leg snares in the Olympic National Park in 1979 and transported to the Woodland Park Zoo developed CM and died within 11 days after capture (Reichard, 1980). All four kids showed signs of hind leg weakness and stiffness. One kid walked on the plantar surface of its left hock joint and partially on the right hock joint. There appeared to be ruptures of the muscle-tendon attachments of the semimembranosus, semitendinosus, gastrocnemius, and biceps femoris muscles. The kid could not extend the left hock joint.

Two of the four kids died 8 and 11 days after capture. Grossly, large areas of the muscles of the hind legs were pale with extensive edema and hemorrhage. Hemorrhage varied from discrete petechiae

to marked echymoses in the form of streaking or splashing. In some areas, the entire cross-section of a muscle was involved.

Histologically, there was an infiltration of inflammatory cells, primarily mononuclear cells and giant cells, which in some cases completely replaced the muscle bundles. Some of the fibers were mineralized. Both kids that died had elevated SGOT values of greater than 300 mU/ml in the post-capture blood samples.

It is likely that CM has often been overlooked in wildlife transplant operations because it can occur up to several weeks after capture. In transplants originating in Washington, we routinely administer 30 grams of sodium bicarbonate orally to adults and 15 grams to yearlings and kids. It is our hypothesis that the bicarbonate will prevent muscle acidosis and help prevent CM.

Other medications that we have administered routinely to goats prior to transport or release after capture are clostridium vaccine to prevent clostridial diseases, an anthelmintic (albendazole or levamisol) to remove internal parasites, vitamin E-selenium (Bo-se) to assist in the prevention of CM, and a long-acting penicillin to help prevent secondary bacterial infections. In addition to these medications, Dr. Jim Foster, DVM, of the Woodland Park Zoo, Seattle, Washington, has administered valium and vitamin B to assist in transport operations.

PARASITES

Parasites of mountain goats in North America are listed in Table 13. Parasites from 17 mountain goats in Washington are tabulated (Table 14), and parasite data obtained from analysis of 227 fecal samples are summarized in Table 15.

In Washington, goats in some populations are heavily parasitized. Parasites can contribute to mortality directly, or indirectly when animals are stressed by nutrition, other diseases, adverse weather, and other factors present in populations.

In February, 1982, a severely emaciated goat with muscle atrophy was brought to Washington State University for necropsy. More than 4,000 parasites, including 20+ lungworms in bronchi and bronchioles (*Protostrongylus rushi*) and several lungworms in lung parenchyma (*Protostrongylus stilesi*) were recovered. Based on histology, a diagnosis of verminous pneumonia was made. The pneumonia probably directly resulted in the demise of the goat; however, the other parasites present were also deleterious (Table 14). Although it has not been reported previously, the lungworm pneumonia complex may be responsible for significant mortality in goat populations where lungworms are numerous. The role of respiratory viruses (PI-3) and bacteria (*Pasteurella* spp.) may also be important in the complex (see Bighorn Sheep section entitled Parasites and Disease).

Two thin goats (a nanny and a kid) were collected in April, 1980, from White Chuck Mountain. The nanny weighed only 38 kilograms and had large numbers of abomasal nematodes (*Ostertagia* spp.) and intestinal nematodes (*Nematodirus* spp.), as well as other parasites (Table 14). The kid weighed 22 kilograms and had 1,710 abomasal nematodes (*Ostertagia* spp.), 7,650 intestinal nematodes (*Nematodirus* spp.), 670

Table 13. Parasites of Mountain Goats.

Parasite	Location in Host	Presence in Washington	Reference
Protozoa			
Sarcocystis sp.	muscle	+	3,6
Eimeria spp.	small intestine	+	6
E. ernesti	small intestine	ND	5
E. montanaensis	small intestine	ND	5
E. oreamin	small intestine	ND	5
Nematoda			
Parelaphostrongylus odocoilei	muscle	+	6
Protostrongylus rushi	lungs	+	1,2,4,6
Protostrongylus stilesi	lungs	+	1,2,4,6
Marshallagia marshalli	s. intestine, abomasum	ND	
Ostertagia spp.	s. intestine, abomasum	+	1,2,4,6
O. circumcincta	abomasum	ND	2,4
O. trifurcata	abomasum	ND	1,2,4
O. ostertagia	abomasum	ND	2,4
Teladorsagia dautiani	abomasum	ND	2,4
Nematodirus spp.	small intestine	+	2,4,6
N. dautiani	small intestine	ND	2,4
N. helvetianus	small intestine	+	2,4,6
N. maculosus	small intestine	ND	
Trichostrongylus spp.	s. intestine, abomasum	+	1,6
T. axei	abomasum	+	1,6
T. colubriformis	small intestine	ND	1
Skrjabinema ovis	large intestine	+	2,4,6
Trichuris ovis	large intestine	ND	2,4
T. schumakovitschi	large intestine	+	2,4,6
Oesophagostomum venulosum	large intestine	+	1,6
Cestoda			
Avitellina sp.	small intestine	ND	4
Moniezia benedeni	small intestine	ND	1,4
Thysanosoma actinioides	bile duct	+	1,4,6
Taenia hydatigena (cysticercus)	peritoneal cavity	+	1,4,6
Anthropoda			
Dermacentor andersoni	skin	+	1,4,6
D. albipictus	skin	ND	2
Bovicola oreamidis	skin	ND	1
Linognathus pedalis	skin	ND	1

1 Boddicker *et al.* (1971)
2 Kerr and Holmes (1966)
3 Mahrt and Colwell (1980)
4 Samuel *et al.* (1977)
5 Todd and O'Gara (1968)
6 This Study
ND = Not Determined

Table 14. Parasites of Individual Mountain Goats in Washington.

Goat #	Date	Sex	Age	Wt (kg)	Location	Parasites Recovered[a]											
						Cap	Chab	Eim	Nemat	Oes	Ost	Parel	Proto	Skrj	Thy	Tricho	Tri
1	Aug 79	M	2	ND	Whitechuck	0	0	+++	3,450	0	2,140	5	0	0	0	3,110	0
2	Apr 80	M	Kid	22	Whitechuck	0	0	+++	7,650	0	1,580	0	482	0	0	130	670
3	Apr 80	F	4	38	Whitechuck	0	0	ND	570	0	840	0	0	10	1	180	0
4	Oct 80	F	10	ND	Black Mtn.	0	0	+	1,330	0	1,310	0	17	0	0	0	80
5	Feb 81	ND	ND	ND	Darrington	10	0	+	0	0	3,600	4	3	0	10	0	0
6	Mar 81	M	2½	ND	Olympics	0	60	0	0	0	2,460	ND	ND	0	0	0	0
7	Mar 81	ND	ND	ND	Whitechuck	0	0	++++	58	0	1,296	0	6	0	0	144	0
8	Apr 81	F	2	37	Olympics	0	0	+	10	0	710	ND	ND	0	0	0	10
9	Apr 81	F	2	48	Olympics	0	60	+++	260	10	1,900	ND	ND	0	0	0	10
10	Apr 81	F	4	56	Olympics	0	20	+++	80	0	690	ND	ND	0	0	0	0
11	May 81	F	7	53	Olympics	0	370	+	580	80	1,970	ND	ND	0	0	0	0
12	May 81	F	4	44	Olympics	0	0	+++	0	0	30	ND	ND	0	0	0	0
13	May 81	F	4	60	Olympics	0	100	+++	0	0	10						0
14	June 81	ND	ND	ND	Olympics	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND
15	June 81	F	4	ND	Olympics	0	0	++	0	340	80	ND	ND	0	0	0	0
16	Feb 82	M	6	ND	White Salmon	0	0	ND	0	0	50	0	5	0	0	0	0
17	Feb 82	M	6	ND	Ross Lake	0	0	+++	650	0	3,510	65	20+	0	0	0	20
Number infected/Number examined						1/16	5/16	13/14	10/16	3/16	16/16	3/8	7/9	1/16	2/16	4/16	5/16
Percent						6%	31%	93%	63%	19%	100%	38%	78%	6%	12%	25%	31%
Mean intensity of parasites						10	122	ND	1,464	143	1,323	25	76	10	5	891	158

[a]Cap = *Capillaria*, Chab = *Chabertia*, Eim = *Eimeria*, Nemat = *Nematodirus*, Oes = *Oesophagostomum*, Ost = *Ostertagia*, Parel = *Parelaphostrongylus*, Proto = *Protostrongylus*, Skrj = *Skrjabinema*, Thy = *Thysanosoma*, Tricho = *Trichostrongylus*, Tri = *Trichuris*, ND = Not Determined

Table 15. Summary of Parasites in Mountain Goats in Washington as Determined by Fecal Analysis[a].

Location	Date	Parasite[b]							
		Cap	Eim	Nemat	Parel	Proto	Skrj	Strong	Tri
Chopaka	1979	0/5	5/5	5/5	0/7	1/7	1/5	2/5	1/5
Nason Ridge	1979	0/3	3/3	3/3	3/9	3/9	1/3	1/3	1/3
Olympics	1979	0/9	9/9	3/9	5/9	1/9	0/9	7/9	2/9
Goat Rocks Wilderness	1979	0/1	1/1	0/1	0/1	0/1	0/1	0/1	1/1
Whitechuck	1979	0/4	3/4	2/4	3/4	0/4	0/4	4/4	0/4
Nason Ridge	1980	0/2	2/2	2/2	1/2	0/2	1/2	2/2	0/2
Chopaka	1980	0/1	1/1	1/1	0/1	0/1	0/1	1/1	0/1
Olympics[c]	1980	0/5	5/5	5/5	4/5	0/5	1/5	5/5	1/5
Olympics	1980	1/107	102/107	69/107	61/107	4/107	9/107	97/107	6/107
Olympics[d]	1981	0/11	11/11	9/11	5/11	1/11	0/11	11/11	5/11
Olympics	1981	0/77	77/77	42/77	31/77	2/77	1/77	71/77	8/77
Total positive/total examined		1/225	219/225	141/225	113/227	12/227	14/225	201/225	25/225
Percent		(<1%)	(97%)	(63%)	(50%)	(5%)	(6%)	(89%)	(11%)

[a]All samples except 4 from Whitechuck were collected from individually marked goats. The Whitechuck samples were collected randomly.

[b]Cap = *Capillaria*, Eim = *Eimeria*, Nemat = *Nematodirus*, Parel = *Parelaphostrongylus*, Proto = *Protostrongylus*, Skrj = *Skrjabinema*, Strong = Strongyles, Tri = *Trichuris*.

[c]Transplanted to Montana.

[d]Transplanted to Hooknose Mountain, Pend Oreille County.

whipworms (*Trichuris* spp.), and 482 lungworms *Protostrongylus rushi*). Parasitism of this magnitude in a domestic goat kid or domestic lamb would usually cause death. It is probable that parasitism at this level adversely affects the health of animals and may contribute to mortality, especially in kids.

Boddicker et al. (1971) detected *Protostrongylus* spp. lungworms in the 28 goats they examined in South Dakota. These goats originated from six goats transplanted from near Banff, Alberta. Heavy infections were observed in seven of the goats, and two with massive infections may have died of the lungworm-pneumonia complex. The lungworm complex has not been reported specifically in mountain goats, but it may be a major mortality factor or population regulating mechanism.

Protostrongylus spp. lungworms were detected in seven of nine (78 percent) of the lungs examined in this study (Table 14). Larvae of *Protostrongylus* spp. were detected in only 12 of 227 (5 percent) fecal samples (Table 15). These incongruous results may indicate a high mortality of infected animals, or the fecal sample analysis may underestimate the prevalence of infection in the wild.

Eimeria spp. are protozoan parasites commonly called coccidia and were detected in 219 of 225 (97 percent) fecal samples examined. Microscopic fecal analysis is the only reliable method of detecting the presence of this parasite because of its microscopic size.

Clinical coccidiosis is an insidious disease of domestic sheep and cattle which is characterized by diarrhea, reduced weight gains, and death. Coccidiosis has not been reported in wild mountain goats, but the prevalence and level of infection are suggestive of borderline clinical disease. The infection level in the Olympics is extremely high, especially in kids.

Three parasites were recovered from mountain goats in this study that have not been reported previously in goats–*Chabertia ovina, Parelaphostrongylus odocoilei,* and *Capillaria* sp.

Chabertia ovina is the large-mouth bowel worm of the large intestine of domestic sheep. We have recovered it from domestic sheep in Washington and recovered it from five of the seven mountain goats collected in the Olympics (Table 14). Although *Chabertia* at the levels detected (Table 14) may not contribute to mortality, they may be a reflection of ecologic conditions in the Olympics as compared to other goat habitat in Washington where the parasite has not been detected.

Parelaphostrongylus odocoilei is a muscleworm normally found in mule deer (*Odocoileus hemionus*). We examined muscle groups (primarily those in the back and rear legs) of eight goats and recovered the parasite from three (Table 14). It is a difficult parasite to locate because of the large amount of muscle one has to examine and the small hair-like size of the worm. More than 65 worms were recovered from muscles of one goat which had been found, weak and staggering, in the Ross Lake drainage. Histologically, no compression, cellular reaction, or fibrosis was associated with the presence of the worms. No inflammatory or bacterial elements were observed in areas where parasites were present. Another parasite, *Sarcocystis* sp. (a protozoan parasite) was also present in several muscles, but no tissue reaction was observed.

In this case, *Parelaphostrongylus odocoilei* did not elicit a tissue response and probably was not responsible for the demise of the goat. Verminous pneumonia (*Protostrongylus* lungworms) was the probable predisposing cause of death (Table 14). In addition to the lungworms, larval stages of *P. odocoilei* were also present in large numbers in the lungs, and large areas of inflammation were observed. Larval stages of *P. odocoilei* enter the blood stream, are filtered out in the lungs, and are then coughed up, swallowed, and passed out in feces where they can be detected by the Baermann technique.

Capillaria sp. was recovered from one goat at Darrington, Washington (Table 14), and in 1 of 225 fecal samples (Olympics). This is probably an insignificant parasite.

Nematodirus is the thread-necked worm of ruminants. Heavy infection can adversely affect domestic ruminants, especially young animals. In this study, 10 of 16 (63 percent) of the goat carcasses we examined had Nematodirus, and 141 of 225 (63 percent) of the fecal samples examined had eggs. *Nematodirus helvetianus* was identified in some of the goats, but other species were also present.

Other parasites identified from cases at necropsy were *Oesophagostomum venulosum* (3 of 16), *Skrjabinema ovis* (1 of 16), *Thysanosoma actinoides* (5 of 16), and *Sarcocystis* sp. (2 of 4 muscles examined).

Treatment with albendazole at the time of trapping probably removed the majority of nematode and cestode parasites in goats. Similar studies in domestic sheep, cattle, and white-tailed deer have indicated greater than 95 percent efficacy (Theodorides et al., 1976; Foreyt and Drawe, 1978).

Analysis of fecal samples with the fecal flotation technique has been a useful technique to evaluate parasitism in mountain goats without killing specimens. Fecal samples can be collected quickly and easily in areas where animals are abundant. Although this technique will underestimate certain parasite populations (immature, hypobiotic, low populations), the technique provides valuable data when monitoring a population, and will detect parasites that cannot be detected at necropsy (i.e. *Eimeria* sp).

The value of field treatment of parasites of mountain goats has not been evaluated. However, in populations that are excessively parasitized, medicated feed or salt may be an effective way of circumventing parasite-related mortality. This may become a useful management technique in the future, especially in areas where reduction of parasite-related mortality is a management objective.

MANAGEMENT

Mountain goats are managed both for hunting and nonhunting outdoor recreationists in Washington. The controlled-permit system for limited geographical areas regulates the hunter harvest on all goat populations. In areas where goat hunting is permitted, goats are managed as a trophy animal. Goat harvest is not aimed toward maximum sustained yield. Some areas adjacent to major highways are closed to hunting to allow motorists and nonhunters an opportunity to view these animals. Many nonhunters believe mountain goats have only aesthetic value and some areas are managed for their consideration.

Most goat populations in Washington State are managed by the State Game Department, but substantial goat populations are found in the North Cascades, Olympic, and Mount Rainier National Parks. Mountain goats in all three national parks are managed by preserving wilderness tracts and providing a place for outdoor enthusiasts to observe mountain goats in a pristine setting. Backpackers and climbers often see goats in the rugged back country and along trails to high lakes and mountain passes. The national parks' interpretive hikes and evening programs by park rangers provide information on the life history and ecology of mountain goats to visitors.

HABITAT

While most wildlife species have suffered from loss of habitat as a result of increasing human population, mountain goats occupy the more inaccessible areas of the state and have lost little native range as a result of human activities. There has been a loss of good goat habitat, however, as a result of fire control and an expanding network of new roads associated with logging activity. In addition, human activities, including helicopter skiing, resort development, and mineral and fossil fuel development are causing more concern each year. As energy supplies dwindle, we can anticipate development of geothermal plants.

Mountain goats depend on microhabitats in a four- to six-square-mile home range. The most important sites are in cliff-terrain on winter ranges. While these are areas generally avoided by man, increased hiking and mountain climbing activities are having an impact. Mountain goats in the Goat Rocks Wilderness, for example, seem to avoid some traditional ranges where hikers pass by on heavily used trails. Of greater concern, however, is harassment by logging trucks. Will Wright (1977) found that goats left their winter range as a result of logging truck activity on Barometer Mountain. In addition, logging roads provide access to noncommercial vehicles, which may also harass goats. Access by hunters and poachers to goat habitat is a critical management problem that must be regulated to maintain goat populations.

Logging, Roads, and Mining

Logging is one of the largest industries in Washington, and most goat ranges are subject to timber harvest. Extensive cutting in the 1920's and 1930's eliminated most old-growth timber in the lower country of

Washington. During the last two decades, timber demand has increased, and in addition to harvest of second growth, some higher country (over 3,500 ft.) is now being logged. Mountain goat winter ranges are frequently below 3,500 feet, but summer ranges have only recently been subject to timber harvest. In western Washington, most timber is Douglas fir and is clear-cut in blocks of varying sizes. In eastern Washington, most logging operations use some type of selective cutting to harvest a variety of species.

The impact of timber harvest on goat range can be beneficial or detrimental. Loggers report goats sometimes forage on mosses and lichens growing on trees as soon as trees are fallen. The most desirable and nutritious forage species are found in areas that have been clear-cut and burned. In many areas, goats forage in clear-cuts when sufficient old growth is left around the perimeter of the unit. Another important consideration is the relationship between timber harvest and total canopy coverage of the area. In some areas, no overstory occurs on cliff terrain, and a surrounding buffer of timber is needed to provide shelter. Other areas have sufficient soil deposits on ledges to provide timber growth. In areas of extensive timber growth on cliff habitat, small cutting units in these areas are beneficial. Requirements of mountain goats are best met where they have access to a diversity of habitats.

The beneficial impacts of this type of timber harvest can be offset by a variety of disturbances. Road building and logging are the initial disturbances, but access provided by roads built during logging is a lasting source of disturbance. Chadwick (1973) found that goats in Montana continued to use cliff areas during initial road-building and logging disturbances. Later, however, frequent blasting and increased activity caused goats to emigrate about three miles from the disturbance. The level of tolerance to disturbances seemed to be surpassed when logging activity involved frequent blasting within 1,000 feet of primary goat habitat.

The timing of logging activities may also be important. As mentioned previously, Wright (1977) reported that goats left their winter range on Barometer Mountain early as a result of logging truck activity, and migrated to their summer range. Dominant nannies typically use the most precipitous habitat of their home range during the kidding period. Where kidding areas are identified, logging should be avoided during the spring and early summer. Attempts should also be made to avoid logging on migration routes during migrations.

The long-term impact of logging disturbances appears to be variable. On Barometer, goats returned to their accustomed winter range the following fall. Chadwick (1973), however, reported goats had failed to return to disturbed sites two years later. Primary winter ranges are most critical, and all disturbances should be curtailed in these areas during the winter.

As discussed previously, elk are encroaching onto mountain goat winter ranges as a result of timber management practices. To prevent elk encroachment on these ranges, a strip of standing timber should be left between goat and elk ranges (Mike Kuttel, pers. comm.). Timber

harvest in goat ranges should be located initially in upper parts of the planning unit. Succeeding cuts should not remove the buffer between elk and goat ranges until timber in the adjacent units has grown sufficiently to prevent elk encroachment onto goat winter range.

Timber harvest has a substantial impact on mountain goat habitat. In Washington State, nearly all mountain goat range is in national forests. Wildlife biologists should identify the habitat requirements of mountain goats in proposed timber harvest areas and provide input for timber management programs.

Another major disturbance to mountain goat habitat results from mining operations. In British Columbia, mountain goat declines have been closely correlated with coal and gas developments (Pendergast and Bindernagel, 1977). The declines in British Columbia, however, appear to be more closely related to roads and access than to actual disturbances to habitat. In Washington State, relatively few mining operations presently occur on goat range. The major impact of mining in Washington is also access provided by roads.

Fire

Fire management in much of the United States and Canada has had a significant effect on mountain goat habitat. Since the 1920's, fire fighting equipment and methods have become so effective they have nearly eliminated wildfire in goat range. As a result, vegetational communities in many areas have continued to mature to successional stages of dense conifer and thick brush stands, which are unsuitable for goat habitat.

Forest Service policy has been to put out all fires, regardless of origin or value of the timber being protected. Comprehensive fire management studies in the Pasayten Wilderness of Washington (Fahnestock, 1976), however, have pointed out the need to change fire management policy. Fahnestock (1976) recommended that suppression of man-caused fires be continued, but suggests that lightning-caused fires be allowed to burn if they do not escape the Wilderness or violate other constraints. Such a fire management policy would save money and allow natural fires to periodically rejuvenate the range.

Cooperative studies between the U.S. Forest Service, Bureau of Land Management, and the Washington Department of Game recently evaluated fire as a habitat improvement practice (Olmsted, 1978). The effective fire suppression policy of the past 50 years has led to deterioration of mountain goat habitat and allowed buildup of high fuel loads. Uncontrolled fires in many of these areas could now result in hot and destructive fires.

There are major differences between the impact of fire on the west and east sides of the Cascades, but mountain goat habitat can be improved in both areas with appropriate burns. Early successional stages (i.e., herbs, grasses, and shrubs) are beneficial to mountain goats because these plants are favored forage species. In western Washington, dense forests prevent these plants from getting a start and surviving. Mountain goat habitat in these areas could be improved by eliminating dense conifer patches and stimulating early successional

species. Prescribed burns could do just that, and at the same time leave undisturbed strips of cover and precipitous rocky terrain. Particularly in western Washington, where dense forest stands offer poor habitat conditions, we have an opportunity to create favorable habitat.

Habitat conditions for the mountain goat in eastern Washington are quite different. Because of limited moisture, conifer stands are generally sparse, and ground cover consists of grasses and shrubs. We have the opportunity here to improve habitat conditions with fire which causes shrubs to resprout and stimulates grass production. Daubenmire (1974) examined the effects of fire on grasslands and suggested that fire is necessary to keep woody vegetation from encroaching on grassland communities. In the state's history, periodic wildfire has been a natural process that leads to favorable habitat conditions for mountain goats and many other wildlife species.

While state game departments manage the wildlife in the states, the U.S. Forest Service manages habitat on national forest lands. In the case of mountain goats in Washington State, nearly all goat range is within national forests. It is imperative, therefore, that the state and Forest Service work together to develop the best management policy.

During the last few years, each of the national forests with mountain goat range has been contacted, and prescribed burns, as a habitat improvement technique, were discussed. Several criteria were identified as important elements in any prescribed burn plan. The most important consideration, of course, is that burns should be in, or adjacent to, good mountain goat winter range. Mountain goat winter range is usually on south-facing slopes along steep ledges, cliffs, or rock outcrops. The primary consideration for a prescribed burn should be suitable winter range topography.

Sizes of prescribed burns should be about 100 acres, but no strict size criteria should be established. Burned areas should take advantage of natural barriers, whether the area is 50 or 500 acres. The cost factor is also important. If a prescribed burn is too expensive, burning will never be a viable management tool.

Prescribed burns should be no higher than 2,000 meters (6,000 ft.) in elevation. Wildfire burns in Washington's high and dry areas require a long time for regeneration. Soils in the higher elevations are usually fragile and can be sterilized by a hot fire.

Other criteria, unique to each site, are evaluated in the planning process. In the last few years, Game Department and Forest Service personnel selected potential sites where a prescribed burn could improve goat range. While a comprehensive burning policy was desired, the variability in habitat types and environmental conditions in the various potential burn sites have dictated unique burn prescriptions.

GOAT POPULATIONS

As mentioned in the introduction, the current distribution of mountain goats is similar to historic range. Management activities have also involved several transplant programs designed to augment depleted populations. With the exception of the Olympic Mountains, all transplants in Washington have been to native ranges.

Restoration and Introductions

Mountain goats were not native to the Olympic Peninsula but were introduced from three releases in the vicinity of Lake Crescent between 1925 and 1929. Mountain goats dispersed easterly and southerly following release in the Olympic Mountains. Thirteen years after the goats were first introduced, most of the Olympic Mountains were included in the creation of Olympic National Park. The mountain goat population in the Olympics has grown from 11 or 12 animals to a dramatic 700 goats within the park (Taber and Stevens, 1980) and nearly 150 goats outside the park. This increase occurred over a 50-year period.

In the 1960's, the Washington Game Department began reintroducing goats to the Selkirks, where they had died out before the turn of the century. All releases in the Selkirk Mountains were made in Pend Oreille County and began in 1962 with a release of seven goats along Cato Creek. A release of six goats near Le Clerc Creek in 1964 and seven goats near Flume Creek in 1965 completed the initial series of reintroductions. Goats obtained for these transplants were trapped in the Cascades on Nason Ridge. Only the last transplant near Flume Creek was successful. By 1972, the population had increased to 30 animals, and a limited-entry hunting season was initiated.

The last release of goats in the Selkirks occurred in 1981 with the release of 11 goats on Hooknose Mountain. These goats were trapped from the expanding population of goats in Olympic National Park. The age, sex, and marking of these goats are listed in Appendix B. While one billy was seen more than 15 miles west of the release site within two months, most of the other goats are believed to have remained in the release area.

In the Cascade Mountains, a total of eight goats were transplanted from Klahhane Ridge in Olympic National Park to Mount Margaret in 1972 and 1973. The reintroduction appeared to be doing well until the eruption of Mount St. Helens in 1980 devastated the preferred goat range on Mount Margaret. Some of these goats have reportedly been seen since the volcanic eruption, but the fate of the transplant is uncertain.

Another transplant of goats from the Olympic Peninsula to the Cascades occurred in 1975 and 1976 with the restocking of Mount Pilchuck. While native goats are found just east of Mount Pilchuck, no goats had been seen in the area for 30 years prior to their release. The transplant was made in Pilchuck State Park. Immediately after release, one of the goats attacked and superficially wounded a hiker. Some of these tame goats wandered down to a residential area near Lake Roesenger shortly after release. While one of the goats is known to have immigrated about 12 miles to Mount Stickney, several of the goats have remained on Pilchuck. Kids of the year have been seen on Pilchuck in recent years, and the transplant appears successful.

In 1981, mountain goats from Olympic National Park were transplanted to Lime and Higgins Mountain in the Darrington Ranger District of Mount Baker/Snoqualmie National Forest. Both transplants consisted of 10 animals (Appendix B, C). While some of these goats are

wandering over a large area, others have remained in the release area. All of the goats transplanted in Washington in recent years have been marked with individually identifiable neck collars and ear tags. This marking system has enabled local Forest Service and Game Department personnel to monitor their movements. The success or failure of the last series of transplants will not be known for several years, but initial observations are encouraging.

Trapping

Trapping techniques developed in Washington take advantage of the goats' craving for salt in the spring. Salt is back-packed or air-dropped to potential trapping sites during late May or early June. In one case, a trapping site was established at a natural salt lick. While some trapping sites (Mount Chopaka and Alpine Lookout) have been salted each year for over 20 years, other sites were salted only during recent years. The salt-hungry goats of the Olympics usually find salt within two weeks after baiting. In the Cascades, however, goats are not as salt-hungry. Established salting sites in the Cascades receive moderate use each year, but new salt licks frequently go unused. During the recent study, about half the salting sites received some use within two years.

Mountain goats have been trapped at salting sites with rope snares and with a drop net. The rope-snare technique was developed by Wadkins (pers. comm.), and works well where goats are fairly tame and densities high. This technique was adopted by Stevens (Taber and Stevens, 1980) in Olympic National Park. The drop-net technique, however, has been used almost exclusively in recent years because goats can be captured with it several hundred feet away from the disturbance of humans, and more goats can be captured in a short time.

The drop net used for mountain goats is 40 feet long on each side. Corners of the net are positioned on six-foot aluminum poles and the center elevated with an aluminum pole 18 feet long. Each corner of the net is tied with a 20-foot rope to stakes or large shrubs. The drop net is dropped by releasing ropes holding the net up from the center pole and two corners.

A pull-pin manual release mechanism works well in Olympic National Park (Johnson and Morehead, 1982), where goats are tame and density high. In the Cascades, however, goats are quite spooky and are scattered over large areas where they are difficult to trap. Normally, blasting caps are fastened to ropes holding the net up from the center pole and two corners. In some cases, blasting wire is strung 100 meters from the net to a concealed person. Electric blasting caps are wired in series to a hand-held magneto. When the magneto is activated, all blasting caps are detonated simultaneously.

When mountain goats are captured, they are immediately immobilized and blindfolded. Hobbles and horn guards are put on goats prior to processing. Since mountain goats are salt-hungry for about six weeks of the year in the Cascades (June 1 to July 15), the kids are frequently small enough to escape through the mesh of the net, and one of the first steps after the net is dropped is to catch kids.

After immobilization, all goats are tagged with a permanent identification number and some type of colored ear tag or neck collar for individual identification. Age is estimated from tooth eruption patterns and horn ring counts. Blood and fecal samples are routinely taken to determine parasite load and monitor other physiological parameters. Goats that are to be transplanted are given a variety of medications. Bicarbonate of soda in gelatin capsules is given to each goat to aid in the prevention of muscle acidosis and capture myopathy. Most of the ungulates in the Northwest have a selenium deficiency, and injections of selenium and vitamin supplements are given as preventive medication. In addition, a long-acting penicillin injection is routinely administered to prevent secondary bacterial infections.

As soon as goats are processed, they are placed in transport crates measuring 20 inches wide, 4 feet long, and 4 feet high. Hobbles are removed, but horn guards and blindfolds are left on during transit. Ice is packed in and around transport crates to cool the goats. This trapping and transporting technique has worked well. In 1981, 52 goats were trapped and transported from Olympic National Park. No losses were incurred during the entire trapping and transplanting operation.

HUNTING

In the last few years, goat hunting regulations have become much more estrictive in nearly all states and provinces. The policy to limit the legal kill to less than 5 percent of the population has been established in Washington, British Columbia (Bone, 1978), and Alberta (Hall, 1978). Statistical studies by Youds et al. (1980) indicate that a 5 percent harvest level can be sustained only if productivity rates are moderate and mortality rates nominal. Conclusions from this study in British Columbia and Alberta indicate that detailed population dynamics information is necessary if harvest levels are to exceed 3 to 5 percent. Detailed population dynamics surveys are not practical for every goat unit, and therefore goat hunting must be conservative.

Hunter Management

Mountain goat sport hunting in Washington began in 1897, when the hunter was limited to taking two goats during a three-month season. In 1913, the hunter was restricted to one goat per hunting season. Hunting areas were restricted in 1917, and the hunting season closed completely in 1925. Mountain goat hunting resumed in 1948, after Anderson (1940) and other biologists determined that the goat populations were stable and had filled the range's carrying capacity. Since then, mountain goat hunting has been sanctioned every year on a controlled-permit basis.

In 1948, only 150 permits were issued, and these were valid in all areas open for goat hunting (Table 16). The open area consisted of portions of Okanogan, Whatcom, Skagit, and Snohomish Counties. In 1949, the number of permits was increased to 400 for the same open areas. Although 400 permits were issued during each of the succeeding years until 1956, hunters tended to concentrate in the more accessible areas.

Concentration of hunting pressure on a few goat populations resulted

in overharvest of these populations, while many goat populations were not hunted. As a result, a unit system was established in 1957. Under the unit system, goat areas were divided into management units and permit quotas established for each of the units. Also, the unit system allowed annual evaluation of permit quotas. In 1957, 600 permits were allocated among 10 management units. Since then, the goat management units have been altered to regulate hunter distribution in proportion to goat populations. The highest permit level was reached in 1968, when 1,065 goat permits were authorized. The trend in recent years has been to decrease the size of goat units, along with number of hunters, to prevent overcropping of local areas. By 1983, only 496 permits were distributed among 43 goat units.

Increased accessibility of goat range makes goats more vulnerable to hunters and poachers alike. The Washington Game Department and

Table 16. History of Mountain Goat Hunting in Washington.

Year	Permits	Harvest	Open Areas
1948	150	55	Parts of Okanogan, Chelan, Snohomish, Skagit and Whatcom Counties. Mt. Chopaka closed.
1949	400	82	Essentially same as 1948 except Chopaka included.
1950	400	99	Additional area opened on Skagit, closure in Monte Cristo area.
1951	400	55	Same as 1950 except Chopaka closed.
1952	400	71	Same as 1951.
1953	400	45	Closures in Darrington area.
1954	400	54	Same as 1953.
1955	400	103	Same as 1953.
1956	400	77	Same as 1953.
1957	600	206	10 management units.
1958	600	199	10 management units.
1959	600	191	10 management units.
1960	800	271	18 management units, previously closed areas included in new units.
1961	800	273	18 management units but part of Unit 10 closed.
1962	880	269	21 management units.
1963	900	291	22 management units.
1964	970	345	24 management units.
1965	1030	387	26 management units.
1966	1005	348	26 management units.
1967	1060	309	28 management units. Archery only hunting in 2 units.
1968	1065	339	Same as 1967.
1969	895	326	28 management units, creation of North Cascades National Park resulted in substantial closures.
1970	925	340	29 management units. (3 archery only)
1971	936	316	30 management units. (3 archery only, 1 muzzleloader)
1972	930	253	30 management units. (3 archery only, 1 muzzleloader)
1973	930	266	30 management units. (3 archery only, 1 muzzleloader)
1974	961	272	33 management units. (3 archery only, 3 muzzleloader)
1975	905	238	30 management units (3 units closed). (3 arch., 2 m.l.)
1976	915	288	31 management units. (4 archery only, 2 muzzleloader)
1977	855	276	29 management units. (4 archery only, 3 muzzleloader)
1978	905	282	33 management units. (5 archery only, 4 muzzleloader)
1979	880	220	33 management units. (5 archery only, 5 muzzleloader)
1980	810	269	34 management units. (7 archery only, 5 muzzleloader)
1981	805	274	40 management units. (8 archery only, 5 muzzleloader)

the U.S. Forest Service have recently initiated road closures to retain the quality of the hunt and protect goats from harassment or poaching. In some areas, goat populations have recovered. In other areas, former rifle units have been converted to archery or muzzleloader only units to reduce harvest and yet provide recreational opportunity.

Far more people seek a hunting opportunity than goat populations can accommodate. Since 1948, the Game Department has conducted an annual lottery for a limited number of permits. In 1981, 7,791 persons applied for 805 mountain goat permits (Table 17).

The bag limit for a goat permittee is one adult goat of either sex with horns at least four inches long. Since kids of the year have horns less than three inches long and yearlings have horns at least five inches long, this regulation excludes only the kids. The mountain goat hunting season is long, and goats killed early in the season have relatively short hair. Hunters are reminded that best trophies with long hair and beards are taken late in the season.

Harvest

The statewide goat harvest is monitored primarily by the goat harvest questionnaire sent to each person purchasing a goat tag. A stamped, self-addressed return envelope is included with the questionnaire which must be returned to the Olympia Game Department office within 10 days after bagging a goat or 10 days following closing date of the season. Those not responding to the initial questionnaire are sent a follow-up questionnaire. While only about 40 percent of the hunters return the original questionnaire, the follow-up increases the questionnaire return to over 85 percent.

Hunter harvest information is particularly important for mountain goat management. Age and sex classification is difficult to distinguish for goats older than yearlings in the field, but quite easily determined from harvested animals. Wadkins (1963) made an effort to contact all taxidermists and determine age of harvested goats from horn ring counts. Wadkins found the average age of goats harvested throughout the state in the early 1960's averaged five years old. Management biologists should periodically check the age structure of harvested goats to determine if the age structure is declining. Age structure can be important in goat management because most nannies do not reproduce until four years of age.

The sex composition of the harvest also influences population structure. In Washington, the harvest has averaged 49 percent billies since goat hunting was initiated in 1948 (Table 18). As Brandborg (1955) observed, the harvest of a nanny with kid frequently results in the loss of the kid. No studies have adequately documented this relationship, but the loss of a nanny undoubtedly reduces the chances for survival of the kid. In 1977, the Washington Game Department began urging hunters to refrain from shooting nannies with kids. Since then, the sex ratio of the harvest has favored billies every year. Hunters should be encouraged to select lone animals, which are frequently adult billies.

Table 17. Mountain Goat Applications Received and Permits Authorized.

MOUNTAIN GOAT UNIT	Hunt Method	1979 Appl. Rcd.	1979 Prmts. Auth.	1979 Pct. Drawn	1980 Appl. Rcd.	1980 Prmts. Auth.	1980 Pct. Drawn	1981 Apl. Rcd.	1981 Prmts. Auth.	1981 Pct. Drawn
1		257	40	16%	197	40	20%	161	35	22%
3	Bow	....	....	....	37	5	14%	43	5	12%
4		164	25	15%	178	25	14%	195	25	13%
5		279	25	9%	287	25	9%	244	25	10%
6		620	40	6%	383	20	5%	....	....	....
8		515	60	12%	553	50	9%	513	50	10%
9		381	70	18%	470	70	15%	350	60	17%
10		256	30	12%	264	30	11%	287	30	10%
11		266	35	13%	239	35	15%	219	35	16%
12		678	50	7%	655	50	8%	....	....	....
13		353	30	8%	249	20	8%	188	10	5%
14		1,114	40	4%	883	40	5%	951	40	4%
14 ML	ML	28	10	36%	56	10	18%	61	10	16%
15		....	....	....	....	....	....	160	5	3%
16		....	....	....	....	....	....	177	5	3%
16 ML	ML	166	10	6%	171	10	6%	53	10	19%
17		866	25	3%	....	....	....	366	15	4%
19		99	15	15%	114	15	13%	81	15	19%
20		397	25	6%	415	25	6%	404	25	6%
22		117	10	9%	168	10	6%	185	10	5%
23		382	30	8%	400	30	8%	423	30	7%
24		92	15	16%	112	15	13%	115	15	13%
25		242	15	6%	116	10	9%	116	10	9%
26		190	25	13%	178	25	14%	148	25	17%
27	Bow	203	30	15%	184	30	16%	192	30	16%
28	Bow	245	30	12%	....	....	....	....	....	....
29		120	25	21%	54	15	28%	109	15	14%
31	Bow	60	15	25%	36	15	42%	30	15	50%
32	ML	58	20	34%	25	20	80%	67	20	30%
33	Bow	81	30	37%	95	30	32%	116	30	26%
35	ML	33	15	45%	72	15	21%	26	15	58%
36	Bow	60	25	42%	59	25	42%	97	25	26%
37		280	25	9%	245	25	10%	320	25	8%
38	ML	36	15	42%	29	15	52%	42	15	36%
39		214	10	5%	262	15	6%	224	15	7%
40		134	15	4%	....	....	....	100	10	10%
41	Bow	....	....	....	47	10	21%	67	10	15%
42	Bow	....	....	....	133	25	19%	187	25	13%
43	Bow	....	....	....	50	10	20%	64	10	16%
44		....	....	....	....	....	....	181	20	11%
45		....	....	....	....	....	....	111	10	9%
46		....	....	....	....	....	....	218	20	9%
47		....	....	....	....	....	....	200	5	3%
TOTAL		9,006	880	10%	6,916	810	12%	7,791	805	10%

The Washington mountain goat harvest has remained fairly consistent on a statewide basis for several years, but fluctuations occur annually from unit to unit (Table 19). The unlawful take of mountain goats is difficult to determine. Brandborg (1955) assumed that 30 percent of the legal harvest could be added to the kill in the form of crippling loss and illegal kill. Obviously, crippling loss and poaching must be considered when setting harvest quotas.

