

ESTABLISHMENT OF ALTITUDINAL MIGRATION IN A REINTRODUCED BIGHORN SHEEP POPULATION

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Abstract: The original Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) population in the North St. Vrain Canyon was migratory and was extirpated prior to 1970. Bighorn sheep were reintroduced in 1980 by the Colorado Division of Wildlife in cooperation with the Arapaho and Roosevelt National Forest. Biologists believed that a small, sedentary bighorn sheep herd would result because a major highway and a band of dense subalpine forest 7-12 km wide separated the Canyon from traditional summer ranges and established bighorn populations in Rocky Mountain National Park. Our study was initiated nearly 12 years after reintroduction. Using a mark-recapture index we estimated the number of adult ewes to be 79 (95% C.I. 64 - 95). The total population was estimated to be 184 bighorn. Three female-juvenile groups with distinct ranges were identified using radio-telemetry: the Buttonrock group used the North St. Vrain Canyon year-round; the Twin Sisters group used the Canyon most of the year but had a lambing and early summer range at higher elevations; and the Olive Ridge group migrated between the Canyon and high elevation ranges on the Continental Divide. We concluded that success of the transplant was related to: lack of competition with domestic livestock; excellent habitat quality; and contact between transplant sheep and native sheep. We provide examples suggesting that where transplanted bighorn contact established populations they typically show faster population growth, larger distributions, more extensive migrations, and larger ultimate population size than transplants into isolated ranges.

Transplants have been instrumental in halting the widespread decline of bighorn sheep populations throughout the western United States and in creating increasing populations in most states in recent years. In Colorado in 1988, over 40% of the total estimated bighorn sheep population was in transplant herds, and several of the largest native herds had received supplemental transplants (Bailey 1990). However, not all transplants have been successful. Only half of 18 transplant herds old enough to evaluate were considered successful in Montana (Janson 1974). In Colorado, 18 of 25 transplants had produced surviving herds of 25 or more sheep, but only 56% of the transplants had produced herds estimated at over 50 bighorn (Bailey 1990).

Many factors have been implicated in transplant failures. Bighorn are vulnerable to competition for forage with other wild and domestic ungulates and are susceptible to diseases transmitted by domestic sheep (Foreyt 1990). Protection from fire has resulted in habitat deterioration on many historic bighorn ranges (Waklyn 1987). But problems also result from an innate lack of exploratory behavior in bighorn. Geist (1971, 1974) pointed out that evolved behavior patterns of bighorn limit success of transplants. In con-

trast to cervids that produce excess numbers of offspring (twins are common) that disperse into available habitat, bighorn sheep produce single offspring that remain with their natal group. Females follow older females and males remain in female groups until between 2-4 years when they begin following older rams. Dispersal is a rare event occurring in response to unusually favorable or disastrous conditions and is undertaken by groups not by individuals (Geist 1971, 1974).

Geist (1974) predicted that if bighorn were transplanted into continuous habitat not interrupted by bands of timber or timbered valleys a gradual dispersal of sheep through the habitat will occur, but that if sheep were introduced into patchy habitat that was interrupted with bands of forest and/or forested valleys they would not reoccupy these patches. The North St. Vrain Canyon transplant herd is an example of a successful transplant adjacent to an occupied range that overcame expected barriers to movement and range establishment.

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BACKGROUND

Evaluation of the North St. Vrain Transplant Site

During 1978-1979, biologists for the Colorado Division of Wildlife and the Roosevelt and Arapaho National Forests considered the low elevation North St. Vrain Canyon and high-elevation St. Vrain Mountain as bighorn sheep transplant sites. Historical information indicated that the North St. Vrain Canyon was originally a winter range from which most or all sheep migrated to high elevation summer ranges, while St. Vrain Mountain was documented as a summer range (Goodson 1978a,b). Because of concerns about inadequate winter range and logistical difficulties of transplanting bighorn into a remote high-elevation range, St. Vrain Mountain was dropped from consideration.

Evaluation of the North St. Vrain Canyon transplant site included consideration of historical occupancy patterns, factors related to loss of the original bighorn herd, and current habitat conditions. Clair Billings, a rancher living in the Canyon in 1978 stated that, according to his father, bighorn sheep were common in the late 1800s and early 1900s. The sheep were generally seen at elevations above 6500 ft, and frequented North and South Sheep, and Cook Mountains in the North St. Vrain Canyon, Cabin Creek (a tributary of North St. Vrain Creek), and Flattop Mountain in Rocky Mountain National Park (pers. commun. Clair Billings).

Bighorn populations apparently declined rapidly between 1935 and 1945. In 1940, Ranger F. Blackmer, Roosevelt National Forest, thought that a bighorn sheep migration route still existed from Wild Basin in Rocky Mountain National Park to the North St. Vrain Canyon where a small herd of bighorn sheep was present (Packard 1941). The last resident herd left the area around 1945. After 1945, sheep sightings were rare (Goodson 1978b).

The decline and disappearance of bighorn in the North St. Vrain Canyon coincided with widespread decline of bighorn sheep throughout Rocky Mountain National Park and the disappearance of resident female-juvenile herds on high elevation ranges believed to be summer ranges of the North St. Vrain Canyon

herd (Goodson 1978b). Bighorn disappeared from the Indian Peaks between 1958 and 1970 (Bear and Jones 1973). Pneumonia (possibly transmitted by domestic sheep that were grazed widely on alpine ranges during this period) was believed to be an important cause of these declines (Packard 1941, Goodson 1980).

