Risk Associated with Long-distance Movements by Desert Tortoises

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Abstract. Since 1991, we studied desert tortoises (*Gopherus agassizii*) to determine the effectiveness of tortoise barrier fences in the western Mojave Desert. We attached small radio transmitters to 54 permanently marked desert tortoises and conducted carcass surveys for these and other tortoises along 24 km of fenced and 24 km of unfenced highway.

Fifteen (28%) of our transmitter-affixed study animals made relatively straight-line movements of 0.8 to 15.5 km during April-June in 1992 and/or 1993. Six (40%) of these long distance movers were immature animals at the start of each study period. Eight (53%) were subadults, while only one was an adult.

Carcass surveys along 24 km of State Highway 58 that had barrier fencing showed that no tortoises perished along this stretch of highway whereas 18 carcasses were found along a comparable stretch of State Hwy 395 without barrier fencing.

Our study results indicate a high proportion of tortoises in the study area made long distance movements and virtually no tortoises were killed along a stretch of highway with a barrier fence. We have not documented that tortoises were killed on the road as a result of long-distance movements during the study, but tortoises probably increase their risk of being killed on roads while making such movements, particularly where major highways remain unfenced.

INTRODUCTION

Animals are generally believed to make long-distance movements to satisfy various life requisites including: foraging, locating mates and suitable habitat for mating, egg laying, rearing of young, and hibernation. Such movements in a relatively pristine environment may represent an adaptive advantage to individual species, in spite of any exposure to increased risk of natural mortality. Expanding human development into natural habitats places animals under additional mortality risk, especially animals engaged in long-distance movements.

During 1990, a jointly sponsored study was initiated by the Bureau of Land Management, California Energy Commission, California Department of Fish and Game, California Department of Transportation, and the U.S. Fish and Wildlife Service to assess the effectiveness of a tortoise fence barrier erected by the California Department of Transportation along a portion of State Highway (Hwy) 58 between Mojave and Barstow, California. The purpose of the fence was to prevent desert tortoises (*Gopherus agassizii*), a state and federal listed "threatened" species, from being hit and killed by vehicles in an area considered to be important tortoise habitat.

The study goal was to address four questions that would serve as the focus of this anticipated long-term project. First, is the fence an effective barrier for preventing tortoises from being killed on the road? Second, does the fence facilitate "recovery" of the tortoise population near the highway? Third, do culverts facilitate movements from one side of the highway to the other. And fourth, how do individual tortoises behave when they encounter the fence and culverts? The overall project background and study design is fully described in Boarman, et al. (1993) and Boarman and Sazaki (1994).

In 1992 and 1993, we noted that during April through June, some of the tortoises affixed with transmitters exhibited what we characterized as net linear or long-distance movements. Net linear movement was the straight-line distance between a given tortoise's location at the start and end of the tracking period each year. We considered these movements outside the bounds of typical activity areas or home ranges, which were more or less established by the majority of known tortoises on our square-mile study plot. In this report we describe these long-distance movements. We discuss the implications of nearby heavily traveled highways posing additional mortality risk to tortoises in the general area of our study plot.

Also, we discuss general results of surveys for dead tortoises conducted on the stretch of highway with a tortoise barrier fence located adjacent to our study plot versus a similar but unfenced stretch of highway in the vicinity. This discussion provides for a preliminary examination of the potential for tortoises traveling long-distances to encounter, attempt to cross, and become killed on highways that act as mortality sinks for the species.

METHODS

All tortoises included in the study were assigned unique numbers for identification and marked systematically by writing the tortoise number on a white paint spot applied to the forth right costal scute and by notching the marginal scutes according to a coding scheme used on BLM permanent study plots in the Mojave Desert (Berry, 1988). In addition, passive integrated transponder (PIT) tags were attached to most tortoises found on or near the study plot and radio transmitters were affixed to the tortoises we intended to track for home range determinations. Methods used to attach PIT tags and transmitters were provided in Boarman (1991).

Attempts were made to locate each transmitter-carrying tortoise two to four times per week during each spring season. Each time a tortoise was found, its location was mapped and its behavior was observed for a minimum of five minutes and noted. At least twice during the spring season, each tortoise was checked for discernable identification marks, weighed, sexed, measured, photographed, and observed for health status using methods outlined in BLM (1991). Aerial-tracking flights were conducted each year to search for tortoises that exhibited long-distance movements or tortoises that had become lost to our ground-based tracking efforts.

Tortoises tracked to the edge of unfenced highways were safely carried across in the direction in which they were traveling to reduce the likelihood of their being killed; thus, for purposes of the highway mortality aspects of the study, these animals were eliminated from further analysis.

Surveys for carcasses were conducted 2 -18 July, 1992 and 13-16 July, 1993. Twenty-four km long transects were surveyed along both edges of the highway east and south of the Highway 58 and Highway 395 junction. Each carcass survey transect was 10 m wide and centered approximately 5 m from the paved roadway. The Highway 58 route was fenced and the carcass survey began approximately 5.8 km east of the junction and extended east for 24 km. The Highway 395 route was not fenced and the survey began 12.3 km south of the junction and ran south for 24 km. Each observer walked parallel to the highway, at the unpaved edge of the graded shoulder, and scanned the ground for any tortoise remains or signs. If several tortoise fragments were found in a cluster generally less than 7 m in diameter, it was assumed they were from a single animal. After locating the remains of a tortoise and prior to any disturbance for closer examination, data were recorded and the remains were photographed. A unique carcass number was assigned and the location along the transect was noted and mapped. The physical conditions of the highway edge, including shoulder width, were recorded. The final step was to collect and bag each group of tortoise remains for later analysis. Similar data were also collected on other dead vertebrate species found on the transects. The species of all carcasses found on the unpaved shoulder were identified, times since death were estimated, and the locations of the carcasses were mapped.

RESULTS

We detected several instances where tortoises made long-distance movements as estimated by determining the straight-line distance between the two most distant locations at which each tortoise was located over the study period. We defined long-distance movement to be greater than or equal to 0.8 km. Also, this movement was obviously external to the normal, seasonal activity area or home range of individual tortoises, as suggested by our tracking results.