Table 18. History of Mountain Goat Harvest By Sex.

Year	Billy	Nanny	Sex Unknown	Percent Billy	Total Goats
1948	27	26	2	51%	55
1949	25	56	1	31%	82
1950	45	53	1	46%	99
1951	17	37	2	31%	56
1952	31	39	1	44%	71
1953	21	23	1	48%	45
1954	17	28	9	38%	54
1955	39	62	2	39%	103
1956	36	40	1	47%	77
1957	99	106	1	48%	206
1958	88	110	1	44%	199
1959	91	100	0	48%	191
1960	134	136	0	50%	270
1961	132	134	4	50%	270
1962	129	134	2	49%	265
1963	161	127	1	56%	289
1964	151	190	3	44%	344
1965	186	200	5	48%	391
1966	179	161	7	53%	347
1967	142	163	4	47%	309
1968	164	172	3	49%	339
1969	148	177	1	46%	326
1970	153	186	1	45%	340
1971	148	166	2	47%	316
1972	110	141	2	43%	253
1973	131	135	0	49%	266
1974	136	132	4	51%	272
1975	121	116	1	51%	238
1976	144	143	1	50%	288
1977**	143	143	1	52%	276
1978	164	118	0	58%	282
1979	114	108	0	51%	222
1980	153	112	4	57%	269
1981	145	128	1	53%	274
TOTAL	3724	3891	69		7684
AVERAGE	110	114	2	49%	226

**Starting in the 1977 Mountain Goat, Sheep and Moose Hunting Seasons Pamphlet, the Game Department has urged hunters to refrain from shooting nannies with kids.

Table 19. Mountain Goat Harvest by Unit, 1975-1981.

Goat Area No.	Name	1975	1976	1977	1978	1979	1980	1981
1	Skagit River	6	7	9	11	6	9	10
2	North Methow	6	2	-----	-----	Closed	-----	-----
3	Castle Mountain	-----	-----	Closed	-----	-----	2	2
3	Lime Mountain	1	---Closed---		0	--------	Closed	--------
4	Ruth Creek	1	12	8	8	8	6	6
5	South Methow	4	7	6	7	6	4	8
6	North Lake Chelan	19	26	11	13	7	2	Closed
7	South Lake Chelan	9	3	4	10	--------	Closed	--------
8	Chiwawa River	11	13	21	14	11	9	14
9	Glacier Park	11	12	10	9	12	16	10
10	Stillaguamish River	13	13	15	14	10	18	14
11	Wallace River	21	28	28	13	16	16	19
12	Snoqualmie	23	26	21	26	15	31	Unit Split
13	N. Wenatchee Mtns.	10	12	17	14	14	6	2
14	S. Wenatchee Mtns.	19	20	23	25	21	24	21
14 (ML)	S. Wenatchee Mtns.	4	5	3	1	4	5	2
15	Naches Pass	-----	-----	Closed	-----	-----	-----	3
16	Bumping River	-----	-----	Closed	-----	-----	-----	3
16 (ML)	Bumping River	-----	Closed	-----	-----	3	6	4
17	Packwood	14	20	14	13	10	Closed	7
18	Tieton River	-----	-----	-----	Closed	-----	-----	-----
19	East Ross Lake	1	4	0	4	4	3	3
20	Tatoosh	5	5	5	10	8	8	8
21	Stehekin River	3	4	4	1	--------	Closed	--------
22	East Stevens Pass	2	8	7	5	6	6	3
23	Baker Lake	9	10	15	6	13	10	10
24	Nooksack River	7	5	5	9	4	9	4
25	Greenwater River	7	9	11	9	1	4	4
26	Foss River	6	6	11	9	5	7	6
27 (A)	Goat & Davis Mtns.	4	3	3	6	4	3	9
28 (A)	Olympic Peninsula	4	8	6	8	6	Unit Split	–
29	Sauk River	7	10	6	6	2	10	2
30	Linton Mountain	8	4	-----	-----	Closed	-----	-----
31 (A)	Barometer Mountain	1	1	5	1	1	1	2
32 (ML)	Sloan Peak	2	1	3	2	2	4	7
33 (A)	Whitechuck	Closed	2	4	4	2	4	2
34	Pasayten	Closed	2	-----	-----	Closed	-----	-----
35 (ML)	Vesper Peak	---Closed---		1	3	6	2	7
36 (A)	Clear Creek	--------	Closed	--------	7	4	6	4
37	Gunn Peak	(formerly part of Unit 11)			12	8	11	12
38 (ML)	Pugh Mountain	--------	Closed	--------	2	2	5	8
39	White River	(new unit formed by splitting Unit 25)				7	3	6
40	Smith Creek	(new unit formed by splitting Unit 17)				4	Closed	7
41 (A)	Elwha River	(Unit 28 split in 1980					4	3
42 (A)	Quilcene River	to form					11	9
43 (A)	Hamma Hamma River	Units 41, 42, and 43)					3	4
44	Pratt River	(new unit formed by splitting Unit 12)						6
45	Bessemer Mtn.	(new unit formed by splitting Unit 12)						7
46	Tolt River	(new unit formed by splitting Unit 12)						12
47	Mount Chopaka							4

(ML) = Muzzleloader Only Unit (A) = Archery Only Unit

SURVEYS

Most states and provinces survey goat populations with fixed-wing aircraft, helicopters, or both. The Yukon Territory conducts aerial surveys in both winter and summer, relying on summer surveys for classification and winter surveys for determining winter range. The states and provinces with annual summer surveys are Alaska, Montana, the Yukon Territory, Alberta, Colorado and Oregon. Only Idaho and Parks Canada conduct aerial population surveys in the winter. In Alberta (Hall and Bibaud, 1978), the change from winter to summer surveys increased the count 2.25 times. Chadwick (1973) suggested that the best time to observe goats would be late March and April, when feeding goats use exposed cliff habitats. Bone (1978) reports that the timing of mountain goat surveys in British Columbia is critical. In the Similkameen River area, mountain goat surveys are conducted in the spring, after snow is gone, but while most goats are still using green-up plants. In Washington State, one goat survey is conducted in midwinter and another in the early spring, during the same critical period reported by Bone (1978).

In recent years, Idaho, Alberta, Colorado, the Yukon Territory, and British Columbia have conducted aerial surveys by helicopter. Alaska and Montana have used helicopter surveys to a limited extent. Classification counts from a helicopter are considered reliable in the Yukon Territory but unsatisfactory in Montana. Kuck (1976) believed helicopters are not well suited to inventory goats during the summer because of the goats' tendency to run or hide when approached by helicopter, and because of the absence of tracking snow. Nevertheless, Idaho uses a helicopter for midwinter goat surveys. Classification by most agencies is limited to the ratio of kids per 100 older goats, but some biologists attempt to classify kids, yearlings, two-year-olds, and adults, as well as sex ratios. The survey technique used in Alberta (Hall, 1977) is comprehensive. Two teams of observers are used in a helicopter leap-frog technique. Mountain goats are spotted from a distance and spotters are dropped off on adjacent ridges for ground classification. With spotting scopes, observers classify adults, yearlings, and kids. A second team of observers is then dropped off for ground classification of goats on another ridge. This leap-frog technique enables more accurate classification, but the technique is costly.

Survey accuracy appears to be extremely variable for fixed-wing, helicopter, and ground counts. In Alaska, Nichols (1980) felt that ground surveys produced nearly 100 percent accuracy, i.e., that all goats in an area under observation were observed and counted. In the Sawtooth Range of Montana, Thompson (1980) felt that March helicopter surveys approached 100 percent of the population. Nichols (1980) estimated that he could census 90 percent of the goat population on the Kenai Peninsula from a Super Cub. Other surveys in Alaska (Ballard, 1977) revealed that counts from a Cessna 180 averaged 66 percent of those observed from a helicopter. Ballard (1977) concluded that summer fixed-wing counts may not reflect annual trends in numbers or productivity, because day-to-day counts were extremely variable. All survey techniques have disadvantages and sources for error.

In 1961, the Washington Game Department conducted a statewide goat survey using mainly ground counts. Surveys were conducted by hiking through goat habitat, making counts, and estimating population numbers. Most surveys were conducted during August 1961. In the Stillaguamish area (Goat Unit 10), for example, 12 Game Department employees counted 70 goats in surveys of seven of the best goat areas. Sightings by Forest Service personnel increased the goat count to 140. Wadkins (1962) estimated that 50 percent of the population could be seen from ground surveys. The population estimate for Unit 10 in 1961 was 250 goats.

Surveys in Goat Unit 9 (Glacier Peak) were also made by hiking, but a helicopter survey augmented the count. The helicopter survey was productive, and Rieck (1962) reported seeing goats never observable from ground surveys. Total counts from Game Department surveys and Forest Service surveys totaled 149 goats in the Glacier Peak Unit. From these surveys, Wadkins (1962) estimated the goat population at 300, or double the number of goats actually seen.

The 1961 surveys in these two units are indicative of census techniques and methods of calculating population numbers.

Few annual mountain goat surveys are conducted in Washington State. In the Lake Chelan area, a goat count is made by boat during the winter and early spring (December and April), the latter just after spring green-up in the lower levations. Annual goat surveys from roads are conducted in the Okanogan (Goat Unit 47), Tumwater Canyon (Goat Unit 13), and along Nason Ridge (Goat Unit 22). Some of the best goat counts are in early spring, when lower elevation slopes are greening up, and goats descend to the lowest elevations to take advantage of new-growth. Bone (1978) reports similar survey results in British Columbia.

The reliability of annual surveys in Washington is dubious because counts are so variable. As Ballard (1977), Nichols (1980), and Casebeer (1950) have reported, mountain goats are easier to see on some days than others. Ideal counting conditions are seldom realized, and management personnel must plan survey dates well in advance of weather changes. Usually two or more surveys are needed per year to increase chances of having a good day. Unfortunately, we cannot determine the accuracy of a count and determine population trends from one year's survey.

The need for better survey information led to the present mountain goat study. In this study, a capture, mark, and release program was initiated to determine survey accuracy. The rationale was to intensively study a few areas and apply the information elsewhere. Mountain goats captured in these areas were marked with brightly colored neck collars and large, numbered ear tags. Surveys were conducted in these areas to find individual marked goats and get a ratio of marked to unmarked goats for population estimates.

Three study areas were selected for the trap, mark, and release program. The western Washington study area was originally the Goat Rocks Wilderness. Several potential trapping sites were selected and baited with salt. Mountain goats did not use the salt initially, but use increased over three years. In May 1980, the eruption of Mount

St. Helens covered the study area with a thick blanket of ash and eliminated Goat Rocks as a study area. The western Washington study area was then changed to Olympic National Forest. Two eastern Washington study areas were Mount Chopaka and Nason Ridge.

Surveys are meaningful only if 10 percent or more of the goats in each study area are marked. That goal was achieved in all three study areas. During the study, 31 mountain goats were captured, tagged, and released at Nason Ridge (Appendix D), 22 goats in Olympic National Forest (Appendix E), and 17 goats on Mount Chopaka (Appendix F).

Adult goats were marked with brightly colored neck collars and ear tags, but kids were marked only with ear tags. Experience has shown that goats with ear tags only are not as easy to identify as collared animals. Therefore, for survey purposes, only collared goats were considered marked animals.

A modification of the simple Lincoln-Peterson Estimator (Seber, 1973)

$$\left(\frac{N = Mn}{m}\right)$$

called Bailey's Binomial Model, was used to calculate population size.

Bailey's Binomial Model $\frac{N = M(n+1)}{m+1}$

Where: N = estimated population size
M = number of marked individuals (collared) in the population
n = number of individuals captured (or sighted)
m = number of marked individuals in n

In the last five years, we gathered the best survey information from Nason Ridge. Nason Ridge is accessible both in winter and summer. Winter surveys are conducted from the Stevens Pass Highway, just south of Nason Ridge. In 1980, several winter ground counts were conducted. During winter, 41 goats were counted, six of which were collared. The calculated goat population from these counts is 124 (Table 20).

Table 20. Nason Ridge Goat Surveys

Technique	Date	Total Goats Seen	Number Collared	No. Kids	Estimated Population
Ground Count	(combination of ground surveys from Jan-March 1980)	41	6	9	102 adults 22 kids 124 Total
Helicopter survey	7/22/80	28	4	8	85 adults 25 kids 110 Total
Helicopter survey	8/6/81	27	1	3	250 adults 28 kids 278 Total

During the summer of 1980, a helicopter survey was conducted in the Nason Ridge area. A total of 28 goats were seen on this survey, including four collared individuals. The calculated goat population was 110 animals. The next summer another helicopter survey was conducted on Nason Ridge, and 27 goats were seen, but only one was collared. While an insufficient number of marked goats were seen on this survey to accurately estimate population numbers, survey calculations are shown in Table 20.

Throughout the study, we assumed an annual over-winter mortality of 10 percent of adult goats, including the collared animals. We also experienced the loss of one collared goat to a hunter during the goat season.

Mountain goat kid numbers were calculated by taking a ratio of kids seen during surveys and adding this to the calculated number of adults. For example, since 9 of 41 goats seen in the Nason Ridge ground surveys were kids, the kid cohort represents 22 percent of the winter survey (22 percent of 102 = 22 kids). The 1980 winter population was therefore assumed to be 124 goats.

The single best goat survey on Nason Ridge was the helicopter survey on July 22, 1980. Using the calculated population of 110 animals, only 25 percent of the goat herd were observed on this survey.

Mountain goat surveys were also conducted on Chopaka Mountain (Table 21). As can be seen in Table 21, too few collared goats were seen during the last three surveys for meaningful population estimates. Our best estimate is 96 goats calculated from the winter 1980 ground count. If 96 is assumed to be the total population, ground count accuracy was 45 and 66 percent of the population on the two surveys.

Assuming the same population number, helicopter surveys revealed only 33 and 38 percent of the population.

Only one helicopter survey was conducted in the Olympic National Forest tagging area. In this August 1981 survey, 33 mountain goats were counted. Calculations from Bailey's Binomial Model reveal a

Table 21. Mount Chopaka Goat Surveys

Technique	Date	Total Goats Seen	Number Collared	No. Kids	Estimated Population
Ground Count	1/20/80	43	4	5	88 adults 8 kids 96 Total
Ground Count	4/14/80	63	1	5	insufficient marked goats seen for pop. estimate
Helicopter	7/24/80	32	0	10	no estimate
Helicopter	8/1/81	36	0	8	no estimate

population of 45 adults and 7 kids, for a total of 52 goats. The survey, therefore, accounted for 63 percent of the goats in the survey area. Mountain goat surveys by Houston (pers. comm.) in Olympic National Park have had similar survey accuracy.

Survey accuracy in this study is considerably lower than reported in Alaska (Nichols, 1980) and Montana (Thompson, 1980). Differences in overstory vegetation obviously have a great deal to do with survey accuracy. The difference in survey accuracy calculated between the three study areas in Washington are also reflections of overstory vegetation. In the Nason Ridge area, dense conifer stands limit goat observability. Mount Chopaka is more open, and the survey area in the Olympics has the most exposed rocky and meadow areas. The percent of goats seen on helicopter counts ranged from 25 to 63, corresponding to overstory vegetation.

Another observation from these surveys is that ground counts tend to give better counts where goats are accessible. Ground counts on Chopaka Mountain were calculated to be 45 and 66 percent of the population. Winter and spring counts are more accurate than summer counts because goats tend to concentrate on a few low-elevation wintering areas, and the observer has ample time to count all individuals.

The most practical surveys in Washington are probably similar to those conducted in the 1961 census. In these surveys, 10 to 15 Game Department people hiked along specified routes through known goat range in each unit. Goat numbers and classification counts from these surveys and Forest Service records were compiled for each herd. In the last few years, sportsmen around the state have asked to become more involved in game management. For example, over 20 sportsmen from the Washington State Archery Association assisted the Department by packing medicated salt blocks to a heavily parasitized area. Other sportsmen from the Inland Empire Big Game Council have assisted the state in conducting goat counts on Linton Mountain. Sportsmen are good sources of manpower for intensive goat surveys at little cost to the state.

Wadkins (1961) estimated survey accuracy was 50 percent of the goats actually present. The surveys conducted in three study areas during the current study indicate the estimates of Wadkins' were amazingly accurate. Surveys in heavily timbered areas reveal only about 25 percent of the goats, while surveys in more open areas are closer to 65 percent of the total population. The average survey accuracy of 50 percent of all goats in an area under observation appears to be a good statewide average.

POPULATION TRENDS

Annual goat counts are useful in establishing trends, but counts are variable. In many cases, a good count is more a reflection of counting conditions than of an increase in population. Goat surveys have been conducted along the Similkameen River using binoculars and a spotting scope since 1940. During high population years, several goats have been found on the marginal ranges of Blue Goat and Aeneas Mountains.

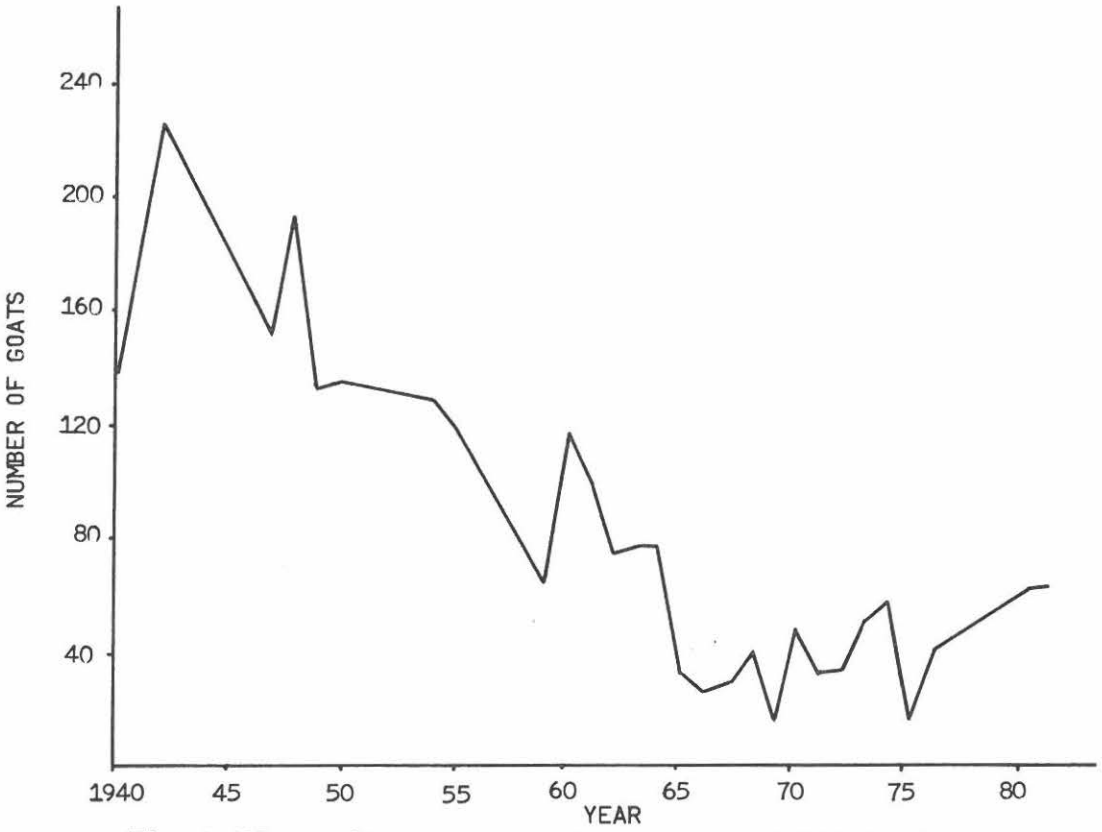

Fig. 8. Mount Chopaka Area Goat Survey (1940-1981).

When populations are low, goats are found only on Mount Chopaka, Grandview, and Hurley Mountains (Figure 8).

The Similkameen River goat population ranges from the Ashnola area in British Columbia to Mount Chopaka in Washington State. Goat surveys in British Columbia reflect the same trend we have observed south of the border. From 1958 to 1970, British Columbia counts declined from 107 to 19. Population counts remained low during the early 1970's, but increased to 102 by 1978 (Bone, 1978). Mount Chopaka is accessible to hunting, and goats are easily spotted on the cliffs above the Similkameen River. Hunting from 1948 to 1950 resulted in excessive harvest, and the season was closed in 1951. Goat hunting reopened in 1957 on a limited-entry basis until 1972, when the season was closed again. This goat herd is easily overharvested because of access and observability of goats. Tagging studies on Mount Chopaka indicate that the age structure is old, and that a few goats should be harvested. In 1981, goat hunting was reopened for only five permittees.

Annual goat surveys were initiated along Lake Chelan in 1954 (Figures 9 and 10). This area is counted from a boat, and the survey route extends from Safety Harbor to Stehekin. The north shore (Goat Unit 6) is normally counted on the first day of the survey, and the south shore (Goat Unit 7) counted the following day. Surveys have been conducted twice annually, once in December and again in March.

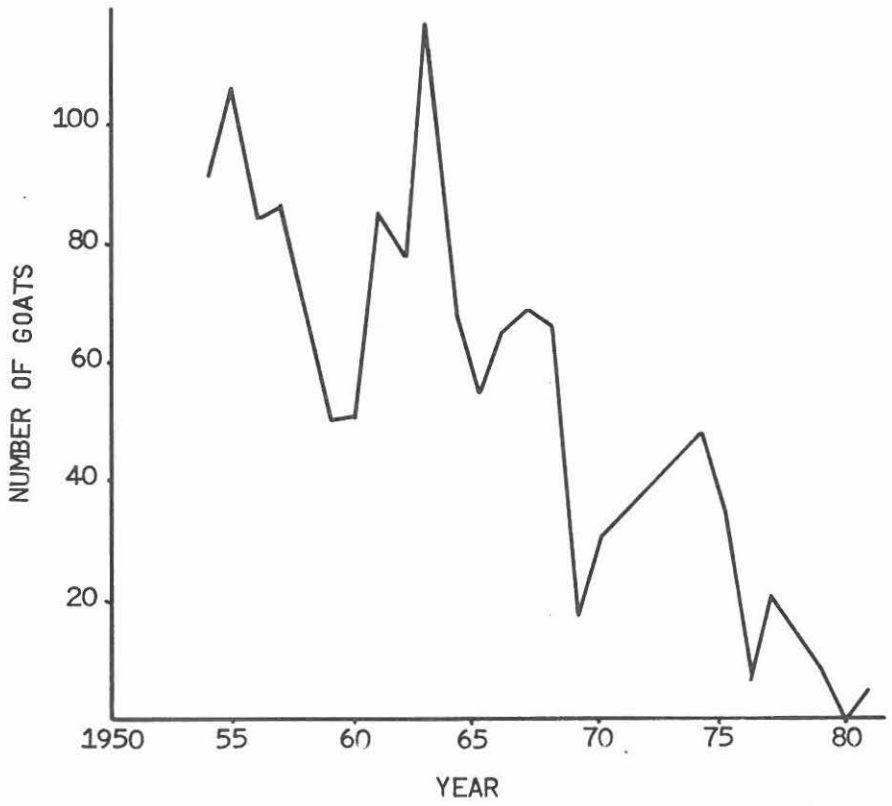

Fig. 9. North Lake Chelan Survey (1954-1981).

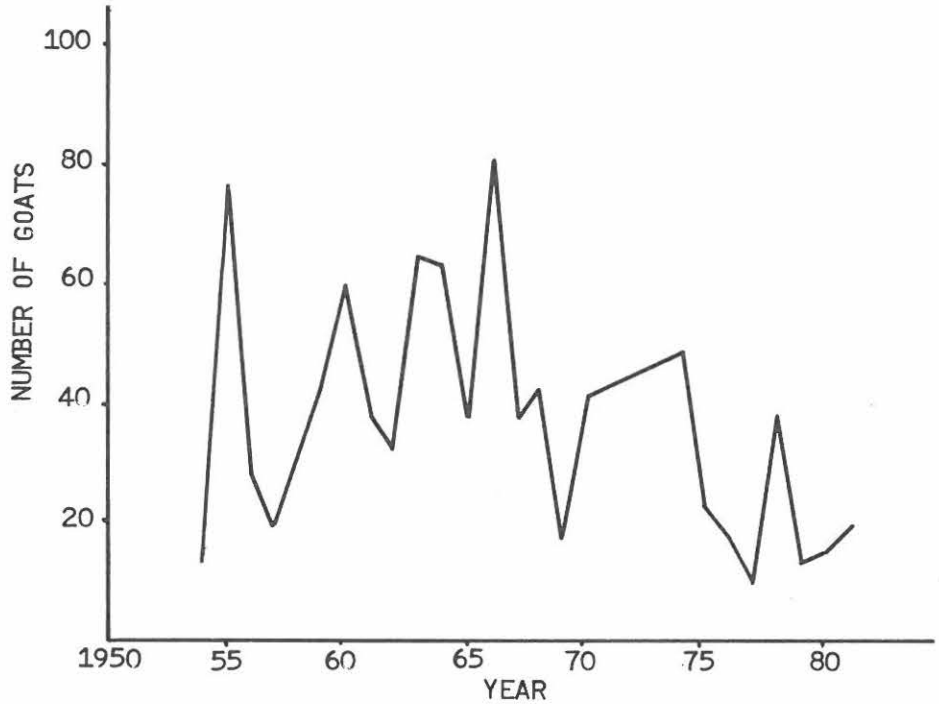

Fig. 10. South Lake Chelan Survey (1954-1981).

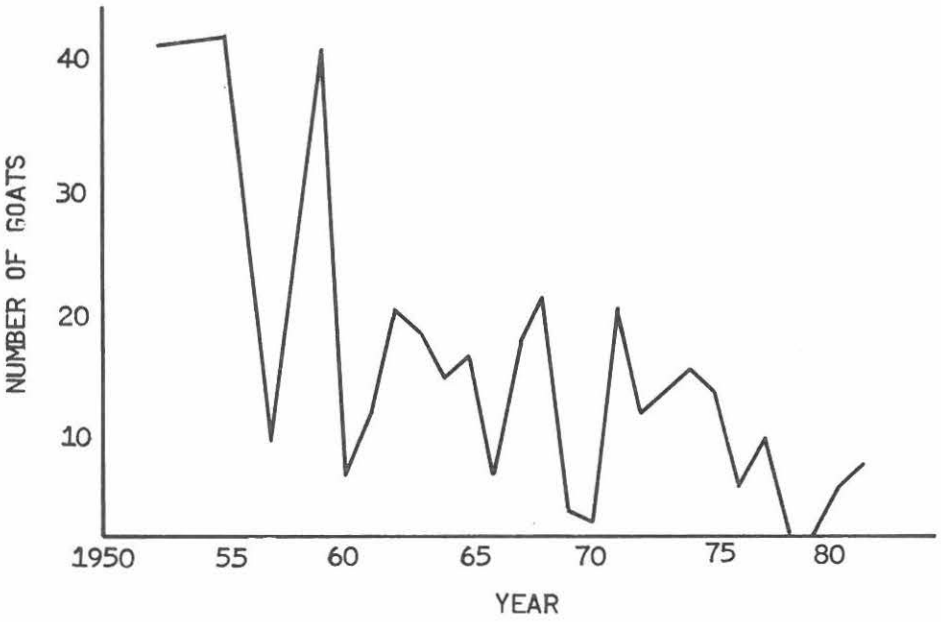

Fig. 11. Tumwater Canyon Survey, (1952-1981).

Only the highest count is recorded each year. Goat numbers have declined in the Chelan area since the 1960's. Poor sightings forced the closure of the south shore (Unit 7) and the Stehekin area (Unit 21) in 1979 and the north shore (Unit 6) in 1981. During the period of rapid decline, kid sightings by hunters were extremely low. After hunting closure for two years, kid sightings are increasing on the south shore of Lake Chelan once again.

Annual goat surveys have been conducted in both Tumwater Canyon (Unit 13) and Nason Ridge (Unit 22) since 1955. In both cases, one survey was conducted in December or January and another in March or April each year. The highest count per year is listed as the year's count (Figures 11 and 12). Tumwater Canyon was first opened to goat hunting in 1962 and the Nason Ridge area in 1963. Tagging studies by Wadkins (1964) indicated the Nason Ridge goat herd reached a peak of about 250 animals in 1964. This peak corresponded to a high count of 141 during the early spring of 1964.

All of these surveys reflect the importance of hunter harvest in population counts. Mountain goats are easier to see when they are not hunted, and seem to avoid human contacts when hunting seasons are initiated. In addition, hunter take of adult nannies in particular is additive to other forms of mortality, and population counts decline. The major problem of mountain goat management is to prevent overharvest of local populations.

A resident of the Darrington area, Mr. Art Ryals, has been conducting goat surveys on his own since 1945. His counts are conducted on winter ranges from November to March and highest counts recorded for each year. The goat counts for each year have been graphed by Phyllis Reed (Figures 13 and 14).

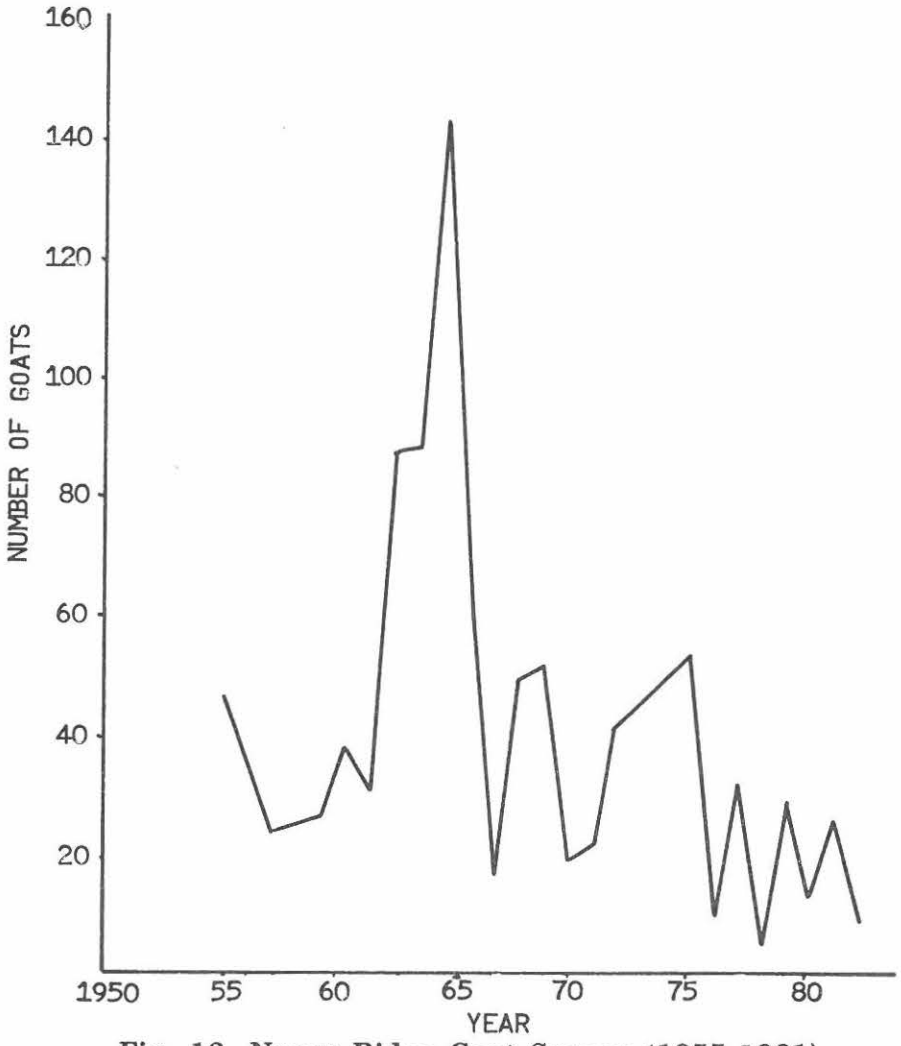

Fig. 12. Nason Ridge Goat Survey (1955-1981).

Perhaps most important, Ryals recorded in his diary changes in habitat conditions and access that have influenced goat populations. In 1945, the railroad was extended up to the Sauk River through Bedal, which opened the area to timber harvest. In 1949, the road from Darrington to White Chuck was improved and a bridge built across the Sauk River. In 1951, the Forest Service initiated timber harvest in the Falls Creek area. Throughout the 1950's, much of the timber in the Falls Creek area was logged. Ryals noted in his diary in 1958 that "outside pressures" are having an impact on the goats. These "outside pressures" are later described as logging, hunting, poaching, and tourist traffic as a result of improved access. Ryals noted that beginning in 1958, goats started moving out of the Falls Creek area into adjacent, more remote areas. As noted in the graph on Figure 13, mountain goat populations in the Falls Creek area have continued to decline.

The other area Art Ryals censused over the years was Penders Canyon in the Pugh Mountain goat unit. Extensive wildfire burns

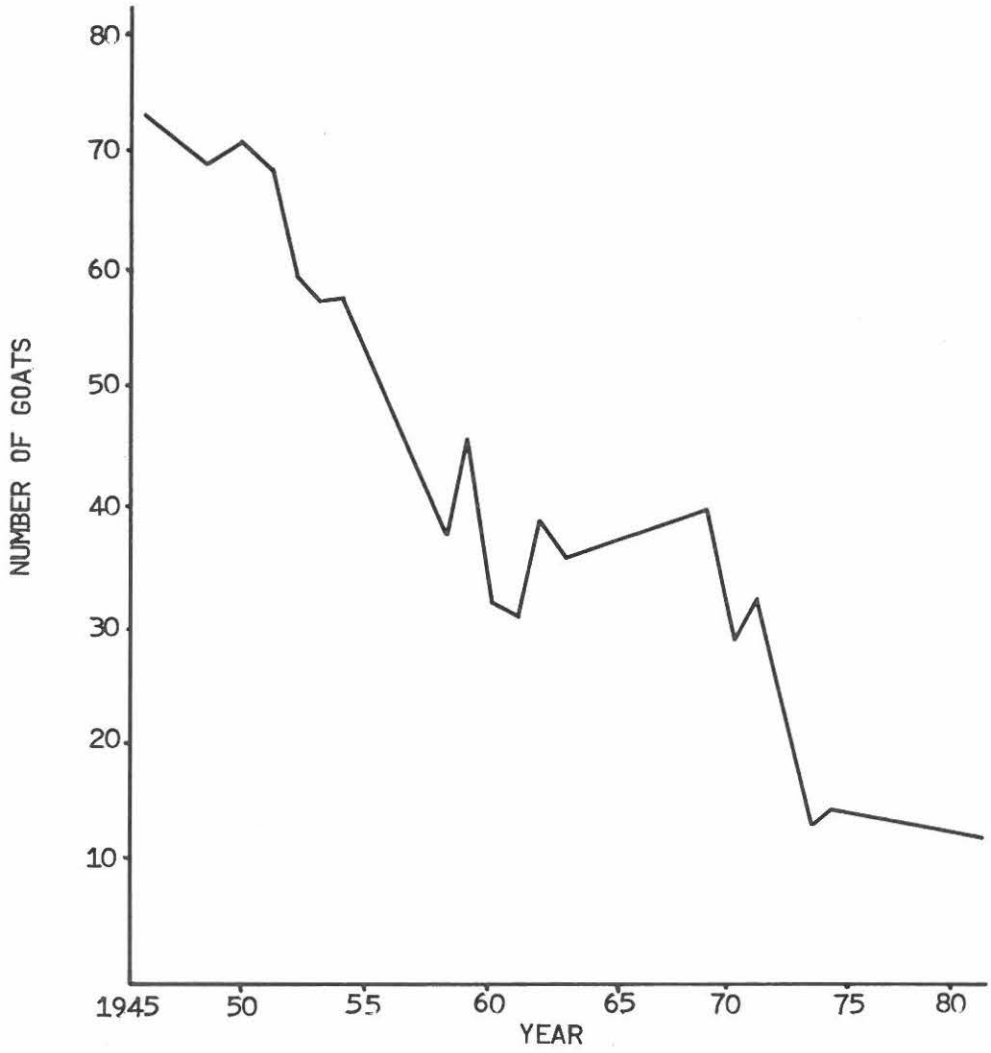

Fig. 13. Falls Creek Goat Count by Art Ryals. (graphed by Phyllis Reed)

in the 1920's and 1930's created excellent goat range in the Pugh Mountain area. Goat populations increased to high levels in the 1940's and 1950's. Even in 1960, Ryals wrote in his diary that he believed 100 to 150 goats wintered in the Pugh Mountain area. Within a few years, however, logging roads provided easy access to the primary winter range of this goat herd. In 1968, Ryals found seven dead goats that had been shot off the cliffs of Pugh Mountain and left. This area, like several others where roads are constructed into critical winter range, also had substantial population declines. Game Department personnel responded to these declines by closing this and several other easily accessible areas to goat hunting. Later, some of these units were reopened to archery- or muzzleloader-only hunting to provide recreation with minimal harvest.