Two additional factors may have contributed to loss of the original bighorn population in the North St. Vrain Canyon. Highway 7 between Allenspark and Estes Park was constructed between 1916 and 1930 and by 1938 the entire road was oil processed (Goodson 1978b). This road bisects the traditional bighorn migration route between the Canyon and Rocky Mountain National Park. Allotments in the Canyon were also severely overgrazed by cattle in the 1920s through 1960s (Goodson 1978b). Four of 6 cattle allotments in the Canyon became vacant in 1969-1970 and use was reduced on two allotments still active in 1979 (Allotment files, Arapaho and Roosevelt National Forests).

The established populations nearest the North St. Vrain Canyon were a recently transplanted (1978) herd on the East boundary of Rocky Mountain National Park (the Fall River herd) and the Continental Divide herd (a native population) in Rocky Mountain National Park (Fig. 1). Female-juvenile bands had not been observed in the southern half of the Park for over 20 years, however, occasional sightings of ram bands occurred on the Continental Divide south to near the Park boundary.

In 1980, we believed that a small, sedentary herd would be the likely outcome of the transplant. Protection from fire had resulted in spread of forest reducing available suitable habitat and increasing habitat fragmentation. A major highway and 7-12 km (5-8 mi) of heavily forested terrain separated the transplant site from traditional summer ranges (Goodson 1978b).

The Transplant and Early Movements

In March 1980, 19 bighorn sheep from the Poudre Canyon were released in the North St. Vrain Canyon (Fig. 1). Some transplanted bighorn dispersed to other areas (Fig. 1). In November, transplanted bighorn were observed in Wild Basin, 8 km (12 mi) west of the transplant site. That same fall, three transplanted sheep were observed 18 km (12 mi) north. One of these joined the Fall River herd. A ram was observed in 1987 on Specimen Mountain in Rocky Mountain National Park, and a second ram died on Lily Mountain on the east boundary of Rocky Mountain National Park in 1988.

Observations of bighorn sheep in southern Rocky Mountain National Park increased steadily during the 1980s (Fig. 1). Bighorn were observed throughout Wild Basin, and crossing the highway

adjacent to the Park. Groups of rams were observed on Mt. Meeker and Long's Peak, areas from which sheep had been absent for 30 years. This increase was concurrent with an increasing native herd north of Bighorn Flats on the Continental Divide (Stevens and Goodson 1993).

Study Objectives

In the winter of 1991-1992, nearly twelve years after the original transplant, we initiated a study on the North St. Vrain transplant herd. Objectives were to estimate size, population structure, and distribution of the new herd. We were especially interested in determining if different herd segments and/or migratory behavior had developed.

STUDY AREA

The North St. Vrain Canyon extends 10.5 km between the towns of Allenspark and Lyons in north-central Colorado. Elevations range from 1970 m (6300 ft) to 2800 m (9,000 ft) in the lower canyon. Topography is rugged. Vegetation is a mosaic of conifer stands, shrub associations, and grassy parks. North and east aspects are dominated by stands of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). On south and west aspects shrub associations and grassy openings are interspersed with clumps and open stands of ponderosa pine and Rocky Mountain juniper (*Juniperus scopulorum*).

North of the North St. Vrain Canyon the terrain rises for approximately 6 km to Twin Sisters Peaks which reach above the treeline to 3500 m (11,200 ft). Forests of lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) cover the lower slopes.

To the west and across Highway 7 a band of subalpine forest 9-12 km in width separates the Canyon from extensive tundra and cliff habitat above tree-line in the high peaks of the Wild Basin area of Rocky Mountain National Park. About 7 km southwest of the Canyon the steep cliffs of the Middle St. Vrain Canyon rise from 2800 m (9,000 ft) to over 3500 m 11,200 ft on the south slope of St. Vrain Mountain, and extend west to the Continental Divide in the Indian Peaks Wilderness. Peaks near the continental Divide exceed 4,060 m (13,000 ft).

METHODS

Field Observations

Fieldwork began in February 1992 with foot and aerial surveys in the North St. Vrain Canyon to locate bighorn sheep and potential trapping sites. Seven ewes

and juveniles were discovered on Olive Ridge near the head of the canyon, and 12 sheep including large rams, ewes, and juveniles were found in the lower canyon near Buttonrock. These 2 groups were baited using alfalfa hay, salt, and fermented apple pulp for several weeks.

A few days prior to trapping, a local resident reported seeing approximately 70 bighorn cross Highway 7 from west to east near Allenspark. On the capture day, March 20, 1992, at Buttonrock we trapped 8 bighorn and placed radio collars on 2 adult ewes, 1 two-year-old female, and 2 rams. At the Olive Ridge trap site, we found over 40 bighorn most of which were not habituated to the net. At Olive Ridge, 5 adult ewes were radio-collared. One adult ram and 2 yearlings at Buttonrock and 5 adult ewes, 1 2-year-old ewe and 4 yearlings at Olive Ridge were cartagged but not collared. Unique combinations of colored ear tags were used on marked sheep to permit individual identification.

Intensive fieldwork was conducted from March 24 - April 4, and May 1 - September 30, 1992; March 22 - April 22, and June 30 - August 4, 1993; and May 3 - October 4, 1994. Additional observations were made on a less intensive basis from April 7 - May 5 and December 1 - January 14, 1994. During periods of intensive fieldwork, we attempted to visually locate each radio-collared bighorn once per week. We obtained radio-locations for telemetered bighorn through triangulation of signals or by backing signals to a prominent ridge when visual observations were not possible.

We made visual observations of 191 (1992), 33 (1993), and 72 (1994) bighorn groups including observations of 3945 (1992), 320 (1993), and 873 (1994) individual sheep. For each visual observation we recorded the following information: Identity of marked bighorn; location and UTM coordinates; habitat(s) used, aspect and elevation; behavior, and movements; for marked ewes, association with a lamb; sex-age classification of the group; weather and snow conditions. Locations of bighorn groups were mapped on U.S.G.S. 7.5 minute topographic maps.

