THE COUGAR IN THE SANTA ANA MOUNTAIN RANGE, CALIFORNIA

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Final Report

ORANGE COUNTY COOPERATIVE MOUNTAIN LION STUDY

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CONTENTS

INTRODUCTION

This report summarizes cougar (mountain lion, Felis concolor) research in Orange County from April 1 1988 through February 1 1993. This research was pursued under interagency agreements FG7510 and FG0217 between the California Department of Fish and Game and the University of California at Berkeley, and Agreements D87-232 and FG0233 between the County of Orange and the California Department of Fish and Game. The following headings encompass the 18 objectives explicitly set forth in the contracts. The language following each heading is taken directly from the objectives contained in the contracts. The 10 chapters in this report follow these same headings.

1. Home ranges and habitat use. Document home range sizes for male and female cougars. Document habitat use in the Santa Ana and Santa Margarita mountain ranges.

2. Population density and structure. Determine the density of cougars, and the sex and age class structure of the cougar population.

3. Distribution and travel corridors. Document cougar use of existing County Parks, including habitat use within these Parks, and travel corridors between Parks. Investigate reports of cougar sightings in the San Joaquin Hills and Laguna Greenbelt areas. Evaluate and document the actual and potential movement corridors necessary to insure the integrity of the cougar population.

4. Population dynamics. Document reproductive activity, litter sizes, and recruitment into the population.

5. Utility of track surveys. Evaluate the validity of track survey information.

6. Activity patterns. Document daily and seasonal activity patterns for male and female cougars. Document movements of individual cougars.

7. Prey relationships. Document cougar prey relationships based on field surveys including deer herd composition surveys and examination of cougar-killed prey carcasses.

8. Impact of urban growth. Determine the actual and potential impacts of expanding urban development on cougar habitat. Provide information applicable to proposed highway projects.

9. Cougar-human encounters. Document factors which may help explain the recent increase in cougar-human encounters. Document the reaction of collared cougars to humans and to artificial food sources including garbage. Determine if such reactions vary with changes in cougar density, age of cougar, or the reproductive status of the cougar. Test the feasibility of conditioning cougars to avoid humans by removing artificial food sources and other practical methods. Monitor trends in cougar use of areas on the fringes of development.

10. Public education. Prepare a slide presentation for use in park Visitor Centers, to include: study results, natural history and social behavior of cougars, information on conservation of cougars, and warnings of the potential dangers inherent in having cougars as part of the wilderness.

This report follows this 10-point outline. We are also providing to the County and the Department data files of cougar locations for use in planning and management activities.

Acknowledgments

We gratefully acknowledge the financial support of the California Department of Fish and Game, and of the County of Orange, California. The Department of Fish and Game also supplied capture specialists, vehicles, telemetry equipment, training in animal handling, and air services. Terry Mansfield. Eric Loft, and Bill Clark of the Department were especially important in insuring continued support for this project. We also thank CDFG employees in Region 5: Rich Anthes, Esther Burkett, Jim Davis, John Fallon, Greg Gerstenberg, Cheryl Heffley, Larry Henson, Lisa Kramer, Art Lawrence, Marty Matorini, John Massey, Larry Sitton, Ralph Sugg, Jeff Veal, Ken Walton, Jan Yost, and Al Zamudio. The County of Orange assisted with access to public and private lands and supported the project in many other ways, most notably in allowing Donna Krucki flexibility in her work schedule at Caspers Wilderness Park so that she could assist us in field work. We especially thank County employees Stan Bengtson, Bruce Buchman, Donna Krucki, Al Macias, Gary Madeiros, Tim Miller, Tim Neely, Cathy Nowak, and Chuck Thornberg.

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Special thanks go to Doug Padley and Joel Weintraub. Padley monitored radio-tagged cougars for the County of Orange in 1986-87 and for US Marine Corps Base Camp Pendleton in 1987-1989; his data are included in this report. He also worked as a volunteer on this study, and shared data from his 1990-1991 work on mule deer. Joel Weintraub of California State University at Fullerton performed the determination of prey remains in cougar scats.

For gracious access to land holdings, we thank Boy Scouts of America, California State Parks, Ford Aerospace, Hon Development Company, Irvine Company, Metropolitan Water District, National Audubon Society, Orange County, Rancho Mission Viejo, Rancho Santa Margarita, Riverside County, San Diego County, San Diego State University, The Nature Conservancy, TRW Corporation, US Forest Service, US Marine Corps Base Camp Pendleton, and US Naval Weapons Station Fallbrook. Camp Pendleton was especially helpful in arranging access, loaning equipment, sharing data, and in many other ways. Rancho Mission Viejo generously provided several kinds of support, including living space for volunteer field workers.

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BACKGROUND, STUDY AREA, METHODS

Background

The cougar (Felis concolor) is also known by the names mountain lion, puma, and panther. Cougars have the broadest distribution of any terrestrial mammal native to the New World, ranging from southern Yukon to southern South America (Lindzey 1987:657). Once native to all of the contiguous United States, cougars now occupy less than half of this historic range, mainly west of the 100th Meridian (Anderson 1983). The main cause of this range contraction was persecution of cougars, which began with European colonization and ended as each state ended its bounty system during 1958-1970. Cougars were present as recently as 1950-1976 in several states where the species is now extinct, including Arkansas, Louisiana, Oklahoma, Tennessee, and West Virginia (Currier 1978, Anderson 1983:80-83). Since the end of the bounty system, cougars have increased in most western states (Smith 1989). However, there are local declines in some areas due to habitat loss and fragmentation. These same processes may prevent cougars from recolonizing the eastern United States. There is no statistically sound and precise estimate of total numbers of cougars for any entire state. The cougar's elusive habits and low density make any such estimate prohibitively expensive. The California population was estimated at 4100-5700 animals in 1984 (Mansfield 1986), a number far larger than for any other U.S. state or Canadian province (Smith 1989).

Hornocker (1969, 1970) carried out the first intensive study on the ecology of cougars, following individually marked animals over time and observing population processes in a well-defined study area. Virtually all our knowledge of cougar ecology has been obtained since 1970. The best summaries of the scientific literature on cougars are provided by Anderson (1983) and Lindzey (1987); Anderson et al. (1992) reference most of the more recent literature. Excluding a half-dozen studies of trends in cougar numbers and depredation incidents, only 3 intensive studies of cougar ecology were carried out in California prior to the present study. Sitton and Wallen (1976) radio-tagged 14 cougars and ear-tagged 2 cubs in a 2-year study in southern Monterey County. Hopkins (1981, 1989) radio-tagged and studied cougars in the Mount Hamilton area (Santa Clara County and adjacent areas) during 1978-1988. Neal et al. (1986) reported on home range use and density in the North Kings River area (west central Sierra Nevada) during 1983-1985.

Until 1986, cougar studies in southern California were limited to track surveys. In that year the National Audubon Society began plans for a radio-telemetry study centered on Starr Ranch Sanctuary. In November 1986, CDFG radio-tagged 2 adult female cougars near Caspers Park and took the lead in planning a larger study. CDFG and County of Orange agreed to jointly fund the study, and in February 1988, the University of California signed a contract to carry out the project; field work began in April 1988. Meanwhile, Camp Pendleton had begun a study using radio-tagged cougars in summer 1987. The two studies were closely coordinated. In late 1989 the Camp Pendleton study terminated and we took over monitoring of those animals. This report treats data from both study sites as a single data set.

The results of the present study appear in several documents in addition to this report:

- Much of the Camp Pendleton data were summarized in Padley's (1990) Master's thesis.
- Padley (in press) reports on social interactions among female cougars in a paper submitted to Journal of Mammalogy.
- Beier (1993) simulated the population dynamics of this cougar population and demonstrated the critical importance of

preserving corridors for wildlife movement. This paper appears as Appendix 1 in this report.

- Beier (1991, 1992) presented the historical record of cougar attacks on humans in the United States and Canada. These papers are included as Appendix 2 and Appendix 3.
- Beier and Loe (1992), in a paper partially related to this study, suggested how to evaluate impacts to wildlife movements. This paper is included as Appendix 3.
- Beier (1993b) described a version of the software used in these simulations, modified for use as a teaching tool.
- Beier reports on "Dispersal movements of cougars in fragmented habitat" in a paper to be submitted for publication this summer.

Additional papers, presently being prepared for publication, will present other results to the scientific community.

Study Area

The Santa Ana Mountain Range was our study area. It included about 2070 square km (800 mi^2) of contiguous wildlands used by cougars; these wildlands include the Santa Margarita Mountains, the Santa Rosa Plateau, the Chino Hills, and the nearby San Joaquin Hills (Figure 1). The study area thus straddled 5 counties and abutted 17 incorporated cities. About 61% of cougar habitat in the study area is in some sort of protected status (Table 1). The largest of these parcels (Trabuco Ranger District, Camp Pendleton, Starr Ranch, and Caspers Park) form a large central habitat area. Many of the smaller protected parcels are at risk of being fragmented from the central habitat area (Table 1), and the central habitat area itself is at risk of being isolated from the adjacent population in the Palomar Range (Figure 1).

The 1988 contract defined the original study area as "Rancho Mission Viejo, Rancho Santa Margarita, Coto de Caza, Starr Ranch Sanctuary, Ronald Caspers Wilderness Park, O'Neill Regional Park, and Wagon Wheel Canyon Regional Park." This area is only about 260 km^2 (100 mi^2, or about 12% of the area used by the cougar population), and we soon realized that meaningful biological results demanded expanding to the entire range. In spring 1989 the study area expanded to include Irvine Company holdings east of I-5 and the Cleveland National Forest. From September 1987 through August 1989, US Marine Corps Base Camp Pendleton funded a companion study of cougars on Camp Pendleton and Fallbrook Naval Weapons Station (Padley 1990). From the beginning, the sister studies co-operated closely, and after September 1989 we formally included these lands in our study. In early 1990 we expanded into the San Joaquin Hills, Chino Hills, and the Santa Rosa Plateau. This final study area included all large wildlands west of Interstate 15 north of State Route 76 and south of State Route 60. These man-made boundaries delimit a biologically meaningful study area because these urban features circumscribe the real confines of a single cougar population. Our study thus encompassed an entire cougar population for its final 2½ years.

The area included a diversity of vegetation communities including:

- **chaparral**, dominated by chamise (Adenostema fasciculatum), ceanothus (Ceanothus spp.), scrub oak (Quercus dumosa), and mountain mahogany (Cercocarpus betuloides). Sumac (Rhus and Malosma spp) and toyon (Heteromeles arbuitifolia) were also common at lower elevations, as was manzanita (Arctostaphylos spp.) at higher elevations.
- **oak woodlands**, dominated by coast live oak (Q. agrifolia) and engelmann oak (Q. engelmannii).

Table 1. Area (hectares) of protected lands contained in cougar habitat in the Santa Ana Mountain Range.

Ownership and Parcel Name	Areas forming a large contiguous block	Areas surrounded by unprotected land
Federal:		
Cleveland National Forest	53,604[a]	
Cleveland National Forest (6 parcels)		626
Camp Pendleton	49,292[b]	
Fallbrook Naval Weapons Station	3,099	
Bureau of Land Management (7 parcels)		550
Bureau of Land Management (1 parcel)	364	
State:		
Chino Hills State Park		5,059
San Diego State University Field Station		1,805[c]
Department of Fish & Game Coal Canyon Preserve	385	
Orange County Parks:		
Caspers	3,085	
Limestone Canyon		2,169[d]
O'Neill		805
Whiting Ranch		632
Irvine		193
Wagon Wheel		178
Santiago Oaks		142
Private Reserves:		
Santa Rosa Plateau Preserve		2,803[e]
National Audubon Society Starr Ranch	1,578	
Rancho Mission Viejo Conservancy		486
Total	111,407	15,448

[a] excludes private inholdings.
[b] includes land leased to San Onofre Beach State Park; excludes 1700 ha in urban uses and airfield; includes some bombing ranges that may not be suitable habitat.
[c] includes 510 ha of BLM land administered by the field station.
[d] expected to be transferred to County from private ownership.
[e] administered by The Nature Conservancy (TNC); includes lands owned by TNC, State of California, and Riverside County.

- **riparian areas**, dominated by coast live oak, sycamore (Platanus racemosa), willow (Salix spp.), mule fat (Baccharis pilularis), and alder (Alnus rhombifolia)
- **coastal sage scrub**, dominated by buckwheat (Eriogonum fasciculatum), true sages (Salvia spp.), and (near the coast) California sagebrush (Artemisia californica),
- **conifer forests**, including bigcone doug-fir (Pseudotsuga macrocarpa), coulter pine (Pinus coulteri), and Tecate cypress (Cupressus forbesii), were found mainly at higher elevations, especially on north-facing slopes.
- **grasslands**, a mixture of native perennials (Stipa spp) and exotic annuals.
- **orchards**, predominantly of oranges or avocados

The topography was rugged, with elevations ranging from sea level to about 1690 m. Very few drainages had perennial surface flow throughout their length, but seeps and other water sources were well-distributed throughout the area. Most water sources remained reliable throughout the drought years that characterized the first half of the study.

Methods

We relied heavily on data obtained from radio-tagged cougars. A total of 32 cougars were captured and radio-tagged during this study. Animals were tagged and died at different times, so that the number monitored at any point in time varied from 4 to 16 (Table 2). To avoid burdening young animals with the stress of pursuit and the weight of a radio-tag, we did not pursue or capture animals under about 10 months of age.

Cougars were captured by using hounds or snares, and immobilized with ketamine hydrochloride and xylazine hydrochloride in a concentrated 5:1 mixture (Jessup and Clark 1986). Immobilized cougars were examined and assigned an age based on tooth wear, pelage, and body mass (Ashman et al. 1983). Some animals were ear-tattooed with a distinctive letter or number code. External body measurements were taken and body mass was measured on a spring scale for most animals. Antibacterial dressing was applied to any wounds, and ophthalmic salve was applied to prevent drug-induced corneal dehydration. Each cougar was assigned a letter-number code, with the letter indicating sex (M, F), and the number indicating the order in which the animal was captured (starting with 1 for the first animal of each sex). Blood was drawn from most cougars and sent to CDFG's Wildlife Investigations Lab (WIL) (Rancho Cordova CA) and/or to National Cancer Institute (NCI) (Frederick MD). WIL tested the blood for pathogens and other characteristics. NCI received tissue from 11 animals (Males 6, 10, 12, 13; Females 2, 5, 15-19) for use in their study of cougar population genetics across the Americas. Johimbine was administered to most cougars to speed recovery from the drugs, and each animal was observed until it was able to walk.

Each captured cougar was fitted with a radio-transmitter collar, weighing about 650g (model 500, Telonics, Inc., Mesa, AZ). Mortality sensors in each collar caused the pulse rate to increase after 6 hours of inactivity. Animals were recaptured to replace the transmitter about 30 months after transmitter deployment.

We regularly determined locations of radio-tagged cougars. Locations were determined from the air about once every 10 days. Ground locations were obtained more frequently, usually every 1-4 days, using standard triangulation techniques (Mech 1983), usually with a single observer.

On over 180 occasions during this study, a focal animal was located by triangulation every 15 minutes for periods of up to 24 hours. Seventy four (74) of the early sessions were for full diel (24-hour) periods, usually noon to noon. Because cougars were rarely active during daylight, 108 of the later session were nocturnal, starting 1 hour before sunset and continuing until 1 hour after sunrise. In selecting the focal animal for a session, we gave strong preference to dispersing juveniles exploring new terrain, to cats at the wildland-urban interface, and to cougars that might yield information on unknown travel routes.

Other field methods included spotlight surveys to determine deer herd composition, track surveys for cougar presence, search of historical records for cougar attacks, building a population simulation model, post-mortem examinations to determine cause of death, and collection and analysis of scats to determine prey. These methods are discussed in the relevant sections of this report.

Table 2. Dates of birth, capture, and death for 32 cougars radio-tagged in the Santa Ana and Santa Margarita Mountain Ranges during 1986-1992. ID# begins with "F" for females or "M" for males. Animals designated "alive" were living as of Feb 1 1993.

ID #	Birth Year	Date of capture	Date of death	Notes:
F1	1981	Oct 31 1986	Jul 1 1989	no litters 1986-89, killed by cougar
F2	1982	Nov 5 1986	Mar 12 1991	litter Jul 1989 (sons M3 & M4), broke femur in vehicle accident Dec 1989, had unusual kinked tail; died of intestinal disease
F3	1983	Sep 16 1987	Dec 28 1989	litters in Nov 1987 (3 cubs, all died by Feb 1989) and Jul 1989 (3 cubs); died of intestinal disease
F4	1979	Jan 8 1988	Jul 20 1990	litter Jul 1989 (2 cubs died within 3 mos); died of "old age"
F5	1984	May 17 1989	alive	no litters 1989-1992; very thin, blue eyes, stump tail
F6	1984	May 20 1989	May 23 1992	litter Aug 1990 (sons M11 & M12), killed by cougar
F7	1986	May 27 1989	--	lost radio contact Aug 15 1992
F8	1986	May 29 1989	Aug 14 1989	killed in vehicle accident on S.R. 91
F9	1983	Oct 17 1987	Mar 1 1992	radio failed Jul 1988, killed on I-15 south of Temecula
F10	1982	Feb 11 1987	Oct 1991?	disappeared Oct 1991 (death suspected); litters Jul 1989 (son M7) and Jun 1991 (2-3 cubs).
F11	1985	Aug 14 1988	Jan 25 1993	litter Jul 1989 (daughter F14), shot (goat depredation)
F12	1983	Aug 15 1988	Dec 21 1990	litter May 1989 (sons M8 & M10), killed on I-5
F13	1981	Mar 25 1990	Oct 10 1990	may have had a yearling cub at capture; killed on S.R. 74
F14	1989	Dec 21 1990	--	collar slipped off
F15	1987	Feb 21 1991	Jun 13 1992	bred several times with M9, but no litters 1991-92; broke hip in vehicle accident Jun 4 1992, died several days later
F16	1989	Jul 28 1991	Sep 19 1991	died 5 weeks after vehicle accident
F17	1989	Jul 28 1991	Jan 7 1992	died of unknown causes (no acute trauma)
F18	1986	Jul 28 1991	alive	litter Dec 1989 (daughters F16 & F17)
F19	1987	Aug 8 1991	alive	no litters during 1991-92
M1	1980	Jan 13 1988	Feb 6 1988	breeding male (several consorts); shot (sheep depredation)
M2	1987	Oct 10 1989	Mar 4 1992	breeding male (many consorts); shot (goat depredation)
M3	1989	Jun 5 1990	Feb 16 1991	entered residential area as a disperser (Feb 8 1991), died of disease
M4	1989	Jun 5 1990	Nov 10 1990	died in vehicle accident or killed by cougar (fed upon by F2 & M3)
M5	1989	Aug 3 1990	Sep 22 1991	captured as disperser in a residential area, broke hip and knee in vehicle accident Apr 23 1991, injuries were major factor in death
M6	1989	Aug 27 1990	alive	captured as disperser; crossed S.R. 91 at Coal Canyon 22 times
M7	1989	Oct 23 1990	alive	successfully dispersed; no breeding documented
M8	1989	Oct 29 1990	May 3 1991	dispersed from Pendleton to Chino Hills, killed on S.R. 60
M9	1986	Feb 17 1991	alive	breeding male (many consorts)
M10	1989	Feb 25 1991	Sep 15 1992	dispersed from Pendleton to S.R. 91, broke femur May 7 1991 in vehicle accident, killed on impact in second accident
M11	1990	May 4 1991	Feb 29 1992	light injury in vehicle accident Feb 4 1992, shot in City of Oceanside
M12	1990	Aug 15 1991	Apr 1 1992	dispersed via Pechanga Corridor into Palomar Range; died of unknown causes
M13	1988	Oct 25 1991	alive	captured as disperser; no breeding documented

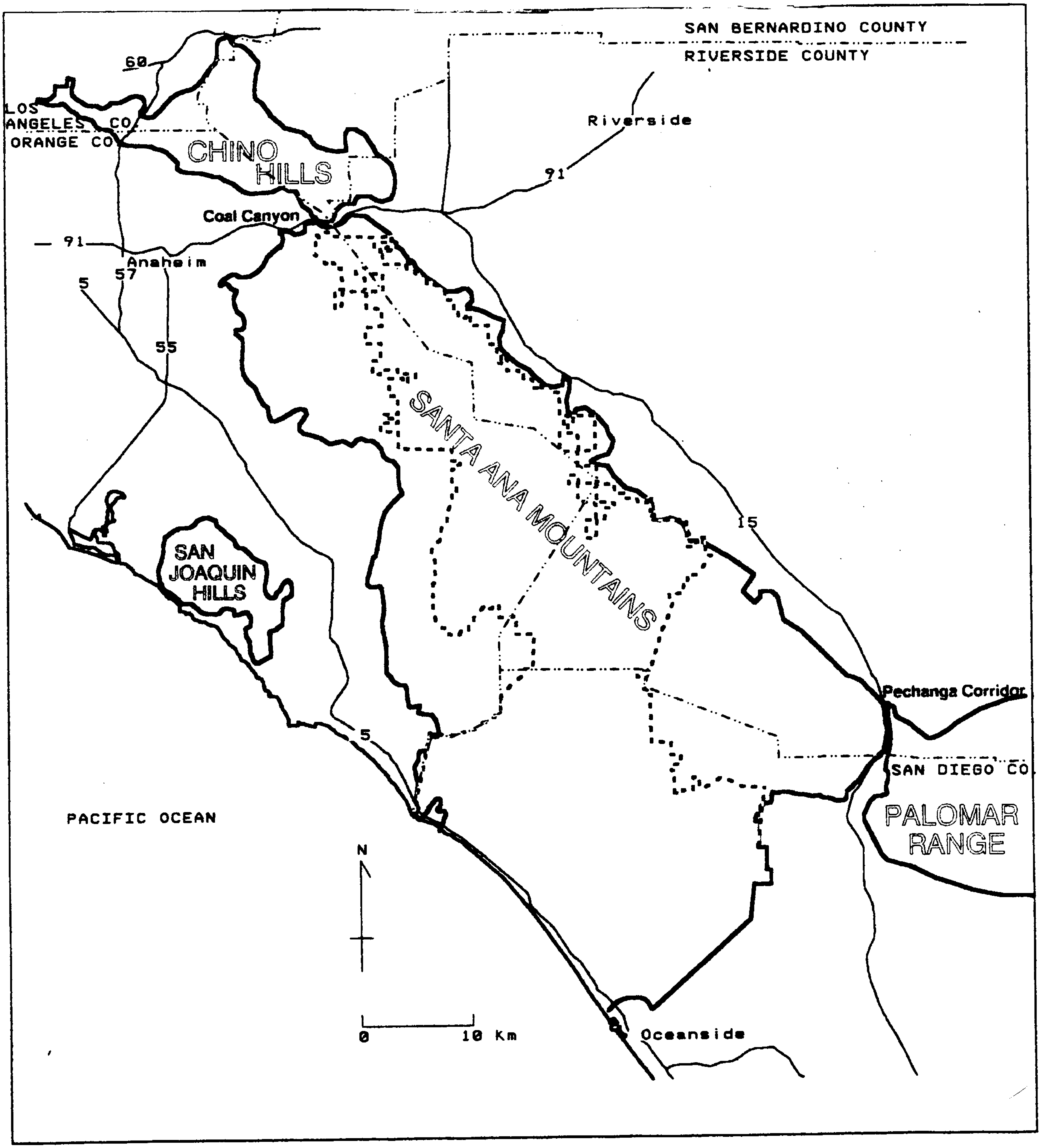

Figure 1: The heavy solid lines enclose 3 areas: 800 mi^2 (2070 km^2) of cougar habitat in the Santa Ana Mountain Range (including the Santa Margarita Mountains and the Chino Hills); 29 mi^2 (75 km^2) of suitable habitat in the San Joaquin Hills (subpopulation recently extinct); and (east of Interstate Highway 15) a portion of the habitat of the adjacent population in the Palomar Range. The heavy dashed line encloses 430 mi^2 of protected areas forming a large contiguous block of habitat (Cleveland National Forest, Camp Pendleton, Fallbrook Naval Weapons Station, Caspers Park, Starr Ranch Sanctuary).

CHAPTER 1. HOME RANGES AND HABITAT USE

Home ranges

The minimum convex polygon (MCP) method was used to calculate seasonal and cumulative home range size for each adult cougar. Home range sizes were calculated separately for the wet season (November-April) and the dry season (May-October). Home ranges were not calculated for: (1) animals monitored for fewer than 160 days out of each season's 182 days, (2) animals with less than 45 locations in a season (unless the home range size was larger than average), or (3) mothers with young (0-8-weeks-old) cubs during that season. In addition, F5 was excluded in several seasons because she exhibited 2 distinct home range areas separated by a large intervening area with little use (see below). Occasionally an animal would make an excursion far outside its normal home range, and these outlying points were excluded from MCP home ranges.

Home ranges of adult females averaged about 113 km^2 (6-month season) and 218 km^2 (cumulative) (Table 3). Male home ranges were about 4 times the size of female ranges, averaging about 485 km^2 (6-month season) and 767 km^2 (cumulative). Home range size did not differ between wet and dry seasons ($P > 0.50$ for females or males). The smallest female seasonal home range was 56 km^2 (F1 in the wet season of 1986-87), and the largest was 195 km^2 (F19 in the 1992 dry season). Seasonal ranges of males varied from a low of 356 km^2 (M2, 1990 dry season) to a high of 635 km^2 (M9, 1991 dry season).

Table 3. Seasonal and cumulative home range areas (km^2) for adult cougars in the Santa Ana Mountain Range, as computed by the minimum convex polygon method. Wet Season = November-April; dry season = May-October; n = number of seasons monitored. We excluded F5's locations for 1989-90, when she wandered widely. See Table 1 for duration of cumulative ranges. Number of locations includes no more than 1 location per day. Areas were computed only when there were at least 45 locations spanning 100 days within a season.

