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MOUNTAIN GOAT FIDELITY TO GIVEN AREAS BY SEASON AND SEASONAL MOVEMENTS

By
Lyman Nichols

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SUMMARY

From fall 1979 through summer 1983, 43 mountain goats (*Oreamnos americanus*) were captured and radio-collared out of a herd of approximately 300 in the Kenai Mountains, Alaska. These goats were captured with the use of a helicopter and drugged darts; only 1 goat died during capturing operations. Of those captured, 34 provided sufficient data for movement and range fidelity analyses. Between late summer 1979 and early winter 1984, 83 radio-tracking flights were made, resulting in 1,498 relocations.

The study area includes the known range of the entire herd under study, including the ranges of 5 wintering subherds. These subherds mix while on their summer ranges and, to some extent, during the fall rut. Generalized movements between winter and summer ranges are described, as well as movements of animals which did not always follow the general movement pattern. Some goats remained on small annual home ranges throughout the year while others migrated at least 24 km (15 mi) between winter and summer ranges. These long distance movements included crossing large ice fields and major drainages. A few goats changed home ranges between years.

All resightings of collared animals were first plotted on maps scaled 1:63,360. Maps and plots by goat number, date, and location were then digitized into a microcomputer. Locations were replotted on maps by time period as desired. Fidelity was calculated as the percentage of all observations of a given animal during a given time period, that were found within the drainage the animal was expected to be in during summer or

winter. Maximum linear distance traveled during a given time period was measured on the computer screen between observations. Fidelity percentage served as an indicator of likelihood of goats being in a given area at a given time, while maximum distance traveled gave an estimate of an animal's mobility during that time. These parameters were compared statistically among sex/age cohorts and time periods.

The percentage of all goats of various cohorts that were 100% faithful to their summer and winter ranges between years were compared. Although variations were found among parameters tested, it appeared that in summer most goats were least mobile and could be found on their expected ranges with the best predictability between mid-July and mid-August. Adult males 5 years or older showed the highest fidelity to their range and the least mobility during this period, followed by females of the same age class. During winter, the situation was reversed, with adult females exhibiting the least mobility and greatest fidelity to winter ranges and adult males the most mobility and least fidelity. Younger females were similar in fidelity and mobility to older females, while younger males were the least faithful to given home ranges on a year-long basis and were the most prone to change ranges.

Management considerations related to aerial censuses are discussed. It is recommended that aerial counts be conducted only under weather conditions conducive to good goat sightability, between mid-July and mid-August when fidelity to summer range is at a maximum and movements are at a minimum. In addition, it is recommended that sample herds be selected and their entire annual ranges be learned to avoid errors caused by unpredictable intra-range movements during summer. These sample herds then should be censused carefully and regularly. Larger population trends then can be estimated with greater accuracy and less cost than estimates arrived at by irregular, large-area aerial counts of herds whose ranges and movements are unknown.

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BACKGROUND

Mountain goats (_Oreamnos americanus_) probably have been studied the least of any North American ungulate. Eastman (1977) attributed this to the inaccessible terrain in which they live, their wide dispersion, and lack of interest by managers. Eastman (1977) determined the highest research priorities for goats were: 1) development of inventory techniques; 2) determination of the impact of hunting on goat populations; 3) development of methods of predicting carrying capacity; and 4) study of home range, migrations, and movements.

Alaskan wildlife biologists held a series of meetings between research and management staff during 1973-81. This activity culminated in the following recommendations for goat studies (in order of priority): 1) determine the best method to inventory goats; 2) determine the impacts of hunting, including the survival rate of kids orphaned by either-sex hunting; and 3) evaluate habitat relationships and habitat modification on the resident goat populations. From these recommendations, 2 studies were initiated concerning an evaluation of mountain goat aerial census techniques and development of aerial mountain goat classification techniques. Both of these studies have been completed (Nichols 1977, Nichols 1980a).

During these 2 studies, it became apparent that unknown goat movements were affecting the accuracy of aerial counts during summer. We concluded that if goats moved between drainages during the summer census period, inaccuracies would result if these areas were counted. Consequently, variations in annual censuses could be caused by movements rather than by changes in numbers.

Preliminary studies involving aerial dye-marking of goats showed that major movements were occurring (Nichols 1977). Therefore, we needed to learn whether such movements were random or predictable, whether the same herds or subherds could be expected in a given area during a given part of the year, and whether their seasonal or intra-seasonal movements could be predicted. If movements were predictable, then censuses could be interpreted more accurately, but if these movements were unpredictable, it would be necessary to establish larger count areas to include the total population. Otherwise, unit management would have to be conservative and accept the possibility of serious counting errors.

This study was designed to determine the fidelity of mountain goats to particular areas during the year. If we can predict their location then we should be able to more accurately assess the herd and formulate management recommendations. The study was also designed to assess major seasonal movements of the herd within the study area as well as to learn whether goats move into or out of the study area.

OBJECTIVES

To determine the seasonal movements of mountain goats in the Kenai Mountains, and to assess the fidelity of goats to given areas within seasons and between years.

STUDY AREA

The area originally chosen for study (Nichols 1977) was in the northeastern Kenai Mountains within the Chugach National Forest. It was bounded on the west by Trail River, and upper and lower Trail Lakes; on the south by Ptarmigan Lake, upper Ptarmigan Creek, and the pass to lower Paradise Lake; on the west by Snow River and Snow River Glacier; and on the north by Trail Glacier. Subsequent data on goat movements led to the inclusion of the north side of the Trail Glacier drainage, and the drainage of King's River and the head of King's Bay and

Prince William Sound (Figs. 1, 2). Latitude and longitude of the center of the area are approximately 148°50'E and 60°30'N.

This area, encompassing about 635 km^2 (245 mi^2), consists of rugged, highly glaciated mountains rising from sea level, to jagged peaks reaching some 1,798 m (5,900 ft) in elevation. Approximately 32% (205 km^2; 79 mi^2) of the land area is covered by glaciers and ice fields, the largest of which forms the head of the Snow River Glacier. Snowbanks commonly last all summer in shaded sites. Timberline reaches 610 m (2,000 ft) elevation, although it is usually lower. Valleys typically are steep and relatively narrow. Snow River, King's River, and Trail River are braided glacial watercourses. Smaller streams are abundant and may be clear of glacial silt. Grant Lake lies within the study area, while Ptarmigan Lake forms part of the southern boundary. Several smaller lakes are present.

The area is roughly divided by the Snow River ice field and glacier into a maritime climatic zone on the east and an "inland" zone on the west. Mean annual snowfall ranges from 1,016 cm (400 in) along the eastern coast to about 254 cm (100 in) on the western portion. Mean annual rainfall similarly declines from about 406 cm (160 in) to 203 cm (80 in) from east to west. January temperatures average -9 C (16 F) on the coast and -11 C (12 F) in the Trail River drainage, while July temperatures are the reverse, averaging 18 C (64 F) on the western portion and 16 C (60 F) in Prince William Sound (Annon. Chugach National Forest, unpubl. data). Snow cover, as a percentage of ground cover in midwinter, increases from west to east and from south to north within the study area (Nichols 1978).

Vegetation in the valley bottoms and on lower slopes includes white spruce (*Picea glauca*), black spruce (*P. mariana*), cottonwood (*Populus trichocarpa*), aspen (*P. tremuloides*), paper birch (*Betula papyrifera*), alder (*Alnus* spp.), willow (*Salix* spp.), and numerous shrubs, forbs, grasses, lichens, and mosses. Higher on the slopes, alder, willow, arctic birch (*B. nana*), and alpine hemlock (*Tsuga mertensiana*) become dominant, giving way to a tundra of crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos* spp.), blueberry (*Vaccinium* spp.), mountain cranberry (*V. vitis-ideae*), mountain avens (*Dryas* spp.), cassiope (*Cassiope* spp.), leutkea (*Leutkea pectinata*), mosses (*Selaginella* spp.), various lichens, and many grasses, forbs, and sedges. With increasing altitude, these give way to cushion plants and, eventually, to bare rock.

The most common large mammals sharing this habitat with mountain goats are Dall's sheep (Ovis dalli), black bear (*Ursus americanus*), and marmot (*Marmota caligata*). Moose (*Alces alces*), brown bear (*U. arctos*), wolf (*Canis lupus*), coyote (*C. latrans*), and wolverine (*Gulo gulo*) are less common visitors.

Golden eagles (Aquila chrysaetos) are numerous as are willow and rock ptarmigan (Lagopus lagopus and L. mutus), ravens (Corvus corvax), magpies (Pica pica), and Canada jays (Perisoreus canadensis). Many species of songbirds pass through during summer. Bald eagles (Haliaeetus leucocephalus) may be seen occasionally but are more common along the river valleys and coastal shores.

Access into the area is limited. Foot trails reach from the Seward Highway to the west ends of both Ptarmigan and Grand Lakes, and a rough mining road goes up Falls Creek. The Alaska Railroad may be walked to near the head of Trail River. Otherwise, light planes can land on a few gravel bars of Snow River, and floatplanes can use the larger lakes as well as King's Bay. Because of this inaccessibility, the area is used only lightly by goat and sheep hunters, with little use the rest of the year except by hikers to the Ptarmigan Lake campground.

PROCEDURES

Capturing, Collaring, and Radio-locating

The methods used to capture, radio-collar, and radio-locate goats have been described in detail (Nichols 1980b, 1982a, 1982b, 1982c, 1984; Schoen and Kirchoff 1981; Smith 1982). Briefly, capturing was accomplished using a standard Cap-Chur gun (NascoWest, Modesto, CA) and darts loaded with M-99 (etorphine hydrochloride, D-M Pharmaceuticals, Rockville, Md.) fired at close range from a Bell 206B Jet Ranger helicopter.

When a goat was anesthetized, its weight and body measurements were recorded, age and reproductive status determined, and blood samples taken. A radio collar (Model MKVM, configuration 5B with mortality-sensing option; Telonics, Inc., Mesa, Ariz.) was then installed. Each collar had a discrete frequency and was individually color-coded for visual identification. The animal was then given an intravenous injection of the antagonist, M50-50 (diprenorphine hydrochloride, D-M Pharmaceuticals, Rockville, Md.) and allowed to recover and escape.

Relocating collared animals was done during periodic flights using a Piper PA-18-150 Super Cub airplane equipped with either wheels, floats, or wheel-skis as the season dictated. A Hygain model RA-3 (Telonics, Inc., Mesa, Ariz.) 3-element Yagi antenna was mounted on the lift struts of each wing to obtain the loudest signal directly off the wing tip, i.e. at 90° to the plane's axis. These antennae were connected via a right-left-both switch to a Telonics mated TR-2 receiver and TS-1 scanner which was, in turn, connected to headphones through the aircraft's radio system.

In practice, all frequencies of interest were preprogrammed into a scanner, the area flown until a signal was heard, that signal "locked in," and the animal located by flying a pattern that enabled the operator to close on the loudest signal. When the animal was located visually, or by the best possible radio fix, its location was plotted on the map. Additional data were either recorded on appropriate forms or on a small tape recorder.

After each flight, all relocations were plotted on base maps (U.S.G.S. quadrangles, 1:63,630), with 1 map overlay for each numbered goat. Thus, all plots by date for each collared goat were accumulated on individual map overlays.

Population Estimates

Aerial counts were conducted twice a year throughout the study period, one in spring to obtain yearling:adult ratios and one in summer to obtain kid:adult ratios. Estimates of total herd numbers and composition were obtained by combining results of these counts each year (Nichols 1980a, 1980b).

Analysis of Movement Data

Analysis of relocation plots required use of a computer. The following equipment was used: Radio Shack TRS-80 Model III computer equipped with a high resolution modification (Grafyx Solution, Micro-Labs, Inc., Richardson, Tex.), a Radio Shack digitizer, and an Epson MX-80 printer. Programs written in BASIC were developed to accomplish the 3 steps necessary for data analysis. In the 1st step, maps of the study area were digitized in high resolution (512 X 192 pixels) and stored on a disk. Because of digitizer limitations, 3 overlapping maps were necessary to cover the study area. A composite of the 3 maps making up the study area was compiled (Fig. 3) as an aid in reading the overlapping maps as they were printed. The composite map was labeled in more detail than the individual maps, with watercourses traced in ink for clarity. The 2nd step involved digitizing, to the same scale, all relocation plots by date and accession number for each goat. A list of dates and X-Y coordinates was accumulated and saved "on disk" for each collared goat. The 3rd program allowed the appropriate map to be called back to the screen and any number of goat relocations by any desired time period to be replotted on the map. Hard copy could be obtained through the printer at any stage.

General seasonal movements were discerned by observing the plots for each goat throughout the study period, and by plotting the locations of all goats at once, or by any desired sex and age class during the various time periods.

To estimate fidelity to given ranges by season, a series of overlapping time periods was selected (Appendix A, Figs. 1-18). Beginning and ending dates of each period were dependent on the amount of data available for each and the dates when radio-locating flights were made. The primary winter and summer ranges of each goat were determined by plotting resighting locations and determining in which drainages the majority of plots occurred during winter (16 September to 12 June) and summer (7 July to 31 October). The drainages used were major watersheds of the type which could be completely surveyed during an aerial census.

Fidelity was calculated as the percentage of all resightings of a goat, during a given time period, which were located in its expected drainage; i.e., if a goat was sighted 10 times during a time period, and 6 of those sightings were in the expected drainage, its fidelity percentage would be 60%. Fidelity percentages were calculated for each goat during each time period during which data were available, and during each year it was observed as well as for all years combined. An animal which changed its annual range could thus show high fidelity to its range during 1 year or season, but lower fidelity when years were combined.

Percentage of fidelity for a cohort was calculated as the mean of all fidelity percentages for all animals of the cohort/time period of interest. It is an indicator of the faithfulness of that cohort to its expected range at a given time period; not a percentage of all animals that could be expected to be there at that time because they were there the previous year(s).

The linear measurement of distance between the most widely spaced sightings for an animal during a given time period was assumed to be the "maximum distance traveled" during that time period, and was used as an indicator of the mobility of that animal during that period. Because of system limitations used in data analysis (i.e., 3 separate maps required to cover the study area, only one of which could be displayed at a time on the computer screen, and because some goats made movements between maps during a given time period), not all "maximum distances" could be measured directly. When an animal's movements went off the displayed map, the maximum distance moved was arbitrarily assumed to be the distance along the direction of travel from the farthest observation to the edge of the screen plus 1 mile, with a maximum of 11 miles. Thus, some movements were underestimated, with the probable result that some of the means of combined data were underestimated.

Fidelity percentages and maximum distances traveled by time period were calculated for each year and by all years combined for each goat. Means of these parameters were then compared between time each year, and by sex and age cohorts. Standard parametric statistical tests were used in all comparisons. All significance tests reported in this paper were considered to be significant at the 0.05 level or less. Those tests resulting in a probability of error greater than 0.05 were considered nonsignificant.

Animal home ranges have been described by many methods. Koeppl et al. (1975) used ellipses with statistical estimates of confidence limits, as did Schoen et al. (1979) and Smith (1982). However, Schoen and Kirchoff (1981) decided that ellipses were not satisfactory in describing mountain goat home ranges because of the extreme 3-dimensional nature of the habitat. Smith (1983) came to the conclusion that ellipses were not appropriate for home ranges of many animals because of their linearity and irregularity. He felt polygons were better but still of limited value. Craig (1981) developed a relief-adjusted polygon method for describing home ranges in mountainous areas, but the method is cumbersome to apply.

Because of these limitations, and because delineation of home range was not an objective of this study, I used the greatest linear distance between observations as an indicator of goat mobility during each time period. This gave an estimate of the maximum linear size of the area used by each animal during each time period. Adams et al. (1982) used a similar method in comparing goat winter and summer ranges. I determined maximum linear distance by measuring the greatest distance between relocation points during that period. These distances were then compared between time periods for all goats and all years, between periods within years, and by sex and age.

RESULTS AND DISCUSSION

Capturing, Radio-collaring, and Radio-locating

Forty-one goats were captured and collared in 1979, 1980, and 1981 (Table 1). Locations of capture sites, weights and body measurements, reproductive status, and results of blood analyses have been presented previously (Nichols 1980a, 1982a, 1982b, 1984).

The capture method worked well and only 1 animal was lost during capturing, probably as a result of mechanical dart injury. The radio collars transmitted far beyond the manufacturer's 2-year life expectancy specifications: 5 to 6 collars installed in 1979 were still transmitting in winter 1983. All of the collars installed in 1980 and 1981, which were on still-living goats, were still transmitting in early 1984 when field work was terminated. Most collars could be identified visually by the color-coded plastic tape wrapped over the neck strap. Eighty-three tracking flights were conducted during the study resulting in 1,498 individual relocations.

Population Estimates

An aerial survey of the entire study area was flown on 7 May 1983 to obtain the ratio of yearlings to total "adults" (non-lambs), and another on 27, 28, and 29 August to get estimates of the total number of goats, and the ratio of kids to the total number of adults. The spring survey was flown prior to the parturition season when the previous year's kids could still be recognized from the air by horn and body size, and facial characteristics (Nichols 1980a). New kids are easily recognized during summer by their small size. By combining results of both counts, a population model was constructed, including estimated numbers of kids, yearlings, total adults (non-kids), and total animals in the herd (Nichols 1980a). These estimates were added to those of previous years (Table 2). When the highest population estimate of 301 goats in 1982 is used, the density is 0.47 goats/km². However, because of erratic distribution, random movements, and diversity of habitat, a density estimate, as expressed by the number of goats per unit of area, is not a very useful measurement for goats in Alaska (Klein 1953).

Herd size in 1983 appears low compared with 1982, and seems to indicate high overwinter mortality. The ratios of both kids and yearlings to total adults also declined, suggesting a severe winter and high mortality. Although snowpack on most of the Kenai Peninsula was lower than normal during winter 1982-83, it was about 10% above average in the higher elevations of the Sound. At the Wolverine Glacier site, which lies just south of King's Bay, snow depth was about 19% above that in winter 1981-82 (Clagett et al. 1983a, 1983b), also suggesting a more severe winter. These winter conditions could have contributed to higher mortality among goats in the area.

On the other hand, overwinter mortality of the radio-collared goats was only 10% overall, and 25% for kids as opposed to 40% and 49%, respectively, for the herd as estimated by aerial counts. In past years, mortality of collared animals has closely paralleled that of the herd as a whole. Because of airplane problems, the summer 1983 count was flown later than it should have been, and in hot, clear weather under poor counting conditions. During previous surveys on hot days, as many as 35% of the collared goats were out of sight (Nichols 1980a). "Good" conditions (Nichols 1980a) were not forthcoming during that period. Even though I flew the counts as late as possible in the evening when goats should have been most observable (Chadwick 1979, Nichols 1978, Fox 1977), I still saw goats resting on snowbanks and in crevices between snowbanks and the mountains where they are readily overlooked. I felt at the time I was missing animals, and further radio-tracking confirmed that some goats were still seeking relief from the day's heat in snow and ice caves where they were not observable. Thus, when one considers the counting conditions as well as the actual number of goats counted, the population decline probably was not as great as the data indicate.

A summer survey was not flown in 1984, but a spring count on 9 May 1984 showed the ratio of yearlings to total adults had increased over 1983, suggesting a low winter mortality and a possible herd increase. Snowpack in the Kenai Mountains during the preceding winter was about 25% below average (Clagett et al. 1984).

Within the study area, 5 subherds were defined by plotting locations observed during winter. The sizes of these wintering populations were based on estimates from the spring and summer counts in 1982. These estimates, by subherd, were: Ptarmigan Lake (67), Grant Lake (47), Moose Creek (11), Trail Glacier (61), and King's River (52). These numbers represent only 1 winter, but suggest the subherd sizes as proportions of the entire herd during other years.