In 1992, eight animals made such linear movements (Table 1) (Figs. 1-3): three females, two males, and three unknown because they were too small to be sexed. All were subadult or immatures. The maximum distance moved by these tortoises was 7.0 km. Tortoise #78 was first found and marked on May 26 about 0.4 km east of

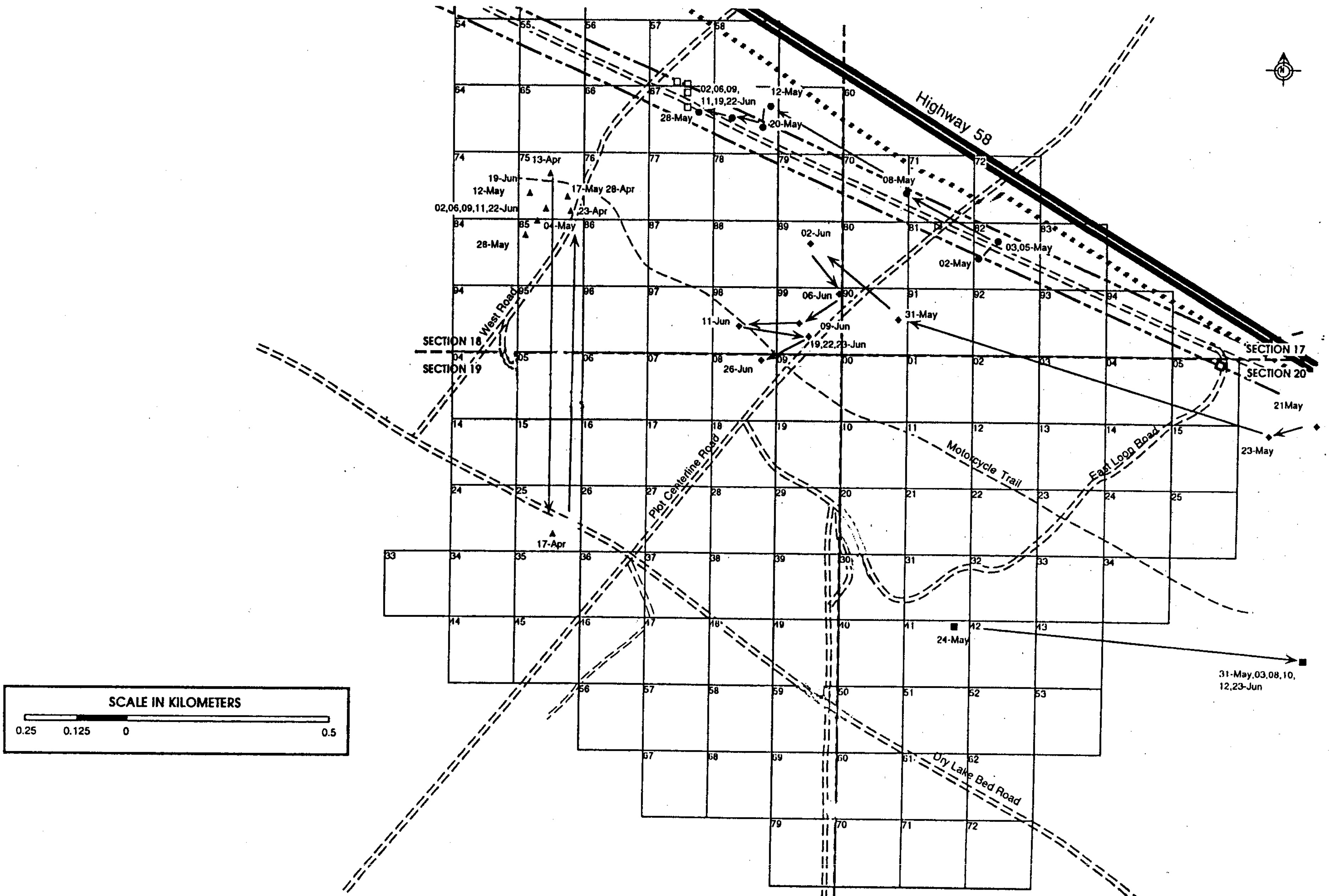

Figure 1. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1992. Various sightings indicated by day and month (▲=Tortoise #52 --- ●=Tortoise #23 --- ♦=Tortoise #75 --- ■=Tortoise #77).