Cougar	Wet Season		Dry Season		Cumulative	
	mean area	n	mean area	n	area	no. of locations
F1	108	3	123	2	252	433
F2	77	4	76	3	268	718
F3	65	2	91	1	112	590
F4	77	2	124	2	208	537
F5	76	2	94	2	127	151
F6	164	2	154	2	272	267
F9	108	1		0	144	213
F10	121	2	135	3	297	380
F11	115	4	87	4	191	357
F12	96	2	97	1	162	304
F15	151	1		0	349	131
F19	145	1	195	1	230	130
Female Mean	**109**		**118**		**218**	
M2	494	3	367	2	705	290
M9	552	1	527	2	829	129
Male Mean	**523**	**4**	**447**	**4**	**767**	**210**

Our sample included only 2 adult males (M2 and M9) with known histories of consorting with females. Most other radio-tagged males died before establishing a stable adult home range. Three of the young males (M6, M7, and M13) exhibited stable home ranges during

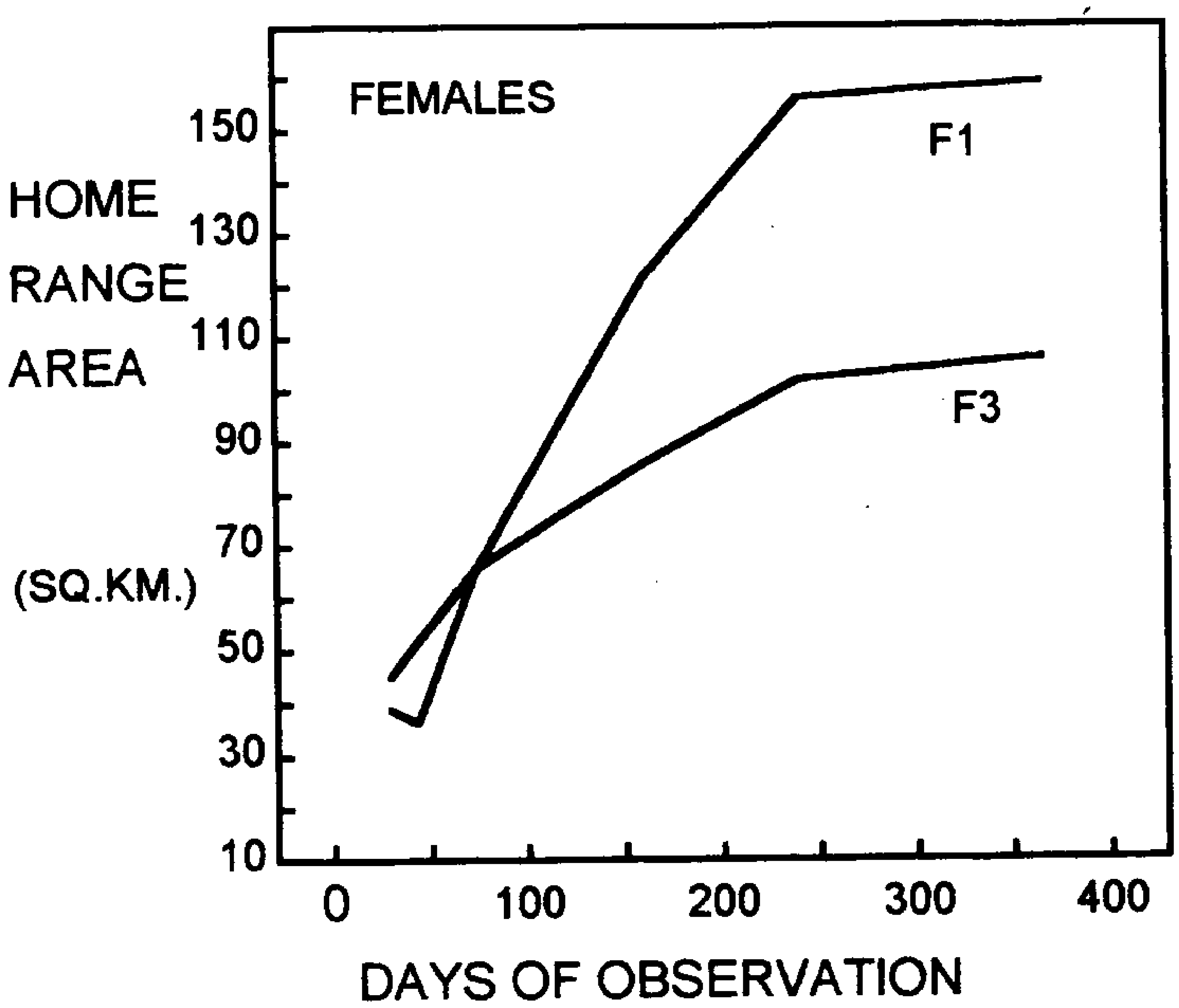

Figure 2. Area used by 2 adult female cougars as a function of length of the observation period.

the last months of the study, and these home ranges will probably form the nucleus of their eventual adult home ranges if they continue to survive. However, their home ranges remained markedly smaller than those of M2 and M9 through the end of the study. The home ranges and movements of these and other dispersing juveniles are discussed in detail in Chapter 6.

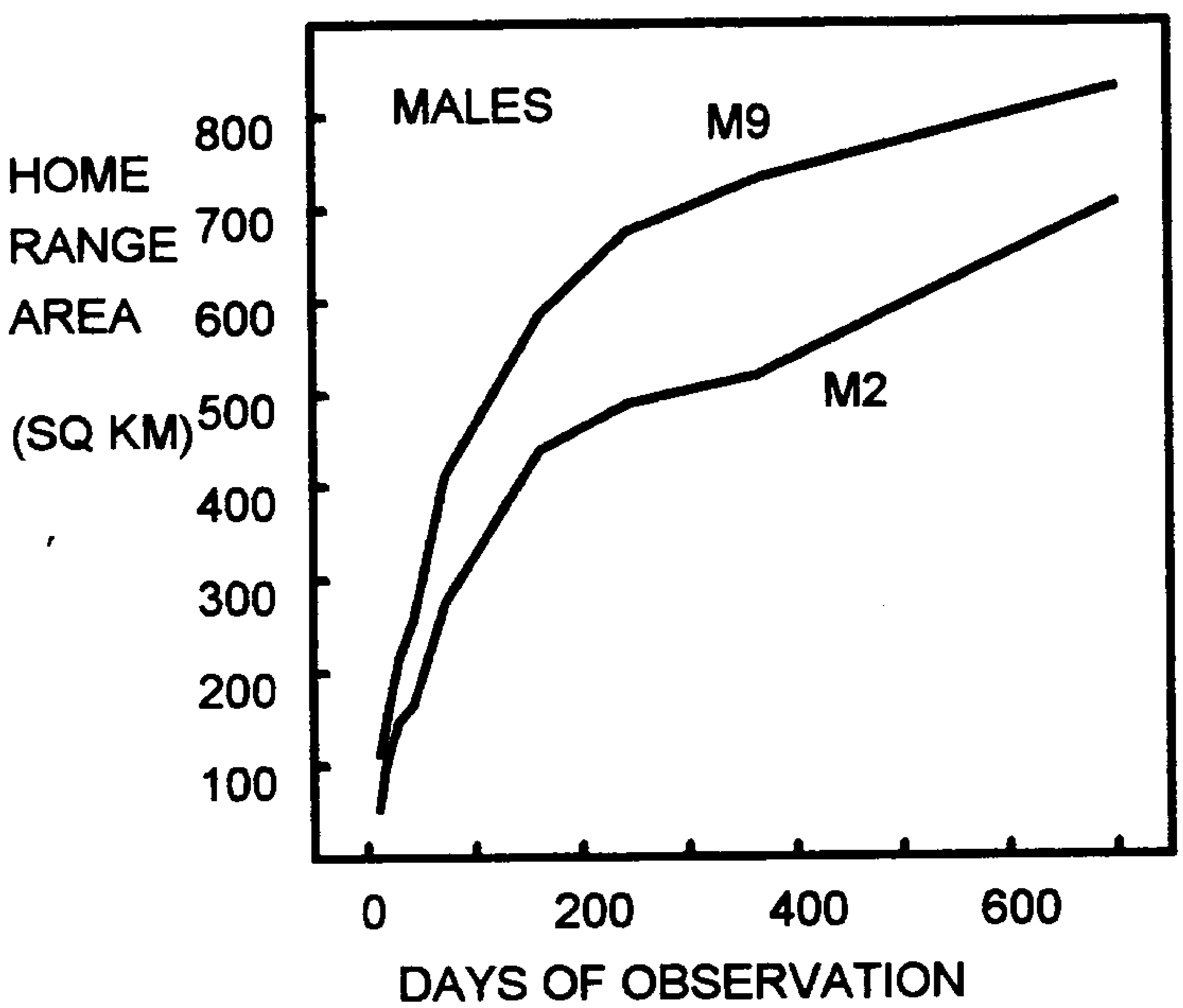

Figure 3. Area used by 2 adult male cougars as a function of length of the observation period.

One adult female, F5, exhibited an unusually large home range during 1989 dry season and the 1990 wet season. During these months she alternated between 2 widely separated home range areas (Figure 4). F5 was unusual in several other respects that may or may not have any bearing on her home range pattern: (1) During 2.5 years of monitoring we could not confirm that she consorted with a male or had any cubs, (2) F5 was markedly thinner than other adult females (although not emaciated), and (3) F5 was the only adult in our study with blue (rather than yellow) eyes. The latter 2 traits were evident both during the initial capture and during recapture to replace her radio-collar 26 months later.

The size of each adult cougar's home range increased with the length of the observation period, but it eventually reached an asymptote (plateau) at about 200-250 days for females, at which point there was only about a 10% increase in area for an additional 200-400 days of observation (Figure 2). For males, home range size continued to increase with increasingly long observation periods (Figure 3), This means that it took about 7 months for an adult cougar to use most of its home range, and that only a fraction of its range was used in any given week or month. An adult female cougar typically used less than a third of her home range in any given month (Figure 2).

This finding has implications for using tracks or other sign to detect cougar presence. For example, such sign is often used to determine whether the site of a proposed project is being used by cougars. No sign for a 200-day sampling period would be strong evidence that the site is not a normal part of any cougar's home range. However, shorter efforts could well fail to detect the presence of a resident cougar.

Overlap among home ranges

Home ranges of adult females overlapped extensively when viewed on an annual basis (Figures 4 & 5). This pattern of wide overlap among adult females has been reported in 14 of 16 studies addressing this issue (references in Anderson 1992:Table 35).

Home ranges of adult males overlapped each other minimally (Map 4). However, home ranges of transient males were overlapped almost entirely by the ranges of adult males. Of 14 previous studies addressing the issue of overlap among males, 8 reported little or no overlap and 6 studies reported considerable overlap among adjacent males (summary in Anderson 1992:Table 35). Because many studies did not distinguish subadult males from territorial adults, some reports of male-male overlap could reflect tolerance of subadult males by adults. Alternatively, the studies reporting non-overlap were based on only 2-4 males (versus 4-7 males in studies noting overlap); they may have failed to detect overlap simply due to under-sampling.

Adult female cougars regularly encountered each other, and on many occasions pairs of adults remained close together (0-300m apart) for 1-3 days. Such pairings were observed on about 20 occasions, and included 8 different females. Observations of such associations among adults have been reported very rarely in previous studies; W. D. Padley (J. Mammalogy, In Review) summarizes most of the data on female-female interactions collected in this study effort.

Habitat use

Radio-tagged cougars in the Santa Ana Mountain Range used all available habitats, although some types were apparently preferred and others avoided. In a future report, we will overlay cougar locations on vegetation maps and give a more formal analysis of habitat use and preference. We have obtained digitized habitat data for Riverside County (west of I-15) and for Camp Pendleton, but Orange County and San Diego County did not have vegetation data ready for release in time for us to analyze the data and include them in this report. We anticipate receiving the San Diego data in June 1993 and the Orange County data in Fall 1993.

In the interim, we offer the following qualitative assessments based on our field experience with respect to 5 factors that influence habitat suitability, namely: vegetation, topography, fire, human use, and habitat size and connectivity. We caution that future conclusions from quantitative analyses of vegetation data may differ from these tentative conclusions.

Vegetation. Cougars clearly used all native vegetation types, but used large grasslands (e.g. Horno Canyon near San Juan Capistrano, large areas in the Chino Hills and Santa Rosa Plateau) much less than would be expected on the basis of relative availability of that habitat type. Horno Canyon, for instance, was used by only 2 cougars, both subadult males, and only on a few occasions. Smaller grassland areas (e.g., much of the Cañada Gobernadora and Cañada Chiquita flood plains) were more readily used than large grasslands. When cougars crossed grasslands during overnight monitoring sessions, they usually moved quickly across them to the nearest woody vegetation. The cougar's reliance on stealth and ambush probably accounts for this tendency to avoid open areas. Row-crop agricultural areas were strongly avoided, and orchards were moderately avoided, by cougars.

There have been 3 previous quantitative assessments of cougar preference for various vegetation types (Laing and Lindzey

1991, Logan and Irwin 1985, and Belden et al. 1988). These studies also reported avoidance of agricultural areas, habitats lacking woody vegetation, and habitats that provided little horizontal (hiding) cover.

Topography. Cougars used all types of terrain, including the steepest slopes and rock outcrops, and all aspects. During all night monitoring we documented that cougars hunted, traveled, and rested in a variety of topographic situations. We suspect there might also be some avoidance of flat areas, as reported by Logan and Irwin (1985) and Laing and Lindzey (1991), but this would be difficult to document in our study because almost all flat areas had been cleared for housing, row crops, or livestock pastures.

During long distance movements, cougars seemed to prefer the scour zones in the bottoms of larger canyons. Dirt roads often paralleled these zones, and typically a cougar alternated between walking in the road and in the wash. Ridgetops were also favored travel routes, especially when a dirt road or hiking trail created an easy path through chaparral or other brushy vegetation. Although the preference for canyon bottoms and ridgetops for travel was pronounced, it was far from absolute; on many occasions cougars traveled midslope along a contour line, along the fall line of a steep slope, or diagonal to the fall line. Even when traveling predominantly along a ridge or wash, cougars made frequent detours into other topographic situations.

Fire. Radio-tagged cougars experienced several large fires during the study. The animals always successfully avoided the flames. When a fire occurred within a cougar's home range, the cat usually re-entered the burned area (or at least the unburned patches within that area) within 2 weeks after the fire. For example, on October 18-20 1989, a 9000-acre fire burned portions of Camp Pendleton, Rancho Mission Viejo, and Cleveland National Forest. The burned area includes large portions of Talega, San Mateo, and La Paz Canyons, which are very important parts of F3's and F4's home ranges. In the first week following the fire, both cats avoided the burn area, but started re-using it within 2 weeks and made extensive use of the burn within 6 weeks. A similar patterns of short-term avoidance of burn areas was exhibited by F11 on Camp Pendleton on 2 occasions.

Human use. Radio-tagged cougars traveled through some rural areas with low housing density, e.g., Williams Canyon, Santiago Canyon just west of Modjeska, the cluster of dwellings on Starr Ranch. Cougars categorically avoided denser areas such as the communities of Modjeska, Silverado, and Trabuco Canyon, although they would skirt these areas within 100 meters of the peripheral homes.

It is difficult to specify the housing density at which cougars will cease to use an area. Cougars clearly tolerate 1 dwelling per 40 acres, if the area is adjacent to unpopulated areas. Our best estimate is that the transition from habitat to nonhabitat occurs at about 1 dwelling per 20 acres. Under ideal conditions (no tall fences, no free-roaming dogs, low-speed roads, minimal loss of native vegetation, no goats or sheep to provoke depredation incidents, tolerant landowners) we suspect that cougars might tolerate housing densities as high as 1 dwelling unit per 10 acres.

Habitat Size and Connectivity. Because cougars have large home ranges and do not reach high population density, habitat must be either contiguous with or connected to at least several hundred square miles of suitable habitat. Because the undeveloped portion of the Santa Ana Mountain Range is only about 2070 km^2 (800 mi^2), connectivity is critically important, and loss of connectivity is the main factor threatening to cause many wildlands to cease being cougar habitat. For example, the

San Joaquin Hills, which was ideal habitat with respect to the first 4 criteria, has not been cougar habitat since it was isolated from larger areas of habitat. It is simply too small to support a cougar population in isolation. This subject is discussed at greater length in Chapters 3 and 4, and in Beier (1993).

In summary, cougars in the Santa Ana Mountain Range were habitat generalists. Although some habitat types were used more than others, cougars were neither obligate users of any particular vegetation type, nor did they show a categorical aversion to any native vegetation type that included woody cover. In general, all land in the Santa Ana Mountain Range (including the Santa Margarita Mountain Range, the Santa Rosa Plateau, and the Chino Hills) was cougar habitat if it met all 5 of the following criteria:

1. The vegetation was predominantly native.
2. There was some woody vegetation.
3. The area had ample prey, especially mule deer.
4. There was a low density of buildings and human dwellings.
5. The area was contiguous or connected to the main block of cougar habitat (see Figure 1).

CHAPTER 2. POPULATION DENSITY AND STRUCTURE

Thirty-two cougars were radio-tagged during this study (Table 2). The number of radio-tagged animals increased in the first 3 years as our effort and the size of the study area increased, and then decreased in the final 1.5 years as we discontinued capture efforts. These changes do not reflect changes in cougar numbers. In all likelihood, the number of adult cougars has not changed markedly during the 5 years of the study. Although the long-term prognosis is for cougar numbers to decrease as habitat is lost and fragmented, we could not detect significant change in this 5 year period.

The sample of radio-tagged cougars was largest in August-September 1991; at that time the population consisted of a minimum of 7 adult females, 3 adult males (counting M6 as an adult who had not yet established a full-size territory), 3 subadult males, 2 female cubs, and 2 male cubs, for a total of 10 adult and 7 juvenile cougars.

Because a relatively large fraction of the population was radio-tagged in September 1991, we estimated cougar numbers in the Santa Ana Mountains for that month. In these estimates, cougars are classed as cub (from birth until dispersing out of its mother's home range at 18-24 months of age), subadult (from age of dispersal until a stable home range is established), or adult (over 24 months of age and exhibiting a stable home range). "Juvenile" refers collectively to cubs and subadults. We estimate that there are about 2070 km^2 (800 mi^2) of suitable cougar habitat (Figure 1).

The true population size in September 1991 was larger than the sample of radio-tagged animals. We made no attempt to capture or radio-collar cubs younger than 10 months of age, and we know that at least 2 such cubs (offspring of F10) were alive at that time. M13 (a subadult collared October 1991) and another young male shot on a depredation permit in January 1992 (see below) were also present in September 1991 (unless they immigrated from the Palomar Range). Tracks indicate that at least 3 other uncollared cougars (females or subadults) were present in easily-surveyed areas in late 1991. Furthermore, much of the Cleveland National Forest is not conducive to capture efforts or track surveys, so probably several more uncollared animals were not detected. Finally, the regular appearance of dispersing subadult males that were not the offspring of radio-tagged females indicates that there were additional adult females.

Nonetheless, 3 lines of evidence suggest that a large fraction of the population (at least those over about 20 months of age) in the Santa Ana Mountain Range was radio-tagged in Fall 1991:

(1) **Depredation incidents.** During 1991, Orange County Animal Control, CDFG wardens, or citizens relayed to our study team about 12 reports of domestic goats or sheep being killed by cougars. Eight cases were promptly investigated (in other cases, the report was received too long after the fact to be useful). In 7 of these 8 cases, a radio-tagged cougar was almost certainly the offending animal, based on its proximity to the fresh carcass. Although 1 cougar (M12) was the offender in 4 of the cases, the other cases involved 1 uncollared and 3 different radio-tagged cougars.

Although 7/8 of these livestock depredations involved radio-tagged cougars, it would be inappropriate to conclude that 7/8 of the entire population was radio-tagged. The depredations all occurred in the western foothills of the range (Santiago Canyon, Williams Canyon, Live Oak Canyon, La Paz Canyon, and San Onofre Canyon). The study team was most active in these foothills throughout the study, and may in fact have collared about 80% of the cougars using these foothills. However, in other parts of the range, a smaller proportion of the cougars was radio-tagged.

(2) **Highway accidents**. Highway Patrol officers, Camp Pendleton wardens, police, local Animal Control agencies, and citizens regularly relayed to us reports of cougars being hit by automobiles. During August 1990 through January 1992, we received 9 such reports (we exclude an incredible and unverifiable report from Dana Point). Seven of these 9 accidents involved radio-tagged cougars (see last Quarterly Report). The other 2 accidents involved an animal killed on I-15 near Temecula (October 1990) and a probably valid report of a non-fatal accident on Basilone Road (Camp Pendleton, August 1990).

Again, the collisions occurred in well-roaded areas which were also the areas where we were most able to detect and radio-tag cougars, so we caution that we probably had not radio-tagged 78% (7/9) of the population. Nonetheless every cougar faced some risk of a vehicle collision (each radio-tagged cougar crossed paved roads on several to many occasions) and clearly these data show that a large fraction of the population was radio-tagged.

(3) **Inadvertent recaptures** in Roblar and lower De Luz Creeks. After F10 and her cubs disappeared in late October 1991, we put 5 snares in her home range and checked them for 33 days. Although we did not catch F10, 3 other radio-tagged animals (M9, F15, and F18) tripped these snares during that time. The snare sites were in peripheral and rarely-used portions of the home ranges of F18 and F15. Most significantly, no uncollared cougar visited any of the 5 snare sites during this time. Although a 30-day effort does not rule out use of these canyons by uncollared animals (Chapter 1: home range size), clearly there were far more radio-tagged than uncollared cougars in the vicinity of Roblar and lower De Luz Canyons.

This evidence strongly indicates that in September 1991 we had captured at least half, but certainly not all, of the adult population. To estimate the total number of adult cougars, we examined maps of cougar home ranges for adults of each sex during 1991 and 1989.

Home ranges of adult females did not vary over the years either in size or in amount of overlap (Chapter 1). Home range overlap is well illustrated in the Camp Pendleton area in 1991 (Figure 5) and in several areas in 1989 (Figure 4). If we extrapolate this amount of overlap throughout the range, we estimate that we had collared about half of the adult females. Thus, there may have been about 14 adult females in the entire Santa Ana Mountain Range in September 1991.

The range may well be capable of supporting more than 14 adult females. There was a failure in reproduction in much of the southern half of the range during 1988 and it is possible that the number of adults in 1991 may not yet have rebounded to normal levels. This would be supported by the fact that 2 adult females used the Caspers Park area as the core of their home ranges in 1989 (Figure 4), whereas no adult female did so during 1991-92 (Figure 5, and road-tracking data: any adult female would have been detected in almost daily track searches by our crew or by trained Park rangers). Because Caspers Park is excellent cougar habitat, it will doubtless be occupied again. As recruits fill in vacancies created by recent adult mortality, it seems reasonable to expect that the mountain range can probably support 3-4 additional adult females.

A similar map of adult male home ranges as of October 1991 (Figure 6) includes 2 young males (M6 and M7) who exhibited stable home ranges for several months. Although the 1991 home ranges of M6 and M7 were significantly smaller than those of M2 and M9, they were far larger and more stable than the ranges of dispersing males, and probably were early adult territories. Based on the minimal overlap among these ranges and the lack of suitable habitat not occupied by these males, probably no more than 1 adult territorial male was not radio-tagged in September 1991. Male territory sizes are probably somewhat plastic, and a larger number of males could probably coexist by using smaller territories and tolerating more overlap. However, it seems that a reasonable estimate for the maximum number of adult territorial males is 7 or 8.

In summary, we estimate that the Santa Ana Mountain Range contained 10-14 adult females in September 1991, and that it may be able to support an average of 10-19 adult females in the long run. We also estimate that the Range contained 4-5 adult (or near-adult) males in September 1991, and that it may be able to support as many as 7-8 adult males in the long run. Juvenile mortality is very high and variable, as is reproduction, so we offer only a very rough estimate of 10-20 juvenile cougars in the Range.

Schoenfelder and Kimple (1979) used road transects to estimate cougar numbers in the Santa Ana Mountain Range in 1977 and 1978. They defined any medium or large size track traveling alone as "adult" (this would include both subadults and adults as defined herein). They estimated 12-18 adult-size cougars within the 400 square miles of the Santa Ana Mountain Range they surveyed. Assuming that about 25% of these animals were subadults, and extrapolating to the current total of 2070 km^2 (800 mi^2) of habitat, their estimate would be 18-27 adults. Our estimate of 14-19 adults (in September 1991) and 14-27 adults (potential long term carrying capacity) is similar to theirs. Given the poor accuracy and precision of track surveys (Van Dyke et al. 1986, Van Sickle and Lindzey 1992, Kendall et al. 1992), this agreement is probably due largely to chance.

Sex Ratio. The ratio of adult females to males in September 1991 was 1.75:1 for radio-tagged animals (counting M6 and M7 as adults; the ratio would be 2.3:1 if M7 is classed as subadult). Using estimated population size for Fall 1991, the adult sex ratio was between 2.5:1 (10/4) and 2.8:1 (14/5). In the long-term the expected sex ratio would be about 2:1 (15/7.5). Most other studies have also reported a sex ratio of approximately 2:1 (Seidensticker et al. 1973, Currier et al. 1977, Ashman et al. 1983, Murphy 1983, Hemker et al. 1984, Logan et al. 1986, Neal et al. 1987, Hopkins 1989). A few studies have reported other adult sex ratios, but all vary between 1:1 and 3:1 (Hornocker 1970, Seidensticker et al. 1973, Currier et al. 1977, Shaw 1977, Hopkins 1981, Quigley et al. 1989).

Carrying capacity. Dividing the long-term number of adults by the total 2070 km^2 of habitat, we estimate carrying capacity as 0.7 adult females and 0.35 adult males per 100 km^2 (or about 2 adult females and 1 adult male per 100 mi^2 of habitat). Previous studies have provided widely varying estimates of density many of which are roughly the same as our estimates (Hornocker 1970, Seidensticker et al. 1973, Sitton and Wallen 1976, Currier et al. 1977, Shaw 1977, Hemker et al. 1984, Logan et al. 1986, Neal et al. 1987, Hopkins 1989). It is difficult to determine how well previously reported densities correspond to our estimate because some studies lump non-breeding subadults with adults and because some study sites were chosen because of atypically high cougar densities.