General Movements

A plot of all resightings during winter (6 December-25 April) for all goats over all years, indicates the winter range of the population (Fig. 4). Despite some random movements, areas of concentrated use occurred above Ptarmigan Lake and Ptarmigan Creek, Grant Lake and Grant Creek, both forks of Moose Creek, both forks of upper Trail River, and King's River.

Comparatively little movement took place during late winter because travel was relatively restricted by deep snow. Most goats occupied lower, south-facing slopes below or just above timberline. In King's River, goats were found most often in heavy timber and frequently occupied habitat down almost to the valley floor. Broken cliffs beneath the canopy of spruce and hemlock provided relatively snow-free forage and escape terrain. The south-facing cliffs of Ptarmigan and Grant Lakes, and the north side of Trail Glacier Valley probably offered the best wintering habitat in the area. Moose Creek, with fewer snow-shedding cliffs and heavier snowpack, offered poorer winter habitat and was used the least. In the latter area goats wintered on small cliffs and on windblown ridges on both north and south sides of the main valley, while a few used the higher, open, south-facing slopes of the north fork. Few goats wintered on the south side of Trail Glacier Valley because of the heavy snowpack and lack of open foraging sites. A few goats wintered in isolated cliffs and even on high, barren ridgetops.

The positions of all collared goats were plotted during the summer period (7 June to 6 September; Fig. 5). In general, goats occupied higher elevations during the summer after moving up valleys or slopes. They often remained close to glaciers, ice fields, and large snowbanks. North- and west-facing slopes and cliffs were used frequently. Goats that wintered above Ptarmigan Lake summered in the glacial cirques of upper Ptarmigan Valley or Grant Lake Valley. Goats that wintered near Grant Lake summered the farthest away, including moving to Moose Creek, Trail Glacier Valley, and King's River. The latter movement (24 km; 15 mi) required crossing the large Snow River Glacier ice field. Some animals from both Moose Creek and Trail Glacier Valley also summered in King's River Valley. Most of the goats that wintered low along King's River moved up the valley or to higher elevations near the ice fields for the summer. Other goats moved from Grant Lake and Moose Creek to the south side of Trail Glacier Valley and to its south fork, as did some animals from the north side of Trail Glacier Valley. These animals moved freely across the glacier and valley floor in spring and fall.

These movements describe the general movements of goats between winter and summer ranges, but numerous individual variations were observed. An adult male 5-year-old, when captured in 1979 (No. 5), consistently wintered above Ptarmigan Lake and summered in a small glacial cirque between Falls Creek and Grant Lake, but each spring, and only between 14 June and 7 July, he was observed in upper King's River Valley (Fig. 6). Apparently, he followed other goats to their summer range above King's River, then returned to his usual summer habitat, a round trip distance of over 48 airline kilometers (30 mi).

Another male (No. 15), a 3-year-old when captured in 1979, spent that summer above King's River, then moved to Grant Lake for the winter, but not until after 6 December when the snow was deep (Fig. 7). The following summer, he moved to King's River Valley and remained there over the winter. However, the next spring, sometime after 29 March but before 25 April and during deep winter snow conditions, this goat and another traveled from King's Bay south, up Nellie Juan River to Nellie Juan Lake (off the map) to the upper reaches of the south fork of Snow River. By early summer, he was back in King's River Valley. This represented a round trip of over 68 straight-line kilometers (42 mi). This pattern was repeated the next year. Such movements illustrate the capability of some males to move long distances through deep snow. Adams et al. (1982) also found that goats were able to travel long distances through deep winter snow.

Another adult male (No. 18) consistently spent summers in upper King's River Valley and winters above Grant Lake (Fig. 8). However, he shifted his winter range after the 2nd year from above Grant Lake to several miles up the valley. Also, he traveled from summer to winter range in mid-winter after the rut the 1st and 3rd years, but before 3 November and probably prior to the rut the 2nd and 4th years. Therefore, my data suggest that individual animals are not always consistent in their seasonal movements.

The most inconsistent goat encountered was another male collared as a yearling (No. 14) in 1979. It shifted its entire annual range over the next 4 years, from wintering in Moose Creek and summering in King's River Valley to remaining on the north side of Trail Glacier Valley both winter and summer (Figs. 9-14).

Other goats, however, were found to be more consistent and predictable in their year-to-year movements. For example, a female yearling collared in 1979 (No. 12), spent the next 4 years on the same ridge, winter and summer (Fig. 15). Another female (No. 4), which was 2 years old when collared in 1979, consistently wintered above Ptarmigan Lake and summered along the south side of Grant Lake and Grant Lake Valley (Fig. 16).

Emigration from the study area appeared to be low. Only 1 male, collared at 3 years of age, left the study area permanently (2% of the collared sample). Immigration could not be determined, but is also believed to be low. All radio-tracking and census flights suggest that the boundaries of this herd's annual range now are well delineated.

These examples typify the types of movements found and are consistent with findings of other researchers (Casebeer et al. 1950, Chadwick 1975, Geist 1964, Johnson 1983, and others). Herd movements between winter and summer ranges may be generalized, but individual variations occur, and it is not always possible to predict where individual goats can be found or when they might be present in a particular area. Observed movements of individual goats suggest that younger males are the most unpredictable in their annual movements, while females and males 5 years and older are more consistent.

Fidelity and Distance Moved

Thirty-four collared goats provided useful information about fidelity. Mean fidelity percentage and maximum distance traveled, by time periods for all years combined, for all goats combined, and for all goats by sex and age classes, were examined by analyses of variance and by standard or paired *t* tests (Appendix A, Tables 1-13). Mean percentage of fidelity and mean maximum distance traveled, by time period and by sex and age class, with their sample sizes and standard deviations, also are illustrated (Appendix A, Figs. 1-18).

Fidelity to a given range, by time period, varied significantly during the year for all goats combined, and for older goats of both sexes. Maximum distance traveled also was variable among time periods for all goats combined and for both older sex and age classes. Younger animals, ages 1 and 2, have similar-sized ranges throughout the year.

Goats of all age classes combined appear to be most faithful to their expected range from 14 July to 20 August, and to move the least distance during that period. However, both percentage of fidelity and distance moved did not show a statistically significant difference from other summer periods. Between 14 July and 20 August all goats could be found on their expected range 91% of the time.

In winter, highest fidelity (95%) and least movement occurred between 6 December and 29 March. However, no clear distinction could be shown between that time period and the longer one from early November to late April.

Males were found to be significantly less faithful to their range than females, and males also moved greater distances. Differences were also noted between the sexes during individual time periods, with males being significantly less faithful to their expected range during the 7 July to 20 August summer period, but not during the slightly later time span of 14 July to 20 August, when presumably movements between winter and summer ranges had ended. Differences in maximum movements were not significant during summer between males and females, but the former appeared to move most during early and later summer, and least between 14 July and 20 August. In winter, males showed significantly less range stability than females, probably as the result of traveling, during and after the rut, by older males. Greatest movement and lowest fidelity for males was in early winter from mid-September to early November.

Comparisons between the sexes by age class showed no significant differences between ages 1 and 2 and ages 3 and 4 in fidelity, either on a year-long basis or by individual time periods. Males 1 and 2 years old did move significantly less distance than females of that age class on an annual basis, but not by any individual time period. The same relationship appeared to exist between males and females aged 3 and 4, but sample sizes were small. Males and females 5 years and older varied significantly from each other both in fidelity and distance traveled during individual time periods but not when compared over the entire year. Male fidelity was higher

($P < 0.10$) than that of females in mid-summer (7 July to 20 August), while distance moved was significantly lower from 14 July to 20 August. On the other hand, older male fidelity was significantly lower, and distance traveled significantly higher in winter, and especially in early winter. The latter should be expected because of rutting movements.

Fidelity and distance comparisons within sexes and between age classes suggest that males aged 1 and 2 show a higher fidelity to their range than males 3 and 4 over the entire year, with no differences found in individual time periods. No differences in distance moved were found. No differences between females in these age classes were found. Three- and 4-year-old males appeared not to differ from older males in fidelity except during the period of 14 July to 20 August. During that time, males aged 5 and older exhibited significantly stronger fidelity (100%) to their range. This age class of males was highly faithful to its range during the longer summer period from 7 July to 6 September as well. Older males moved significantly more than 3- and 4-year-old males on an annual basis, but not by any particular time period, although movements appeared greater after mid-September. Both age classes moved the least during summer, and especially from 14 July to 20 August.

Older males (5+) are significantly less faithful to given ranges than males aged 1 and 2 over the entire year, but not by individual time period. They move significantly less than the younger males between 14 July and 20 August, but more after mid-September. Both 1 and 2-year-old males and females showed a strong fidelity to their ranges during summer.

Females aged 3 and 4 showed significantly less fidelity to their range on a year-long basis than did older females, but differed significantly by time period only during late summer. They also exhibited greater movements annually and during late summer.

Older females (age 5+) were significantly more faithful to their range than young females (ages 1 and 2) only during late summer, but not year-long. The young animals moved significantly greater distances during late summer and early winter. In general, the older females appeared very stable throughout the year in both fidelity and distance moved.

Fidelity and predictability also may be examined by the percentage of all goats that were 100% faithful to their expected range by season; i.e. those that were found on their expected range during every radio-tracking flight all years that they were collared. It is the actual percentage of the herd or a given cohort that can be expected to be in a given area at a given time if they were observed there in the past and had not died in the interim. Of the 34 collared animals used, 71% were 100% faithful to their expected range during mid-summer (14 July-20 August) and 77% were 100% faithful in winter (6 December-29 March).

To compare the proportions that were 100% predictable by sex and age class, Chi-squared analyses were used (Appendix A, Table 13). Because of small sample sizes, only 2 age classes were used: age 5 years and older, and age 4 years and younger. In summer, there was no difference in fidelity between all males and all females combined, but the occurrence of younger animals was less predictable than older ones. Older males in the sample examined were the most faithful of all, and were found where expected all of the time. Older females were less predictable than older males, but more so than younger animals of both sexes, which were similar. In winter, the situation reversed, with older males becoming the least predictable; only 33% were found where expected all of the time. Younger males showed higher fidelity to their range than did older males, but less than females of both age classes. About 90% of all females were completely faithful to their winter ranges.

Summary of Movement and Fidelity Findings

Within the study area, general seasonal movements of the goat herd may be described as follows: the 5 wintering subherds located in Ptarmigan Lake Valley, Grant Lake Valley, Moose Creek Valley, Trail Glacier Valley, and King's River Valley, move towards their summer ranges in June and early July, and become established on summer ranges by mid-July. Most movements are towards areas which retain some snow all summer, such as glaciers or snow fields, or else the goats summer on north-facing slopes. All of these areas provide relief from mid-summer heat and insects while at the same time offering adequate cliff escape terrain and lush summer forage.

Some movements are merely altitudinal, but many are true migrations. Goats that winter above Ptarmigan Lake typically travel to the upper glacial cirques of Ptarmigan Valley or to those on the south side of Grant Lake Valley. Goats wintering above Grant Lake may merely move up the north side of the valley, but many migrate to the north fork of Moose Creek, the south fork and slope of Trail Glacier Valley, and across the Snow River Glacier ice field to King's River Valley. Other animals from both Moose Creek and Trail Glacier also cross this extensive ice field to summer range in upper King's River Valley. Some goats that winter in Moose Creek and on the north side of Trail Glacier Valley travel to the south side of this valley where they remain for the summer.

King's River Valley offers a large area of what appears to be prime summer habitat, but it receives heavy winter snowfall and its winter habitat is limited in size. The slopes above Grant Lake provide goats with good winter habitat but relatively little suitable summer range. Moose Creek drainage and the south side of Trail Glacier Valley receive heavy winter snowfall; each provides winter habitat to a small subherd under harsh conditions. Moose Creek appears to offer little suitable summer habitat in the form of permanent snowfields or shady, north-facing cliffs in conjunction with lush feeding areas. The south side of Trail Glacier contains cool north slopes and cliffs and large foraging areas near a large glacier and several smaller ones; it appears to be preferred summer habitat. These factors may account for the movements to King's River and the south side of Trail Glacier Valley in summer and back to Grant Lake, Moose Creek, and the north side of Trail Glacier in winter. The glacial cirques, ice fields, and lush foraging areas of upper Ptarmigan Valley, and the north-facing cliffs and cirques of the south side of Grant Lake Valley appear to be adequate and attractive summer habitat for the subherd of goats which winters above Ptarmigan Lake. My data suggest that few, if any, goats travel from this area to King's River or Trail Glacier in summer.

Not all such movements are equally predictable. Some animals, apparently mostly males, make excursions en route or in late winter, possibly following other goats, then return by mid-July to their normal summer habitats. Others may move to new summer ranges by following other groups, but they may not return to their previous winter ranges. This appears true primarily of young males and has been noted by other investigators (Taber and Stevens 1980, Johnson 1983).

By mid-September, and possibly as early as mid-August, some movement back towards winter ranges begins, with most goats reaching them before early November and before deep snow arrives. Some adult males may remain with resident summering populations until after the rut, which occurs probably during the 1st half of November, and not returning to their winter ranges until early December. This late return necessitates traveling through deep snow en route. Other adult males appear to travel between wintering subherds during the rut; they are found on their established wintering grounds with much less predictability than are other sex and age classes in fall and through mid-winter.

The mean fidelity percentage for all goats in mid-summer was found to be 91%; it reached a maximum of 95% in mid-winter. This suggests a strong affinity to mid-summer and mid-winter ranges by most goats. Mean fidelity percent was lower at all other seasons. Lower fidelity to given ranges would be expected in spring and fall, considering migrations from winter to summer ranges and back, and male rutting movements. However, fidelity varied considerably by sex/age cohort and time periods, but indicated that older males and females (age 5+) generally were more faithful to their expected ranges in summer than were younger animals of either sex. Also, older animals moved less during this season. Older females showed more stability in range use on a year-long basis than did males, especially older males. Older males, probably because of rutting activities, were least predictable in their movements, and moved more in fall and winter. Younger males, of all cohorts, appeared to be the least attached to specific home ranges, and more willing to change annual ranges.

Of all goats in the radio-collared sample, about 70% returned to their mid-summer range each year, unless they died. All adult males aged 5 years and older returned to their mid-summer ranges, as did about 80% of adult females. In winter, however, only about 30% of adult males returned to their expected range, whereas approximately 90% of all females returned to their expected range. Younger males, which probably participated in the rut less than older males and hence traveled less, were more predictable; about 70% could be found where they had wintered in the past.

MANAGEMENT CONSIDERATIONS

Because of many variables including sex, age, and time periods examined, and the lack, at times, of clear-cut differences in percentage of fidelity and distance moved between areas, interpretation of the analyses presented is difficult. However, the data strongly suggest the period of mid-July to mid-August as being a time during which most goats will be most consistent in their use of summer range, and during which movements will be at a minimum. This, then, is the recommended period during which aerial counts should be conducted on the Kenai. Censuses conducted during this period should provide the most uniform results. In this area, aerial census during winter is not useful because observability of goats is very poor.

Aerial surveys conducted during this study reiterate former findings; that aerial goat counts by fixed-wing aircraft should be conducted only when conditions are favorable; i.e., on days with a high overcast, little sun glare, and cool conditions (Nichols 1980a). Under these conditions, goats will be most observable and count results most accurate, with accuracy levels approaching 90%. However, on warm, sunny days, goats often seek shade and shelter on and under snowbanks and glaciers, and in cliff crevices or caves. Bright sunshine causes glare, making goats difficult to observe against some backgrounds. On such days, accuracy is unpredictable despite diligence in searching, and results may be meaningless.

During the mid-July to mid-August period, about 70% of all goats in this herd were found in the same drainages as in previous summers. The remaining 30% was made up of animals that may or may not have been in that area the previous year. If the entire annual home range of a herd to be censused is known and the entire area is covered during a census, all, or a high percentage of that herd presumably will be counted regardless of fidelity and movements within the area. However, if, as is usually the case, the entire annual range is not known and surveyed, predictability of goats from year-to-year must be taken into consideration, and census results interpreted accordingly. Variations in total animals counted of up to 30% (realistically, probably less than 20%) may be accounted for by unpredictable movements rather than by true changes in numbers.

If real accuracy in determining goat populations trends is desired, I recommend that the effort be expended to learn the annual range of 1 or more sample goat herds in an area. These herds should be counted carefully each year and overall population trends estimated from the results. This would eliminate most of the variability resulting from unpredictable movements within an annual range, gain better data on annual population changes, and probably result in a significant time and cost savings compared to counting large areas with little knowledge of goat movements within the area.

ACKNOWLEDGEMENTS

Many people helped during the field work phase of this study, and I would like to express my gratitude to them all. In particular, my thanks go to Ted Spraker, Al Franzmann, Dave Holdermann, and Chuck Schwartz for much-needed assistance in capturing, handling, and collaring the goats, and to Vern Lofstedt, of Kenai Air Alaska, Inc., for his helicopter piloting skill, without which none of this would have been possible. Karl Schneider gave supervisory support to the study and helped make financing and time available for its completions. Steve Peterson gave valuable help in editing this report.

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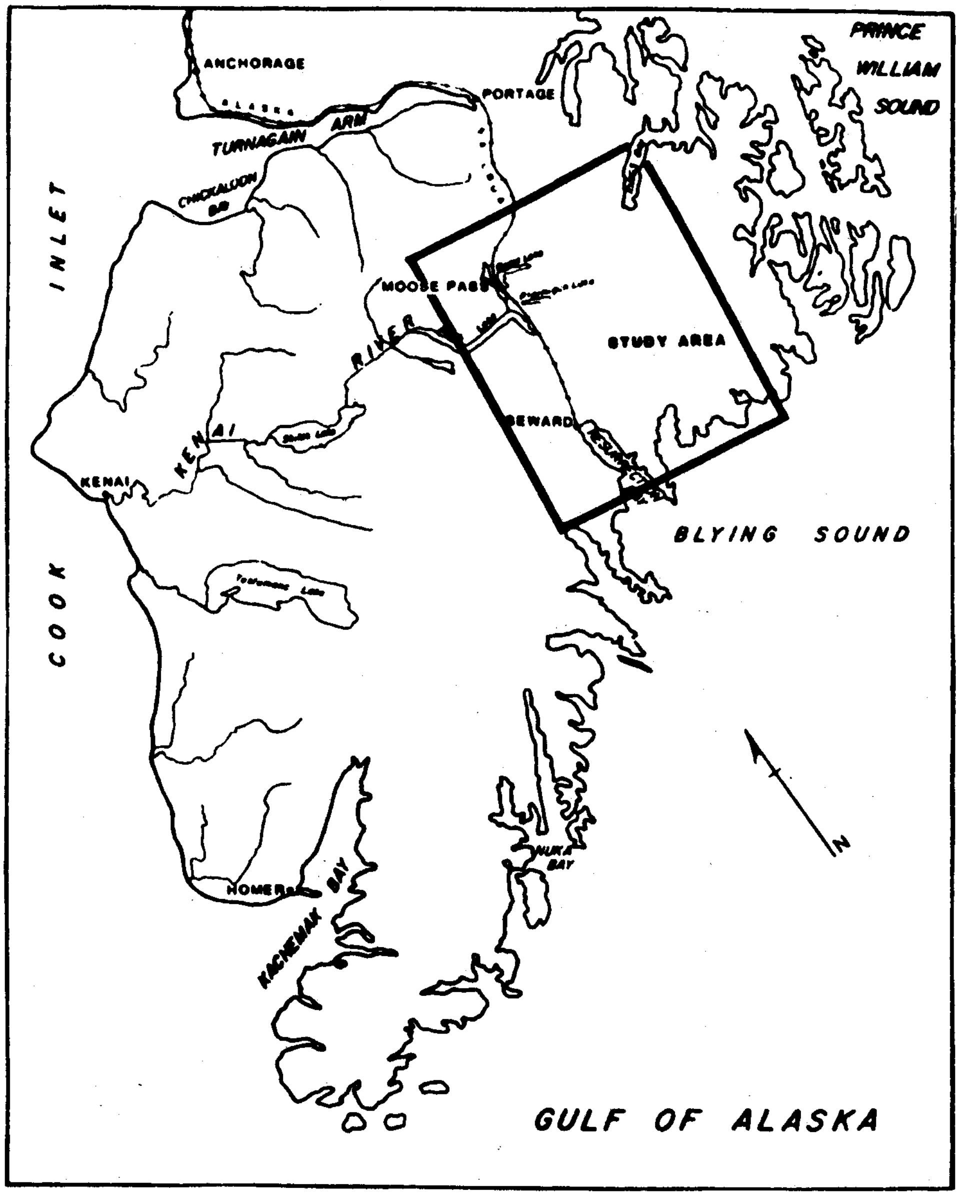


Fig. 1. The mountain goat fidelity study area on the Kenai Peninsula, Alaska, 1979-84.

