COMPARING METHODS TO DETERMINE DISTRIBUTION AND MOVEMENT PATTERNS OF FOREST-DWELLING MOUNTAIN GOATS

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Abstract: We compared direct and indirect methods of observation to record the presence of mountain goats (*Oreamnos americanus*) along Pinto Creek, Alberta. Observation methods consisted of visual sightings of goats, the use of remote cameras, and locating goat sign (i.e., hair, tracks, and pellets) within belt transects and plots along the top of 29 discontinuous cliffs within the study area from February to October 1997. Belt transects were the most reliable single method of recording presence of goats on cliffs during winter and summer 1997. Belt transects alone, however, were limited to recording presence-absence data. The other methods are required if data on population structure, individuals, behaviour, daily activity, or intensity of use are needed.
Key Words: mountain goat, (*Oreamnos americanus*), wildlife inventory, remote cameras, activity indices.

INTRODUCTION

Biologists monitor movements and distributions of ungulates by direct and indirect observations. In open areas, where visibility is good, aerial and ground surveys enable biologists to census populations and record behaviour and habitat use (e.g., Bowden and Kufeld 1995, Varley 1994, Côté 1996, Romeo and Lovari 1996). Where visibility is poor, biologists collect data on movements, habitat use, and activity patterns with very high frequency (VHF) transmitters (e.g., Singer and Doherty 1985, Haynes 1994, Fritzen et al. 1995, Warren et al. 1996) or Global Positioning System (GPS) technology (e.g., Moen et al. 1996, Biggs et al. 1997, Poole and Heard 1998). Locating sign (i.e., tracks, pellets, hair) within plots or along transects has been used to monitor., Neff 1968, Mooty and Karns 1984, the presence of ungulates in a variety of habitats (e.g Loft and Kie 1988, Poole and Fear 1998). Jacobson et al. (1997), censused white-tailed deer (*Odocoileus virginianus)* with infrared-triggered cameras.

The Pinto Creek mountain goat herd is atypical of goat populations because of its year-round use of forests. Standardised methods for monitoring movements and habitat use of goats in forests are not well developed and methods for studying goats in open areas may not be suitable for forest-dwelling populations where visibility is low. Penner and Jalkotzy (1982) observed goats most often on the cliffs along Pinto Creek and less often in the forests. Pellet-group counts revealed that use of forests by goats in the Pinto Creek Goat Reserve was greater and more widespread than expected from direct observations alone (Niederleitner 1994). Those data

data illustrate the potential bias associated with direct observation alone; goats in forests are not easily observed, therefore, use of forest is underrepresented.

We compared the seasonal distribution, movements, and use of forests by mountain goats along Pinto Creek using 4 methods during winter and summer: visual observations, remote cameras, and observation of goat sign (i.e., tracks, pellets, hair) within belt transects and within plots. We then determined the best combinations of methods to obtain the most comprehensive pattern of distribution of mountain goats.

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Study area

STUDY AREA

The study area, which encompasses the lower Pinto Creek valley, lies on the eastern slopes of the Rocky Mountain Foothills and is located between 53°49'N and 53°43'N and 117°52'W and 117°47'W (Fig. 1). This area is approximately 50 km northwest of Hinton, Alberta, and is separated from the Rocky Mountain ranges by at least 40 km of coniferous forest.

Pinto Creek cuts through several high, rounded hills, composed of Mesozoic and Paleozoic sedimentary rock (Strong 1992). Stream erosion has formed a steep-sided canyon along parts of the valley. Habitat used by goats in the study area includes a series of discontinuous cliffs along the slopes of Pinto Creek and the lower reaches of Hightower and Wroe Creeks (Fig. 1). Penner and Jalkotzy (1982) identified 34 discrete cliffs along Pinto Creek and its tributaries; 29 of these cliffs are located within our study area (Fig. 1).