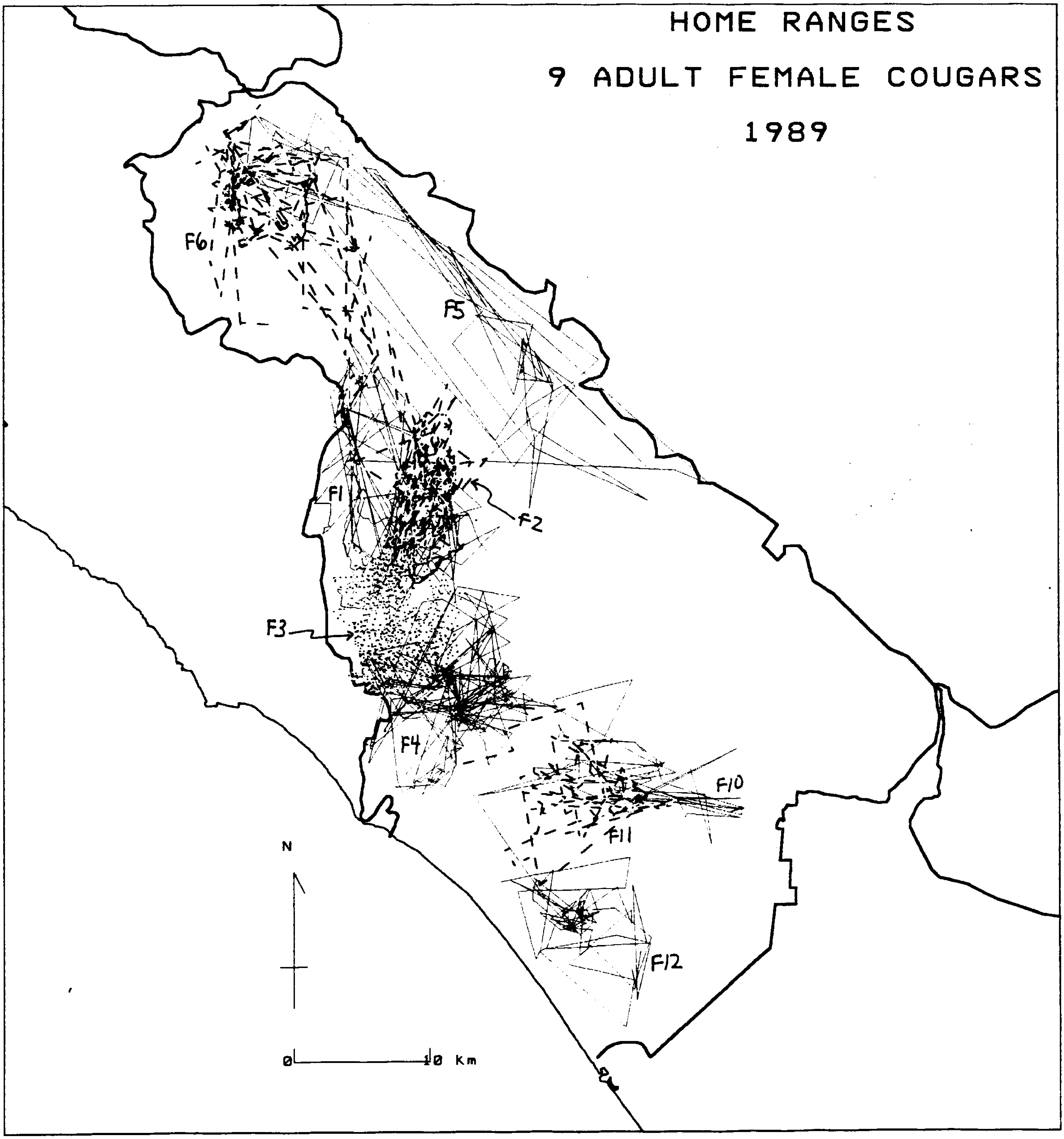

Figure 4. Home ranges of the 9 adult female cougars radio-tagged in July 1989. For each home range all locations for 1989 are connected in chronological order. The heavy solid line encloses 800 mi^2 of cougar habitat in the Santa Ana Mountain Range.

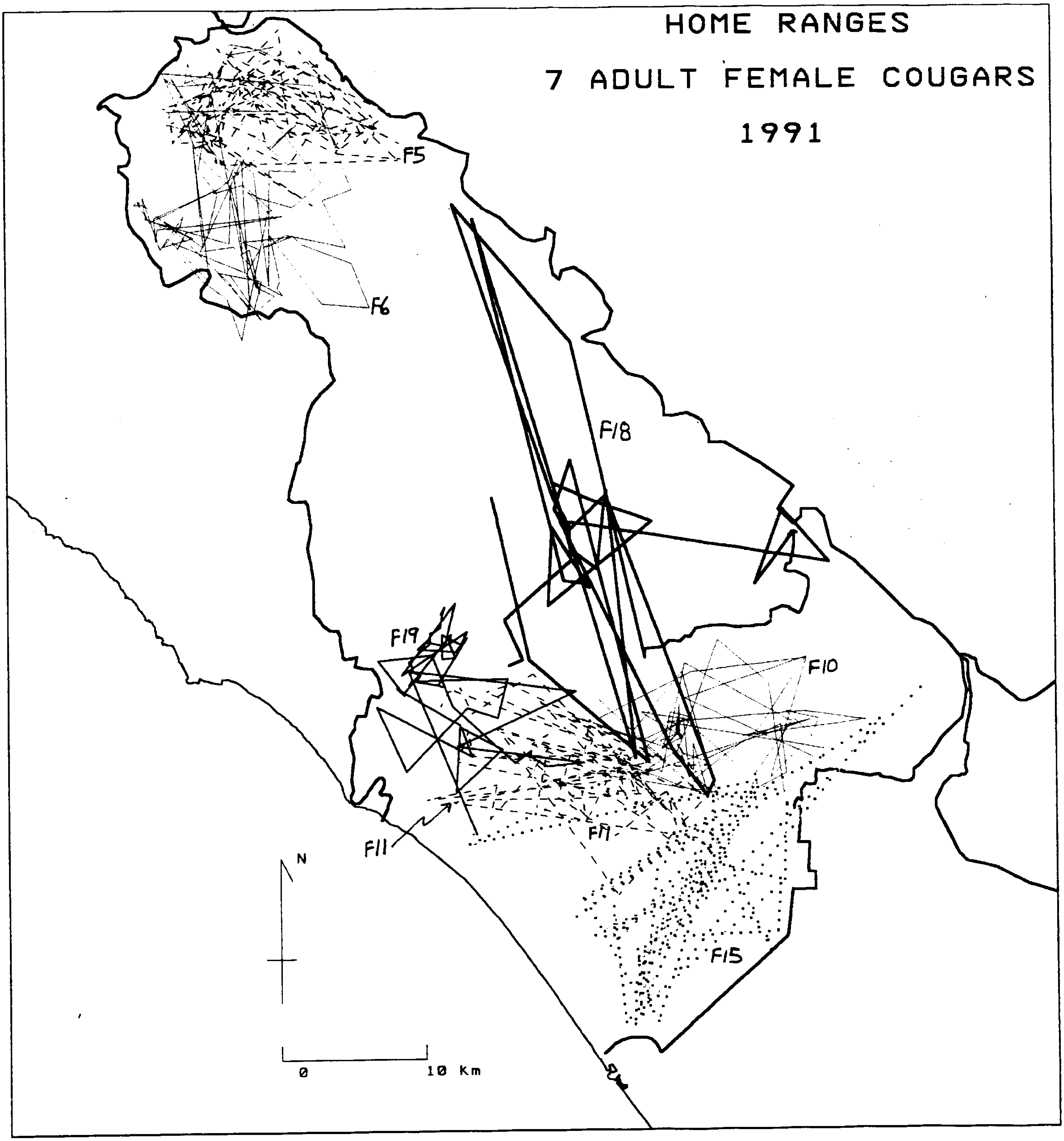

Figure 5. Home ranges of the 7 adult female cougars radio-tagged in September 1991. For each home range all locations for 1991 are connected in chronological order. The heavy solid line encloses 800 mi^2 of cougar habitat in the Santa Ana Mountain Range.

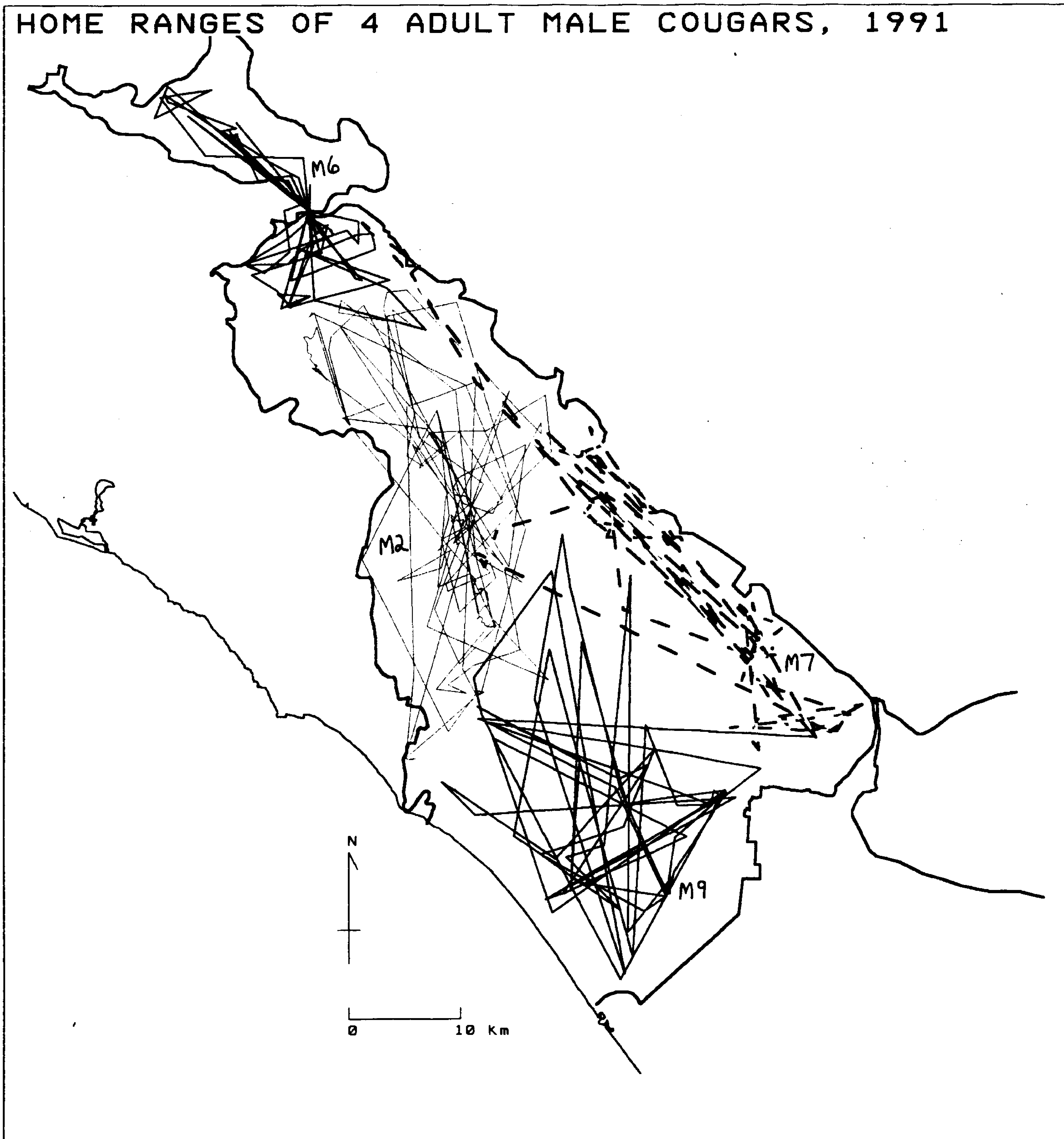

Figure 6: Home ranges of the 2 adult male cougars (M2 and M9) radio-tagged in December 1991 and 2 near-adults (M6 and M7). M6 and M7 continued to expand on these home ranges throughout 1992. For each home range all locations for 1991 are connected in chronological order, except for M6 (whose range excludes dispersal movements and includes only Oct 91-Jan 92 locations). The heavy solid line encloses 800 mi^2 of cougar habitat in the Santa Ana Mountain Range.

CHAPTER 3. DISTRIBUTION AND TRAVEL CORRIDORS

Cougar Habitat in the Santa Ana Mountain Range

Using the 5 criteria listed at the end of Chapter 1, there was about 2070 km^2 (800 mi^2) of cougar habitat in the Santa Ana Mountain Range during 1988-1992. We obtain the same estimate by computing the area within a polygon enclosing all cougar locations. The largest uncertainty in this estimate concerns over 50 km^2 of land in and around the Santa Rosa Plateau that had a mix of orchards, low-density housing, and semi-open pasture. These areas were included in our estimate on the basis of documented cougar use (usually brief visits). However, much of this area was clearly marginal habitat, and will become unusable if human use intensifies.

Cougar Use of County Parks East of I-5

All major regional parks east of I-5 were cougar habitat. Caspers Wilderness Park, Limestone Canyon Regional Park, Whiting Ranch Regional Park, Wagon Wheel Regional Park, Weir Canyon Regional Park (proposed), Irvine Regional Park (including the Villa Park impoundment) and O'Neill Regional Park (including the Arroyo Trabuco) were all used regularly by radio-tagged adult cougars. Each of these 7 parks was an important part of the home range of at least 1 radio-tagged adult cougar.

In addition, Peters Canyon Reservoir Regional Park and Santiago Oaks Regional Park were both used by subadult radio-tagged cougars, although we never documented use by any adult cougar. Only one cougar (M5) used Peters Canyon Reservoir. He first encountered and used the reservoir during his dispersal explorations, but most of his use of the area was after he broke his hip and knee in a vehicle accident. Both M5 and M10 used Santiago Oaks Regional Park (both after their vehicle accidents). Although both parks offered excellent habitat in terms of good native vegetation, ample woody cover, and ample prey, each was marginal with respect to housing density and connectivity (see Chapter 1: habitat use). Both parks were immediately adjacent to and nearly surrounded by high density housing tracts, and both had only a narrow connection to the central block of habitat. Indeed the only non-urban terrain adjacent to Peters Canyon Reservoir was an open grassy area nearly 400 m wide, with only 2 thin stringers of shrubs leading toward larger suitable habitat.

Peters Canyon Reservoir will become unusable by cats if the Eastern Tollroad or East Orange Project is built. Even without these projects, it will remain marginal and rarely-used habitat.

In contrast, good riparian vegetation connects Santiago Oaks Regional Park to Irvine and Weir Canyon Parks. Santiago Oaks Regional Park will probably continue to receive occasional use by cougars, especially by dispersing juveniles and injured animals. However, if the proposed Eastern Tollroad (and the tract homes that follow it) isolates Irvine and Weir Canyon Regional Parks from the central habitat area to the east, it will remove cougars from all 3 of these Regional Parks.

We never documented any cougar use of Carbon Canyon Regional Park in the Chino Hills. Nonetheless it did meet all 5 criteria for cougar habitat, and we believe that it was occasionally used by cougars during 1988-1992. It certainly will be potential cougar habitat as long as cougars remain in the Chino Hills.

All regional parks, except Caspers Wilderness Park, will become unusable by cougars if urbanization isolates them from the central habitat block. Loss of the Limestone Canyon-Whiting Ranch Parks complex would be a severe blow to the cougar population, and such isolation is certain to occur without careful management of urban growth along Santiago Canyon Road. The proposed Eastern Tollroad and the housing tracts that will follow it will (unless carefully planned) similarly prevent cougars from using Irvine Regional Park and the proposed Weir Canyon Regional Park. Ongoing and future urbanization, especially that associated with the proposed Foothill Tollroad, threaten to isolate O'Neill and Wagon Wheel Regional Parks. These issues are discussed at greater length under "corridors" below.

Cougar Use of the San Joaquin Hills

West of Interstate 5 there is only 1 area - the San Joaquin Hills - that meets 4 of the 5 criteria for cougar habitat. The San Joaquin Hills offer ample native vegetation, woody cover, and prey (including mule deer). About 75 km^2 (29 mi^2) of the area had low (essentially zero) housing density in 1990-91. The area included 5 relatively pristine canyons: Muddy Canyon, Moro Canyon, Emerald Canyon, Bommer Canyon, Shady Canyon, and Wood Canyon. Good habitat also existed in portions of Laguna Canyon and about half of Los Trancos Canyon. The only missing habitat element lacking was connectivity, with about 5 km (3 mi) of urban sprawl isolating these hills from the main block of cougar habitat. Although this area became isolated only about a decade ago and probably supported a few cougars for several years afterward, our population model (Chapter 4) demonstrates that an area of this size cannot sustain a breeding population of cougars.

Nonetheless, there were persistent reports of cougars being sighted in the San Joaquin Hills. On several occasions (October 8 1989, 2 dates in winter 1990, and September 21, September 30, and October 3 1992) we were able to initiate track surveys within hours of such reports. On each occasion we searched the site of the report and adjacent washes, ridges, trails, and dirt roads for tracks. Although tracks of many species were evident, no cougar tracks were seen.

On the chance that 1-2 cougars might still be hanging on in the San Joaquin Hills, we undertook intensive track surveys in the San Joaquin Hills from May 21 through May 26 1990 (6 consecutive days). Dusty road conditions were optimal for tracking on all survey routes. On each survey, we covered a Basic Survey Route consisting of 2 tributaries of Laguna Canyon and the full lengths of Moro, Shady, Emerald, and Wood Canyons. Portions of Bommer, Los Trancos, and Muddy Canyons were covered on some of the survey dates. A detailed route map was included in this study's Quarterly Report dated August 1 1990. To design the Basic Survey Route we first identified the roads that traversed the best cougar habitat, selecting those that crossed the area from one developed edge to the other. In addition to the Basic Survey Route, on each day we also covered some road segments on secondary canyons or ridges. On average, each secondary segment was covered twice during the survey period.

Our rationale in repeatedly checking the same long roads daily for a week was based on the habits of radio-tagged cougars. Although a cougar may remain in one place for 3-4 days while feeding on a deer, over the course of a week there are several nights during which the cat hunts, traveling several km per night. The only exception is a mother with newborn cubs who may remain within 2 km of the den for the first few weeks postpartum. In all other circumstances, we would expect a cougar to cross dirt roads on several occasions during a week-long period.

The track survey was usually carried out by a 2-person team. One person drove the vehicle at 5-8 mph while the second sat on the hood and searched the ground for tracks. On 2 survey dates, the route was covered by a single observer. On these days the observer attempted to compensate by driving very slowly and frequently stopping to investigate on foot.

No cougar tracks were detected on any of the surveys. We did find tracks of prey species, including deer, cottontail rabbits, coyotes, raccoon, fox, opossum, and bobcat. Emerald Canyon had markedly more deer tracks than the other canyons surveyed.

Because our coverage of the area was so thorough and the tracking conditions so good, we conclude that cougars no longer live in the San Joaquin Hills.

Wildlife corridors

A wildlife corridor is a piece of habitat, usually longer than wide, with vegetation and topography that facilitate the movements of wild plants and animals from 1 large patch of suitable habitat to another (Harris and Gallagher 1989). Forman and Godron (1986:364-426), Adams and Dove (1989), and Harris and Gallagher (1989) provide comprehensive reviews of the literature on corridors.

Over most of the cougar's range in North America, cougars have access to a vast interconnected landscape and there is no pressing need for corridors. In the Santa Ana Mountain Range, however, urbanization has nearly isolated the cougar population from the only adjacent population (in the Palomar Range) and urban growth will fragment most or all of the population into non-viable sub-units unless linkages are maintained among habitat patches. Without careful planning, the 5059-ha (12,500-acre) Chino Hills State Park and all but one of Orange County's Regional Parks will soon become isolated and unusable as cougar habitat. Even cougars in the central block of habitat, including Caspers Wilderness Park, are at great risk if the Santa Ana Mountain Range becomes isolated from the Palomar Range (Chapter 4, Beier 1993). Our dispersal data (Chapter 6, Beier 1993, manuscript in preparation) clearly demonstrates that dispersing cougars will find and use suitable corridors if available.

Factors influencing corridor suitability for cougars

Although this section deals solely with factors influencing corridor suitability for cougars, any corridor design should consider the needs of more than a single species. Beier and Loe (1992; included as Appendix 4 in this report) and Harrison (1992) should be consulted for an overview of such issues. In evaluating a potential corridor, it is important to keep in mind that a corridor facilitates travel for the entire distance between 2 significant habitat areas, not simply for the length of a highway underpass or other constriction. In rapidly urbanizing southern California, no corridor will be effective unless it encompasses the entire corridor length and explicitly connects to 2 or more larger habitat areas.

Applied to wildlife corridors, the term "design" is not used in its traditional sense of drawing a plan on a blank slate. Instead corridor design involves preservation of an existing travel route, minimizing impacts to an existing route, or leaving a route in an area that formerly allowed unobstructed movement. We cannot usually design corridors that force animals to travel in locations that are convenient for development plans. Therefore, if a project may impact a corridor, the project proponent should be required to monitor animal use of the corridor area both pre- and post-project (Beier and Loe 1992).

For cougars, the major factors influencing success of a movement corridor are:

- **location**: a cougar cannot use the corridor unless its normal travel pattern causes it to encounter the corridor entrance. Conversely, a corridor along a natural travel route is likely to be used even if habitat conditions within the corridor are suboptimal. Foster and Humphrey (1992:17) noted: "Most importantly, [corridors] must be located where animals naturally [travel]. Thus prior knowledge of traditional travel landscape-determined travel routes of the target animals is essential. [Corridors and] underpasses installed away from such crossing points are ineffective." Thus cougars are much more likely to cross State Route 91 via the suboptimal crossing at Coal Canyon than via the superior undercrossing 1.6 km east, simply because Coal Canyon is a well-used cougar travel route. In our intensive monitoring sessions, we have identified the routes by which cougars traveled among various parks and protected areas. In planning future urban growth, these routes provide ideal corridor sites. In the absence of data from radio-tagged animals, canyons with scour zones, or ridgelines free of artificial light, are likely locations for cougar travel routes.
- **cover**: Some native woody vegetation should be present to provide visual cover. Cougars will move up to 400 m across open terrain within a wildland matrix, but would not move across this length of open terrain with dense housing on either side.
- **lighting**: cougars travel mostly at night and avoid brightly-lit areas. Lights are especially detrimental in a bridged undercrossing. In several monitoring sessions, radio-tagged dispersers exploring new terrain apparently oriented toward dark areas and away from city lights. Thus lighting would probably also be effective in deterring an animal from entering a "cul-de-sac corridor" that looks inviting at its entrance but which leads to urban areas instead of good habitat (e.g., Temecula Creek).
- **roads:** Roads can render a corridor useless or cause animal injury and mortality. Where heavily-used roads cross a corridor, a bridged undercrossing is preferable to a culvert, and fencing can guide animals away from a high-speed road and toward the underpass. In Florida, an 8' x 24' precast segmental box culvert with 2.5% grades was a cost effective design with high probability of use by large wildlife, including cougars (Florida Department of Transportation 1992). Foster and Humphrey (1992:25) recommend that animals should have an unobstructed view of the habitat or horizon on the opposite side of a crossing structure, and that medians be open rather than covered. However, if the median is narrow, an opening may admit more noise and debris than light, and should probably be covered (Reed et al. 1975). The Florida study found that a 10-12-ft high chain-link fence topped with 3 strands of barbed wire was effective in inducing cougars to stay off highway right-of-way and use underpasses. We believe that a chain-link fence 8 feet high topped with 1-2 outrigger strands of barbed wire would also be effective and cheaper. A cougar could, but probably would not, climb or jump such a fence. Humphrey (1992) provides an excellent annotated bibliography on the limited literature relating to wildlife undercrossings and highway fencing. We believe that overpasses would also be readily used by cougars if the roadbed is recessed into the terrain, if the overcrossing is free of artificial light, and if there is appropriate visual screening so that the animal does not expose itself to view. On rural roads,

vehicle speeds can be kept low through appropriate design elements (e.g., curves, grades, narrow road width, speed limits). Rural access roads should be 1.5 lanes wide with pullouts to encourage slow driving; wildlife undercrossings would not be necessary on such roads.

- **disturbances**: Unrestrained domestic dogs can harass cougars (and other wildlife) and render a potential corridor unusable. Dogs may be less of a problem adjacent to tract homes (where pets are usually restrained at night) than adjacent to a rural community, where dogs often roam free. Daytime use of a corridor by equestrians and hikers is fully compatible with use for cougar movement. Rural housing impacts can be minimized by having housing pads set back from stream courses or ridgetops, and by requiring large (10-40 acre) minimum parcel sizes.
- **frequency of use**: A corridor between the Santa Ana Mountains and the Palomar Range need be used only by a handful of immigrants per decade, with each animal making a single passage. In contrast, because the Chino Hills is smaller than an adult male home range, it requires a linkage that will allow a male to repeatedly use the corridor to breed with the resident females. The Regional Parks, being smaller than an adult female home range, require high-quality, preferably multiple linkages, to allow resident females to use them as part of their home range.
- **width**: It is impossible to specify a general minimum width, because the width needed depends on all of the above factors, and also on the length of the corridor. Width can also vary along a corridor. For instance, a width of 10 feet may be acceptable for a road undercrossing but not for the entire length of a corridor. As a rule of thumb, if other conditions (woody cover, no lighting, freedom from dogs, canyon bottom location, etc.) are met, we suggest that a corridor designed for use by cougars should be at least 100 m (300 ft) wide if the total distance to be spanned is 800 m (½ mi) or less. To the extent that other elements are deficient, and as the corridor length increases, corridor width should also be increased.

As mentioned above, knowledge of the traditional movement patterns of the target animal is the most important factor in corridor design. By intensive monitoring of individual focal animals, we learned the actual routes by which cougars traveled from the protected core area (Table 1, Figure 1) to most regional parks and smaller protected parcels. We describe these routes in the remaining sections of this chapter. Although most these routes now traverse pristine open space, they will become corridors (at best) as continued urban growth removes the adjacent habitat.

The most critical link: the Pechanga Corridor from the Palomar Range to the Santa Ana Mountain Range

Due to past urban growth, the cougar population in the Santa Ana Mountain Range is isolated from all other cougar populations except that in the Palomar Range to the southeast (Figure 1). Aerial photographs suggest that the amount of habitat and the size of the cougar population are much larger in the Palomar Range. A corridor to allow immigration from the Palomar Range is necessary to insure survival of our cougar population (Chapter 4, Beier 1993). Any viable corridor must link the Palomar District of Cleveland National Forest and the adjacent Pechanga Indian Reservation (the westernmost protected area in the Palomar Range) to San Diego State University's Margarita Field Station (the easternmost protected area in our mountain range) (Figure 7). If successful, The Nature Conservancy's Santa Margarita River Project will allow movement westward from the

SDSU parcel to Camp Pendleton and the Trabuco Ranger District.

We have named this linkage the "Pechanga Corridor" because Pechanga Creek is the main watercourse leading between the 2 areas. The 2 main threats to this linkage are I-15 and urban growth in and south of the City of Temecula. Although I-15 is the biggest hurdle today, within a few short years urbanization, if not controlled, will present an even more impenetrable barrier. This report's focus on I-15 should not obscure the fact that an effective corridor must be much longer than a highway underpass. In the following discussion, bear in mind that only west-bound immigration will reduce extinction risk. Because the cougar population in the Palomar Range is much larger, it does not need immigrants from the Santa Ana Mountain Range.

During our study several cougars attempted to cross I-15 to move between the 2 mountain ranges (Figure 8). Between October 1 1990 and December 31 1992, 3 cougars were killed on I-15 just north of the Border Patrol Station and a fourth cougar was killed on I-15 just north of Flynn Nursery at the north edge of the village of Rainbow. The dispersing M12 crossed I-15 about 500 m south of the Santa Margarita River. The dispersing M5 was initially captured and radio-tagged after being treed by domestic dogs in the city of Temecula; his tracks indicated that he had come from the confluence of Pechanga and Temecula Creeks, about 700 m upstream from the Santa Margarita Bridge. He probably had reached this confluence from the Santa Margarita River. From the west, M7 approached I-15 at the Santa Margarita River on several occasions, and may have made short forays east of I-15. During our study no cougars were road-killed elsewhere along I-15, nor did we have evidence that any cougars approached I-15 outside of this same area.

These patterns clearly show that the natural travel route for cougars leads them to cross I-15 at the crest just north of the Border Patrol Station. This is certainly **the** crossing point for any cougar traveling in the critically important westward direction, because urban sprawl strongly discourages west-bound cougars from approaching I-15 north or south of this area.

Beier (1993) was pessimistic about the present utility of this corridor. But the number of attempted crossings since that paper went to press suggests that dispersing cougars occasionally have crossed from east to west across I-15, and in sufficient numbers to benefit the cougar population. During 1990-92, night-time traffic on I-15 was light and the five road-kills may have been matched by a similar number of successful (but less detectable) crossings. As few as 1 or 2 successful west-bound dispersals during that 2-year period would significantly benefit the cougar population in the Santa Ana Mountain Range (Beier 1993). Nonetheless, we have not documented a single successful west-bound crossing of I-15.