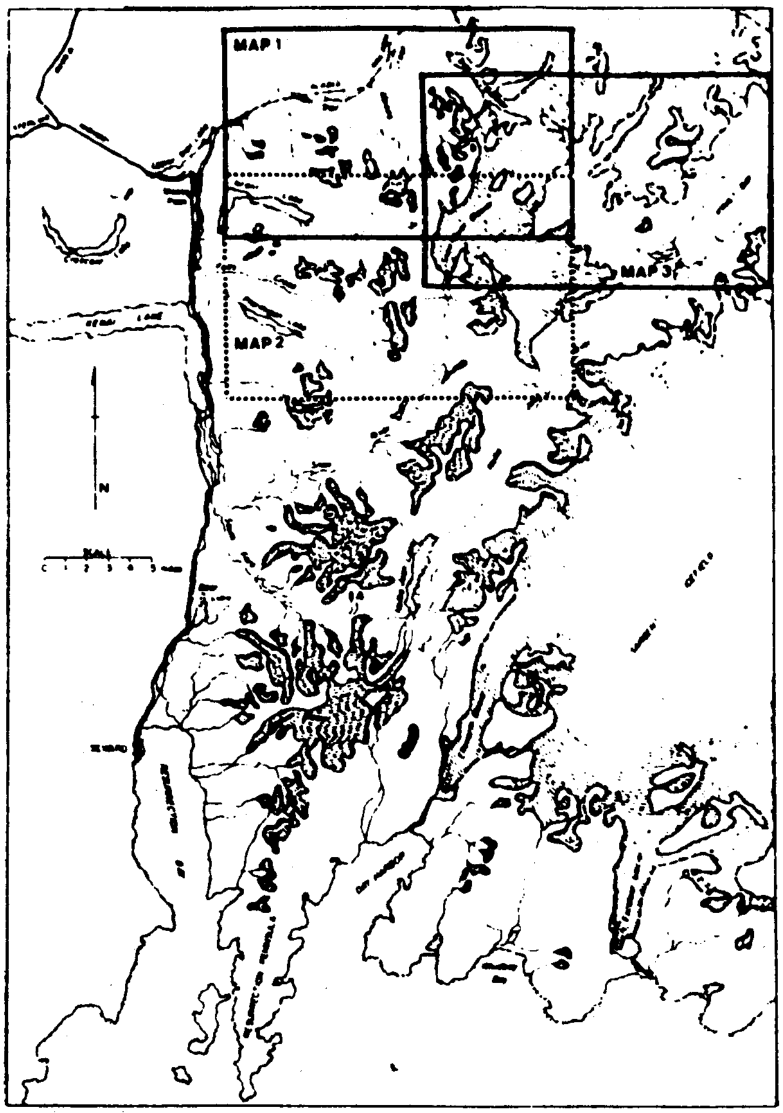


Fig. 2. Location and overlap of digitized study area maps for determining mountain goat fidelity on the Kenai Peninsula, Alaska, 1979-84.

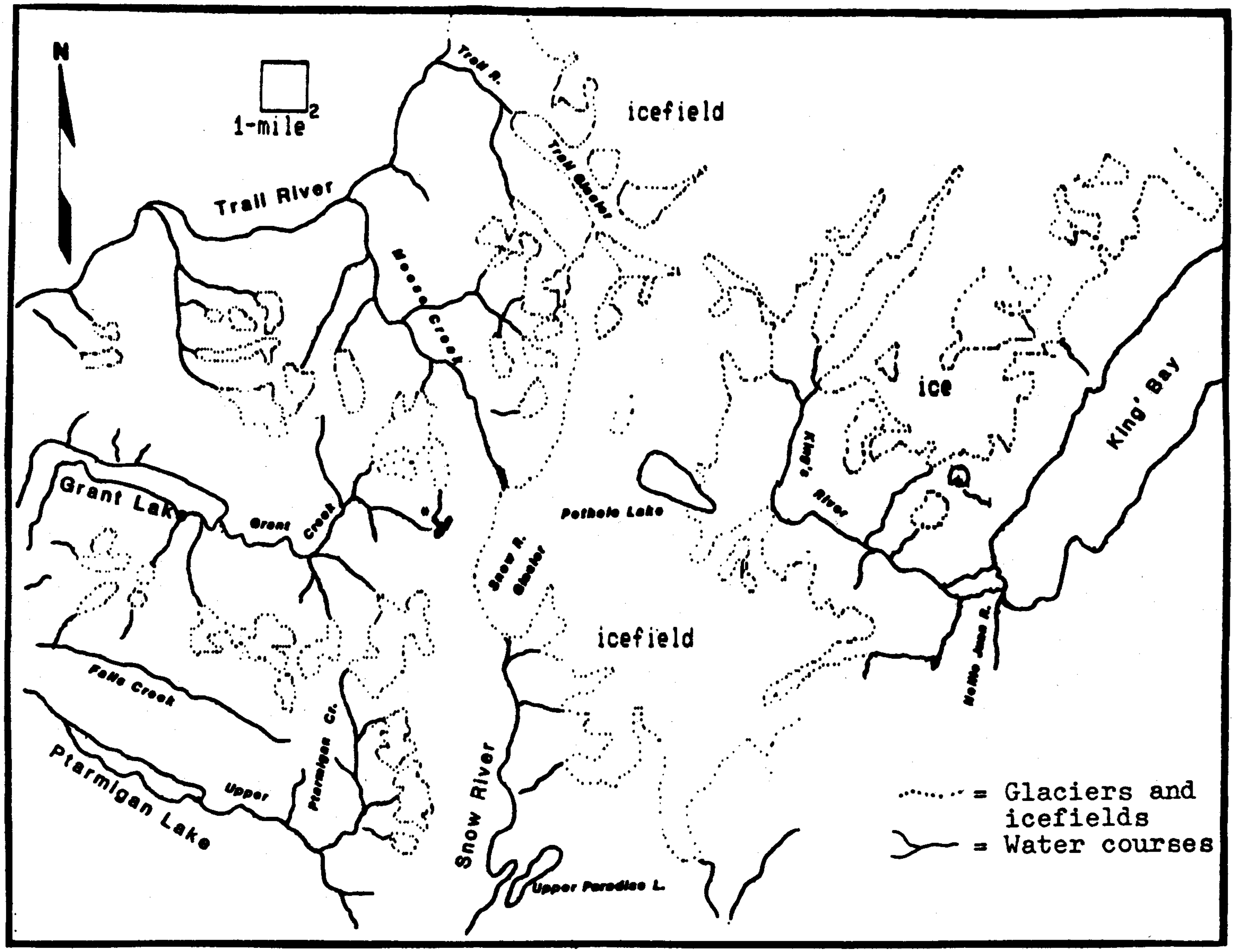


Fig. 3. Composite of 3 digitized maps of mountain goat study area on the Kenai Peninsula, Alaska, with main features and drainages named.

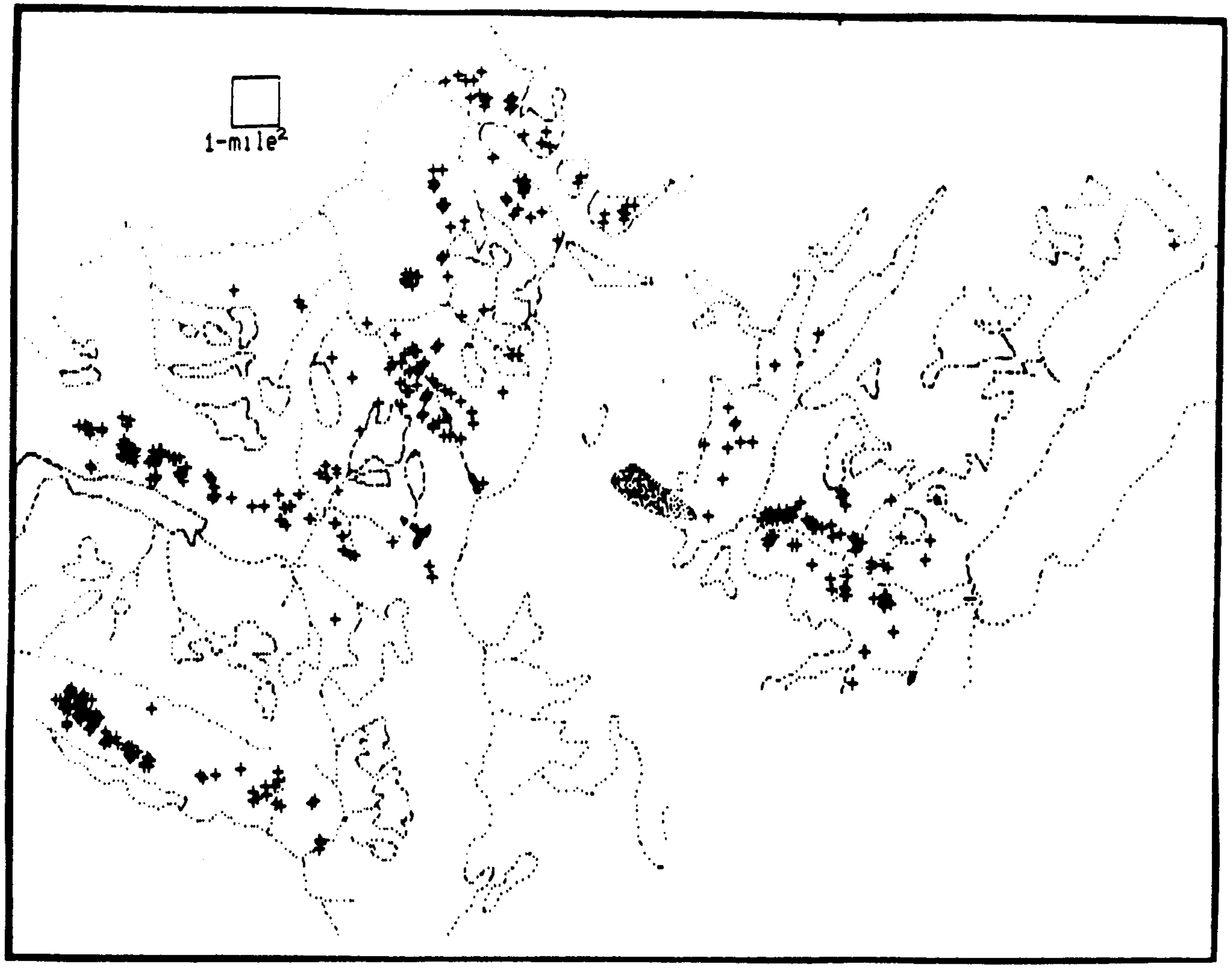


Fig. 4. Locations of all collared mountain goat resightings during all winters of the study (1979-84) plotted on composite of 3 digitized maps, Kenai Peninsula, Alaska.

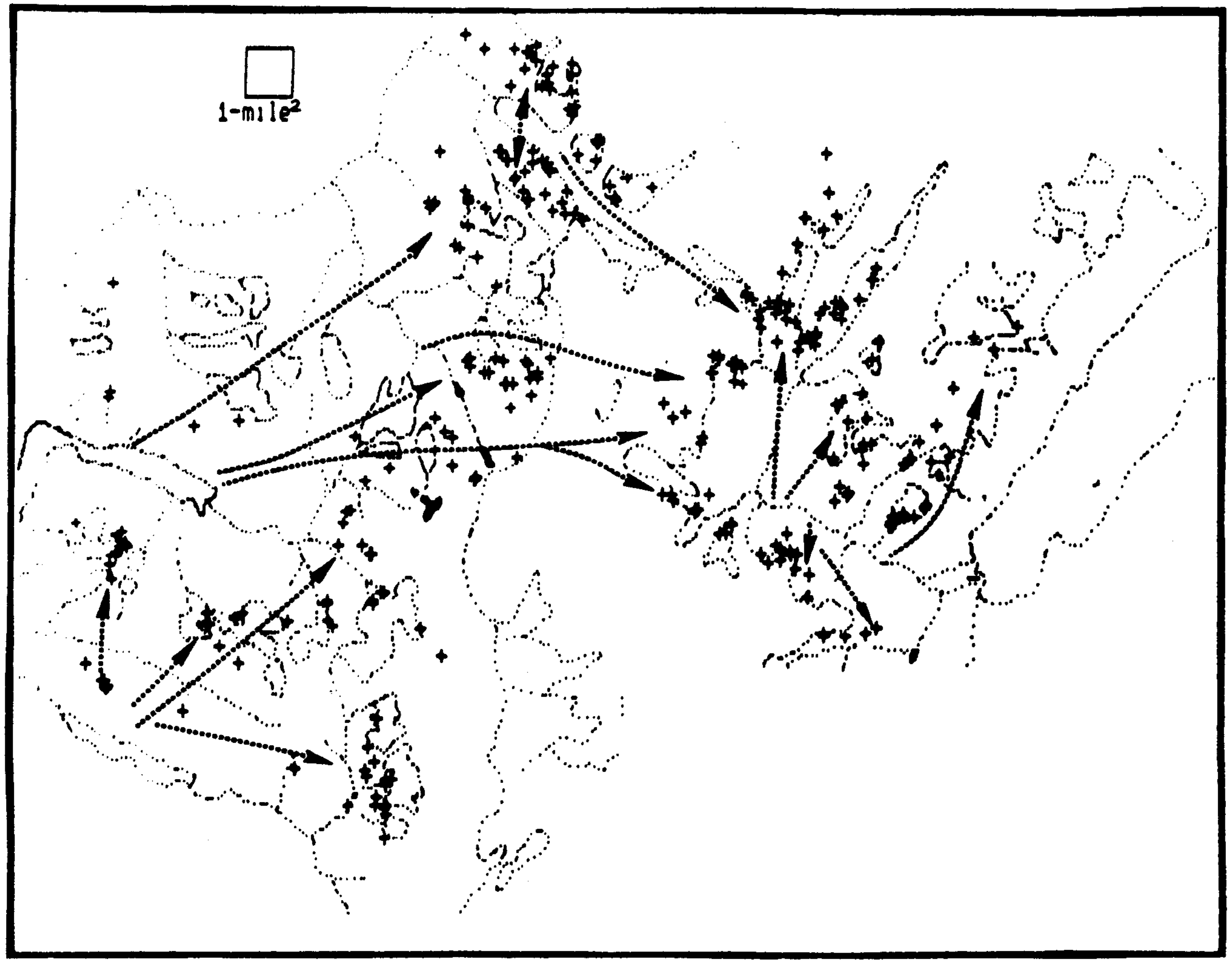


Fig. 5. Locations of all collared mountain goat resightings during all summers of the study (1979-84), plotted on composite of 3 digitized maps, Kenai Peninsula, Alaska. Arrows indicate major patterns of migration from winter to summer ranges.

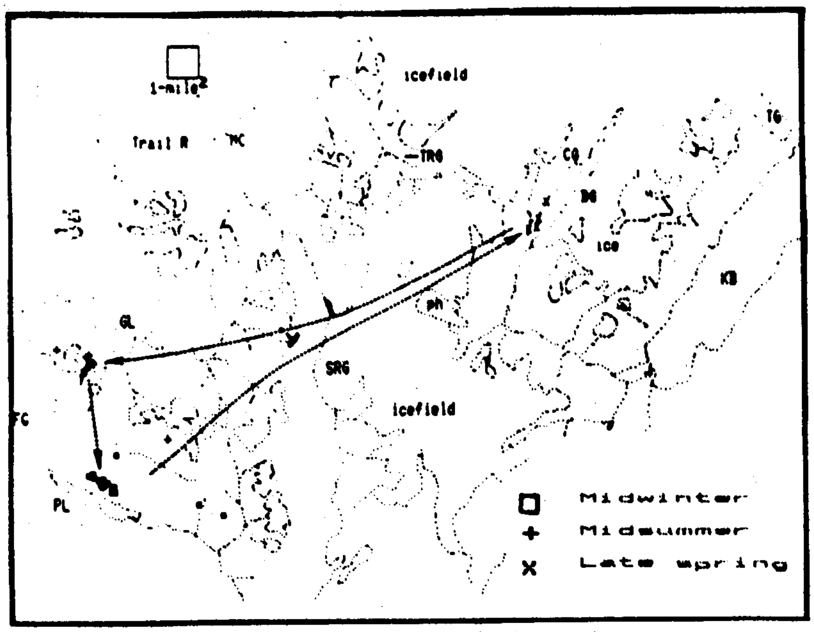


Fig. 6. Resightings of male mountain goat No. 5 on the Kenai Peninsula, Alaska, study area, 1979-84. Arrows indicate movements from winter to late spring to summer ranges.

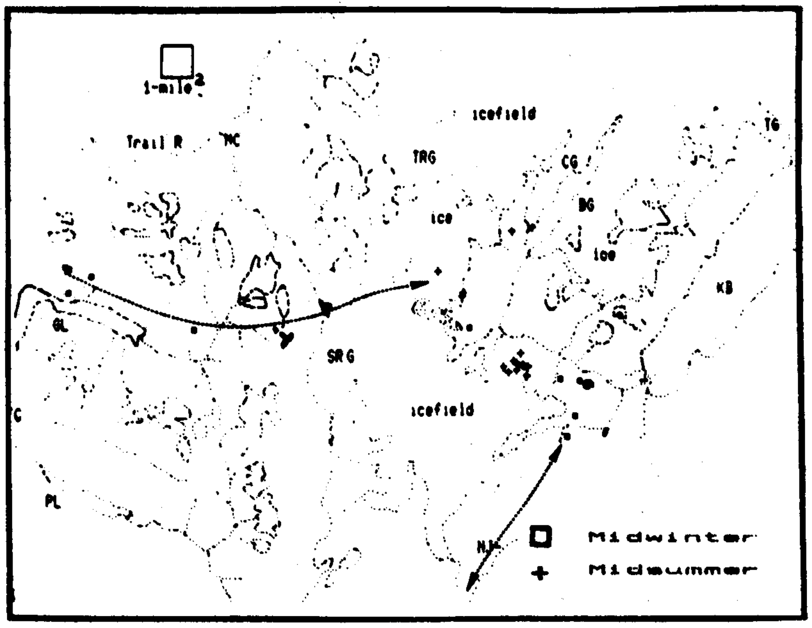


Fig. 7. Resightings of male mountain goat No. 15 on the Kenai Peninsula, Alaska, study area, 1979-84. Arrows indicate movements from original winter range to summer range, then from new winter range to and from spring range (off the map).