Cliffs generally consist of 4 vegetation zones: riparian, talus, cliff-face, and above-cliff. Located at the bottom of most cliffs is a narrow riparian zone adjacent to the creek. Vegetation within this zone includes aspen seedlings (*Populus tremuloides*), willow (*Salix spp.*), and occasional mature white spruce (*Picea glauca*). The talus zone is predominantly loose sand with patches of aspen seedlings, bluejoint (*Calamagrostis canadensis*), hairy wild rye (*Elymus innovatus*), and common juniper (*Juniperus communis*). On some cliffs, the riparian and talus zones are absent and the cliff-face zone ends abruptly at water's edge. The cliff-face zone consists of loose sandstone and rocky outcrops used as escape terrain by goats. The vegetated portions of the cliff-face zone include bearberry (*Arctostaphylos uva-ursi*), common juniper, bluejoint, and fescues (*Festuca* sp.). Small clumps of lodgepole pine (*Pinus contorta*) or aspen grow within the cliff-face zone of some cliffs where the soil is stable. We considered the top edge of the cliff-face zone to end where loose sandstone meets firm, stable soil. Individual cliffs range in size from 30 m to 420 m in length and from 18 m to 90 m in vertical height. We considered the above-cliff zone to begin at the cliff edge and extend 20 m behind the cliff. This zone is generally forested with an overstory dominated by lodgepole pine and aspen. The groundcover within this zone is predominately graminoids (bluejoint and hairy wild rye) and the shrub understory is dominated by buffalo-berry (*Shepherdia canadensis*), wolf-willow (*Elaeagnus commutata*), and aspen seedlings.

The forested plateau above the cliffs is dominated by lodgepole pine and white spruce, with minor components of trembling aspen and balsam poplar (*Populus balsamifera balsamifera*). Labrador tea (*Ledum groenlandicum*) and mosses, particularly red-stemmed feathermoss (*Pleurozium schreberi*), make up the understory (Beckingham et al. 1996). Black spruce (*Picea mariana*) is a common species on poorly drained areas. Along the steep valley breaks, aspen is abundant at cliff edges and in the steep gullies between cliffs. Buffalo-berry, wolf-willow, wild rose (*Rosa acicularus*), willow, bearberry, wild vetch (*Vicia americana*), and various graminoids are common understory plants of aspen stands. Mixedwood forests on floodplains contain white spruce, aspen, balsam poplar, and paper birch (*Beltula papyrifera*). Total relief varies less than 110 m (1110 -1220 m elevation) along the gently-rolling forested plateau behind the cliffs. Macroclimatic conditions of this area are characterised by cold and dry winters and cool and moist summers (Beckingham et al. 1996). The mean annual precipitation is 540 mm with maximum precipitation occurring in July and the majority of winter precipitation falling as snow (Beckingham et al. 1996). Mean seasonal temperatures range from -13 to +17°C, where February is the coolest month and July the warmest. During winter, this area is often influenced by cold Arctic air masses and also moderated by Chinook winds (Beckingham et al. 1996). Within the study area, topographic features largely influence microclimate. Windswept cliffs are typically snow-free during most of winter and south-facing cliffs experience more rapid snow-melt than north-facing cliffs.

METHODS

We used direct and indirect observation methods to monitor the distribution of mountain goats along Pinto Creek. Direct observations were visual sightings of goats on cliffs within the study area. Indirect observations were remote cameras and the location of goat sign (i.e., tracks, pellets, hair) within belt transects and plots along the top of cliffs. We used all observation methods, except plots, during each sampling interval from February 1997 through October 1997. Plots were also used from May 1997 through October 1997. During winter (Feb through Mar), sampling intervals were 3 to 5 days with 10 to 14 days between intervals. Sampling intervals were 10 days in summer (May through Oct) with 4 days between intervals. Additional visual observations of cliffs were made while conducting monthly population surveys and when collecting vegetation data.