Population Estimates

We used a mark-resight index (White and Garrot 1990, p. 256) to estimate the number of adult ewes because we had an adequate sample of marked animals only for adult ewes. The number of ewes that were marked but not radio-collared was the marked sample. The radio-collared ewes were used to locate as many as possible of the entire ewe population during a short period (2-3 days) that made duplication of observations unlikely. The ratio of marked to unmarked

ewes observed was used to estimate the population of ewes without radio-collars using the following equation (White and Garrott 1990, p. 256):

$$N = \frac{(n_1 + 1)(n_2 + 1)}{(m_1 + 1)} - 1$$

where n_1 is the number of marked ewes without radio collars, n_2 is the total number of ewes observed and m_1 is the number of marked ewes observed.

The number of ewes with active radio-collars was added to the estimate of the number of ewes without radio-collars to estimate the total ewe population. We averaged estimates from 2 periods to derive our final estimate and confidence limits.

The numbers of lambs, yearlings and rams were estimated from the observed ratios between observations of these age-classes and adult ewes. Cumulative observations throughout the field season were used to estimate the ratios of yearlings and rams to ewes. Ratios of lambs to ewes were based on observations after July 7 because after this date no new lambs were observed.

RESULTS

Population Size and Structure

Estimates of population size and structure were based on 2 periods of 2-3 days during the 1992 field season. A minimum of 91 bighorn sheep including 76 ewes and juveniles and 15 rams were observed in late March 1992 in the lower Canyon. These included bighorn marked at both trap sites. In August all Olive Ridge sheep were on alpine range and Buttonrock sheep were in the lower canyon and counts in both areas were combined. The arithmetic mean of these estimates (White and Garrott 1990, p. 257) provided the mark-resight estimate of the total number of adult ewes: 79 (95% CL 64 - 95). The observed cumulative ratios of lambs to ewes was 0.52, of yearlings to ewes was 0.32, and of rams to ewes was 0.49. Using these ratios and the mark-resight estimate of adult ewes, the population was estimated to be 79 ewes, 41 lambs, 25 yearlings and 39 rams, a total of 184 bighorn sheep.

On the high elevation summer range used by ewes captured at Olive Ridge the maximum count of ewes (including 2-year-olds) was 24 and the maximum count of ewes and juveniles was 40. On Twin Sisters and in the lower North St. Vrain Canyon summer ranges used by ewes captured at Buttonrock the maximum count of ewes (including 2-year-olds) was 26 and the maximum count of ewes and juveniles was 47. We observed a minimum of 22 rams 1/4 curl or larger during the summer of 1992. These included 4 1/4 curl, 9 1/2 curl, 8 3/4 curl and 1 full curl ram.

Distribution and Movements

Olive Ridge Group. -- In 1992, all ewes radio-collared at Olive Ridge and 5 of 6 ewes ear-tagged (but not radio-collared) at Olive Ridge moved from the lower Canyon to southwest-facing cliffs of St. Vrain Mountain above the Middle St. Vrain drainage prior to lambing (Fig. 2). During lambing and while lambs were less than one month old ewes used an extensive cliff area on the southwest side of St. Vrain Mountain, and south facing cliffs further up the canyon (Fig. 2). In July and early August ewe-juvenile groups used more extensive areas including the north side of St. Vrain Mountain, and areas north and west of St. Vrain Mountain (Fig. 2). Later in August they shifted to the west side of the Continental Divide. All marked ewes of this group remained near treeline or above treeline through late September.

During late March and early April 1993, 4 of the ewes marked at Olive Ridge (Olive Ridge group) were observed above treeline on the Middle St. Vrain drainage, and 3 ewes and a yearling marked at Olive Ridge were observed in the lower canyon. The radio of 1 ewe of the Olive Ridge group was recovered in a meadow west of the Rock Creek Road between the lower canyon and the Middle St. Vrain Canyon. All 4 surviving radio-collared Olive Ridge ewes were radio-located above treeline in the Middle St. Vrain drainage during July - early August 1993.

In 1994, the single surviving ewe with an active radio-collar from the Olive Ridge group was observed with companions on Meadow Mountain (between St. Vrain Mountain and the lower Canyon) in mid - April when intensive fieldwork began. Olive Ridge ewes including this radio-collared female used the south and southwest-facing cliffs of St. Vrain Mountain during the lambing period. They were consistently located in this area through the end of July. In mid-August, the radio-collared ewe and a large group of Olive Ridge ewes and juveniles were located west of the Continental Divide, where they remained through early October.

Buttonrock and Twin Sisters Groups. -- During early May 1992 the 3 radio-collared ewes trapped near the mouth of the North St. Vrain Canyon on North Sheep Mountain were observed in large groups on North Sheep Mountain and at the east end of Doer Ridge (Fig. 3). Two radio-collared ewes lambled in cliff areas in the lower Canyon. The third radio-collared ewe (691) moved to the south ridge of Twin Sisters early in June. Although this ewe, a 2-year-old, did not have a lamb she was observed in groups with ewes with small lambs (Fig. 4). Throughout most of the summer, the 2 radio-collared ewes that lambled in the

lower canyon were in ewe-juvenile groups that divided their use between major cliff areas on North Sheep Mountain and at the east end of Deer Ridge. In September they extended their range to the west end of the lower canyon.

The radio-collared 2-year-old ewe (691) remained with ewe-juvenile groups on Twin Sisters Mountain through mid-July in 1992. In late July she returned to the lower Canyon, rejoining groups including the other 2 radio-collared ewes. In late September she returned to Twin Sisters Mountain.