The Barometer Mountain goat population near Mount Baker has a similar history. Nearly the entire south- and southwest-facing slope of

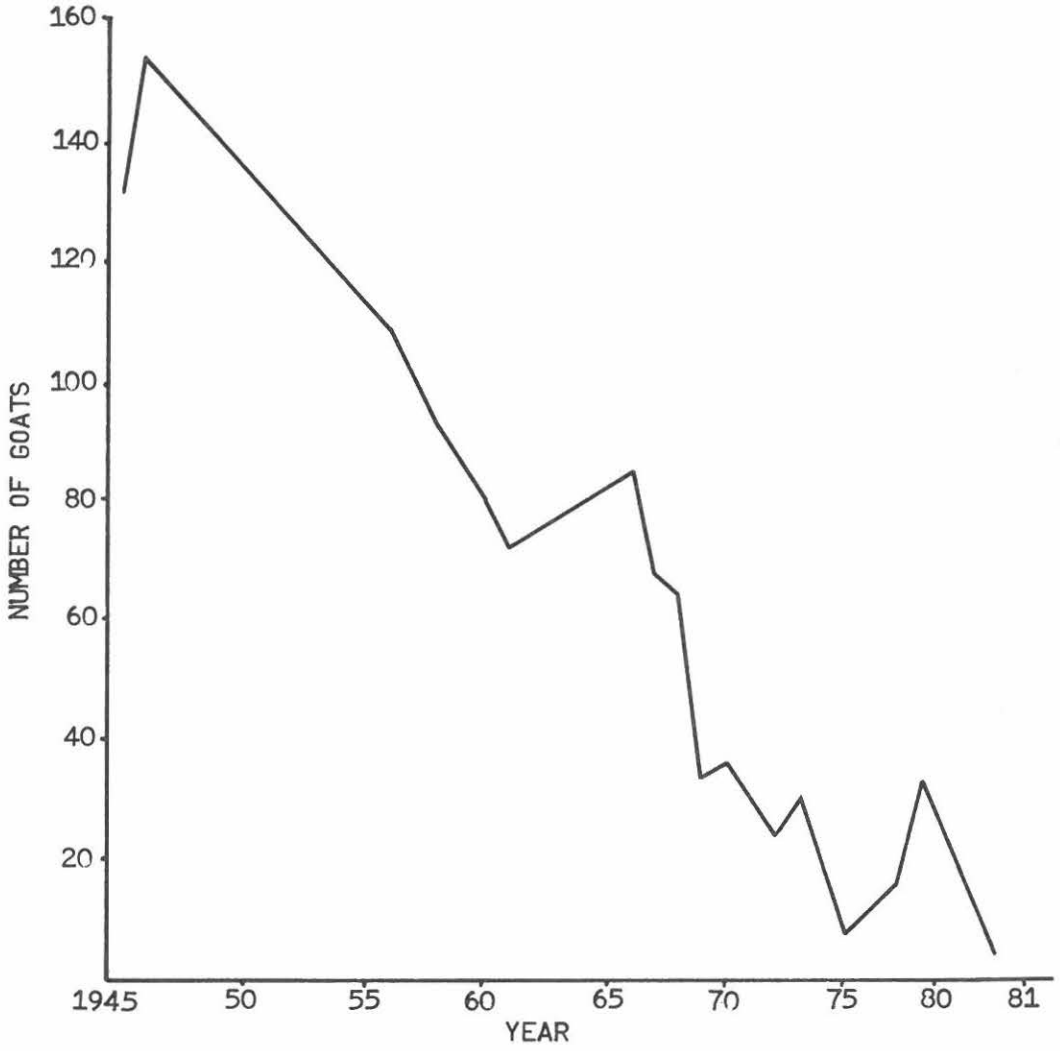

Fig. 14. Penders Canyon Goat Count by Art Ryals. (graphed by Phyllis Reed)

Barometer Mountain was burnt in 1931 and again in 1942. Mountain goat populations irrupted here, as they have in other areas of the state after a fire. In 1949, the first timber harvest in the Barometer Mountain area provided easy access to the goats. By 1968, excessive goat harvest occurred on Barometer, and the area was closed to hunting. In 1969, a separate Barometer Mountain goat unit was created to restrict hunter take in this area. Unfortunately, easy access provided for extremely high hunter success, and the unit was closed again in 1972. This area was reopened as an archery-only area in 1974, and harvest levels have remained low.

The primary method used to evaluate goat population trends in Washington is the mountain goat hunting report. Every goat hunter since 1948 has been sent a questionnaire requesting sighting information as well as harvest data. Many goat hunters document observations extremely well, and these observations are tabulated and compared to

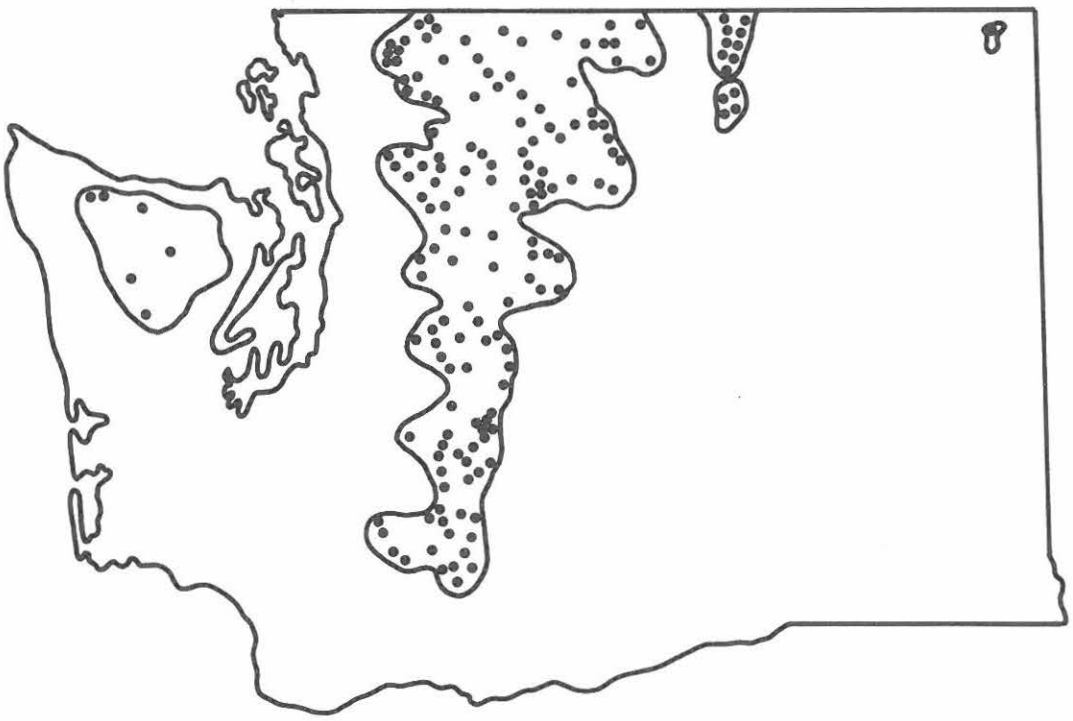

Fig. 15. Distribution of Washington's Mountain Goat Population, 1961.

previous years. Trends in sighting information have proven to be good indicators of stable, declining, or increasing populations.

As noted previously, the population estimates by Wadkins in 1961 are believed to be quite accurate and a good reference for current population status (Table 1 and Figure 15). One of the trend indicators obtained from hunter sightings is average number of goats seen per successful hunter. As can be seen in Table 22, the trend counts for units 15 and 16 indicated a declining population that recovered after several years of hunting closure.

For the last 10 years, trend counts from hunter sightings have been monitored for each goat unit in the state. In addition, hunter sightings from 1962 are included in some units which have remained similar in geographical area for the last 20 years. These trends are listed by region and game management unit in Appendix G.

Sightings of goats per hunter-day and percent of kids observed are key indicators for every unit. These two indicators in particular are important in determining whether the population is stable, declining, or increasing. The accuracy of hunter sighting data has been substantiated by Game Department surveys and also the goat study by Wright (1977). Wright remained with the goat herd on Barometer Mountain for two years and obtained accurate herd classification. In 1976, hunter sightings revealed 12 percent kids, while Wright found the kids represented 17 percent of the population. The fact that these two estimates are so close reflects the value of hunter sightings of kids.

Goat units in the state with poor sightings of kids have also had decreasing populations. In some cases, where hunting quotas were not restricted following poor kid sightings, the units eventually had to be closed to hunting. As mentioned previously, hunter harvest is not an indicator of population trends but a reflection of number of permits and type of hunting seasons.

The overall trend in Washington State has been declining goat populations since Wadkins' 1961 surveys. In the two eastern Washington study areas, declines have been substantial, but these populations are starting to recover. In the Nason Ridge area, the number of goats declined from 250 (Wadkins, 1961) to less than 100 in the mid-1970's, but have recently increased to 125. Goat numbers on Mount Chopaka declined from 200 (Wadkins, 1961) to about 60 in the mid-1970's, but have since increased to about 100 animals. In both cases, goat herds are presently about 50 percent of the population of 20 years ago. Other areas of eastern Washington have experienced even greater declines. In the Chelan area, for example, goat units 6, 7, and 21 have been closed because of severe population declines.

The trend in goat harvest (a reflection of permit level) has been a

Table 22. Average Number Goats Seen Per Successful Hunter

UNIT		AVERAGE NUMBER SEEN PER YEAR					
No.	Name	1960-63	1964-67	1968-71	1972-75	1976-79	1980-81
1.	Skagit	4.3	5.7	6.5	5.0	3.6	7.0
2.	North Methow	7.0	7.5	3.4	4.9	1.5[1]	Closed
3.	Okanogan River	9.0	13.5	12.5	Closed[2]	Closed[2]	22.0
4.	Nooksack River	16.0	7.3	8.1	8.1	8.5	7.0
5.	South Methow	6.2	7.6	7.9	8.1	10.8	8.5
6.	North Lake Chelan	6.1	8.0	8.6	13.2	8.0	3.0[3]
7.	South Lake Chelan	7.2	7.4	5.5	5.8	5.0[4]	Closed
8.	Chiwawa	14.4	11.7	10.6	7.6	9.1	6.4
9.	Glacier Peak	10.0	12.0	9.1	11.6	12.2	5.4
10.	Stillaguamish	9.2	11.3	9.8	7.1	8.9	13.7
11.	West Stevens Pass	8.9	7.3	8.1	6.7	7.8	6.1
12.	Snoqualmie	8.3	6.7	6.9	7.4	8.8	7.6
13.	N. Wenatchee Mtns.	5.3	5.7	7.3	7.0	6.4	7.9
14.	S. Wenatchee Mtns.	10.5	8.7	12.6	8.3	9.1	10.3
15.	Naches	15.3	11.5	3.4	2.3[5]	Closed	17.0
16.	Bumping River	18.5	10.6	8.6	6.0[6]	10.3	18.7
17.	Packwood	19.6	14.4	12.3	10.2	10.9	12.0[7]
18.	Tieton River	14.3	12.8	6.8	3.2[8]	Closed	Closed

[1]Unit 2 closed 1977 through 1981
[2]Unit 3 closed 1972 to present; part of unit opened as unit 47 in 1981
[3]Unit 6 closed in 1981
[4]Unit 7 closed 1979 through 1981
[5]Unit 15 closed 1974 through 1980
[6]Unit 16 closed 1975 through 1978
[7]Unit 17 closed in 1980 due to eruption of Mt. St. Helens
[8]Unit 18 closed 1975 through 1981

shift from eastern to western Washington (Table 23). It seems likely that mountain goat populations in eastern Washington have declined about 50 percent, from 4,655 in 1961 (Wadkins, 1961) to about 2,300 today.

Mountain goat declines in western Washington have not been as extensive, although as noted in Figures 13 and 14, accessibility has led to local declines. Many of the rifle units in the accessible areas

Table 23. Mountain Goat Harvest in Eastern and Western Washington.

Year	Permits Issued	Tags Sold*	Percent Success	Goat Harvest Eastside	Goat Harvest Westside	Goat Harvest Total
1948	150	....	37%	31	24	55
1949	400	....	21%	57	25	82
1950	400	....	25%	83	16	99
1951	400	....	14%	32	24	56
1952	400	....	18%	39	32	71
1953	400	333	14%	29	16	45
1954	400	329	16%	46	8	54
1955	400	325	32%	78	25	103
1956	400	302	35%	64	13	77
1957	600	512	40%	143	63	206
1958	600	516	39%	132	67	199
1959	600	502	38%	122	69	191
1960	800	692	39%	162	108	270
1961	800	703	38%	156	114	270
1962	800	773	34%	162	103	265
1963	900	791	37%	175	114	289
1964	970	870	40%	191	153	344
1965	1,030	934	42%	206	185	391
1966	1,005	943	37%	200	147	347
1967	1,060	1,000	31%	154	155	309
1968	1,065	986	34%	168	171	339
1969	895	850	38%	164	162	326
1970	925	870	39%	155	185	340
1971	936	892	43%	152	164	316
1972	930	876	34%	118	135	253
1973	930	889	37%	127	139	266
1974	961	899	38%	123	149	272
1975	905	851	36%	99	139	238
1976	915	872	41%	109	179	288
1977	855	805	40%	99	177	276
1978	905	868	41%	96	186	282
1979	880	832	34%	66	156	222
1980	810	773	43%	61	204	269
1981	805	749	43%	73	201	274
TOTAL	25,312	21,537		3,872	3,730	7,684
AVERAGE	744	743	34%	114	110	226

*1953-1981: 29 years only

have been converted to less successful archery units. In addition, many of the areas closed to hunting in 1961 have been opened to limited harvest. The net impact appears to be a decline of about 20 percent, from 3,900 in 1961 to 3,100 goats today on the western side of the Cascade Mountains.

The fastest growing goat population in the state inhabits the Olympic Mountains. This population increased from 11 or 12 goats in 1930 to at least 700 in 1981 (Hutchins and Stevens, 1981). While most of these goats reside permanently in Olympic National Park, perhaps as many as 150 goats are found outside the park at various times of the year. The statewide mountain goat population outside parks and reservations appears to number about 5,550. In addition, populations in the three national parks and on the Yakima Indian Reservation probably have another 1,800 goats. The total state population approximates 7,350.

SUMMARY

Mountain goats are native to the Cascade and Selkirk Mountains of Washington and range over most of the same areas occupied when the first white men arrived. Mountain goat sport hunting in Washington began in 1897, when hunters were limited to taking two goats each during a three-month season. In 1913, hunters were restricted to one goat per hunting season. Hunting areas were restricted in 1917, and the hunting season closed completely in 1925. Mountain goat hunting resumed in 1948 after biologists determined that the goat population was stable. Since then, mountain goat hunting has been sanctioned every year on a controlled permit basis. A unit system was established in 1957 in which geographical areas were divided into management units and permit quotas allocated among 10 units. Goat management units have since been altered to regulate hunter distribution in proportion to goat populations. A total of 47 goat units have been created over the years, but in 1981 only 38 had a hunting season.

The current distribution of mountain goats in the Cascades is nearly identical to the historic range. Transplants of mountain goats have been made to Mount Margaret, Mount Pilchuck, Lime Mountain, and Higgins Mountain. Mountain goats are not native to the Olympic Peninsula but were introduced in three transplants from Alaska and Alberta, Canada, between 1925 and 1929. The mountain goats have done extremely well in the Olympics and now number at least 700 animals. Mountain goats occurred historically in the Selkirks, but their distribution and number were never substantial. All native goats were extirpated from the Selkirks in Washington about the turn of the century. Successful transplants have been made to Flume and Hooknose Mountains.

The most universal characteristic of mountain goat range is steep, rocky terrain. Mountain goats are more closely associated with rock-cliff habitats, known as escape terrain, than any other ungulate. During the present study, goats seldom traveled more than one-half mile from this habitat, while mountain sheep frequently foraged on grasslands up to two miles from escape terrain. The climate and vegetation found in goat range is extremely diverse. During the last 40 years, biologists in Washington State have observed the beneficial impact of wildfires on goat populations. Fire suppression has obviously caused loss of quality habitat and deterioration of range condition.

Studies and observations in Washington in recent years indicate parasitism and disease may be more important than previously realized. Food habit studies on Mount Chopaka indicate substantial variability both within and between seasons. Mountain goat food habits appear to depend more on forages found in areas with preferred topographical features than on a purposeful selection of plant species. The relationship between forage availability and mountain goat populations has been documented with wildfire on Chopaka Mountain. As with other big game animals, the mountain goat population irrupted after fire created early plant successional communities, which included abundant forage.

Mountain goats occupy a niche rarely inhabited by other ungulates, particularly on critical winter ranges. While competition from cattle, elk, deer, and bighorns could be serious, normally the niche occupied by goats does not lead to forage or space competition.

Mountain goats have a home range of four to six square miles, but during the winter they restrict their movements. Migration from summer to winter ranges is usually a matter of finding suitable habitat by descending 600 to 1,400 meters in elevation. Dispersal from normal ranges appears to be a response by goats to overcrowding.

While most wildlife species have suffered from loss of habitat as a result of increasing human population, mountain goats occupy the more inaccessible areas of the state and have lost little native range as a result of human activities. There has been a loss of good goat habitat, however, from fire control and an expanding network of new roads associated with logging activity.

Annual mountain goat surveys are conducted in a variety of ways in Washington, but survey counts are extremely variable. Survey accuracy was evaluated in the current study and found to range from 25 to 63 percent for summer helicopter counts in three study areas.

In 1961, the Washington Game Department conducted a statewide goat survey using mainly ground counts. Wadkins estimated 50 percent of the goats in each survey area were observable from ground surveys. The surveys conducted in three study areas during the current study indicate Wadkins' estimates were accurate. The most practical surveys in Washington are probably ground counts similar to those conducted in 1961.

The statewide goat harvest is monitored primarily by the goat hunting report sent to each person purchasing a goat tag. Goat population trends are also monitored by sightings reported on hunter questionnaires. Sightings of goats per hunter per day and percent of kids observed are key indicators for every goat unit. These two indicators in particular are important in determining whether the population is stable, declining, or increasing. The overall trend in Washington has been declining goat populations since Wadkins' 1961 census. The statewide mountain goat population appears to number about 7,350 with approximately 1,800 of these on federally managed lands.

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Appendix A. Mountain Goats Transplanted to Hooknose Mountain in Pend Oreille County, 1981.

Metal Ear Tag No.	Age	Sex	Marking
20	1 yr.	F	Green ear tag #397 left ear, no neck collar
26	1 yr.	F	Green ear tag #392 left ear, black neck collar
18	1 yr.	M	Blue ear tag #338 right ear, blue neck collar
	2 yrs.	F	Green ear tag #395 left ear, blue/white neck collar
19	4 yrs.	F	Green ear tag #396 left ear, no neck collar
25	2 yrs.	M	Green ear tag #393 right ear, green/white neck collar
26	3 yrs.	F	Yellow ear tag #139 left ear, orange/white neck collar
27	3 yrs.	M	Yellow ear tag #113 right ear, green neck collar
28	2 yrs.	M	Blue ear tag #341 right ear, red neck collar
24	2 yrs.	F	Green ear tag #399 left ear, green neck collar
23	1 yr.	M	Green ear tag #398 right ear, orange/black neck collar

APPENDIX B. Mountain Goats Transplanted to Lime Mountain in Snohomish County, 1981.

Metal Ear Tag No.	Age	Sex	Marking
B0008	4 yrs.	F	Lime green neck collar, yellow ear tag #115 left ear
B0025	4 yrs.	F	Orange neck collar, yellow ear tag #58 left ear (Has (F) kid marked with yellow ear #100 right ear)
	Kid (Mother is B0025)	M	Yellow ear tag #100 right ear
13	2 yrs.	F	Dark blue/light blue neck collar, blue ear tag #323 left ear
14	1 yr.	M	Collar: none. Yellow ear tag #89 right ear
15	1 yr.	M	Orange neck collar, blue ear tag #344 right ear
16	4 yrs.	F	Yellow neck collar, yellow ear tag #75 left ear
17	3 yrs.	M	Orange neck collar, blue ear tag #346 right ear
	1 yr.	M	Collar: none. Blue ear tag #345 right ear
	2 yrs.	M	Collar: none. Blue ear tag #350 right ear

Appendix C. Mountain Goats Transplanted to Higgins Mountain in Skagit County, 1981.

Metal Ear Tag No.	Age	Sex	Marking
2	2 yrs.	F	Black neck collar, blue ear tag #314 left ear
3	6 yrs.	F	Black/blue neck collar, yellow ear tag #80 left ear
4	1 yr.	M	Light blue neck collar, blue ear tag #315 right ear; (mother is #3, yellow ear tag #80)
5	2 yrs.	M	Blue/white neck collar, blue ear tag #313 right ear
6	6 yrs.	F	Dark blue neck collar, yellow ear tag #21 left ear
8	kid	M	Yellow ear tag #91 right ear (mother is #9, yellow ear tag #71 left ear)
9	4 yrs.	F	Orange neck collar, yellow ear tag #71 left ear
10	1 yr.	M	Dark blue neck collar, blue ear tag #308 right ear
11	2 yrs.	F	Light blue/black neck collar, blue ear tag #306 left ear
12	2 yrs.	F	Light blue/orange neck collar, yellow ear tag #85 left ear

Appendix D. Mountain Goats Captured at Alpine Lookout (Nason Ridge), 1978-1980.

Date	Tag No.	Sex	Age	Marker
6/26/78	414	F	1 yr.	Orange patch, right ear. Orange ear tag, left ear #14
6/27/78	415	F	3 yrs.	Lime green neck collar. Orange ear tag #13
7/5/78	416	F	4 yrs.	Blaze orange neck collar. Orange ear tag, right ear #15; blue ear patch, left ear
7/6/78	417	M	kid (6 wks.)	Orange streamer, right ear. Accompanying nannie, #418
7/6/78	418	F	3 yrs.	Blue neck collar. Orange ear tag, right ear #16; blue patch, left ear
6/7/79	153	M	3 yrs.	Black/red neck collar. Orange ear tag, right ear #12; red patch, left ear
6/8/79	54	F	4 yrs.	Blue/black neck collar. Orange ear tag, left ear #18; blue patch, right ear
6/8/79	156	M	kid (2 wks.)	Orange patch, left ear
6/8/79	155	M	6 yrs.	Yellow collar, green patch, right ear. Orange ear tag, left ear #19
6/8/79	161	M	3 yrs.	Silver/red neck collar, green patch, right ear. Orange ear tag, left ear #20
6/9/79	160	F	10 yrs.	Purple/white neck collar. Orange ear tag #21 and Blue ear patch
6/9/79	157	F	kid (2 wks.)	Orange ear patch, right ear
6/19/79	158	M	4 yrs.	Blue/purple/black/white collar. Orange tag, right ear #24 and orange patch, left ear
6/20/79	185	F	2 yrs.	Orange/green neck collar, green streamer left ear and orange ear tag, right ear #25
6/20/79	159	M	1 yr.	Blue/white/green neck collar. Orange ear tag, right ear #26 and red patch, left ear
6/20/79	184	M	6 yrs.	Blue/white neck collar. Blue patch, left ear; orange ear tag, right ear #27
6/20/79	183	M	kid (3 wks.)	Orange patch, left ear. On 6/21/79 recaptured, ear tag pulled, kid escaped
6/21/79	181	F	kid (4 wks.)	Orange patch in right ear
6/22/79	180	F	7 yrs.	Yellow neck collar (small orange stripe). Orange ear tag, right ear #28; blue patch, left ear
6/22/79	179	M	1 yr.	Yellow/orange neck collar. Orange ear tag, left ear #29; black patch, right ear
6/22/79	178	F	2 yrs.	Orange/blue neck collar, orange ear tag, right ear #30; green patch, left ear
6/18/80	152	F	1 yr.	Lime green streamer, right ear. Yellow ear tag #51, left ear
7/1/80	162	M	3 yrs.	Orange neck collar, yellow ear tag #52, right ear
7/1/80	174	F	2 yrs.	Orange neck collar, yellow ear tag #53, left ear; blue patch, right ear
7/1/80	176	M	kid	Yellow ear tag #54; green patch, left ear

Appendix E. Mountain Goats Captured in the Olympic Mountains, 1979-1980.

Date	Tag No.	Sex	Age	Location	Marker
7/24/79	441	M	1 yr.	Charlia Lake	Orange neck collar. Orange ear tag, left ear #36; green tag, right ear
7/25/79	442	F	4 yrs.	Charlia Lake	Lime green neck collar. Orange ear tag, left ear #11; black patch, right ear
8/1/79	443	M	3 yrs.	Iron Mtn.	Lime green neck collar. Orange ear tag, left ear #39; green patch, right ear
7/15/80	420	F	1 yr.	Iron Mtn.	Yellow neck collar. Red streamer, left ear; yellow ear tag #56 right ear
7/15/80	421	M	2 yrs.	Iron Mtn.	Yellow neck collar. Orange streamer, right ear; yellow ear tag #57, left ear
7/17/80	422	F	2 yrs.	Iron Mtn.	Yellow neck collar. Yellow ear tag #58
7/17/80	423	F	3 yrs.	Iron Mtn.	Yellow neck collar. Yellow ear tag #60, left ear
7/17/80	424	F	1 yr.	Iron Mtn.	Yellow neck collar. Yellow ear tag #59
7/17/80	425	M	1 yr.	Iron Mtn.	Yellow neck collar. Yellow ear tag #61
7/17/80	426	F	2 yrs.	Iron Mtn.	Yellow neck collar. Yellow ear tag #52, left ear
7/17/80	427	M	2 yrs.	Iron Mtn.	Yellow neck collar. Yellow ear tag #63, right ear
7/17/80	428	M	2 yrs.	Iron Mtn.	Black radio collar (from Park) Frequency 151.018. Orange ear tag #22, left ear
7/17/80	429	M	2 yrs.	Iron Mtn.	Orange neck collar. Yellow ear tag #64, left ear
7/29/80	467	F	3 yrs.	Charlia Lake	Lime green neck collar. Orange ear tag #42, left ear
7/29/80	466	F	Kid	Charlia Lake	Red streamer, right ear. Orange ear tag #47, left ear
7/29/80	465	F	Kid	Charlia Lake	Orange ear tag #48, right ear
7/30/80	473	F	2 yrs.	Charlia Lake	Lime green neck collar. Orange ear tag #49, right ear
7/30/80	470	M	1 yr.	Charlia Lake	Blaze orange neck collar. Orange ear tag #50, left ear
7/30/80	468	F	5 yrs.	Charlia Lake	Blaze orange neck collar. Orange ear tag #9, left ear. (Tagged previously by ONP on Constance)
7/30/80	469	F	Kid	Charlia Lake	Yellow ear tag #65, right ear (kid of #468)
7/30/80	472	F	3 yrs.	Charlia Lake	Red/green neck collar. Orange ear tag #3 (Captured previously by ONP on Constance) (has kid #471)
7/30/80	471	M	Kid	Charlia Lake	Yellow ear tag #66, right ear. Orange ear patch, left ear. Killed 9/17/81 by hunter

Appendix F. Mountain Goats Captured on Mount Chopaka, 1977-1980.

Date	Tag No.	Sex	Age	Weight	Marker
6/21/77	142	F	3 wks.	14 lbs.	Blaze orange ear patch, right ear
6/21/77	406	F	10 yrs.	167 lbs.	Blue ear tag right ear. Blaze orange neck collar
6/21/77	407	F	9 yrs.	161 lbs.	Blue ear patch left ear. Lime green neck collar
6/23/77	408	M	2 yrs.	125 lbs.	Blaze orange patch left ear. Light blue neck collar
6/23/77	410	F	1 yr.	77 lbs.	Orange/white neck collar. Lime green ear tag, right ear
6/24/77	411	M	3 yrs.	171 lbs.	Black neck collar. Orange patch, left ear
7/17/77	412	M	6 yrs.	242 lbs.	Blue/blaze orange neck collar. Lime green ear patch, left ear
7/17/77	413	M	3 yrs.	194 lbs.	White/lime green/black collar. Lime green/blaze orange ear streamer, left ear
5/24/79	170	M	6 yrs.	not weighed	Lime green neck collar. Orange ear tag, #17 right ear
6/25/79	177	F	4 yrs.	150 lbs.	Orange/green neck collar. Blue tag right ear, orange ear tag #31
6/25/79	173	M	kid	30 lbs.	Green patch right ear
6/26/79	143	F	6 yrs.	148 lbs.	Yellow neck collar. Orange ear tag #32
6/26/79	144	M	2 yrs.	170 lbs.	Blaze orange neck collar. Orange ear tag #33
6/27/79	145	M	2 yrs.	140 lbs.	Orange/black neck collar. Green patch, right ear. Orange ear tag #34, left ear
7/15/79	146	F	4 yrs.	163 lbs.	Orange/yellow neck collar. Blue tag, right ear; orange ear tag #35
7/15/79	440	F	kid (6 wks.)	59 lbs.	Black patch right ear. Orange ear tag #37
7/8/80	419	M	6 yrs.	170 lbs.	Orange/lime green neck collar. Black ear tag, left ear. Yellow ear tag #55, right ear

Appendix G. Goat Population Trend by Region and Management Unit.

Region 1 Goat Summary

The only mountain goat unit in this region is Goat Unit 30 (Linton Mountain).

All goats taken in this unit were derived from an introduction of seven goats in 1965. Washington Game Department personnel captured these goats on Nason Ridge in Chelan County and transplanted them to Flume Creek in Pend Oreille County. The seven goats consisted of two billies, four nannies and one female kid.

Mountain goat hunting seasons on Linton Mountain were initiated in 1972 when the goat population had increased to about 35. The hunter take was excessive, however, and the unit closed in 1977.

Region 1 Sighting and Harvest Summary (1972-1981)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 30 (Linton Mtn.)							
1972	5	6	18.3	9.2	41%	5	83%
1973	10	7	16.0	4.5	35%	6	86%
1974	15	14	13.9	3.8	27%	11	79%
1975	10	10	12.0	3.4	43%	8	80%
1976	5	5	5.4	1.9	30%	4	80%
1977	Closed						
1978	Closed						
1979	Closed						
1980	Closed						
1981	Closed						

Region 2 Goat Summary

This region includes Goat Units 2, 5, 34 and 47. The old unit 3 (Okanogan River) was closed to hunting in 1972. Part of this area was reopened in 1981 as Unit 47 (Mount Chopaka). Goat Units 2 and 34 have been closed since 1976.

Region 2 Sighting and Harvest Summary (1971-1981) with reference to 1962 data

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 2 (Methow River)							
1962	60	63	4.7	0.7	?	16	25%
1971	60	43	1.0	0.2	20%	9	21%
1972	60	40	1.6	0.4	22%	5	13%
1973	60	42	1.7	0.4	24%	7	17%
1974	60	39	2.1	0.5	23%	10	26%
1975	30	22	3.8	0.9	20%	6	27%
1976	20	12	1.3	0.2	0%	2	16%
1977	Closed						
1978	Closed						
1979	Closed						
1980	Closed						
1981	Closed						

Region 2 Sighting and Harvest Summary (1971-1981) with reference to 1962 data

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 5 (South Methow River)							
1962	25	23	4.1	0.7	?	7	31%
1971	25	17	4.3	0.9	33%	7	41%
1972	25	19	5.4	1.1	29%	7	37%
1973	25	18	5.7	1.4	16%	6	33%
1974	25	18	3.5	1.1	29%	5	29%
1975	25	21	4.1	1.0	35%	4	19%
1976	25	21	4.4	0.9	29%	7	33%
1977	25	12	8.7	1.5	39%	6	50%
1978	25	17	5.0	0.9	24%	7	41%
1979	25	18	6.3	1.3	45%	6	33%
1980	25	15	6.2	1.3	17%	4	27%
1981	25	18	7.3	1.5	40%	8	44%
Goat Unit 34 (Pasayten)							
1976	10	6	2.5	0.3	20%	2	33%
1977	Closed						
1978	Closed						
1979	Closed						
1980	Closed						
1981	Closed						
Goat Unit 47 (Mount Chopaka)							
1962	30	27	6.1	2.3	?	14	56%
1981	5	5	23.8	10.8	22%	4	80%

Region 2 Goat Harvest Summary (1960-1981)

Year	Permits Authorized	Hunters	Goat Harvest	Percent Success
1960	150	106	43	41%
1961	130	96	35	36%
1962	115	94	37	39%
1963	110	89	29	33%
1964	110	81	42	52%
1965	110	83	46	55%
1966	110	89	49	55%
1967	110	87	33	38%
1968	105	83	24	29%
1969	105	65	23	35%
1970	105	66	24	36%
1971	100	73	26	36%
1972	85	59	12	20%
1973	85	60	13	22%
1974	85	57	15	26%
1975	55	43	10	23%
1976	55	39	11	28%
1977	25	12	6	50%
1978	25	17	7	41%
1979	25	18	6	33%
1980	25	15	4	27%
1981	30	23	12	53%

Region 3 Goat Summary

This region includes Goat Units 6, 7, 8, 13, 14, 14ML, 15, 16, 16ML, 18, 21, 22, and 27. Goat Unit 27 is restricted to archery only. Units 14ML and 16ML are muzzleloader units. Units 6, 7, 18 and 21 were closed in 1981.

Region 3 Sighting and Harvest Summary (1971-1981) with reference to 1962 data.

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 6 (North Lake Chelan)							
1962	60	44	6.5	1.6	?	20	46%
1971	60	50	6.3	1.5	26%	21	42%
1972	61	42	8.9	2.5	22%	19	45%
1973	60	46	7.5	1.7	23%	19	41%
1974	60	37	10.2	2.8	20%	15	40%
1975	60	42	7.4	1.5	26%	19	45%
1976	60	48	5.0	1.1	25%	26	54%
1977	60	45	3.5	0.8	19%	11	24%
1978	60	37	4.4	0.8	12%	13	35%
1979	40	29	2.7	0.7	35%	7	24%
1980	20	12	0.6	0.2	0%	2	17%
1981	Closed						
Goat Unit 7 (South Lake Chelan)							
1962	40	30	4.8	1.2	?	9	36%
1971	40	29	4.5	0.9	21%	9	31%
1972	40	33	4.8	0.9	15%	12	36%
1973	40	22	2.2	0.5	19%	6	27%
1974	40	33	4.4	0.9	27%	9	27%
1975	40	26	2.8	0.5	26%	9	35%
1976	40	25	2.6	0.4	20%	3	12%
1977	25	15	4.2	0.7	11%	4	27%
1978	25	23	2.1	0.4	2%	10	43%
1979	Closed						
1980	Closed						
1981	Closed						
Goat Unit 8 (Chiwawa River)							
1962	65	50	4.8	1.8	?	18	36%
1971	65	55	6.2	1.3	28%	19	35%
1972	65	52	2.7	0.6	25%	11	21%
1973	65	51	6.1	1.0	24%	19	37%
1974	65	55	3.7	0.8	24%	13	24%
1975	60	41	2.6	0.6	23%	11	27%
1976	60	43	3.9	0.7	16%	13	30%
1977	60	45	4.3	0.9	20%	21	47%
1978	60	47	7.6	1.2	18%	14	30%
1979	60	41	2.6	0.6	26%	11	27%
1980	50	32	6.8	1.3	31%	9	28%
1981	50	37	3.3	0.7	27%	14	38%

Region 3 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 13 (North Wenatchee Mountains)							
1962	30	26	5.8	1.4	?	14	54%
1971	30	25	6.4	1.6	22%	15	60%
1972	30	23	5.0	0.9	21%	12	52%
1973	30	21	6.4	1.9	25%	6	29%
1974	30	21	3.9	1.1	17%	12	57%
1975	30	20	3.8	0.9	17%	10	50%
1976	30	25	4.8	1.2	19%	12	48%
1977	30	26	7.9	1.8	32%	17	65%
1978	30	27	4.0	0.9	23%	14	52%
1979	30	20	3.1	0.5	5%	4	20%
1980	20	16	3.8	1.0	28%	6	38%
1981	10	8	5.9	1.5	30%	2	25%
Goat Unit 14 (South Wenatchee Mountains)							
1962	45	40	10.1	3.2	?	21	53%
1971	40	27	11.7	3.1	19%	21	78%
1972	40	32	9.8	2.4	26%	25	78%
1973	40	35	13.0	3.0	20%	28	80%
1974	40	31	7.1	2.0	22%	21	68%
1975	40	36	6.0	1.4	26%	19	53%
1976	40	32	8.0	1.8	25%	20	63%
1977	40	34	7.4	1.9	24%	23	68%
1978	40	33	9.5	2.4	31%	25	76%
1979	40	33	7.7	1.5	24%	21	64%
1980	40	36	8.7	1.7	27%	24	67%
1981	40	36	8.6	2.1	23%	21	58%
Goat Unit 14 ML (South Wenatchee Mountains)							
1974	10	5	6.8	1.1	12%	2	40%
1975	10	7	8.3	2.4	31%	4	57%
1976	10	8	12.3	2.2	30%	5	62%
1977	10	7	8.4	1.6	19%	3	43%
1978	10	5	6.0	1.2	10%	1	20%
1979	10	9	7.4	1.3	27%	4	44%
1980	10	8	7.3	1.3	31%	5	63%
1981	10	8	15.8	2.1	34%	2	25%
Goat Unit 15 (Naches Pass)							
1962	50	47	6.4	1.4	?	15	31%
1971	10	8	2.1	0.2	29%	1	13%
1972	10	9	2.1	0.5	26%	2	22%
1973	10	6	0.7	0.2	0%	1	17%
1974	Closed						
1975	Closed						
1976	Closed						
1977	Closed						
1978	Closed						
1979	Closed						
1980	Closed						
1981	5	4	17.5	4.4	31%	3	75%

Region 3 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 16 (Bumping River)							
1962	40	33	15.6	3.7	?	15	46%
1971	30	23	2.9	0.7	31%	11	48%
1972	30	24	3.4	0.6	21%	3	13%
1973	30	23	1.3	0.2	17%	2	9%
1974	20	16	2.2	0.4	14%	4	25%
1975	Closed						
1976	Closed						
1977	Closed						
1978	Closed						
1979	Closed						
1980	Closed						
1981	5	5	15.4	1.4	30%	3	60%
Goat Unit 16ML (Bumping River)							
1971	7	3	6.7	0.9	5%	2	67%
1972	10	8	3.0	0.5	17%	1	13%
1973	10	5	4.2	0.6	10%	2	40%
1974	10	8	7.6	1.0	18%	3	37%
1975	Closed						
1976	Closed						
1977	Closed						
1978	Closed						
1979	10	9	10.1	2.2	34%	3	33%
1980	10	7	9.7	3.4	13%	6	89%
1981	10	7	6.9	1.1	13%	4	57%
Goat Unit 18 (Tieton River)							
1962	35	34	13.9	3.6	?	11	32%
1971	15	11	11.4	1.8	20%	2	18%
1972	15	11	1.9	0.3	14%	2	18%
1973	15	12	4.1	0.9	39%	5	42%
1974	15	12	1.4	0.3	12%	3	25%
1975	Closed						
1976	Closed						
1977	Closed						
1978	Closed						
1979	Closed						
1980	Closed						
1981	Closed						

Region 3 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 21 (Stehekin River)							
1962	25	23	5.5	0.7	?	5	22%
1971	25	18	4.2	0.9	30%	8	44%
1972	24	17	2.1	0.4	29%	5	29%
1973	25	19	8.7	1.5	18%	8	42%
1974	25	19	3.9	0.9	5%	6	32%
1975	25	15	2.5	0.4	29%	3	20%
1976	25	17	1.2	0.3	33%	4	24%
1977	15	11	4.9	1.0	24%	4	36%
1978	15	9	0.7	0.1	0%	1	11%
1979	----------	----------	----------	Closed	----------	----------	----------
1980	----------	----------	----------	Closed	----------	----------	----------
1981	----------	----------	----------	Closed	----------	----------	----------
Goat Unit 22 (East Stevens Pass)							
1971	10	10	5.0	1.2	10%	6	50%
1972	11	9	5.7	1.7	27%	6	67%
1973	10	9	2.7	0.8	13%	4	44%
1974	11	9	7.6	1.3	32%	4	44%
1975	10	6	7.0	1.7	19%	2	33%
1976	10	10	6.5	3.3	34%	8	80%
1977	10	9	12.3	1.9	27%	7	78%
1978	10	10	8.6	1.7	28%	5	50%
1979	10	8	11.5	1.9	21%	6	75%
1980	10	8	13.7	2.6	23%	6	67%
1981	10	9	5.6	1.4	32%	3	33%
Goat Unit 27 (Goat and Davis Mountains)							
1971	30	26	64.1	10.7	21%	0	38%
1972	30	27	47.6	7.8	26%	4	15%
1973	30	25	39.4	7.0	33%	2	8%
1974	30	21	60.8	7.7	25%	5	24%
1975	30	20	15.0	3.0	24%	4	20%
1976	30	22	31.8	4.2	30%	3	14%
1977	30	18	16.8	2.9	32%	3	17%
1978	30	25	23.2	3.8	22%	6	24%
1979	30	23	20.0	3.1	28%	4	17%
1980	30	26	25.9	4.1	25%	3	12%
1981	30	26	30.0	5.3	29%	9	35%

Region 3 Goat Harvest Summary (1960-1981)

Year	Permits Authorized	Hunters	Goat Harvest	Percent Success
1960	330	259	119	46%
1961	350	273	121	44%
1962	390	313	122	39%
1963	415	348	144	41%
1964	415	317	148	47%
1965	405	310	159	51%
1966	380	299	152	51%
1967	403	317	121	38%
1968	410	305	143	47%
1969	360	265	140	53%
1970	364	276	133	48%
1971	362	285	125	44%
1972	366	287	102	28%
1973	365	274	102	37%
1974	356	267	97	36%
1975	305	213	81	38%
1976	306	230	94	41%
1977	280	210	93	44%
1978	280	216	89	41%
1979	230	172	60	35%
1980	190	146	61	42%
1981	170	140	61	44%

Region 4 Goat Summary

Region 4 includes Goat Units: 1, 3, 4, 9, 10, 11, 12, 19, 23, 25, 26, 29, 31, 32, 33, 35, 36, 37, 38, 39, 44, 45, and 46. Goat Unit 3 (Lime Mountain) was closed in 1979. Castle Mountain (Unit 3) was opened as an archery only area in 1980. Goat Units 3, 31, 33, and 36 are restricted to archery only, while Units 32, 35, and 38 are muzzleloader only. Goat Unit 12 was split into Units 44, 45, and 46 in 1981.