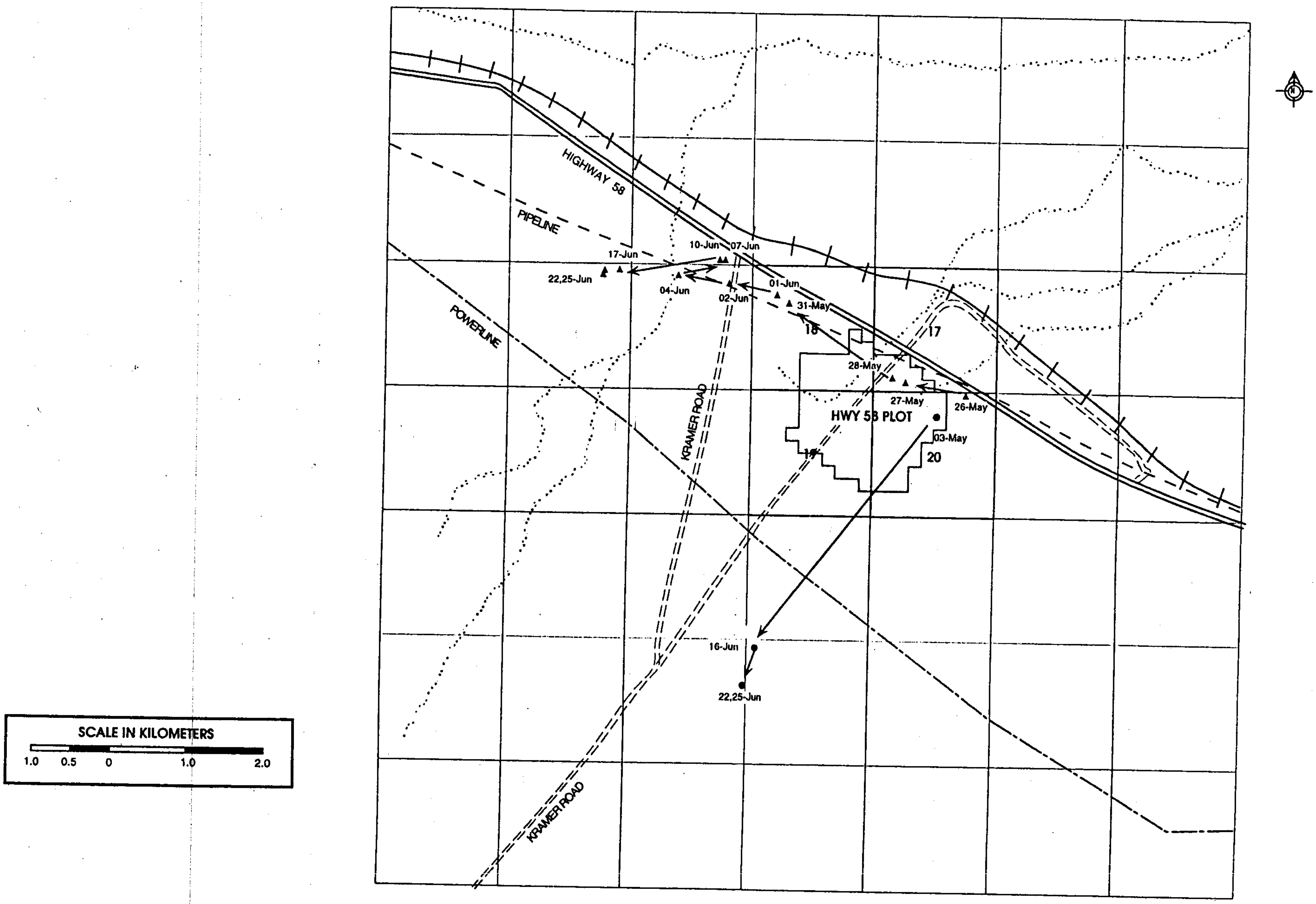

Figure 2. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1992. Various sightings indicated by day and month (▲=Tortoise #78 --- ●=Tortoise #32).

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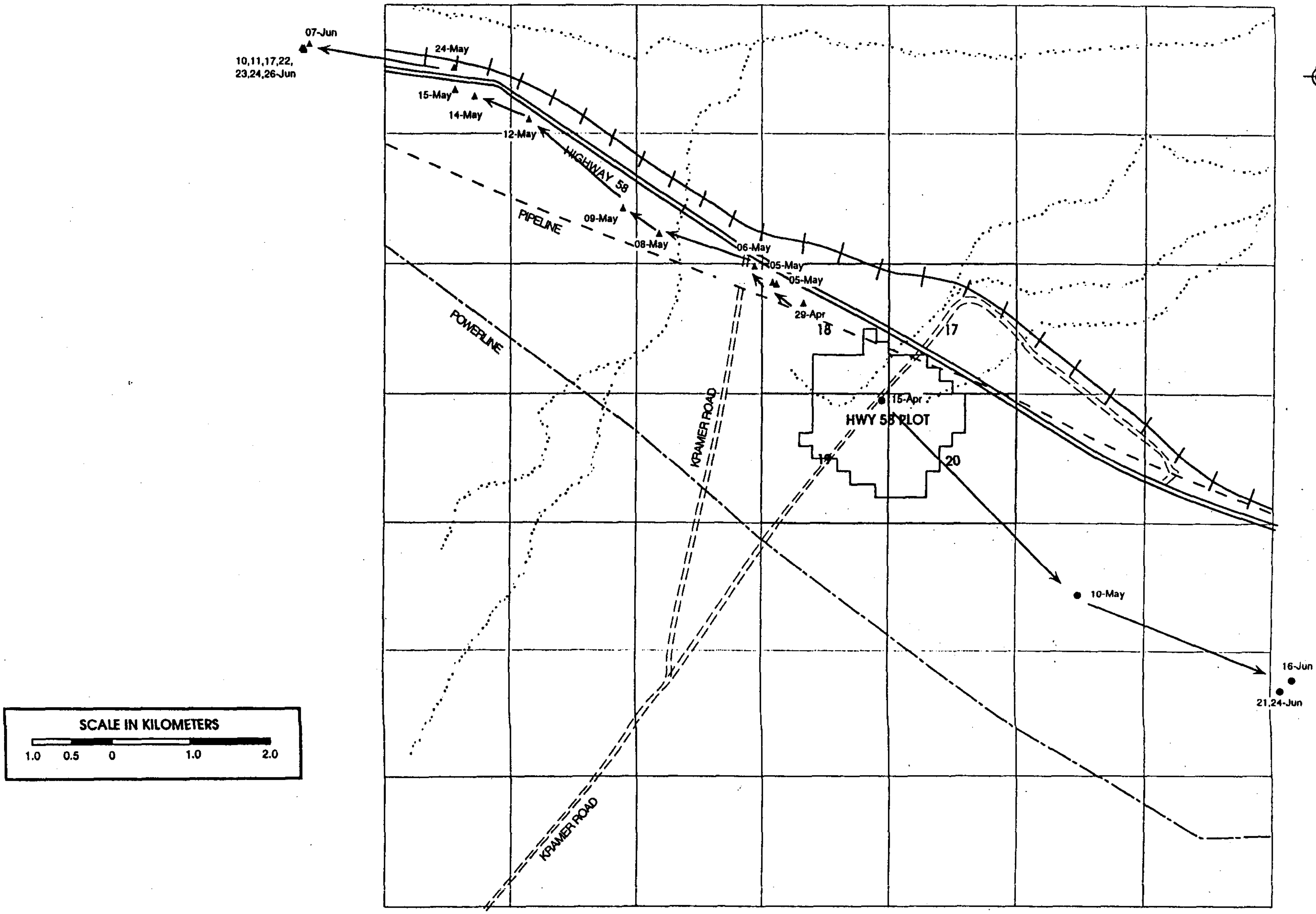

Figure 3. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1992. Various sightings indicated by day and month (▲=Tortoise #72 --- ●=Tortoise #15).