Observations in 1993 and 1994 indicated that range-use patterns of the Buttonrock and Twin Sisters' groups were generally consistent between years during spring-early fall. During late March-April, 1993, 2 ewes radio-collared at Buttonrock were observed in the lower canyon, and the carcass of the third radio-collared ewe was discovered in the lower canyon. The 2 surviving ewes were observed in the lower canyon during July - early August.

Only one ewe with an active radio-collar, 691 of the Twin Sisters group survived in 1994. She was located in the lower Canyon when fieldwork began in early April of 1994 and remained there through early June. On June 11, 691 was located on Twin Sisters with a week-old lamb. She remained on Twin Sisters through June. She was located with her lamb in the lower canyon on July 1. She remained in the lower canyon in groups with other ewes and juveniles through early October.

Ram Group. — Two 1/2 curl rams were radio-collared and one 3/4 curl ram was ear-tagged on North Sheep Mountain in March 1992. These rams remained in the lower canyon through early June (Fig. 5). In mid-June both radio-collared rams moved to Twin Sisters Mountain. They were joined by the ear-tagged ram and the 3 marked rams remained with all-male groups in the Twin Sisters area through late September (Fig. 5).

Observations of rams during 1993 indicated that range-use patterns of rams were consistent between years. The signal of 1 radio-collared ram was last received in November 1992 from Olive Ridge. During March-April 1993, the other radio-collared ram was located in the lower canyon. The ram that was ear-tagged but not radio-collared was also observed in the same area. In July - August, the single remaining radio-collared ram was observed in the lower canyon and on Twin Sisters with the ear-tagged ram (Fig. 5).

Our information on distribution and movements of rams in 1994 was limited because no rams with active radio-collars remained in the study area. We located ram groups in May in the lower canyon on

North Sheep Mountain, and droppings and tracks indicated rams used Twin Sister in early - late summer. Small ram groups were observed on St. Vrain Mountain in May and west of the Continental Divide in late August.

Group Fidelity. — One marked sheep, a yearling ram ear-tagged in 1992 at Buttonrock, changed group affiliation. He was observed consistently with Olive Ridge sheep during 1994. No other marked bighorn changed group affiliation.

SUMMARY AND DISCUSSION

Population Size

Growth of the North St. Vrain Canyon transplant herd was excellent. The actual population may have been considerably larger than the estimate of 184 in 1992 because we observed only about half as many rams as ewes. The herd is lightly hunted and it is unlikely that this is the true ram:ewe ratio. We expect that we missed about half of the rams because they use different areas than ewes during much of the year and because we did not conduct fieldwork during the rut (November - December).

It is likely that Olive Ridge ewes remain above treeline for the rut and that ram groups that breed with them include transplant rams and native rams from the Continental Divide population in Rocky Mountain National Park. In 1994, mature unmarked rams were observed above treeline on St. Vrain Mountain, and west of the Continental Divide on summer range of the Olive Ridge ewe-juvenile group. A marked ram from the original transplant was also observed on Specimen Mountain in Rocky Mountain National Park in 1987 in company with rams from the Continental Divide population. Since the transplant, ram groups originating either from the transplant stock or native bighorn have been observed regularly in the Long's Peak - Mt. Meeker area, following an absence of over 30 years (Goodson 1978a).

Distribution and Movements

Radio tracking confirmed that females and juveniles of the Olive Ridge group and of the Buttonrock and Twin Sisters groups had distinct seasonal ranges and migration patterns. The Olive Ridge group moved between the lower canyon and high-elevation ranges straddling the Continental Divide in Rocky Mountain Park and the Indian Peaks Wilderness. The Buttonrock group used the lower canyon year-round. The Twin Sisters group consistently used higher elevations on Twin Sisters Mountain during spring-early summer. Marked rams used a range similar to the Twin Sisters

female-juvenile group, however, rams used a greater area and range of habitats at higher elevations.

Movements between high elevation ranges and the lower canyon varied in timing from year to year. Some years (or all years) some ewes remained on the high elevation range most (or all) of the winter.

Evaluation of Success of Transplant

The North St. Vrain transplant was remarkably successful. Within 13 years of the original transplant, a population estimated at 184 sheep and likely over 200 sheep was established. For comparison in Bailey's (1990) review of bighorn populations in Colorado, he found only 9 of 53 herds established in 1980 or before were estimated to include more than 160 bighorn.

The population included three groups of females and juveniles with distinct movement patterns and seasonal ranges. One adult ram group was identified with a range similar to the Twin Sisters group. The existence of an additional ram group or groups that use high elevation ranges was indicated by observations of rams above treeline on summer range of the Olive Ridge group. Groups derived from the initial transplant established a range of approximately 60 sq km, that includes elevation ranging from 1,875-4060 m (6,000-13,000 ft).

The range-use pattern established by the North St. Vrain bighorn sheep herd is similar to the range-use pattern of original bighorn sheep populations in north central Colorado (Goodson 1978b) and relatively undisturbed mountain sheep populations in Canada (Geist 1971). Like original populations, this herd consists of multiple subgroups with distinct seasonal range-use patterns, some of which include extensive altitudinal migration. This transplant demonstrates that bighorn sheep are capable of reestablishing populations that mimic the structure, distribution and migration patterns of original populations.

Factors Related to Success of Transplant

We believe several factors contributed to the rapid growth, and large size of the North St. Vrain bighorn population and to its establishment of a productive and natural range-use pattern. These factors were:

1. A low level of competition with domestic livestock. Most allotments in lower canyon became vacant in the early 1970s. No domestic livestock grazing occurs in Rocky Mountain National Park including the Twin Sisters area. Grazing in the Indian Peaks Wilderness is limited to cattle that use drainage bottoms and subalpine meadows. No domestic

sheep are known to occur within the range established by the North St. Vrain herd.