DIRECT OBSERVATION METHODS

Visual observations. We scanned each cliff using binoculars (8X or 10X) and a 15-45X spotting scope (Bushnell Spacemaster, Bushnell Sports Optics Worldwide, Richmond Hill, Ont., Canada). We observed some cliffs while walking along trails at the top of a cliff; other cliffs were observed from trail locations directly opposite a cliff. Location, time, age and sex class of goats,

goats, behaviour of the goats, cliff vegetation zone, and weather conditions were recorded for each visual observation. We identified individual goats as kids (young of year), yearlings (1-year-old), 2-year-olds, adult females (> 2 years old), adult males (> 2 years old) or unclassified adult based on horn morphology, body size, and urination posture (Chadwick 1973, Smith 1988).

INDIRECT OBSERVATION METHODS

Remote Cameras.— We used Trailmaster (TM1500) active-infrared remote camera systems (Model TM1500, Goodson and Associates, Inc., Lenexa, KS) to record the presence of goats. Each camera system consisted of a sending and receiving unit, and a 35-mm camera. We positioned the camera systems on goat trails along the top edge of selected cliffs within the above-cliff zone. We selected cliffs where we consistently observed goats as well as cliffs at the periphery of the study area. We mounted the sending and receiving units on trees 0.5 to 1 m above the ground and on opposite sides of goat trails such that the infrared beam crossed the goat trail. The distance between the sending and receiving units was 3 to 5 m. We mounted the cameras on trees along goat trails 5 to 8 m from the infrared beam. We wrapped the cable connecting the sending unit to the camera with tinfoil to prevent damage by rodents and birds. During winter 1997, we placed an individual camera unit on each of 6 cliffs. During summer 1997, cameras were placed on 4 additional cliffs. We enabled the flash and set the cameras to be active 24 hours per day throughout each sampling interval. We used 400 ASA, 36-exposure colour print film. We set the camera delay on the Trailmaster unit at 30 seconds to ensure that cameras did not take a picture when there were multiple events within 30 seconds. We changed camera batteries (2 AA batteries) at the beginning of every sampling interval to ensure adequate battery power for the duration of the interval. We programmed the cameras to date and time stamp each photo. Printed photographs from exposed film were used to determine the number, age class and sex of goats present.

Belt Transects.— We established a 5-m wide belt transect along the top edge of all cliffs within the above-cliff zone. The length of transects depended on the distance along the top of each cliff: distances ranged from 30 to 420 m. Transects were centred on the main trail used by goats at the top of each cliff. We selected the main trail based on the relative amount of accumulated goat sign and relative degree of erosion. We marked the main trail on each cliff with flagging tape. During each sampling interval, observers walked along the trail at the top of each cliff and searched for new goat sign within the belt transect. Goat pellets, hair, or tracks were recorded as present or absent and then all sign was eliminated from the belt transect.

Plots.— Permanent plots were established within the belt transect along the top of all cliffs. We chose the location of plots within the belt transect by first stratifying the area along the main goat trail into high or low use based on accumulated goat pellets. On each cliff, we placed 5, 4 x 2 m plots in areas of high pellet accumulation. We removed all pellets, tracks, and hair from each plot on the date the plots were established. During each sampling interval, we recorded the number of goat-pellet groups, number of track sets, and presence of goat hair found within each plot. We raked all plots to remove goat sign after data were recorded.

DATA ANALYSIS

We analysed data only from those cliffs where all methods were used concurrently. In order to compare results among methods, we created a dummy variable called "goats detected". This variable indicated if goats were recorded as present or absent on a cliff during a sampling interval. We determined values for goats detected by examining the results from all methods for each sampling interval. If the presence of goats was recorded by any 1 method during the sampling interval, then goats detected = 1. If the presence of goats was not recorded by any method, then goats detected = 0. To compare the detection rates among methods, we compared the result of each method (either goats present or absent) to goats detected for each sampling interval. If the result from the individual method matched goats detected, than a value of "1" (match) was assigned; if the result did not match, a value of "0" (no match) was assigned. We did this for each individual method and combinations of methods (see example in Table 1). We determined the proportion of matches for all methods on each cliff. We combined the results from all cliffs to determine the mean proportion and standard error (SE) of matches for all methods.