Region 4 Sighting and Harvest Summary (1971-1981) with reference to 1962 data.

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 1 (Skagit River)							
1962	95	70	4.7	0.7	?	14	20%
1971	40	27	2.9	0.6	28%	6	22%
1972	40	35	2.0	0.4	25%	9	26%
1973	40	30	2.8	0.5	35%	7	23%
1974	40	30	3.0	0.5	21%	9	21%
1975	40	26	2.7	0.5	27%	6	23%
1976	40	27	2.4	0.4	24%	7	25%
1977	40	32	3.1	0.5	21%	9	28%
1978	40	23	2.9	0.5	19%	11	48%
1979	40	32	2.0	0.4	19%	6	19%
1980	40	31	5.3	0.9	27%	9	29%
1981	35	20	4.3	0.8	24%	10	50%

Region 4 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 3 (Lime Mountain)							
1974	20	16	1.6	0.3	12%	1	6%
1975	20	15	0.1	0.1	0%	1	7%
1976	----------	----------	----------	Closed	----------	----------	----------
1977	----------	----------	----------	Closed	----------	----------	----------
1978	10	8	0	0	0%	0	0%
1979	----------	----------	----------	Closed	----------	----------	----------
1980	----------	----------	----------	Closed	----------	----------	----------
1981	----------	----------	----------	Closed	----------	----------	----------
Goat Unit 3 (Castle Mountain)							
1980	5	5	29.4	4.9	35%	2	40%
1981	5	4	67.0	6.5	31%	2	50%
Goat Unit 4 (Ruth Creek)							
1962	25	21	9.0	2.8	?	9	43%
1971	25	21	3.7	0.8	17%	5	24%
1972	26	23	2.0	0.3	19%	1	5%
1973	25	23	3.3	0.7	16%	9	39%
1974	25	21	9.8	1.5	25%	7	33%
1975	25	15	3.7	0.6	21%	1	7%
1976	25	22	6.5	1.6	25%	12	54%
1977	25	17	9.4	1.7	26%	8	47%
1978	25	21	4.1	1.0	8%	8	38%
1979	25	22	5.6	0.7	27%	8	36%
1980	25	19	6.4	1.1	13%	6	32%
1981	25	23	3.3	0.5	25%	6	26%
Goat Unit 9 (Glacier Peak)							
1962	35	28	9.3	2.7	?	10	35%
1971	39	30	5.4	1.2	22%	14	47%
1972	40	23	3.6	0.8	21%	9	39%
1973	40	31	6.2	1.2	24%	3	10%
1974	40	30	5.0	0.9	26%	8	27%
1975	60	40	4.1	1.1	38%	11	28%
1976	70	42	6.4	1.4	28%	12	29%
1977	70	44	3.6	0.8	28%	10	23%
1978	70	43	4.5	1.0	18%	9	21%
1979	70	45	2.6	0.5	30%	12	27%
1980	70	51	3.8	0.9	23%	16	31%
1981	60	40	2.2	0.5	20%	10	25%

Region 4 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 10 (Stillaguamish River)							
1962	20	18	9.1	5.1	?	11	61%
1971	25	20	9.3	2.8	21%	16	80%
1972	25	20	4.9	1.2	22%	4	20%
1973	25	17	16.0	2.5	22%	10	59%
1974	25	19	5.3	1.3	15%	12	63%
1975	25	24	8.3	1.9	26%	13	54%
1976	25	21	6.5	1.3	21%	13	61%
1977	30	26	9.3	2.0	29%	15	58%
1978	31	27	9.6	2.0	21%	14	52%
1979	30	22	7.4	1.5	27%	10	45%
1980	30	24	13.0	2.7	24%	18	75%
1981	30	23	12.7	1.9	21%	14	61%
Goat Unit 11 (Wallace River) formerly part of the West Stevens Pass Unit							
1962	60	47	9.4	1.8	?	15	32%
1971	70	59	6.8	1.5	24%	24	41%
1972	70	51	6.8	1.3	20%	31	61%
1973	70	52	4.6	1.1	24%	25	48%
1974	70	56	5.9	1.2	23%	28	50%
1975	70	50	4.2	1.0	22%	21	42%
1976	70	56	4.0	0.9	13%	28	50%
1977	60	42	8.4	1.6	28%	28	67%
1978	35	22	4.9	1.1	20%	13	59%
1979	35	27	7.3	1.8	21%	16	59%
1980	35	27	6.2	1.5	24%	16	59%
1981	35	27	5.3	1.0	24%	19	70%
Goat Unit 12 (Snoqualmie)							
1962	60	49	7.7	2.3	?	27	55%
1971	50	44	4.3	0.8	19%	24	55%
1972	50	38	5.4	0.9	20%	17	45%
1973	50	40	4.7	1.1	20%	21	53%
1974	50	41	4.9	1.2	22%	19	46%
1975	50	35	5.4	1.2	23%	23	66%
1976	50	44	7.7	1.0	15%	26	59%
1977	50	38	8.6	1.9	30%	21	55%
1978	50	41	6.4	1.3	28%	26	63%
1979	50	39	5.0	1.1	23%	15	38%
1980	50	43	7.6	1.8	23%	31	72%
1981	---------- Split into Units 44, 45 and 46 in 1981 ----------						

Region 4 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 19 (East Ross Lake)							
1962	20	17	7.3	0.7	?	3	18%
1971	25	14	5.1	1.2	15%	7	50%
1972	26	19	3.7	0.8	20%	7	37%
1973	25	16	2.2	0.3	20%	2	13%
1974	15	8	0.7	0.1	0%	1	12%
1975	10	4	1.0	0.2	0%	1	25%
1976	10	8	4.0	0.6	25%	4	50%
1977	10	8	0.6	0.1	40%	0	0%
1978	10	8	9.4	1.7	32%	4	50%
1979	15	12	1.7	0.2	32%	4	36%
1980	15	9	2.7	0.5	13%	3	33%
1981	15	9	4.9	1.3	25%	3	33%
Goat Unit 23 (Baker Lake)							
1971	25	19	24.1	4.9	36%	13	68%
1972	25	21	5.7	1.4	33%	7	33%
1973	25	20	9.8	2.6	18%	10	50%
1974	25	17	14.7	2.2	16%	8	47%
1975	25	18	14.2	3.7	30%	9	50%
1976	25	23	10.6	2.0	26%	10	43%
1977	25	23	11.6	3.5	31%	15	65%
1978	25	20	16.4	3.5	23%	6	30%
1979	30	27	19.7	3.0	18%	13	48%
1980	30	24	18.6	3.6	30%	10	42%
1981	30	25	15.4	3.2	22%	10	40%
Goat Unit 24 (Nooksack River)							
1971	20	19	6.7	1.3	24%	3	16%
1972	15	12	3.8	0.7	13%	3	25%
1973	15	11	4.1	0.9	29%	6	55%
1974	15	13	7.7	1.7	21%	4	31%
1975	15	11	11.5	3.0	33%	7	64%
1976	15	13	8.3	1.4	19%	5	38%
1977	15	9	6.7	1.9	37%	5	56%
1978	15	15	10.1	1.9	34%	9	60%
1979	15	11	2.7	0.5	10%	4	36%
1980	15	14	16.5	3.3	22%	9	64%
1981	15	10	3.5	0.6	6%	4	40%
Goat Unit 25 (Greenwater River)							
1971	20	16	6.4	0.9	15%	6	38%
1972	21	18	9.3	1.9	24%	8	44%
1973	20	18	3.1	0.7	27%	11	61%
1974	20	12	8.5	1.5	17%	6	50%

Region 4 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 25 (Greenwater River) (Cont.)							
1975	20	14	10.4	1.3	30%	7	50%
1976	20	18	6.6	0.9	17%	9	50%
1977	20	16	12.0	2.1	41%	11	69%
1978	25	19	4.2	0.6	21%	9	47%
1979	15	11	4.0	0.6	32%	1	9%
1980	10	7	8.7	1.3	28%	4	57%
1981	10	7	5.7	1.2	20%	4	57%
Goat Unit 26 (Foss River)							
1971	25	17	4.0	1.3	15%	7	41%
1972	25	20	1.5	0.3	7%	6	30%
1973	25	22	2.8	0.6	23%	7	32%
1974	25	16	3.9	0.8	11%	6	37%
1975	25	19	2.1	0.4	31%	6	32%
1976	25	22	3.3	0.7	33%	6	27%
1977	25	21	4.2	1.1	32%	11	52%
1978	25	21	4.9	1.0	27%	9	43%
1979	25	19	5.8	1.0	28%	5	26%
1980	25	19	5.1	1.2	35%	7	37%
1981	25	21	3.2	0.7	19%	6	29%
Goat Unit 29 (Sauk River)							
1971	25	18	4.6	1.3	23%	9	50%
1972	25	24	6.3	1.8	23%	7	29%
1973	25	22	5.6	1.0	11%	6	27%
1974	25	19	9.8	2.3	20%	9	47%
1975	25	20	3.8	0.9	25%	7	35%
1976	25	19	5.2	1.4	11%	10	53%
1977	25	19	2.9	0.7	25%	6	32%
1978	25	14	3.6	1.1	18%	6	43%
1979	25	22	3.8	0.7	15%	2	9%
1980	15	14	4.6	1.0	16%	10	71%
1981	15	6	4.2	1.1	24%	2	33%
Goat Unit 31 (Barometer Mountain)							
1974	10	8	16.9	2.3	37%	3	37%
1975	10	8	13.9	2.8	29%	1	13%
1976	10	8	7.5	1.2	12%	1	13%
1977	10	8	23.5	2.7	35%	5	63%
1978	10	9	24.0	2.6	29%	1	11%
1979	15	12	18.6	1.9	35%	1	8%
1980	15	13	22.6	2.8	26%	2	15%
1981	15	12	23.8	3.4	33%	2	17%

Region 4 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 32 (Sloan Peak)							
1974A	15	14	16.9	2.5	12%	2	14%
1975A	30	25	4.2	0.6	14%	2	8%
1976A	35	24	9.5	1.5	9%	1	4%
1977ML	20	17	6.2	1.5	25%	3	18%
1978ML	20	15	6.0	1.5	16%	2	13%
1979ML	20	11	3.4	0.7	8%	2	18%
1980ML	20	15	7.1	1.6	19%	4	27%
1981ML	20	15	4.5	1.0	13%	7	47%
Goat Unit 33 (Whitechuck)							
1976	20	12	25.8	4.1	17%	2	17%
1977	30	19	57.6	9.4	22%	4	21%
1978	20	15	23.0	2.9	30%	4	27%
1979	30	21	27.1	3.2	21%	2	9%
1980	30	19	18.8	3.4	21%	4	21%
1981	30	21	23.3	2.6	24%	2	10%
Goat Unit 35 (Vesper Peak)							
1977	10	9	11.6	3.6	41%	1	11%
1978	15	8	9.2	1.5	17%	3	33%
1979	15	11	12.3	2.4	19%	6	54%
1980	15	10	5.3	1.4	23%	2	20%
1981	15	13	3.9	0.8	22%	7	54%
Goat Unit 36 (Clear Creek)							
1978	25	21	17.6	2.3	29%	7	33%
1979	25	17	12.5	2.0	22%	4	23%
1980	25	19	17.5	2.3	27%	6	32%
1981	25	15	9.3	1.8	26%	4	27%
Goat Unit 37 (Gunn Peak)							
1978	25	20	13.8	3.0	21%	12	60%
1979	25	23	6.9	1.1	16%	8	35%
1980	25	20	8.2	2.2	26%	11	55%
1981	25	19	7.1	1.7	15%	12	63%
Goat Unit 38 (Pugh Mountain)							
1978	15	12	4.8	0.9	12%	2	17%
1979	15	6	4.0	1.2	29%	2	33%
1980	15	10	5.6	1.9	18%	5	50%
1981	15	14	7.9	1.5	23%	8	57%

Region 4 Sighting and Harvest Summary (1971-1981) (Cont.)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 39 (White River)							
1979	10	9	6.1	1.5	38%	7	78%
1980	15	13	2.4	0.3	17%	3	23%
1981	15	12	3.7	0.6	9%	6	50%
Goat Unit 44 (Pratt River)							
1981	20	14	7.4	1.2	27%	6	43%
Goat Unit 45 (Bessemer Mountain)							
1981	10	9	5.4	2.2	14%	7	78%
Goat Unit 46 (Tolt River)							
1981	20	17	5.9	1.4	24%	12	71%

Region 4 Goat Harvest Summary (1960-1981)

Year	Permits Authorized	Hunters	Goat Harvest	Percent Success
1960	290	214	92	43%
1961	285	215	98	46%
1962	341	232	92	40%
1963	340	268	104	39%
1964	400	304	138	45%
1965	470	366	169	46%
1966	470	376	132	35%
1967	481	364	137	38%
1968	430	330	149	45%
1969	345	254	130	51%
1970	370	294	153	52%
1971	389	303	134	44%
1972	388	301	109	36%
1973	385	302	117	39%
1974	420	321	122	38%
1975	450	323	116	36%
1976	464	359	145	40%
1977	465	348	152	44%
1978	516	383	155	40%
1979	530	399	128	32%
1980	525	406	178	44%
1981	510	376	163	43%

Region 5 Goat Summary

This region includes Goat Units 17, 20, and 40. In 1980, Goat Units 17 and 40 were closed due to the eruption of Mt. St. Helens and subsequent restrictive zones.

Region 5 Sighting and Harvest Summary (1971-1981) with reference to 1962 data.

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 17 (Packwood Area)							
1962	35	30	20.9	7.1	?	14	47%
1971	50	44	12.6	1.8	19%	22	50%
1972	50	45	5.8	1.4	24%	16	36%
1973	50	45	5.7	1.2	24%	18	40%
1974	50	37	10.6	1.6	23%	16	43%
1975	50	37	5.7	1.0	29%	14	38%
1976	50	41	8.1	1.6	26%	20	49%
1977	50	40	6.8	1.2	23%	14	35%
1978	40	32	7.0	1.6	27%	13	41%
1979	25	19	5.5	1.1	27%	10	53%
1980	Closed due to eruption of Mt. St. Helens						
1981	15	11	15.0	2.5	28%	7	64%
Goat Unit 20 (North Packwood Area)							
1971	15	12	3.6	0.7	23%	6	50%
1972	15	12	3.3	0.6	5%	3	25%
1973	15	12	3.5	1.0	33%	5	42%
1974	15	10	4.8	0.8	10%	3	30%
1975	15	13	1.5	0.3	10%	5	38%
1976	15	12	1.8	0.3	24%	5	42%
1977	15	10	6.0	1.3	25%	5	50%
1978	15	14	5.5	1.2	23%	10	71%
1979	25	19	4.3	0.6	5%	8	42%
1980	25	20	5.4	0.7	25%	8	40%
1981	25	21	3.8	0.6	25%	8	38%
Goat Unit 40 (Smith Creek)							
1979	15	12	2.6	0.3	29%	4	33%
1980	Closed due to eruption of Mt. St. Helens						
1981	10	8	10.0	2.5	30%	7	88%

Region 5 Goat Harvest Summary (1960-1981)

Year	Permits Authorized	Hunters	Goat Harvest	Percent Success
1960	30	24	16	67%
1961	35	30	13	43%
1962	35	30	14	47%
1963	35	29	13	45%
1964	45	39	17	44%
1965	45	37	17	46%
1966	45	38	14	37%
1967	50	40	11	28%
1968	50	45	20	44%
1969	65	43	30	70%
1970	65	56	26	46%
1971	65	56	28	50%
1972	65	57	23	40%
1973	65	57	23	40%
1974	65	47	20	43%
1975	65	50	19	38%
1976	65	53	25	47%
1977	65	50	19	38%
1978	55	46	23	50%
1979	65	50	22	44%
1980	25	20	8	40%
1981	50	40	22	55%

Region 6 Goat Summary

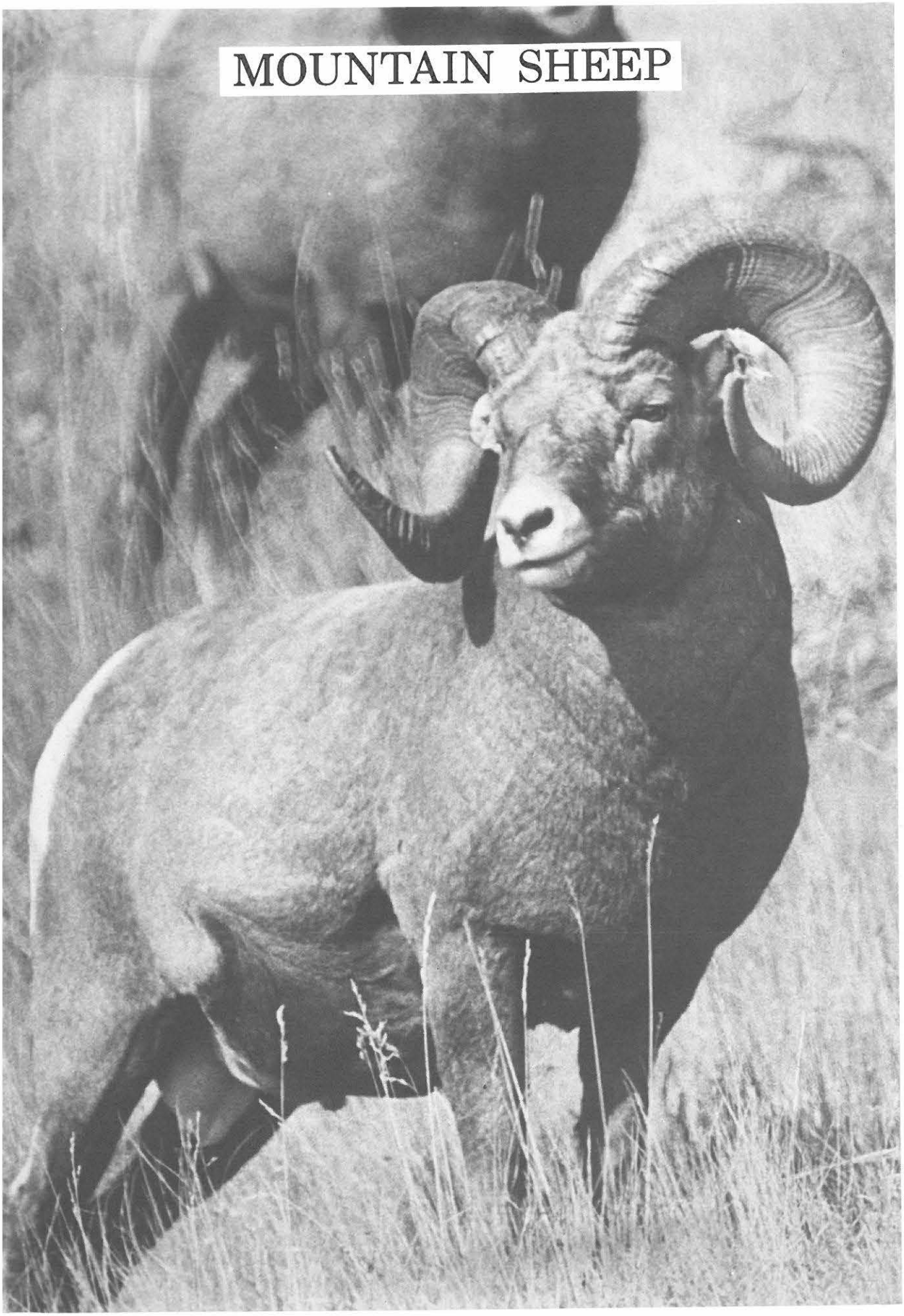
In 1980, the Olympic Peninsula was split into three goat units. Goat Unit 28 was divided into Goat Unit 41 (Elwha River), Goat Unit 42 (Quilcene River) and Goat Unit 43 (Hamma Hamma River). All three units are archery hunting only.

Region 6 Sighting and Harvest Summary (1971-1981)

Year	Permits Authorized	Number Hunters	Average No. Goats Seen Per Hunter	Average No. Goats Seen Per Hunter/Day	Percent Kids Observed	Goat Harvest	Percent Success
Goat Unit 28 (Olympic Peninsula)							
1971	20	15	9.8	1.5	18%	3	20%
1972	20	17	7.5	1.5	13%	6	35%
1973	20	17	4.6	1.0	9%	5	29%
1974	20	15	8.2	1.4	11%	7	47%
1975	20	18	5.3	0.8	21%	4	22%
1976	20	17	5.4	0.9	7%	8	47%
1977	20	11	6.3	1.5	28%	6	55%
1978	30	21	10.1	1.3	14%	8	33%
1979	30	20	7.2	1.0	17%	6	30%
1980	Split into Units 41, 42, and 43 in 1980						
Goat Unit 41 (Elwha River)							
1980	10	8	7.3	1.3	17%	4	50%
1981	10	6	10.7	1.6	14%	3	50%
Goat Unit 42 (Quilcene River)							
1980	25	17	16.2	2.8	18%	11	65%
1981	25	16	12.0	2.8	27%	9	56%
Goat Unit 43 (Hamma Hamma River)							
1980	10	8	11.6	2.5	23%	3	38%
1981	10	8	4.4	0.6	20%	4	50%

Region 6 Goat Harvest Summary (1967-1981)

Year	Permits Authorized	Hunters	Goat Harvest	Percent Success
1967	20	17	7	41%
1968	20	17	3	18%
1969	20	12	3	25%
1970	20	12	4	33%
1971	20	15	3	20%
1972	20	17	6	35%
1973	20	17	5	29%
1974	20	15	7	47%
1975	20	18	4	22%
1976	20	17	8	47%
1977	20	11	6	55%
1978	30	21	8	33%
1979	30	20	6	30%
1980	45	33	18	55%
1981	45	30	16	53%


MOUNTAIN SHEEP

INTRODUCTION

Bighorn sheep are among the most majestic animals on the North American continent. The adult ram has massive curling horns which give the species its name. Jack O'Connor (1974) stated, "No trophy in the world has more prestige." Two races of mountain sheep, the California bighorn (*Ovis canadensis californiana*) and the Rocky Mountain bighorn (*Ovis canadensis canadensis*) are found in Washington. Resident native bighorns of both races were extirpated from Washington State by 1935. In the last three decades, however, bighorns of both subspecies have been successfully reintroduced in Washington.

NATIVE MOUNTAIN SHEEP

Mountain sheep are members of the family bovidae and genus *Ovis*. Mountain sheep evolved during the early Pleistocene in Eurasia. During the late Pleistocene, descendants of these sheep migrated via the Bering land bridge to an area in North America between the northern Brooks and Alaska mountain ranges (Cowan, 1940). During this period one or more ice sheets separated two groups of sheep long enough for speciation to occur. One group of sheep became the thinhorns (*Ovis dalli*) and the other group the bighorns (*Ovis canadensis*).

While five races of bighorns evolved in the western half of the United States, two subspecies inhabited Washington State. Geographical distribution of the two bighorn races in this state is not well documented, but California bighorns probably were found scattered on the eastern slopes of the Cascade Mountains. These mountains include relatively little of the sheep's preferred habitat of bunchgrass slopes near cliffs and rocky ridges. Although the animals were scattered throughout the entire length of the Cascades, they lived in isolated populations on widely separated mountains.

The larger Rocky Mountain subspecies (*O. c. canadensis*) lived in the northeastern and southeastern corners of the state at edges of major sheep population centers in Idaho and Oregon.

Remains of mountain sheep in Washingon State dating back to the middle Pleistocene (Osborn, 1912:474) have been found at Lake Washtucna. The type specimen for California bighorns was collected from our state in 1826 by David Douglas. This specimen is believed by Dalquest (1948) to have been taken near Mount Adams in Yakima County, but Buechner (1960) indicated no mountain sheep were present on Mount Adams because of heavy snowfall. Very likely, the type specimen was collected by native Americans north of Mount Adams.

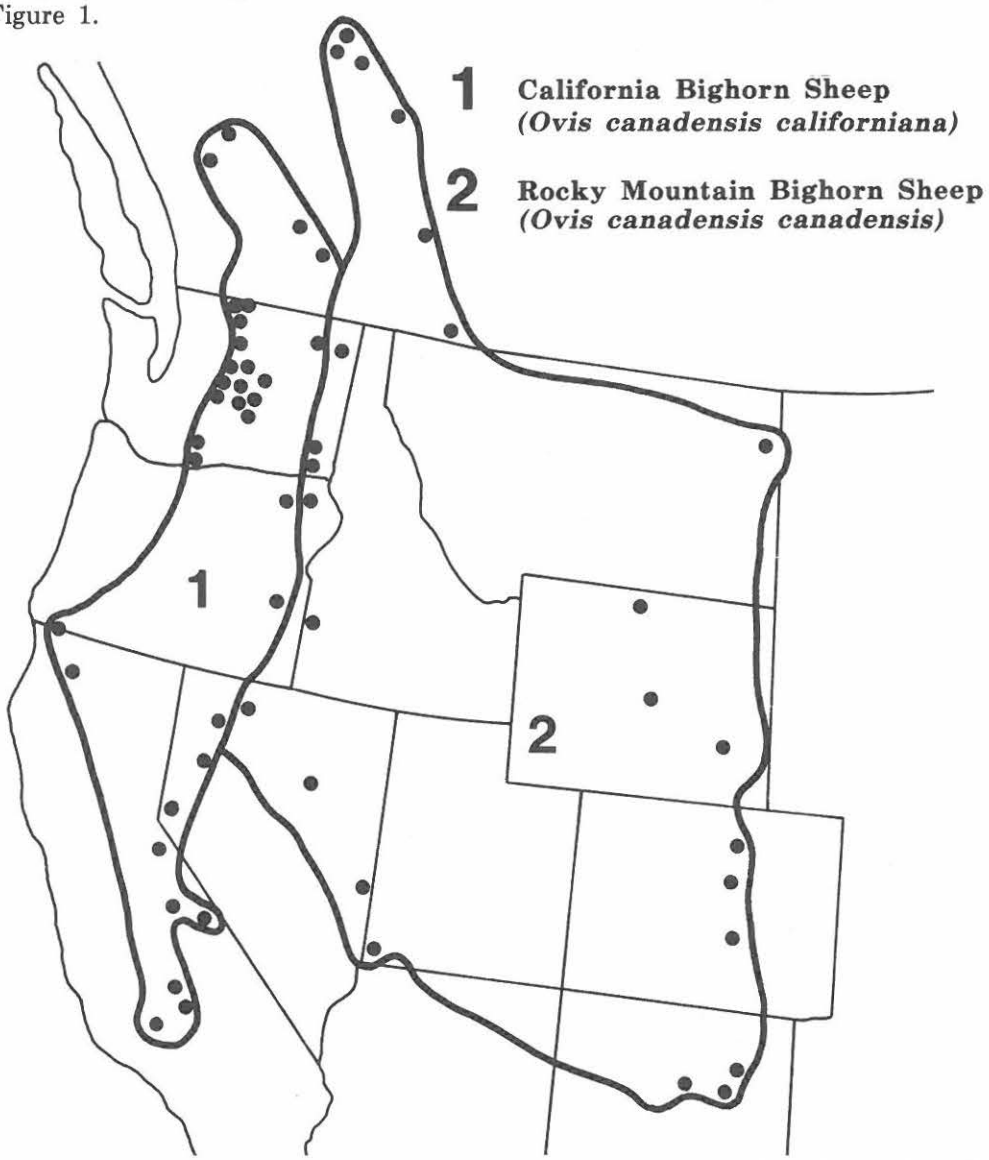
SIGHTINGS OF NATIVE MOUNTAIN SHEEP IN WASHINGTON

The only records of living bighorns in Washington are those of the last surviving populations in the north-central part of the state and the Blue Mountains of southeast Washington. In 1887, G. D. Elliot saw bighorn sheep in the Ashnola area of the Similkameen country, just south of the Canadian border (Grinnell, 1928). In 1889, Professor Dyche saw approximately 500 California bighorns near the British Columbia-Washington border (Dalquest and Hoffmeister, 1948). On this trip Professor Dyche collected 54 bighorns from Mount Chopaka in Washington.

Game Department biologists Fred Zwickel and C. F. Martinsen consulted with residents in the town of Loomis, Washington, near Mount Chopaka, and noted several observations of bighorns. Dan Welch claimed to have seen about 300 bighorn sheep on the ice of Palmer Lake in the early 1900's. Ray Kinchelo saw three sheep on the breaks of Chopaka Creek in August 1916. Tarr Hill and his family claimed to have subsisted on Chopaka bighorns in the late 1800's (Buechner, 1960).

Cowan (1940:558) referred to a band of sheep occupying Azurite Peak near Harts Pass until about 1925. These bighorns were probably the last resident native California bighorn sheep seen alive in Washington.

The Rocky Mountain bighorn was limited in distribution to the eastern edge of the state, with evidence of former habitation limited to the Blue Mountain area of southeastern Washington and the Selkirk Mountains of northeastern Washington (Dalquest, 1948). Probable former distribution of both races is illustrated in Figure 1. Since most sheep populations are isolated bands of local populations, however, the sheep were probably never distributed over all the areas depicted in Figure 1.



The dots are located where evidence of bighorn occupation has been found.
(Based on Hall and Kelson, 1959)

Fig. 1. Distribution of Rocky Mountain and California Bighorn Sheep prior to settlement by white man.

EVIDENCE FOUND INDICATING AREAS OF NATIVE MOUNTAIN SHEEP HABITATION

Mountain sheep skull and skeletal remains have been found in several areas of eastern Washington. A summary of this evidence for each area of habitation is presented in the following pages by location and source of report:

North-Central Washington

Mount Chopaka (Okanogan County)–source Dalquest and Hoffmeister, 1948.
Professor Dyche collected 54 bighorns on Mount Chopaka in 1889. Most of these skulls are found in the Museum of Natural History, University of Kansas.

Corral Lake (Ashnola drainage of Okanogan County)–source Washington Game Dept.
Walt Bens found a bighorn ram skull in 1969.

Tiffany Mountain (Okanogan County)–source Washington Game Dept.
A skull was found by hunters and examined by biologist John Patterson in 1941.

North Fork of Methow River (Okanogan County)–source Cowan, 1940:559.
The specimen is reportedly in the United States National Museum.

Stehekin (Chelan County)–source Cowan, 1940:559.
Specimen reported in U.S. National Museum, Biological Survey Collection.

Hellgate District (southeast Ferry County)–source Cowan, 1940:559.
Cowan notes that this specimen was not identifiable as to species.

Roaring Creek (Entiat Valley of Chelan County)–source Washington Game Dept.
A horn sheath was found on a talus slide in 1966 by an unidentified person and turned over to the Game Department.

Central Washington

Burch Mountain (near Swakane Canyon in Chelan County)–source Washington Game Dept.
A horn sheath was found by Dick Nickel and examined by biologist John Patterson.

Mission Creek (near Sheep Rocks south of Cashmere in Chelan County)– source Washington Game Dept.
A bighorn skull was found in the early 1950's by an orchardist and given to biologist Fred Zwickel.

Grand and Moses Coulees (Grant and Douglas Counties)–source Cowan, 1940:558.
Cowan reported a private skull collections by Mr. Phil Linville of Ephrata and Mr. Earl Simmons of Quincy.

Table Mountain (Wenatchee Mountains in Kittitas County)–source Cowan 1940:559.
The specimen is reported in the U.S. National Museum. Quilomene Creek (along west bank of Columbia River in Kittitas County)–source Buechner, 1960.

Buechner reported that Robert Brown found a skull fragment from a bighorn one mile north of the Quilomene Creek along the west bank of the Columbia. The skull fragment was found in an Indian fire pit in 1955.

East side of Columbia River (Grant County)–source Dalquest 1948:405 and Buechner 1960:72.
Bighorn sheep bones were reported to have been found in caves along the Columbia River in the same area as the preceding reference.

Vantage (Kittitas County)–source The Washington Archaeologist. Archaeological Evidence of Rim Rock Sheep in Washington by Jack Thompson Vol. VI No. 12 December 1962.
Shirley Donner excavated skeletal remains near the Montgomery Ranch west of the Columbia River and five miles south of Vantage. She found several bones and brought them to Jack Thomson for identification. Some of the skeletal remains were of Mule deer (*Odocoileus hemionus hemionus*) but most of them were mountain sheep (*Ovis canadensis californiana*).

South-Central Washington

Mount Adams (Yakima County)–source Hall and Kelson, 1959.
The type specimen was collected by David Douglas on August 27, 1826, near Mount Adams. The specimen is now in the British Museum.

Klickitat Valley (Klickitat County)–source Taylor and Shaw, 1929:31.

Northeast Washington

Pend Oreille River (Pend Oreille County)–source Linsley, 1889:227; Cowan, 1940; Buechner, 1960.
Linsley reported three sheep killed about 20 miles upstream from the mouth of the Pend Oreille River. Cowan referred to these sheep as the race *californiana*, while Dalquest considered them to be the race *canadensis*. We agree with Dalquest and assume these sheep were Rocky Mountain bighorns.

Southeast Washington

Tucannon River (Columbia County)–source Cowan, 1940:559.
Cowan reported a ram's skull was found in the upper Tucannon River area of Columbia County. He indicated the skull was badly broken, but on the basis of a couple of skull measurements considered it a Rocky Mountain Bighorn.

Asotin Creek (Asotin County)–source Buechner, 1960.
Albert Baker of Walla Walla reported a bighorn was killed by Otto Long in 1917 near Deadhorse Spring at the head of the middle branch of the north fork of Asotin Creek.

BIGHORN LOSSES

Since the beginning of the 20th century, severe die-offs of bighorn sheep have been recorded in Idaho (Smith, 1954), Montana (Berwick, 1968), Colorado (Hunter and Pillmore, 1954), Wyoming (Honess and Frost, 1942), and British Columbia (Smith and Demarchi, 1969). Although several factors have contributed to these die-offs, lung disorders have been implicated in most of these declines.

While many bighorns were probably extirpated because of indiscriminate hunting before the creation of state fish and game departments, disease is probably the principal cause of bighorn declines. Bighorns are very susceptible to a variety of diseases. Direct competition with domestic livestock for adequate range may have predisposed bighorns to more serious disease disorders. Bacteria and parasites of domestic stock may be particularly devastating because bighorns have no natural resistance to these organisms. (See section entitled Disease and Parasites.)

In Washington State, bighorn declines occurred shortly after cattle and particularly sheep grazing became common in the high country. In the Pasayten Wilderness, for example, several thousand domestic sheep ranged the high country shortly after the turn of the century. Recent studies by veterinarians at Washington State University (Foreyt and Jessup, 1982) speculated that bacteria common in domestic sheep that come in close contact with bighorns can be transmitted to bighorns, causing immediate death by acute pneumonia. During a recent research study (Foreyt and Jessup, 1982), 13 of 14 bighorns succumbed to bacteria probably contracted from domestic sheep.

MOUNTAIN SHEEP REINTRODUCTION

CALIFORNIA BIGHORN

In November 1957, California bighorn sheep were reintroduced into Washington State. Through the cooperation of the Canadian province of British Columbia, the Washington Department of Game obtained 18 California bighorns. These sheep were trapped by personnel of the B.C. Fish and Wildlife Branch, Department of Recreation and Conservation, from the Riske Creek area near Williams Lake, B.C., and released on the Sinlahekin Habitat Management Area[1] in Okanogan County. Acting upon the advice of the B.C. Fish and Wildlife Branch, these sheep were released in a confined pasture on the theory that the sheep, unless confined, would wander away from the release site and ultimately become too widely dispersed for effective reintroduction. These sheep were, therefore, confined to a 500-acre pasture so they would adopt the region as their home territory. Bighorns adapted well to the Sinlahekin pasture and rapidly increased in numbers.

In this and later releases, sheep were reintroduced to areas that had been within the ranges of original native populations. Winter forage availability was considered the key criterion, and areas where the sheep might compete with mountain goats or cattle were avoided. To meet these conditions, nearly all bighorns have been released on Game Department land.

In January 1960, six sheep from the Sinlahekin pasture were transplanted to a pasture on the William T. Wooten HMA in southeastern Washington. In February 1962, eight sheep from the Sinlahekin pasture were released on a pasture in the Colockum. In 1962, 12 sheep from the Sinlahekin pasture were released into the wild from their confined pasture. This was followed by the release of 15 bighorns in 1963 and 9 in 1964 from the Sinlahekin pasture. Also in 1964, 23 sheep from the Colockum pasture and 21 sheep from the Wooten pasture were released into the wild.

Having released sheep from their pastures and noting no sudden loss by dispersal, Game Department biologists released a band of sheep without confinement on Clemans Mountain (Oak Creek HMA) in 1967. This transplant did well and subsequent releases have been made without confinement.

From the original transplant at Sinlahekin and later from the releases at the Colockum and Wooten pastures, California bighorn sheep have now been released into the wild in 10 areas of eastern Washington (Table 1).