2. Excellent habitat quality. Adequate snow-free winter range and extensive escape terrain exists in the lower canyon. The heart of the high elevation range is a series of south facing cliffs forming the Middle St. Vrain canyon that range in elevation from about 9,000 to over 11,000 ft and that are adjacent to extensive areas of steep to rolling alpine tundra.
3. Contact with bighorn rams (and possibly ewes) from the Continental Divide herd in Rocky Mountain National Park. Scattered bands of rams were known to drift down the Continental Divide from occupied ranges north of Bighorn Flats to near the Park boundary prior to the initial release. Evidence for contact with the transplant herd includes a transplanted ram observed with Park rams on Specimen Mountain, Rocky Mountain National Park, in 1987, and unmarked rams observed on alpine range in proximity to Olive Ridge ewes. Additional evidence of contact was unusually high mortality in the introduced herd during winters 1992-1993 and 1993-1994. This mortality was concurrent with pneumonia-caused declines documented in 2 herds located approximately 20 km north of the North St. Vrain Canyon that had known contact with rams from Rocky Mountain National Park.

There are several other examples of successful transplants of bighorn sheep where contact with established populations occurred. At Walling Reef, Montana, 37 bighorn sheep were released in 1976. In 1982, the population was estimated to be 87 bighorn. Contact was documented with a subpopulation of the indigenous Sun River metapopulation. Factors related to the success of the transplant were historically good habitat, mild weather following introduction, closure to livestock, and contact between transplanted bighorn and dispersing bighorn from an established population (Andryk and Irby 1986).

The Fall River-Cow Creek herd resulted from a transplant near the east boundary of Rocky Mountain National Park (Stevens and Hanson 1986). In 1977, 20 bighorn sheep were transplanted into the Cow Creek drainage. A radio-telemetry study of the population conducted from 1980-1985 documented establishment of altitudinal migration, a distribution of about 50 sq km, and a population of over 100 for the transplant herd. The transplant more than doubled the bighorn sheep population on the east side of the Park and provided 46 bighorn for transplants by 1988 (Bailey

1990). Factors contributing to its success were historically productive habitat, lack of domestic sheep grazing and limited cattle grazing, and contact with the native bighorn sheep population on summer range.

Fifteen bighorn sheep were reintroduced to Trickle Mountain, Colorado, in 1951 (Bear and Jones 1973). The herd increased rapidly. It was estimated to number 225 bighorn in 1988 and supplied 336 sheep for transplants between 1971 and 1988 (Bailey 1990). Contact between transplant sheep and a native bighorn population in the Collegiate Range was documented (Bear and Jones 1973). Rams (and possibly ewes) migrated from Trickle Mountain to summer range on Mt. Antero in the Collegiate Range, a distance of 30 km. Exchange was also considered likely between the Trickle Mountain herd and the LaGarita herd (Bear and Jones 1973). Factors in the outstanding success of this transplant included extensive open habitat, lack of competition from domestic sheep, and contact with bighorn from established populations.

Eighteen bighorn sheep were transplanted in 2 groups in 1976 and 1977 to the Cebolla Creek Wildlife Area in Colorado (Bear 1979). This area originally supported a migratory bighorn herd but by 1970s only small group of rams migrated from alpine range near San Luis Peak to the low elevation winter range on Cebolla Creek. The transplant succeeded in establishing an ewe-juvenile group that used the winter range and a summer range nearby. The San Luis Peak herd has increased from about 125 to 300 bighorn sheep since the transplant (Bailey 1990).

In conclusion, transplanting bighorn into areas where they will contact bighorn from established herds has been shown to result in populations with larger distributions, longer migrations, more rapid population growth, and larger ultimate population size than typical of transplants into isolated ranges. In these cases transplants have succeeded in establishing populations with structure similar to successful native herds: multiple ewe-juvenile and ram subgroups with distinct seasonal ranges and movements patterns including altitudinal migration. This natural distribution pattern results in effective use of habitat patches and significant increases in population size.

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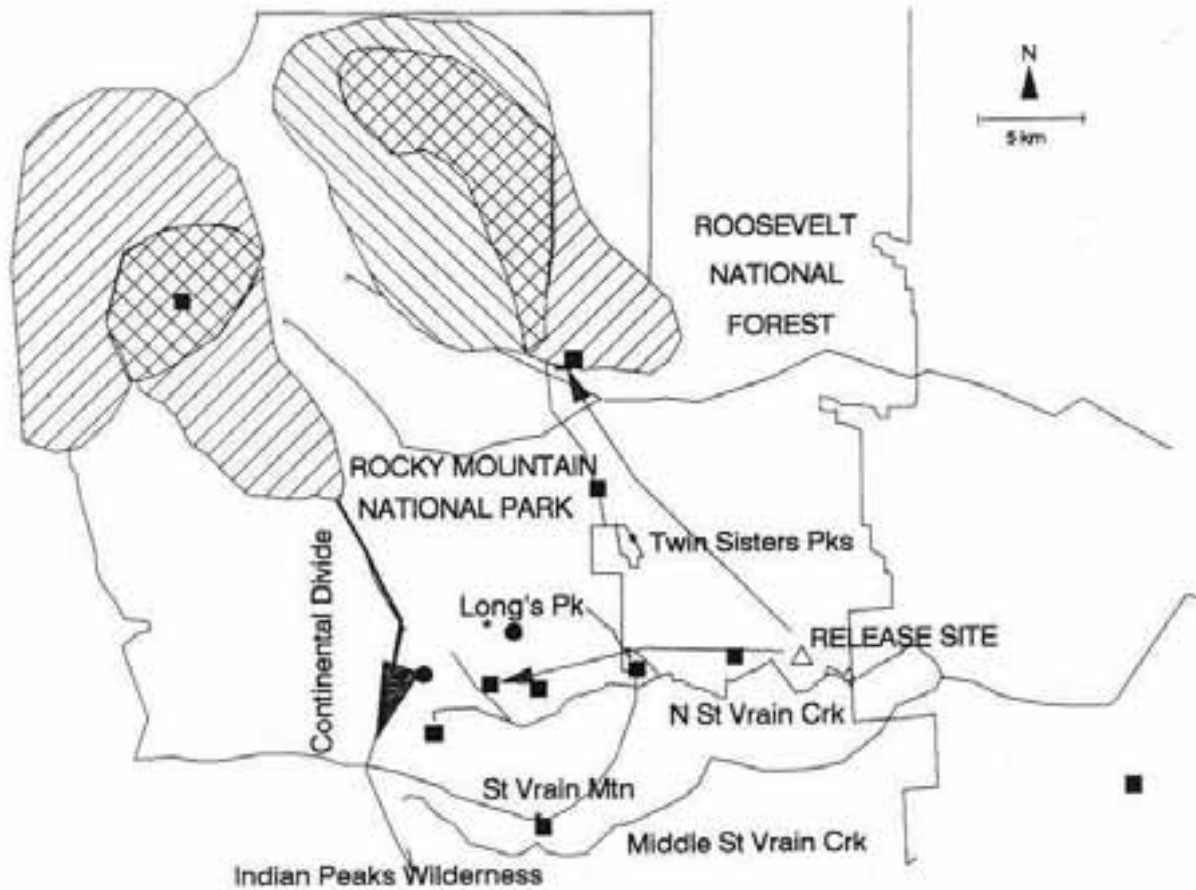