We then used an arcsine square-root transformation (Zar 1984) to normalise mean proportions before conducting statistical analyses. To compare results for those methods used during both winter and summer, we conducted a 2-way analysis of variance (ANOVA; Zar 1984) with season and method as the independent variables and proportion of matches as the dependent variable. We used 2 seasons (winter and summer) and 6 methods (visual, belt, camera, visual-belt, visual-camera, and camera-belt). We also used a 2-way ANOVA to compare indicators of goat presence within belt transects by season. Season and type of sign were independent variables and proportion of times each type of sign was recorded was the dependent variable. We used 3 types of sign: tracks, hair, and pellets. We used 1-way ANOVA to test the null hypothesis that all types of sign (i.e., hair, tracks, pellets) recorded within belt transects indicated the presence of goats equally. We used 1-way ANOVA to test the null hypothesis that the proportion of matches between the results of individual methods and goats detected was equal among observation methods. We used Scheffé's test (Zar 1984) to examine multiple comparisons among observation methods and types of sign. All statistical analyses were performed using STATISTICA (StatSoft Inc. 1997).

RESULTS

The proportion of matches with goats detected did not vary between seasons ($F_{1,84} = 0.01$, $P = 0.909$) and there was no significant interaction between season and type of method ($F_{5,84} = 0.67$, $P = 0.647$). The proportion of matches with goats detected was significantly different among methods ($F_{5,84} = 12.33$, $P < 0.001$). We analysed the data from winter and summer separately because during winter 1997 we used and compared 3 methods and during summer 1997 we used 1 additional method.

In winter 1997, the mean proportion of matches with goats detected varied from 0.47 ± 0.14 to 0.89 ± 0.07 for single methods and 0.72 ± 0.13 to 0.95 ± 0.06 for combinations of 2 methods

(Fig. 2). Belt transects had the greatest proportion of matches with goats detected. The result for belt transects, however, was not significantly different from other single methods ($F_{2,15}$ = 2.40, P = 0.124, Fig. 2). The combined methods of belt transect-visual and belt transect-camera had the greatest proportion of matches with goats detected, but were not significantly different from visual-camera ($F_{2,15}$ = 1.73, P = 0.211, Fig. 2). There was no significant difference in the proportion of matches with goats detected when only the belt transect method was used and when belt transect was paired with any 1 other type of observation method ($F_{2,15}$ = 0.28, P = 0.761).

In summer 1997, the proportion of matches with goats detected varied among single methods ($F_{3,36}$ = 8.87, P < 0.001). Proportions of matches for belt transects were greater than visual, camera, and plot methods (Fig. 3). The mean proportion of matches with goats detected varied among combinations of 2 methods ($F_{5,54}$ = 8.05, P < 0.001). There was a significant difference between some combinations that included belt transects and those without. Visual-belt was greater than visual-plot (P = 0.002; Fig. 3), and belt-camera was greater than visual-camera (P = 0.001; Fig. 3) and visual-plot (P < 0.001; Fig. 3). We did not find a significant difference among the proportion of matches for combinations of 3 methods ($F_{3,36}$ = 1.96, P = 0.138, Fig. 3). We did not find a significant difference between the proportion of matches with goats detected using belt transect alone and when belt transect was combined with 1 additional method ($F_{3,36}$= 1.53, P < 0.223). We did find a greater proportion of matches with goats detected when 2 methods were added to belt transect ($F_{3,36}$ = 3.47, P = 0.026) as compared to belt transect alone. The proportion of matches for the combinations of belt-visual-camera (P = 0.049) and belt-camera-plot (P = 0.049) were greater than for belt alone.

When we combined the results for winter and summer, 5% of observations of goats were detected by remote cameras alone while being missed by all other methods. During July 1997, we disabled the flash on 3 cameras that were located on frequently used cliffs and used 1000 ASA film. All 3 cameras recorded the presence of goats during the day and we obtained 1 photo of a goat during the night. We replaced the film in the 3 cameras with 400 ASA and enabled the flash. Subsequent photographs of goats were recorded during the day and night when the flash was activated. Although inconclusive, we believe that goats did not avoid the camera area when the flash was activated.