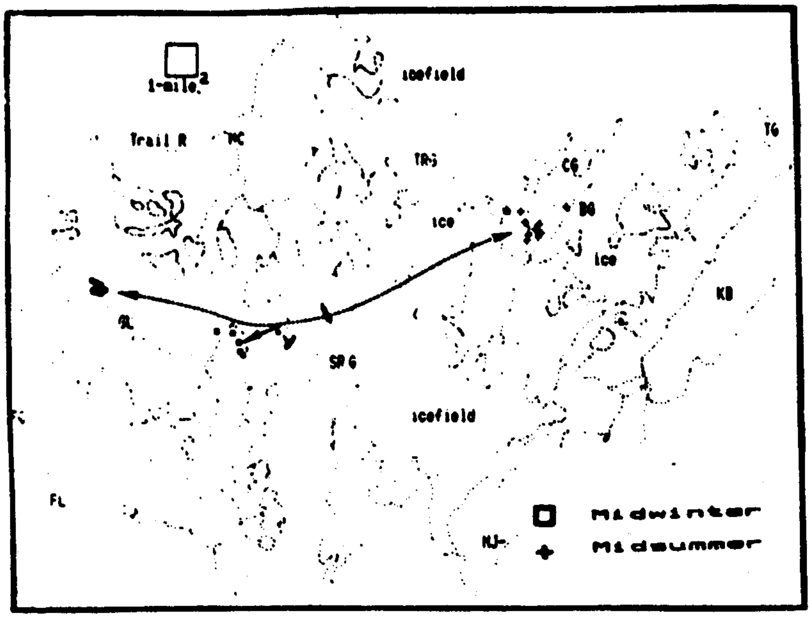


Fig. 8. Resightings of male mountain goat No. 18 on the Kenai Peninsula, Alaska, study area, 1979-84. Arrows indicate movement from original winter range to summer range, then to new winter range.

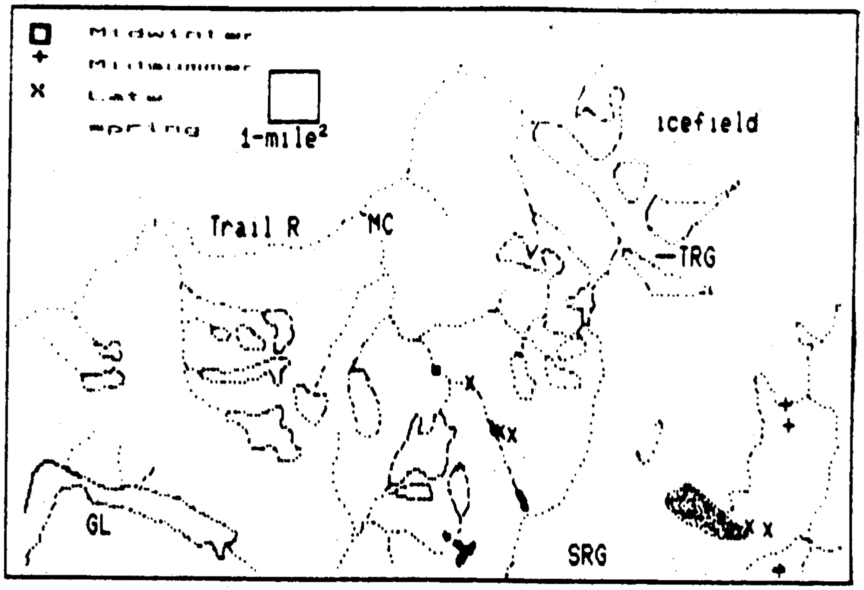


Fig. 9. Resightings of male yearling mountain goat No. 14 on the Kenai Peninsula, Alaska, study area, 1979-80.

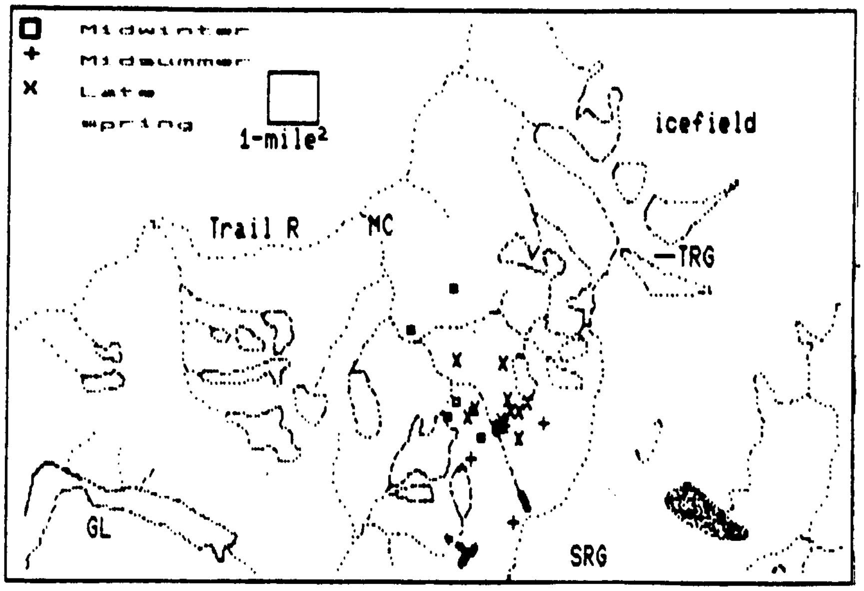


Fig. 10. Resightings of male 2-year-old mountain goat No. 14 on the Kenai Peninsula, Alaska, study area, 1980-81.

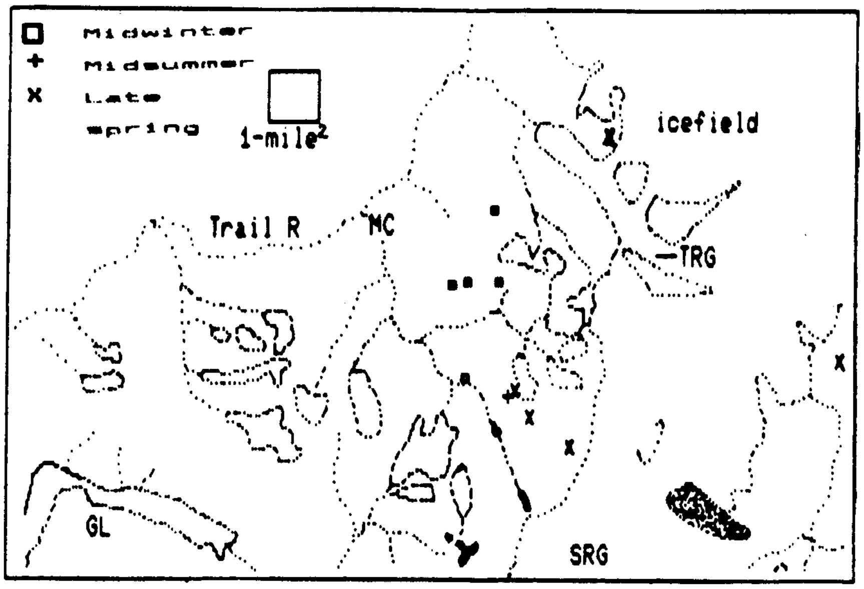


Fig. 11. Resightings of male 3-year-old mountain goat No. 14 on the Kenai Peninsula, Alaska, study area, 1981-82.

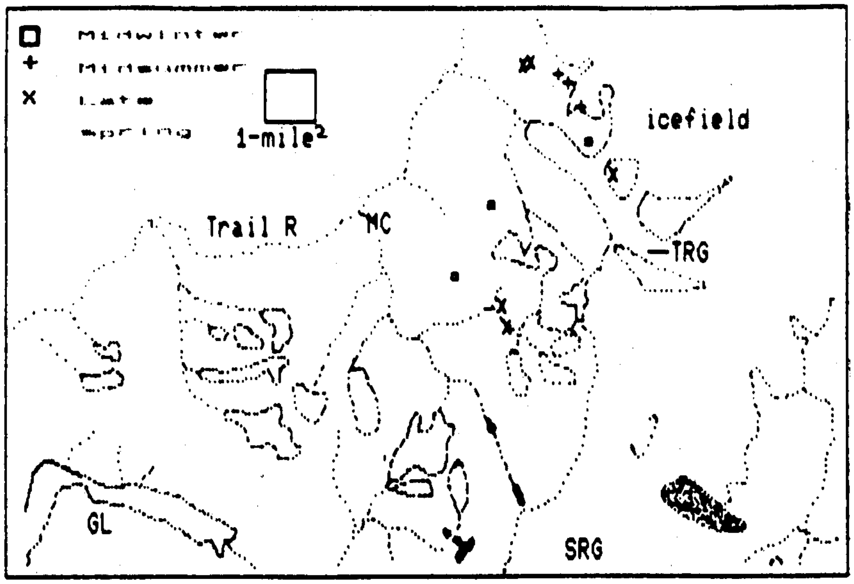


Fig. 12. Resightings of male 4-year-old mountain goat No. 14 on the Kenai Peninsula, Alaska, study area, 1982-83.

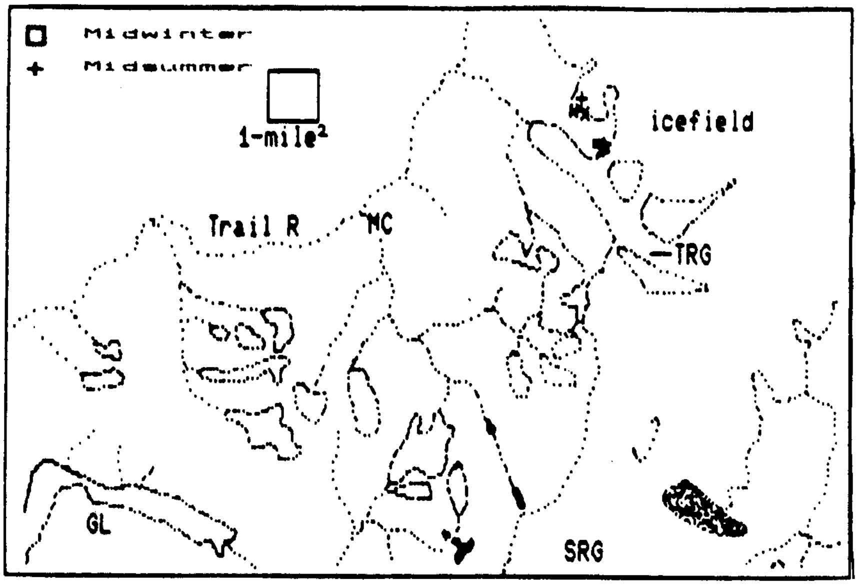


Fig. 13. Resightings of male 5-year-old mountain goat No. 14 on the Kenai Peninsula, Alaska, study area, 1983-84.

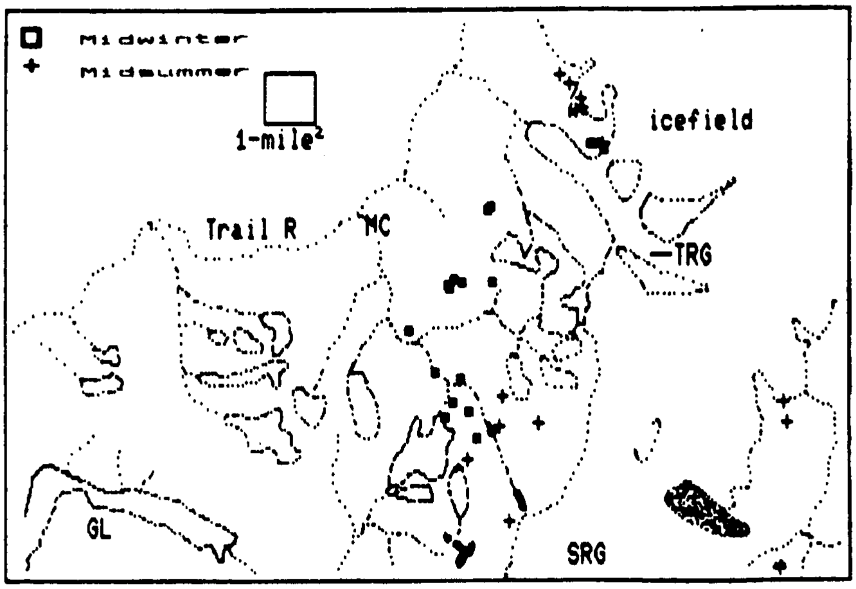


Fig. 14. All midsummer and midwinter re-sightings of male mountain goat No. 14 during the 5-year period he was tracked on the Kenai Peninsula, Alaska, study area, 1979-84.

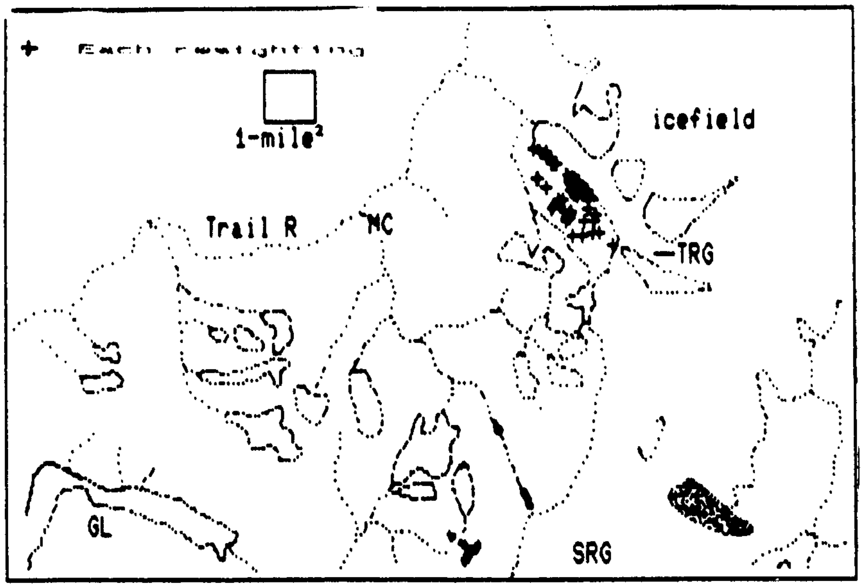


Fig. 15. All resightings of female mountain goat No. 12 from late summer 1979 to early winter 1984 on the Kenai Peninsula, Alaska, study area.

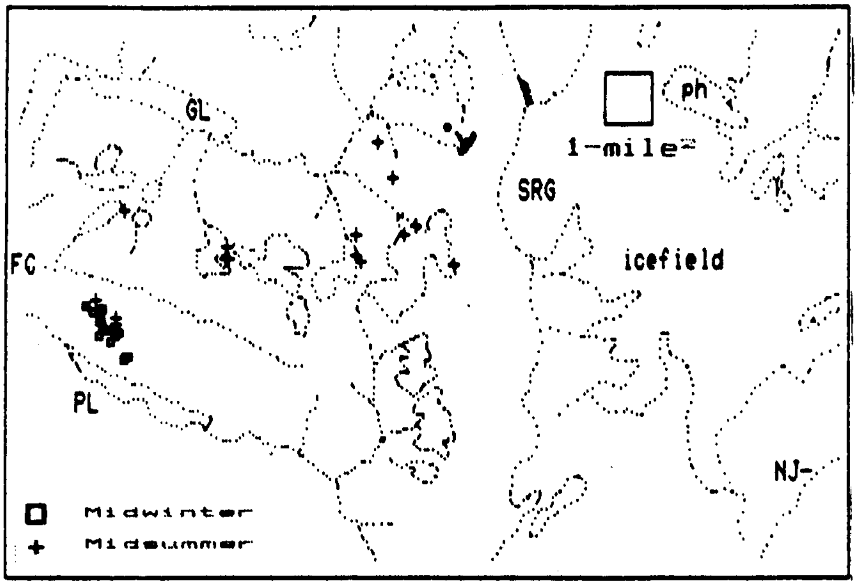


Fig. 16. All midwinter and midsummer resightings of female mountain goat No. 4 from 1979 to 1984 on the Kenai Peninsula, Alaska, study area.

Table 1. Sex and age of mountain goats radio-collared on the Kenai Peninsula, Alaska 1979-1981.

Date	Yearlings		2 years old		3 years old		4 years old		Over 4 years old	
	M	F	M	F	M	F	M	F	M	F
8/79	1	1	1	2	2	1		1	3	8
8/80					1			1	1	
6/81	2	1	1	1	1	3		2	3	4
Totals	3	2	2	3	4	4	0	4	7	12

Table 2. Population estimates for the mountain goat study herd in the Kenai Mountains, Alaska, 1977-83.

Year	Total goats[a]	Total adults[b]	Yrlgs	Yrlgs per 100 adults	Kids	Kids per 100 adults	Estimated hunter harvest
1977	203	150	24	16	53	35	--[c]
1978	198	150	26	17	48	32	--
1979	246	191	25	13	55	29	6
1980	169	138	23	17	31	22	5
1981	218	166	34	20	52	31	2
1982	257	202	47		55		--
1982a[d]	301	238	57	24	63	26	7
1983	178	147	26		31		--
1983a[d]	221 (235)[e]	180 (194)[e]	32	18	41	23	9[f]

[a] Totals corrected for estimated counting error = total observed divided by 0.9 (Nichols 1980*a*).

[b] Total adults = total non-kids; includes yearlings.

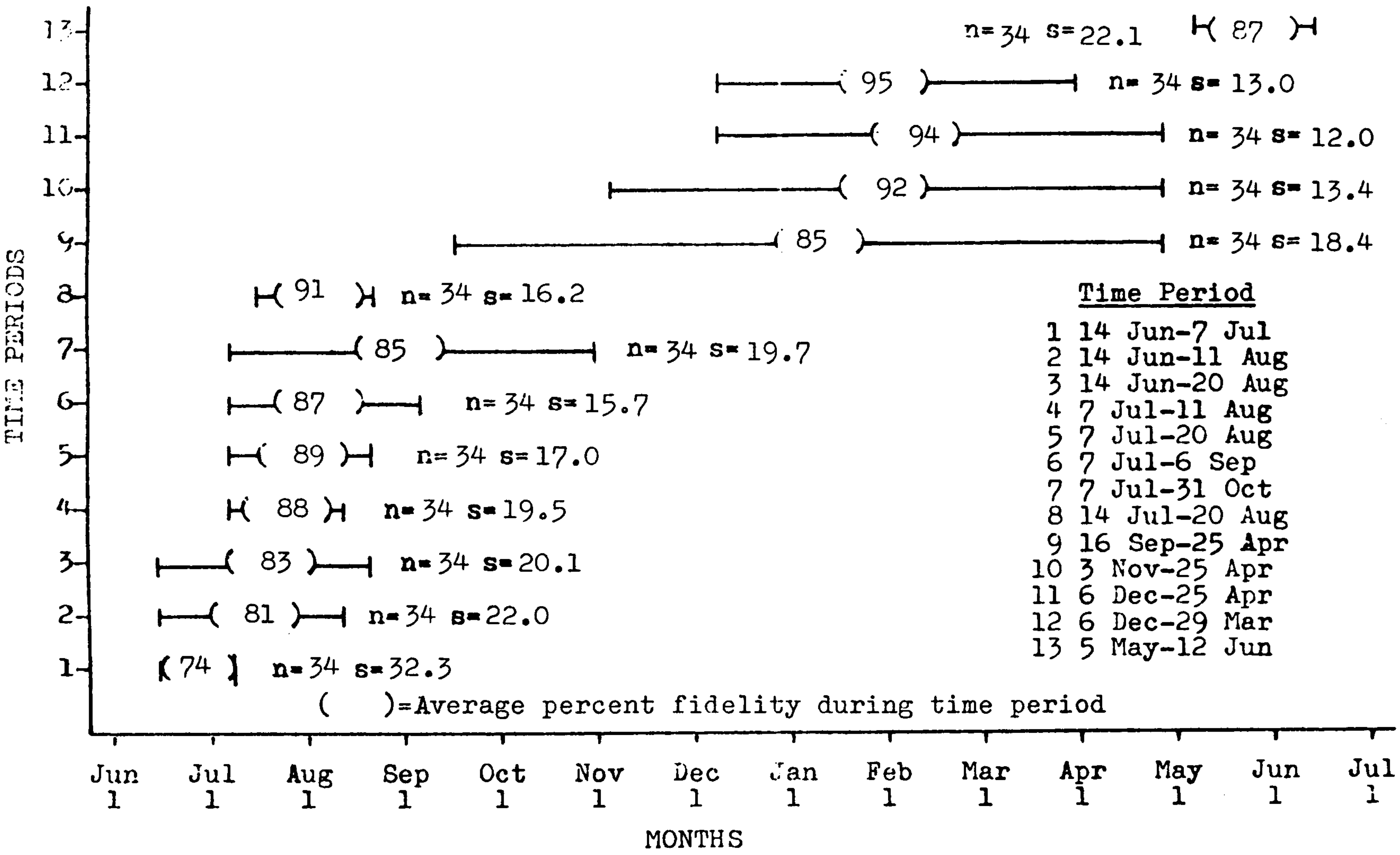
[c] Harvest data unavailable.