Figure 1. The release site for the 1980 transplant of bighorn sheep into the North St. Vrain Canyon is shown in relation to existing bighorn populations (hatched areas). The crosshatched areas indicate where ranges of established groups overlap. Movements of rams from the established populations in Rocky Mountain National Park down the Continental Divide are indicated by the large arrow. Small arrows indicate movements of marked sheep from the North St. Vrain transplant within a year after the transplant. Solid squares indicate observations of groups of bighorn including marked bighorn from the North St. Vrain transplant during 1980-1992. Solid circles indicate observations of bighorn groups during 1980 - 1992 that did not include marked sheep but that occurred in areas where bighorn had not been observed for over 20 years prior to the transplant.

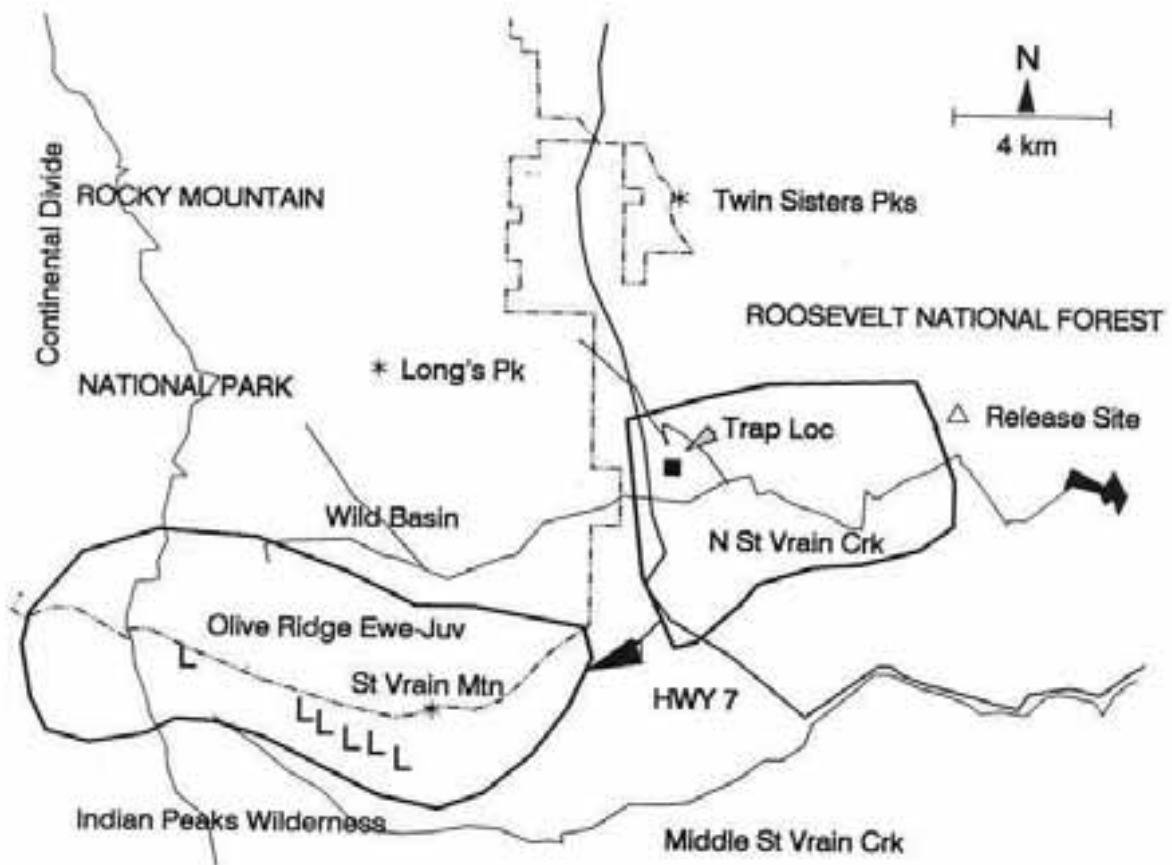


Figure 2. Distribution of radio-marked ewes that were trapped at Olive Ridge, in relation to the initial release site, and the location where they were trapped. Lambing areas within their range are indicated by L's. A likely migration route between the low elevation range and the high elevation range is indicated by a large arrow. The small open square indicates the location where the radio-collar of an Olive Ridge ewe was discovered.