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[1]Prior to 1968, Habitat Management Areas were called Wildlife Recreation Areas and Game Ranges. Hereafter, all Habitat Management Areas will be abbreviated HMA.

ROCKY MOUNTAIN BIGHORN

The other subspecies of bighorn sheep once native to Washington State, the Rocky Mountain bighorn, was reintroduced to our state on April 28, 1972. Sheep were obtained from Waterton Lakes National Park, Alberta, and were released on Hall Mountain (Pend Oreille

Table 1. Releases of California Bighorn Sheep in Washington.

Date	Transplanted Sheep Males	Females	Total	Sources of Sheep	Release Site
10/57	5	13	18	British Columbia (Wild)[1]	Sinlahekin (Encl)[2]
1/60	2	4*	6	Sinlahekin (Encl)	Wooten (Encl)
2/62	2	6	8	Sinlahekin (Encl)	Colockum (Encl)
1962	?	?	12	Sinlahekin (Encl)	Sinlahekin (Wild)
1963	?	?	15	Sinlahekin (Encl)	Sinlahekin (Wild)
1964	?	?	9	Sinlahekin (Encl)	Sinlahekin (Wild)
1964	?	?	23	Colockum (Encl)	Colockum (Wild)
1964	?	?	21	Tucannon (Encl)	Tucannon (Wild)
2/67	2	6	8	Sinlahekin (Encl)	Oak Creek (Wild)
3/69	3	6	9	Sinlahekin (Wild)	Swakane Canyon (Wild)
1/70	2	6	8	Colockum (Wild)	Murray WRA (Wild)
2/70	2	6	8	Colockum (Wild)	Klickitat (Wild)
12/70	2	5	7	Colockum (Wild)	Mount Hull (Wild)
1/71	2	6	8	Colockum (Wild)	Vulcan Mtn. (Wild)
1/73	0	4	4	Tucannon (Wild)	Asotin Crk. (Wild)

*One female died after release in pasture.

[1](Wild) — Indicates wild

[2](Encl) — Indicates enclosure

County) in the Selkirks. The 18 transplanted sheep consisted of 5 rams and 13 ewes.

In 1977, 10 of the Rocky Mountain bighorns on Hall Mountain were captured and transplanted to Joseph Creek HMA (Asotin County) in the Blue Mountains of southeastern Washington. This release consisted of two lambs, six ewes, one ram, and one bighorn that appeared to be a ram but later was determined to be a hermaphrodite.

In January 1981, a supplemental release of 10 Rocky Mountain bighorns (four rams and six ewes) was made at Joseph Creek HMA. These bighorns were transplanted from the Lostine Creek area in Oregon. All Rocky Mountain transplants in Washington are listed in Table 2.

Table 2. Releases of Rocky Mountain Bighorn Sheep in Washington.

Date	Transplanted Sheep			Total	Sources of Sheep	Release Site
	Rams	Ewes	Other			
4/28/72	5	13		18	Alberta (Waterton Lakes)	Hall Mtn.
1/11/77	1	6	1 hermaphrodite 2 lambs	10	Hall Mtn.	Joseph Creek
1/31/81	4	6		10	Oregon (Lostine River)	Joseph Creek

BIGHORN HABITAT

Throughout North America, mountain sheep are found in association with climax plant communities of subalpine, grassland, shrub-grass, desert, and fire-created grassland types. Although temperatures often vary greatly in bighorn habitat, bighorns are found only in relatively dry regions. Probably because of rainfall, bighorns never occurred historically west of the Cascade crest in Washington State.

CHARACTERISTICS

Characteristic habitats of California and Rocky Mountain bighorns differ somewhat, but such distinctions are not always supported by native bighorn presence. California bighorns typically occupy grassland habitats, while Rocky Mountain bighorns are found in areas where shrubs are more common. This habitat distinction does not always fit the native ranges of each of these subspecies in Washington. California bighorns typically occupy grassland habitat, but some Rocky Mountain bighorns occupy a similar habitat. The last surviving Rocky Mountain bighorns occurred in the Blue Mountains of southeastern Washington, an area of typically rolling grasslands.

Rocky Mountain bighorns in the Selkirk Mountains of northeastern Washington occupy a shrub-dominated habitat, but some California bighorn range also has areas of high shrub densities. In British Columbia (Dennis Demarchi, pers. comm.), bighorns of each subspecies have been known to occupy similar habitat.

Bighorns of both subspecies seem to thrive where grasslands or grass/shrub habitats are found adjacent to or intermixed with precipitous terrain characterized by rocky slopes, ridges, and cliffs or rugged canyons. These areas are dominated by low-growing vegetation that lets bighorns see predators from far away.

In Washington State, bighorns are not found at the high elevations typical of bighorn habitat in other states and provinces. High elevation bighorn habitat is not present in Washington. Elevation ranges from about 1,000 feet found along the breaks of the Columbia and Snake Rivers to about 7,000 feet on the highest summer ranges.

VEGETATION

Vegetation characteristics of bighorn habitat in Washington generally consist of bunchgrasses or shrubs with scattered or isolated stands of trees. Buechner (1960) indicated that bighorn sheep are dependent more on vegetation than on any other component of their environment. Demarchi and Mitchel (1973) noted that, unlike native populations of California bighorn sheep in British Columbia and California, the Chilcotin River bighorns do not migrate between a summer range and a winter range. Since the same range must support bighorn sheep derived from this stock year-round, forage abundance is extremely important. When California bighorn sheep were reintroduced in Washington, biologists selected release sites that had good winter forage quality and availability. This criterion probably has more to do with the present distribution of sheep in Washington than any other factor.

Blood (1961) and Demarchi (1965) reported that the best winter ranges for California bighorns in British Columbia are south-facing slopes that contain bluebunch wheatgrass (*Agropyron spicatum*), Sandberg bluegrass (*Poa sandbergii*), Junegrass (*Koeleria cristata*), and Idaho fescue (*Festuca idahoensis*). This generalization is probably true for California bighorns in Washington. Rocky Mountain bighorns in the Selkirks would depend more on shrubs if they were not artificially fed grasses during the winter.

Sheep tend to avoid thick forests, although they select forested areas to escape from predators, as well as seek refuge from adverse weather. In addition, native bighorns in some areas have migration routes through dense timber (Sugden, 1961; Geist, 1971). Geist (1971) observed that during the winter, sheep spend a great deal more time digging in snow for forage than do mountain goats. Mountain sheep prefer to forage on open slopes even if snow accumulation is a factor, but goats tend to remain on steep slopes that shed snow, even if forage quality is reduced.

ESCAPE TERRAIN

Escape terrain is also a very important habitat requirement. While bighorns are not always found in precipitous mountain areas, ewes typically select the most rugged and remote habitat of their range for lambing (Smith, 1954; Wilson, 1968; Welch, 1969; Geist, 1971; Hansen, 1971; Demarchi and Mitchel, 1973). Escape cover is characterized by precipitous, rocky terrain which is extensive enough to allow escape from predators. Bighorns depend on these areas for security and spend much of their time in or adjacent to escape cover. Wilson (1968) found California bighorns spent an average of 12 or more hours in escape cover during any 24-hour period. While ewes, especially during lambing periods, remain close to escape cover, rams tend to wander farther away from this security (Blood, 1963; Wilson, 1968; Drewek, 1970).

FIRE

Fire is an important influence on bighorn habitat. Historically, many bighorn habitats have been maintained or enhanced through periodic fires. Demarchi (1975) noted that large fires in the past opened up dense forests and formed grasslands which supported large numbers of sheep. Some of the best sheep forage species, such as bluebunch wheatgrass and Idaho fescue, are enhanced by fire (Franklin and Dyrness, 1973). Fire causes a release of minerals from old plant matter that is taken up rather quickly by herbaceous plants and resprouting shrubs. Lyon and Pengelly (1970) found that these plants are likely to be more nutritious, productive, and abundant than pre-fire plants. Consequently, fire has created high quality bighorn forage.

The last era of grassland-producing forest fires occurred in the 1920's and 1930's. In the last 40 to 60 years, fire control has been quite successful, and trees have invaded grassland habitats. Plant succession has resulted in conifer growth on some bighorn ranges and has reduced the area available to bighorns. Brown (1979) noted that plant succession favoring densely forested Douglas fir (*Pseudotsuga*

menziesii) communities is gradually replacing ponderosa pine/bunchgrass associations in northwestern Montana. Fire control policies and practices have impaired the natural productivity of many ranges as well.

POPULATION CHARACTERISTICS

POPULATION DYNAMICS

Age and sex composition of a population and the forces controlling the past and future composition of that population enable one to determine population dynamics. Classification surveys are a prerequisite for determining the population status of a sheep herd. A comparison of the number of lambs with the number of ewes, for example, provides an indication of lamb production. Since most sheep populations in Washington number less than 100, and surveys conducted for inventory purposes are usually considerably less than population size, ratios must be interpreted with some caution. In addition, comparable lamb:ewe ratios are difficult to compare when surveys are conducted at different times of the year. Unfortunately, terrain, access, and availability of aerial surveys dictate to some extent when and how thoroughly sheep surveys can be conducted.

Age and Sex Classification

In Washington State, most lambs are born in early May. Perhaps the most important sheep surveys of the year are the lamb:ewe counts conducted during April, May, and June. While lambs have been born as early as April 10, the peak of lambing is about May 5. During classification counts, age groups recorded are:

Lambs–birth to 12 months of age
Yearling females–12 to 24 months of age
Mature ewes–25 or more months of age
Yearling rams–12 to 24 months of age and identified by up to 1/2-horn curl
Two-year-old rams–24 to 36 months old, identified by 1/2- to 5/8-horn curl
Three-year-old rams–36 to 48 months old, identified by 5/8- to 3/4-horn curl
Mature rams–generally over four years old and identified as 3/4- or full- horn curl

Geist (1971) describes rams which are two years old or older by horn curl size and separates them into four classes. This classification system is useful, but for population dynamics, grouping sheep by age is more important.

Classification counts are conducted between April and June to determine lamb production. During the fall and winter, classification counts are conducted to determine sex ratios and lamb survival. Some counts are conducted with the aid of sheep permit hunters during sheep seasons. In areas where supplemental feeding is conducted during

winter, classification counts are usually more reliable and easier to conduct.

Classification counts are used to determine a ratio of any age class in question per 100 adult ewes. For classification purposes, a ewe is considered to be an adult when two years of age. Tables 3 and 4 show classification counts conducted for Aeneas Mountain and the Tucannon River area. Classification counts for the remainder of the state are found in Appendix C and D.

Lamb production is a good indicator of population quality and a key element in population dynamics. Usually lamb:ewe ratios that are less than 30 lambs per 100 ewes indicate declining bighorn populations, 30 to 50 lambs per 100 ewes reflect stable populations, and more than 50 lambs per 100 ewes are indicative of an increasing population.

A review of the lamb production surveys throughout Washington are informative of the history of our sheep. During the first few years after introduction, for example, growth was excellent. Sheep released in enclosures at Sinlahekin and Wooten HMA's had excellent production records (Tables 3 and 4). In one case, a lamb:ewe ratio over 100 was documented for the Tucannon. Later, when sheep were released from enclosures, classification counts were not conducted on a regular basis.

The winter of 1968-69 was severe, and bighorns in Washington, as well as in adjacent states and provinces, experienced high losses. On

Table 3. Lamb:ewe classification counts on Aeneas Mountain.

Date	Classification	Ratio	Source
May 1958*	5:6	83/100	PR reports
May 1959*	10:13	77/100	PR reports
May 1960*	8:9	89/100	PR reports
May 1961*	8:9	89/100	PR reports
May 1962*	6:12	50/100	PR reports
May 1964*	5:5	100/100	PR reports
March 1974	6:17	35/100	J. King (WDG)
May 1975	9:25	36/100	Johnson, Burbury (WDG, DNR)
Sept. 1975	25:51	49/100	Sheep hunters
Dec. 1975	6:30	20/100	Burbury (DNR)
May 1976	2:5	40/100	Burbury (DNR)
Sept. 1976	13:42	31/100	Sheep hunters
May 1977	15:20	75/100	Johnson (WDG)
Sept. 1977	7:16	44/100	Sheep hunters
Sept. 1978	25:52	48/100	Sheep hunters
Nov. 1979	7:15	47/100	Johnson (WDG)
June 1980	9:41	22/100	Hebner, Burbury (WDG, DNR)
Sept. 1980	20:55	36/100	Sheep hunters
Dec. 1980	6:19	32/100	J. King (WDG)
June 1981	6:9	67/100	J. King (WDG)

*Enclosure (Classification counts from 1958 to 1964 were sheep confined to an enclosure.)

Aeneas Mountain in north-central Washington, an estimated 40 percent of the sheep succumbed during the 1968 winter. Surviving sheep were in poor physical condition, and less-than-optimum winter weather during subsequent years resulted in slow recovery.

The loss of sheep during the late 1960's and early 1970's prompted more attention to classification counts and initiation of sheep research. Lamb:ewe ratios in the Tucannon (Table 4) were low in 1973 and 1974. Lamb production improved in the Tucannon in 1975, but lamb survival was poor. While the April-June surveys determine lamb production, surveys conducted in the fall and winter determine survival (Tables 3 and 4, Appendix C). These ratios in many cases reflect a gradual loss of lambs throughout the year after initial high losses. A few of our sheep populations, notably those at Hall Mountain, Joseph Creek, and Cottonwood Creek have experienced low lamb mortality. Sheep herds in these areas are increasing rapidly.

Reproduction

Bighorn sheep have a fairly low reproductive potential and seem to be more sensitive to disturbances than other big game species. On the average, bighorns become sexually mature later than either deer or elk and produce fewer lambs per ewe. Bighorns, on the other hand, tend to have a fairly long life expectancy, after they survive their first year.

Ewes are monestrous and in Washington State come into heat during late November and early December. Anestrous ewes may be courted

Table 4. Lamb:ewe classification counts on the Tucannon River (Wooten HMA).

Date	Classification	Ratio	Source
May 1960*	3:3	100/100	PR reports
May 1961*	4:3	133/100	PR reports
May 1962*	5:6	83/100	PR reports
April 1973	2:20	10/100	Stout
Sept. 1973	0:20	0/100	Johnson
June 1974	0:9	0/100	Fowler
May 1975	4:8	50/100	Fowler
Dec. 1975	4:7	57:100	Fowler
May 1976	4:9	44/100	Fowler
Dec. 1976	4:8	50/100	Fowler
May 1977	2:10	20/100	Fowler
May 1978	4:10	40/100	Fowler
April 1979	4:10	40/100	Fowler
May 1980	3:13	23/100	Fowler
Coyote Control Initiated			
May 1981	9:14	64/100	Fowler

*Enclosure (Classification counts from 1960 to 1962 were sheep confined to an enclosure.)

throughout the year, particularly by young rams, but they tend to avoid rams and withdraw from mounting attempts (Geist, 1968). The receptive period lasts only a few days for ewes, and during this time ewes become aggressive. An estrous ewe searches for the largest horned ram, accepts his mounting attempts, and may even court another ram if the initial ram is exhausted.

The largest rams become aggressive during the rut and wander over a large area in search of receptive ewes. The largest and dominant rams nearly stop eating and deplete fat reserves during this period.

Breeding Age

The age at which ewes attain puberty is variable and depends on their physical condition. Cowan and Geist (1971) indicate that most bighorn ewes become sexually mature at 2-1/2 years of age and have their first lamb at three years of age. Woodgerd (1964) reported that yearling Rocky Mountain bighorn ewes in good condition or in captivity may become mature and breed at 18 months of age. In Washington, Estes (1979) observed a yearling ewe at Wooten and a yearling ewe at Joseph Creek; both participated in rutting activities and each gave birth to a lamb. Since sheep at Wooten are California bighorns and those at Joseph Creek are Rocky Mountain bighorns, we have ewes of both races that are known to breed as yearlings. While yearling ewes occasionally breed in Washington, classification surveys indicate the incidence is low.

A 3-1/2-year-old ewe collected in the Tucannon in September 1973 had no degenerating corpora lutea (either of pregnancy or ovulation from previous years) and, therefore, no previous pregnancy. Older ewes examined in this study (Johnson, 1973) had one or more degenerating corpora lutea from a previous year. In general, most ewes probably have their first lambs at three years of age, but a few ewes have their first lamb at two years of age, and others do not produce their first lamb until four years of age. During years of good forage and following a mild winter, more younger ewes produce lambs.

Rams mature at a similar age to ewes. Large-bodied rams may reach sexual maturity within 18 months, but smaller rams may not become sexually mature until 42 months of age (Woodgerd, 1964). Cowan and Geist (1971) reported that most bighorn rams are physically capable of breeding by 2-1/2 years of age. The age at which rams are capable of breeding is usually of little consequence, however, because old rams do most of the breeding. The largest horned ram, whether 2-1/2 or 8-1/2 years old, courts estrous ewes and attempts to prevent smaller rams from breeding. Since ewes prefer mating with large rams, a younger ram in the presence of a larger ram would probably not have the opportunity to breed.

Lambing

Bighorn sheep have a gestation period of only 170 to 180 days, or nearly six months. Although incidence of twinning was once considered quite rare, a number of studies (Blood, 1961: Spalding, 1966; Van Dyke, 1978; Estes, 1979; Eccles and Shakleton, 1979) indicate the twinning rate is higher than previously reported. Classification counts of wild bighorns in Washington, however, do not support a high rate

of twinning. Mortality rates are probably high for at least one of the twins, except under artificial conditions.

Throughout bighorn sheep range in North America, the lambing period tends to be earlier in the south and later in the north (Thompson and Turner, 1980). In Washington State, lambing appears to be earliest in the Blue Mountains–our most southerly sheep range. The earliest recorded lambing date in Washington State was April 10, and occurred along the Tucannon River in 1963. Lambs are born during a period of about seven weeks, but most of the lambs are born at about midpoint of the lambing period. In the Blue Mountains, the peak of lambing is the last week in April. Throughout the rest of the state, the peak lambing period occurs during the first week of May. All of Washington's California bighorns are derived from stock obtained from the Chilcotin River herd in British Columbia. The earliest lambing period for that herd is about 10 days later than the lambing period of sheep in Washington (Sugden, 1961; Demarchi, 1968).

The sex ratio of sheep is assumed to be 50:50 at birth, even though normal adult ratios vary widely. Constan (1972) reported a ratio of 31 rams:100 ewes in Wyoming, while Buechner (1960) reported 137 rams:100 ewes in an Arizona population. Various social factors are apparently responsible for the observed differential rate of survival between the sexes. The ratio for bighorns in Washington appears to be approximately 50:50 at birth, but rams have a lower survival rate, even in nonhunted populations.

Inbreeding

Bighorn sheep tend to occupy selected "islands of optimal habitat," and many populations have little genetic interchange with other populations. In domestic stock, inbreeding causes a decline in vigor and lowers reproductive rates. The effect of inbreeding on bighorn sheep has not been determined, but some researchers believe inbreeding may be a serious factor in genetically isolated sheep populations.

Since all of Washington's California bighorns were derived from 18 individuals obtained from the Chilcotin River area in British Columbia, our sheep have become inbred over the years. Furthermore, transplants from the original introduction at Sinlahekin to other areas of the state generally consisted of six to seven individuals, and the opportunity for inbreeding has been enhanced.

Since inbreeding is the breeding of related individuals, offspring have a greater opportunity to allelic homozygosity, which in domestic stock leads to "inbreeding depression." Characteristics of inbreeding depression are small litter size, stunted growth, and poor milk production. Hutt (1964) reported that "capability to reproduce" is affected in highly inbred populations.

Although we have never considered inbreeding depression as the cause of any bighorn population declines, a scientific analysis of this factor is difficult to document. In Montana, Berwick (1968) reported that sheep in the Rock Creek area were comparatively small, and attributed their small size to effects of inbreeding. Estes (1979) considered inbreeding a possible factor in the decline of bighorns in the Tucannon. Recent studies by Peterson and Bottrel (1978) initiated

at the Okanogan Game Farm in Penticton, B.C., are attempting to evaluate inbreeding in California bighorn sheep. While this study was initiated in 1977, research over several generations will be needed to document any impact of inbreeding on reproductive performance.

In 1981, Oregon Fish and Game officials requested a sheep trade with Washington in order to provide for genetic diversity for their bighorns. We are also attempting to obtain different genetic stock to supplement existing populations.

Mortality

The highest rate of natural mortality for bighorn sheep occurs during the first year of life. While difficult to monitor, fetal resorption is also fairly common for bighorn populations on poor range associated with severe winter weather, drought, or high population densities (Heimer, 1976). Fetal resorption, for example, was documented for a declining Rocky Mountain bighorn herd in Rock Creek, Montana (Berwick, 1968).

Inclement weather during the lambing period may cause postnatal mortality in bighorns (Geist, 1971 and Thorne et al., 1979). While weather during the lambing period is generally mild in Washington, periods of severe winter weather and poor nutrition during gestation may result in birth of small lambs subject to high mortality. In Colorado, cold, wet weather following lambing in conjunction with lungworm infections has been known to cause high mortality among lambs (Schmidt et al. 1979).

Although most mortality studies for bighorns indicate low mortality of yearlings and two-year-old sheep (Buechner, 1960; Woodgerd, 1964; Bradley and Baker, 1967; Geist, 1971), a comprehensive study in Stillwater, Montana (Stewart, 1980), indicated high mortality rates for yearlings of both sexes and two-year-old rams. A similar ram mortality situation exists on Aeneas Mountain in north-central Washington. In both the Stillwater and Aeneas Mountain areas, few mature rams are present in the population. Between 1974 and 1980, ages of 13 bighorn rams harvested in Sheep Unit 1 were calculated to be 4.2 years. Geist (1971) noted that mortality among rams increases when they begin to participate in breeding activities. As noted previously, during the rut breeding rams become physically exhausted because of their strong sexual urge and apparent disregard of food. Although this is the period of greatest ram mortality, most mature rams are capable of surviving this stressful period because of their fat reserves. Young rams, on the other hand, may not have the fat reserves to carry them through such a period. Since the rut immediately precedes winter, young rams that get a chance to participate in breeding activities because of the absence of older rams may be subject to high mortality. The preceding hypothesis has been suggested by Geist (1971), and observations in Washington seem to substantiate this speculation. Early ram mortality is also characteristic of a high quality population which is typical of introduced populations (see section entitled Population Quality).

Bighorn ewes tend to have a fairly long life expectancy once they reach maturity. Life expectancy seems variable and ranges from 10 to

20 years (Clark, 1970; Hansen, 1967; Bunnell, 1978). Some studies, however, (Sugden, 1961; Murie, 1944) have found that ewes have a shorter life expectancy than rams. However, one of the original tagged ewes released in Washington is known to have lived at least 19 years. Obviously, most ewes do not live that long, but an average age is probably 10 to 12 years in Washington. Maximum life expectancy for Rocky Mountain bighorn rams on Wildhorse Island, Montana (Woodgerd, 1964), was estimated to be 10 years. Sugden (1961) found 12 years was the maximum life span for California bighorn rams in British Columbia.

Mortality rates are extremely variable, and causes of mortality differ from year to year and between populations. One mortality factor may be devastating to one population and yet insignificant in another population.

Weather

During some years winter weather may be the most significant mortality factor, especially for nonmigrating sheep. California bighorns in Washington are nonmigratory, since their parent population at Chilcotin, British Columbia, was nonmigratory. During the 1968-69 winter, bighorns at Chilcotin experienced a die-off (Demarchi and Mitchell, 1973). During that same winter, loss of sheep in north-central Washington was high. Captive sheep in an enclosure at Sinlahekin HMA experienced a loss of nearly 40 percent despite supplemental feeding. Sheep that were not supplementally fed would have probably experienced losses at least as great.

During long periods of deep or crusted snow, energy reserves of bighorns, especially in the young, are depleted. Not only did the deep snow in 1968 cause immediate mortality, but lamb production was poor the next year in both British Columbia (Mitchell and Demarchi, 1973) and north-central Washington.

A weather problem more typical of desert habitats is drought. Drought reduces forage availability and consequently milk production in lactating ewes, thereby increasing the potential for lamb mortality. Drought may also increase predation by concentrating sheep near watering areas. In the Blue Mountains of southeastern Washington, Fowler (pers. comm.) attributed high losses of deer and bighorns to drought in 1973. Physical condition parameters of Tucannon bighorns in 1973 (Johnson, 1974) indicated lactating ewes were in poor physical condition, which undoubtedly contributed to high lamb losses. Meteorological records indicate 1973 was one of the worst drought years in the Blue Mountains. Obviously, drought contributed to poor forage production and was a factor in the high mortality experienced in the Tucannon bighorn population.

Predation

In some areas predation is the most serious mortality factor, especially for lambs, but in most areas of the state incidence of predation seems to be minimal. Predators capable of taking bighorns in Washington are cougar, (*Felis concolor*), bobcat (*Lynx rufus*), lynx (*Lynx lynx*), coyote (*Canis latrans*), golden eagle (*Aquila chrysaetos*), black bear (*Ursus americanus*), and common raven (*Corvus corax*).

Coyote predation in the Tucannon area of southeastern Washington was examined by Stream (1977). After collecting and examining coyote scats from bighorn range (Stream op. cit.), Stream concluded that coyotes were not feeding on bighorns. Estes (1979), meanwhile, monitored this band of sheep for two years and, although he never saw coyotes kill a bighorn, he concluded that coyotes were probably responsible for high lamb mortality. In 1981, Department of Game personnel implemented a coyote control program in the Tucannon area after several years of high lamb mortality. From January 15 to April 23, 1981, a total of 12 coyotes were removed from the Tucannon lambing area. Lamb survival improved from 23 lambs:100 ewes in 1980 to 64 lambs:100 ewes in 1981. It appears that coyotes may be responsible for high lamb mortality in the Tucannon, but additional data are needed. Before making broad generalizations about coyote predation, it is important to note that the Tucannon area has the poorest escape terrain of any sheep range in the state. It is, therefore, not surprising that in this situation, coyote predation could be a significant mortality factor.

Some authors believe coyote predation is inconsequential (McQuirey, 1978; Brown, 1979), while others document significant losses (Thorne et al., 1979). Very likely the primary distinction between these incidents is the quality of escape terrain. Thorne et al. (1970) noted that while coyotes were observed hunting and taking sheep, they did not pursue sheep into precipitous, rocky terrain, nor would they follow sheep if it was evident their prey could reach precipitous, rocky terrain. It is evident that quality of escape terrain should be a prime consideration in any reintroduction of native ranges.

Perhaps the next most serious sheep predator is the cougar. A few cougar are found on nearly all sheep ranges in Washington, and cougar undoubtedly take a few bighorn. Two Rocky Mountain bighorns on Hall Mountain have apparently been taken by cougar. One was taken in 1973 and the other in 1979. Brown (1979) documented the taking of a 5-1/2-year-old ram by a cougar in Montana, and Smith (1954) and Hornocker (1970) documented several cases of cougar predation in Idaho. Most sheep range in Washington is fairly open with good visual cover for sheep. In this habitat, cougar are probably not effective predators on sheep. There are a few cases, however, where restricted visibility would give the cougar an excellent opportunity to take bighorns.

The incident in Montana where a cougar took a mature ram is noteworthy. Gordon Stuart (pers. comm.), after observing and evaluating predator-prey relationships in the high country for over 40 years, found that cougar hunt for the biggest and strongest of the species. Rams are nearly always the largest and most prime bighorns and tend to wander further from escape terrain and over a larger area than ewes and lambs. This habit would appear to make rams more vulnerable to cougar predation.

Bobcat and lynx are known to occur in bighorn range, but no case of predation by these predators has been documented in Washington. Incidences of golden eagle predation on bighorns have been reported

by several authors (Streeter, 1970; McCann, 1956; Kennedy, 1948). In 1978, a biologist for Burlington Northern Railroad reported seeing a golden eagle take a lamb on Vulcan Mountain.

A few black bear inhabit most of the bighorn ranges in Washington, but no reports of predation on sheep have been documented. In British Columbia a black bear devoured a bighorn (Mitchell and Demarchi, 1973), but it is unknown whether the bear killed the sheep or picked it up as carrion. Very likely, the only time of year when bear could effectively take bighorns is in May when lambs are less than a month old. During this time, however, bighorn ewes and lambs remain in the most precipitous part of their range, and few bear are found in these areas. Bear predation is not considered a serious mortality factor.

While Jones (1950) reported that the common raven has killed lambs by pecking their eyes, the incidence of this occurrence is probably rare. Ravens are more typically carrion feeders.

Harvest

The legal hunter harvest is strictly regulated and closely monitored. Only 5 of 12 bighorn sheep populations in the state currently have any type of harvest management program. The annual harvest is increasing as bighorn populations build and additional units are opened up to a limited harvest.

Bighorn sheep hunting is restricted to taking mature rams in most states and provinces. In a few states, however, "ewe only" or "any ram" seasons have been implemented for research purposes or to satisfy management problems. Most management agencies have a 3/4-curl or a full-curl policy, although one state has a 7/8-curl and one province a 4/5-curl regulation. In addition, Nevada has a horn-curl regulation based on a point system. No single horn-curl regulation or method of describing that regulation is shared by more than two states or provinces.

The Washington State Game Commission adopted a 3/4-curl horn rule policy in 1966 when bighorn sheep hunting was initiated in Washington. Each year since then, except for a special either-sex season in 1973, bighorn hunting has been regulated by a 3/4-curl horn rule. The statewide harvest is listed in Table 5. After about six years of fairly high harvest rates, Washington adopted more conservative seasons, and the harvest level declined. Harvest statistics of individual units are summarized in Appendix B.

The 3/4-curl law puts most hunting pressure on prime age (three- to seven-year-old) rams. Within these age classes, most hunting mortality would be additive. In Washington State, the permit quota and method of hunting established for each unit regulates the harvest. The 3/4-curl regulation protects younger age classes of rams, but under a limited entry system does not dictate harvest level.

The age structure of harvested animals can sometimes give insight into population dynamics. The age of rams can be determined fairly accurately from horn ring counts, but this technique is ineffective for mature ewes. The only accurate means of determining age of ewes over four years old is from annual layers in tooth cementum. In 1973, the age structure of bighorn sheep in the Tucannon was sampled by

determining the age of six hunter-harvested bighorns. Five of these sheep were ewes. This sampling indicated the average age of ewes was seven years. Since poor lamb survival had been recorded in this unit for several years, the rather high mean age was not surprising.

While the age of rams harvested in Washington has not been systematically monitored, the age composition of rams in Sheep Unit 1 has been very low for several years. In this unit the age of harvested rams has ranged from 3-1/2 to 5-1/2 years since 1974. Rams harvested in Units 2, 3, and 4 have been from 7 to 12 years old.

Illegal Kill

In dealing with any animal as highly prized as the bighorn, illegal harvest (poaching and inadvertent kill) is always a concern. Bighorn rams normally group together in a social unit known as a "ram band." Frequently three to five rams will remain grouped together in a ram band during the hunting season. The close physical proximity of these animals makes them subject to "flock shooting" or killing of nontarget animals. A few hunters have killed nontarget rams, some of them illegal, as a result of ill-timed or poorly placed shots. Other hunters have underestimated the horn curl standard and have taken rams with horns with less than a 3/4 curl. A better 3/4-curl description and sheep hunter orientation sessions have been implemented to reduce this type of illegal harvest.

Poaching of bighorns has been a major mortality factor in some

Table 5. Washington Bighorn Sheep Harvest.

Year	Harvest	Hunters
1966	6	10
1967	11	19
1968	10	19
1969	12	18
1970	10	22
1971	13	25
1972	9	24
1973	9	25
1974	3	14
1975	7	23
1976	9	24
1977	7	21
1978	3	23
1979	4	26
1980	8	29
1981	12	40
TOTAL	133	362

states. Welsh (1971) found that poaching accounted for 41 percent of the bighorn mortalities found in Arizona and southern Nevada. In southern Utah, both Wilson (1968) and Dean (1975) found that illegal hunting was an important mortality factor. While large-scale sheep poaching operations have been discovered in southern California and elsewhere, Washington as yet does not have sufficient numbers of bighorns to support such an operation. Nevertheless, some taxidermists in Washington have been implicated in out-of-state sheep poaching. It is obvious that poaching opportunity will increase as bighorn populations expand in Washington. Management procedures (see section on Management), including permanent horn branding, are currently being implemented to deter poaching activities.

Poaching and inadvertent killing of bighorns could be a major mortality factor in some populations. In the Tucannnon area of the Blue Mountains, for example, ram survival was poor between 1973 and 1977. During this time, sheep seasons were closed. Local Game officials (Fowler, pers. comm.) reported three poaching incidents involving mature rams during this period. In 1977, a sheep study was initiated and several rams were marked with radio collars. Between 1977 and 1981, the ram segment of the population increased substantially and no ram losses were detected. Fowler (pers. comm.) believes poaching activities diminished because of the radio telemetry study and ability to trace radio-collared rams.

Deliberate sheep poaching activities are probably limited in Washington, but several have been killed by errant hunters during deer and elk seasons. While the extent of these losses is unknown, three mature rams are known to have been killed in the Clemans Unit during the 1975 elk season. In Sheep Unit 1 (Aeneas Mountain), one of two collared rams died of suspicious causes during the deer season. Although the cause of death could not be determined with confidence because the ram was badly decomposed when found, it is believed he was shot by an errant deer hunter. The Aeneas Mountain Unit is a popular deer hunting area and several hunters probably mistake bighorns for deer each year. The incidence of reported illegal kills seems to be particularly high in the Clemans Mountain area. In this unit and possibly others in the state, the illegal take has exceeded the legal harvest.

PHYSICAL CONDITION

Several physical condition indices are important in determining herd health. The more useful indices are body weight, kidney fat, and femur marrow fat. In Washington State, each of these have been evaluated.

BODY WEIGHT

Body weight is usually a reflection of range quality and frequently used to judge the condition and growth of individuals in a population. One very important limitation to this index, however, is that it fails to take seasonal weight fluctuations into account. Generally late spring, summer, and fall are periods of weight gain while winter and early spring are periods of weight loss. Depending on severity of the winter, weight loss could be as high as 30 percent for some individuals. Table 6 lists weight data for California bighorns in Washington. While Washington has few Rocky Mountain bighorns, weight data for the introduced and Hall Mountain sheep are listed in Table 7.

California bighorns in Washington appear to be slightly heavier than those in similar age and sex classes in southern British Columbia. The average weight of "mature" ewes in British Columbia was 117 pounds (Blood, 1961; Sugden, 1961), while the average weight of ewes older than three years in Washington was 127 pounds (sample size 9, Table 6). Mature rams in B.C. averaged 193 pounds (Sugden, 1961; Blood, 1961), while a sample of 13 rams over three years of age harvested in Washington averaged slightly over 200 pounds. There appears to be a great deal of variation between individuals (range 158 to 236), however, and sample sizes are too small for reliable comparison.

Rocky Mountain bighorns throughout North America are known to be somewhat heavier than the *O.c. californiana* subspecies (Blood, Flook, and Wishart, 1970). The extent of that difference, however, is usually not as great as that observed on Hall Mountain in northeastern Washington. Supplemental feeding of Rocky Mountain bighorns there appears to make a significant difference in body weight. These sheep appear to be much larger than those from the parent population in Alberta, Canada.

The weight of 18 Rocky Mountain bighorns introduced from Alberta is compared to their progeny on Hall Mountain five years later in Table 7. Yearling and older ewes introduced from Alberta averaged 137-1/2 pounds, while five years later, after supplemental winter feeding, these sheep and their progeny averaged 166 pounds. Unfortunately, initial weights were taken in April when the animals were probably at their lowest weight of the year, and follow-up weights were taken in January before much of the winter weight loss had occurred.

Three lambs at seven months of age (January, 1977) weighed an average of 89 pounds (75-102). Lambs at Whiskey Mountain, Wyoming, at this same age weighed 56-63 pounds (Thorne et al., 1979). Hall Mountain lambs are also heavier than lambs on high quality forage at Sybille Wildlife Research Unit, Wyoming, which average 78-80 pounds (Thorne, op. cit.).

The growth of rams since their introduction on Hall Mountain has been excellent, but unfortunately, insufficient data exists for comparison to other populations. Rams four years old and older average 207 pounds in Waterton Park, Alberta, Canada (Blood, Flook, and Wishart, 1970). In 1977, several rams were captured and weighed on Hall Mountain. Two mature rams were not weighed because of inadequate equipment. A 3-1/2-year-old ram weighed 240 pounds while the captured seven- and eight-year-old rams were estimated to weigh over 300 pounds. The exceptional weight of these sheep is a reflection of a recently introduced quality population, good forage, and supplemental winter feeding.

Table 6. Weight of California Bighorns in Washington State.

Age	Date	Location	Weight (lbs.)
		EWES AND LAMBS	
6 months	1/5/77	NW Trek (captive)	57
6 months	1/5/77	NW Trek (captive)	55
6 months	1/5/77	NW Trek (captive)	55
3½ yrs.	1/23/77	Wooten	105
3½ yrs.	9/26/73	Wooten	131
4½ yrs.	12/31/73	Colockum	122
4½ yrs.	1/23/77	Wooten	140
5½ yrs.	1/77	Wooten	118
5½ yrs.	9/24/73	Wooten	147
7½ yrs.	1/77	Wooten	130
7½ yrs.	9/73	Wooten	132
12½ yrs.	9/73	Wooten	118
		RAMS	
1½ yrs.	1/77	Wooten	120
1½ yrs.	1/77	Wooten	144
2½ yrs.	1/77	Wooten	132
3½ yrs.	1/77	Wooten	180
3½ yrs.	9/73	Wooten	173
3½ yrs.	9/74	Sinlahekin	158
3½ yrs.	9/76	Sinlahekin	224
3½ yrs.	9/76	Sinlahekin	195
3½ yrs.	9/76	Sinlahekin	200
3½ yrs.	9/79	Sinlahekin	182
3½ yrs.	9/75	Sinlahekin	207
3½ yrs.	9/75	Sinlahekin	200
4½ yrs.	1/77	Wooten	190
4½ yrs.	9/74	Sinlahekin	162
4½ yrs.	9/76	Sinlahekin	221
4½ yrs.	9/75	Sinlahekin	220
5½ yrs.	9/74	Sinlahekin	230
5½ yrs.	9/76	Sinlahekin	236
5½ yrs.	9/79	Sinlahekin	225

KIDNEY AND BONE MARROW FAT

Both kidney and bone marrow fat have been used as indicators of physical condition of various wildlife species. Riney (1955) reported that weight of kidney fat expressed as a percent of kidney weight is a reliable indicator of physical condition. Other investigators (Cheatum, 1949; Neiland, 1973; Verme and Holland, 1973) have used percent bone marrow fat as indicators of physical condition. Ransom (1965) reported that complimentary use of the two measurements is a better means of assessing physical condition.

The major disadvantage of either of these techniques is that the animal must be dead before tissues can be taken for analysis. In

Table 7. Weight of Rocky Mountain Bighorns in Washington State.