[d] Study area expanded to include north side of Trail Glacier.

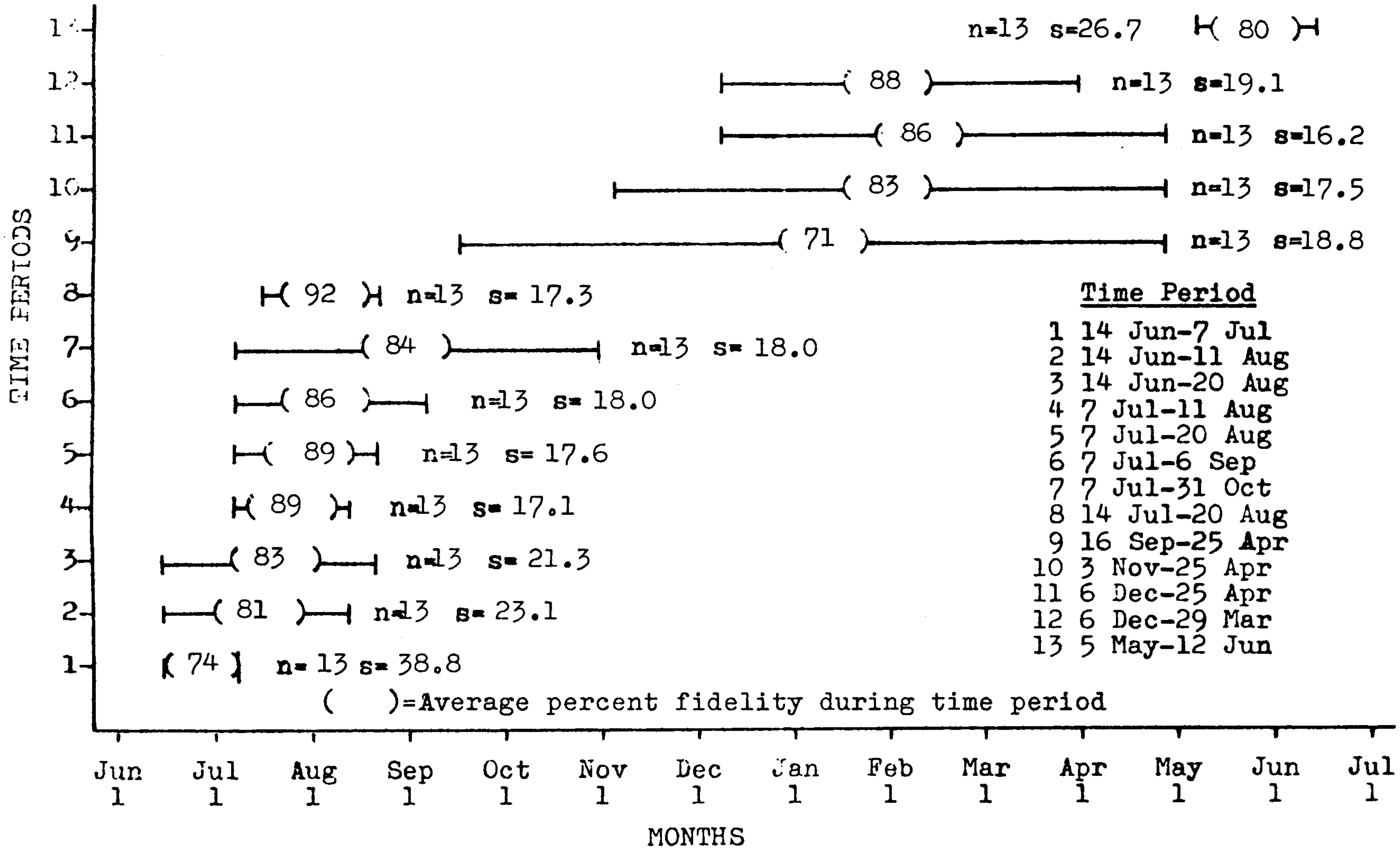
[e] Expected without removal of 14 for transplant project.

[f] Plus 14 removed for transplant.

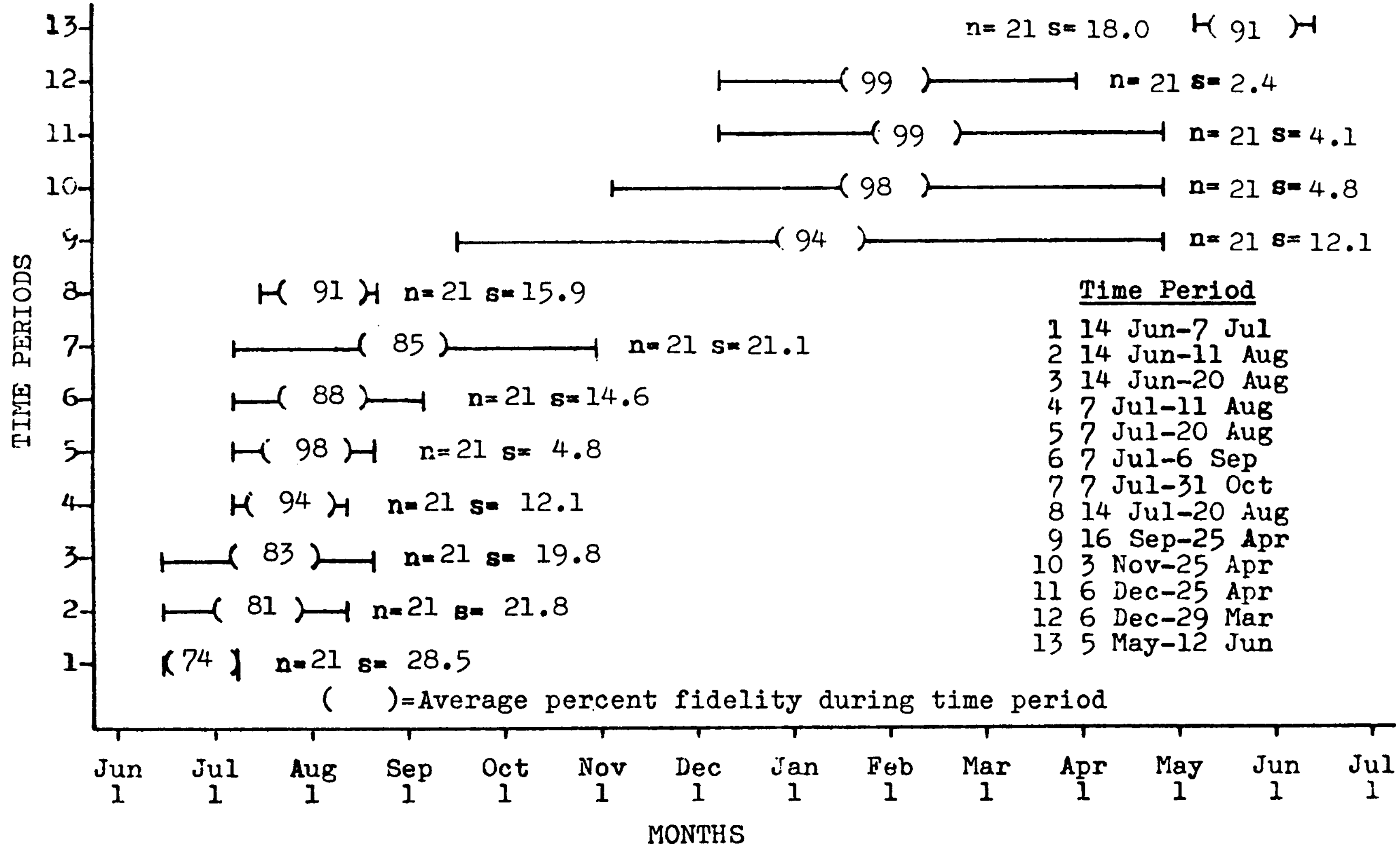
Appendix A. Figures 1-18. Mean percentages of fidelity and mean maximum distances traveled with sample sizes and standard deviations.



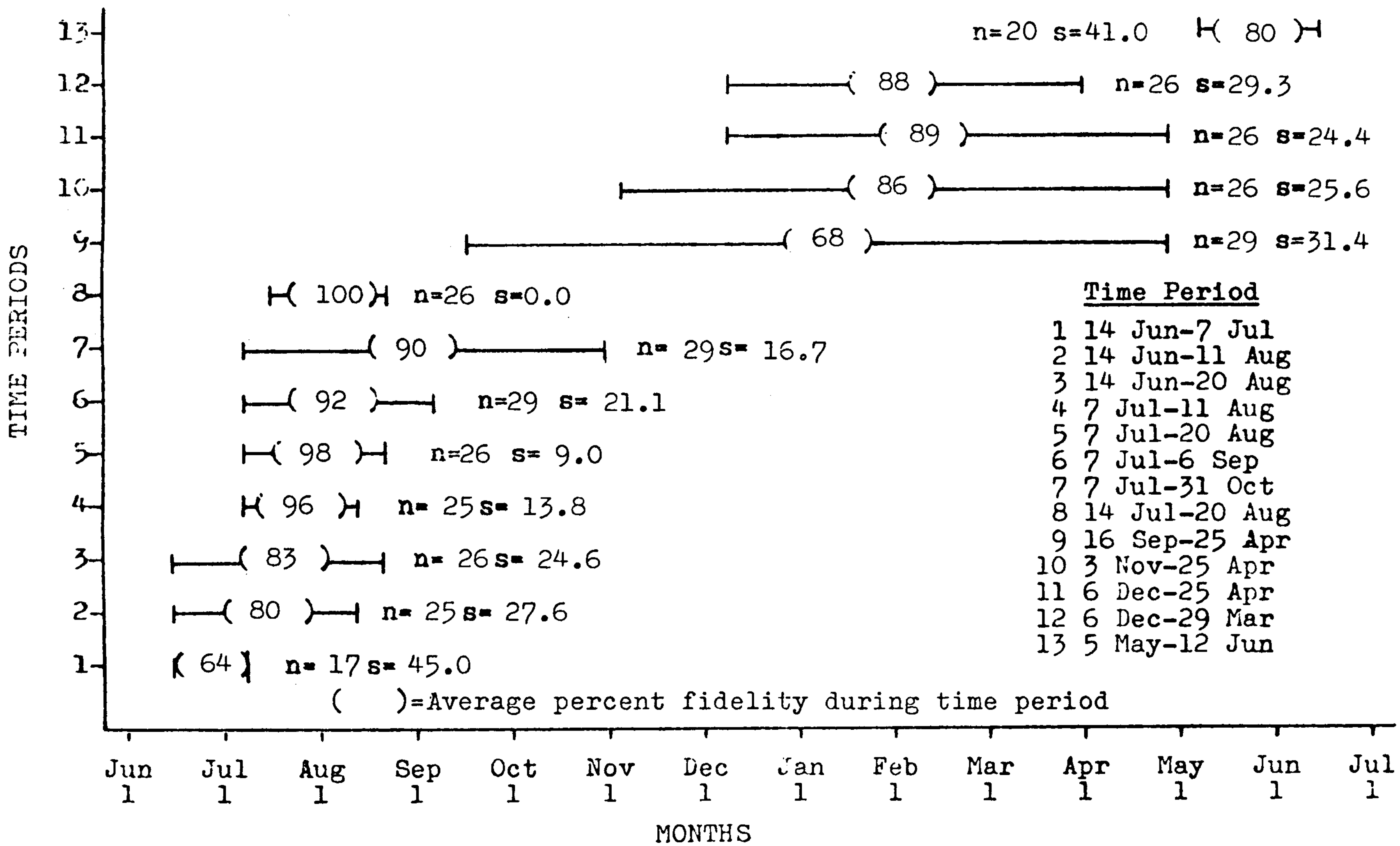
Appendix A. Fig. 1. Average percent fidelity by time period for all collared goats combined, 1979-1984.



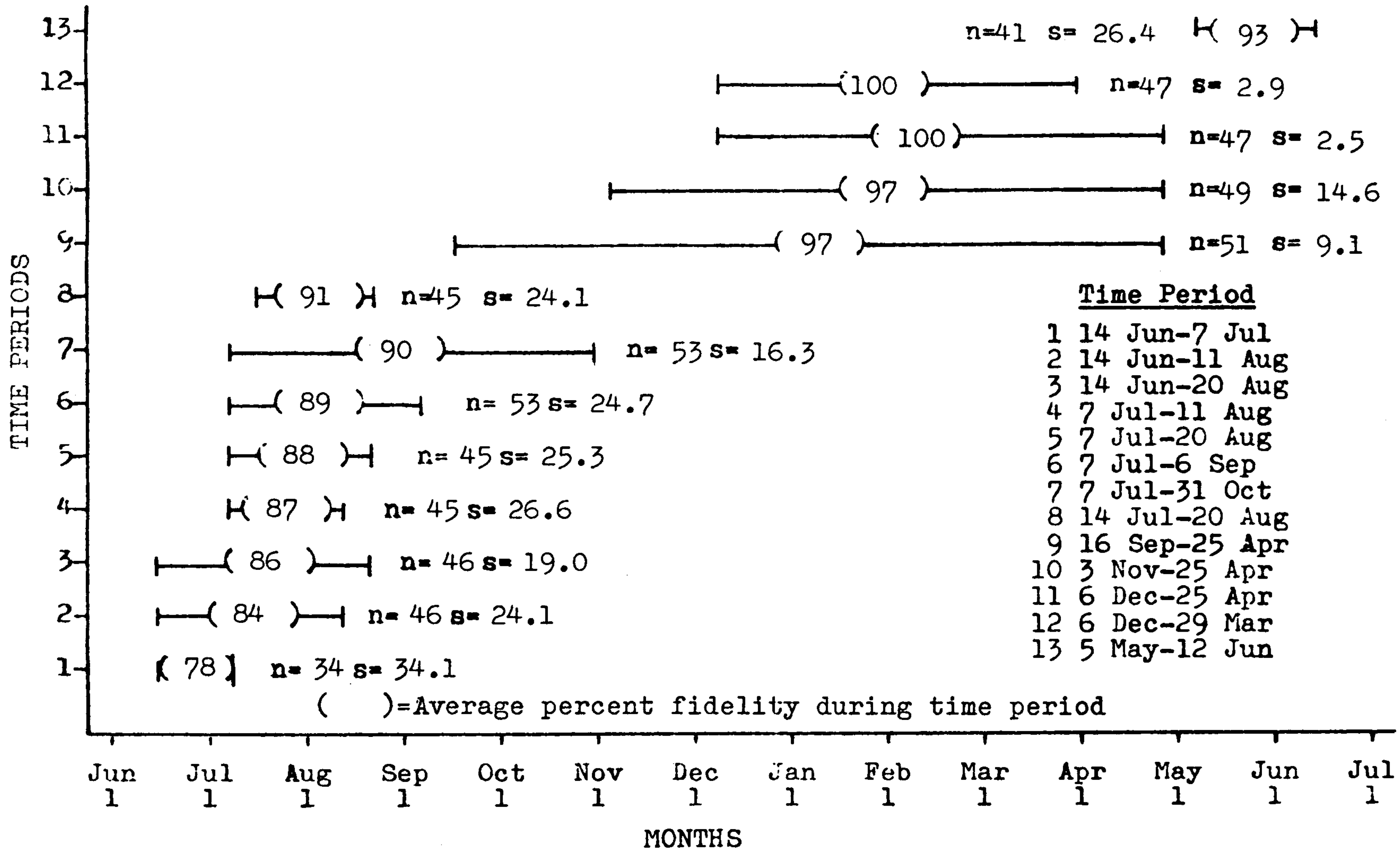
Appendix A. Fig. 2. Average percent fidelity by time period for all collared male goats, 1979-1984.



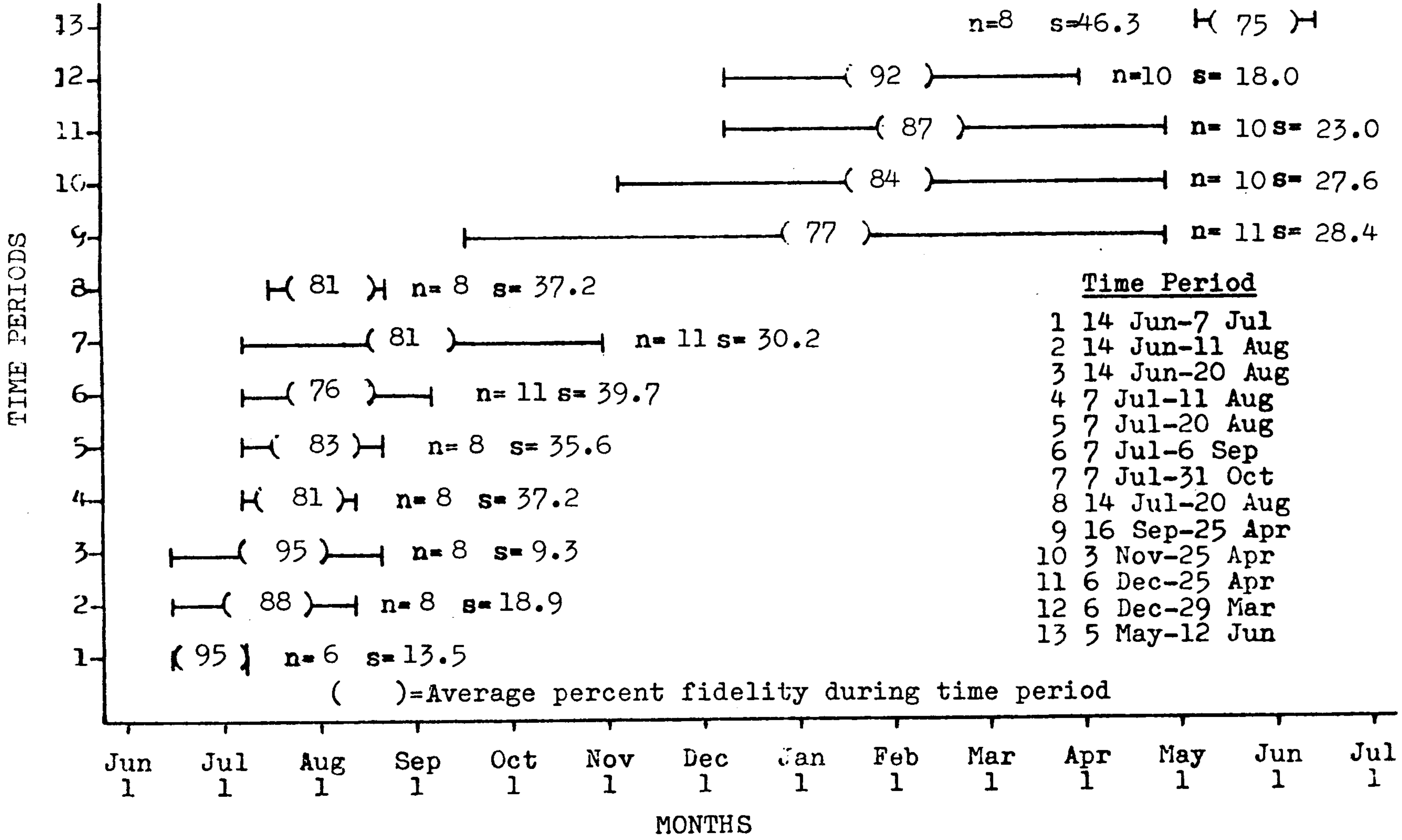
Appendix A. Fig. 3. Average percent fidelity by time period for all collared female goats, 1979-1984.