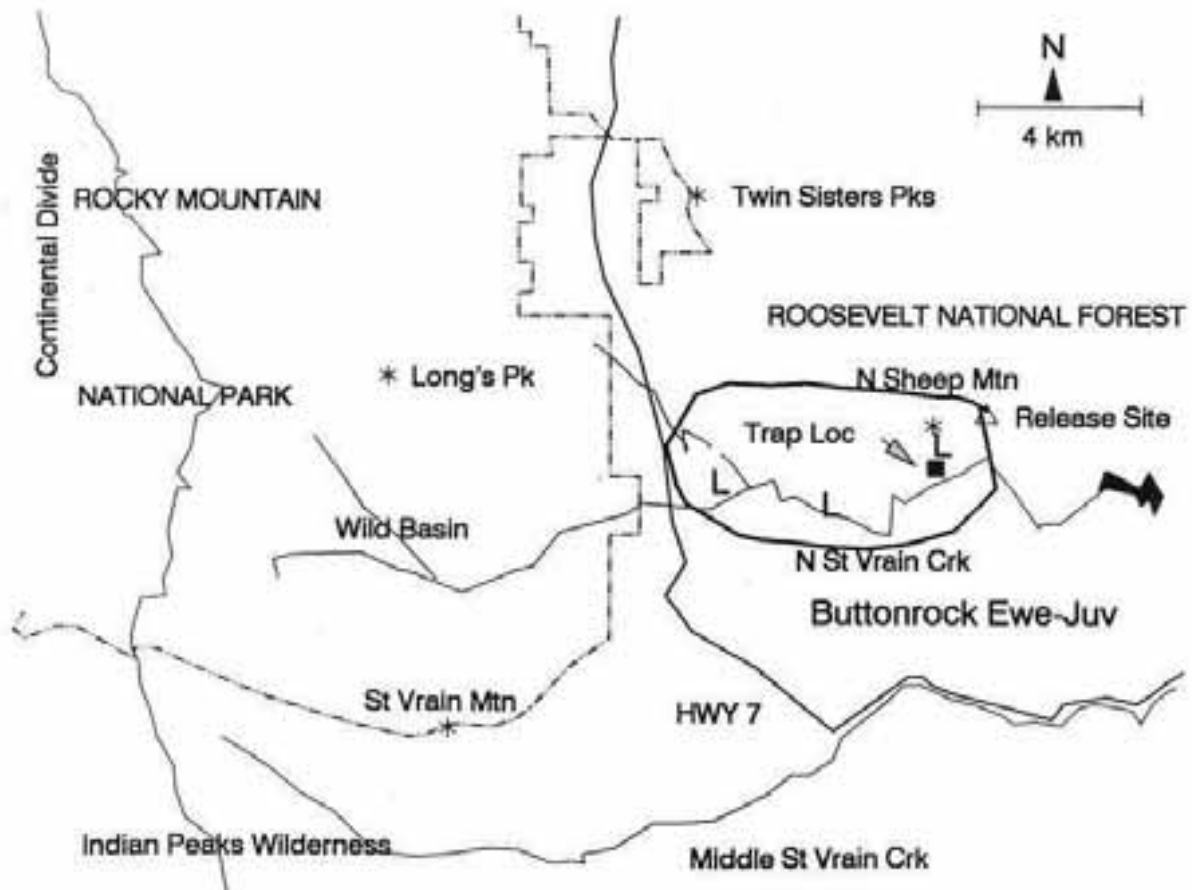


Figure 3. Distribution of radio-marked ewes that were trapped at Buttonrock and remained in the lower canyon is indicated in relation to the initial release site, and the location where they were trapped. Lambing areas within their range are indicated by L's.