Age	Date	Location	Weight (lbs.)
		EWES AND LAMBS	
7 mos.	12/22/77	Hall Mtn.	75
7 mos.	12/22/77	Hall Mtn.	102
7 mos.	12/22/77	Hall Mtn.	90
1½ yrs.	12/22/77	Hall Mtn.	150
1½ yrs.	12/22/77	Hall Mtn.	138
1½ yrs.	12/22/77	Hall Mtn.	145
2 yrs.	4/26/72	Alberta to Hall	87
2½ yrs.	12/22/77	Hall Mtn.	150
3 yrs.	4/26/72	Alberta to Hall	99
4 yrs.	4/26/72	Alberta to Hall	131
4 yrs.	4/26/72	Alberta to Hall	123
4½ yrs.	12/22/77	Hall Mtn.	220
5 yrs.	4/26/72	Alberta to Hall	137
5 yrs.	4/26/72	Alberta to Hall	157
5 yrs.	4/26/72	Alberta to Hall	141
5½ yrs.	12/22/77	Hall Mtn.	192
6 yrs.	4/26/72	Alberta to Hall	158
7 yrs.	4/26/72	Alberta to Hall	142
8 yrs.	4/26/72	Alberta to Hall	161
8 yrs.	4/26/72	Alberta to Hall	158
8 yrs.	4/26/72	Alberta to Hall	164
10 yrs.	4/26/72	Alberta to Hall	129
		RAMS	
7 mos.	12/22/77	Hall Mtn.	102
7 mos.	12/22/77	Hall Mtn.	90
1½ yrs.	12/22/77	Hall Mtn.	185
3 yrs.	4/26/72	Alberta to Hall	129
3 yrs.	4/26/72	Alberta to Hall	118
3½ yrs.	12/22/77	Hall Mtn.	240
4 yrs.	4/26/72	Alberta to Hall	157
8 yrs.	4/26/72	Alberta to Hall	227

Washington, most samples were taken from hunter-harvested sheep. In 1973, a special either-sex season was authorized by the Game Commission to assess physical condition of a declining band of bighorns in the Tucannon area of southeastern Washington. In this case, ewes were sampled, but since that time nearly all of the bone marrow and kidney fat samples have been from rams.

Kidney fat indices were calculated by removing each kidney along with all perirenal fat. Kidneys and perirenal fat were weighed to within 0.1 gram. Perirenal fat was then removed from each kidney and weighed. Values for both kidneys in a sheep were summed so that only one kidney fat index was calculated for each sheep. The kidney fat index for each sheep was then calculated by the formula:

$$Kidney\ Fat\ Index = \frac{Kidney\ (perirenal)\ Fat\ Weight}{Kidney\ Weight} X100$$

The method described by Verme and Holland (1973) was used to determine percent fat in femur marrow. This technique involved weighing a small amount (2-3 grams) of femur marrow to an accuracy of four decimal places and dissolving fat marrow with a 2:1 solution of chloroform and methanol and reweighing marrow to determine the total fat content. The major problem with this technique is that marrow weights must be measured with great precision. Kidney fat and bone marrow fat indices for sheep examined in Washington are listed in Table 8.

Results of the kidney and bone marrow fat tests indicate most sheep are in good physical condition, at least in the fall. Ranson (1965) suggested that percent kidney fat be used to assess physical condition while indices remain at 30 or above, and femur fat be used when kidney fat falls below 30. Results of the present investigation on bighorn sheep confirm Ranson's theory, but both measurements are complementary as indicators of body condition.

Riney (1955) found that in deer the first fat deposit to respond to a favorable metabolic change was bone marrow, followed by fat around the kidney, intestines, and stomach, in that order. Mobilization of these fat reserves has been found to occur in reverse order: stomach, intestinal, kidney, and finally, bone marrow fat (Riney, 1955; Ranson, 1965). During the fall of the year, as fat reserves begin to be mobilized, kidney fat reserves would decrease before bone marrow fat.

Ranson (1965) indicated that in deer, kidney fat reserves dropped to an index of 30 without appreciable drop in femur fat levels. This level appears to be the same with bighorns in our study. Percent bone marrow fat, the last fat reserve to be mobilized, was above 80 percent for all sheep examined, except for two ewes which had kidney fat levels below 30 and a lamb (no kidney fat sample). The two ewes were taken from the Tucannon area, and both were lactating.

As a result of the physical condition analysis, we know that bighorns in Washington are generally in good health. From these tests it is obvious that most bighorns are in good condition during late spring, summer, and fall. In winter, however, fat reserves deteriorate. Supplemental winter feeding obviously cushions the harshness of winter and may moderate weight loss.

Bone marrow and kidney fat testing indicates mature rams enter the winter with large fat reserves. A ram (#74-5) wounded by an archer during October was found dead 14 days later. Bone marrow analysis revealed 97 percent fat content. Apparently bone marrow does not lose fat as a result of a short-term illness or within a few days after death. No samples were taken from mature rams after the rut, the period of greatest weight loss. Rams appear to spend little time eating during this period and must live off their fat reserves.

Ewes and lambs appear to enter the winter with lower fat reserves than rams. At six months of age, a male lamb from Northwest Trek Wildlife Park (#76-6) had 43 percent fat in its bone marrow. Another male lamb from Hall Mountain, however, seemed to thrive on the supplemental feeding program and had 94 percent fat in its bone

Table 8. Kidney Fat Index and Percent Bone Marrow Fat taken from Bighorn Sheep in Washington State.

Sheep No.	Date Collected	Sex	Age	Bone Marrow Fat	Kidney Fat Index
73-1	9/22/73	male	3½	88%	72
73-2	2/24/73	female	5½	96%	390
73-3	9/24/73	female	7½	53%	13
73-4	9/25/73	female	12½	19%	12
73-5	9/26/73	female	3½	96%	232
73-6	12/15/73	female	9½	91%	78
73-7	9/28/73	female	3½	96%	No analysis
73-8	12/31/73	female	4½	83%	74
74-1	9/25/74	male	3½	97%	No analysis
74-2	9/25/74	male	4½	95%	206
74-3	9/26/74	male	5½	94%	332
74-5	10/74	male	3½	97%	No analysis
75-1	9/21/75	male	4½	88%	44
75-2	9/21/75	male	3½	No sample	240
75-3	9/23/75	male	4½	91%	164
75-4	9/23/75	male	3½	92%	187
75-5	9/23/75	male	3½	94%	175
76-0	3/76	female	3½	92%	No analysis
76-1	9/18/76	male	4½	96%	No analysis
76-2	9/18/76	male	3½	97%	No analysis
76-3	9/22/76	male	3½	97%	No analysis
76-4	9/25/76	male	4½	98%	No analysis
76-6	12/76	male	6 mos.	43%	No analysis
77-1	1/11/77	male	6 mos.	94%	No analysis
77-2	1/11/77	male	6 mos.	90%	No analysis
77-3	1/11/77	male	6 mos.	97%	No analysis

marrow. Physical condition of Hall Mountain sheep is probably unique, however, and most lambs elsewhere probably enter the winter with low fat reserves. Bone marrow and kidney fat levels in ewes were generally lower than in rams, but there also seemed to be a large difference between lactating and nonlactating ewes. While our sample size is limited, (sheep numbers 73-3 and 73-4) lactating ewes appear to enter the winter with much lower fat reserves than other ewes. The physical drain of nursing a lamb may be a real handicap in making it through a tough winter. Very likely, lactating ewes in poor physical condition would not give birth to a healthy lamb the next spring. Cowan and Geist (1971) report that the most important factor in loss of lambs is suboptimal nutrition for the gestating female in the last month of pregnancy. They report that poor nutrition or excessive drain of energy and nutrients from the maternal body results in small, weak lambs, and in small udders that cannot supply adequate milk. Obviously, range condition, as influenced by winter weather or drought, generally dictates physical condition of bighorn offspring.

FOOD HABITS

Many food habit studies have been conducted on bighorn sheep, and while forage preferences depend a great deal on availability within each local area, they are less variable than those of mountain goats. Both mountain sheep and mountain goats are dependent upon precipitous, rocky terrain (escape cover), and only those forages within and adjacent to this terrain are eaten. Mountain goats seem to be more dependent on escape cover, and seldom venture more than one-half mile from this habitat. Mountain sheep, however, frequently range over less precipitous slopes, up to two miles from escape terrain. In this way sheep can be more selective for nutritious foods in their food habits. One of the more nutritious forages throughout the winter is bluebunch wheatgrass (Demarchi, 1968).

Bunchgrasses are typically found on the rolling topography in sheep range, where they are the staple forage of bighorns (Smith, 1954; Sugden, 1961; Blood, 1967; Berwick, 1968; Drewek, 1970; Oldemeyer et al., 1971). In southern British Columbia (Blood, 1967), bunchgrasses made up 40 percent of the bighorn diet. Some investigators have noted a difference in forage preferences between Rocky Mountain and California bighorns. The generalization that Rocky Mountain bighorns eat more browse and less grass appears to be valid. Vegetation in the ranges occupied by these subspecies, however, seems to influence selectivity. Rocky Mountain bighorns are generally found in more brushy habitat, while California bighorns are typically found on bunchgrass habitats. In Washington, native range of Rocky Mountain bighorns is limited to the northeastern and southeastern parts of the state. Sheep habitat in these two areas is quite different. The Selkirk Mountains of northeastern Washington are heavily timbered, and brush makes up a large percentage of the sheep habitat. The Blue Mountains of southeastern Washington, however, are typically rolling hills with a high percentage of bunchgrass. Naturally, sheep in the Blue Mountains tend to eat more grass, and sheep in the Selkirks forage more on browse.

Forage Preference

A graduate student from WSU (Estes, 1979) conducted a study of the food habits of California bighorns in the Blue Mountains. This study revealed that grasses were the main forage item throughout the year, except during the summer when browse was preferred (Figure 2). During the spring, grasses were the most consumed forage item, but forbs were preferred when available (Estes, 1979; Pitt and Wikeem, 1978). Estes (1979) noted that sheep select flowers of some forbs, mainly balsamroot (*Balsamorhiza* sp.), paintbrush (*Castilleja hispida*), milk vetch (*Astragalus reventus*), and lupines (*Lupinus* sp.). While lupines and death camas (*Zygadenus venosus*) are poisonous to domestic livestock, Blood (1967) noted that bighorns eat these plants without ill effect.

Many studies have identified foods present in the diet, but in addition, recent studies have examined species availability and preference of foods. Both the studies in southeastern Washington (Estes, op. cit.) and

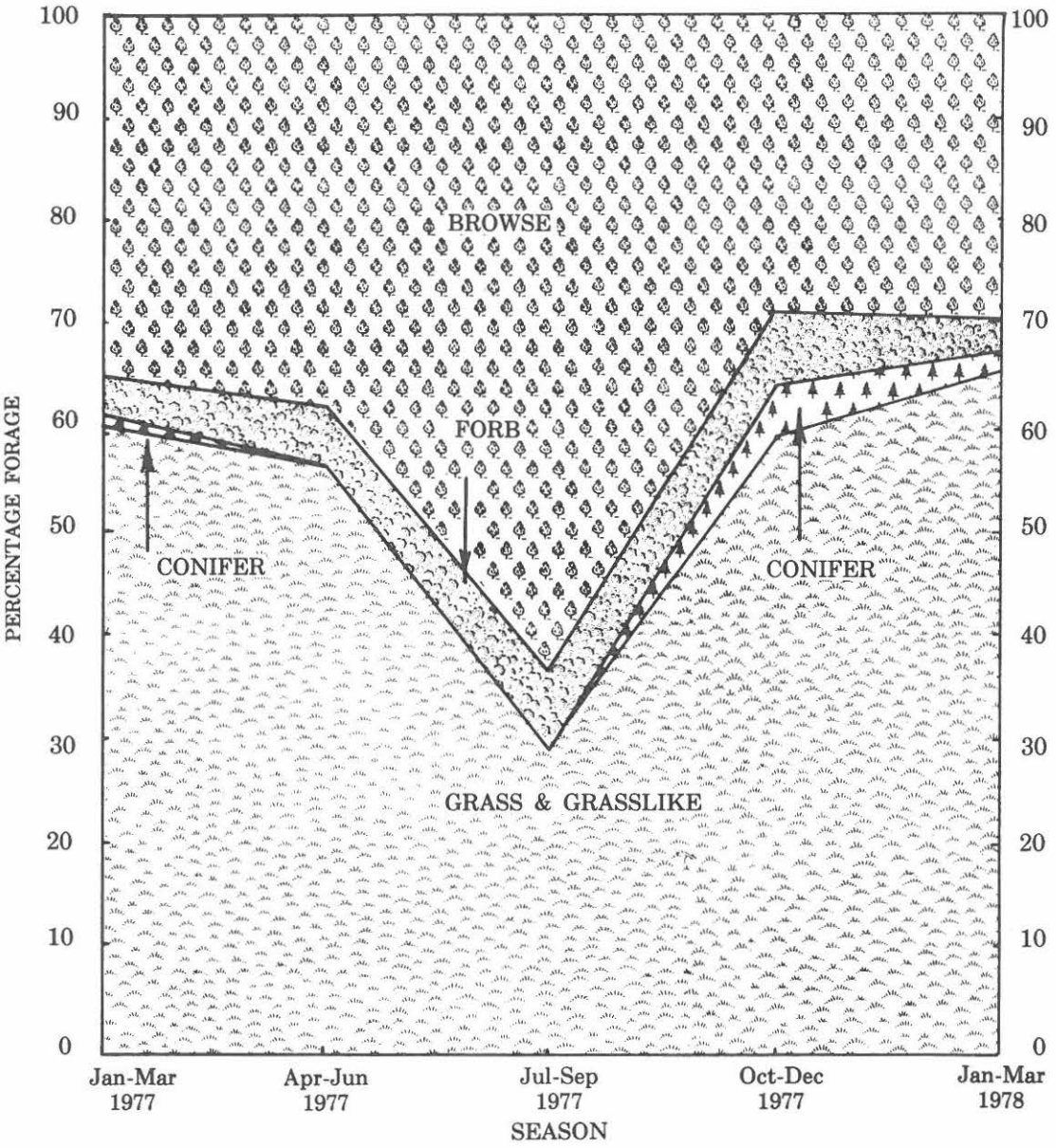

Fig. 2. Relative seasonal consumption of forage classes by Wooten Bighorn sheep as determined by fecal analysis. (From Estes, 1979)

British Columbia (Pitt and Wikeem, 1978) noted that, while bluebunch wheatgrass was abundant and highly consumed, bighorns preferred other species during most of the year. Estes (op. cit.) found that Sandberg's blue grass and brome grasses (*Bromus* sp.) were preferred, while bluebunch wheatgrass and Idaho fescue were consumed less than expected based on their availability. Several browse species, namely serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginia*), and snowberry (*Symphoricarpos albus*) were noted by Pitt and Wikeem (1978) as preferred species in the summer. In general, however, relative

abundance of various food items is determined by floristic composition on each of the bighorn ranges.

Normally, bighorns seem to prefer the more nutritious forage items. Some species and even certain plants are preferred over others; the basis for bighorn selectivity is unknown. Crude protein levels have been used as a guide in determining forage palatability. Bluebunch wheatgrass, for example, maintains a high (18 percent) crude protein level (Pitt and Wikeem, 1979) in autumn from regrowth. Todd (1975) suggested that bighorn selectivity is based on plant succulence, nutrient content, and availability. Bighorns seem to prefer succulent green forage, especially in winter. Whatever determines preference, bighorn food habits are closely related to phenological succession. Throughout the year bighorns prefer early stages of growth when nutritional content of plants is highest. Grasses and forbs generally have highly variable nutritive values, while shrubs maintain a relatively constant nutritive value (Cook, 1971) throughout the year. Crude protein levels for Idaho fescue, for example, range from 17.7 percent in March to 2.8 percent in September. McReynolds (1976) found native grasses in central Washington were deficient in crude protein during the winter. New growth of highly nutritious cheatgrass (*Bromus tectorum*) or Sandberg's bluegrass during warming periods in early spring may be important for bighorns. In domestic ewes, a minimum level of 8.2 percent crude protein is required in the last six weeks of gestation. In southeastern Washington, mid- and late-winter chinook winds frequently cause regrowth of cheatgrass and other bromes. Undoubtedly these warming periods in late winter and early spring are important to ewes and lambs. During the winter any green-up as a result of warm weather is probably more important than any particular plant species.

Minerals

Mineral content of forages have also been identified as a possible limiting factor for bighorns. Ray Demanchi (1965) found unfavorable calcium-phosphorus ratios in the forage of bighorns in the Okanogan area of British Columbia. A deficiency or imbalance of these minerals could adversely affect growth and skeletal development. Deficiencies of minerals, including iodine, magnesium, sulphur, potasium, iron, copper, cobalt, manganese, or zinc could adversely affect health. The Pacific Northwest has low levels of selenium and this deficiency could predispose sheep to white muscle disease. While possible mineral deficiencies of sheep forage have not been evaluated in Washington, it is apparent that sheep are attracted to mineral licks. Cowan and Brink (1949) noted that domestic livestock benefit materially from the addition of certain minerals to those obtained from normal forage. Geist (1971) noted that licking salt may be a means of replenishing bone mineral reserves after the winter's depletion. On many sheep ranges in Washington, trace mineral salt blocks are provided on sheep range annually.

It is apparent that one or more trace elements could be lacking in bighorn forages and providing supplemental trace minerals could be important. While salt licks have been found to be a common

denominator in outbreaks of contagious ecthyma (sore mouth) in Alberta (Samuel et al., 1975), no cases of this disease have been detected in Washington.

Competition

Competition occurs when animals of the same or different species use resources in short supply (e.g., forage items). If resources are not limited, competition can also occur when the animals harm one another in the process of seeking a resource. Competition is regarded as an important factor influencing bighorn sheep populations throughout North America.

Cattle

The effect of grazing by domestic livestock on bighorn sheep range is controversial and depends on proximity and population size of competing species. Domestic livestock have been reported to have little deleterious effect if they do not graze on critical winter ranges of bighorns (Hudson et al., 1976; Jones, 1959; McCann, 1956). Anderson and Scherzinger (1975) indicated that light cattle grazing will cause an improvement in forage quality for bighorns. Extensive competition between livestock and bighorns, however, has been found to be one of the main reasons for declines of bighorn populations in North America (Buechner, 1960; Woodard et al., 1974).

Competition between bighorn sheep and cattle has been reported to be a serious problem in British Columbia (Demarchi, 1962) and in Idaho (Morgan, 1973). Demarchi (1970), for example, found weights and densities of bunchgrass to decline on bighorn range due to cattle grazing. In addition, livestock grazing may have been responsible for converting some Idaho bighorn habitat from grassland to shrubland (Morgan, 1971). McCann (1956) suggested cattle may indirectly affect mountain sheep by competing with elk (*Cervus elephus*) and forcing elk onto sheep range. Other studies (Sugden, 1961; McCollough, Cooperrider, and Bailey, 1980), however, have found little forage competition between bighorns and cattle.

Perhaps the most important factor in cattle-bighorn competition is range topography. In some areas steep and precipitous topography prevents cattle encroachment, but in most areas of rolling topography at least part of native sheep ranges are shared by both species. Regulation of cattle numbers on these ranges appears to be very important. Spalding and Boone (1969) found little competition where cattlemen in British Columbia adhered to stocking quotas and kept the range in good condition. In Washington State, cattle-bighorn competition is usually not a factor because most ranges are owned by the Department of Game, and stocking rates are regulated.

While winter forage is usually considered the key factor in competition analysis, Wilson et al. (no date) noted that competition for space can be more important. Wilson cited an example (in Trefethen, 1975, pg. 104-5) in Utah where removal of cattle for six months resulted in bighorn immigration into the area. Wilson cited another example (op. cit.) where stocking of 30 cattle for two weeks caused bighorns to leave their former range for eight months. Obviously the small number

of cattle did not adversely impact the availability of food or water for the sheep. Other studies (Hudson et al., 1976; Drewek, 1970), however, have found mountain sheep distributions were only weakly influenced by grazing cattle. These contradictory reports indicate that space competition can sometimes be important. Further studies are needed to determine the critical factor in space requirements and social intolerance.

Domestic Sheep

The other domestic animal which most often competes with bighorns is the domestic sheep, which may eat the same forage as wild sheep. In Idaho, Morgan (1968) described a severe competition problem where domestic sheep were allowed to graze year-round on public lands. In British Columbia, Sugden (1961) found only slight competition between domestic sheep and bighorns because of little range overlap. In general, there is little spatial overlap of domestic sheep and bighorn ranges except where bighorns migrate through domestic sheep range, or where domestic sheep have usurped bighorn summer alpine ranges as in parts of Colorado and Wyoming (Buechner, 1960). Recent studies in Washington indicate the greatest cause for concern between domestic sheep and bighorns is transmission of diseases (see section on Parasites and Disease). In one case, bacteria normal to domestic sheep were transmitted to bighorns, resulting in large-scale mortality in the bighorns.

These studies raise the speculation that heavy grazing by domestic sheep in the Pasayten Wilderness of Washington near the turn of the century may have contributed significantly to the demise of native bighorns.

Elk

Elk can be serious competitors with bighorn sheep where winter ranges overlap. Studies of competition in Washington (Estes, 1979) revealed California Bighorn and Rocky Mountain elk food habits were similar in forage class composition throughout the year. Estes (1979) concluded, however, that although forage class composition of both elk and sheep showed remarkable similarity, many differences were apparent in plant species composition. When winter weather is mild and population levels are normal, elk remain in valleys. Severe weather, often coupled with overpopulation, may force elk to migrate to higher elevations, where sheep are found (McCann, 1956; Oldemeyer et al., 1971). Elk may become so numerous that large areas of potential forage for sheep become unavailable due to the icy crust which forms as a result of elk trampling the snow (Cowan, 1947). Likewise, Stelfox (1976) found that sheep winter ranges were grazed heavily by elk during the summer. In addition, Estes (1979) speculated that sheep feared elk, because they quickly retreated when elk approached. Naturally, under these conditions, an overpopulation of elk would have a detrimental impact on bighorns. Because there is extreme similarity of the preferred forage of bighorns and elk (Constan, 1972; Cowan, 1947; McCann, 1956; Oldemeyer et al., 1971; Stelfox, 1976) where their ranges are sympatric, the two species can be serious competitors.

Deer

Another potentially important ungulate competitor is the mule deer (*Odocoileus hemionus*). Deer use of sheep ranges varies according to season, weather, range conditions, and population densities. Studies in British Columbia (Demarchi, 1962; Blood, 1967; Sugden, 1961) found that few deer use winter ranges of sheep. Other studies (Morgan, 1968; Drewek, 1970; Berwick, 1968; Schallenberger, 1966) indicate competition between deer and bighorns can occur, especially during the winter. In the Blue Mountains of Washington, Estes (1979) found little competition between deer and bighorns. It is apparent that the two species are generally not serious competitors, because large numbers of deer are seldom found on sheep ranges.

Mountain Goat

Few studies have evaluated possible competition between bighorns and mountain goats. Although the ranges of these two species do overlap, their preferred niches within these habitats differ somewhat. Goats are dependent on cliff terrain, but sheep prefer grassland adjacent to rocky escape terrain. During a severe winter, however, both species could be forced onto the same site. Geist (1971) speculated that sheep would suffer if they depended exclusively on cliff habitat and if absence of subalpine fir (*Abies lasiocarpa*) forced goats to feed extensively on grasses and herbs. In Washington, food habit studies support Geist's speculation. Bighorns are quite dependent on grasses, while goats eat a variety of forage items and seem less selective in their feeding habits. The high percentage of conifers in the winter diet of mountain goats on Mount Chopaka (Johnson and Campbell, in press) indicates goats can survive on low-quality forage.

In Alaska, Klein (1953) noted that mountain goats were indifferent to the presence of sheep, but sheep tended to avoid goats. It seems likely that if both species were confined to the same range, severe competition could result. For this reason, bighorns have not been reintroduced to mountain goat range in Washington.

MOVEMENTS

MIGRATION

Most bighorns in North America migrate seasonally, while some sheep, especially introduced populations, spend their entire year in one area. Since migration routes of ewes and rams are usually different, young ewes learn migration routes from older ewes, and young rams learn different movement patterns from mature rams.

Bighorn sheep are traditional in their use of areas and have little ability to adapt and pioneer other ranges, regardless of forage condition (Geist, 1971). All California bighorns in Washington were obtained from a resident population of bighorns at Chilcotin River, British Columbia. Chilcotin River bighorns do not migrate seasonally and remain on basically the same range year-round (Demarchi and Mitchell, 1973). Although most California bighorns in Washington are nonmigratory, those at Cottonwood Creek and a few rams at Vulcan Mountain, derived from the same parent population, have established an annual migration. Since none of the other California bighorns in Washington migrate, the migration of these sheep of eight to ten miles is puzzling. California bighorns in some other states and most Rocky Mountain bighorns, however, do migrate to and from summer and winter ranges.

Although Rocky Mountain bighorns are a fairly recent reintroduction in Washington, bighorns at Hall Mountain appear to have established an annual migration pattern. In addition, Rocky Mountain bighorns released at Joseph Creek in 1977 have an extensive home range, although no migration route has been identified.

EMIGRATION

All Washington bighorns take part in unpredictable and sporadic movements away from home ranges. In one case, several sheep from the Tucannon apparently emigrated to Cottonwood Creek, where they joined other ewes and established a separate population. These sheep never returned to the Tucannon. While they included both ewes and rams, most emigrating sheep are only rams. Frequently, one or two rams will wander away from home ranges and may or may not return. Rams from Aeneas Mountain, for example, have been seen north, south, east, and west of their normal home range. Shortly after release from the Sinlahekin pasture on Aeneas, one ram returned to Canada and was killed during a sheep season in British Columbia.

Unfavorable conditions seem to precipitate widespread emigration from an area. In the Tucannon, for example, Estes (1979) noted several factors which probably contributed to widespread emigration during the late 1960's. These factors were: road improvements adjacent to their range, accompanied by increases in human use; termination of predator control programs; severe winters with concomitant increases in numbers of wintering elk; and the initiation of an annual bighorn sheep hunting season. Widespread emigration of ewes and lambs such as occurred at Wooten has not been noted elsewhere in Washington.

Nevertheless, bighorn rams occasionally wander several miles from all of our introduced populations.

HOME RANGE

Home ranges of bighorns vary in extent, depending on habitat quality and topography. In the Blue Mountains, Estes (1979) monitored home ranges of Tucannon bighorns with the aid of radio telemetry. The ram band had a range of 345 acres in winter, 750 acres in spring, 178 acres in summer, and 1,890 acres in fall. The ewe-lamb-yearling band had a separate and much larger home range during all seasons except the fall rut. The home range of this band was 1,026 acres in winter, 1,649 acres in spring, 739 acres in summer, and 1,507 acres in fall.

Bighorn sheep range is quite limited in Washington, and movements are usually centered around islands of quality habitat. Escape terrain in particular is quite limited in our state. Since sheep seldom roam more than two miles from escape terrain, topographical features generally dictate the extent of sheep home ranges.

DISEASE AND PARASITES

A large number of parasites and diseases have been reported from bighorn sheep, but their impact on population dynamics is not well understood.

DISEASES

Major diseases of bighorn sheep in North America include the lungworm pneumonia complex, which results from massive infections of lungworms (*Protostrongylus stilesi* and *Protostrongylus rushi*), scabies, which is caused by a mite (*Psorpotes ovis*), and bacterial pneumonia (*Pasteurella* spp.). These diseases have probably been responsible for large-scale mortalities in many bighorn populations in North America.

Lungworm Pneumonia Complex

The lungworm-pneumonia complex has been described as a major mortality factor for Rocky Mountain bighorn sheep (*Ovis c. canadensis*) populations in North America (Buechner, 1960; Forrester, 1971). Mortality results from bacterial invasion of the lungs which have been damaged by lungworm infections. The pneumonia that precedes death is generally the result of a combination of lungworms (*Protostrongylus* spp.), bacteria (*Corynebacteria* or *Pasteurella* spp.), and a virus (Parainfluenza-3 virus).

Mortality is most frequently observed in lambs. It occurs as a result of prenatal infections, and the maturing lungworms overwhelm the young lambs before they are three months of age. In populations where lungworm infection causes high mortality, the loss of breeding stock may exceed the recruitment of lambs in the population, resulting in population extirpation.

The life cycle of *Protostrongylus* is indirect in that it involves intermediate land snails in the families Puppilidae, Valloniidae, and Zonitidae. Adult worms live in the lungs of bighorns. The larvae are coughed up, swallowed, and excreted in feces. Snails eat the larvae from fecal material, and bighorns then become infected when they inadvertently eat snails with forage. Transplacental transmission occurs from larvae stored in somatic tissues of the pregnant ewe (Schmidt et al., 1979), and pneumonia-induced mortality usually occurs in lambs that are less than three months of age.

Protostrongylus spp. lungworms are prevalent in both races of bighorns in Washington, but numbers of worms per infected animal are relatively low. Larvae were detected in 71 percent of the fecal samples that were examined from individual Rocky Mountain bighorns between 1977 and 1982 (Table 9).

Albendazole at approximately 15 mg/kg of body weight has been used to treat Washington bighorns and has been effective against the major groups of parasites, including lungworms (Foreyt and Johnson, 1979; 1980).

Table 9. Parasites Detected by Fecal Examination from Rocky Mountain Bighorn Sheep in Washington[a]

Location	Date	*Eimeria* # infected/ # examined (%)	*Nematodirus* # infected/ # examined (%)	Strongyles # infected/ # examined (%)	*Trichuris* # infected/ # examined (%)	*Protostrongylus* # infected/ # examined (%)
Hall Mtn[b]	Jan., 1977	11/12 (92)	8/12 (67)	1/12 (8)	2/12 (17)	4/12 (33)
Hall Mtn[c]	Dec., 1977	Not examined	8/10 (80)	Not examined	Not examined	11/12 (92)
Joseph Creek[d]	Jan., 1981	10/10 (100)	8/10 (80)	8/10 (80)	1/10 (10)	10/10 (100)
Joseph Creek[e]	Jan., 1982	12/12 (100)	11/12 (92)	0/12 (0)	6/12 (50)	10/12 (83)
Hall Mtn[f]	Jan., 1982	31/34 (91)	34/34 (100)	0/34 (0)	27/34 (79)	20/24 (59)
	Total	57/68 (84)	69/78 (88)	9/68 (13)	36/68 (53)	55/78 (71)

[a]Other parasites detected in very low numbers were *Capillaria* (3/68), *Parelaphostrongylus* (3/68), *Skrjabinema* (1/68), and *Moniezia* (1/68).

[b]Transplanted to Joseph Creek.

[c]Trapped and released.

[d]Transplanted from Lostine River, Oregon. Dewormed with Albendazole.

[e]Transplanted from Sun River, Montana. Dewormed with Albendazole.

[f]Trapped and released. Dewormed with Albendazole.

Scabies

Scabies is a contagious skin disease of bighorn sheep which is caused by a mite (*Psoroptes ovis*). The disease is characterized by hair loss and scabs on the surface of the skin. Mites burrow into the skin where they feed on lymphatic fluid which is produced as a result of irritation caused by the mite. Serum oozes from wounds and hardens into scabs and the skin becomes thickened and dry.

Infected animals scratch, rub, and lick affected areas to relieve the intense itching caused by the mites. Infection causes animals to stop eating, which leads to severe weight loss and eventual death through environmental or other disease factors.

Outbreaks of scabies in bighorn sheep in California, Colorado, Idaho, Montana, New Mexico, Oregon, and Wyoming have resulted in significant population declines (Buechner, Lange et al., 1980). The most recent outbreak occurred in desert bighorns in New Mexico in 1978-1979 and resulted in significant mortality in the population (Lange et al., 1980).

In Washington, lesions indicative of scabies have not been observed in bighorn sheep. We have seen no mites on any bighorn in Washington, but scabies is an important potential disease for bighorn populations.

Bacterial Pneumonias

Bacterial pneumonias in domestic livestock are often caused by species of *Pasteurella*, usually *P. haemmolytica* or *P. multocida*. In bighorns, bacteria of the genera *Pasteurella, Diplococcus*, and *Corynebacterium* are most often isolated from respiratory tracts (Parks et al., 1972) and have been implicated in mortality. Many other bacteria and a mycoplasma (*Mycoplasma arginini*) have also been isolated from pneumonic lungs (Al-Aubaidi et al., 1972).

Potentially pathogenic bacteria are probably enzootic in many bighorn populations. However, stress may be the predisposing factor in clinical disease. Stress may be induced by weather, movement, other diseases, parasites, human disturbance, behavioral stress, etc., and may result in lowered resistance to pneumonic bacterial infections.

Pasteurella spp. are the most common and pathogenic bacteria in bighorns and produce an acute pneumonia. Affected bighorns die quickly and appear to be in good condition preceding death. Recently, outbreaks of *Pasteurella* pneumonia occurred in Washington and California (Foreyt and Jessup, 1982). In both outbreaks, it was suggested that a strain of *Pasteurella* was transmitted from domestic sheep to bighorns through direct contact. Apparently, the bacteria were nonpathogenic for domestic sheep, but were pathogenic for bighorns. In the Washington outbreak, 13 of 14 Rocky Mountain bighorns which were obtained from Montana and maintained in an enclosure at the Methow Game Range, Okanogan County, Washington, died of acute pneumonia shortly after being exposed to domestic sheep. The bighorns had been in the enclosure for almost one year before being exposed to domestic sheep, and had been healthy up to the time of death. At necropsy, lesions indicated an acute fibrinous bronchopneumonia was present, and *Pasteurella multocida* was isolated in the California

episode. As a result of these die-offs, Foreyt and Jessup (1982) concluded that bighorn sheep and domestic sheep should not occupy the same ranges or be managed in close proximity to each other.

Between 1977 and 1982, blood samples were collected from both races of bighorns in Washington to determine the prevalence of antibodies in serum to selected diseases. Serologic tests were done at the Washington Animal Disease Diagnostic Laboratory, Pullman, Washington. Results are listed in Tables 10 and 11. In Rocky Mountain bighorns, parainfluenza-3 virus (PI-3) antibody titers were present in 22 of 77 (29 percent) samples tested, with titers between 1:10 and 1:80 (Table 10). Bovine virus diarrhea (BVD) virus titers ranging from 1:5 to 1:320 were detected in 6 of 77 (8 percent) samples. Antibodies were not detected against infectious bovine rhinotracheitis (IBR) virus, bluetongue virus, ovine progressive pneumonia, toxoplasmosis (a protozoan disease), leptospirosis, or brucellosis.

Blood samples were also collected and analyzed from 13 California bighorns in Washington. Results are in Table 11. Antibodies against PI-3 virus were detected in 9 of 13 (69 percent) sheep, with titers between 1:5 and 1:80. Antibodies were not detected against BVD virus, IBR virus, or bluetongue virus (Table 11).

Results indicate that PI-3 virus is the most prevalent virus infection in bighorns in Washington. The infection rate is lower in Washington when compared to data from Colorado and Wyoming, where 18 of 29 (62 percent) had antibodies against PI-3 virus (Parks and England, 1974). Parks et al. (1972) isolated PI-3 virus from 3 of 10 captive bighorns in Wyoming. All 10 eventually died from pneumonia, but the role of PI-3 virus in the pneumonia could not be determined. PI-3 virus may be an important predisposing cause of pneumonia in bighorns and is considered to be an important component in the bighorn lungworm pneumonia complex.

Other important viruses in bighorn sheep are contagious ecthyma, bluetongue, and epizootic hemorrhagic disease (Parks et al., 1972; Lance et al., 1981). Evidence of these virus diseases was not observed in Washington bighorns.

Other Diseases

Other infectious diseases that may be important in bighorn populations are actinomycosis (lumpy jaw), tumors, foot rot, necrobacillosis, conjunctokeratenitis, leptospirosis, caseous lymphadenitis (pseudotuberculosis), contagious ecthyma, and listeriosis (Buechner, 1960; Post, 1971; Maegher, unpub.).

Caseous lymphadenitis is a bacterial infection caused by *Corynebacterium* spp. and is characterized by pus-filled abscesses in lungs, liver, and muscles. The disease is prevalent in domestic sheep and can be debilitating. In severe infections, it can predispose to death. It was diagnosed in three of five rams from Aeneas Mountain in 1975 and in one of two rams in 1976.

Paratuberculosis (Johne's Disease) is a chronic wasting disease of domestic livestock and is caused by an acid-fast bacteria, *Mycobacterium paratuberculosis*. It is characterized by gradual loss of weight, diarrhea,

Table 10. Presence of Antibodies to Selected Diseases of Rocky Mountain Bighorn Sheep in Washington[a]

Location	Date	Parainfluenza 3 Virus	Bovine Virus Diarrhea Virus	Infectious Bovine Rhinotracheitis Virus	Bluetongue Virus
		# positive/# examined (range of titers)	# positive/# examined (range of titers)	# positive/# examined	# positive/ # examined
Hall Mtn[b]	Jan., 1977	5/10	0/10	0/10	0/10
Hall Mtn[c]	Dec., 1977	2/11 (1:10)	4/11 (1:160-1:320)	0/11	0/11
Joseph Creek[d]	Jan., 1981 (OR)	10/10 (1:5-1:80)	0/10	0/10	0/10
Joseph Creek[e]	Jan., 1982 (MT)	4/12 (1:5-1:40)	1/12 (1:20)	0/12	0/12
Hall Mtn[f]	Jan., 1982	1/34 (1:10)	1/34 (1:5)	0/34	0/34

[a]Samples were negative for antibodies to ovine progressive pneumonia toxoplasmosis, leptospirosis and brucellosis.

[b]Transplanted to Joseph Creek, Asotin County, Washington.

[c]Trapped and released.

[d]Transplanted from Lostine River, Oregon.

[e]Transplanted from Sun River, Montana. Two sheep were sent to Hall Mountain.

[f]Trapped and released.

Table 11. Presence of Antibodies to Selected Diseases of California Bighorn Sheep in Washington

Location	Date	Parainfluenza 3 Virus	Bovine Virus Diarrhea Virus	Infectious Bovine Rhinotracheitis Virus	Bluetongue Virus
		# positive/# examined (range of titers)	# positive/# examined	# positive/# examined	# positive/ # examined
Tucannon	Jan., 1977	3/7 (1:5-1:10)	0/7	0/7	0/7
Aeneas Mtn[a]	Feb., 1980	6/6 (1:5-1:80)	0/6	0/6	0/6

[a]Transported to Colockum Game Range.

and an incubation period of several years before death. Paratuberculosis has been diagnosed in six bighorns in Colorado (Williams et al., 1979). In these clinical cases, sheep were emaciated and had rough hair coats. Organisms were present within intestinal cells and lymph nodes. Paratuberculosis has not been diagnosed in bighorns in Washington.

Necropsies of carcasses and serological evaluations of bighorns in Washington have not revealed any important enzootic diseases at this time. Continued surveillance is important in areas where bighorn populations are increasing or decreasing to determine the impact of selected diseases on the populations. This is especially important in areas where nutrition and other stresses are present in the population.

Capture Myopathy

Capture myopathy (CM) is a stress-related disease which usually occurs from a few hours to several weeks after the capture of wild species (see mountain goat section). CM is characterized by muscle stiffness, weakness, paralysis, myoglobinuria, and death (Hadlow, 1973; Chalmers and Barrett, 1977), and has been reported in bighorn sheep (Spraker, 1975).