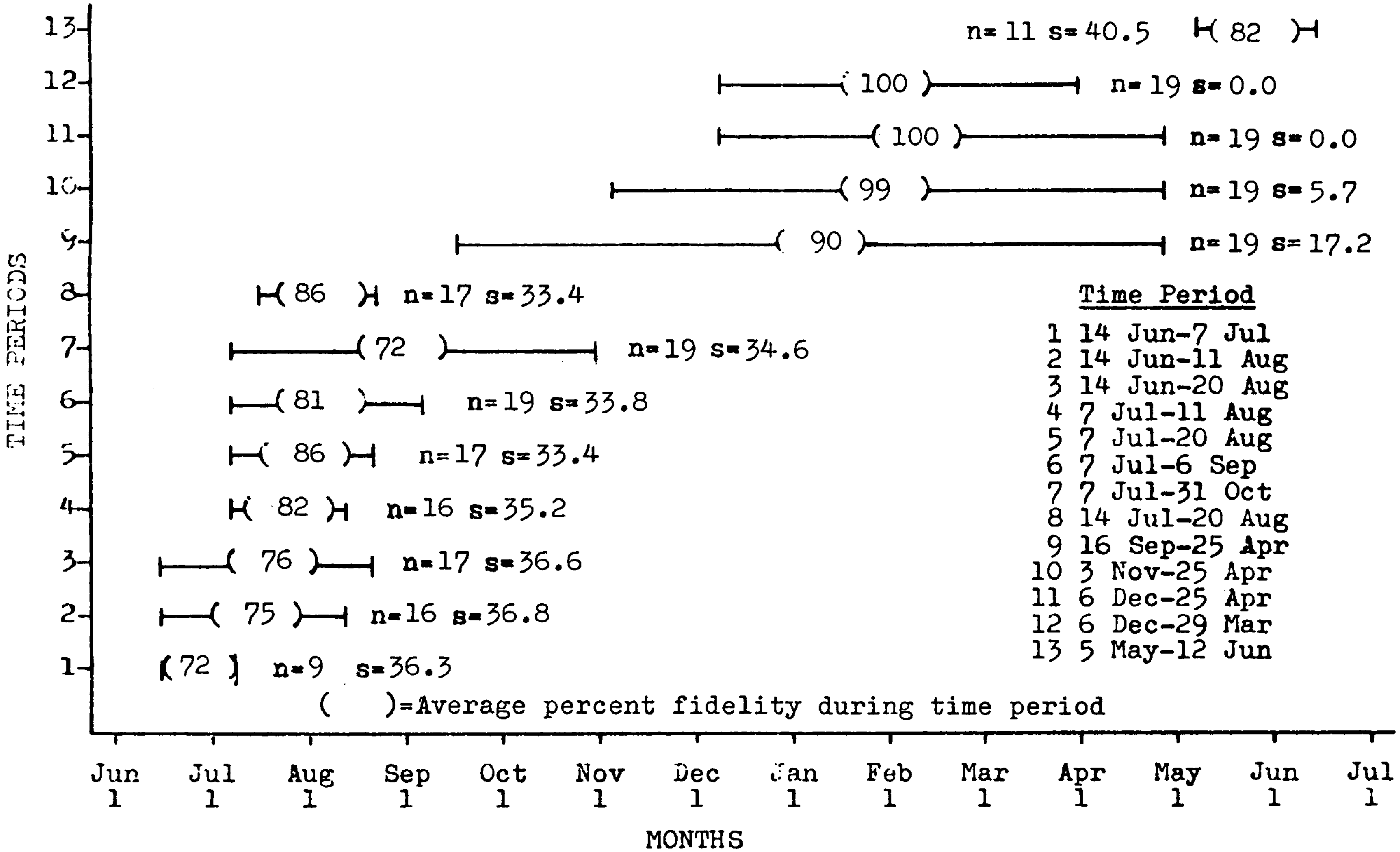
Appendix A. Fig. 4. Average percent fidelity by time period for all collared male goats age 5 and over, 1979-1984.



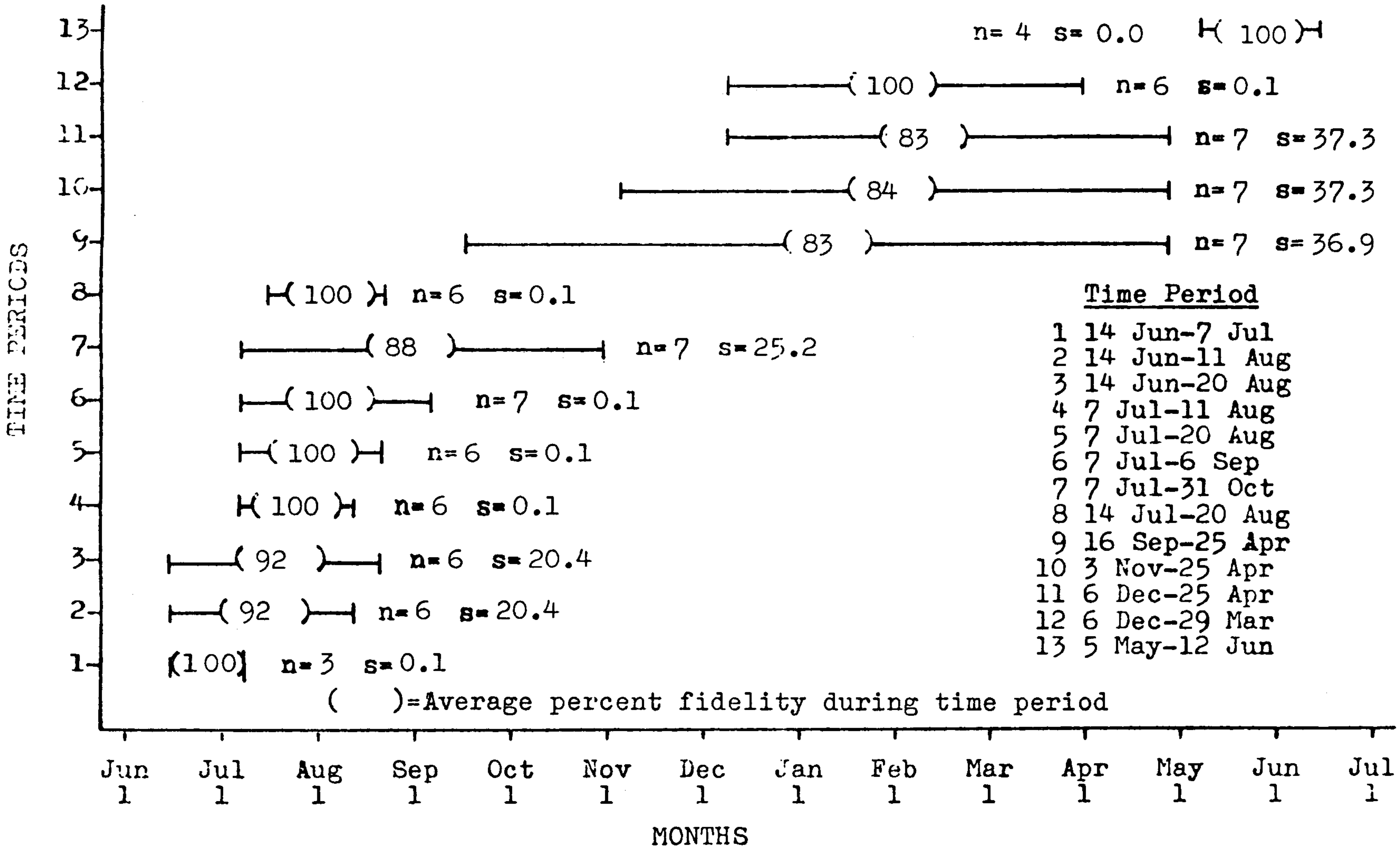
Appendix A. Fig. 5. Average percent fidelity by time period for all collared female goats age 5 and over, 1979-1984.



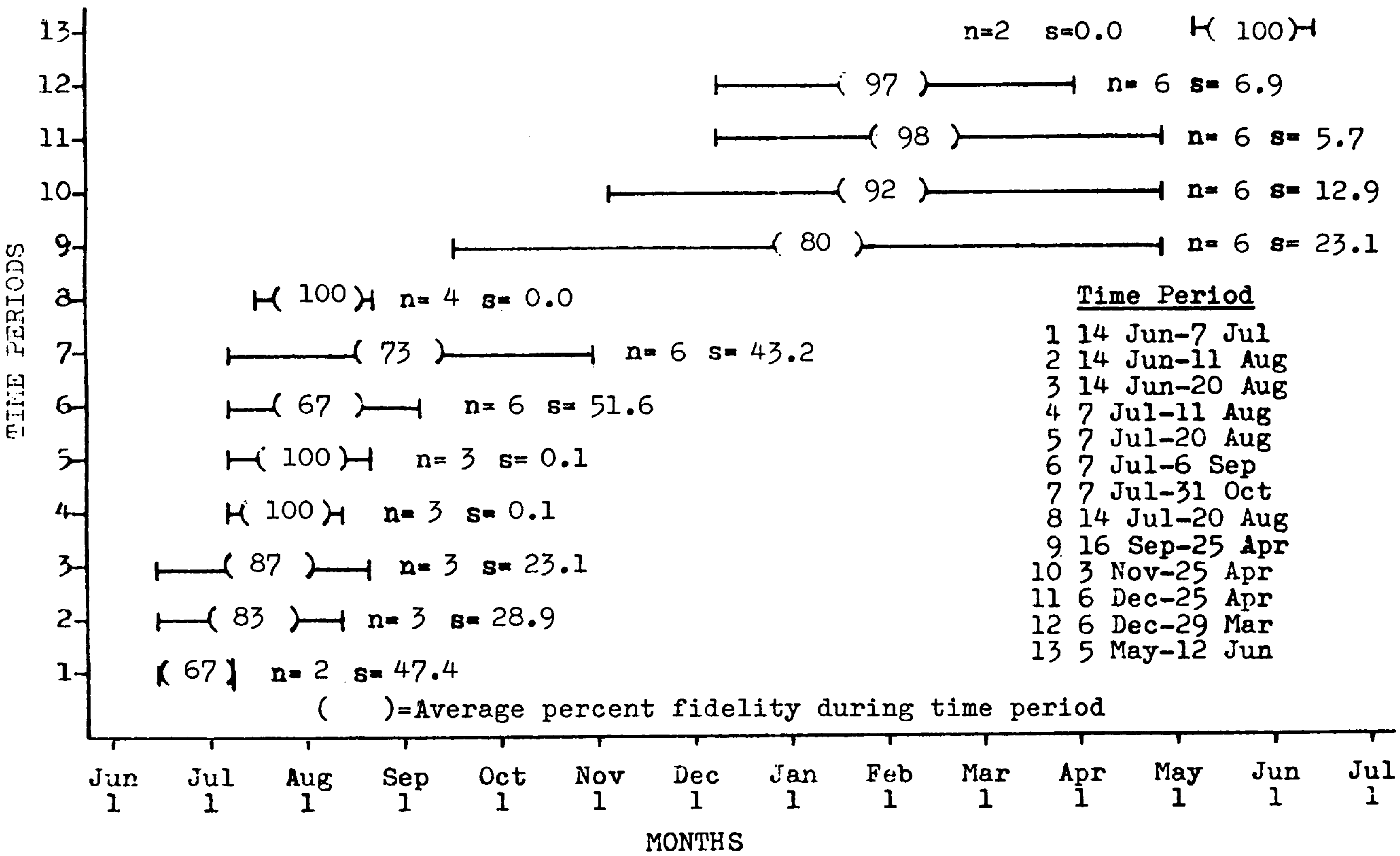
Appendix A. Fig. 6. Average percent fidelity by time period for all collared male goats age 3 and 4, 1979-1984.



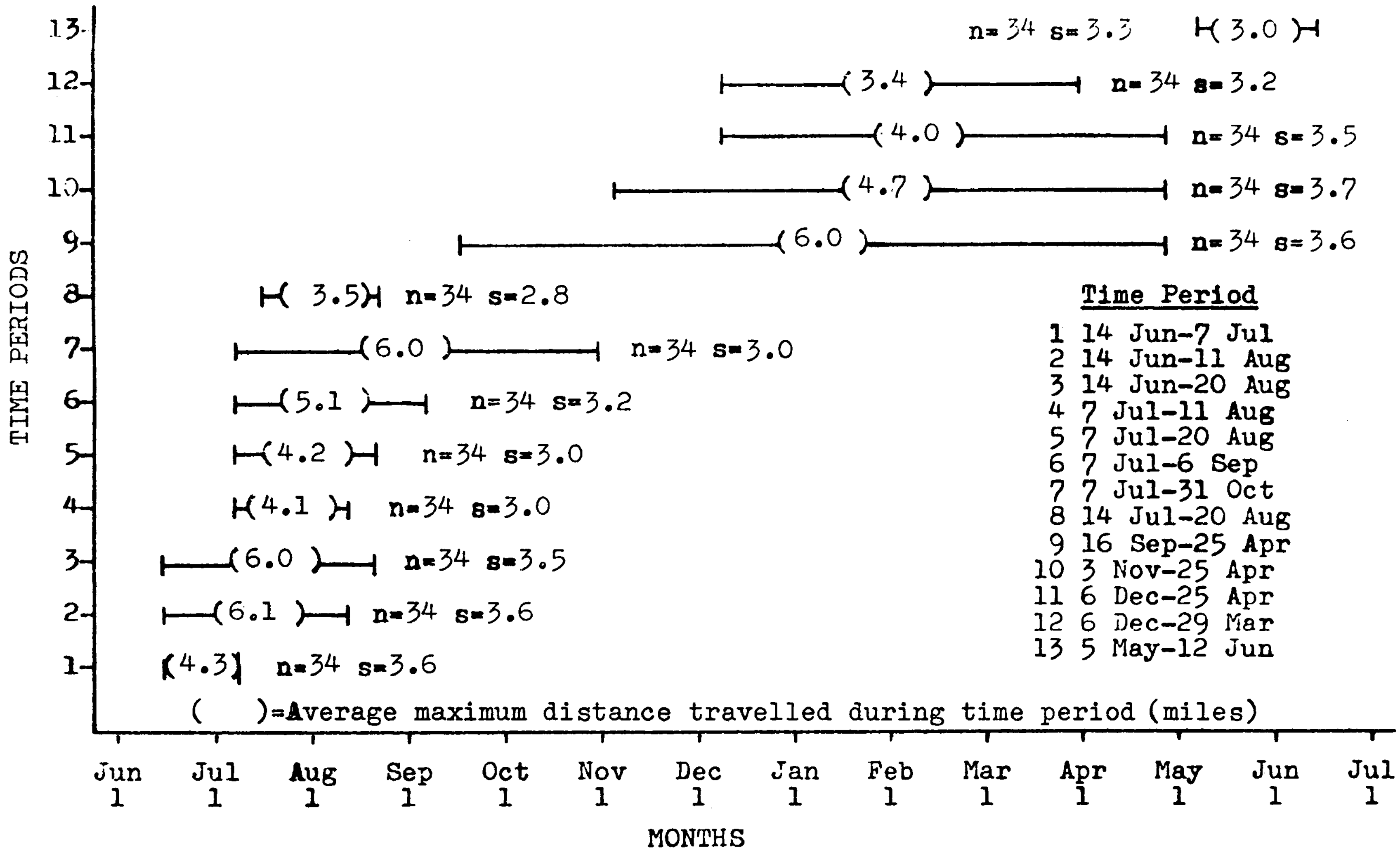
Appendix A. Fig. 7. Average percent fidelity by time period for all collared female goats age 3 and 4, 1979-1984.



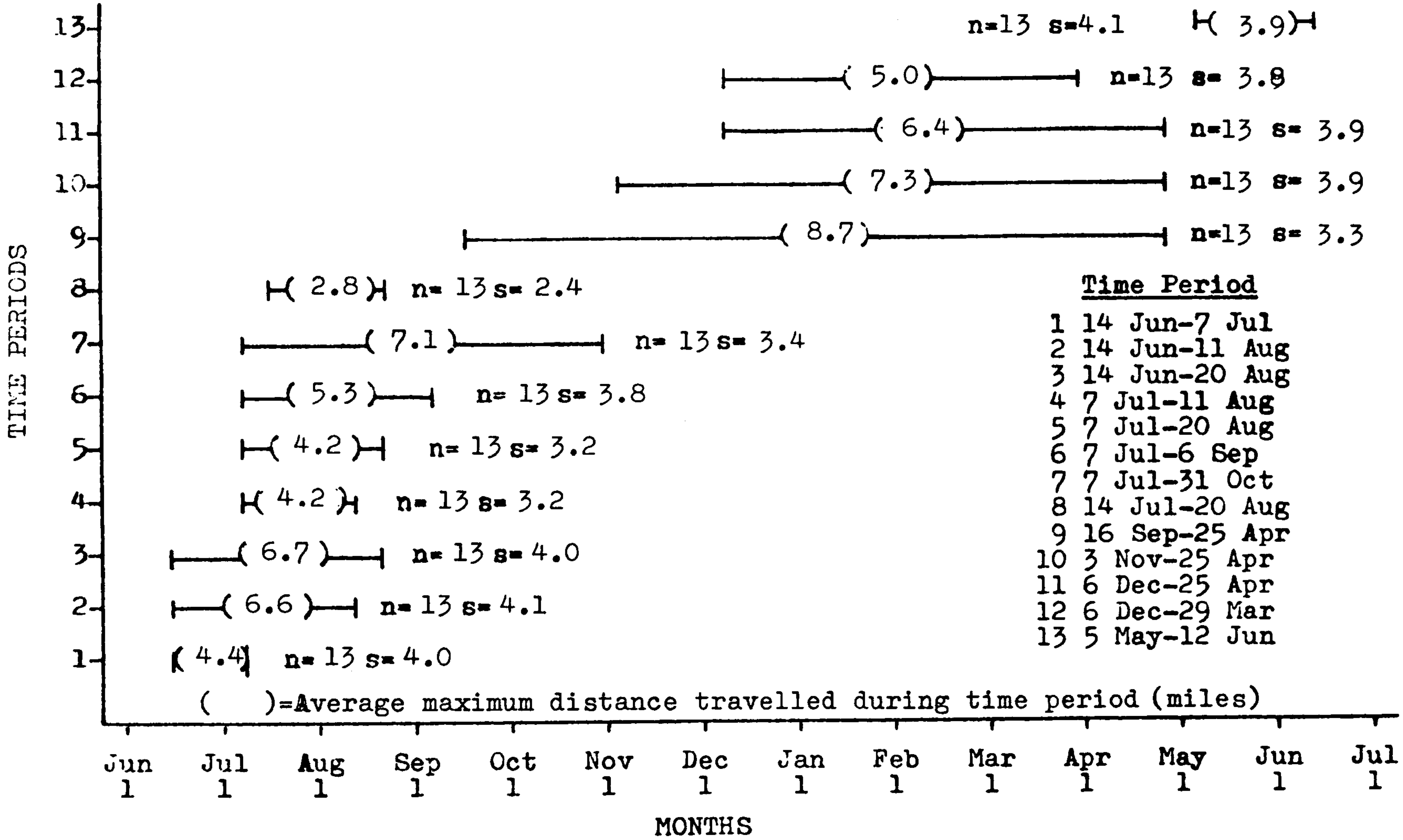
Appendix A. Fig. 8. Average percent fidelity by time period for all collared male goats age 1 and 2, 1979-1984.