COMPARISON OF TYPES OF GOAT SIGN RECORDED WITHIN BELT TRANSECTS

Season affected the proportion of times each type of sign (i.e., hair, tracks, pellets) was detected within belt transects ($F_{1,42}$ = 8.47, P = 0.006). Independent of season, we found an overall difference among the proportion of times each type of sign was detected ($F_{2,42}$ = 14.22, P < 0.001). There was no interaction, however, between season and type of sign ($F_{2,42}$ = 2.56, P = 0.089). During winter, the mean proportion (± SE) of times tracks were recorded within belt transects (0.72 ± 0.13) was greater than hair (0.04 ± 0.04, P = 0.003), but not different than pellets (0.46 ± 0.15, P = 0.292). There was no significant difference in the proportion of times hair and pellets were observed (P = 0.057). Similar to winter results, the proportion of times tracks were recorded during summer (0.88 ± 0.04) was greater than hair (0.55 ± 0.08, P = 0.027) but not different from pellets (0.63 ± 0.11, $P = 0.080$). There was no significant difference between the proportion of times pellets and hair were detected during summer ($P = 0.872$).

DISCUSSION

Belt transects were the most effective method for monitoring the presence of mountain goats in forests. We believe belt transects were more effective than other indirect methods because they covered a large area over a relatively long time. In contrast, plots and remote cameras collected data over a small area and at specific locations, while direct visual observations were sampled over a short time and the view of parts of cliffs was frequently obstructed. There is a level of dependence between goats detected and each individual method result because of the way our "goat detected" variable was calculated. By definition there is a high correlation between the best method (i.e., belt transect in most cases) and "goats detected". In summer belt correctly predicted "goats detected" 90% of the sampling intervals (range 60 - 100%); in winter belt transects correctly predicted "goats detected" 90% of the sampling intervals (range 67 - 100%). Despite using a very conservative post-hoc comparison (Scheffé's test), this dependency may still be influencing the significance of belt transect method. Therefore, the most conservative way to view this analysis, is as a comparison of each method to the performance of belt transects. We believe that this dependency had little effect on comparisons of multiple methods.

Although belt transects were inexpensive to establish and maintain, they were the most time consuming and did not always detect the presence of goats on cliffs. One reason for this error may be observer error. Robinette et al. (1974) and Neff (1968) reported that observers occasionally overlooked goat sign on belt transects, particularly on those greater than 1000 ft (256 m) long. Observer error also may have been affected by vegetation cover within the belt transect. Unlike plots that were placed in areas with little vegetation, belt transects encompassed many areas of dense understory, thus reducing the ability of observers to see goat pellets and tracks. Belt transects did not provide detailed information as to population size and structure, behaviour, or daily activity.

The proportion of times that goat tracks were recorded within belt transects was greater than for hair during winter and summer. Unlike during late spring and early summer, goats do not shed large amounts of hair during winter. During winter, goat hair is shed in small amounts that are difficult to observe (D.G. Harrison, personal observation). We believe this explains why hair was observed less frequently than tracks during winter. Although goats shed large, conspicuous amounts of hair in summer, the period of shedding is relatively short (2 months) and this may explain why tracks were observed more often than hair within belt transects. Because tracks and pellets occur during all seasons, these 2 types of sign are more consistently deposited and observed within belt transects.

The reliability of plots and remote cameras was limited by their number and location. It is possible that goats were present within a belt transect but not at specific plot or camera stations. Adding more plots or camera stations along cliffs, especially large cliffs, may have increased the reliability of those methods. Plots and cameras, however, represent sub-samples of the belt transect. As more plots or cameras are added to a cliff, the sub-sample becomes more representative of a belt transect.

The ability of cameras alone to detect the presence of goats was not substantial and we concluded that remote cameras did not contribute significantly to our ability to record the presence or absence of goats. However, remote cameras provided information about population size and structure and behaviour of individual goats (e.g., bedding, feeding, nursing).