Unfortunately, as traffic volumes increase in concert with urban growth, cougars will soon be unable to make at-grade crossings of I-15. Of equal concern, there is no safe underpass within 1 km of the ridgetop crossing area. Cougar habitat abuts I-15 only for about 6 km starting at and south of the Santa Margarita River bridge. There were 3 bridges and about 10 culverts on I-15 between Temecula and Mission Road (Fallbrook). None of the culverts offered a suitable undercrossing. All culverts were corrugated metal pipes 3 or 3½ feet in diameter (except 1 that was 6 feet in diameter), at least 150 feet in length, and steeply sloped with no light visible from the other end.

Of the 3 bridges, only the bridge over the Santa Margarita River is currently a feasible undercrossing for regular use by cougars. The bridge at Rainbow Creek is unusable because a trailer park lies squarely under and alongside this bridge, and to the east the creek meanders through an open area with large container-stock nurseries. The bridge for a 2-lane paved road 650 m south of Rainbow Creek does not lie along a natural travel corridor for cougars, especially for a west-bound animal, due to the village of Rainbow with its housing and large nurseries. The Santa Margarita Bridge is an excellent undercrossing structure, and the River itself would readily lead a west-bound cougar into the central habitat block. However, urban sprawl in Temecula makes it difficult for a cougar to encounter the underpass from the west. Pechanga Creek (the best watercourse leading west toward the bridge) has been highly devegetated, lined with concrete on parts of its north bank, subject to light pollution from adjacent housing tracts on the north bank, and has a large golf course resort on the south side.

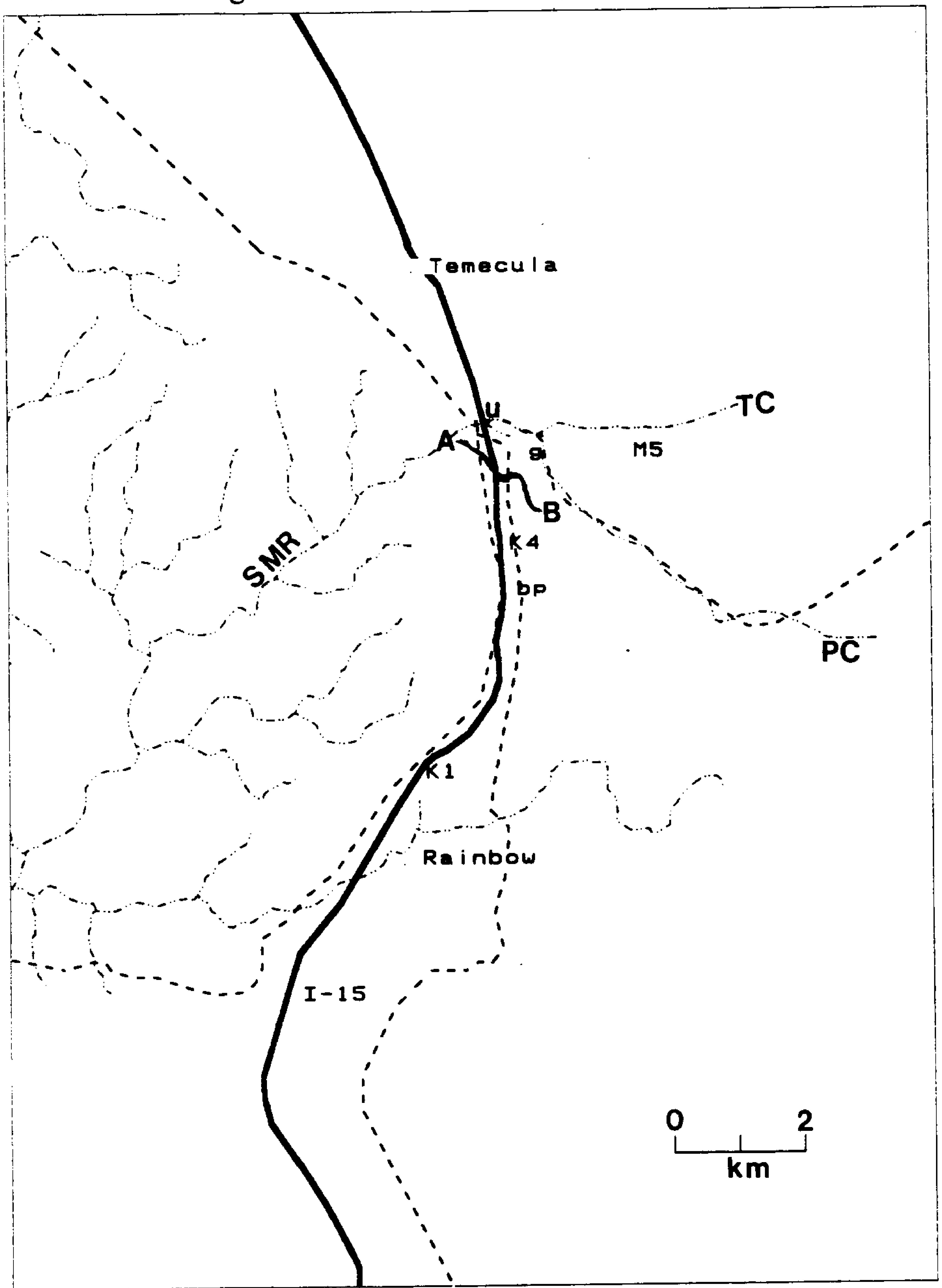

Figure 7: The Pechanga Corridor is the only potential area for cougar movement between the Santa Ana Mountain Range (west of I-15) and the adjacent population in the Palomar Range (east of I-15). Thick dashed line = wildland/urban edge. Note that Temecula Creek, **TC**, is a cul-de-sac corridor (it dead-ends in unsuitable habitat). During August 1990-December 1992, 3 cougars were road-killed at point **K4** (just north of the Border Patrol station, **bp**), 1 cougar was killed at **K1**, 1 cougar (M5) was treed by domestic dogs near the Temecula cul-de-sac at **M5**, and M12 crossed eastward along line **A-B**, passing near the golf course, **g**. The 3 options for allowing safe west-bound animal movement are restoration of Pechanga Creek (**PC**), using fencing to divert animals to the suitable underpass at **u**, or an overpass at **K4**. **SMR** = Santa Margarita River.

Without preventive action, this corridor will be lost. There are 3 options for insuring the future integrity of this linkage, and a 4th option requiring continued human intervention:

1. Restore Pechanga Creek. Pechanga Creek leads directly to the only suitable undercrossing. Restoring the creek would be costly but would protect a corridor of regional significance. If this option were taken, restoration measures should include:

- Physically prevent vehicles from driving in the creek bottom
- Enhance native vegetation in Pechanga Creek. Revegetate a strip of land (at least 35m wide) along the Creek-Golf Course edge.
- Direct lighting from creekside homes away from the creek. Prevent free-roaming dogs in the creek. Unleashed dogs keep out not only cougars but also deer and other species whose presence would make the creek attractive to cougars. In 1990 we found no deer tracks, pellets, or other deer sign in the Creek, probably due to high use of the Creek by dogs.
- Discourage cougars from moving upstream along Temecula Creek from its confluence with Pechanga Creek. In 1990-92, Temecula Creek had a denser riparian forest and greater water flow, and probably would appear more inviting to a dispersing animal than Pechanga Creek. However, 800 m above the confluence it "dead-ends" in tract homes. Cougars can probably be deterred from entering the cul-de-sac by installing bright lights and removing a small amount of riparian vegetation near the Wolf Valley bridge.
- Prevent further urbanization along and south of Pechanga Creek.
- Fence I-15 south of the Margarita Bridge to prevent animals from being killed there.

2. Divert animals from the ridge route toward the River undercrossing. The natural travel route for west-bound cougars follows the ridge to an at-grade freeway crossing just north of the Border Patrol station. As traffic volumes increase, animal mortality will increase and eventually this route will become infeasible. To prevent road-kills and preserve a crossing, several measures would be needed:

- Fence I-15 from the village of Rainbow to the Santa Margarita River; the fence should be at least 8 ft high with a barbed-wire outrigger. Hopefully at least some west-bound animals encountering this fence would make the "right" decision to turn north rather than south.
- Keep the area along the fence as wild as possible. A west-bound cougar deflected by the fence would have to follow the fence north for 1500m, including 700m of golf course, before reaching the Santa Margarita River. The golf course along most of this area is relatively wild, and was traversed by M12 in January 1992. However, it would help to redesign the open area around the driving range area; its large fences intersect the animal travel route.
- Prevent urbanization along the wooded ridge that leads from the east to the current crossing area.

3. Build an overpass at the natural crossing area. A freeway <u>over</u>crossing at the natural travel area just north of the border patrol station would maintain the linkage. Because I-15 is dug into bedrock for about 1.5 km north and south of this crossing area, it would be nearly impossible to retro-fit an underpass here. The overpass would in effect create a tunnel for vehicular traffic on I-15. If wide (say 100 ft), covered with natural substrate and vegetation, and with sidewalls to block vehicle light and noise, such an overcrossing would probably facilitate cougar movements at least as well as any other option.

Dirt roads (closed to motor vehicles at night) leading to either end of the overpass would further enhance the corridor, because cougars and other animals often to use such roads to travel through woody vegetation. Such roads would also allow the overcrossing to be used by hikers and equestrians. This option should also include freeway fencing and preventing urbanization along the ridge east of the crossing point. This option is novel but may be appropriate given this region's accelerating urbanization.

4. Import animals into the Santa Ana Mountain Range. When a cougar enters a residential area without posing a threat to human property or safety, the current policy of California Department of Fish and Game (CDFG) is that the animal is captured and moved to the nearest appropriate habitat. Such incidents occur regularly in southern California. Several administrators have suggested to us that this policy could be modified to favor translocating such non-problem animals into the Santa Ana Mountain Range. Although clearly more artificial and less aesthetically pleasing than maintaining natural connectivity and letting cougars immigrate on their own, such an approach may be feasible. However, it would clearly be an unprecedented experiment, and would require a commitment (by CDFG) and funding (most appropriately from the planning agencies and developers that cause loss of existing linkages) in perpetuity. If such an option is pursued, it should include:

- importing only animals of dispersal age (12-28 months of age).
- importing only animals from a similar habitat type in southern California.
- monitoring the results. This would be a large experiment. Transplanted animals would suffer high mortality, and could disrupt the social structure or resident cougars; such impacts would depend on the existing demographics of the population. If the translocation option is chosen, many resident cougars and all transplanted animals should be radio-tagged and monitored. The monitoring effort should continue for at least 20 years, with annual support similar to that expended in our study.

Chino Hills State Park to Trabuco Ranger District

A wildlife corridor for cougars between the Santa Ana Mountain Range and the Chino Hills will allow cougars to use an area (the Chino Hills) that cannot support a population of cougars if it were to become isolated (Beier 1993). Quite simply, if there is no corridor, then there will be no cougars in the Chino Hills. To be effective, such a corridor must not simply be a freeway underpass, but must reach from Trabuco Ranger District and the adjacent Tecate Cypress Reserve in upper Coal Canyon (the northernmost protected parcels in the Santa Ana Mountain Range) to Chino Hills State Park (the southernmost protected parcel in the Chino Hills).

We approached our evaluation of potential movement corridors from the perspective of a cougar attempting to travel north from the Santa Ana Mountain Range into the Chino Hills (Figure 8). State Route 91 (Riverside Freeway) and associated urban growth form a narrow band separating the Chino Hills on the north from the Santa Ana Mountain Range to the south. Cougars can approach the south side of Highway 91 along the entire 5.5 km from Gypsum Canyon to the Green River Road exit. Unlike I-15 near Temecula, the Riverside Freeway's 8 lanes are too busy at night to allow safe at-grade crossings by wildlife. There were 11 culverts and 3 vehicle underpasses in this 5.5-km section. Seven of the culverts were < 3 ft in width and height and were located such that it would be nearly impossible for a cougar to find the entrance. Two others (a 4-ft diameter cylinder and a 5-ft wide box) were similarly inaccessible. On May 7 1991 M10 was struck by a vehicle on the Riverside Freeway within 50 feet of the 5x5-foot box culvert, which was inconspicuous from as close as 20 feet away. Only 2 culverts (B Canyon and Coal Canyon) were large (10 ft wide and 8-12 ft high) and located at canyon mouths where cougars could reasonably be expected to encounter the entrance; these are considered in greater detail below.

Of the 3 underpasses, the Mindermann or Green River underpass (a 1-lane paved access road for the old Minderman Ranch) did not lie along a canyon or ridge and would not be encountered by a traveling cougar. The Gypsum Canyon Road underpass was at an excellent location with respect to topography and cougar travel patterns, but the 500-m long underpass was occupied by the Gypsum Canyon Road interchange, where heavy traffic precluded cougar use. In August 1989 (even before the interchange was opened to Bridge traffic), F8 was road-killed at this interchange. Only 1 vehicle underpass (Coal Canyon) was located along a natural travel route and was undisturbed enough to allow cougar passage. Because this underpass lies immediately adjacent to the Coal Canyon culvert, the 2 are considered together below.

The 2 potential culverts and 1 vehicle underpass thus yield only 2 potential crossings of SR-91:

1. **Coal Canyon**. The Coal Canyon Road vehicle underpass and the twin box culverts alongside it offer by far the best route to cross SR-91. The main factor is that it lies at the mouth of Coal Canyon, a major wildlife travel route. We have abundant evidence that Coal Canyon is a major travel route. Coal Canyon was used by 6 radio-tagged cougars (F5, F6, F17, M6, M8, and M10), three of which either crossed or attempted to cross the freeway there. The dispersing juvenile M10 moved from Camp Pendleton, entered upper Coal Canyon for the first time on May 8 1991, moved rapidly down the Coal Canyon to the freeway on May 9, and was struck on the freeway May 10. In April 1991, M8 entered the Chino Hills, almost certainly via this corridor, and was later road-killed at the north end of the Chino Hills. Most dramatically, M6 traveled this corridor at least 22 times during June 1 1991 - December 31 1992 (Figure 8). Finally, 1-2 uncollared cougars (probably 1 juvenile female based on track size) used the culvert to cross the freeway in 1991.

On 18 of his 22 crossings, M6 used the box culvert under SR-91. On the other 4 crossings we found no tracks in the excellent substrate in the B Canyon or Coal Canyon culverts, so we conclude he used the (paved) vehicle underpass. M6's preference for a culvert is not typical of cougars confronted with roads. Other radio-tagged cougars preferred to cross 2-lane paved roads at grade rather than use a culvert directly in front of them, and all cougars used bridged undercrossings without hesitation. Certainly with enhancement of woody vegetation in the underpass, the vehicle underpass would be the preferred route for all animals.

2. **B Canyon**. The B Canyon culvert lies about 400 m east of the clubhouse for the Green River Golf Courses. Its canyon is well-wooded and has a spring in its headlands. A cougar in B Canyon could follow it to the culvert, which is physically ideal for animal movement. The problem then becomes getting into B Canyon, which now receives little cougar use. Even M6's, whose home range straddles SR-91 (Figure 8, Figure 23), has never used the B Canyon crossing and has never been located in B Canyon. Only 2 radio-tagged cougars (M10, F5) were documented using B Canyon; both of them entered via the lowermost main tributary of Coal Canyon (Cut-Across Canyon in Figure 8). Thus B Canyon, already rarely used, would receive extremely little use if the main access via Cut-Across Canyon is removed

by urban growth. Dispersing cougars are so proficient at finding travel routes that a rare disperser probably would use B Canyon to enter the Chino Hills even if Coal Canyon is destroyed. However, the Chino Hills is such a small area of habitat that it needs more than 1 immigrant every few years; it needs regular visitation by an adult male (Beier 1993). In short, the Chino Hills need visitation such as was demonstrated by M6's use of Coal Canyon Corridor in 1991 and 1992 (Figure 8, Figure 23). B Canyon does not allow this level of use today, and it is inconceivable that it would do so if access to B Canyon from Cut-Across Canyon were lost.

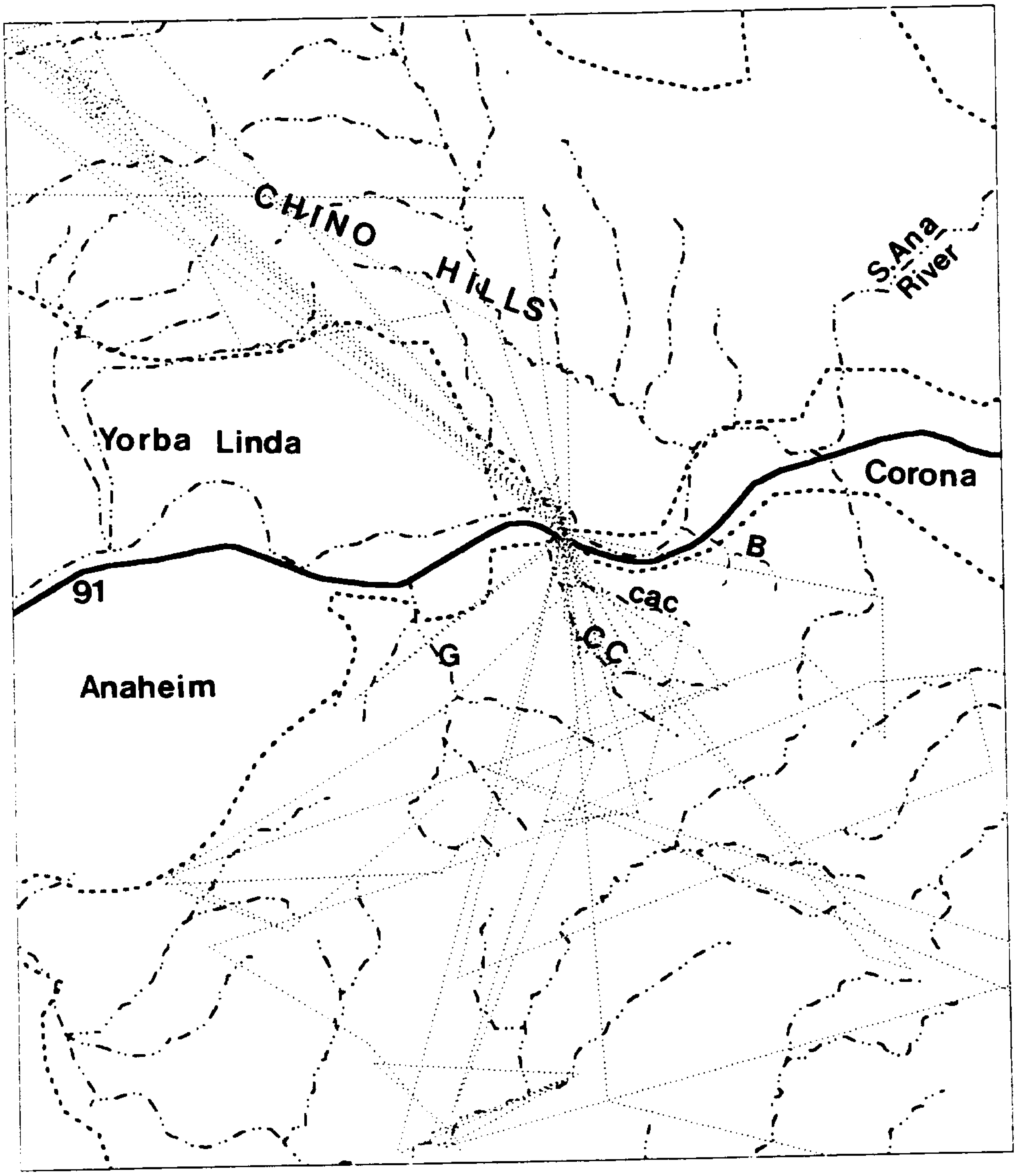

Figure 8. The corridor at Coal Canyon (**CC**), is the only route capable of allowing the frequent movements needed to maintain cougars in the Chino Hills. B Canyon (**B**) provides a suitable undercrossing but is not a major travel route. Cougars access B Canyon via Cut-Across Canyon (**cac**). A proposed housing tract would block both Coal and Cut-Across Canyons. **G** = Gypsum Canyon. Dotted lines indicate M6's travels during May-Dec 1991, including 12 of his 22 passages through the Coal Canyon Corridor.

On March 3 1992, the Anaheim City Council voted to allow construction of up to 1500 homes in Coal Canyon. The Council did so despite the conclusion in the City's EIR that the project would "result in the loss of potential for a cougar population to occur in the Chino Hills." By guaranteeing the loss of cougars from the Chino Hills, the project would also reduce the amount of habitat available to the cougar population in the Santa Ana Mountain Range by about 8%. adding to the risk of extinction for the larger population (Figure 11).

No construction has begun on the Coal Canyon project, in part because the City stipulated that no building permit can be issued nor any homes sold in Coal Canyon until additional lanes are added to SR-91. Thus there is still an opportunity to plan urban growth in a way that preserves the Coal Canyon Corridor. The following steps are necessary for corridor preservation:

- minimize urban growth in Coal Canyon (including the parcel in Yorba Linda just north of SR-91) and along the Green River Golf Course.
- Increase the amount of woody vegetation near the underpass. Ideally take the creek out of the culvert and into the underpass, removing the pavement and adding vegetation to the underpass.
- fence SR-91 to funnel animals toward the underpass and culvert and keep them off the freeway.
- keep night-time vehicle traffic at the Coal Canyon Road interchange at its present level, (i.e., virtually no vehicle use at night). Remove the existing lighting in the underpass.
- If possible, increase shrub and tree cover at the edges of the golf courses, and on the large grassy field just northeast of Scully Hill.

Because many of these steps could be implemented when new lanes are added to the Riverside Freeway, Paul Beier conveyed these recommendations to CalTrans on February 6 1992; Beier stressed that the growth-inducing impacts of the freeway were the most critical issue to address and quoted the City of Anaheim's conditions of approval to the effect that 9,500 homes could not be built or sold in Gypsum and Coal Canyons until CalTrans widened SR-91. CEQA requires an EIR for any project with growth-inducing impacts, and an appropriate mitigation for this induced growth would be for CalTrans to work with the Cities of Anaheim and Yorba Linda to develop a cross-jurisdictional plan to preserve the wildlife movement corridor. In late February 1992 CalTrans issued a statement that no EIR was needed for the project.

The third entity with planning authority over the Coal Canyon Corridor is the City of Yorba Linda. During 1992, Yorba Linda approved language in its General Plan stating that the Yorba Linda will protect the corridor if the City of Anaheim will co-operate in the effort.

O'Neill-Arroyo Trabuco-Wagon Wheel Regional Parks to the Protected Core Area

At least 10 radio-tagged cougars (F1, F2, F13, M2, M3, M4, M8, M10, M12, M13) used the Arroyo Trabuco and Wagon Wheel Parks during this study. Animals moved to these Parks from the central habitat block by using both northern and eastern routes (Figure 9). The 2 northern routes are based on overnight monitoring sessions on F1 and M12, and the 2 eastern routes are based on overnight monitoring on M8, M1, F2, and M2, and a long series of tracks by an uncollared cougar. Although the Arroyo Trabuco appears a logical corridor on a map, cougars avoided the Arroyo Trabuco for about 2 km of its length, starting at the developed portions of O'Neill Park and continuing well north of Live Oak Canyon Road.

These routes will remain viable only if protected along their entire length between these smaller parks on one end and either National Forest Land (to the north) or Caspers Park (to the east) on the other ends. Maps describing these routes were given to the County of Orange and the Transportation Corridor Agencies (TCA) in 1991. Both the County and the TCA responded with good-faith efforts to minimize impacts to these routes.

Excellent regulations for protecting wildlife movement along the northern routes were included in the recent Foothill-Trabuco Specific Plan. If these regulations are strictly enforced. these northern routes should remain usable by cougars and other wildlife.

. Significant planning has also been made to protect the eastern corridors, although problems remain. To mitigate impacts to wildlife movement, the County of Orange modified the southern edge of the proposed Las Flores Planned Community and added plans for a bridge to Antonio Parkway just south of Oso Parkway. These measures will effectively mitigate the impact of these 2 projects on wildlife movement. To mitigate impacts further east, the TCA added several bridges, and shifted part of the alignment of the Foothill Tollroad. As of late 1991, however, the TCA had not resolved the problem of how to build the interchange with Crown Valley Parkway without blocking one of the routes. Most importantly, the underpasses provided by TCA do not in themselves protect the entire length of these travel routes. In the long term, Tollroad-induced urban growth will cut off these corridors unless effective restrictions are put on future land use.

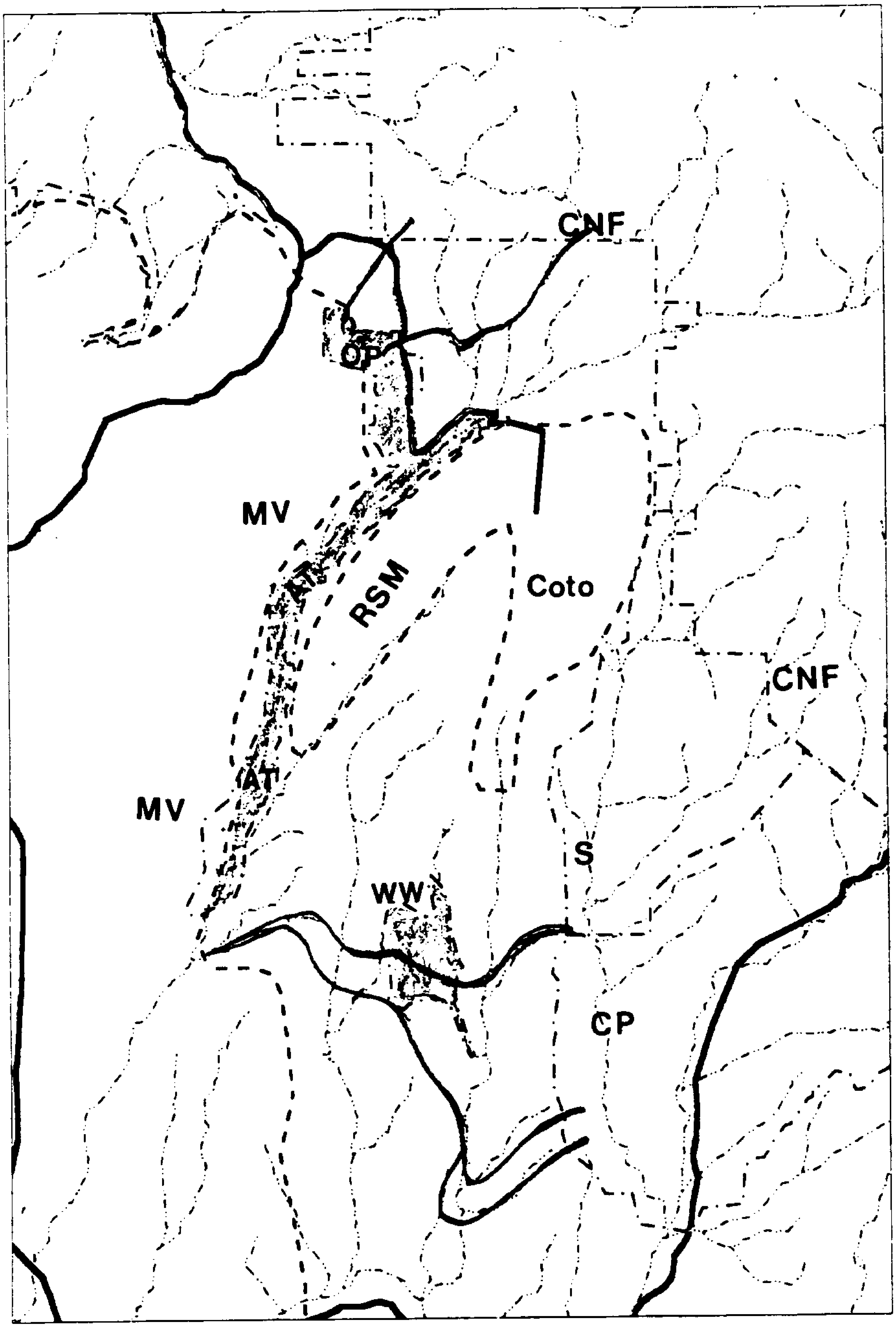

Figure 9. Linkages between O'Neill Park (**OP**), Arroyo Trabuco (**AT**), Wagon Wheel Park (**WW**) and the central habitat block (Cleveland National Forest - **CNF**, Caspers Park - **CP**, and Starr Ranch - **S**). Dashed lines indicate approximate edge of habitat, thick lines indicate paved roads, thin lines indicate approximate cougar travel routes. **MV** = City of Mission Viejo; **RSM** = Rancho Santa Margarita; **Coto** = Coto de Caza. Note that the Arroyo Trabuco is a narrow corridor of habitat lined with tract homes.