Table 1. Long-distance (≥ 0.8 km) linear movements of desert tortoises at the Highway 58 tortoise barrier study plot during April - June, 1992.

Tortoise ID #	Sex	Size/Age Class	Size MCL[1] (mm)	Linear Distance[2] (km)
15 Female	Subadult	191	6.2	
23	Unknown	Immature 2	142	0.8
32	Male	Subadult	202	4.5
52	Unknown	Immature 2	162	4.6
72	Unknown	Immature 2	163	7.0
75	Female	Subadult	201	1.8
77	Female	Subadult	199	0.8
78	Male	Subadult	183	5.0

1 - MCL = Midline Carapace Length
2 - Linear distance = straight-line distance between two most distant points.

Table 2. Long-distance (≥ 0.8 km) linear movements of desert tortoises at the Highway 58 tortoise barrier study plot during April - June, 1993.

Tortoise ID #	Sex	Size/Age Class	Size MCL[1] (mm)	Linear Distance[2] (km)
48	Unknown	Immature 2	157	1.6
62	Unknown	Immature 1	123	7.0
77	Female	Subadult-Adult 1	208	2.6
88	Unknown	Immature 2	151	2.9
91	Female	Subadult	193	5.0
111	Male	Adult 1	214	13.3
114	Female	Subadult	200	15.5
123	Female	Subadult	183	4.5

1 - MCL = Midline Carapace Length
2 - Linear distance = straight-line distance between two most distant points.

the study plot. By June 25, it had crossed through the plot and was about 3.5 km to the west when the tracking period concluded. This tortoise was classified as a transient because it traveled completely through the study plot.

Four of the tortoises (#15, 32, 52, and 72) were not found again after the 1992 tracking season, three (#23, 75, and 78) stayed in the vicinity of their final 1992 locations throughout the 1993 season, and one (#77) moved to a new location in 1993.

In 1993, eight tortoises made long-distance movements (Table 2) (Figs. 4-8), ranging from 1.6 to 15.5 km. Tortoise #77, a long-distance mover in 1992, repeated as a long-distance mover in 1993. Four of the eight tortoises were females, one was a male, and the remaining three were too small to make sex determinations. All the tortoises making long-distance movements in 1993, except for one adult male, were subadult or immatures at the start of the tracking season. One subadult female grew into an adult 1 age class before the end of the 1993 tracking period. The sex composition of long-distance movers was similar in both years.

Tortoise #111 and 114 were transients in 1993, and made the longest movements, 13.3 and 15.5 km respectively. Overall, the majority of long-distance movements by individuals of known sex were made by females (7 versus 3 males). Two tortoises made excursions out of their respective activity areas and subsequently returned before the end of the tracking period. Tortoise #52 (Fig. 1) did so in 1992 and tortoise #77 (Fig. 4) did it in 1993.

Field investigators carried tortoise #72 safely across Hwy 58 in 1992, and tortoise #111 across Hwy 395 in 1993. Both tortoises appeared to be attempting to cross these highways at the time. After its initial encounter and processing by field investigators, tortoise #114 passed under a gate in the Hwy 58 fence. This tortoise was found on the highway side of the fence apparently attempting to get back onto the study plot side. The tortoise was captured and released on the study plot side of the fence. Subsequently, it moved off the plot to the south.

Tortoise carcass surveys revealed that after an attempt to remove all prior evidence of dead tortoises was made in 1991, remains were found of one tortoise in 1992 and none in 1993, along the 24 km fenced section of Hwy 58 (Table 3). The remains of the one tortoise found along the fenced portion of Hwy 58 was judged to have been overlooked in 1991, based on a shell disintegration assessment devised by Woodman and Berry (1984). Along the 24 km unfenced section of State Highway 395, remains of 14 desert tortoises were collected in 1992, and 5 in 1993.

DISCUSSION

In a paper describing likely reasons for long-distance movements by freshwater turtles on the Savannah River Plant in South Carolina, Gibbons (1986) considered whether there could be any applicability of the movement patterns of these populations to the management of the desert tortoise. He was particularly interested in relocation of tortoises to avoid the impacts of human related development. He suggested four long-distance movement phenomena including mate-seeking movement by males, nesting site selection, movement in response to adverse environmental conditions, and movement to hibernacula. Gibbons also stated that no information was available to suggest that desert tortoises were actually exhibiting long-distance movements for these reasons, but until more study could explain this aspect of desert tortoise behavior, successful relocation of tortoises as a management tool would lead to uncertain results.

Regardless of the reasons that desert tortoises make long-distance movements, many investigators have noted this phenomenon. In the western Rand Mountains northeast of California City, Kern County, California, Berry (1975) studied the movements of twenty-five translocated desert tortoise in the early 1970's. Of the seven tortoises affixed with transmitters, three exhibited straight-line movements from 1.26 to 1.44 km. Berry utilized aerial tracking to assist in making these determinations.

Burge (1977) monitored desert tortoises near the base of the Spring Mountains southwest of Las Vegas, Nevada, to determine daily and seasonal activity, distances traveled, and home range. She found that single trip distances did not exceed .434 km. Included in her study were ten tortoises affixed with transmitters. Four of these tortoises were only tracked for two to nine months of the fifteen month study period. Burge (1977) offered no