Data from cameras also showed that goats were active throughout the day and night. Although we had few problems with cameras during summer, cameras were difficult to maintain during winter. During prolonged cold temperatures ($\leq$ -20°C), the response time of the camera increased by up to 15 seconds (D.G. Harrison, personal observation). As a result, goats may have triggered the camera, but were out of the camera field of view before a picture was taken; the result was pictures with no animals in them. Bull et al. (1992) had similar problems with remote cameras during winter in Oregon. Perhaps the greatest restriction to using remote cameras during winter was maintaining battery power. During winter, camera batteries lasted a maximum of 10 days as compared to 25 days during summer. Consequently, the length of our sampling interval was based on the life of camera batteries. To alleviate these problems, we recommend that during winter a larger, external battery be used.

The advantage of visual observations is that they allow for the collection of population, behaviour, and habitat use data. A number of factors, however, may limit the reliability of this method. Probably the most limiting factor in our study was the obstruction of view of cliffs by vegetation and topography. Penner and Jalkotzy (1982) also reported difficulty observing cliffs along Pinto Creek because of vegetation and topography. Occasionally, weather conditions, such as heavy rain and snow, also obscured the view of cliffs. Unlike indirect-observation methods, visual observations were not continuous over the sampling interval but rather were limited to daylight hours and were used only on 2 or 3 days during the sampling interval. It is likely that the presence of goats was not recorded using the visual method because the goats were present at night when cliffs were not being observed. Observer presence also may have affected the reliability of this method. Goats may have been aware of observers and moved away before the goats presence could be observed.

The methods that we compared provided evidence that goats were present at particular cliffs. These methods, however, did not conclusively show that goats were not present at a particular cliff. The indirect observation methods monitored only the top portion of cliffs and visual observations of some portions of cliffs were impaired by vegetation, topography, and weather conditions. Consequently, goats may have been present on those cliff areas that we did not monitor. A definitive test of these methods would be to radiocollar all goats within the study area and compare radio-locations to each individual method or saturate cliffs with remote cameras.

We have discussed 4 methods that are useful for recording the presence of goats in forests. The methods we compared have the ability to record animal presence in specific habitat types (e.g., along the top of cliffs) over time. More traditional methods for recording animal movements and habitat use, such as radio telemetry, often do not provide the level of precision that is sometimes required. For example, VHF radio telemetry indicates the general area in which an animal is located. For a precise location, however, visual confirmation is required. For those species that are susceptible to disturbance by humans or aircraft, such as mountain goats (Côté 1996), close approaches by humans may disrupt normal daily activities and movement patterns. Very high frequency radio telemetry is generally limited to daylight hours and collared animals may move significant distances and into other habitats between location fixes. Global Positioning System radio collars alleviate the problem of observer presence and some larger collars can continuously record and store animal locations over a 24-hr period. Both VHF and GPS radio telemetry will provide information as to the location of collared individuals. These methods, however, do not provide any information about the presence of other uncollared animals found with collared individuals. Indirect observation methods (e.g., belt transects, plots, and remote cameras) are non-intrusive and can continuously record animal presence. Additionally, some of these methods can provide information about groups of animals and individual behaviours.

MANAGEMENT RECOMMENDATIONS

Where more conventional methods such as radio collars and aerial surveys are not practical, the use of belt transects can provide useful information on mountain goat movements and distribution in a canyon habitat. We recommend searching for more than 1 type of goat sign to reduce error associated with the lack of persistence of some types of sign and to maximise the probability of detecting the presence of goats based on the presence of sign. Although remote cameras provide data on population structure, the use of cameras did not appreciably increase our ability to detect the presence of goats. Therefore, we believe that goat presence data collected with belt transects, plots, and visual observations adequately describes the distribution and movements of goats within the Pinto Creek study area.

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Table 1. An example of how results from direct and indirect observation methods were combined for cliff 9, 18 February 1997 to 30 March 1997. A count of 1 indicates presence of goats and 0 indicates absence (see text).