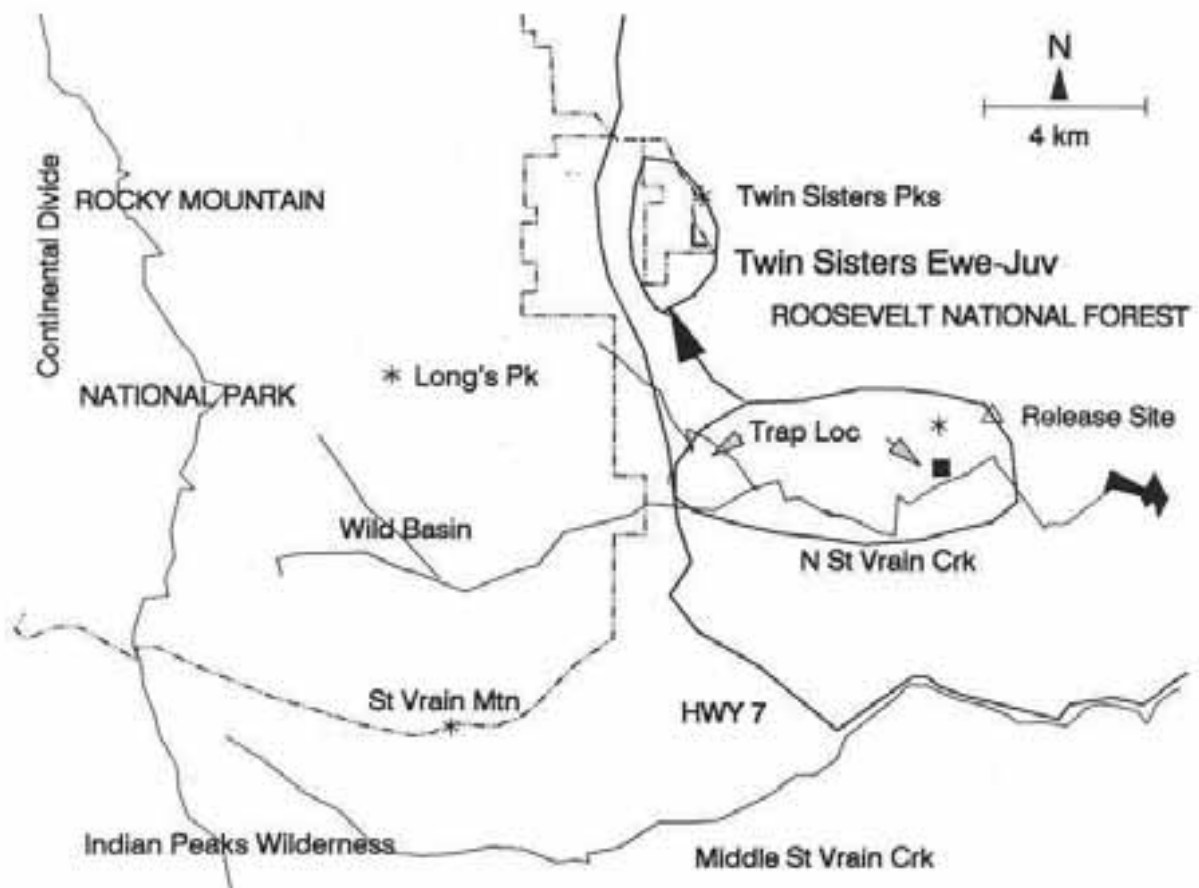


Figure 4. Distribution of radio-marked ewes that were trapped at Buttonrock and that moved to Twin Sisters' Peak is indicated in relation to the initial release site, and the location where they were trapped. The lambing area used by the Twin Sisters' group is indicated by an L. A likely migration route between the low elevation range and the high elevation range is indicated by the large arrow.

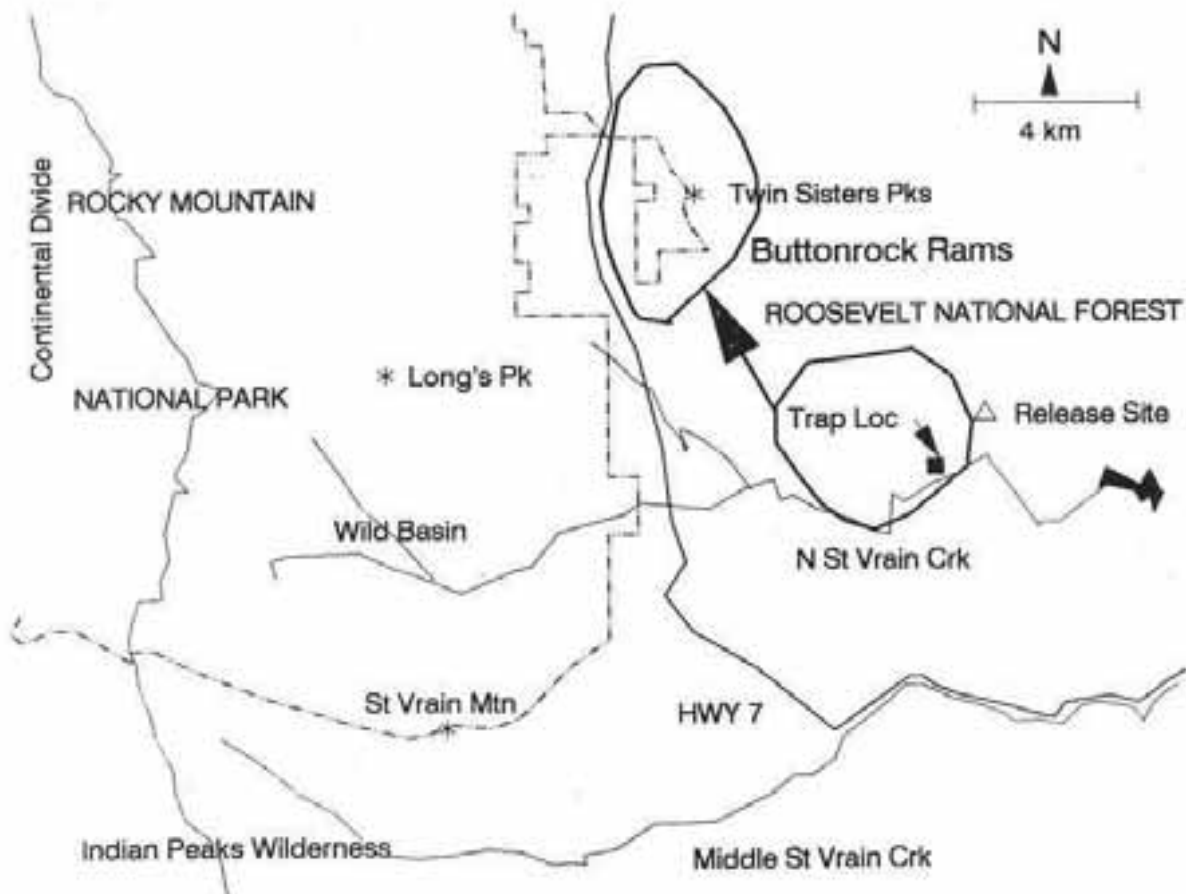


Figure 5. Distribution of radio-marked rams that were trapped at Buttonrock is indicated in relation to the initial release site, and the location where they were trapped. A likely migration route between the low elevation range and the high elevation range is indicated by the large arrow.