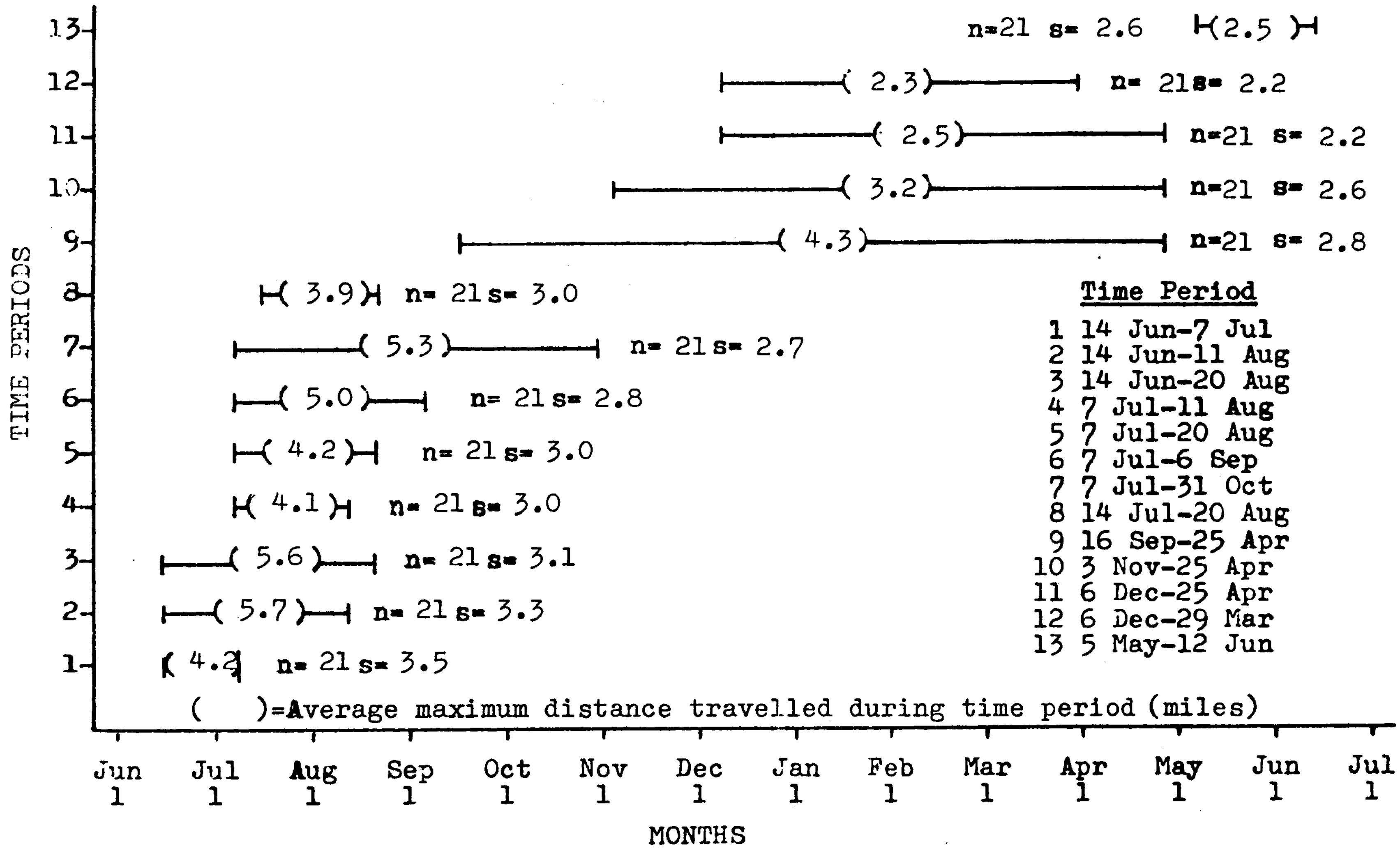
Appendix A. Fig. 9. Average percent fidelity by time period for all collared female goats age 1 and 2, 1979-1984.



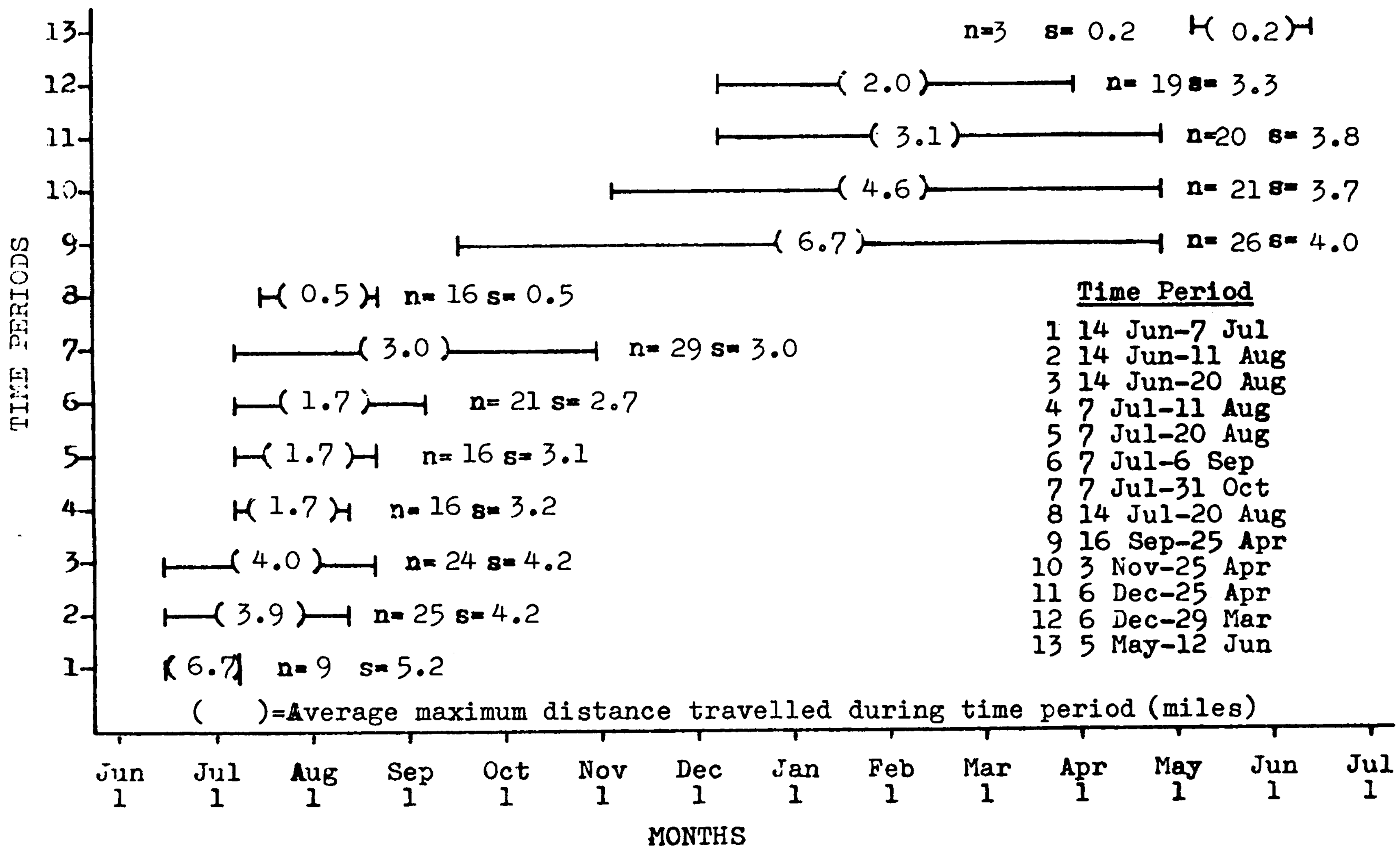
Appendix A. Fig.10. Average maximum distance travelled in miles by time period for all collared goats combined, 1979-1984.



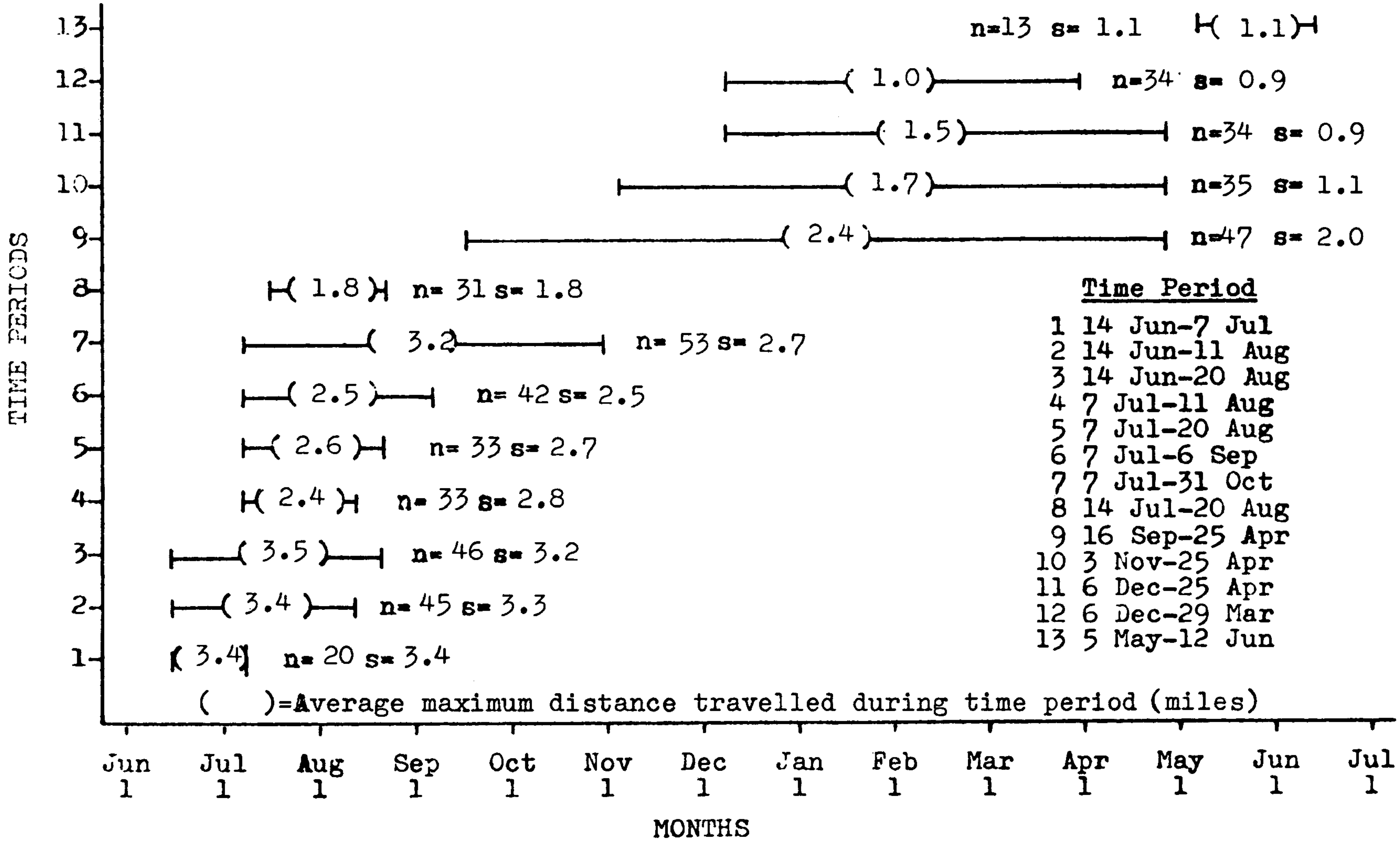
Appendix A. Fig. 11. Average maximum distance travelled in miles by time period for all collared male goats, 1979-1984.



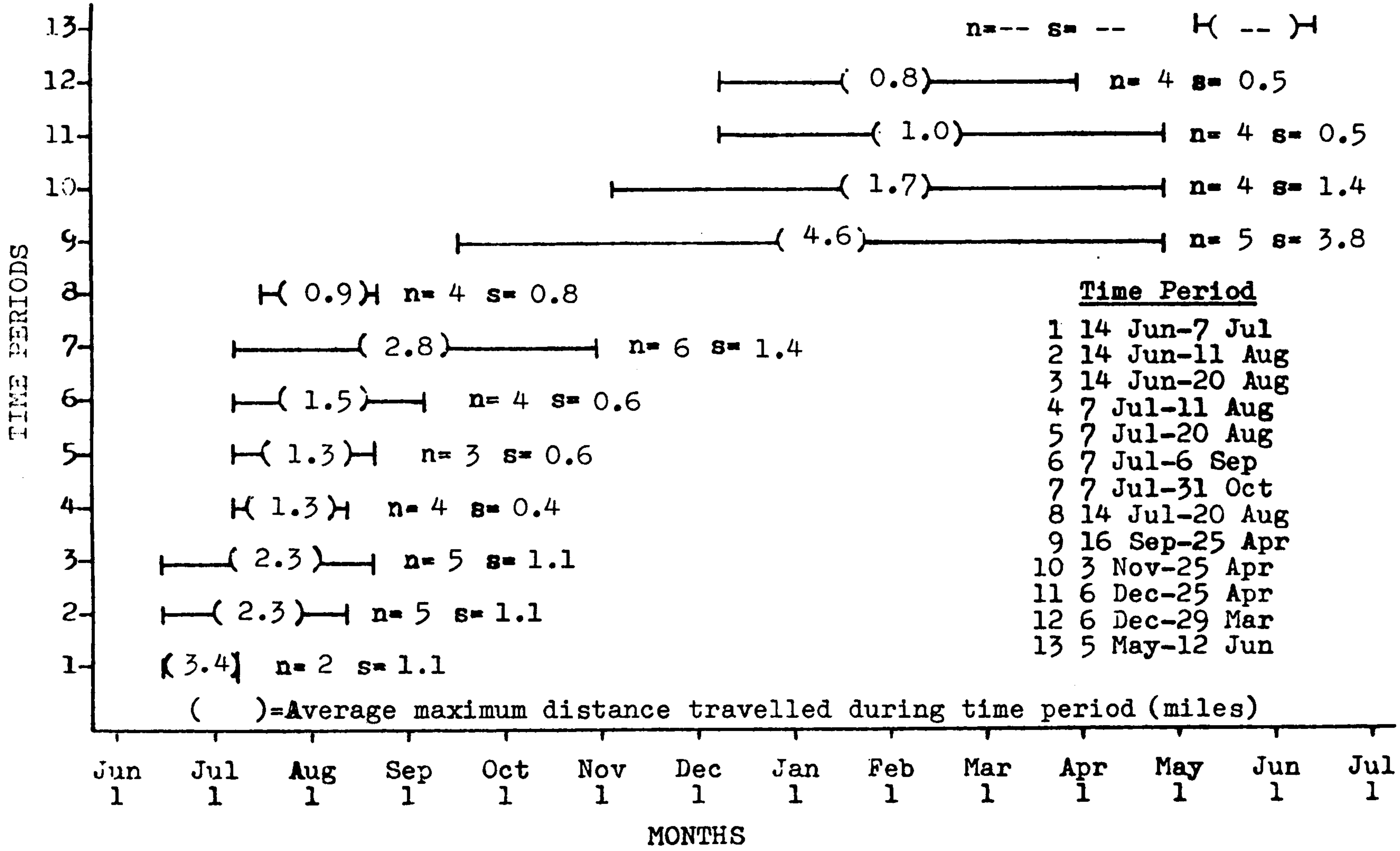
Appendix A. Fig. 12. Average maximum distance travelled in miles by time period for all collared female goats, 1979-1984.



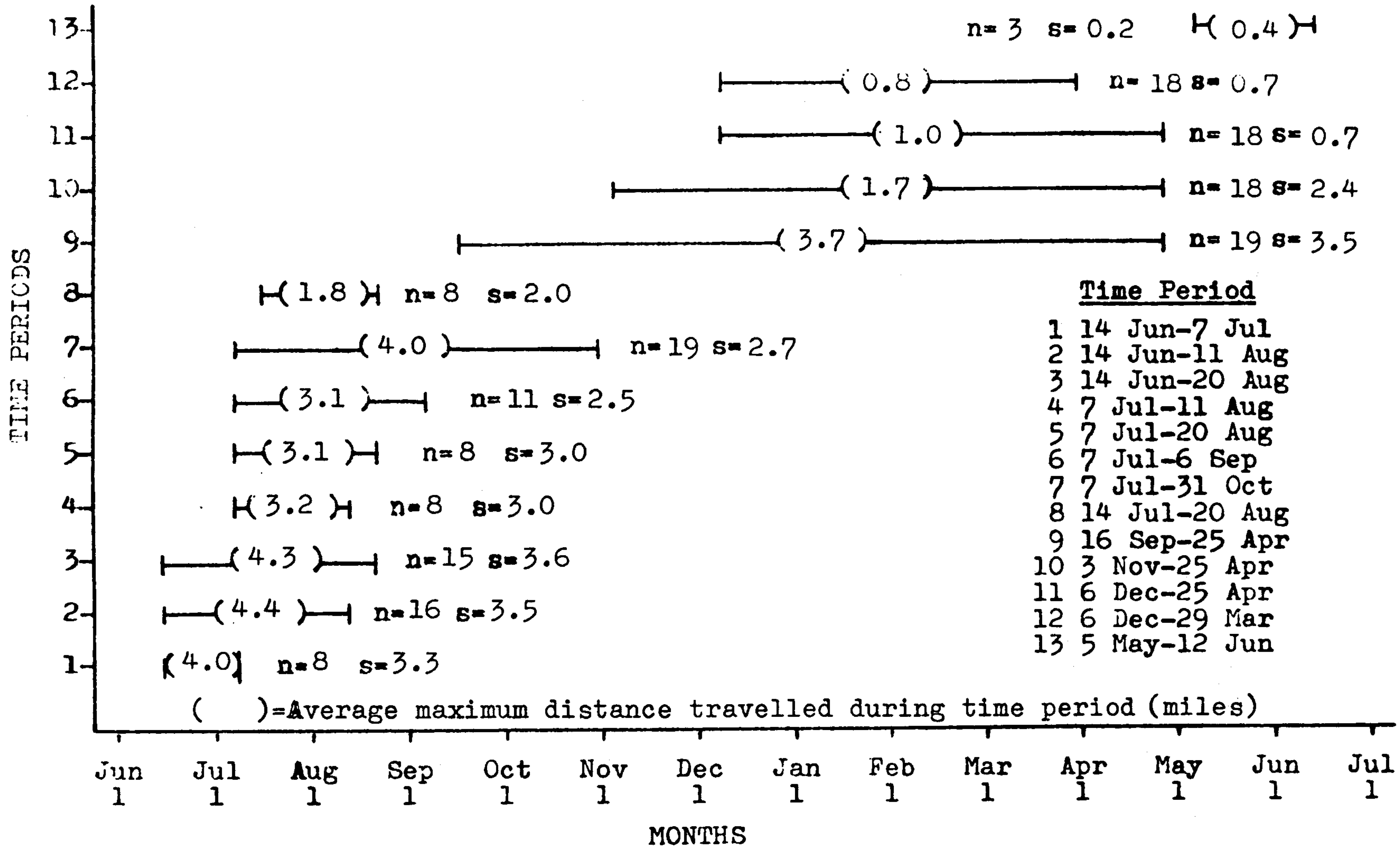
Appendix A. Fig. 13. Average maximum distance travelled in miles by time period for all collared male goats age 5 and over, 1979-1984.