In 1977, 1 of 11 bighorns transported to Joseph Creek was found dead three days after transport. Areas of skeletal muscle showed complete destruction of fibers, and a diagnosis was made of diffuse subacute myopathy with calcification. Since then we have routinely administered 30 grams of sodium bicarbonate orally to sheep, and vitamin E selenium (Bo-se) in all trapping and transplant operations in Washington to prevent an increase of lactic acid in muscles, and thereby reduce the likelihood of CM.

Other medications given to trapped or transported sheep include the dewormer albendazole to remove parasites, a long-acting penicillin (antibiotic) to help prevent secondary bacterial infections, and a combination vaccine to prevent seven *Clostridium* diseases.

PARASITES

At least 51 species of parasites have been identified from bighorn sheep in North America (Becklund and Senger, 1967; Post, 1971; Samuel, 1977)(Table 12). In addition to lungworms, parasite eggs and larvae recovered from feces from Rocky Mountain bighorns in Washington include *Eimeria* (84 percent), *Nematodirus* (88 percent), stongyles (13 percent), *Trichuris* (53 percent), *Capillaria* (4 percent), and *Skrjabinema* (1 percent). Strongyles, as indicated in Table 9, generally refer to abomasal worms (*Haemonchus, Ostertagia,* or *Trichostrongylus*) or intestinal worms (*Osteragia, Oesophagostomum,* or *Cooperia*). These eggs are grouped as "strongyles" in the Family Trichostrongyloidea because the eggs are similar, and it is not usually possible to distinguish between them.

Fecal pellets were examined for parasite eggs and oocysts with the fecal flotation technique (sugar solution, specific gravity of 1.27). Larvae were isolated with the Baermann technique. Most parasites identified by the fecal flotation technique cannot be identified to genus or species because many eggs are morphologically similar. Fecal analysis for

parasites may underestimate parasite prevalence, but is a useful method for detecting parasites that pass eggs, oocysts, or larvae in feces, and animals do not have to be killed for analysis.

Specific identification of parasites was accomplished in selected animals that were killed by hunters or found dead.

Lungworms

The bighorns obtained from British Columbia in 1957 had lungworms. In 1967, three lungs collected from rams at Sinlahekin were examined, and one of these had a few lungworms. Four of five bighorns collected during the hunt at the Colockum had moderate lungworm burdens (Johnson, 1974). Three lungs collected from rams on Aeneas Mountain in September 1980 were negative for lungworms. Lungworm prevalence and burdens have appeared to remain stable in both races of bighorns.

Table 12. Parasites of Bighorn Sheep[a]

		Occurrence in Washington	
	Common Name	***O. c. canadensis***	***O. c. californa***
Protozoans			
Eimeria ahasta, E. arloingi, E. crandallis, E. faurei, E. granulosa, E. intricata, E. ninakohlyakimovae, E. parva	coccidia	common	common
Sarcocystis sp. (In muscles)	muscle parasite	common	common
Cestodes			
Mature Cestodes			
Moniezia benedeni, M. expansa	cattle and sheep tapeworm	uncommon	uncommon
Thysanosoma actinioides	fringed tapeworm	uncommon	uncommon
Wyominia tetoni	bile duct tapeworm	uncommon	common
Immature Cestodes			
Taenia hydatigena	bladderworm	uncommon	uncommon
Nematodes			
Abomosal Worms			
Haemonchus contortus, H. placei	large stomach worm	uncommon	uncommon
Ostertagia marshalli, O. circumciacta, O. trifurcata	brown or medium stomach worm	common	common
Pseudostertagia bullosa	—	uncommon	uncommon
Trichostrongylus axei	small stomach worm	common	common
Intestinal worms			
Cooperia oncophora, E. surnabada	Cooper's worm	uncommon	uncommon
Nematodirus abnormalis, N. archari, N. daviani, N. filicollis, N. helvetianus, N. lanceolatus, N. spathiger	thin necked worm	common	common
Trichostrongylus colubriformis, T. rugatus	small stomach worm	common	common
Oesophagostamum venulosum	nodular worm	uncommon	uncommon
Skrjabinema ovis, S. discolor	pinworm	uncommon	common
Trichuris discolor, T. schumakovitschi	whipworm	common	common
Capillaria sp.	capillary worm	uncommon	uncommon
Chabertia ovina	bowel worm	uncommon	uncommon
Lungworms			
Dictyocaulus viviparus	large lungworm	uncommon	uncommon
Protostrongylus rushi, P. stilesi	small lungworm	common	common
Abdominal worm			
Setaria cervi	abdominal worm	uncommon	uncommon
Muscle worm			
Parelaphostrongylus odocoilei	muscle worm	uncommon	uncommon
Arthropods			
Psoroptes ovis	scabies mite	uncommon	uncommon
Sarcoptes scabei	sarcoptic mange mite	uncommon	uncommon
Dermacentor albipictus, D. hunteri, D. andersoni	ticks	uncommon	uncommon
Otobius megnini	ear tick	uncommon	uncommon
Bovicola jellisoni, B. ovis	biting louse	uncommon	uncommon
Oestris ovis	nasal bot	uncommon	uncommon

[a]From Becklund and Senger, 1967; Kistner *et al.*, 1977; Uhazy *et al.*, 1971; Samuel *et al.*, 1977; present study.

Intestinal Nematodes

Nematodirus spp. are the most common parasites in bighorn sheep in Washington. Eggs were detected in 88 percent of the fecal samples examined between 1977 and 1982 from Rocky Mountain bighorns (Table 9). Survey results from California bighorns in Washington also indicate *Nematodirus* to be prevalent. *Nematodirus* was detected in all 6 sheep analyzed in 1967, 6 of 17 in 1973, 3 of 5 in 1975, and 3 of 3 in 1980. Adult worms were recovered from 2 of 3 sheep examined from Aeneas Mountain in 1980. One had 180 worms and the other had 1,850 worms. Based on available data, it appears that *Nematodirus* is a potential pathogen in bighorns, especially lambs.

Skrjabinema ovis, the pinworm of sheep, was recovered from a bighorn examined from the Colockum in 1973. In 1980, three of three bighorns from Aeneas Mountain had pinworms. Numbers of worms recovered were 1,280; 170; and 50, respectively. Pinworms are not important pathogens in ruminants.

Haemonchus contortus, the large stomach worm or wire worm of ruminants, was recovered from two of two sheep from Aeneas in 1980. One had 610 and the other had 440 worms. *Haemonchus* is a voracious bloodsucking worm and infections can result in anemia and emaciation.

Trichuris schumakovitschi was recovered from three of three sheep from Aenaes Mountain in 1980. Numbers of worms were 10, 30, and 50, respectively. It is not likely that these low numbers of worms are pathogenic.

Eimeria spp. (coccidia) are protozoan parasites of the small intestine that destroy epithelial cells and often cause diarrhea. At least nine species of *Eimeria* have been reported from bighorns (Table 12). Overall, prevalence in Rocky Mountain bighorns was 85 percent. Coccidia were also prevalent in California bighorns, but insufficient sample size precluded meaningful analysis.

When present in high numbers, *Eimeria* can result in the clinical disease coccidiosis, which is characterized by diarrhea, weight loss, and death. Coccidiosis is a major problem in young domestic ruminants, but the clinical disease has not been reported from bighorn sheep. Coccidiosis may be an important disease in bighorns in areas where sheep are concentrated and are under nutritional or other stresses.

Chabertia ovina, the large-mouth bowel worm, was recovered from the large intestine of bighorn sheep for the first time in this survey. Worms were recovered from two Rocky Mountain bighorns that were transported from Montana and maintained for one year on the Methow Game Range. Numbers of worms recovered were 480 and 870, respectively.

Other Parasites

Spined larvae, indistinguishable from the muscleworm, *Parelaphostrongylus odocoilei* were recovered from feces from three bighorns at Hall Mountain. This parasite has not been reported from bighorns before, and may be an evolving parasite in western North America (Platt and Samuel, 1978). It is usually found in the musculature of mule deer.

Wyominia tetoni, a tapeworm in sheep, was first found in California

bighorns in 1973 (Johnson, 1974), and was found in four of six bighorns collected on the Wooten HMA in 1974.

Cysticerci of *Taenia hydatigena* were observed infrequently in bighorns of both races.

External parasites on bighorns in Washington were observed infrequently. However, ticks were occasionally collected from both races of bighorns. All ticks collected were identified as *Dermacentor andersoni.*

Parasites are present in bighorns in Washington, but are not considered major pathogens. The important parasite for surveillance is the lungworm group (*Protostrongylus* spp.). If numbers of parasite larvae in feces are increasing, or clinical disease is evident in the herd, animals should be dewormed with albendazole at 15 mg/kg of body weight, or other effective dewormer in medicated feed, or treated individually. Albendazole at that dosage also eliminates other internal helminths in ruminants (Foreyt and Johnson, 1980). In Colorado, Schmidt et al. (1979) have used the drugs cambendazole and fenbendazole against lungworm in bighorn sheep to reduce lungworm burdens and improve lamb survival.

POPULATION QUALITY

Geist (1971) noted that sheep from different populations differ in size, age of maturation, yearling development, and reproductive performance. He differentiated these populations by labeling some "high quality" and others "low quality" populations. Main characteristics of rams from high quality populations are: large size, early maturity, and vigorous individuals which grow large skulls and horns. In a high quality population, ewes bear a larger number of large, vigorous lambs and suckle them longer, while the rams fight more frequently and die earlier than those in a low quality population. Average life span for individuals in these populations is only 6 to 7 years, while sheep from low quality populations usually exceed 10 years of age, and may reach 20 to 24 years (Geist, 1971).

In Washington, all sheep have been reintroduced to native ranges where the species has been absent for at least 25 years. Introduced populations are usually high quality populations, generally because of optimum forage availability. These "high quality" characteristics seem to describe nearly all bighorns in Washington. Rams mature early, grow large horns at a young age, and die young. Weights of both California and Rocky Mountain bighorns in Washington are heavier than sheep from resident populations elsewhere. Franzman (1972) tested physiologic values from blood of bighorns from several areas of North America, including Washington. He found packed cell volume (indicative of physical condition) for Washington bighorns was highest of four populations tested. In addition, the parasite load of sheep in Washington is fairly low. While mortality rates for rams in particular are high, physical condition of Washington sheep is excellent. The task of the manager will be to maintain the high quality populations now established in Washington.

MANAGEMENT

The major goal, initially, in the bighorn management program was to restore native bighorns to native ranges. Reintroduction has been very successful, and many of the better historic sheep ranges in Washington have been restocked. Following restocking, other management programs have been implemented. A limited-entry bighorn hunting season was initiated in 1966. New sheep units have been added, and others will be added later as sheep populations build in other release sites. A variety of weapon seasons, including rifle, muzzleloader, and archery seasons, have been adopted to allow the harvest of surplus animals without harming the resource. Hunting regulations have been modified over the years to satisfy management problems and better manage the resource.

REINTRODUCTION

The Washington Department of Game has reintroduced bighorns to many former native ranges in the state. Experience over the years has led to a management plan for these reintroductions. Before we restock native ranges, some type of environmental assessment must be prepared by the landowner.

Reintroduction management procedures have evolved over the years as a result of experiences gained in previous reintroductions. The key elements of future bighorn introductions are: habitat, present land management practices, status of wildlife populations, temporary enclosures, physical criteria of released sheep, and follow-up reintroduction.

Habitat

All reintroductions should be made on native ranges of the appropriate subspecies. The environmental assessment should evaluate the availability of food, water, and cover. Forage conditions, especially during the winter, are an important consideration. Temporary winter feeding should be considered for sheep, whether they are released into the wild or into an enclosure. While bighorns should not be dependent on supplemental feed, initial winter feeding may result in healthier animals which increase at a faster rate. Geist (1971) stated that the most productive bighorn populations in North America are in areas of climax plant communities. Escape terrain is frequently limited on native sheep ranges in Washington, and this factor is more important than previously realized. Release sites should have an elevation diversity so bighorns have different seasonal ranges available to them. The size of the release area should be large enough to accommodate at least 125 bighorns.

Present Land Management Practices in Release Area

Ownership of range can be an important consideration. Frequently, cattle grazing, logging, mining, oil exploration, and hydroelectric projects have an adverse impact on bighorns. In addition, past abuse of the

range, including overgrazing, may alter plant species' occurrence for generations. Former fire management policies have frequently resulted in forest encroachment and habitat deterioration. As human populations increase, urban sprawl will undoubtedly result in loss of bighorn habitat to commercial and residential development.

All of these factors are dependent on land management policies adopted by the landowner. For this reason, most reintroductions in Washington have been on Game Department owned or managed land. Cooperative agreements are written with federal agencies where bighorns are released on federal lands.

Status of Other Wildlife Populations

Prior to reintroduction, the abundance of possible competitive or predatory animals should be evaluated. Elk could seriously compete with introduced bighorns if restricted to the same range. Predator populations should be evaluated to determine if control measures are desirable before reintroduction of sheep; coyotes in particular could take advantage of recently introduced sheep. It may be necessary to depress a coyote population to get sheep established.

Feasibility of Constructing Temporary Enclosure

Reintroduced bighorns have increased faster where a temporary enclosure was constructed at the release site. Unfortunately, fencing costs are high, and lack of financial resources often prohibits this option. If an enclosure is constructed, it should encompass at least 600 acres. Supplemental winter feeding may be necessary for sheep released in an enclosure.

Physical Criteria of Released Bighorns

Whenever possible, young sheep should be selected for transplants. Older bighorns, particularly rams, do not adapt well to new surroundings. Old rams also tend to wander away from the release site. A sex ratio of one ram to three or four ewes should be selected. While most of Washington's reintroductions have been of 6 to 8 animals, the minimum size of future introductions should be 15 to 20 bighorns to increase genetic diversity, and give each introduction a better chance of success.

Supplemental Reintroduction

A follow-up supplemental release of at least one ram within five years of reintroduction should be made to provide genetic diversity. In small populations, Rutherford (1972) found supplemental transplants improved reproductive vigor and population growth over a 10- to 15-year period. This management procedure is sometimes overlooked, but should be followed for genetically isolated populations.

BIGHORN POPULATION GROWTH

Since reintroduction of 18 California bighorns in 1957, some of these animals and their progeny have been transplanted to 10 different sites in eastern Washington. All but one of these reintroductions has been successful (Table 1). The only failure was a release on the Klickitat Habitat Management Area in south-central Washington.

Eight sheep were transplanted to this area in 1972, but shortly after release one of two rams was killed. The other ram apparently died, and the population eventually diminished with no reproduction. All other California bighorns have become established in their release areas. About 10 years after sheep were released on the Colockum, however, an unknown mortality factor nearly extirpated the sheep, and they never recovered. Only a few animals of this population remain in the Colockum.

Rocky Mountain bighorns were reintroduced in 1972 from Alberta, Canada. In 1977, a band of 10 sheep from Hall Mountain was trapped and transplanted to Joseph Creek HMA in the southeastern corner of the state. A supplemental release of 10 Rocky Mountain bighorns was successful, although several of these sheep have wandered away from the release area into adjacent states. Despite these losses, the reintroduction program has been very successful. California bighorns occur in nine areas of the state, and Rocky Mountain bighorns in two areas of the state. In 1981, the bighorn population was estimated to be 580 California and 77 Rocky Mountain bighorns.

The First Release

In November 1957, California bighorn sheep were captured from Riske Creek near Williams Lake, British Columbia, and transplanted to the Sinlahekin Game Range in Okanogan County, which is now known as the Sinlahekin Habitat Management Area. The area consists of about 12,000 acres of sparsely timbered grassland foothills, as well as lakes and alder thickets in the valley floor. Most of this land was purchased in 1939 by the Department of Game, primarily as winter range for mule deer. In addition, some DNR and Federal Land Bank acreage in the Sinlahekin is managed by the Game Department.

Acting on the advice of the B.C. Fish and Wildlife Branch, bighorns were released in a confined pasture. The confinement rationale was based on the theory that the sheep, unless confined, would wander away from the release site and ultimately be lost by dispersal. These sheep were, therefore, confined to a 500-acre pasture so they would adopt the region as their home territory. The age and sex of these animals are listed in Appendix E. The bighorns adapted well to the Sinlahekin pasture and rapidly increased in numbers. The history of bighorn sheep at Sinlahekin HMA is presented in the following summary:

1957 In November 18 California bighorns, 1 adult ram, 4 yearling rams, 6 adult ewes, and 7 female lambs, were transplanted to a 500-acre pasture on the Sinlahekin HMA.

1958 All 18 sheep survived in 1958, and 5 lambs were born, thereby increasing the population to 23 bighorns by the end of 1958.

1959 Ten lambs were produced in 1959, increasing the population to 33. In addition to 5 yearlings, adult sheep now consisted of 5 rams and 13 ewes.

1960 In February, 6 bighorns were transplanted from the Sinlahekin pasture to the Wooten pasture in southeast Washington. One of the transplanted ewes died in shipment. Eight lambs were

produced in the spring of 1960. Thirty-five sheep remained in the Sinlahekin pasture at the end of 1960.

1961 During the 1960-61 winter, 1 ram and 3 ewes died in the pasture. Ten lambs were recruited to the bighorn population in 1961, bringing the total to 41 bighorns. In December 1961, 2 rams and 3 ewes were transplanted to the Colockum Game Range (later, Colockum HMA). At the end of 1961, 36 bighorns remained in the pasture at the Sinlahekin HMA.

1962 In January, 8 rams were released from the Sinlahekin pasture to the wild, and in February, 1 more ram and 3 ewes were released. Six lambs were born in the enclosure. Also in 1962, 2 rams and 6 ewes were transplanted from the Sinlahekin enclosure to the Colockum enclosure. During the trapping operation, 1 ewe died in the trap. During 1962, 9 rams and 3 ewes were released to the wild, leaving 21 sheep in the Sinlahekin enclosure. After release of some of the bighorns from the enclosure, several rams and possibly some of the ewes jumped the fence into and out of the enclosure. As a result of this situation, counts of sheep varied from day to day. The sheep population at the end of 1962 was believed to consist of 8 rams, 12 ewes, and 6 lambs in the enclosure, and about 10 surviving sheep in the wild.

1963 Ten lambs were born to ewes in the pasture and 3 lambs are believed to have been produced by wild ewes. In December, 15 bighorns in the pasture were released to the wild. One of the rams released in 1962 was legally killed near the mouth of the Ashnola River approximately 30 miles north of the Sinlahekin release area. At the end of 1963, 21 bighorns remained in the Sinlahekin enclosure, and if no other mortality occurred, 27 bighorns resided in the wild.

1964 In February, 9 more bighorns from the Sinlahekin enclosure were released to the wild. This release left 12 bighorns in the pasture at Sinlahekin and 36 bighorns released in the wild. The recruitment of 5 lambs to the captive ewes in 1964 increased the sheep population to 17 in the enclosure. The population of wild bighorns on Aeneas Mountain and elsewhere in the Sinlahekin area at the end of 1964 was estimated at 44.

1965 No mortalities were noted in 1965, and the estimated wild sheep population increased to 56. Captive ewes produced 6 lambs in 1965, and 23 bighorns inhabited the pasture by year's end.

1966 One of the released rams was found dead about 1-1/2 miles northwest of Riverside. The first bighorn sheep hunt was authorized and 10 permits were issued. Six permit holders successfully bagged 3/4-curl rams. The liberated bighorn population at the end of 1966 was estimated at 66 sheep.

1967 All but 9 of the bighorns in the pasture were released to the wild in 1967. Ten permits were again authorized, and three persons successfully killed 3/4-curl rams. The bighorn population at the end of the year was estimated at 100 sheep.

1968 Ten permits were again authorized, and two persons killed 3/4-curl rams. The population climbed to about 130 before the 1968-69 winter.

1969 An estimated 40 percent of the sheep population succumbed during the severe winter of 1968-69, and many surviving ewes failed to produce young in 1969.

1970 One bighorn ram was trapped from the wild and transplanted to the Klickitat area, along with several ewes from Colockum HMA. Ten permits were again authorized, but only two persons killed 3/4-curl rams. The population at the end of 1970 was estimated at 64.

1971 Ten permits were authorized, and three hunters were successful. The population at the end of 1971 was about 75.

1972 Ten permits were authorized, and six hunters were successful. The bighorn population was estimated at 85.

1973 Ten permits were authorized, and four hunters were successful. The bighorn population was about 100.

1974 During the first week of March, Game Department employees Jerry King and Luke Morgan saw 28 different sheep on Aeneas Mountain. During September, however, sheep hunters identified 67 different bighorns. The necropsy of 3 of 4 bighorns harvested on Aeneas in 1974 revealed no serious parasite or disease problems. The bighorn population increased to the previous peak population of 130 animals.

1975 Game Department and sheep hunters conducted a "sheep count" on opening day of the sheep season. A total of 115 different sheep were tabulated. Classification of 96 of these sheep was: rams, 18; ewes, 51; yearlings, 2; lambs, 25. The yearling count in the above tabulation was undoubtedly underrepresented because of difficulty in differentiating these animals from mature ewes. The population estimate was 150 bighorns.

1976 Once again, a sheep count was conducted on opening day of sheep season, but few sheep were seen. A total of 67 sheep were classified as: rams, 12; ewes, 42; lambs, 13. Hunters reported seeing 7 legal rams. Attempts to trap sheep in midwinter were unsuccessful due to mild weather. The population estimate was 175 bighorns.

1977 Opening day counts and classification increased in 1977 to 84 sheep. Some hunters failed to distinguish ewes from lambs, so these were classified together: rams, 16; ewes and lambs, 68. Again, attempts to trap sheep in midwinter were unsuccessful due to mild weather. The population estimate was 175 bighorns.

1978 Sheep hunters reported seeing 149 sheep on opening day of the sheep season. Of these, 119 sheep were classified as follows: rams, 42; ewes, 52; lambs, 25. Productivity continued to be good as noted in classification counts. The ram segment of the population on Aeneas, however, consisted almost exclusively of young animals. Attempts to trap sheep for tagging, marking, and release, as well as for transplant, were again unsuccessful due to another mild winter. The population estimate increased to 200 sheep.

1979 Only 7 of 10 hunters appeared for opening day of the sheep season, and no opening day classification count was obtained. Although 50 percent of the hunters were successful, more mature rams should have been seen by hunters. Necropsy of hunter-harvested bighorns revealed no significant problems but continued presence of corynebacterium infections. Winter trapping was finally successful. Six sheep were captured and transplanted to an enclosure on the Colockum HMA. In addition, 2 rams were captured and outfitted with radio collars. One ram died shortly after release of apparently natural causes. The population estimate remained at 200 sheep.

1980 The opening day sheep survey among hunters revealed a count of 118 sheep. While not all sheep were classified, the sightings were as follows: rams, 34; ewes, 55; lambs, 20; and unclassified sheep, 9. The remaining radio-collared ram was found dead in early December 1980. He had moved seven miles south of the capture site but remained on Aeneas Mountain. This ram died during the deer season, and while no bullet was found, he was probably shot by an errant deer hunter. Radio telemetry of two rams in 1979 and 1980 failed to reveal any one cause of ram losses. While fewer sheep were seen that year, the best population estimate remained at 200.

1981 Sheep hunters counted only 61 bighorns on opening day of the sheep season. These sightings included 28 rams, 25 ewes, and 8 lambs. While the ratio of lambs to adults seen on this survey was down, spring lamb production surveys remained good. Fifty percent of the harvested rams harbored bacterial infections (Corynebacterium sp.), but no serious health hazards were found. The population estimate remained at 200.

Subsequent California Bighorn Reintroductions

Tucannon

In January 1960, six sheep from the Sinlahekin pasture (two rams and four ewes) were transplanted to a similar pasture on Wooten Habitat Management Area in southeast Washington. This small band quickly multiplied (Table 4), with excellent lamb production and survival while the sheep remained in the enclosure. After release from the enclosure in 1963, few sheep surveys were conducted until losses became apparent about 1970. During this time, the sheep population increased to about 75 before dispersal from Wooten, and poor lamb survival resulted in declines. In 1973, an either-sex sheep hunt was authorized by the Game Commission to collect biological information from hunter-harvested animals and determine causes for apparent losses (Johnson, 1974). This study (Johnson, op. cit.) revealed no significant parasite or disease problems. The population apparently declined as a result of dispersal from Wooten and poor lamb survival. Examination of the six sheep harvested in September revealed that the non-lactating ewes and the ram were in good condition. The two lactating ewes, however, had low bone marrow and kidney fat reserves.

No doubt a series of rather severe winters in the late 1960's and early 1970's, along with a drought in 1973, were primarily responsible for the declines. The harsh winters and drought also caused large numbers of elk to winter on a range shared with bighorn sheep. The severe weather and competition from elk undoubtedly contributed to poor forage availability. In addition, the Tucannon has the poorest escape terrain of any sheep range in Washington, and coyotes likely killed many of the lambs during this stressful period. No lambs survived during 1973 and 1974. The population reached a low of 18 animals in 1974. During the next few years, however, a few lambs survived, and the population slowly began to increase once again.

In 1977, Rick Estes (1979) initiated a sheep study in the Tucannon. Several sheep were captured and monitored with radio collars. Between 1973 and 1977, ram survival was poor. After marking rams with radio collars, however, all rams appeared to survive, and no ram losses were detected. It is likely that the radio collars curtailed poaching.

Although the population continued to grow slowly, lamb survival remained low through 1980. In January 1981, a coyote control program was initiated in the sheep lambing area. Between January 15 and April 23, 1981, 12 coyotes were killed. Lamb survival improved from 23 lambs per 100 ewes in 1980 to 64 lambs per 100 ewes in 1981. Although several years of coyote control will be necessary to prove coyotes are responsible for high lamb mortality, 1981 surveys indicate coyotes are a major mortality factor.

Intensive sheep surveys were conducted from April through June to monitor lamb production. In 1981, 33 bighorns were classified as follows: 10 rams, 14 ewes, and 9 lambs. The ram:ewe ratio became high in this herd during the late 1970's. In 1981, seven of the animals were 3/4-curl rams or larger, and four of the seven were exceptional trophy rams in the 7- to 10-year age class. An archery-only season was initiated in 1981, with three permits authorized. One of the largest rams was harvested. This ram had been captured and radio collared in January 1977 at the age of 5-1/2 years. This was the oldest known ram in the herd (10-1/2 years). The ram still wore his neck collar, which had no detrimental effect on the cape.

Colockum

In February 1962, two rams and six ewes were captured in the Sinlahekin pasture and transplanted to a similar pasture on the Colockum. Sheep were released from the pasture in 1964. During the first few years after introduction, lamb production and survival were excellent. In 1967, a sheep season was initiated in the Colockum. By 1970, the population had increased to about 100 sheep. In 1970 and 1971, a total of 31 sheep were transplanted from the Colockum to other areas in eastern Washington. In addition, 20 bighorns were legally taken by sheep hunters from 1967 to 1971. In 1971, some mortality was noted, and sightings were down. The population estimate for 1971 was 60 sheep. In 1972, a major decline occurred. Some sheep died during the summer of 1972, but only 12 sheep could be found in the fall. The decline from 60 in 1971 to 12 sheep in 1972 was dramatic and puzzling. Sheep hunting was terminated after the 1971 season. During

the 1970's, a few sheep were seen in the Devil's Gulch and Blewett Pass areas. By 1977, only three ewes remained in the Colockum. The rapid demise of bighorns in the Colockum is still a mystery. Al Franzman (1972) collected blood samples from bighorns throughout North America and found Colockum bighorns had the healthiest physiological values. Disease was considered a likely cause, but surveys failed to turn up sick animals or remains of more than a few dead animals. This, of course, does not rule out disease as a possible mortality factor, because coyotes could quickly eliminate carcasses. Too many bighorns may have been removed over a short period of time. Bighorns are a social animal that do not tolerate disturbances to the population. Just as presence of cattle can cause bighorns to leave their home range (Wilson in Trefenthen, 1975), removal of nearly 50 percent of the population over four years was probably a disturbing factor. This removal, however, does not explain the sudden decline from 1971 to 1972. It seems likely that a disease occurred in the population in 1971, causing widespread mortality.

In early February 1980, a band of six bighorns (one young ram, three ewes, and two female lambs) were trapped on the Sinlahekin HMA and released within the 700-acre enclosure on the Colockum. Two lambs were born in the enclosure in the spring of 1980, but one died. The yearling ram disappeared from the enclosure in 1981, as well.

While three ewes from the original plant remain outside the enclosure, no ram has been seen for several years. Their favorite range is private property, which is now being developed for rural housing. The future of bighorn sheep in the Colockum does not look promising.

Oak Creek (Clemans Mountain)

In February 1967, six ewes and two rams were trapped from the enclosure at Sinlahekin and transported to Oak Creek HMA in Yakima County. Unlike previous releases, these sheep were not held in a temporary enclosure, but released directly into the wild. The sheep did well, although they did not increase in number as fast as sheep transplanted into enclosures at Sinlahekin, Tucannon, and Colockum. An archery-only season with two permits was initiated in 1971. The population continued to grow and increased to 30 in 1972. The first successful archer took a trophy ram in 1973. The population had increased to about 40 in 1973, when the Game Commission authorized a season for five archery permits to be followed by a season for two muzzleloader-only hunters. A supplemental winter feeding program enabled the sheep to increase rapidly, and by 1974, some 50 bighorns roamed on Clemans Mountain.

In 1975, two muzzleloaders were successful in taking full-curl rams. In addition, two other rams were lost that year. One ram died after it was crippled by an archer's arrow, and the other ram was shot during the elk season. In 1976, good productivity was noted once again, and the population increased to 60. While no other legal rams were taken, in 1977 a permittee shot a ram less than 3/4 curl. A band of 32 ewes and lambs were seen during the winter in 1978, but the band of 11 mature rams did not return to the winter feeding site. While both

bow and muzzleloader hunters were unsuccessful in 1978, a ewe was killed during the deer season and another ewe badly crippled. Lamb production and survival in the Clemans herd was lower in 1979 than in previous years. Only 24 sheep visited the winter feeding site, and this band had only 3 lambs. Two more illegally killed sheep were found in 1979. By 1980, the Clemans herd had increased to nearly 75. During 1981, lamb survival was poor. In February 1981, a band of 27 sheep were classified as 8 rams, 13 ewes, and 6 lambs. Sheep hunters during the 1981 season harvested two rams. The population was estimated at 75 sheep in 1981.

Swakane Canyon

In March of 1969, six ewes and three rams were trapped in the Sinlahekin enclosure and released into the wild in Swakane Canyon. The sheep increased slowly over the years, with poor lamb production and survival noted in most years. The population numbered about 20 in 1972, but by 1981 it had only increased to about 32. The sheep range along the breaks of the Columbia River between the Entiat River and Swakane Canyon. A high coyote density in the area and periodic kills by errant deer hunters appear to be restricting the population.

Umtanum

In January 1970, a band of eight sheep (six ewes and two rams) was trapped from the wild in the Colockum and released into the wild on the Murray HMA. This band increased to about 25 in 1973, and two archery-only permits were authorized by the Game Commission. Although no legal kills were made, in 1974 a ewe and ram were killed by errant hunters. Productivity remained fairly low for several years, and by 1975, the population had only increased to about 30. In the following year, however, these bighorns began expanding their home range. Sheep were seen from the mouth of Roza Creek, along the west rim of the Ellensburg Canyon, to Umtanum Creek. Lamb production also was good in 1976. These sheep continued to increase, although a young ram was illegally killed in 1978. Sightings of sheep from the canyon highway indicated continued good lamb production and survival. The sheep continued to expand their range, and by 1979 about 10 sheep (3 rams and 7 ewes) had crossed the Yakima River onto private rangeland. Another band of sheep moved west of the old Wenas-Ellensburg road near the observatory. In the fall of 1979, four more mountain sheep were reported killed illegally. Three of these kills (two rams and one ewe) were located. The reported death of a third ram was not verified but is believed to be true. Of the two rams located, one was a large 10-year-old ram, and the other was 5 years old.

The archery sheep season was opened later in 1979 to give the archers a better opportunity for a successful hunt. Despite the late season, which began in 1979, no bighorn has been legally taken in the Umtanum Unit. In 1980, lamb production was good, but lamb survival, as reflected by the number of yearlings observed, was poor. Between 1974 and 1979, seven bighorns (five rams and two ewes) are known to have been killed illegally from this unit. Just before the 1981 archery

season, another ram was killed. This population also remained stable at 65 sheep in 1981.

Klickitat River

In February 1970, eight sheep (six ewes and two rams) were trapped from a free-roaming population on the Colockum and released into the wild on the Klickitat HMA. Shortly after release, one of the rams was killed illegally. A few sheep were seen for a few years, but they gradually declined and died out about 1974.

Mount Hull

In December 1970, seven free-roaming sheep were captured in the Colockum and released on Mount Hull in Okanogan County. The plant consisted of five ewes and two rams. Although productivity or lamb survival seemed to remain low for several years, local residents reported seeing as many as 22 in 1975. These sheep developed a preference for Scott and Sylvia Sullivan's third-cutting alfalfa hay, and during August each year foraged in their fields. The Game Department gave hay to the farmers to compensate them for their losses. In 1977, the sheep population split into two or three bands and increased to about 30 animals. The sheep stayed away from the alfalfa fields in 1978 but returned in 1979, 1980, and 1981. Lamb production appears to be good, but population numbers are increasing slowly. Sylvia and Scott Sullivan reported seeing a band of 20 to 25 bighorns in their alfalfa fields in 1979, 1980, and 1981. In the spring of 1980 (April 18), a sheep count was organized among sportsmen, Forest Service, and Game Department employees. Only 11 sheep were seen on this survey. Although some reports of larger numbers of sheep are occasionally received, the total population on Mount Hull was estimated at 35 in 1981.

Vulcan Mountain

Eight more California bighorns (six ewes and two rams) were trapped from the Colockum and released on Vulcan Mountain in 1971. A few of the rams wandered north and were seen near Myers Creek in British Columbia in 1972. For several years, starting in 1972, a band of four or five rams migrated north to Myers Creek just north of the Canadian boundary in the summer. In the fall they migrated back to the ewes and lambs on Vulcan. In 1974, one of the migratory rams was poached. Lamb production and survival were quite good for several years and the band had increased to about 30 by 1975. Several rams continued their annual migration to British Columbia and spent several summers on hillsides across from the Midway Weigh Station, outside of Midway, British Columbia. Weighmaster Jack Keswick developed a keen interest in the bighorns and periodically reported on his sightings. Two rams were killed crossing highways in British Columbia during 1975. Keswick reported that only three rams made the annual trek in 1976. While reports of sheep on Vulcan were sporadic for several years, lamb production and survival were quite good. In 1978, a biologist for the Burlington Northern Railroad reported seeing an eagle take a lamb on Vulcan. Reduced sightings of sheep prompted initiation of a winter trapping effort in 1979. Unfortunately, the sheep did not become habituated to the winter feeding, and no sheep were captured.

In 1980, more comprehensive sheep surveys were conducted, and many more sheep were observed than had been previously reported. In the spring of 1980, 51 sheep were seen (10 rams, 27 ewes, 14 lambs). Eighteen rams were seen in September 1980, 14 of which were 3/4-curl or larger. During trapping attempts in the winter of 1980, a band of nine ewes with seven lambs was observed. These surveys reflect excellent lamb production and survival in 1980. Population estimates increased to 65 by the fall of 1980. In the spring of 1981, sheep counts were even better. A May sighting of 17 adult ewes with 14 lambs reflected excellent lamb survival. A local rancher, Carl Strandberg, saw 22 lambs in 1981. In 1981, a sheep hunt was initiated on Vulcan for three rifle permittees. All three permittees took large rams. The bighorn population on Vulcan reached about 80 in 1981. The BLM owns much of the bighorn range on Vulcan and has maintained this range in good condition by limiting grazing permits. In addition, the ranchers holding the permits have gone out of their way to ensure sufficient forage remained for the bighorns. Many of the rams are exceptionally large on Vulcan, and the hunting outlook here is excellent.

Asotin Creek–Cottonwood Creek

In January 1973, four ewes were captured from the Tucannon and released on Asotin Creek. These ewes had been bred before transplant and produced three lambs in the spring of 1973. One of the ewes was marked with a neck collar and during the 1974 deer season, a hunter found the collar in the Cottonwood Creek area. Also in the fall of 1973, a band of 14 sheep, including three rams and four or five lambs, was seen in the Cottonwood Creek drainage. Apparently, some sheep from both Asotin Creek and the Tucannon immigrated to this area from their former range. Any rams in this area had to come from the Tucannon, since no rams were included in the Asotin transplant. The Cottonwood band of sheep, therefore, originated from the four ewes released on Asotin Creek, and rams as well as some ewes from the Tucannon. In 1976, the sheep split up into two different bands. In addition, bighorn sightings indicated a migration route had been established. These bighorns were seen in the Cottonwood Creek area in the summer, but during winter they were seen near the Grande Ronde. They apparently started an annual migration of six to eight miles. By 1976, the population had increased to about 20. Lamb production and survival increased from the mid- through the late 1970's. In 1975, only three lambs were seen, but in 1980, lamb production increased to nine. In June 1980, 33 sheep were classified (9 rams, 15 ewes, 9 lambs). In addition, the rams had expanded their range into the Wenatchee Creek drainage. In the spring of 1981, a helicopter survey revealed only 26 sheep–2 rams, 16 ewes, and 8 lambs. The ram band was not observed. Ground counts in June 1981 resulted in a count of 36 sheep (7 rams, 17 ewes, and 12 lambs). The band of five mature rams was observed in the Coyote Gulch area of Wenatchee Creek again in 1981. The Cottonwood Creek sheep have increased rapidly in the last few years and about 50 bighorns were present in 1981.

Reintroduction of Rocky Mountain Bighorns

Hall Mountain

In 1972, Rocky Mountain bighorns from Waterton Lakes National Park, Alberta, Canada, were transplanted to Hall Mountain in the Selkirks. Eighteen sheep were introduced (Appendix F), including 5 rams and 13 ewes. The sheep were marked by Canadian export tags

Table 13. Rocky Mountain Bighorn Sheep sightings in the Selkirk Mountains (Wadkins, 1973).