	Observation method result				Match between observation method result and goats detected					
Monitoring session	Visual	Belt	Camera	Goats detected	Visual	Belt	Camera	Visual-belt	Visual-camera	Belt-camera
1	0	0	0	0	1	1	1	1	1	1
2	1	0	0	1	1	0	0	1	1	0
3	1	1	1	1	1	1	1	1	1	1

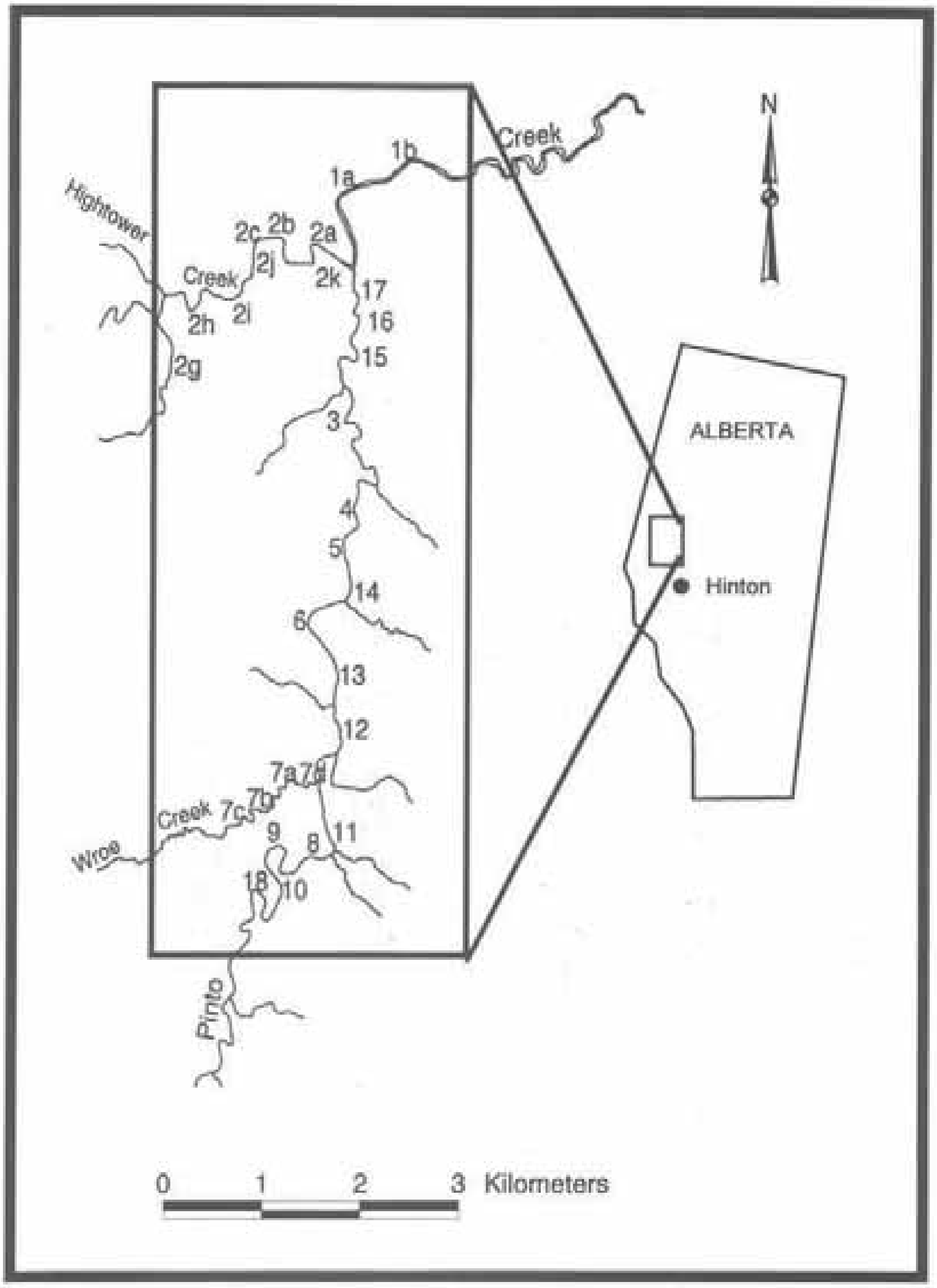

Figure 1. Locations of numbered cliffs (following Penner and Jalkowsky 1982) within the Pinto Creek study area. The inset box shows the location of the study area within Alberta, Canada.