Weir Canyon-Santiago Oaks-Irvine Regional Parks to Trabuco Ranger District

Eight radio-tagged cougars (M5, M6, M10, M11, M12, F6, F5, F8) used the proposed Weir Canyon Regional Park. Most of these animals also used at least the Villa Park impoundment within Irvine Park, but we believe that only 2 (M5, M10) used Santiago Oaks Park. During 1988-1992, there were no significant barriers to animal movements in the 6 km (4 mi) between these contiguous 3 parks and the Trabuco Ranger District (the nearest parcel in the protected core area).

However, the combined impact of the proposed 8000-home Mountain Park project, the proposed 13,000-home East Orange project, the proposed Eastern Tollroad, and future (Tollroad-induced) urban growth threatens to sever the connection between these 3 parks and National Forest land. In the draft EIR released in late 1991, the TCA committed itself to only 1 wildlife undercrossing, to be provided by a bridge over Santiago Creek. Unfortunately, this bridge does not correspond with the travel routes of radio-tagged cougars and it is unlikely that it would be used by them. It will become impossible for cougars to use the Santiago Creek undercrossing after the 13,000-home East Orange project is built upstream. TCA listed (but did not promise bridges at) 5 additional potential crossing points, 4 of which would be useless as wildlife crossings due to topography, approved housing projects, or planned interchanges. TCA's potential bridge at "WC4" is at an excellent crossing area, but is located in an area that is already being considered for the new county landfill and for tract homes. In January 1992, we suggested including measures to protect the approaches to WC4 or building a bridge to accommodate a different cougar travel route in the uppermost part of Blind Canyon. Our new route was used by several radio-tagged cougars, is in a steeper (less developable) area, and would require less habitat to be preserved between Weir and Fremont Canyons than the routes leading to TCA's potential bridge sites. As of spring 1992, TCA had elected not to incorporate these suggestions.

Limestone-Whiting Regional Parks to Trabuco Ranger District

Nine radio-tagged cougars (F6, F17, M2, M5, M6, M8, M10, M11, M12) used these contiguous wilderness parks. The parks offered excellent cougar habitat and at 6920 combined acres, they approached the size of Caspers Park (7620 acres). Unlike Caspers Park, however, these parks did not abut the Cleveland National Forest, but were surrounded by private property. If urban growth on the private land is not controlled, these parks will become isolated from the National Forest. Because 6920 acres is smaller than a single cougar home range, this area will be lost to cougars unless high quality connections are maintained to the main block of wildlands to the east. A marginal corridor that allows only occasional cougar use would greatly reduce or eliminate the ability of this land to help maintain a cougar population in the Santa Ana Mountain Range.

Based on data from radio-tagged cougars, topography, and the location of existing roads and housing, there are presently 2, and possibly 3, such linkages that can be maintained in the long term. These linkages are described in detail and shown in 3 maps in our Quarterly Report of October 1 1992. The northern corridor ("South Silverado") and the southern corridor ("Equestrian") have each been used by radio-tagged cougars on several occasions. The large size and importance of these wildlands warrants maintaining both of these corridors. Reliance on a single corridor may prove disastrous if we miscalculate what is needed to protect it, or if a single defiant landowner ignored protective regulations. Furthermore, even if a single corridor is adequate for cougars, many other species need corridors and some of these species may not be served by the limited number of habitat types, soil conditions, etc., that can be contained in a single corridor.

We have no data to indicate that the "Pancho Canyon Corridor" was used by cougars, and in July 1992 we noted active grading in the mouth of Pancho Canyon continuing north nearly to the mouth of Williams Canyon. We mention it mainly to consider all feasible options. With appropriate screening from the new project, the topography and habitat suggest that this could be a functional corridor. Although it is also relatively long, the eastern portion (Harding Canyon) may already be protected if strict zoning prohibits building there to protect water quality in Modjeska Reservoir.

A critically important step in protecting each of these corridors is to construct a wildlife undercrossing under Santiago Canyon Road where each corridor's major drainage crosses the road, along with fencing to keep animals off the road and to funnel them toward the undercrossing. Santiago Canyon Road is a busy, high-speed road, and use will increase greatly if the proposed 13,000-home East Orange Project and the proposed Eastern Tollroad are built. The County is already planning to rebuild the Road to accommodate projected traffic, and the road rebuilding can be used as an opportunity to construct bridges beneath which cougars and other animals can walk.

Our data for radio-tagged cougars along the South Silverado Corridor indicate that they crossed Santiago Canyon Road at grade just a few feet north of a 5-ft box culvert there. Fencing could be used to guide animals to the existing culvert. However, a better solution (when the road is rebuilt) would be to build a bridge to allow a larger undercrossing.

At the Santiago Equestrian Center, a larger undercrossing could be built during the rebuilding of Santiago Canyon Road by moving the road about 200m north for about 300m on either side of the stables. This would get the Road out of Aliso Creek and allow the road to bridge the 2 tributaries of upper Aliso Creek which meet just below the Stables. As configured in 1991, the equestrian center apparently was not a barrier to cougars. If the corridor is to be maintained, there should be no increase in night-time human use or lighting at the stables, and no additional clearing of vegetation near the stables. It is especially important to avoid any significant loss of habitat on the ridge immediately west of the stables; animals must cross this ridge to reach the Parks. Constructing one or more unlit trails (for hikers or equestrians) over this ridge would not degrade its utility as a wildlife corridor, and may make it more acceptable for some species, including cougars

In addition to the 3 corridors mentioned above, we have documented that cougars cross Santiago Canyon Road at 2 other locations further west. Because both of these areas lie in or adjacent to the approved East Orange Project, they will remain functional only if the project is not built. One well-used crossing point was the first small canyon east of the hillcrest fire station. The sparse vegetation made this a surprising location for cougar movement, but both M5 and M10 were struck crossing Santiago Canyon Road at this canyon, and 2 uncollared cougars were killed there in 1989. The second area was about 200m southeast of the junction of Hicks Haul Road and Santiago Canyon Road.

Rancho Mission Viejo Conservancy to Camp Pendleton

The Rancho Mission Viejo Conservancy was used by 13 radio-tagged cougars (M2, M6, M8, M9, M10, M11, M12, M13, F3, F4, F13, F17, and F19) and is excellent cougar habitat. F3 chose a canyon in this parcel for her parturition site in 1989. The alignment for the Foothill Tollroad lies near the eastern edge of the Conservancy, and threatens to isolate it from Camp Pendleton (the nearest large protected parcel). Cougars now access the Conservancy across an unobstructed landscape. With the tollway and tollway-induced urban growth there will be at most 2 routes, namely Gabino-Blind Canyon and upper Christianitos Creek. The TCA has promised bridges at both sites. TCA's late 1991 map of the alignment omitted the *upper* Christianitos bridge, because TCA thought our suggestion was for a bridge where the Tollroad crosses *lower* Christianitos Creek. However, TCA responded to this misunderstanding by verbally promising the upper bridge. Assuming that the bridges are built, long term protection of these corridors requires protecting an unbroken route to Camp Pendleton.

CHAPTER 4. POPULATION DYNAMICS

Reproductive activity and litter sizes

Prior to expansion of the study area (May 1989), 3 full-time biologists and several volunteers intensively monitored 7 radio-tagged females in the vicinity of Caspers Wilderness Park, Rancho Mission Viejo, and Camp Pendleton, locating most cougars daily and looking carefully for sign of cubs or adult males. The evidence overwhelmingly indicates that there was no reproductive activity in this area for over 12 months due to lack of a breeding male in this portion of the mountain range (our Quarterly Reports; Padley 1990). Despite intense searches, there was no evidence (e.g., tracks, scrapes) of a breeding male. Only 1 female had cubs at heel (F3's litter born November 1987) and none of the 7 females gave birth during 1988. In early 1989, 2 young males (who we believe we later radio-tagged as M2 and M9) established adjacent territories that overlapped these 7 females. We immediately detected the tracks of these males and heard the northern male (presumably M2) copulating with 4 females in April 1989 . Exactly 83-104 days (1 gestation period) after we first noted sign of these adult males, 6 of the 7 females bore cubs. Such a reproductive failure, although it was temporary, demonstrates that the population was demographically unstable. Such demographic instability is to be expected in small, isolated populations of cougars (Beier 1993).

Of 9 known parturition dates for radio-tagged cougars, 5 litters were born in July, and 1 litter in each of May, June, August, and November (Table 1). A 10th litter probably occurred in December, based on the estimated ages at capture of F18's cubs. These data show a birth peak in late spring through summer, with no litters being born during the months of January-April. In previous North American studies (summarized by Anderson 1983, 1992), about 60% of births occured during April-August; the others were scattered among all other months. The more pronounced peak noted in this study (about 80% of births during May-August) was largely due to 2 new breeding males entering the study area in early 1989, causing a burst of 5 litters in July that ended a year of reproductive failure in the southern part of the range.

For 9 litters, the mean known litter size was 2.4 cubs per litter. However, in most cases we did not attempt to document litter sizes until several weeks or months after the suspected parturition date. Because some mortality likely occurred during the first weeks after birth, the mean litter size at birth was certainly higher than 2.4. Across the cougar's range, litter sizes average about 2.7 cubs per litter (summarized by Anderson 1983:34).

For 3 cougars, we can estimate the gestation period based on dates of copulation (as evidenced by vocalizations) and parturition. F3 and F4 were bred by the same male in the same canyon during April 4-7 1989, and their neonates (eyes closed, poor mobility) were seen and photographed on July 13 1989. Both F3 and F4 had arrived and stayed at their respective den sites on July 7 or 8. We believe that the parturition date for each cat was during July 7-9, and thus the gestation periods were between 91 days (if they conceived on April 7 and gave birth July 7) and 96 days (conceived April 4, born July 9). F2 was bred during April 21-23 1989; although her neonates were not observed, her greatly constricted movements indicate that she established her den site during July 25-August 3. Assuming that her cubs were born within 24 hours of establishing the site, her gestation period was 93-104 days.

We can also estimate gestation period for F10. Although we did not get close enough to hear copulatory vocalizations, F10 apparently consorted with M9 during April 8-10 1991 (16 days after her son M7 dispersed). She moved to her den site during July 2-10 1991, indicating a gestation period of 83-93 days. Using the midpoints of these ranges as our best estimate, we observed 4 gestation periods that averaged 93 days and ranged from 88 to 96 days. To our knowledge, our data are the first to estimate gestation period for wild cougars. The mean gestation period for 42 litters born to captive cougars averaged 92 days and ranged from 84-98 days (Anderson 1983).

We inspected the exact den sites of F3 and F4 within a week of parturition, and revisited these sites a week after the cubs were moved. In addition, we knew the den sites of F12 and F2 to within 100m and investigated these sites after the cubs had been moved. Several traits were common to all 4 sites. Each site was in a small tributary canyon with very dense brush on the canyon sides and in the canyon bottom, lacked a well-developed scour zone in the canyon bottom, had no detectable animal trails, and had very few trees (except for some Rhus or Malosma plants with shrubby growth form). Each canyon was away from regular cougar travel routes, and the vegetation made it very difficult for a person to crawl to the birth site. The micro-sites were in drainage bottoms and in the upper ¼ of the drainage. No site was associated with a cave or rock outcrop.

At the 2 den sites where neonates were observed, there was no physical modification of the soil or vegetation at the site; the cubs were simply in a location that looked much like any other nearby spot in the dense shrubs. Even after 40 days of use, the only sign of use was some compression of the leaf litter. In particular there were no scats, no urine odors, and no noticeable trampling or breaking of live vegetation. Because these sites lacked distinctive topographic features (e.g., a cave) and any "nest" or other modification, we use the term "den site" simply to designate the place where cubs spend their first few weeks. These observations suggest that den sites are selected mainly because they are unlikely to be visited by other predators, and that mother cougars avoid enlarging passageways or leaving scents that might increase the likelihood of such visits. Movement patterns of the adult females suggest that the den site was used for about 6 weeks.

In addition to the 10 known litters, tracks indicated that F4 probably had a yearling at heel when she was initially captured in January 1988. Tracks of this cub were no longer evident after May 1988, indicating either death or dispersal occurred at about that time. Similarly, tracks suggested that a small-footed cat may have accompanied F13 just prior to her initial capture in March 1990. However, the tracks may also have been F13 doubling back on her route, and there was no subsequent evidence of a cub accompanying her.

In all cases of known parturition, the adult female greatly constricted her movements for the next 5-7 weeks. During the first 2 weeks, her daytime locations were almost always at the parturition site. About 7 weeks after birth, cub tracks could often be seen near their mother's tracks. Thus birth of a litter was easy to detect at our level of monitoring. Twelve females were monitored for over 12 months with sufficient intensity to detect successful cub-rearing if it occurred. To our surprise, 4 of these 12 females never gave birth during these years of monitoring, or if they did give birth, their cubs died within days of birth. We followed 3 of these females with sufficient intensity that we are quite certain that they had no litters that survived more than 2 weeks during the time they were monitored. The 4th female (F5) ranged widely and used many remote areas, and was not monitored as intensively. Although F5 may have had litters that we did not detect, it is very unlikely that any such litter survived more than a month. The non-reproducers were:

- **F1**: no successful litter during October 1986-July 1 1989. F1 was bred May 2-4 1989 (copulatory vocalizations heard), but at her death in early July 1989 she was not pregnant nor lactating.
- **F5**: no successful litter during May 1989-January 1993. F5 was located very close

to M2 on 2 occasions, and with M6 on 2 occasions (we were unable to get close enough to hear copulatory vocalizations). F5 was very thin, which may have contributed to her lack of reproduction. During the first year of monitoring, May 1989-May 1990, she exhibited a home range over twice as large as any other adult female. Perhaps the lack of home range stability during that first year inhibited her from reproducing (Seidensticker et al. 1973), but this would not explain her last 2.5 years of non-productivity. F5 was also unusual in having blue eyes, unlike the normal yellow eye of adults.

- **F15**: no successful litter during February 1991-June 1992. F15 definitely bred (copulatory screams heard all night long) with M9 on July 29-30 1991. She also apparently consorted (we did not get close enough to hear vocalizations) with M9 April 4-8 1991, August 31 1991, January 9 1992, and January 27-February 4 1992. At her death following a vehicle accident in June 1992, F15 was not pregnant or lactating.
- **F19**: no successful litter during August 1991-December 1992. She possibly consorted with M9 in early October 1992, but apparently there was no other breeding activity.

Four other adult females (F7, F8, F9, F13) were not confirmed to have any offspring during the time they were radio-tagged. However, each of these animals was monitored for less than 7 months, and it would be inappropriate to draw any conclusions from the lack of breeding evidence for these cats.

We had expected that virtually all females would bear cubs in any year in which they had no surviving cubs from the previous year, and we were surprised to learn that 4 of 12 adult females failed to reproduce. To our knowledge, no previous research has reported a similar lack of births in adult females followed through time. Robinette et. al. (1961) necropsied 199 female cougars and reported the pregnancy rates and the proportion whose tracks were accompanied by cub tracks. Although our inspection of their data show that nearly 40% of those females apparently were neither pregnant nor accompanied by young, Robinette et al. (1961) did not mention this apparent lack of fecundity. Certainly not all dependent cubs would be detected by a track search near the female, some immature females were probably included in their sample (Robinette et al. 1961:216), and they were unable to detect pregnancy during the first 2.5 weeks after conception (p.216); these factors probably caused them to avoid speculating on infertility rates. Perhaps this result was so unexpected that they were reluctant to mention it. We do not know if this is typical of parturition rates of cougars in other populations, nor if it is typical of our population in the long run.

Beier's (1993) population model presumed that all adult females would either have young at heel or have a new litter each year. This assumption is violated by the presence of females that do not bear young for several years. Therefore the predictions of Beier's model are probably unrealistically optimistic, and true extinction risk is probably somewhat higher than predicted.

Juvenile survivorship

Each cougar was considered a juvenile from birth until establishing a stable home range independent of its mother. Nineteen cubs were monitored for periods ranging from 1 to 22 months each, for a total of 288 juvenile-months of monitoring (Table 4). We calculated survival rates from these data using 1-month time intervals and the product limit (or Kaplan-Meier) procedure with staggered entry (Pollock et al. 1989). The product of 12 monthly rates yielded an estimate of annual survival rate, and the average of these running products yielded a single point estimate.

The annual survival rate for juveniles was 0.52. Thus a cub in the Santa Ana Mountain Range had a 52% chance of living for another 12 months. Assuming that on average 30 months (2.5 years) elapsed between birth and adulthood (defined by a stable, independent home range), then about 20% ($0.524^{2.5}$) of cubs born could expect to reach adulthood. There were insufficient data to determine if juvenile survivorship varied for first-year versus second-year animals, or by sex.

The actual juvenile survival rate was certainly somewhat lower than 52%, because we always estimated each litter at the minimum known number. We intruded on new families to count neonates in only 2 cases (both in July 1989, when F3 had 3 cubs and F4 had twins). In other cases we waited several weeks to count cub tracks accompanying females. By this time some cubs probably died, and when cubs were small it was often difficult to detect how many distinct sets of cub tracks were present. Although the most common litter size in cougars is 3 cubs, our analyses included only the number of cubs that we actually verified by handling or on the basis of clearly unique tracks. Thus our computations presumed that F10 had 1 cub (M7) in July 1989 and 2 cubs in June 1991, that F2 had 2 cubs (M3, M4), that F6 had 2 cubs (M11, M12), that F12 had 2 cubs (M8, M10), and that F18 had 2 cubs (F16, F17). A reanalysis presuming that each litter had 3 cubs and that the "added" cubs died by age 12 months yielded an estimate of 0.45. The true juvenile survival rate for our population probably lay between 45% and 52%.

Table 4. Survivorship and causes of death for juvenile cougars in the Santa Ana Mountain Range 1987-1992. In addition, 3 surviving cougars (M7, M6, M13) were used in the survival rate estimates.

Animal ID	Birth Month	Death Month	Cause of death
son of F3[a]	Nov 1987	Aug 1988	vehicle accident
son of F3[a]	Nov 1987	Feb 1989	injured by cougar, died during capture attempt
daughter of F3[a]	Nov 1987	Feb 1989	killed and eaten by cougar
M3	July 1989	Jan 1991	disease
M4	Jul 1989	Nov 1990	killed by cougar? eaten by brother and mother
3 offspring of F3	Jul 1989	Dec 1989	died after being orphaned
2 offspring of F10	Jul 1991	Oct 1991	died after mom disappeared; 1 may have been captured illegally
2 daughters of F4	Jul 1989	Sep 1989	not known, "disappeared"
M8	Jul 1989	May 1991	vehicle accident
M10	Jul 1989	Sep 1992	vehicle accident
M5	early 1989	Sep 1991	vehicle accident
M11	Aug 1990	Feb 1992	unknown, not caused by vehicle, cougar, or acute physical trauma
M12	Aug 1990	Apr 1992	shot
F16	Dec 1989	Sep 1991	vehicle accident
F17	Dec 1989	Jan 1992	unknown, not caused by vehicle, cougar, or acute physical trauma

[a] not included in survival rate computation, due to small sample size in 1987-88; including these animals would have lowered the survival rate estimate.

Our juvenile survival rates were lower than other published estimates, perhaps because high vehicle mortality in our population was only partially compensated by reductions in other types of mortality (e.g., shooting). However, we suspect that our rate of 52%

may be typical of, or only moderately less than, that of other populations. Three of the 4 previously published rates provided unrealistically high estimates of true survival rates. Comparing mean litter sizes near birth and at 12 months (not the same litters followed through time) Ashman et al. (1983), suggested a value of 78%. Similar data in Robinette et al. (1961:213, inferring age from weight) suggested a survival rate of about 73%. However this method considers only litters in which at least 1 cub survived to 12 months of age. Whenever all cubs in a litter died within 12 months, the method would not detect a litter, thus ignoring a large number of cub deaths (Robinette et al 1961:213). Hemker et al. (1986) followed marked animals over time, reporting a survival rate of 72% for cubs between 3 and 10 months of age and 92% for cubs from 10 months to dispersal at 16-19 months, in an area of extremely low cougar density (gross density of 0.5 cougars per 100 km^2). Hemker et al. (1986:330) cautioned that their estimates did not reflect overall juvenile survivorship because they excluded the 2 periods of highest mortality, namely the early neonatal period (age 0-3 months) and the post-dispersal period. Their estimates also may reflect density-dependent enhancement of survival rates at low density. Using methods similar to ours, Anderson et al. (1992) computed the survival rate for yearling cougars as 0.642, an estimate much closer to ours than the previous reports; they did not attempt to monitor or estimate density for juveniles less than 1 year old.

In many cases, we could infer cause of death of juveniles (Table 4). Vehicle accidents and being orphaned were the leading causes of death for juvenile cougars (5 cases each). Cougar-inflicted injuries were implicated in 3 deaths. These cases are discussed in greater detail in later sections of this chapter. In most other cases, the cause of death could not be determined.

Adult survivorship

Adult survivorship was computed from data on 20 adults monitored for periods of time varying from 2 to 58 months, or a total of 497 cougar-months. There were insufficient data to compute survival rates separately for males and females, and our sample was mostly females. We analyzed these data using 1-month time intervals and the product limit procedure with staggered entry (Pollock et al. 1989). The product of 12 monthly rates yielded an estimate of annual survival rate, and the average of these running products yielded a single point estimate.

The annual survival rate for adults was 75%. This means that on average an adult had a 75% chance of being alive in 12 months. F7 and F10 were dropped from the computations in the month we lost their signal. If these animals in fact died at the time of disappearance (which is probably true for F10 at least), then the adult survival rate was 72%. As with juveniles, vehicle accidents were the leading cause of death (Table 5), killing 5 adults (F8, F9, F12, F13, F15). Two adult cougars (F1, F6) were killed by other cougars. Two (F2, F3) died of intestinal illnesses (probably not the same disease). Three adults (M1, M2, F11) were shot on depredation permits after eating goats or sheep. Two cougars (F7, F10) disappeared abruptly; there is some evidence that F10 may have been poached. Each cause of death is considered in greater detail in the following sections.

Our estimated adult survival rate of 75% is higher than the approximately 68% inferred from hunting returns of marked animals by Ashman et al. (1983) and from existing age structure by Robinette et al. 1977:123). Our estimate is nearly identical to the 74% observed in Utah by Lindzey et al. (1988), and somewhat lower than the approximately 80-92% observed in Colorado

Table 5. Causes of death for radio-tagged cougars and their offspring in the Santa Ana Mountains, 1988-1993.

Cause of Death	Juveniles	Adults	Total	Per Cent
Vehicle accidents	5	5	10	32%
Orphaned	5	0	5	16%
Probable intestinal disease	1	2	3	10%
Probable other disease	2	1[a]	3	10%
Intraspecific strife	3[b]	2	5	16%
Illegally killed	0	1(?)[c]	1(?)	3%
Depredation permit	0	3	3	10%
Shot legally by police	1	0	1	3%
Total	17	14	31	100%

[a] "old age" and capture stress contributed to F4's death
[b] includes a severely-injured juvenile that died during capture attempt
[c] Just after F10's disappearance, we received a report of a poaching in that vicinity. In addition, F7 abruptly disappeared 3 months after transmitter deployment.

by Anderson et al. (1992:53). The latter estimates, like ours, were derived using the Kaplan-Meier procedure on data from radio-tagged cougars in non-hunted populations (although several cougars in the Colorado study were killed by hunters off the study area).

Mortality factors

Collisions with motor vehicles caused 32% of the 27 documented cougar deaths in all age classes (Table 5). Vehicle accidents were not a mortality factor in any other study in the western states, but caused 49% of cougar deaths in Florida (Maehr et al. 1991). In most previous studies, hunting and predator-control activities caused most deaths (Shaw 1977, Shaw 1980, Hornocker 1970, Anderson et al. 1992, Murphy 1983), although natural deaths predominated in studies by Sweanor (1990) and Lindzey et al. (1988).

Disease

Three cougars (F3, M3, F2) apparently died of intestinal diseases, although no pathogen or other cause was identified. Disease was a likely factor in 3 other cougar deaths (F4, F17, M12).

Cougar **F3** died on December 27 1989; we retrieved her carcass within 24 hours. Pale mucous membranes and submucosal bleeding in the small bowel suggested that she died due to loss of circulating blood. The patchy distribution of the bleeding suggested that the bleeding was caused by a bacterial infection in the bowel. The bleeding could also have been caused by trauma to the abdomen, but there was no evidence to suggest trauma from collision with a vehicle, ingested poison, a gunshot wound, or being kicked by a large hoofed animal. The cougar had low fat reserves and an empty stomach, but was in fair condition and certainly not emaciated. She weighed 86 pounds at death.

M3 died on February 16 or 17 1991. A previous severe injury to his palate (sometime during June-October 1990) had healed remarkably well and had not prevented him from growing to normal size and weight. He had just started dispersing from his mother's home range on January 27 1991, when on the night of February 8 was treed by a domestic dog in a residential area adjacent to cougar habitat. Animal Control officers injected M3 with 6cc of ketamine via tranquilizer dart. M3 fell out of the small tree, striking his head on a planter box. On release that night in his mother's home range, his physical condition appeared good and his movements appeared normal for an animal recovering from ketamine.