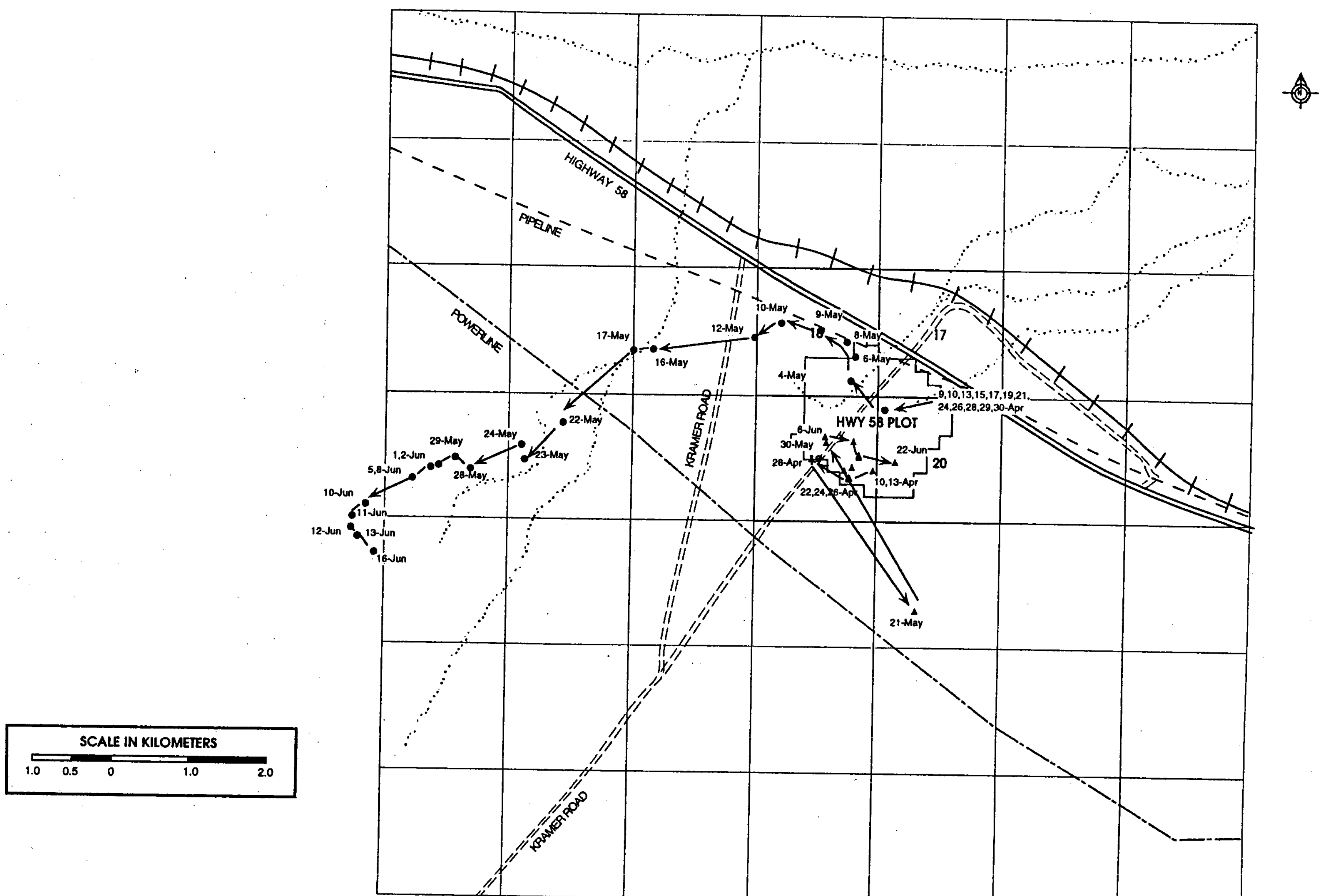

Figure 4. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #77 --- ●=Tortoise #62).