Date	Number of Sheep Seen				Seen By	Distance from Release Point—Airline Miles	
	Male	Female	Lamb	Total			
7/1/72				3	U.S.F.S.	1½	Northeast
7/1/72	2	5		7	Costa	0	Release point
7/2/72	3	3	1	7	U.S.F.S.	3¼	North
7/2/72				5	Costa	0	Release point
7/2/72				5	Loggers	3	Northeast
7/6/72		2		2	Costa	0	Release point
7/7/72	2	3		5	Costa	0	Release point
7/9/72		4		4	U.S.F.S.	1	South
7/10/72		2		2	Costa	0	Release point
7/12/72	1	4		5	U.S.F.S.	5	South
7/17/72	1	3		4	U.S.F.S.	10	Northeast
7/22/72		1		1	U.S.F.S.	6	North
7/23/72		1	1	2	U.S.F.S.	6	North
7/27/72		1	1	2	U.S.F.S.	5½	Northeast
8/3/72		2	1	3	U.S.F.S.	10½	East by south
8/5/72		3	1	4	U.S.F.S.	3	North
8/7/72	1			1	U.S.F.S.	7	Northwest (Metaline)
8/8/72		2		3	U.S.F.S.	3¼	North
8/12/72	1	3		4	U.S.F.S.	6	North
8/24/72	3			3	U.S.F.S.	3	North
9/3/72				1	U.S.F.S.	6	North
9/5/72		1	1	2	U.S.F.S.	3¼	East by north
9/27/72	1			1	U.S.F.S.	6½	Northwest (Metaline)
9/28/72	3	1		4	U.S.F.S.	1½	Northeast
10/11/72	3	1		4	W.G.D. & U.S.F.S.	2½	East
11/12/72	1			1	U.S.F.S.	3½	North (Ranger Sta.)
1/6/73	3	8		11	D. Shriner		Hall Mountain
1/7/73	1			1	D. Shriner		Hall Mountain
1/12/73	3			3	D. Shriner		Hall Mountain
1/15/73	1			1	D. Shriner		Hall Mountain
1/19/73	3	5	1	9	D. Shriner		Hall Mountain
3/16/73				3	W.G.D. & U.S.F.S.		Hall Mountain
6/6/73	1	7	2	10	U.S.F.S.	3½	North (Ranger Sta.)
6/23/73		1		1	U.S.F.S.	5	Southwest

Sightings reported for January by D. Shriner were arrived at during the course of an investigation carried on from December 27, 1972 to January 21, 1973 as a part of his studies at Whitworth College, located at Spokane, Washington. He also reports hearing of a sighting on Abercrombie Mountain some 12½ miles airline from the release point. This animal would have had to cross the Pend Oreille River and move northwest through some rugged mountains to reach that point.

Fig. 3. Bighorn Sheep Feeder At Hall Mountain

on their left ear and by Washington Department of Game tags on their right ear. In addition, rams were marked with green saflag patches and ewes with red saflag patches in their right ear. During the first year after release, Forest Service sightings indicated the bighorns had spread over 170 square miles. A summary of these sightings is compiled in Table 13. Two of the sheep were seen within the town of Metaline Falls. One of the rams (#222) was killed by a cougar in 1973.

A prospector, Mr. Costa, having a mineral claim at the Noisy Creek release site, immediately began a winter feeding program. He built a feeder and stocked it with good quality alfalfa. In addition, he offered the sheep a variety of salt blocks, including plain, sulfur, trace mineral, and iodized. These sheep were tame in Alberta before reintroduction in Washington and quickly became his pets. Several of the sheep ate out of his hand in the winter.

The sheep wandered throughout a large corner of northeastern Washington, but the population did not grow during the first couple of years. Very likely, some of the sheep emigrated from the release area and never returned. Nevertheless, in 1974 a total of 21 sheep were seen in the release area. In August 1975, a Game Department/Forest Service survey counted 14 sheep in an area extending from Watch Lake to Hall Mountain. Also in 1975, the Inland Empire Big Game Council

took over the winter feeding of sheep at Noisy Creek. The population had increased to about 30 in 1976.

In January 1977, 16 Rocky Mountain bighorns were captured at the Noisy Creek winter feeding site, where 28 different sheep had been seen at the trap site in one day. Ten of the captured sheep were transplanted to Joseph Creek HMA in southeastern Washington (Appendix G). Four bighorns were tagged, marked, and released at the capture site. Two died during trapping operations. After the removal, the Hall Mountain population dropped to about 20. In December 1977, another group of 12 sheep was captured at the Hall Mountain winter feeding site in conjunction with a sheep disease study. One ewe died from stress immediately after capture. All 11 sheep were marked with large, individually numbered ear tags and given a thorough physical exam by Dr. Bill Foreyt of Washington State University and his crew of veterinary students. Randy Bennett, graduate student from WSU, carried out the two-year sheep disease study on Hall Mountain, starting in 1977. In January 1978, Randy initiated a lungworm treatment procedure . At first, non-medicated alfalfa pellets were made available to the sheep at the feeder. After the sheep became accustomed to the pellets, other alfalfa pellets containing a dewormer, albendazole, were substituted. The medicated pellets, available only one day a week for three weeks, were successful in reducing lungworm levels (Bennet, 1979). Seven lambs were born in 1978, and all survived. In late October 1978, two rams from Hall Mountain were seen in British Columbia, about five miles north of the border on Salmo Pass. In 1979, productivity was excellent again, with eight lambs born. Also, another ram was killed by a cougar in 1979.

In 1980 and 1981, the Rocky Mountain bighorns continued to roam over a large area in the summer, but most of them seemed to return to Hall Mountain again in the winter. Several of the sheep, including ewes and lambs, apparently developed an annual summer migration to the Gypsy Peak area. In the fall of 1980, a classification of 32 sheep (4 rams, 18 ewes, 10 lambs) indicated lamb production remained good. During the 1980-81 winter, the highest count at the feeder was 28 sheep. The Rocky Mountain bighorn population at Hall Mountain is growing fast, and about 50 were present in 1981.

Joseph Creek

In January 1977, a band of 10 Rocky Mountain bighorns was trapped on Hall Mountain and transplanted to Joseph Creek HMA in southeastern Washington. A description of sexes, ages, and marking devices is listed in Appendix G. All 10 sheep were first taken to the Veterinary School at WSU, where blood samples, nasal swabs, and fecal pellets were taken from each animal. Anthelminthics and antibiotic injections were also given to each sheep. The plant consisted of two lambs (one male, one female), six ewes, one ram, and one hermaphrodite. The hermaphrodite appeared to be a 2-1/2-year-old ram when caught at Hall Mountain. However, closer inspection at the Veterinary School revealed that, although this animal had the body build and horns of a normal ram, it also had some of the reproductive organs of a ewe. While it had a vagina, it will never produce offspring.

The oldest ewe (#230) died a few days after release. The sheep wandered for many miles in all directions the first few months after release. Several went south to Tamarack Creek in Oregon but returned to Joseph Creek. Later in 1977, several of the sheep crossed the Snake River into Idaho. Although they returned to Washington, the Snake River proved to be no barrier, and they frequently crossed back and forth. About half of the sheep apparently took up permanent residence just across the border in Idaho. One of the sheep, however, identified by its black and white radio collar, was reportedly seen between Wallace and Kellog, Idaho, by Idaho Fish and Game officials. This ewe would have traveled a straight-line distance of about 130 miles. Reportedly, ewe #136 took time out during her trek to have a lamb, but never returned to Joseph Creek. In October 1977, another ewe (#135) was found dead at Limestone Point. In 1977, only one lamb was born, but two lambs were produced in 1978. By the end of 1978, however, production on both sides of the Snake River had only matched losses, and the population remained at 10. In 1979, four lambs were born, and all survived the winter. The band then totaled 13 sheep, consisting of 2 rams, 6 ewes, 4 lambs, and the hermaphrodite. In the summer of 1980, 15 different bighorns were observed by HMA Manager Roger Holland. In January 1981, a supplemental release of 10 Rocky Mountain bighorns was made at Joseph Creek. These sheep were transplanted from the Lostine River population in Oregon, about 100 miles to the south. Their age, sex, and marking devices are listed in Appendix H. Oregon Fish and Game supplied two radio collars for monitoring the sheep. In March 1981, one of the ewes (#463) was found dead in the release area. The other Oregon sheep apparently scattered, and about half the transplant returned to Oregon. Vic Coggins, Oregon game biologist, reported ram #95 had moved back to Troy, Oregon, in April. By June, however, the ram had moved north onto Saddle Butte, near Snow Springs in Washington. In March 1981, a helicopter survey was made to classify the Joseph Creek bighorns. Unfortunately, only nine sheep were observed, and none were newly transplanted animals. The nine sheep consisted of five ewes and four lambs. In the fall of 1981, 6 of the 10 recently introduced sheep had emigrated back to Oregon. These sheep seemed to scatter just as much as the original transplant to Joseph Creek in 1977. In December 1981, Pat Fowler saw 22 bighorns back at Joseph Creek, and these included most of the sheep transplanted from Oregon earlier in the year. Although sightings were extremely scattered, lamb production was excellent. The most recent classification was 10 ewes with 7 lambs in December 1981. The total Rocky Mountain bighorn population near Joseph Creek increased to 27 in 1981.

HABITAT MANAGEMENT

The most important factor in management of bighorn sheep is habitat. Bighorns occupy a variety of habitats, and while some of these have had little impact by man, others have been destroyed as bighorn range. Unfortunately, bighorns do not tolerate a variety of disturbances to their habitat. In many cases, proper management of habitat for bighorns is difficult if not impossible without ownership of the land. Washington has been one of the lead states in acquiring land to protect habitat for a variety of wildlife, including bighorns. Bighorns have been reestablished in 12 areas of the state, of which eight release sites are on Game Department owned or managed land. This is an important consideration for reintroduction of bighorns to native ranges. A variety of inimical uses of the range are impossible to regulate without acquisition.

Access to critical bighorn ranges is a management consideration that is becoming more important as human populations increase. Activities such as hiking, camping, picknicking, sightseeing, and hunting may adversely affect bighorns during critical times of the year.

Hicks (1977) in California indicated hiker disturbance was not critical on the summer range but suggested several management regulations to minimize human-bighorn contacts during winter. Other activities such as road construction, all-terrain vehicle use and access for a variety of purposes may be detrimental and should be regulated. Power transmission lines over bighorn ranges in Washington are not presently a problem, but access to lines should be controlled.

Mineral and Fossil Fuel Development

Few mineral and fossil fuel sites have been developed in Washington. Natural gas reserves are currently being explored in the Yakima area adjacent to bighorn sheep range. If reserves are located, development of these reserves must be managed so the habitat needs of bighorn sheep are preserved. Considerations may include seasonally important events and locations. All of the habitat requirements should be considered in the environmental impact statement prepared prior to development. As noted by Wishart (in Trefethen, 1975), the overall objective of the wildlife agency is to identify areas of possible conflict and suggest procedures and alternatives to minimize these conflicts.

Logging

Timber harvest and associated road construction occur on many bighorn ranges. Harvest management practices can result in improvement or detrimental impacts on bighorn range. Logging programs should be formulated by forest industry and Forest Service representatives with input from biologists. The method of cutting (selective, clear-cutting, or other) should be considered, as well as subsequent slash burning. Roads are nearly always constructed in conjunction with logging, and subsequent road closures should be considered. In some cases, logging activities will occur on migration routes from a summer to a winter

range. In such cases, timing of logging operations should be regulated so migration routes are not blocked during migrations. All logging activities should be conducted when bighorns are least likely to be dependent on that range.

Fire

Fire is a natural phenomenon that has had a substantial impact on bighorn ranges. Historically, many bighorn ranges have been maintained and enhanced by periodic wildfires. Rocky Mountain bighorns in particular are animals that occur on grasslands that result after forest fires in Douglas fir forests (Demarchi in Trefethen, 1975). Large wildfires in the past opened up forests and formed grasslands. These grasslands supported large numbers of sheep in Canada and the United States before arrival of man. Forests gradually encroached upon these grasslands, and bighorn populations declined as a result of habitat loss. The most recent grassland-producing fires occurred in the 1920's and 1930's. Since that time, however, fire suppression has prevented large fires in bighorn range, and forests have gradually encroached upon grasslands on many ranges. While bighorns still inhabit some of these areas, the less productive range under a forest canopy does not support nearly as many bighorns. Some of the most palatable bighorn forage plants such as bluebunch wheatgrass and Idaho fescue are relatively insensitive to fire (Franklin and Dyrness, 1973). Resprouting of these species after a fire creates a high-quality bighorn forage.

Studies by Elliot (1978) on stone sheep in British Columbia documents the value of fire in improving ranges. In this experiment, prescribed burning was used as a range enhancement technique for the production of trophy stone sheep. Sheep grew faster on the burned range, which produced more trophy sheep than the non-burned control area.

Fire is an important factor in range regeneration and preventing forest encroachment on grasslands. The blanket fire control policies of the last 30 to 50 years have impaired the natural productivity of many ranges. One of the few wildfire burns in the last 50 years on sheep range in Washington occurred on the Colockum. The burn here attracted sheep to the burnt-over area immediately after the fire. Prescribed burning should be incorporated in land management planning where fire formerly occurred naturally.

Ungulate Competition

The effect of competition between bighorns and other ungulates was discussed previously. Bighorns are tolerant of a few individuals of some species on their range but are intolerant of others. Habitat management must therefore involve management of other animals. No domestic sheep or domestic goats, for example, should be permitted to graze on bighorn range. While these animals are forage competitors, the primary concern is the transmission of parasites and diseases (See section entitled Disease and Parasites).

Bighorns should not be introduced to mountain goat ranges, because these species could be direct competitors on critical winter ranges. Presence of other animals on bighorn range may be tolerated but

should be managed. Livestock grazing should be prohibited where bighorns are at carrying capacity. Cattle grazing should be encouraged only where limited grazing will benefit bighorns. In some areas, limited grazing for a restricted period may enhance range conditions. Space competition should be considered in any livestock grazing program, however, and steps taken to minimize cattle-bighorn contacts. Cattle grazing, for example, should be restricted to areas and periods when bighorns do not use the ranges. Horses are detrimental to bighorn ranges, and their presence should be restricted.

A variety of wildlife species occur on bighorn ranges, but most do not have detrimental impacts on bighorns. Elk, however, must be managed so they will not overpopulate bighorn winter ranges. They eat basically the same forages as bighorns when on the same range. Large numbers of elk may trample snow-covered grassland and make forage unavailable, and their presence may force bighorns to leave traditional wintering areas. Bighorns should not be introduced to areas managed primarily for elk. While deer are found on bighorn ranges, they are usually not present in sufficient numbers to create competition.

HUNTING

Bighorn sheep are highly social animals, for which hunting must be managed differently than for other big game. Mountain sheep do not adapt well to habitat disturbances or high population losses. While not always restricted to wilderness areas, bighorns are best managed where access is controlled. The illegal harvest in highly accessible areas is frequently a management problem. If the area is to produce trophy rams for recreational hunting, then human disturbance must be kept to a minimum. The hunting of other species on bighorn range also causes bighorns to take evasive actions that deplete energy reserves. Recreational activities such as hiking, camping, and even birdwatching are a source of disturbance to sheep if the population is hunted. If not hunted, bighorns become accustomed to these activities and may become tolerant of human presence. Since there is very little sport in killing tame bighorns, frequent human-bighorn contacts present problems to the resource manager.

The harvest of bighorns must also be conservative. Bighorns have a lower reproductive potential than many other big game species and depend on leadership from older ewes and rams for survival. Most management agencies find the best way to manage bighorns is to restrict hunting to trophy rams. In Washington, we have a 3/4-curl standard, and a permit-only system is used to manage for trophy rams.

Hunter Management

As the bearer of a 1904 Washington hunting license, one would have been allowed, in season, two rams, two male goats, one male moose, one antelope, elk, or caribou, and four adult deer. Hunter management has changed over the years. Today, far more people seek a bighorn hunting opportunity than the resource can accommodate. Washington State has developed a system to allow a few rams to be taken each year without overharvest of the resource.

In each area where huntable numbers of sheep are present, Game Department personnel annually evaluate the status of sheep populations and recommend a permit level for hunters in that area. Recommendations from the Department of Game, as well as the public, are considered by the Washington Game Commission before setting hunting seasons. Sheep season and application instructions are summarized in a goat, sheep, and moose hunting pamphlet published each year in May. Persons drawn for a sheep hunt must wait five years before applying again in the lottery. Applicants must have a current Washington hunting license and may apply for only one of the sheep units. Out-of-state hunters may apply for a sheep permit, but the cost of a non-resident hunting license and poor chance of being drawn result in few applications.

Sheep permit applications are sorted by unit, and a drawing for the coveted sheep tags is held in July of each year. Some units are for rifle hunters, while other units are restricted to archery or muzzleloader only. In the 1970's, about 5,000 hunters applied for the annual quota of 20 to 40 bighorn sheep tags. In 1981, however, an up-front fee of $150 was required with the hunter's application. The up-front fee resulted in only 866 applications for sheep permits. The up-front application fee and waiting period after being drawn for a permit are management considerations that will require periodic review.

The basic management regulation for bighorn sheep hunting in Washington is the 3/4-curl horn rule. The Washington State Game Commission adopted the 3/4-curl horn policy in 1966 when bighorn sheep hunting was initiated in Washington State. Each year since then, except for a special either-sex season in 1973, bighorn sheep hunting has been regulated by the 3/4-curl horn rule. Over the years, we realized that many hunters had little knowledge of sheep hunting and did not understand the 3/4-curl rule. Changes have been made in the 3/4-curl description to make it more definitive and understandable. The horn curl regulation and description is similar to the one used in British Columbia. Each hunter is sent a copy of the 3/4-curl standard (Figure 4) and sheep hunting information.

In 1978, a voluntary bighorn sheep hunter orientation session was initiated to educate hunters and make sure they understood our 3/4-curl horn rule. Hunting tips, as well as procedures for preserving the head and horns for mounting, are discussed. Most hunters seem to enjoy these sessions, and the program has been successful in reducing the number of sub-legal kills. While mandatory attendance at sheep hunter orientation sessions has been considered, current programs do not warrant mandatory attendance.

The harvest of bighorns is monitored primarily by the Mountain Sheep Hunting report sent to all sheep hunters. This questionnaire requests information on area hunted, as well as dates, game seen and game killed. Hunters are asked to distinguish between 3/4-curl rams, ewes, and lambs on their hunting report. Persons failing to return this questionnaire are sent another. Return of this questionnaire has been extremely good (over 95%), and hunters provide useful sighting information. Harvest results are tabulated each year in the Game

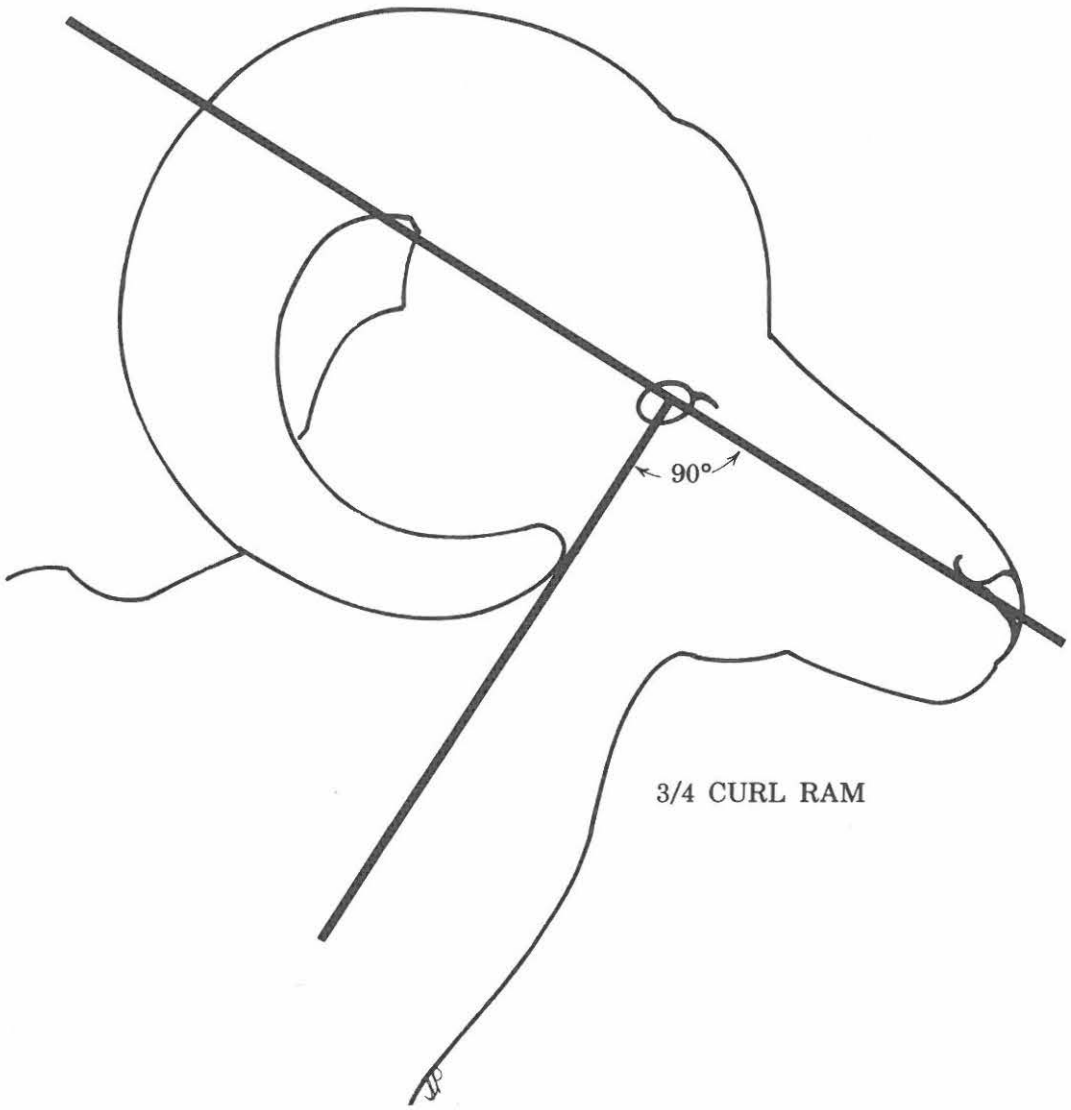

Fig. 4. DESCRIPTION OF 3/4 CURL HORN RULE.

3/4 curl rams are defined as: any ram whose horn growth, when viewed from the side, extends beyond a straight line drawn through the center of the eye at right angles (90 degrees) through a line drawn between the center of the nostril and the lowest hindmost portion of the base of the horn.

Department's Big Game Status Report. A summary of bighorn sheep harvest in Washington is found in Table 5 and Appendix B.

Law Enforcement

The illegal harvest of bighorn sheep has resulted in strict regulations and new law enforcement techniques. In 1974, biologists managing Rocky Mountain bighorns in North America (Wishart in Trefethen, 1975) urged mandatory tagging or marking for all legally harvested bighorn sheep. Since then, many states and provinces have adopted

some method for permanently marking harvested sheep. In 1981, Washington adopted a horn branding regulation. Each hunter is required to bring the horns of his sheep to a Department office for branding within 10 days after the kill. In addition, the hunter and his sheep are photographed for further identification.

Remains of mountain sheep can also be accurately identified for law enforcement purposes in a number of ways. Hemoglobin patterns provide accurate identity of fresh blood (Bunch et al., 1976). Keiss and Morrison (1956) described the precipitation reaction for identification of blood, bloodstains, and meat, and Belden (1975) outlined hemagglutination of uncooked blood and meat.

Research and management activities such as radiotelemetry and tagging studies can also be useful in law enforcement, an integral part of the bighorn management program.

SURVEYS

Wildlife biologists have attempted to determine lamb production and classification counts from a variety of inventory methods. Unfortunately, no one technique provides all the answers to management needs. Bighorns occupy rugged and mountainous terrain, which makes accurate surveys difficult to to conduct. In addition, bighorns, especially rams, tend to be scattered over a large area.

Spring surveys (April-June) help biologists determine lamb production and survival of the previous year's lambs. Fall and winter surveys give better classification counts for the entire population. The best ram classification counts are frequently conducted during the rut when rams range is restricted to ewe range. Where bighorns are given supplemental feed in the winter, a large percentage of the population may be classified from the feeding station.

Bighorn surveys are much more accurate when some of the sheep are marked with ear tags or neck collars. The presence of these animals provides inexperienced observers with animals of known age and sex to which they can refer for comparison in classifying other members of the population, and helps prevent duplication of counts.

One of the most accurate census techniques for sheep is an aerial count, using either fixed-wing aircraft or helicopter. The percentage of sheep sighted from aerial surveys varies, depending on topography, vegetation, cover, time of year, and type of aircraft.

Fixed-wing aircraft are often preferred over helicopters for financial reasons. Accuracy of fixed-wing surveys may be low for desert bighorns (McQuivey, 1978) but quite high for Dall sheep (Pitzman, 1970). In Washington, the accuracy of fixed-wing surveys for Rocky Mountain or California bighorns varies and depends mostly on pre-survey sightings of sheep. Recent sightings and location of sheep contribute substantially to the success of classification surveys. The use of helicopters has several advantages over the use of airplanes and usually results in better surveys. Not only can a helicopter get closer to the animals, but hovering allows more accurate classification of individuals. The main disadvantage of a helicopter is that if it hovers too close to bighorns it may cause them to panic, which could result in injury or death.

The best use of helicopter time requires planning the survey route in advance and flying canyon-by-canyon routes. Recent sightings should be summarized before a classification survey so these areas can be thoroughly searched.

Ground surveys are conducted by Department of Game personnel, occasionally with the assistance of sportsmen's organizations. These surveys are most often conducted in the winter when sheep tend to be more concentrated. When a large number of sportsmen or students are available, some individuals are assigned hiking routes, while others are designated as spotters. Spotters remain at one location throughout the survey and use spotting scopes and field glasses to classify bighorns flushed by the hikers. These surveys give sportsmen an opportunity to work with Game personnel, frequently resulting in better rapport between the two, to the benefit of both.

Another ground survey using the assistance of sportsmen is the opening day sheep count in sheep hunting areas. Before the sheep hunt, Department of Game personnel brief the hunters on classification criteria and other required information. On opening day, hunters tabulate sightings by time, group size, and location so the number of different animals can be classified. These surveys are frequently more comprehensive than other survey methods. Accuracy, of course, depends on the hunters' skill and how well Game personnel have coached them. Still another survey is conducted by sending a questionnaire to all sheep hunters. Each hunter is asked to record the number of rams, ewes, and lambs he or she saw during his or her hunt. These surveys do not indicate a population number, but sightings per hunter-day reflect year-to-year trends.

Most often, ground surveys are conducted by the individual research or management biologist. There is no substitute for information collected by a professional biologist as he hikes through bighorn range, classifying bighorns and evaluating the condition of range and animals.

SUMMARY

Native bighorns of both Rocky Mountain and California subspecies were extirpated from Washington about 1935. Historically, California bighorns were found scattered on the eastern slopes of the Cascade Mountains. The larger Rocky Mountain subspecies lived in the northeastern and southeastern corners of the state. Although several factors probably contributed to the demise of Washington's native bighorns, diseases contracted from domestic livestock are believed to be the principal cause.

In 1957, California bighorn sheep were reintroduced to Washington State from British Columbia. From the original transplant at Sinlahekin HMA, California bighorns have now been released into the wild in 10 areas of eastern Washington. Rocky Mountain bighorns were reintroduced to Washington in 1972 from Alberta. Some of these sheep were transplanted to another site in 1977, and now Rocky Mountain bighorns occur in two areas of the state.

Bighorn habitat is typically made up of grassland or grass/shrub habitat adjacent to or intermixed with precipitous terrain. Bunchgrasses are the most common plant species found on bighorn range in Washington. Escape terrain is very important for bighorns and may be the most limiting habitat requirement in this state. Wildfires have been an important influence on bighorn habitat, and fire suppression has resulted in conifer encroachment on native grasslands.

Lamb production is a good indicator of population quality and a key element in population dynamics. During the first few years of the reintroduction program, sheep were released in large enclosures. Classification counts reveal lamb production and survival were excellent while sheep remained in enclosures, but declined after release from enclosures.

Mortality rates seem to be extremely variable, and causes differ from year to year and between populations. One mortality factor may be devastating to one population, and yet this same factor may have little or no effect on another population. Unusually harsh winter weather in one area and record drought in another area are known to have caused extensive mortality. Predation is thought to cause a high mortality rate in some areas with inadequate escape terrain. The most serious predator of bighorns in Washington is undoubtedly the coyote.

The legal hunter harvest of bighorns is a minor mortality factor. While deliberate sheep poaching activities are probably limited in Washington so far, several sheep have been killed by errant hunters during deer and elk seasons. In some units, these losses exceeded the legal harvest.

Physical condition of bighorn sheep in Washington is good. Body weights of both California and Rocky Mountain bighorns in this state are higher than average measurements in other states. The body weight of Rocky Mountain bighorns on Hall Mountain is particularly outstanding; these sheep are among the largest in North America. Bone marrow and kidney fat tests also show that most of our sheep are in good condition. The only sheep found to have low fat reserves

were lactating ewes sampled in the Tucannon area of southeastern Washington.

Food habit studies indicate grasses are the main forage item of California bighorns. In general, the relative abundance of the various food items is determined by floristic composition on each of the bighorn ranges. Warming periods during late winter and early spring appear to be more important than any particular plant species.

The most serious competition problems in Washington involve domestic cattle and elk. Few deer are found on bighorn winter ranges, and bighorn have not been introduced on mountain goat ranges. Domestic sheep could be serious competitors, but few domestic sheep are currently ranged in Washington.

California bighorn sheep in Washington are non-migratory, except for those at Cottonwood Creek and a few rams at Vulcan Mountain. Rocky Mountain bighorns at Hall Mountain appear to have established an annual migration pattern, while those at Joseph Creek have extensive movements but no migration pattern.

Most bighorn sheep in Washington are members of high-quality populations. Rams mature early, grow large horns at an early age and die young.

The major bighorn management goal has been to restore native bighorns to native ranges. Reintroduction criteria and procedures involve: habitat, present land management practices, status of wildlife populations, temporary enclosures, physical criteria of released sheep, and follow-up reintroductions. The reintroduction program in Washington has been an outstanding success. California bighorns introduced in 1957 are now established in nine different areas of the state. Rocky Mountain bighorns introduced in 1972 are now established in two areas of the state.

Habitat is the most important factor in management of bighorn sheep. A variety of inimical uses of the range are nearly impossible to regulate without land acquisition. Washington has been one of the lead states in the country in acquiring land to protect habitat and manage the range. Mineral and fossil fuel development, logging, fire, and ungulate competition have substantial impacts on bighorn range. Wildlife managers must identify areas of possible conflict and present management alternatives.

Hunting is an integral part of the management program, but harvest must be conservative. The basic management regulation for bighorn sheep hunting in Washington is the 3/4-curl horn rule. A voluntary sheep hunter orientation has been recently added to the management program. Harvest of bighorns is monitored through questionnaires sent to each hunter and through horn branding. Washington adopted a horn-branding regulation in 1981 to permanently identify all legally taken rams and deter illegal trafficking of sheep.

A variety of bighorn surveys are conducted in Washington, but no single inventory satisfies all management needs. While Game Department aerial and ground surveys are conducted, many inventories use sightings by sportsmen. Hunter sightings on opening day, as well as questionnaire results, are compared to previous years' data to reflect trends. Most accurate classification counts, however, are conducted by professional wildlife biologists during spring and winter surveys.

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APPENDIX A. WASHINGTON TROPHY LIST

CALIFORNIA BIGHORN SHEEP (*Ovis canadensis californiana*)

Score	Length of Horn R	Length of Horn L	Circumference at Base R	Circumference at Base L	Circumference 3rd Quarter R	Circumference 3rd Quarter L	Greatest Spread	Tip to Tip Spread	Killed: County	Killed: Date	Killed: By Whom	Killed: Owner	Wash. Rank
177.6	38.4	39.2	15.2	15.1	7.3	7.5	25.3	25.3	Okanogan	1966	Vern Addington	Vern Addington	1
168.1	35.3	35.2	14.3	14.2	8.4	9.1	21.3	19.1	Columbia	1969	Chuck Downen	Chuck Downen	2
164.7	38.0	37.3	14.3	14.4	6.0	6.1	20.1	20.1	Yakima	1973	Al Rinaldi	Al Rinaldi	3

NOTE: Decimal indicates eighths

APPENDIX B. Washington Bighorn Sheep Harvest by Unit

Unit 1 (Aeneas Mountain)

Year	Harvest
1966	6
1967	3
1968	2
1969	4
1970	2
1971	3
1972	6
1973	4
1974	3
1975	5
1976	8
1977	6
1978	3
1979	4
1980	8
1981	6
TOTAL	23

Unit 2 (Vulcan Mountain)

Year	Harvest
1981	3

Unit 2 (Colockum)

Year	Harvest
1967	3
1968	4
1969	4
1970	3
1971	4
1972	Season Closed
TOTAL	20

Unit 3 (Tucannon)

Year	Harvest
1967	3
1968	4
1969	4
1970	5
1971	6
1972	3
1973	4
Season closed 1974 to 1981; reopened 1981 as archery only	
1981	1
TOTAL	30

Unit 4 (Clemans Mtn.) archery only

Year	Harvest
1971	0
1972	0
1973	1
1974	0
1975	0
1976	1*
1977	0
1978	0
1979	0
1980	0
1981	0
TOTAL	2

Unit 4 (Clemans Mtn.) muzzleloader only

Year	Harvest
1973	0
1974	0
1975	2
1976	0
1977	0
1978	0
1979	0
1980	0
1981	2
TOTAL	4

Unit 5 (Umtanum) archery only

Year	Harvest
1973	0
1974	0
1975	0
1976	0
1977	0
1978	0
1979	0
1980	0
1981	0
TOTAL	0

* ram taken less than ¾ curl

APPENDIX C. Lamb:ewe classification counts for all California Bighorns except those on Aeneas Mountain and Tucannon River (see Tables 3 and 4).

Date	Classification	Ratio	Source
	HULL MOUNTAIN		
July 1972	2:4	50/100	Bob Thorndike
March 1978	5:4	125/100	Dr. Dixon
April 1980	4:5	80/100	J. King, J. Danielson
Aug. 1980	4:12	33/100	Johnson
	VULCAN MOUNTAIN		
Jan. 1977	1:4	25/100	Zender, Burke
Aug. 1978	4:17	24/100	Zender, Burke
May 1980	14:27	52/100	Zender, Hickman
Nov. 1980	7:9	78/100	Johnson
May 1980	14:17	82/100	Zender
	SWAKANE		
Feb. 1976	0:8	0/100	Musser
	UMTANUM		
June 1975	4:9	44/100	Melliguard
Sept. 1975	2:5	40/100	Andrews
May 1976	6:10	60/100	Geoff Monk
	CLEMANS MOUNTAIN		
Sept. 1975	5:7	71/100	Konen
Jan. 1977	7:9	77/100	Konen
Dec. 1978	3:15	20/100	Bowhay
	COTTONWOOD CREEK		
May 1973	3:4	75/100	Hunter
Oct. 1974	4:7	57/100	Hunter
May 1975	3:4	75/100	Fowler
Aug. 1976	3:6	50/100	Fowler
May 1977	5:7	71/100	Fowler
May 1978	6:7	86/100	Fowler
May 1979	6:8	75/100	Fowler
May 1980	9:16	56/100	Fowler
March 1981	20:31	65/100	Fowler
May 1981	12:17	71/100	Fowler

APPENDIX D. Lamb:ewe classification counts for Rocky Mountain Bighorns.

Date	Classification	Ratio	Source
		HALL MOUNTAIN	
Nov. 1973	1:1	100/100	Johnson
Aug. 1975	2:5	40/100	Zender
Jan. 1977	2:7	29/100	Zender
Dec. 1977	4:8	50/100	Johnson, Zender
Dec. 1980	10:18	56/100	Zender
		JOSEPH CREEK	
May 1979	4:5	80/100	Fowler
May 1980	4:5	80/100	Fowler
May 1981	8:10	80/100	Fowler

APPENDIX E. Age and sex of California Bighorn Sheep released at Sinlahekin, 1957.

Tag No.	Sex	Age
7876	Male	1½ years
7877	Female	Adult
7878	Female	Adult
7879	Female	Adult
7880	Female	6 months
7881	Female	Adult
7882	Female	6 months
7883	Female	6 months
7884	Female	6 months
7885	Female	6 months
7886	Male	1½ years
7887	Male	1½ years
7888	Male	1½ years
7889	Female	Adult
7890	Female	Adult
7891	Female	6 months
7892	Female	6 months
7893	Male	Adult

APPENDIX F. Age, sex, and weight of Rocky Mountain Bighorn Sheep released at Hall Mountain, 1972.

Tagging		Color Patch*	Weight		
Left Ear	Right Ear	Right Ear	(pounds)	Sex	Age
588-601	236	Green	129	Male	3 yrs.
588-603	237	Red	137	Female	5 yrs.
588-604	238	Red	161	Female	8 yrs.
588-605	235	Red	158	Female	8 yrs.
588-606	234	Red	142	Female	7 yrs.
588-607	233	Green	201	Male	7 yrs.
588-608	232	Green	227	Male	8 yrs.
588-609	231	Green	157	Male	4 yrs.
588-610	230	Red	158	Female	6 yrs.
588-611	229	Green	118	Male	3 yrs.
588-612	228	Red	129	Female	10 yrs.
588-613	227	Red	164	Female	8 yrs.
588-614	226	Red	157	Female	5 yrs.
588-615	225	Red	131	Female	4 yrs.
588-616	224	Red	141	Female	5 yrs.
588-617	223	Red	123	Female	4 yrs.
588-618	222	Red	87	Female	2 yrs.
588-619	221	Red	99	Female	3 yrs.

* Ear patches are 3" x 3" safety flat material.

APPENDIX G. Description of Rocky Mountain Bighorns transplanted from Hall Mountain to Joseph Creek, 1977.

Sheep Number	Age	Sex	Marking Device and Observations
126	6 mos.	Male	Orange patch left ear
127	6 mos.	Female	Yellow patch right ear
129	3½ yrs.	Female	Red neck collar
132	2½ yrs.	Female	Yellow/blue neck collar
135	1½ yrs.	Female	Yellow/orange patch in right ear, and yellow neck collar
136	10½ yrs. #588616	Female	Black/white radio collar This ewe is one of the original sheep transplanted from Alberta to Washington
137	2½ yrs.	Female	Green/black neck collar
138	1½ yrs.	Male	Yellow/black radio collar
139	2½ yrs.	"it"	Black radio collar. This animal has horns typical of a ram but has a vagina.
230	11½ yrs.	Female	This ewe is one of original sheep transplanted from Alberta to Washington. She did not transplant well and left the truck reluctantly. She died a few days after release.

APPENDIX H. Description of Rocky Mountain Bighorns transplanted from Lostine River in Oregon to Joseph Creek, Washington in January, 1981.

Sheep Number	Age	Sex	Marking Device and Observations
430	3½ yrs.	Female	Yellow ear tag #90; dark blue neck collar
431	3½ yrs.	Female	Yellow ear tag #91; blue/white neck collar
432	1½ yrs.	Male	Yellow ear tag #92; yellow radio collar (Ch. 8-4470)
433	4½ yrs.	Female	Yellow ear tag #93; white/black neck collar
463	3½ yrs.	Female	Yellow ear tag #87; green neck collar
464	4½ yrs.	Female	Yellow ear tag #89; orange neck collar
475	2½ yrs.	Male	Yellow ear tag #95; orange/green neck collar
476	2½ yrs.	Male	Yellow ear tag #94; black/green neck collar
477	1½ yrs.	Male	Yellow ear tag #88; orange radio collar (Ch. 5-4468)
478	6½ yrs.	Female	Yellow ear tag #81; black neck collar

All sheep given one (1) baking soda capsule, a 5 ml subcutaneous injection of BOSE and a 3 ml shot of long acting penicillin.