By morning he had walked 200m up canyon but he remained at that site for the next week until he died. He apparently had not eaten during that week. Tracks indicated that he had walked 20m to a small pool of water at least once during February 12-18. The carcass weight was 79 pounds with moderate subcutaneous fat; he had obviously lost some weight during the previous week. We recovered his carcass on February 19, by which time no cause of death could be determined. There was no apparent skull or neck injury at death. We suspect intestinal disease simply because his mother died of intestinal disease after encountering his carcass.

F2 (M3's mother) had been in another part of her home range during the time M3 was dying. After necropsy we left M3's carcass in a trench near some dwellings on Starr Ranch. On the night of February 21-22, F2 arrived at M3's carcass, apparently encountering it by chance, and was seen walking away from his carcass at dawn on February 22. At that time, a strip of muscle had been torn from the carcass, presumably by F2, but left at the site, uneaten. F2 had covered the carcass with grass and leaves in the manner of a cougar covering a fresh prey carcass, but she did not return to feed on it. F2 bedded within 250m of the carcass for the next 3 days, and then moved about 600m further from the site to a confluence of 2 streams. She killed and ate a raccoon at that confluence on March 4. On March 10 we walked in on her after she had been daybedding at this confluence for 2 weeks. We observed that she was weak and losing weight and we conferred with veterinarians at the San Diego Zoo, who agreed to evaluate her. However, she died a few hours before we arrived to capture her on the morning of March 12. She weighed 73 pounds, a loss of 17 pounds since we last handled her on December 13 1990. Amy Shima, DVM (San Diego Zoo) reported that her death was apparently related to dehydration and diarrhea, but no pathogen could be identified.

F4 died on July 20 1990, at 12-14 years of age, which approaches the maximum lifespan for cougars. She had the most severe tick infestation we observed on a cougar during the study. Her upper left canine tooth and both upper carnassial (shearing) teeth were missing, the other canines were short and blunt, and her incisors were worn to the gumline. Her 70-pound weight did not look thin on her light frame and her pelage and body fat reserves were normal. Four days prior to her death she had moved about 3 km west of her previous home range into open grassland habitat where she bedded near a spring in a small arroyo, killing and eating at least 2 coyotes there. We recaptured her to replace her collar at that site on July 18, and the capture operation went smoothly with no sign of abnormal recovery. She fed on a coyote carcass the night after the capture but died 2 days later. In this case a combination of "old age," capture stress, and extreme heat probably all contributed to F4's death.

Two other carcasses **(F17, M12)** clearly had not suffered acute physical trauma (gunshot, vehicle accident, cougar-inflicted injuries, etc.) and it appeared each cougar had crawled into a typical wooded daybed site before death. Neither animal appeared emaciated. It seems likely that disease played the dominant role in these deaths.

M12 died under an oak tree in dense chaparral. His carcass was too decomposed to allow examination of soft tissues or tests for pathogens. The intact skin on the right side of his body showed no sign of trauma; his skull and leg bones had no injuries. The 2nd cheek tooth on the right mandible was missing, and the adult tooth, fully formed, lay below the bone, as if ready to erupt. However, part of the new tooth lay below the 3rd (fully erupted adult) cheek tooth, and the gap between the erupted teeth appeared too small for the new tooth. Thickening of the mandible alongside the unerupted tooth suggested that the delayed eruption was causing some bone disease. Otherwise all the adult teeth were in good condition and formed a functional shearing apparatus.

F17's carcass was in good condition for an exam, due to cool temperatures at her death. She appeared in excellent condition with no sign of external injury and a thick layer of subcutaneous fat. The only remarkable internal finding was the presence of blood in her lungs and bronchi. The intestinal tract lacked any evidence of recent feeding; there was a small amount of tarry black stool in the colon.

Intraspecific strife

Three cougar deaths were unambiguously due to fights with other cougars; 2 of these 3 carcasses were also cannibalized. In a 4th case, a cougar was fed upon by other cougars, but death may have been due to other causes. A cougar-inflicted injury and capture trauma contributed to a fifth death. In all, about 16% of deaths were related to intraspecific strife. In addition to these cases, F13 had multiple wounds on the right side of her face and on her left shoulder at her initial capture; these injuries had almost certainly been inflicted by another cougar; the injuries had completely healed by her death 6 months later.

This level of intraspecific aggression is not unusual in cougars. Our observation that 16% of mortalities were cougar-related falls about midway between a rate of 3-5% in populations that have high man-caused mortality (hunting and predator control) (Anderson 1983:58, and Anderson et al. 1992:51) and a rate of 31% in a population with very low man-caused mortality (Sweanor 1990:36).

Two uncollared cubs of F3. During intensive monitoring on the night on February 8 1989, F3 traveled a short distance and spent almost the entire night in 1 location before moving to a more secluded location at dawn. We expected to find that she had been feeding on deer, but at the site where she had spent the night we found the very fresh and partially consumed carcass of F3's yearling daughter (not radio-tagged). She was in very good physical condition prior to death (abdominal fat 26mm). There was extensive subcutaneous bleeding and muscle trauma on her forelimbs and face, indicative of a prolonged fight using her forelimbs for defense, and her neck was broken between the skull and top vertebra. We set snares on her carcass and captured a yearling cougar, almost certainly her sibling, the following night. The male cub had severe, infected wounds from cougar bites to his hind quarters, and died during the capture operation. Fat reserves and overall size in relation to age indicated that the male yearling was also in good physical condition before the attack. Steady night-time rainfall obliterated tracks in the vicinity of the kill, and we could not determine the identity of the cougar that killed the female cub and injured the male. Perhaps the 2 cubs injured each other in a fight, but we speculate that an uncollared male was responsible. Five months later, F1 was killed (but not eaten) by a cougar less than 250m from the same location.

F1. F1 was killed by an uncollared cougar on July 3 or 4 1989. Her carcass was lying among some cattails adjacent to a creek near the confluence with the small dry tributary in which the 2 yearling offspring of F3 died in February 1989. Her position indicated that she had crawled there on her own; the only wounds were two conspicuous canine punctures, one entering her skull downward above her right eye (crushing the supraorbital arch) and the other entering upward near the posterior margin of the right mandible. Tooth size, distance, and position indicate that this bite was delivered by another cougar; the attacker did not feed on her. Her stomach contained a freshly consumed opossum, and she had minimal abdominal fat (approx. 5 mm). No tracks (not even those of F1) were found in the immediate vicinity of the cougar carcass. However, tracks of an uncollared male had been seen on several occasions within a 2-km radius for several days both before and after her death.

M4. During intensive monitoring on the night of November 11 1990, F2 and her 15-month-old cubs (M3 and M4) stayed in 1 location all night long. We presumed they were feeding on a deer, but at the site where they had spent the night we discovered that they had almost totally consumed M4. Their feeding activity had kept M4's collar from entering mortality mode. The amount of consumption and the locations of the 3 animals on the preceding days indicate that F2 and M3 also fed on him the nights of November 9 (when M4 probably died) and November 10. The trio had been together for several days both before and after M4's death.

Because of the near-total consumption, we could not determine cause of death. M4 could have been mortally injured crossing the Ortega Highway on the night of November 9-10, when the trio crossed the highway. If so, the injured M4 walked 1.3 km (0.8 mi) up Horsetail Canyon from the Ortega (a 220-foot elevation gain). Because Horsetail Canyon offers excellent cover much closer to the road, it is not likely that M3 and F2 dragged his carcass that distance, nor was a drag mark evident on November 12.

M4 could have died of disease, but we have no evidence for this. The final possibility is that he was killed by his brother, his mother, or another cougar. It is extremely unlikely that F2 killed her son after investing 18 months of pregnancy, lactation, teaching, and feeding on him. Fratricide is also maladaptive (on average siblings share 50% of the same genetic material) but siblings do not have the same energetic investment in each other as a mother has in them, and siblings are competitors for their mother's hunting skills. And the fact that M3 enjoyed superior growth during the interval between previous captures (June 5-October 1) suggests that such competition may be intense and that M3 may have been more aggressive, dominating his brother at shared carcasses. If M4 was killed by a cougar other than M3, the most likely suspect would be M2 (the resident male in the area, and the presumed sire of M4). On November 9, M2 was 1.5 km WSW of where M4 died, with only 1 major ridge separating them. However, on the next 2 nights, M2 moved successively further west, and there is no evidence to suggest that he traveled east toward M4 or that he fed on M4. If M2 killed M4, he apparently was not injured in the fight (on Nov 12, we treed and examined him through binoculars, looking for sign of a recent fight).

F6. F6 was killed by another cougar on about May 23 1992. She had been dragged about 70m from the kill site to a location where her carcass was largely consumed. There were several canine punctures in her skull, and the top of the skull had been broken and the brain consumed. There were no tracks at the site clear enough to indicate the sex-age class of the cougar that killed her.

An unusual injury

Between captures on June 5 and October 1 1990, juvenile M3 suffered a severe, non-fatal, and apparently natural injury. His palette had been broken along the midline and the left premaxillary was pressed about 10mm upward into the skull, so that the 3 left incisors no longer occluded with the lowers. There was very little wear on the left incisors, suggesting that the injury occurred early during the interval, but the scar tissue still appeared fresh on October 1. At his death in February 1991, the injury had healed remarkably well but there was persistent malocclusion of the incisors and canines on his left side. Despite this injury, M3 was otherwise quite healthy on October 1, with ample fat reserves and minimal ectoparasites. His sibling M4 was larger framed than M3 on both June 5 and October 1. Although the animals were of similar weight on June 5, M3 had a thicker layer of subcutaneous fat, despite his injury which must have made feeding painful for several weeks. No other injuries were evident. His skull is now in the Museum of Vertebrate Zoology at the University of California at Berkeley.

Highway mortality and injuries

Nineteen cougars (12 radio-tagged and 7 uncollared) were involved in 20 collisions with automobiles during 1988-1992 (M10 was in 2 accidents). This list (Table 6) probably includes all or almost all accidents during September 1990-January 1993, but almost certainly excludes some accidents involving non-radioed cougars during April 1988-August 1990, especially if they occurred in San Diego or Riverside Counties.

The roads with the most accidents were Santiago Canyon Road (4), Ortega Highway (4), Interstate 15 (4), and State Route 91 (2). All 4 accidents on Santiago Canyon Road were on the 2-km grade leading west from Irvine Lake up to the fire station at the crest of the road. All 3 accidents on the Ortega were in Caspers Park or just west of the Park. Three of the 5 accidents on I-15 were just north of the border patrol station midway between Temecula and Rainbow; the fifth was about 3 km (2 mi.) further south. The cluster of locations on I-15 coincide with the point where M12 successfully crossed I-15, and clearly indicate a threatened point along the critically important corridor linking our cougar population to the only adjacent population.

There was 1 accident on each of the following roads: Pomona Freeway, Interstate-5 (at Las Flores Creek), Clinton Keith Road, Basilone Road, Van De Grift Road, and Fallbrook Naval Weapons Station Road. Eight of the 12 accidents involving radio-tagged cougars were promptly reported to law

Table 6. Fate of 18 cougars involved in automobile accidents. There were no reports of human injury in any accident.

Fate	Cougar
Died near accident site	F8, M8, F12, M10[a], F9, F15, UF1[b], UC1[b], UC2[b], UC3[b], UF2[b], UM1[b], UX[b]
Euthanized at accident site[c]	F13
Did not recover, but survived 30 days	F16
Did not recover, but survived 6 months	M5
Apparently recovered	"FX"[d]
Fully recovered	F2, M10[a], M11

[a] M10 fully recovered from his first accident in May 1991, but was killed in a second accident in September 1992.

[b] "U" = uncollared. UF1 was an adult female killed on Santiago Canyon Road in fall 1988; cub UC1 was killed at the same site 1 week later. UC2 was a 9-month old cub of F3 killed on the Ortega Highway in Aug 1988. In Dec 1992, the small cub UC3 was killed on the Ortega Highway and juvenile female UF2 and adult male UM1 were killed on I-15 at the border patrol station, where UX was killed in October 1990.

[c] shot because she appeared unable to walk away from the accident site. The recoveries of F2, M10, and "FX" suggest that this may not have been necessary. There were no major injuries to bones or internal organs.

[d] We never identified the radio-tagged cougar struck on Fallbrook Naval Weapons Station (Dec 23 1991); when we arrived the next day all collared cougars were at least 1.5 km away and showed no abnormal movements in the days that followed.

enforcement agencies; the non-reported accidents involved F2, F8, F15, and M8.

Eleven of 16 accidents (69%) were at locations where wooded canyons intersected roads; we never precisely identified the location of the other 4 sites. The one clear exception to this pattern of crossing at major drainages is provided by the 3 accidents on I-15 which occurred along a wooded ridge. This site is somewhat surprising because there is an excellent canyon-bottom crossing site 1.5 km north (the Santa Margarita River). This illustrates that crossing points might not always occur where one might guess by looking at aerial photographs.

We documented the nature of some of the injuries sustained. M5 broke his left hip and his right femur just above the knee. F8 died of massive internal injuries. F12 was completely destroyed by the impact. F13 had no apparent skeletal injuries, or any gross internal injuries. M8 broke his pelvis near the midline and again through the right acetabulum (hip socket) and separated his right shoulder, but had no broken limb bones. F2 broke her left femur. M10 broke his left femur in his first accident, recovered, and then died of massive internal injuries in his second accident. M11 broke no major bones and was apparently only lightly injured.

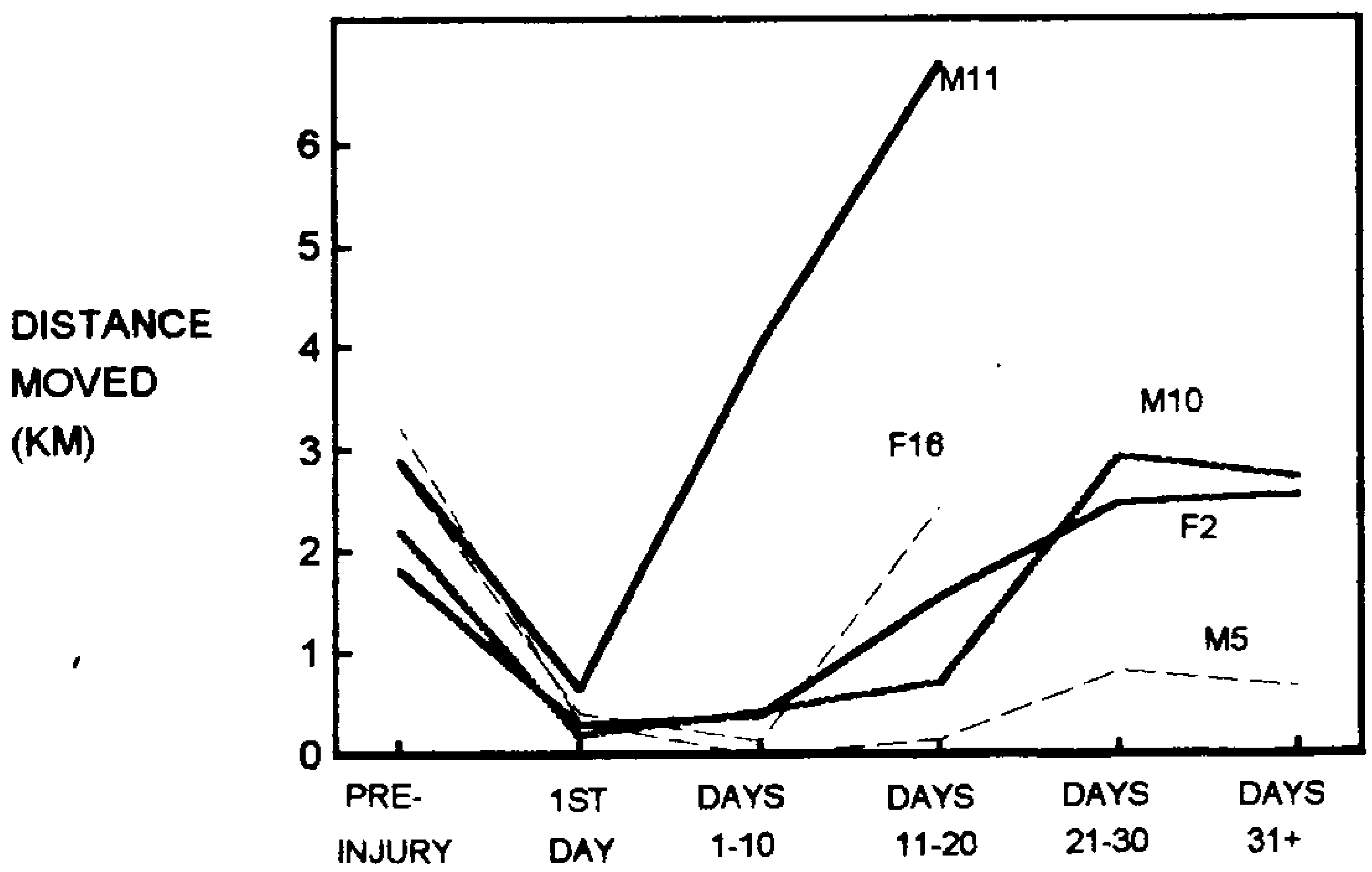

Figure 10: Distance moved by 5 cougars injured in vehicle collisions. Each point (except "1st day") is the average of at least 6 straight-line distances between consecutive locations obtained at least 1 day apart. Dashed lines indicate cougars that eventually died as a result of their injuries; solid lines indicate animals that apparently recovered fully. F16's last point = days 11-30. M11 was shot 20 days after his accident.

Of 5 animals that survived for more than 10 days after their accident, 3 apparently recovered, and 2 eventually died as a result of the injuries. Of the 3 recovered animals, M11 was apparently not severely injured, and F2 and M10 suffered broken femurs. F2 managed to raise her 2 cubs (4½ months old at the time of the accident) and lived for 14 months before dying of an intestinal disease. M10 was photographed in the freeway median with blood trickling from his face 15 minutes after the accident, but he then moved back off the freeway and soon recovered. He lived another 16 months and was of normal weight at death. Figure 10 contrasts the movement patterns of the "recovered" animals to the pattern for the cats that eventually died of their injuries ("temporary survivors"). Each of the 4 animals traveled 200-650m from the apparent accident site to their location the next morning. The recovered cats differed most markedly from the temporary survivors in the average distance moved during the first 10 days: recovering cats averaged over 400m between daily locations versus 0m and 149m for the 2 temporary survivors.

The individual accidents are described below:

F2: Ortega Highway at Cold Springs confluence, December 18 1989. F2 broke her left femur and remained close to flowing water in San Juan Creek during December 18-27. She recovered sufficiently well to kill a deer on December 29, although her tracks clearly showed that she was avoiding her left hind foot at that time. During visual observation on January 6, 1990 this leg was still unable to take the cougar's full weight, but she did not avoid using it. During diel monitoring on January 6-7 and again on January 14-15, F2 traveled at normal speeds. During recapture on June 5 1990, she showed no evidence of the injury. She successfully raised 2 male cubs (4 months old at the time of the accident) to dispersal age. F2 died in March 1991.

F8: Riverside Freeway at Gypsum Canyon, 3:00 AM August 14 1989. F8 walked 800 m south of the freeway before dying. She died of massive internal injuries, but appeared in otherwise excellent condition with large fat reserves. Her carcass was delivered to Irvine Park so that the mounted skin, skull, and other material could be used in the new Visitor Center in Irvine Park.

"FX" (F9?): Fallbrook Naval Weapons Station Road, 4:00 PM December 23 1991. Camp Pendleton wardens, responding to a report of an accident involving a cougar, observed a radio-tagged cougar on the south side of the road, bleeding slightly from the face. After about 10 minutes, she moved through a 4-strand barbed wire fence into the nearest cover, where she remained out of sight for at least 20 minutes. Then as wardens advanced toward her, she flushed and crossed back through the fence, across the road, and through the fence on the north side, and into a clump of shrubs 20m north of the road. The wardens watched her there for several minutes until she got up and walked over a slight grassy rise (20 ft elevation) and out of sight to the north. We investigated the scene on foot the following morning, and with hounds on December 25, but found no evidence of a cougar in the area. Evidently the animal's injuries were less severe than any we have previously documented, because she apparently moved away from the scene fairly rapidly.

We had located all of the cougars with functional radio-transmitters on the morning of the accident and again on the morning after the accident. The only feasible victim with a functioning transmitter was F15. However, F15 had been 3.5 km from the site 6 hours before the accident, and by December 24, she was about 6 km from the accident site, and on succeeding days she moved distances typical of an uninjured animal. Most likely the injured animal was F9 (whose collar had failed in August 1988 and was later killed on I-15). The accident site was within F9's home range.

F9: I-15 south of Temecula, 8:30 PM March 1 1992. The accident site was near the Flynn Nursery at the north end of the village of Rainbow, at the southern edge of the last potential corridor linking the Santa Ana Mountain Range with the Palomar Range. F9 weighed 92 pounds, was not pregnant, had a scant 5mm of subcutaneous abdominal fat, but appeared in otherwise good condition. F9's transmitter had failed in July 1988.

F12: Interstate 5 at Las Flores Creek, 2:00 AM December 21 1990. F12 was demolished by multiple impacts. She weighed 103 pounds (the heaviest female weight we have recorded in this population), was 5-6 years old, and had been in excellent physical condition.

F13: Ortega Highway, 7:00 PM October 10 1990. F13 was killed about 1 km north of the Caspers Gate while crossing from east to west. This crossing point was used by several cougars, and lies about 300m north of a 12-foot wide culvert unused by cougars. She was in excellent condition and suffered no major injury in the accident, but was euthanized by a law officer at the scene because she appeared unable to walk. Her carefully skinned hide was also delivered to Orange County Harbors Beaches and Parks.

F15: Van De Grift Road, June 6 1992. Starting June 6, F15 stayed in a very small area in a dense riparian thicket in the Santa Margarita River, where she died on June 15, having moved no more than 100m during June

9-15. Her left pelvis had been shattered at the hip socket, with several bone fragments (up to 2 inches long) separated from the rest of the bone, and no visible growth of scar tissue. The femur was not damaged.

F16: Clinton Keith Road, 06:30 AM August 15 1991. The yearling F16 was struck near the crest of the road west of Murietta. She remained in a wooded canyon with flowing water at the accident site during August 16-27. She left the accident area by August 31 1991 and traveled considerable distances around Mesa de Burro, Mesa de Colorado, and upper De Luz Creek during August 31- September 16. Her movements seemed to reflect recovery from the accident, but she died about September 19. F16 had been accompanied by her mother 24 hours before the accident, but never after the injury. F16's sister (F17) dispersed from her mother a few days later and perhaps the accident occurred during agonistic interactions accompanying family breakup. The accident injuries combined with the stress of being newly independent were the primary factors in her death.

M5: Santiago Canyon Road, 6:00 AM April 23 1991. Shortly after the accident M5 moved about 400 m from the accident site into a well-wooded canyon. He moved very little for 3 weeks after this collision. A small seep about 250m away was M5's nearest source of water but a lack of tracks suggests that he went a full week without water. Tracks show that he did drink from the seep between April 30 and May 5; the seep dried up between May 7 and May 11. He also appeared not to have eaten for the first 7 days. A thorough search on April 30 turned up 1 dried scat from his last meal before the collision. An opossum that died at the seep about April 28 rotted there untouched by M5. A fresh scat indicated that M5 killed and ate an opossum on about May 10. On May 17, M5 moved 3.5 km (2.2 miles) to Peters Canyon Reservoir, which had ample water, dense woody cover, and abundant small prey; for the next 3 weeks he remained in the small dense willow forest surrounding this lake.

For the remaining 5 months of his life, M5 moved very short distances per day, repeatedly covering the same short travel routes in areas of very level terrain. M5's preference for level terrain brought him into areas of intense human use (described in greater detail in Chapter 9), including Irvine Regional Park, Santiago Oaks Regional Park, and Santiago Creek downstream from these parks. In 6 post-accident months of travel in such areas, there were only 2 reported sightings of M5, and this underweight animal never acted in a way that threatened humans or their pets. His only documented kills after the accident were opossums. On about September 22 1991, M5 died in the willow forest behind Villa Park Dam. All of his daytime locations (n = 10) during the preceding 3 weeks had been within 400m of the death site and within the level impoundment area. There was no sign of fresh injury on his carcass. He was markedly underweight for a 3-year-old male (82 pounds), but his skull and skeleton were of normal size for his age.

His skeletal remains revealed 2 severe leg injuries from his accident. His right femur was broken about 2 cm above the knee, and had rotated backwards about 90^{o}, and laterally (outward) about 20^{o}. Massive scar tissue had created a solid replacement bone, and the wear pattern on the femur and tibia indicated that the knee joint functioned normally in this new position. The more severe injury was to M5's left hip. The ball joint on his left femur was completely sheared off at its base, and was no longer part of the joint. New articular surfaces had formed on the fracture surface at the top end of the femur and on the dorsal ridge of the acetabulum (socket). The articular surface on the femur was about 1 cm^2 and rubbed against a worn area at least 6 times this large along the entire upper half of the socket ridge. Thus this replacement hip joint must have been weak and sloppy. Large rough tuberosities had grown around the acetabulum and on the medial surface of the upper 6 cm of the femur. It is remarkable that he survived 5 months with injuries this severe.

M8: Pomona Freeway, about May 1 1990. M8 had a separated right shoulder and internal injuries, but no broken bones. His carcass was found about 3 days after the accident in weeds alongside the road.

M10: Riverside Freeway at Coal Canyon, 9:00 PM May 7 1991. M10 was hit broadside, breaking his left femur and both car headlights, and knocking off the car's front license plate. He was photographed in the freeway median with blood trickling from his face 15 minutes after the accident, but when police arrived he moved south of the freeway. He spent the next 7 days in a small canyon along the freeway. Then on the 8th and 9th nights he moved 0.7 and 2.0 km, respectively. We monitored his movements overnight on May 22-23 and again on May 23-24; he exhibited almost normal movement patterns, and killed and ate a skunk at 0030 on May 24. For the next 15 months, his movement patterns suggested no impairment of his locomotor abilities, and he weighed a normal 137 pounds at his death in September 1992. However, his elongate temporary home ranges were located along the urban-wildland interface, suggesting that he remained a subordinate male, probably because his injuries prevented him from attempting to defend a territory.

M10: Santiago Canyon Road, about 10:00 PM September 15 1992. At death, M10 weighed 137 pounds, had ample fat reserves, and appeared to have been in good condition. His spleen had ruptured and there was extensive bleeding in the abdominal cavity.

Illegal take and harassment

We encountered little evidence of illegal take and harassment of cougars. Chasing cougars with hounds (the dominant method of capture) is a high-profile activity and is difficult to hide in most of the study area. Access is strictly controlled on Camp Pendleton and is limited by topography and lack of roads on most National Forest land in the study area. The owners of private wildlands in Orange County actively discourage trespassers, who would be very conspicuous in these large holdings. However, on the Santa Rosa Plateau and north and west of the Plateau there are many small and medium-sized private ownerships, many non-resident landowners, ample roads, and relatively good access to National Forest land. This area offers the greatest potential for cougar harassment, and 3 such incidents were related to us during 1988-1992. Doubtless other cases were not brought to our attention. In none of these incidents do we have proof that local cougars were harassed or killed. The 3 incidents were:

1. In March 1992 we learned that CDFG wardens had seized a cougar skin several months earlier at an estate residence on upper De Luz Creek. The warden indicated that there was substantial evidence that the homeowner had captured the animal locally, had raised it in a cage on his property for 4 years, and had then had it killed and mounted because of the difficulties of continuing to maintain it in captivity. The evidence (statements that homeowner allegedly made to several other persons) was not strong enough to prove in court that the animal was trapped locally.