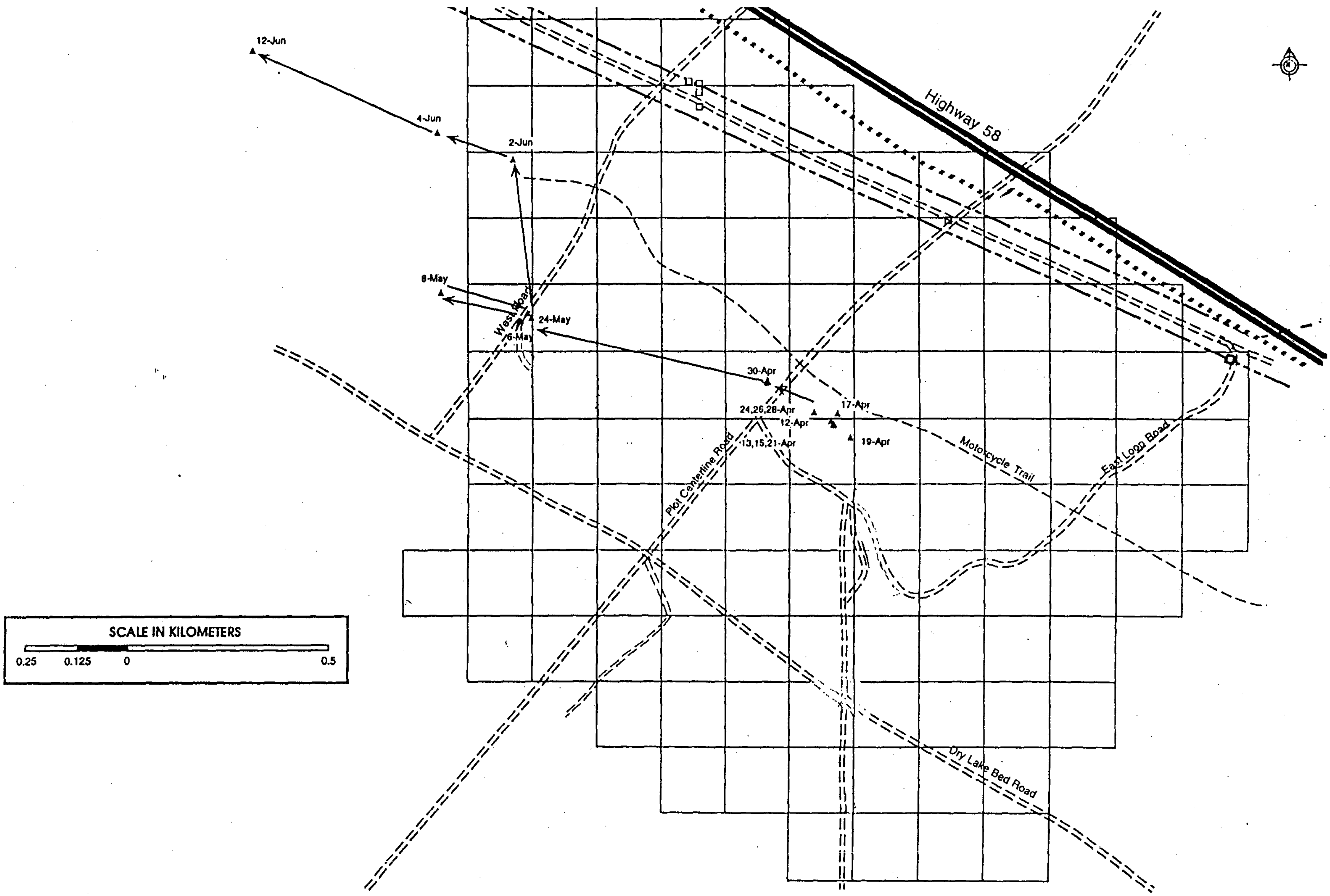

Figure 5. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #48).

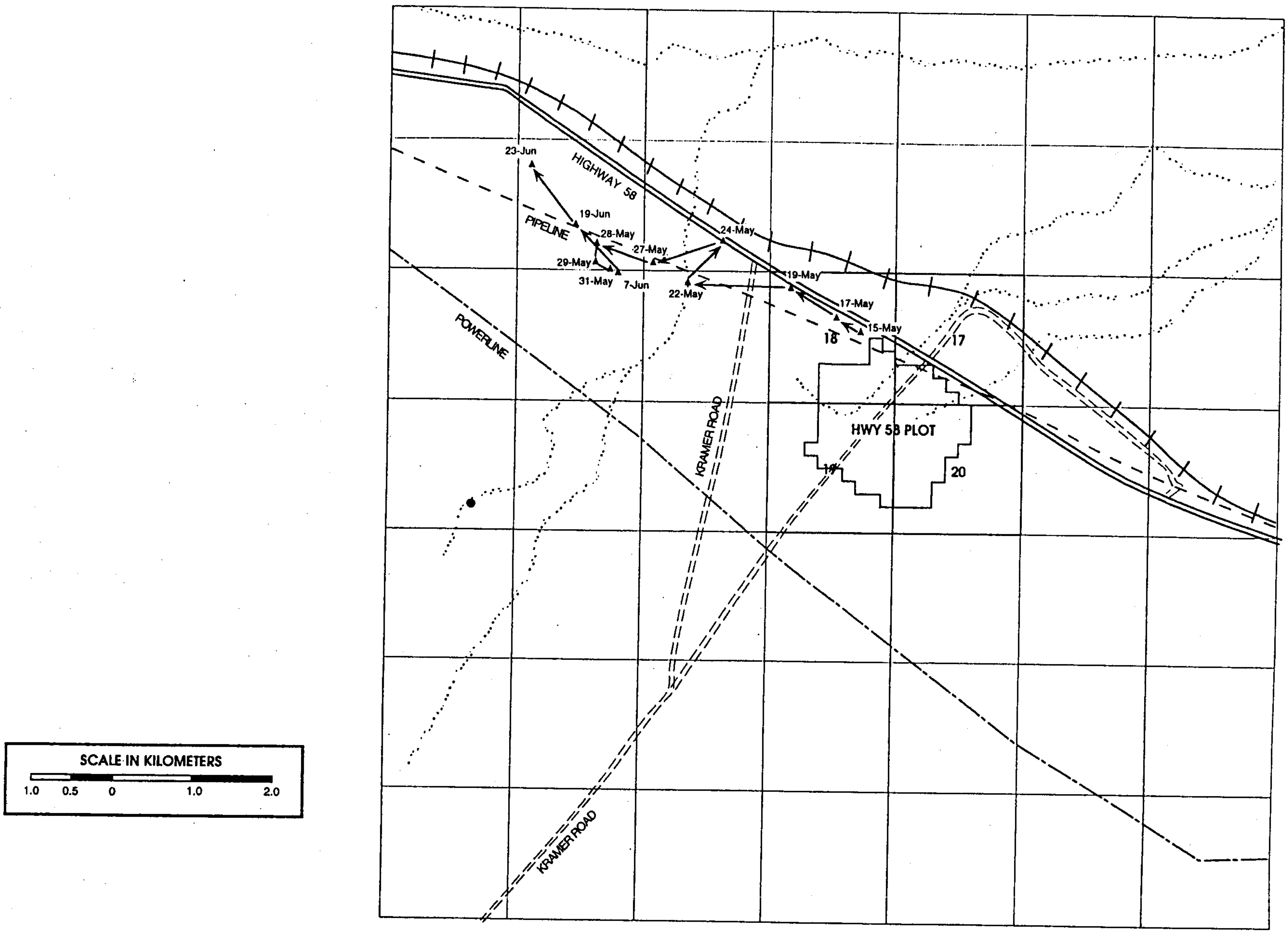

Figure 6. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #123).