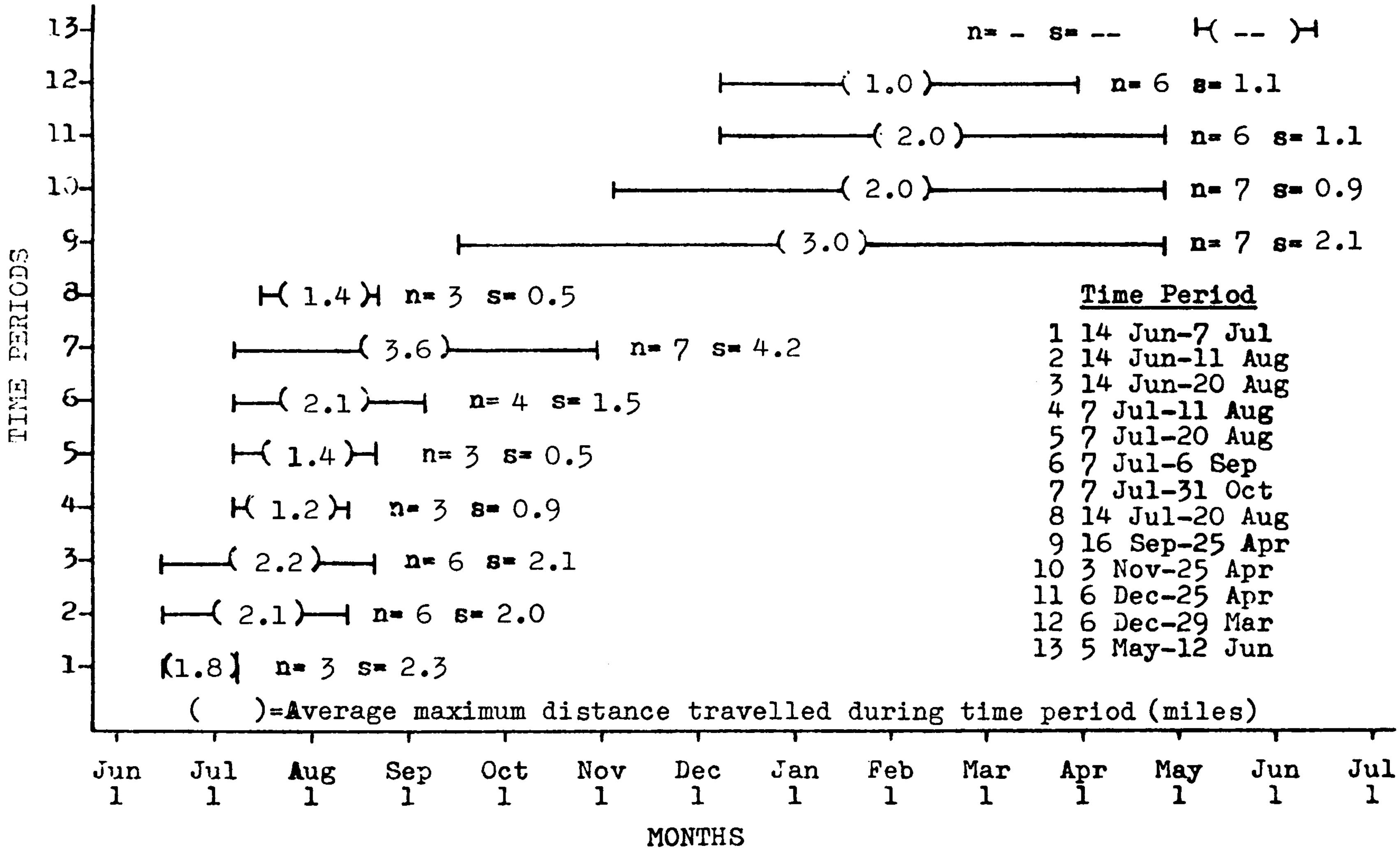
Appendix A. Fig. 14. Average maximum distance travelled in miles by time period for all collared female goats age 5 and over, 1979-1984.



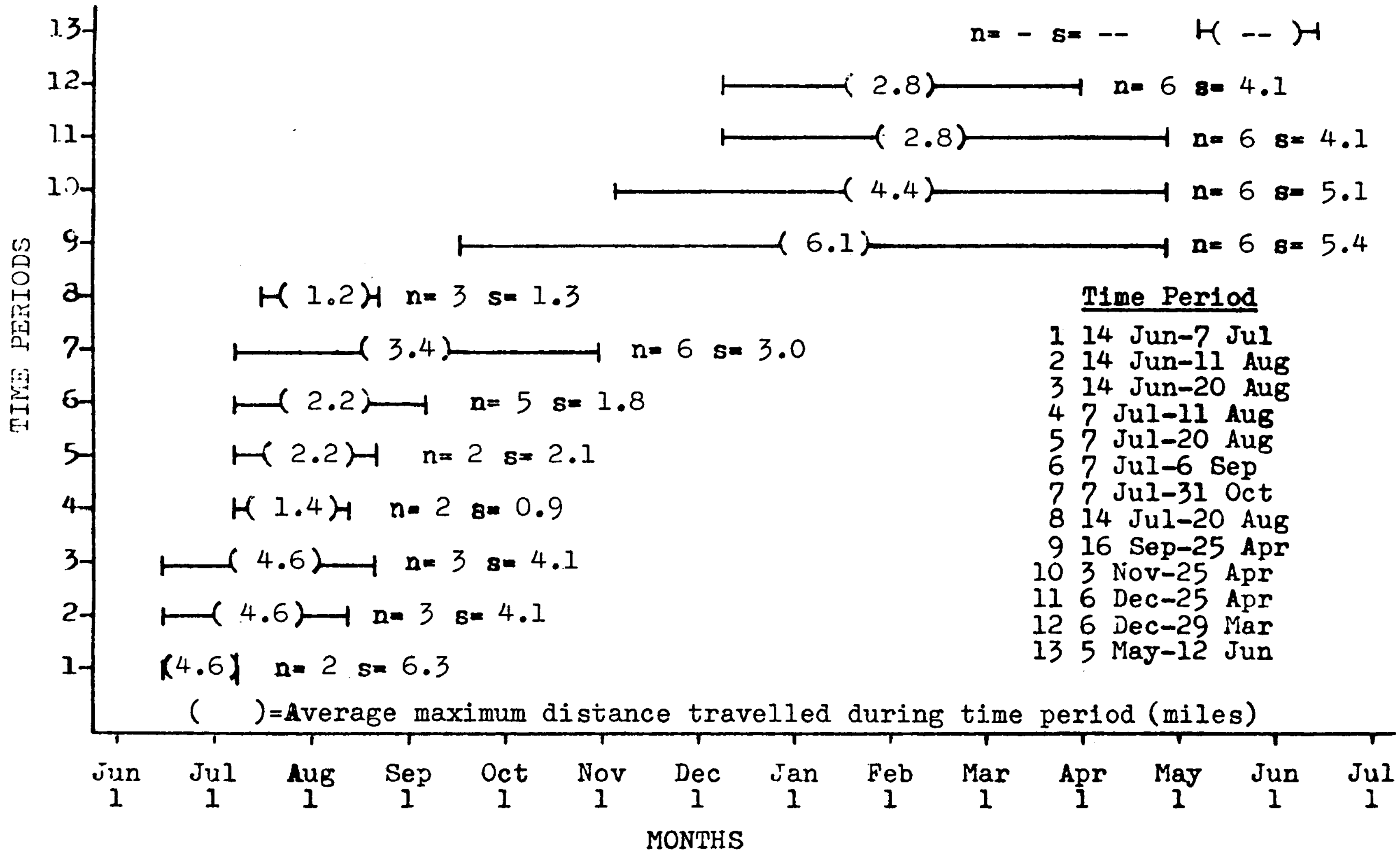
Appendix A. Fig. 15. Average maximum distance travelled in miles by time period for all collared male goats age 3 and 4, 1979-1984.



Appendix A. Fig. 16. Average maximum distance travelled in miles by time period for all collared female goats age 3 and 4, 1979-1984.



Appendix A. Fig. 17. Average maximum distance travelled in miles by time period for all collared male goats age 1 and 2, 1979-1984.



Appendix A. Fig. 18. Average maximum distance travelled in miles by time period for all collared female goats age 1 and 2, 1979-1984.

Appendix A. Tables 1-13. Mean fidelity percentages and maximum distances traveled, as examined by variance and by standard or paired t tests.

Appendix A.

Table 1. Fidelity percentage results of one-way ANOVAR. (Ho: there is no difference in expected fidelity to home range between time periods within each sex or age class).

Sex-Age cohort	df	F	Significance
All goats, all years	12,429	2.849	$P < 0.01$
Male age 1 & 2	12,65	0.659	$P > 0.10$
Male age 3 & 4	12,104	0.415	$P > 0.10$
Male age 5+	12,317	4.247	$P < 0.01$
Female age 1 & 2	12,43	0.940	$P > 0.10$
Female age 3 & 4	12,204	2.091	$P > 0.10$
Female age 5+	12,589	4.183	$P < 0.01$

Appendix A.

Table 2. Maximum distance traveled--results of one-way ANOVAR. (Ho: there is no difference in expected maximum distance traveled between time periods within each sex or age class).

Sex-Age cohort	df	F	Significance
All goats, all years	12,429	3.663	$P < 0.01$
Male age 1 & 2	12,49	0.662	$P > 0.10$
Male age 3 & 4	11,38	2.354	$P < 0.05$
Male age 5+	12,232	5.215	$P < 0.01$
Female age 1 & 2	12,38	0.564	$P > 0.10$
Female age 3 & 4	12,156	3.609	$P < 0.01$
Female age 5+	12,453	4.333	$P < 0.01$

Appendix A.

Table 3. Comparisons of percent fidelity between time periods, all goats all years; only periods with significant differences at $P < 0.05$ or less are shown (standard *t* test, df = 66).

Periods compared	Means percent
1 (6/14 - 7/7)	74.2
4 (7/7 - 8/11)	88.1
1 (6/14 - 7/7)	74.2
5 (7/7 - 8/20)	89.0
1 (6/14 - 7/7)	74.2
8 (7/14 - 8/20)	91.0
1 (6/14 - 7/7)	74.2
10 (11/3 - 4/25)	91.8
1 (6/14 - 7/7)	74.2
11 (12/6 - 4/25)	93.7
1 (6/14 - 7/7)	74.2
12 (12/6 - 3/29)	94.8
2 (6/14 - 8/11)	81.3
8 (7/14 - 8/20)	91.0
2 (6/14 - 8/11)	81.3
10 (11/3 - 4/25)	91.8
2 (6/14 - 8/11)	81.3
11 (12/6 - 4/25)	93.7
2 (6/14 - 8/11)	81.3
12 (12/6 - 3/29)	94.8
3 (6/14 - 8/20)	82.9
10 (11/3 - 4/25)	91.8
3 (6/14 - 8/20)	82.9
11 (12/6 - 4/25)	93.7
3 (6/14 - 8/20)	82.9
12 (12/6 - 3/29)	94.8

Appendix A.

Table 3. Continued.

Periods compared	Means percent
6 (7/7 - 9/6)	87.1
12 (12/6 - 3/29)	94.8
7 (7/7 - 10/31)	84.6
12 (12/6 - 3/29)	94.8
9 (9/16 - 4/25)	85.1
12 (12/6 - 3/29)	94.8
9 (9/16 - 4/25)	85.1
11 (12/6 - 4/25)	93.7

Appendix A.

Table 4. Comparisons between time periods of maximum distance traveled, all goats all years; only periods with significant differences at P < 0.05 or less are shown (standard *t* test, df = 66).

Periods compared	Means percent
1 (6/14 - 7/7)	4.3
2 (6/14 - 8/11)	6.1
1 (6/14 - 7/7)	4.3
3 (6/14 - 8/20)	6.0
1 (6/14 - 7/7)	4.3
7 (7/7 - 10/31)	6.0
2 (6/14 - 8/11)	6.1
4 (7/7 - 8/11)	4.1
2 (6/14 - 8/11)	6.1
8 (7/14 - 8/20)	3.5
2 (6/14 - 8/11)	6.1
11 (12/6 - 4/25)	4.0
2 (6/14 - 8/11)	6.1
12 (12/6 - 3/29)	3.4
2 (6/14 - 8/11)	6.1
13 (5/5 - 6/12)	3.0
3 (6/14 - 8/20)	6.0
4 (7/7 - 8/11)	4.1
3 (6/14 - 8/20)	6.0
8 (7/14 - 8/20)	3.5
3 (6/14 - 8/20)	6.0
11 (12/6 - 4/25)	4.0
3 (6/14 - 8/20)	6.0
12 (12/6 - 3/29)	3.4
3 (6/14 - 8/20)	6.0
13 (5/5 - 6/12)	3.0
4 (7/7 - 8/11)	4.1
7 (7/7 - 10/31)	6.0

Appendix A.

Table 4. Continued.

Periods compared	Means percent
5 (7/7 - 8/20)	4.2
7 (7/7 - 10/31)	6.0
6 (7/7 - 9/6)	5.1
8 (7/14 - 8/20)	3.5
6 (7/7 - 9/6)	5.1
12 (12/6 - 3/29)	3.4
6 (7/7 - 9/6)	5.1
13 (5/5 - 6/12)	3.0
7 (7/7 - 10/31)	6.0
8 (7/14 - 8/20)	3.5
7 (7/7 - 10/31)	6.0
11 (12/6 - 4/25)	4.0
7 (7/7 - 10/31)	6.0
12 (12/6 - 3/29)	3.4
7 (7/7 - 10/31)	6.0
13 (5/5 - 6/12)	3.0
8 (7/14 - 8/20)	3.5
9 (9/16 - 4/25)	6.0
9 (9/16 - 4/25)	6.0
11 (12/6 - 4/25)	4.0
9 (9/16 - 4/25)	6.0
12 (12/6 - 3/29)	3.4
9 (9/16 - 4/25)	6.0
13 (5/5 - 6/12)	3.0
10 (11/3 - 4/25)	4.7
13 (5/5 - 6/12)	3.0

Appendix A.

Table 5. Comparisons of percentage of fidelity by sex and age class over all time periods and years; only cohorts with significant differences at $P < 0.05$ or less are shown (paired *t* test).

Cohorts compared	Mean	df	*t*
All males	83.5		
All females	90.2	440	3.651
Male ages 1 & 2	94.0		
Male ages 3 & 4	84.2	12	3.559
Male ages 1 & 2	94.0		
Male ages 5+	85.6	12	2.654
Female ages 3 & 4	84.7		
Female ages 5+	90.7	12	3.895

Appendix A.

Table 6. Comparisons of maximum distance traveled by sex and age class over all time periods and years; only cohorts with significant differences at P < 0.05 or less are shown (paired *t* test).

Cohorts compared	Mean miles	df	*t*
All males	5.6		
All females	4.1	440	4.689
Male ages 3 & 4	2.0		
Male ages 5+	3.3	11	3.877
Male ages 1 & 2	2.0		
Male ages 5+	3.3	11	2.594
Female ages 3 & 4	2.7		
Female ages 5+	2.3	12	2.281
Male ages 1 & 2	2.0		
Female ages 1 & 2	3.4	11	3.811
Male ages 3 & 4	2.0		
Female ages 3 & 4	2.9	11	3.265

Appendix A.

Table 7. Comparisons of percent fidelity between sexes by time period; only periods with significant differences at $P < 0.05$ or less are shown (standard *t* test, df = 32.

Period	Mean male percent	Mean female percent	*t*
5 (7/7 - 8/20)	89.0	97.5	2.118
9 (9/16 - 4/25)	71.4	93.7	4.220
10 (11/3 - 4/25)	82.5	97.5	3.743
11 (12/6 - 4/25)	85.9	98.6	3.437
12 (12/6 - 3/29)	87.5	99.2	2.797

Appendix A.

Table 8. Comparisons between sexes of maximum distance traveled by time period; only periods with significant differences at $P < 0.05$ or less are shown (standard *t* test, df = 32).

Period	Mean male miles	Mean female miles	*t*
9 (9/16 - 4/25)	8.7	4.3	4.179
10 (11/3 - 4/25)	7.3	3.2	3.738
11 (12/6 - 4/25)	6.4	2.5	3.764
12 (12/6 - 3/29)	5.0	2.3	2.605

Appendix A.

Table 9. Comparisons between sexes of percent fidelity by age class and time period; only periods and sex-age cohorts with significant differences of $P < 0.05$ or less are shown (standard *t* test).

Time period	Age cohort	Male mean percentage	Female mean percentage	df	*t*
9 (9/16 - 4/25)	5+	67.7	97.2	78	6.287
10 (11/3 - 4/25)	5+	86.2	97.2	73	2.392
11 (12/6 - 4/25)	5+	89.2	99.6	71	2.908
12 (12/6 - 3/29)	5+	87.8	99.6	71	2.746

Appendix A.

Table 10. Comparisons between sexes of maximum distance traveled by age class and time period; only periods and sex-age cohorts with significant differences at $P < 0.05$ or less are shown (standard *t* test).

Time period	Age cohort	Mean male distance/mi	Mean female distance/mi	df	*t*
8 (7/14 - 8/20)	5+	0.5	1.8	45	2.791
9 (9/16 - 4/25)	5+	6.7	2.4	71	6.217
10 (11/3 - 4/25)	5+	4.6	1.7	54	4.380
11 (12/6 - 4/25)	5+	3.1	1.5	52	2.443

Appendix A.

Table 11. Comparisons between age cohorts of fidelity percentage by time period and sex; only time periods and sex-age cohorts with significant differences at $P < 0.05$ or less are shown (standard *t* test).

Time period	Sex	Age cohort	Mean percentage	df	*t*
8 (7/14 - 8/20)	M	3 & 4	81.3		
		5+	100.0	32	2.665
7 (7/7 - 10/31)	F	3 & 4	71.6		
		5+	89.9	70	3.039
9 (9/16 - 4/25)	F	3 & 4	90.1		
		5+	97.2	68	2.243
9 (9/16 - 4/25)	F	1 & 2	79.5		
		5+	97.2	55	3.694

Appendix A.

Table 12. Comparisons between age cohorts of maximum distance traveled by sex and time period; only time periods and sex-age cohorts with significant differences at $P < 0.05$ or less are shown (standard *t* test).

Time period	Sex	Age cohort	Mean distance/mi	df	*t*
8 (7/14 - 8/20)	M	1 & 2	1.4		
		5+	0.5	17	3.154
9 (9/16 - 4/25)	M	1 & 2	3.0		
		5+	6.7	31	2.343
9 (9/16 - 4/25)	F	3 & 4	3.7		
		5+	2.4	64	2.035
9 (9/16 - 4/25)	F	1 & 2	6.1		
		5+	2.4	51	3.453
10 (11/3 - 4/25)	F	1 & 2	4.4		
		5+	1.7	39	2.945
12 (12/6 - 3/29)	F	1 & 2	2.8		
		5+	1.0	38	2.312

Appendix A.

Table 13. Chi-squared comparisons between percentage of sex and age classes that are 100% faithful to their expected range in summer (7/14-8/20) and in winter (12/6-3/29). Only those percentages and sex-age cohorts that are significantly different at $P < 0.05$ or less are shown (df = 1).

Classes compared[a]	Mean of class 1	Mean of class 2	χ^2
Summer			
All vs all age 5+	71	87	6.79
All vs M age 5+	71	100	32.16
All 5+ vs all 4-	87	58	19.29
M 5+ vs F 5+	100	78	22.77
M 5+ vs M 4-	100	57	52.10
F 5+ vs F 4-	78	58	7.87
F 5+ vs M 4-	78	57	8.84
Winter			
All vs all M	77	54	10.37
All vs all F	77	91	6.13
All vs M age 5+	77	33	35.78
All vs F age 5+	77	89	4.54
All vs F age 4-	77	92	7.54
All M vs all F	54	91	31.71
All 5+ vs all 4-	67	84	7.35
M 5+ vs F 5+	33	89	62.71
M 4- vs F 4-	71	92	12.38
M 5+ vs M 4-	33	71	27.59
F 5+ vs M 4-	89	71	8.56

[a] "All" refers to all collared goats used in analysis (n = 34); age 5+ refers to all goats collared at age 5 or older; age 4- refers to all collared at age 4 or less.