2. In spring 1992 we were called by an Orange County resident who had been hiking in the National Forest near the Santa Rosa Plateau the previous day. Near dusk he was approached by some tired dogs wearing radio-collars and tags with a phone number. When no one came

looking for the dogs for about an hour, the reporting party took the dogs home and called the owner, who came to pick up the dogs the next day. When the dog owner came by, he stated that he had been using his dogs "to chase mountain lions."

3. F10 disappeared in mid-October 1991. Our last ground fix on her and her family was October 11 1991, when tracks indicated that F10 and 2 or 3 cubs (born July 1991) were alive in Roblar Canyon. Since then, we were unable to locate her or any sign of her cubs, despite many telemetry flights, intense track searches, and a 5-week trapping effort. In the latter effort, we put 5 snares in the core of her home range and checked them daily during November 19-22 and November 25-December 24 1991. It is unlikely that she and her cubs could have avoided these areas for 5 weeks, and they probably died. On January 31 1992, a person telephoned us to report that a female cougar had been poached by 2 orchard workers in a western tributary ("Conquistador Canyon") of lower Sandia Canyon on October 19 1991. The caller claimed that he had confronted the 2 men as they were dragging out a live male cub wired to a makeshift noose-pole. He says he took the cub from the 2 men and announced his intention to release the cub. The 2 men responded that they had just killed the mother and that release would probably be fatal to the cub. The caller claimed that he kept the cub and that the cub was then (January 1992) nearly 40 pounds in weight and being kept by his "brother in Ohio." The man called us because the cub was becoming difficult to keep and he wanted some sort of permit that would enable him to legally transfer the animal to a better facility. We advised him to contact CDFG for how to dispose of the cub, and promptly relayed the report to CDFG wardens. We cannot confirm that the incident took place, and have no firm evidence that F10 and her cubs were involved if it did take place. However, Conquistador Canyon had been part of F10's home range.

The only evidence of illegal harassment in Orange County comes from 3 observations on Irvine Ranch property north of Santiago Canyon Road; the most recent occurrences were March 27 1991 and April 13 1992 (we failed to record the date of the first incident). On each occasion tracks of several hounds, 2-3 men, and 1-2 cougars strongly suggested that long chases had taken place within the previous 24 hours. These apparent chases occurred in Gypsum, Weir, Blind and Fremont Canyons. In none of the cases was there any evidence that a cougar had been killed. After the second incident we asked the cattle lessee on that property if he was aware of the activity; he claimed he had been out at night trying to break his dogs from chasing deer.

A final observation may or may not be related to illegal harassment. On July 17 1991, we recaptured F5 to replace the transmitter deployed in May 1989. In the interim she had lost all but the basal 31cm of her tail. Scar tissue had formed over some small wounds (apparently canine punctures) on her tail and left hip, but not on the surface of the stump, so the tail loss appeared more recent than the other injuries. Based on his experience with hounds, field assistant Duggins Wroe believes the tail and other injuries were inflicted by dogs. However, the injuries could also be cougar-inflicted.

Depredation

All depredation losses involved cougars being shot for eating goats or sheep. Although there were 4 large cattle operations in the study area, to our knowledge there were no requests for depredation permits due to loss of calves or cows. We were aware of only 1 large sheep operation in the study area, namely the sheep-grazing lease on Camp Pendleton. Since 1989, Camp Pendleton has required the sheep lessee to bear the cost of depredation losses without recourse to depredation permits. Most goats in the Santa Ana Mountain Range were kept as pets or for fuel control near rural homes; most owners had 1-3 goats. We were aware of only 3 ownerships with more than 5 goats, 2 of which attempted to generate some revenue from them.

Depredation losses are summarized below.

Sheep: In February 1988, M1 and an uncollared adult female cougar were shot on Camp Pendleton.

Goats: On January 28 1992, an uncollared male cougar (2 years old, excellent condition, 135 lbs) was shot near Bolero Peak in Santiago Canyon. His carcass was donated to Irvine Regional Park which will mount the skin for display in their visitor center. At about 9 PM March 4 1992, M2 (4-5 years old, excellent condition, 155 lbs) was shot by the same goat rancher. On January 26 1993, F11 (about 8 years old, excellent condition, blunt and worn teeth normal for age, 80 lbs) was shot about 3 km east of Redondo Mesa, and about 5 km (3 mi) outside the home range she had used during the previous 5 years of monitoring. On February 4 1993, 2 uncollared male cougars were shot by the same livestock owner that killed F11. The CDFG official reported that the first male was about 1-2 years old, in good condition, and weighed 88 lbs, and that the second male was 5-6 years old and weighed 114 lbs. If the latter age estimate was accurate, then the older male was markedly underweight.

Synthesis: a population model

Population dynamics involves only 4 basic processes, namely birth, death, immigration, and emigration. This study has provided some information on each of these processes. However, to move from observed data to an understanding of population dynamics is much more complex, because these processes vary with age and sex of the animal, population density relative to carrying capacity, area of habitat available, and availability of movement corridors. Forecasting how the cougar population will grow or decline in the future requires a mathematical method of integrating these data and projecting them over time.

To do this, we developed a simulation model to forecast the likelihood that a cougar population can persist, under various estimates for the important biological parameters (birth and death rates, carrying capacity, etc.) and various projections about management decisions (amount of habitat protected, preservation of habitat corridors). This model is described in detail by Beier (1993, included as Appendix 1 in this report); this paper should be considered one of the most important parts of this Final Report. In brief, the model demonstrates that if thousands of square miles of suitable habitat containing cougars were divided into isolated chunks, each less than 500 square miles in size, cougars would inevitably become extinct over the entire area because of this fragmentation. However, if the habitat areas are instead connected by movement corridors, the cougar population will likely survive.

All models are defective to some unknown degree, and extinction is a serious consequence. Therefore, in evaluating the results of this sort of model, an "acceptable" level of risk is generally at most 1-2% (Shaffer 1987). Model predictions are also sensitive to errors in our estimates for carrying capacity, birth rates, or survival rates (Beier 1993). As mentioned elsewhere, the model used a birth rate estimate that may be higher than the true rate ("Reproductive Activity" earlier in this chapter), and true carrying capacity may also be somewhat lower than the estimate used in the model (last section in Chapter 7). Both of these errors would cause the results shown in Figure 11 to underestimate the extinction risk.

With respect to the cougar population in the Santa Ana Mountain Range, the model makes several clear predictions (Figure 11):

- The 2070 km2 of habitat remaining is precariously close to the smallest isolated area that can support a cougar population.
- Without a corridor for immigration from the Palomar Range, every additional parcel of habitat lost to urban growth increases the risk of extinction.
- If only the central habitat block (Figure 1, Table 1) is preserved, the extinction risk is 33% in the short term, and a virtual certainty in the long term.
- With a high-quality corridor to Palomar and good connections among existing protected lands, the extinction risk can remain low even while adding thousands of new homes and losing many acres of wildlands to urbanization.
- Loss of the Coal Canyon Corridor would cause the extinction of cougars from the Chino Hills. Because the Chino Hills is 8% of the total habitat area in the Mountain Range, this also would increase the risk to the larger population and push the population to the steeply rising part of the extinction risk curve (Figure 11).
- Without corridor protection, cougars will be lost from Limestone Canyon-Whiting Ranch Regional Park and all smaller protected parcels in the Mountain Range.

Perhaps the most surprising result of the model is the finding that a corridor that allows even rare immigration (1-4 juvenile immigrants per decade) dramatically reduces extinction risk. The model results are made much more meaningful by 2 additional findings in this study:

1. Our data on dispersal of juvenile cougars (Chapter 6) show that cougars will find and use corridors. In particular, dispersing cougars used all 3 major corridors (Coal Canyon, Pechanga Creek, Arroyo Trabuco) in the study area.

2. By closely following radio-tagged cougars, especially on intensive monitoring sessions, we have mapped the actual routes by which animals move between protected habitat parcels. Although many of these routes are now pristine open space, they will become corridors (at best) as urban growth removes the adjacent habitat. These maps have been provided to the County and other appropriate agencies in previous reports.

Finally, the model and related data underscore the need for regional planning. The Santa Ana Mountain Range straddles 5

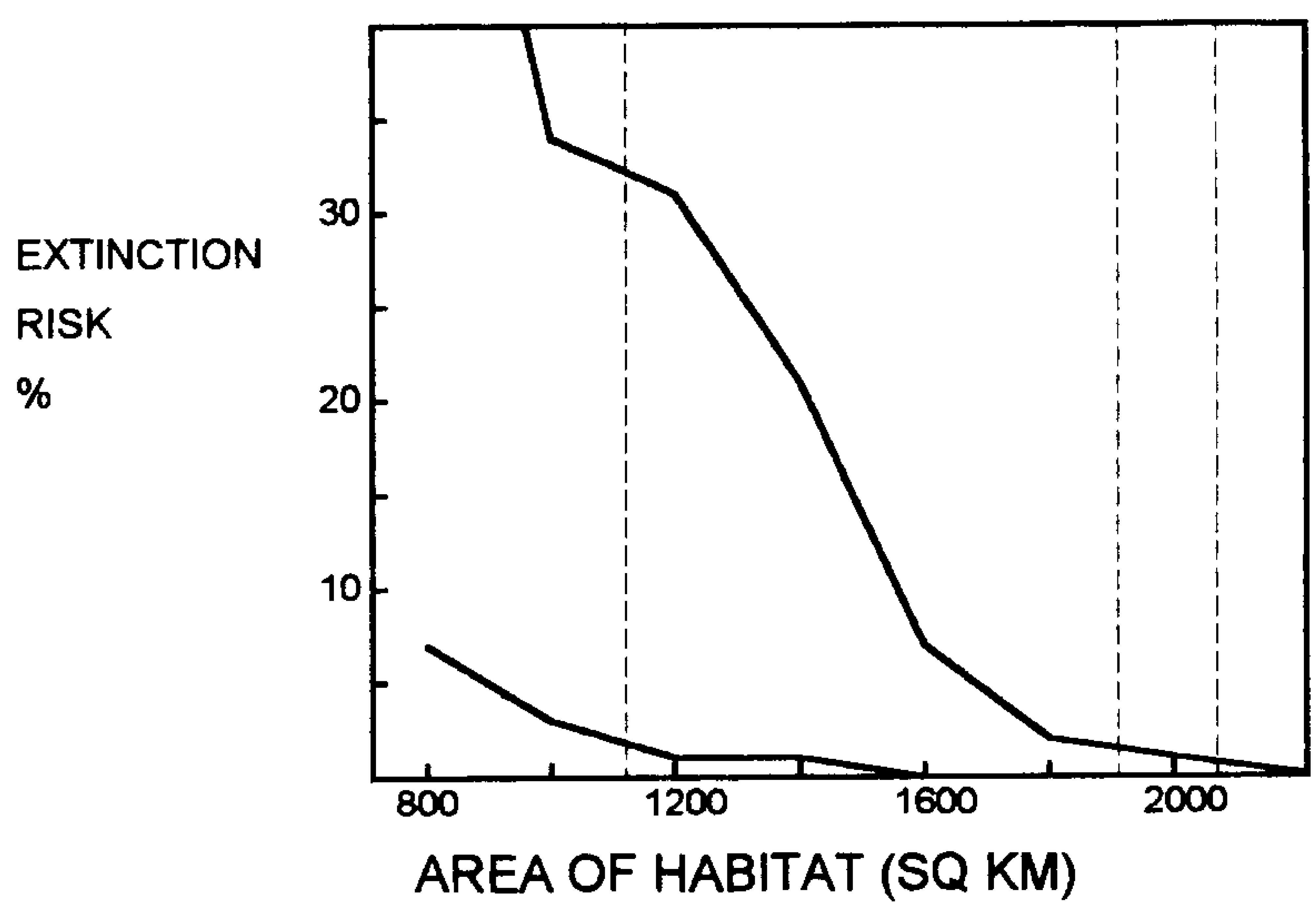

Figure 11. Extinction risk (percent of simulated populations that went extinct within 100 years) for the cougar population in the Santa Ana Mountain Range. The upper line gives the risk if the Pechanga Corridor is lost to urban growth, and the lower line the risk if that Corridor can be maintained. From *right* to *left*, the dashed vertical lines indicate total habitat available in 1992, total habitat available if the Coal Canyon corridor is lost, and total area of the protected and interconnected habitat block (Table 1, Figure 1).

counties and abuts 17 incorporated cities. Two freeway-building agencies and the world's largest water district also make critical land-use decisions. Because the cougar population needs large habitat areas and viable connections between protected habitat parcels, no single agency takes account of the cumulative impacts of land-use decisions on viability of this cougar population. For instance, the short wildlife corridor at Coal Canyon lies within the jurisdiction of Yorba Linda, Anaheim, and CalTrans, and the latter 2 entities refused to engage in a multi-jurisdictional attempt to preserve the corridor. Without dramatic changes in land-use plans at a regional scale, there is little hope for survival of this cougar population.

CHAPTER 5. UTILITY OF TRACK SURVEYS

Track surveys for cougars can be used for 3 purposes: (1) to detect simple presence of cougars, (2) to detect increases or decreases in population size, or (3) to estimate the total number of animals in a population. The first type of survey is relatively inexpensive and potentially useful, and is discussed in the first part of this chapter. The second type of survey is very expensive and has low power to detect change in numbers. It is nonetheless feasible and is discussed at the end of this chapter. The third type of track survey (to estimate numbers) would be extremely expensive, probably requires surveying more road mileage than exists in our study area, would produce estimates of low precision and unknown accuracy, and will not be discussed further.

Surveys to detect cougar presence

There are frequent reports of cougar sightings within County Parks. Under most circumstances it is unlikely that County Parks would want to use a track survey to validate or discredit a report, because valuable manpower would be spent without gaining any new information. However, in certain circumstances (e.g., a report of a cougar engaged in unusual or bold behavior) a track survey to detect cougar presence might be appropriate. Track surveys for presence are also useful to detect whether cougars are still using an area that has been impacted by urban growth.

Most cougar sightings are bogus and do not need validating

In our experience during 1988-1992, at least 75% and perhaps as many as 95% of the routine sightings were cases where the observer has misidentified a bobcat, coyote, domestic dog, domestic cat, raccoon, or deer. The following 3 examples illustrate that even people with extensive experience with animals mistakenly identify other animals as cougars, even under ideal viewing conditions.

1. In 1988 we received occasional reports of cougar sightings from security personnel at the TRW facility on Rancho Mission Viejo. These reports seemed credible because the guard station had a fine view, because 2 radio-tagged cougars used the areas within their view, and because each guard spent 40 hours a week in the station. At about 8:00 on December 25 1988, as one of the study team drove up to the guard station, 2 guards excitedly stated that they had been watching a cougar in the canyon below, using binoculars, from a distance of about 250 yards, for about 5 minutes. They pointed to a shrub behind which the animal had just walked. A minute later a coyote walked out from behind the shrub.

2. Rancho Carillo is a community completely surrounded by designated wilderness areas, inhabited by about 70 families who have chosen a remote lifestyle. They live in the middle of cougar habitat, and we tended to believe many of their reports of cougar sightings. In July 1989, a resident of Rancho Carillo reported that for 2 days a cougar had been resting near a woodpile and trailer about 200 feet from his house. He had watched the animal several times, during the daytime, using a spotting scope, and several of his neighbors had also seen it. When 2 members of the study team went to investigate on the morning of July 28 1989, the informant and several other observers said they had just seen the cougar bed down behind the trailer. The informant stood by his spotting scope while we went to investigate. As we approached the trailer, a house cat ran out from under the trailer and the observers shouted: "There goes the lion."

3. At 12:45 PM on February 5 1990, Orange County Animal Control called to report that an adult cougar and a spotted cub were in a clump of pampas grass at 24252 Cataluna Circle in the City of Mission Viejo. An animal control officer had been called to the scene by a local resident, saw the cats himself, watched the cats enter the pampas grass at noon, and had watched the clump of grass continuously since that time, calling for assistance with his hand-held radio. The officer was certain that he was watching so closely that the cats could not have escaped. When we arrived we crawled into the pampas grass to flush the animals into the open where the assembled Animal Control Officers and CDFG wardens could attempt to shoot the cougars with tranquilizer darts. We flushed a 10-pound yellow house cat.

Finally, the power of suggestion can greatly increase the number of reported sightings. We usually received fewer than 6 reported sightings per month during 1988-1992. However, as a result of publicity surrounding the court hearings on the Laura Small case, we received about 6 reported sighting per week. We could investigate only a fraction of these reports; none of them could be verified by the presence of cougar tracks or other sign.

Given the unreliability of sightings, we make the following conclusion:

If

(a) the report did not allege that the cat acted aggressively toward people, and

(b) the Park is already known to be cougar habitat,

then,

it is a waste of time to investigate the report, **because**

(a) the report is probably in error, and

(b) even if the report is confirmed, no new information will be gained from the effort. If the park was known to be cougar habitat before the sighting, a confirmed sighting would not change this fact in any way.

When a track survey for presence may be warranted

If a reported sighting of a cougar includes an account of unusual behavior (e.g., the cat deliberately approached the park visitor at close range) or if the sighting occurs in an area thought to be outside cougar habitat (e.g., any park west of I-5), Harbors Beaches and Parks (HBP) may wish to validate these reports. There may be reasons why HBP may prefer not to investigate; for instance, HBP may feel that chasing phantasms is diverting resources from important work or they may decide to refer the report to CDFG. Our purpose here is merely to point out that if HBP wishes to validate a report of unusual cougar activity, a prompt track survey can be a useful approach.

Track surveys for presence can also be used to monitor the success of wildlife movement corridors impacted or created by human activities. In approving projects with narrow habitat strips for animal movement, planners often decline to require wider corridors because it is impossible to know in advance that the narrow corridor won't work. However, we would soon gain such knowledge if we monitored animal use of such habitat strips (Beier and Loe 1992:438). If track surveys are used to detect cougar use of a site, it may be necessary to rake the ground or import dirt to increase the detectability of tracks, and sites should be checked at dawn (before nocturnal tracks are degraded). Because cougar home ranges are so large, track monitoring should take place at least twice a week for several months, with equal sampling intensity before and after project impacts. Further suggestions for such monitoring are given by Beier and Loe (1992:438).

Using tracks to verify a reported sighting

In the course of investigating many reported sightings, our staff and the personnel at several county parks have developed a simple procedure for using tracks in an attempt to verify a reported sighting. If the followup investigation is carried out within an hour of the sighting, there will usually be some useful evidence. Fresh dog or bobcat tracks at the very point where the sighting occurred would disprove the sighting. Fresh cougar tracks in the vicinity would verify the report. In some cases the sighted animal will still be present if the investigator arrives promptly. However, we caution that in some cases no useful evidence will be found; such lack of evidence should be used neither to accept nor to reject the sighting. We first presented the following procedure at a seminar for HBP Rangers at Santiago Oaks Regional Park on September 5 1991.

1. Have the informant describe the animal in their own words. Prompt the informant by asking questions such as "What colors did you see on its coat?" and "Describe the tail." Do not ask leading questions such as "Was it brown all over?" or "Did it have a real long tail?"

A cougar has a black tip on its tail, but no black elsewhere. If they describe "some black" on the sides or belly, it was probably a bobcat. A, cougar's tail appears nearly as long as its body (although it's not really that long), and is usually held so that it nearly touches the ground.

2. If the informant described a cougar, visit the site promptly to look for tracks. Hikers, bikers, equestrians, and winds can obliterate tracks within minutes. When you go to the site, bring a track identification guide (Figure 12). If possible, have the informant take you to the exact location where they saw the animal.

3. While holding a track identification guide (Figure 12) in your hand, check for tracks everywhere within about 400 m (¼ mile) of the sighting area. If the cougar walked in a dirt trail it will almost always leave tracks. If the cougar was not reported to have walked in a trail, check nearby portions of the trail anyway.

4. If you find cougar tracks in an unusual location (e.g., west of I-5, in a city park) or in connection with reported aggressive behavior, document the fact with photographs. Use a camera that can focus on a track a few inches from the lens. Take under-exposed photos in addition to normally exposed photographs; overexposed photos do not reveal the details needed for a positive identification. Try to get strong side-lighting so that the edges of the tracks cast big shadows. In low light,

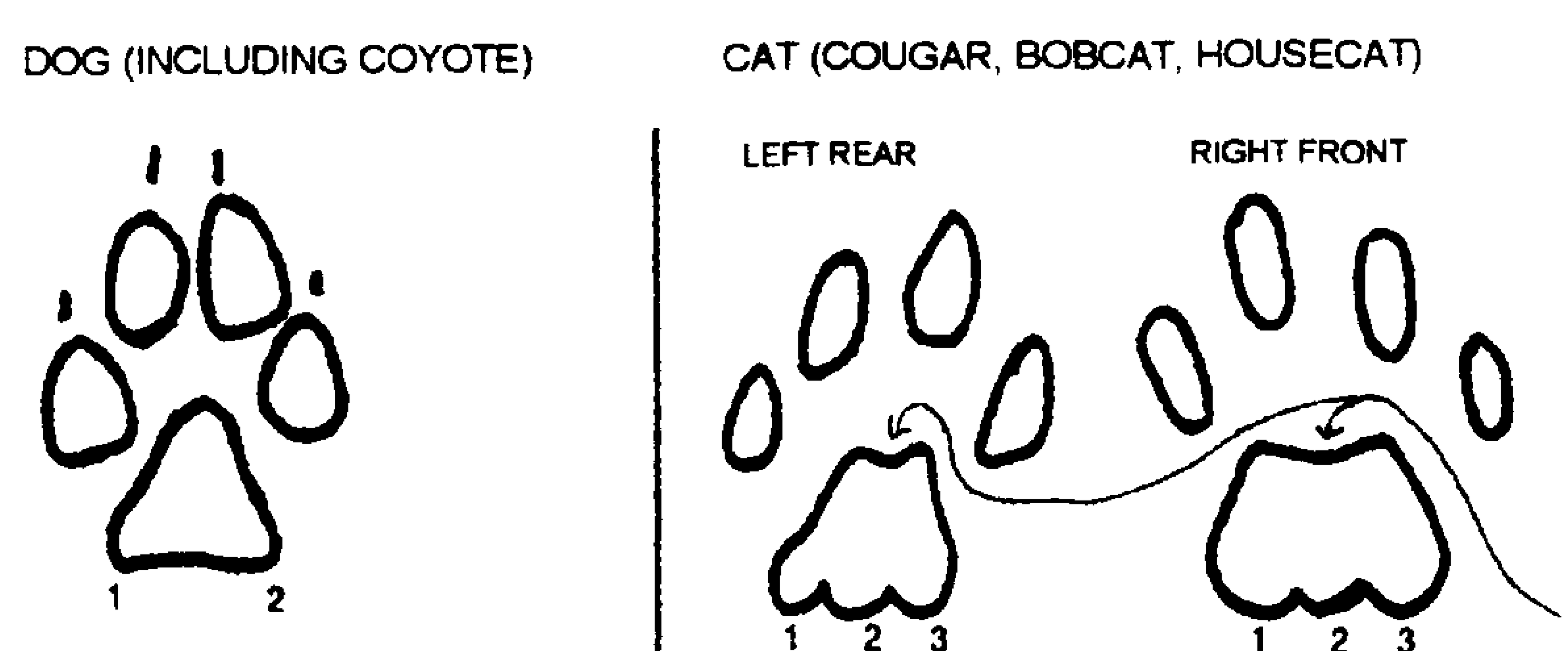

Figure 12. A field guide to distinguish cougar tracks from dog tracks. Size is worthless as a criterion: some dog tracks are larger than cougar tracks. If you can see claw marks, it is a dog track; however, tracks without claw marks can also be dog tracks. **The critical field marks relate to track *shape***: A dog track has a roughly triangular 'heel' pad with 2 lobes at rear, and near-perfect symmetry (you can rarely tell right from left). The 'heel' pad of a cat track has 3 lobes at the rear margin and a dimple in front (arrows). A cat track is also asymmetric: you can tell right from left. If the heel pad of a cat track is over 37 mm (1.5") wide, it is a cougar track; if narrower, it is a bobcat or housecat.

use a lantern, auto headlights, or a detachable flash to create strong side lighting.

Surveys to monitor population trend

By resurveying dirt roads and trails on an annual or multi-annual schedule, it would be possible to detect long-term changes in population size. In the case of the Santa Ana Mountain Range, such information could be used to detect whether cougar numbers are declining, so that remedial measures could be taken. We do not feel that such monitoring would be useful, however, because simulation modeling (Chapter 4 and Beier 1993), present population size (Chapter 2), the near-isolation and accelerating fragmentation of the population (Chapter 3), and highway mortality (Chapter 4) all clearly indicate that our cougar population faces a bleak future unless careful land-use planning is implemented rapidly. Data from an expensive long-term track survey would add little to the urgency that already exists, and could be used to delay effective action.

Such a survey also has limited ability to detect change in numbers. As Kendall et al. (1992:428) cautioned, a well-designed track survey for trend "will not detect small, annual population fluctuations but may reveal long-term trends or impending disaster.... We emphasize that, at best, such data will reliably detect only substantial, potentially threatening declines, and then only with large sample sizes [and] relatively abundant sign." Similarly Van Dyke et al. (1986) and Van Sickle and Lindzey (1992) found weak correlations between track density and cougar numbers (r^2 = 0.38 and 0.73, respectively) and the latter cautioned that the technique can detect "only relatively large changes in cougar population size."

Despite these reservations, a trend survey using tracks is technically feasible and managers may decide to implement such a survey. Based on our experience and our survey of the literature, we offer the following survey procedures, designed to detect a 20% decline in cougar numbers with a statistical power of 0.8 (80% chance of detecting a real decline) and significance level of 0.1 (10% risk of falsely suggesting a decline, one-tailed test). We chose a procedure that uses presence-absence data on each mile surveyed, rather than track density because the 2 types of data provide highly correlated results (Kendall et al. 1992), because our procedure avoids subjective judgments of whether or not a new track occurrence represents a different animal, and because our procedure (by allowing the observer to stop observing in each 1-mile segment after a track is detected) is much less expensive. This is not a highly sensitive procedure, but further sensitivity would require considerably greater effort. Indeed the limited length of dirt roads in the mountain range may preclude design of a more sensitive survey.

If such surveys are to be carried out, the following simple procedures are recommended:

1. Train observers to recognize cougar tracks. On a map, allocate dirt roads in the Santa Ana Mountain Range into Routes, each 30 miles long. This is the maximum distance that can be covered by a single observer in a single session. Some Routes can consist of a few short roads totaling 30 miles, with minimal transit time between the road segments. For statistical purposes, each Route must be run 3 times per year, and there must be at least 900 total miles (30 Routes) surveyed. Foot trails can also be used. Arrange the routes so as to achieve an even coverage of the entire mountain range. The 900-1000 miles needed probably approaches the total mileage of dirt roads and trails in the mountain range. Try to select routes that will not be paved in the future.