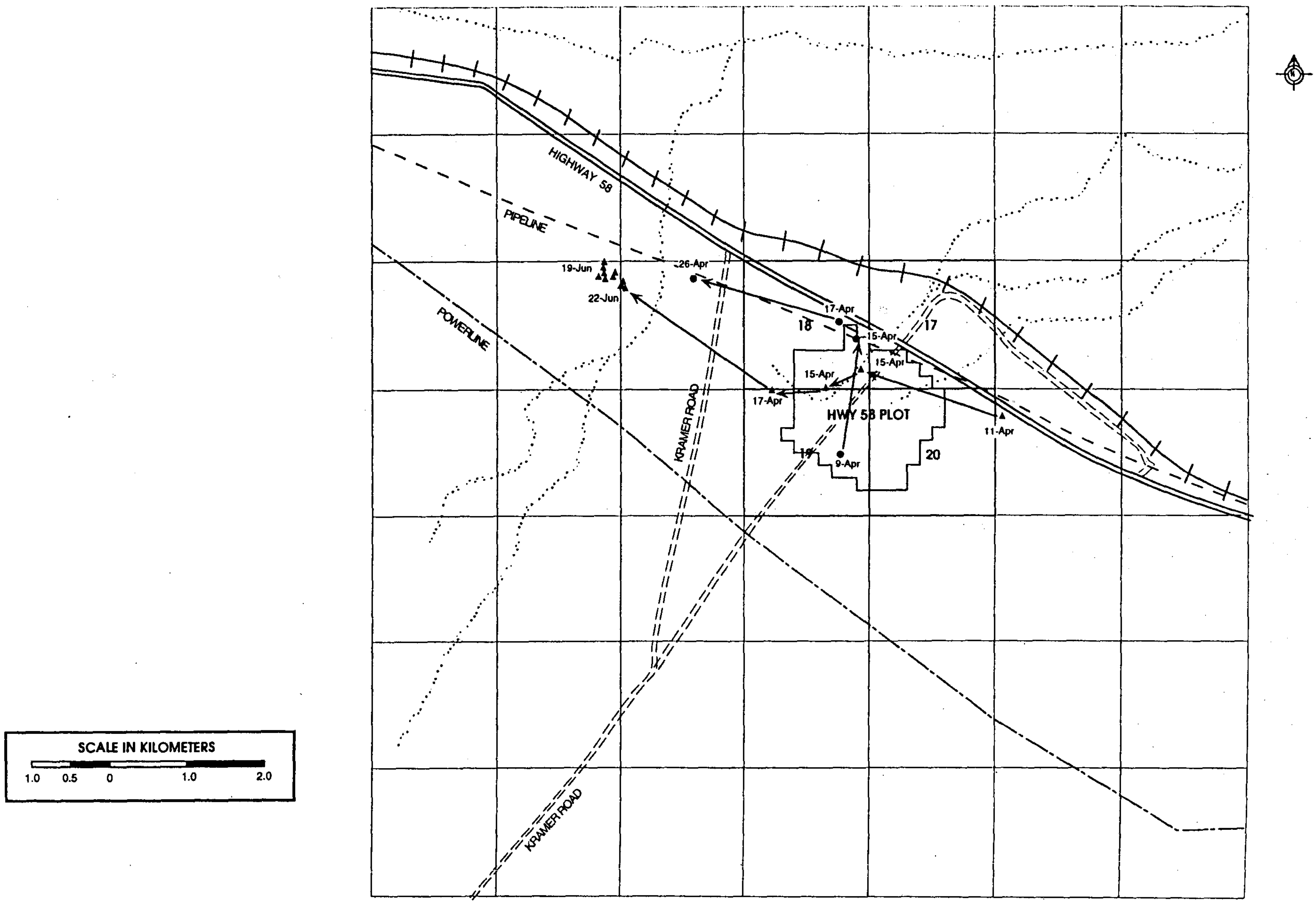

Figure 7. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #91 --- ●=Tortoise #88).

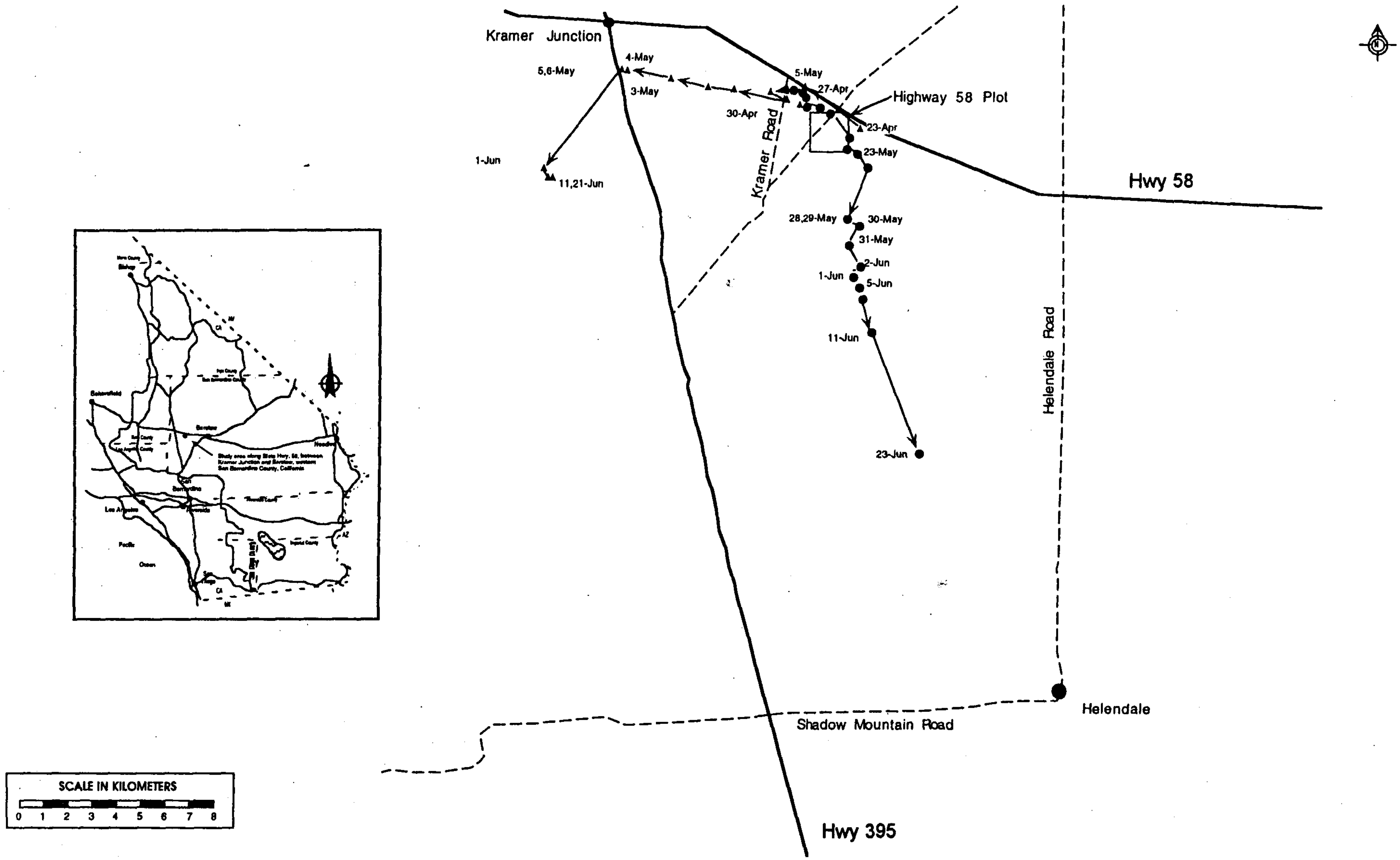

Figure 8. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #111 --- ●=Tortoise #114).

explanation for not tracking these tortoises for the entire study. Tracking them may have been discontinued due to transmitter failure, or because these tortoises moved beyond the range of the telemetry equipment being used. Aerial tracking was not done.