Figure 2. Mean proportion of matches with goats detected for each observation method on 6 cliffs during winter 1997 at Pinto Creek, Alberta. Error bars indicate 1 SE.

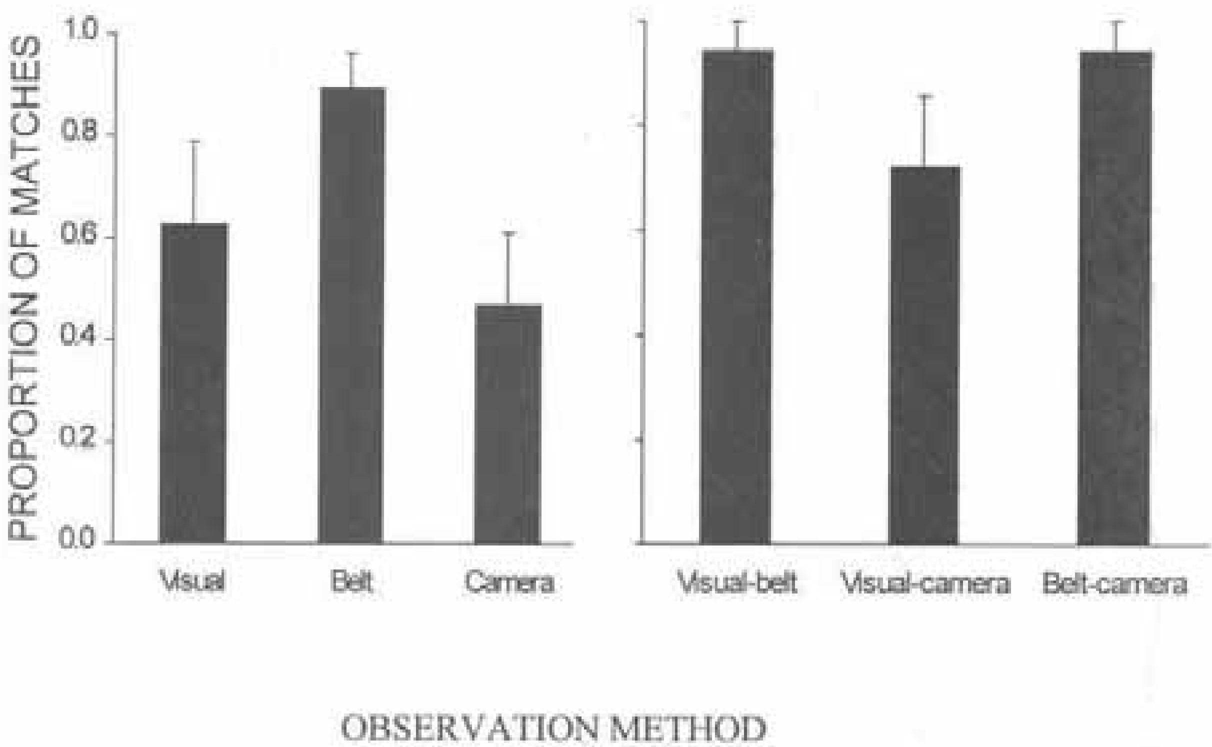

Figure 3. Mean proportion of matches with goats detected for each observation method on 10 cliffs during summer 1997 at Pinto Creek, Alberta. The abbreviations above the bars indicate significant differences between the observation method indicated at the bottom of the bar and those methods abbreviated above the bar where V is visual, C is camera, and P is plot. Error bars indicate 1 SE.