Table 3. Desert Tortoise carcasses (remains) found along 24 km stretches of fenced State Highway 58 and unfenced State Highway 395 in 1992 and 1993.

	1992	1993
Hwy 58 Fenced	1[1]	0
Hwy 395 Unfenced	13	5

1 - Presumably overlooked in 1991, based on condition of shell fragments.

During the mid-1970's, while studying the Beaver Dam Slope desert tortoise population in Arizona, Hohman (Personal Communication, 1994) was unable to locate an adult female two weeks after its last sighting because of a weak transmitter signal. After an extensive systematic ground search, she assumed the transmitter had failed and gave the animal up for lost. Two years later another investigator found this tortoise about 6.4 km from where Hohman had last detected it. The tortoise was reportedly healthy and the transmitter was functioning properly.

In researching desert tortoise physiology in the Mojave Desert, Peterson (1994) reported that four of his thirty-three study animals near the Desert Tortoise Natural Area exhibited long-distance movements over one to twenty-four month periods. The distances traveled by these adult tortoises were 1.6, 1.6, 4.6, and 5.6 km with the only male of the group traveling the intermediate distance. The tortoises included in Peterson's study were preselected as adults by design. Two of the tortoises were found dead. At least three of these long-distance movers were located either by investigators not associated with Peterson's study, or found by taking advantage of donated aerial reconnaissance flights.

It appears in general that individuals who have studied various aspects of desert tortoise biology usually defined and delineated a study plot for mapping purposes. Except for the Berry study cited above, the scope of their searches for study animals was intentionally limited to suit the needs of their projects. Time and effort necessary to track an occasional wayward tortoise presumably would have been considered too costly.

Conversely, from 1985-1987 Stewart (1992) investigated a desert tortoise relocation effort associated with a solar power plant at Kramer Junction, San Bernardino County, California. Tortoises were collected at the power plant site prior to construction and moved to a site 5.6 km to the northeast. Stewart's objective was to see if any of the relocated tortoises would return to close proximity of their original burrow sites. This required tracking beyond the limits of the square mile relocation site. The study's field investigator tracked the relocated tortoises as well as resident tortoises and found that 7 of 14 relocatees exhibited long-distance movements greater than 0.8 km while 3 of 8 residents did the same. One of the relocatees traveled 6.8 km, whereas the longest distance traveled by a resident was 1.6 km. Two of the tortoises that were about to cross Hwy 395 were carried safely across by a field investigator.

To our knowledge, EG&G (1993) documented the longest non-linear journey undertaken by a desert tortoise. A tortoise that was residing on a work site at the Yucca Mountain Project in Nevada was relocated to an alternate burrow approximately 5 km away from its established hibernaculum. After emerging from hibernation, it traveled a total of 30 km in a circuitous route away from its relocation burrow. It returned about 95 days later and established itself in a different burrow within 2.5 km of its initial relocation burrow. The distance this tortoise traveled before reversing its general direction of travel was about 10.5 km. The tortoise, of unknown sex, was 178 mm (mid-carapace length) long.

Our study demonstrates that a conspicuous number of the tortoises we tracked on the Hwy 58 study plot exhibited long-distance movements within the range of similar movements reported by other researchers. Aerial tracking aided us in locating tortoises that had moved off the plot. This aspect of our study design and a concerted effort to continue tracking tortoises that moved off the plot were extremely important in allowing us to document this behavior.

Some of the tortoises on the Hwy 58 study plot could be considered residents in the sense that over the three years of study to date, they remain on the plot. This includes two tortoises that took long-distance journeys, but returned to their established activity area or local home range. Other tortoises that were classified as long-distance movers in 1992 did not make similar movements in 1993.

A few tortoises appear to have been transient tortoises that were included in our study because after first being encountered off-plot and affixed with a transmitter, they traversed the study plot over the springtime tracking period, travelling well beyond its boundary. Of course, this characterization is only relative to our study plot and may be important in understanding the dynamics of some of our study questions; but in terms of examining the phenomenon of long-distance movements, it is probably unimportant.

The propensity for some tortoises to embark on long-distance movements may only occur irregularly at some time in their lives. At this time, our data are insufficient to determine if these movements represented dispersal events or relatively uncommon movements within a broad "lifetime" home range. Nevertheless, this activity has potentially life-threatening consequences for tortoises when heavily traveled highways and roads are encountered.

Nicholson (1978), Boarman (1992), and LaRue (1992) describe apparent tortoise depletion zones that extend out 1 km, 0.8 km and 0.3 km respectively along well traveled highways in various parts of the Mojave Desert in California. The results of their work suggest that highway road kills may account for this depletion. Considering our findings as well as incidental observations made by other tortoise researchers, the effects of roads and highways on tortoise populations may be more pervasive than suspected because of long-distance movers.

As Gibbons (1986) has suggested, if the biology of the animal were better understood, then appropriate management strategies could be devised and implemented to protect and preserve the species, eventually leading to its recovery. Because desert tortoise populations are threatened with extinction, it is important to understand the nature of long distance movements, the level of risk caused by the movements, and ways of reducing those risks. We suggest that until reasons for these long-distance movements are determined and can be factored in, the most immediate and appropriate management prescription to effectively deal with tortoises suffering road kill losses along heavily used highways is to install effective barrier fences along such highways.

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