2. To reduce vehicle and manpower costs and increase detection of tracks, use a single observer driving a motorcycle on dirt

road Routes. Alternatively, it is equally effective (but with added costs and safety concerns) to use a team of 1 driver and 1 observer in a car or truck, the latter riding on the hood of the vehicle.

3. When driving each Route, start at dawn (before winds and vehicle traffic obliterate nocturnal tracks), maximize the time spent driving into the sun (this increases track detection), and stop before the sun is high. On roads with no vehicle traffic and calm daytime winds, late afternoon is also an acceptable time to survey.

4. Drive at about 5-8 mph, scanning the ground in front and alongside the vehicle carefully for tracks. When cougar tracks are suspected, stop and look closely. For each mile as measured on the odometer, record whether or not cougar tracks were detected. Do not attempt to determine how many different cougars made tracks. Thus if a cougar track is detected at 0.1 miles, you can stop looking for the rest of the mile and resume looking at the next whole mile. Use the same data form for each of the 3 surveys during a single year; if a track was detected on a given mile during 1 the times that Route was previously surveyed in a given year, you can omit checking on that mile.

5. Repeat the routes 3 times per year. The 3 repetitions should be run at the same times each survey year. We suggest running them about June 1, August 1, and October 1, because dusty road and trail conditions maximize track detection and the interval is sufficient to insure that you will never count the same track twice. The 2-month interval also increases the chance of detecting a mother with cubs whose restricted movements might not be detected if all 3 surveys fell in the early neonatal period. There is no particular advantage to longer (e.g., 3-4 month) intervals, and such spacing would risk encountering rain, floods, or washed-out roads.

6. The index of cougar density is simply the fraction of the 900-1000 miles sampled that had cougar tracks at least once during the year. Compute the standard error following Kendall et al. (1992).

7. Repeat the entire procedure every 2 or 3 years, looking for changes in the index since the last survey.

CHAPTER 6. ACTIVITY PATTERNS

Daily activity patterns

We carried out 180 intensive monitoring sessions, during which we determined location of the focal animal every 15 minutes. Most of the early sessions were for 24-hour periods (usually noon-to-noon). Because these early sessions showed that cougars were overwhelmingly nocturnal in their movements, later sessions started 1 hour before sunset and ended 1 hour after sunrise. Data from these sessions were analyzed by computing the straight-line distance moved between 1 location and the next location (15 minutes later). In each 15 minute interval, the cougar's behavior was categorized as traveling (distance > 0) or as static (distance = 0). Consecutive intervals of traveling or stasis were termed "travel bouts" or "periods of stasis," respectively. By simple addition, we computed the total elapsed time (always a multiple of 15 minutes) and distance traveled in each bout ot travel or stasis. Travel speed was computed as the distance traveled divided by the duration of a travel bout. Percent of time moving was computed separately for daylight and dark hours.

For the entire monitoring session, total distance was computed as the grand total of all 15-minute distances, and net distance was computed as the straight-line distance between the first and last location of the session. All times were converted to Pacific Standard Time before averaging across sessions.

On the day following most sessions, we walked the animal's route, often assisted by hounds, looking for prey remains, scats, or other evidence that would allow us to identify the behaviors associated with several distinct movement patterns. In this chapter, we summarize data from the first 78 sessions of monitoring (almost all of them for a full 24 hours). We are preparing a manuscript for scientific publication using all 180 sessions, but these analyses were not completed in time for this report.

There were 4 distinctive movement patterns. Our followup showed these patterns were associated with 4 different behaviors. Each of these 4 patterns is discussed in greater detail in the following sections:

1. walking all night (which we refer to as "hunting" although in fact we do not know what motivated the cougar to move steadily all night long),
2. feeding on a previously killed deer,
3. killing a deer during the session and then feeding on it, and
4. killing and eating smaller prey.

We observed the hunting pattern on half (49%) of the sessions; on these days the cougar walked steadily and our followup suggests that it did not kill anything as large as an opossum. This was a surprising result, and suggests that cougars frequently went several days without eating. The patterns and our followup show that cougars killed an opossum-sized animal about once very 6 days (13% of sessions), killed a deer about once every 10 days (10% of sessions), and fed on a previously killed deer carcass on 23% of the sessions. The latter 2 frequencies suggest that cougars fed on a single deer for about 3½ nights (including the night of the kill). Thus days of non-feeding alternate with days of only-feeding creating an overall pattern of "feast or famine."

Three other behavior types were observed. (1) The focal animal was primarily involved in social interactions (breeding, or prolonged vocalizations between adult females) in 5% of the sessions. These movements usually followed a pattern similar to feeding on a previously-killed deer. (2) In 6 sessions the focal animal was an adult female with young (< 6-week-old) cubs; these sessions showed the "hunting" pattern for the first half of the night, and the mother usually spent the rest of the night with her cubs. Thus the movements plotted against time resembled the pattern when a deer was killed near midnight (Figure 13: curve B). However, the starting and ending location was always the site where the cubs were hiding. (3) Dispersing juveniles generally displayed a "hunting" pattern, but were doubtless exploring at the same time; data from these animals were excluded from the results presented here.

Table 7. Summary statistics for cougar movement patterns while presumably hunting. Data are from 33 monitoring sessions, in which the focal animal was located every 15 minutes.

Trait measured - units	Average	Modal class[a]	Range
percent of night time traveling - %	51	41-50	25-83
percent of daylight time traveling - %	13	0-10	0-42
total distance traveled in 24 hours - km	9.0	8.0-8.9	2.1-19.4
traveling speed - meters/hr	920	500-750	120-3400
number of travel bouts per 24 hours - n	9	8	4-14
number of travel bouts per night	7.4	7	3-14
number of travel bouts in daylight	1.6	1	0-6
duration of travel bout - hours	0.91	0.25&0.75[b]	0.25-6.75
duration of periods of stasis (night time) - hours	0.78	0.25	0.25-3.75
distance traveled in 1 travel bout - m	975	50-250	50-9800

[a] In some cases the mode (the most frequently occurring value or class) is a better indicator of "typical" behavior than the average.
[b] bimodal

Hunting

This pattern consisted of walking most of the night, with no period of stasis longer than 3.75 hours. Because the cougar moved steadily and almost certainly did not kill any prey as large as an opossum, we have labeled this pattern "hunting" although the cougar may have been moving for some other reasons.

Data from 33 sessions showing this pattern are summarized in Table 7. A "hunting" cougar spent about half the night traveling, and did virtually no traveling during daylight hours. On only 2 of the 33 sessions did the cougar travel over 3 km during the daytime. Hunting cougars usually traveled at a leisurely pace of about 900m/hr. Travel occurred in about 9 short bouts per day, each typically less than 1 hour in duration and less than 1 km in distance moved. Night-time travel bouts alternated with shorter periods of stasis. The overall pattern thus consisted of short, slow-speed travel bouts, during which the animal probably searched for prey or moved to a new site, alternating with shorter periods of stasis, during which the cougar probably stalked prey or waited in ambush. During some periods of stasis, the cougar may have fed on small prey, drank water, or rested. Daytime sedentary periods typically lasted all day; during these periods the cougar probably simply rested.

The overall pattern exhibited by a "hunting" cougar is illustrated and contrasted to other patterns in Figure 13 (line A).

Killing and/or feeding on prey

In contrast to the steady alternating between travel and stasis, a very different pattern was evident when cougars made a kill or fed on a previously-killed deer. In the sessions when the focal cougar fed on a previously-killed a deer, the cougar traveled very little, with virtually no activity between 8AM and 2PM, and very little movement at night (Figure 13: line C). The peak activity periods were at dusk and dawn, reflecting movements between the carcass and a daytime rest site.

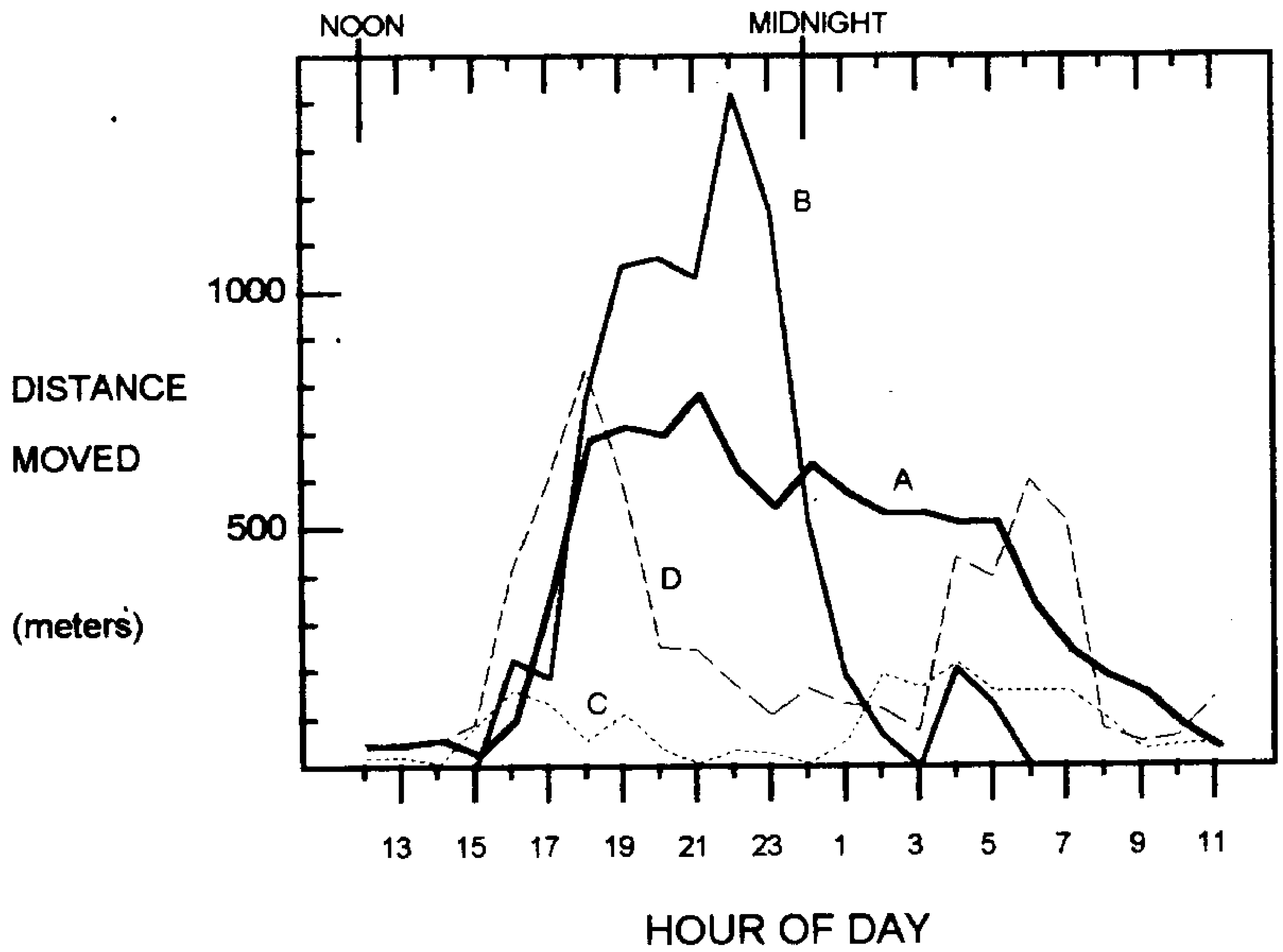

Figure 13. Twenty-four hour patterns of distance moved per hour by radio-tagged adult cougars that (A) were presumably hunting, (B) killed a deer near midnight, (C) fed on a previously-killed deer, or (D) killed and ate an opossum.

When the cougar killed a deer during a monitoring session, the "hunting" pattern was evident up to the time of the kill, after which the cougar moved very little for the rest of the night (Figure 13:line B). After some deer kills, there was a travel peak near dawn; in some cases this reflected a quick movement to water and a quick return to the carcass, and in other cases the cougar moved to a daybed site at some distance from the carcass.

Cougars killed medium-sized prey (mostly opossums) on 13% of the sessions. In these sessions, the movement pattern resembled the "hunting" pattern up to the time of the kill, and returned to that pattern after about 6 hours (at which time the prey was fully consumed) (Figure 13: line D). In most cases the medium-sized prey was killed about 3-4 hours after sunset.

Seasonal changes in distance moved per day

We used "net daily distance" moved per day as an index of activity. "Net daily distance" is simply the straight-line distance between 1 animal's locations on 2 consecutive days. We calculated about 2800 such distances, and then averaged them for each cougar in each month, deleting any case based on fewer than 3 distances. To evaluate seasonal changes in cougar activity, we plotted average net daily distances against month (Figure 14).

Males traveled much longer net distances per day (average = 5.7 km) than females (average = 3.2 km). The variation

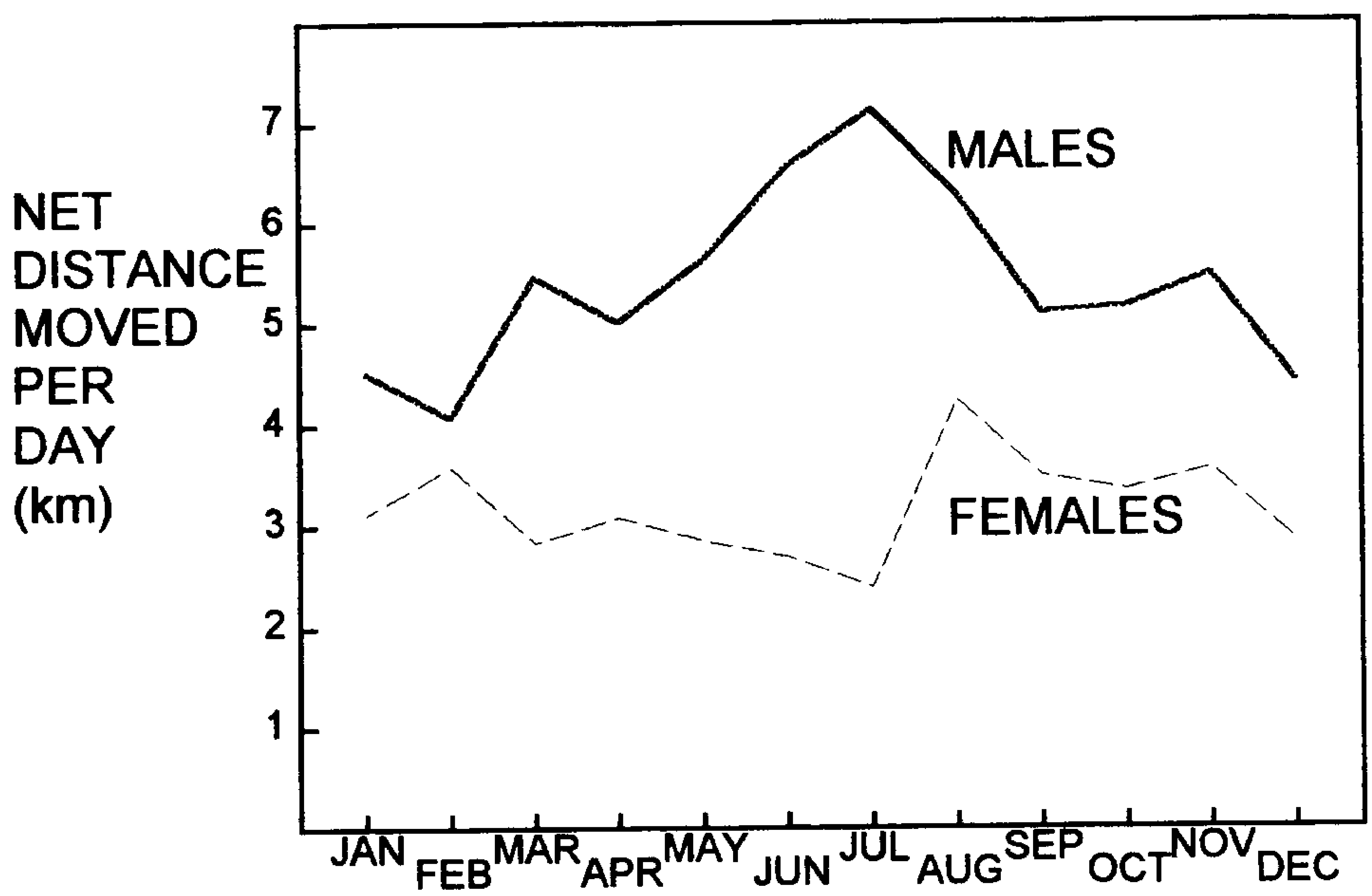

Figure 14. Seasonal pattern in average net distance moved in 24 hours by adult cougars. Males moved much longer distances. Within sex, there was no significant differences among months.

among months was not statistically significant (ANOVA, $P > 0.50$ for both males and females).

Dispersal movements of juveniles

Dispersal is the movement of an animal away from its place of birth to establish a new home range elsewhere. For cougars, the process of dispersal usually begins at 12-24 months of age, and continues for several months, during which the animal searches for suitable habitat that has minimum risk of conflict with other resident adults of the same sex. Adult males are especially intolerant of a young male taking up residence within the adult's range. As a result, juvenile male cougars usually travel into a different mountain range to find an area without an adult male. In Nevada, 75% of the yearling males and 20% of the yearling females moved out of the mountain range in which they were born (Ashman et al. 1983).

Juvenile dispersal in cougars is important in maintaining small populations and for recolonizing habitat where chance local extinction has occurred (Hemker et al. 1984, Beier 1993). Seidensticker et al. (1973) concluded that recruitment into the adult population occurred mainly via immigration of juveniles from adjacent populations, with the population's own offspring emigrating to other areas. Dispersal may also help maintain gene flow among populations (Greenwood 1980). Data on dispersal can be important in maintaining appropriate habitat for dispersal movements and for conserving genetic variation. Despite its importance, dispersal is "amongst the least understood factors of population biology" (Gadgil 1971:253).

In the Santa Ana Mountain range, dispersal is increasingly impeded by urban growth which has created many impenetrable barriers to animal movement. Pitted against these barriers is an innate tendency to disperse, evolved over millions of years. Our study was the first to examine how cougars attempted to disperse in confined and fragmented habitat.

Urban expansion has also created several narrow corridors, and we were most interested in whether dispersing cougars would find and use them. The 3 main corridors of interest were:

1. The Pechanga Corridor (Figure 7) provided the only possible link to the adjacent cougar population in the Palomar Range (Chapter 3).
2. The Coal Canyon Corridor (Figure 8) provided the only cougar travel corridor to the Chino Hills (Chapter 3).
3. The Arroyo Trabuco (Figure 9) was a redundant corridor in the sense that a cougar can travel between the large wildlands north and south of the Arroyo by a longer route to the east. Nonetheless it was of interest because it was a very long (about 6 km, or 3.8 mi.) and narrow (300-600m , or 0.2-0.4 mi.) strip, hemmed in by dense tract homes on either side, but with excellent cougar habitat within the Arroyo (Figure 9).

We followed the dispersal movements of 8 male cougars and 1 female cougar (Table 7). The juveniles were 9-18 months old at the time of capture, and were monitored until death or a stable adult home range was established. We had radio-tagged the mothers of 7 of these 9 animals, and thus we know their predispersal history in some detail. The other 2 animals (both males) were tagged as dispersers; their predispersal home ranges and ages at dispersal were not known. We found:

1. Mean dispersal age for 6 male cougars was 18.3 months (range 13-21); their ages were accurately known because the dam was radiotagged before birth (Table 1). The males captured as dispersers (M5, M6) were about 19 months of age based on weight and tooth wear (Ashman et al 1983:19-27). At

Table 8. Dates of birth and dispersal, and maximum dispersal distances for 1 female and 8 male juvenile cougars (Felis concolor) in southern California.

ID	birth date	capture date	dispersal start date[a]	dispersal end date[a]	N1[b]	N2[c]
F17	Dec 1989[e]	28 Jul 1991	3-10 Sep 1991	died 6-9 Jan 1992	39	5
M3	5 Aug 1989[f]	5 Jun 1990	26-29 Jan 1991	died 15-18 Feb 1991	14	0
M5	Jan 1989[g]	3 Aug 1990	pre 3 Aug 1990	died 18-24 Sep 1991	163	3
M6	Jan 1989[g]	27 Aug 1990	pre 27 Aug 1990	16 Dec 1991	117	2
M7	15 Jul 1989[f]	23 Oct 1990	28 Mar-4 Apr 1991	continues		1
M8	15 May 1989[f]	29 Oct 1990	4-7 Dec 1990	died 1-5 May 1991	73	8
M10	15 May 1989[f]	25 Feb 1991	22 Mar-3Apr 1991	died 15 Sep 1992		8
M11	9 Aug 1989[f]	4 May 1991	16-22 Jan 1992	died 29 Feb 1992	20	1
M12	9 Aug 1989[f]	15 Aug 1991	25-28 Sep 1991	died 24 Mar-10 Apr 1992	37	3

[a] Starting date range is last date within mother's home range until first date off natal range, or (M5, M6) date captured as a disperser. For death date, range is last date known alive until date found dead. For M6, end date = date on which 60% of the animal's stable home range had been visited (Minimum convex polygon).

[b] number of days with locations between start and end (or death) dates.

[c] number of sessions of intensive (overnight) monitoring between start and end (or death) dates.

[e] F17's mother was also radio-tagged 28 Jul 91, so maternal home range is known, but birthdate is estimate.

[f] ± 4 days; mother was radio-tagged before birth of the juvenile.

[g] Estimate (captured as a disperser, mother not radio-tagged)

[h] In addition, travel path out of the mountain range on about 20 Jan 1992 was traced from tracks and scent.

dispersal, the female was probably about 19 months old based on weight (although tooth wear suggested an age of about 13 months). Littermates (2 pairs) did not disperse at the same time. M12 was the youngest disperser at 13 months of age, 4 months before his brother M11. M8 dispersed at 18 months, and his brother M10 was the oldest disperser at 21 months.

2. Dispersal was often initiated by the mother leaving the cub at one edge of her home range while she moved to the opposite edge of her home range for about 2 weeks. In some cases, the mother moved off of her home range temporarily. The cub usually stayed in a very small area where its mother had abandoned it. After about 2 weeks, the cub abruptly and rapidly moved out of its mother's home range, usually in the direction away from its mother. Dispersal began in January (2), March (2), September (2), and December (1); M6 and M5 were captured as dispersers in August after starting dispersing some days or weeks earlier.

3. Dispersal took several weeks to months, during which a succession of temporary home ranges were occupied; following Hornocker (1970), we refer to these as "transient" ranges. The move from 1 transient range to the next was usually very rapid. Some juveniles returned to their natal ranges several weeks after dispersal and stayed 7-20 days before departing again; no juvenile returned more than once. For males, a transient home range was occupied from 2 weeks-8 months, and was much smaller than (1% to 30%) the size of an area an adult male would use in the same time span. Transient home ranges were usually near the urban-wildland interface, and often elongate along that edge.

4. All dispersers explored extensively throughout the Santa Ana Mountain Range. Cubs born and raised at the southern edge of the range (M8, M10) dispersed northward and cubs born at the north edge (M11, M12)

dispersed south, apparent trying to move to a new mountain range.

5. Seven of the 9 dispersers died before establishing a stable home range, usually (4 of 7) as a result of vehicle collisions. In addition to the 4 fatal accidents, dispersers were involved in 2 nonfatal vehicle collisions.

6. Dispersers explored the urban-wildland interface very thoroughly with remarkably little human interaction. All dispersers came within 100 m of urban areas and heavily used parklands for periods of time ranging from several hours to several weeks (following sections, and Chapter 9). Dispersers often crossed and used terrain avoided by adult cougars (e.g., M12's exploration of the grasslands west of San Juan landfill, M11's exploration of the San Luis Rey River, M5's exploration of Temecula Creek, F17's foray to the Anaheim Hills). Such exploration of marginal and edge habitat is very important because it is how juveniles find and use corridors (next point) and how they learn to avoid these areas by adulthood. None of the 9 dispersers behaved aggressively toward humans, although some livestock were taken in rural areas and 3 dispersers entered urban areas, apparently by mistake. We received only 5 reports (involving 3 cats: M3, M5, M11) of a disperser being seen by humans; no case involved cougar aggression.

7. Dispersers found and used movement corridors. Three of the 9 dispersers found and tried to use the Coal Canyon Corridor (2 succeeded and 1 was hit by a vehicle); 1 of them (M6) used the Coal Canyon Corridor (Chapter 3) at least 22 times. In addition an uncollared juvenile cougar also found and used the Coal Canyon Corridor. Three dispersers also found the Pechanga Corridor, 2 of them used it, 1 successfully (M12) and 1 unsuccessfully (M5). In addition, there were 5 vehicle mortalities in this corridor during October 1990-December 1992. At least 2, and probably 3 of the dispersers found, used, and explored the Arroyo Trabuco (M8, M10, and probably M12). Three dispersers each used 2 of the 3 corridors. <u>Only 3 of the 9 dispersers *failed* to find and use at least 1 of the 3 corridors.</u>

The last finding has very important implications for land-use planning, because it clearly demonstrates that efforts to retain and enhance existing linkages will not be in vain. In the following sections, we briefly summarize the dispersal history of all 9 dispersers. We are preparing a manuscript on cougar dispersal for publication in a scientific journal.

Dispersal of M8

After F12 and M8 had spent several days together in the northern part of her home range, F12 abandoned M8 on November 27 1990, moving to the southern edge of her home range. M8 stayed in a small area for several days, then moved off to the north sometime during December 4-7. On December 8 we documented M8's first independent kill of a mule deer (a male fawn). He fed on it for 3 nights. During December 17 1990-January 4 1991, M8 stayed mostly in the small (0.3 km^2) estuary of San Mateo Creek between the Pacific Ocean and I-5, known locally as Trestles Beach (Figure 15: Tr and HR1). M8 stayed in the estuary's thick willow forest and marsh, and there were no reported sightings from the many surfers and beachgoers during his stay.

We believe that no other radio-tagged cougar used Trestles Beach during our study, although the habitat just east of I-5 was regularly used by several cougars. M8 made only short local movements during intensive monitoring December 17-18. On December 23 we documented that he had killed and eaten at least 2 opossum and 2 raccoons in the area. M8 made 2 brief excursions (December 27 and December 31) east of I-5 during his stay at Trestles, crossing I-5 under the San Mateo Creek bridge and moving up to 3 km inland. On his second excursion M8 daybedded near adult male M2 and presumably the 2 cougars encountered each other. M8 returned to Trestles Beach the next day and M2 remained in the vicinity during January 1-5. On about January 4, M8 left Trestles Beach and returned to the center of his mother's home range.

Meanwhile his mother had been killed on I-5 on December 20 1990. On January 15 1991, M8 left his natal area for good, soon moving further north than before. He killed 2 mule deer in Gabino Canyon during January 17-19, consuming only 1 of the carcasses before moving north again.

On January 20-21, we observed M8's movements over terrain that he was exploring for the first time. One hour after sunset on

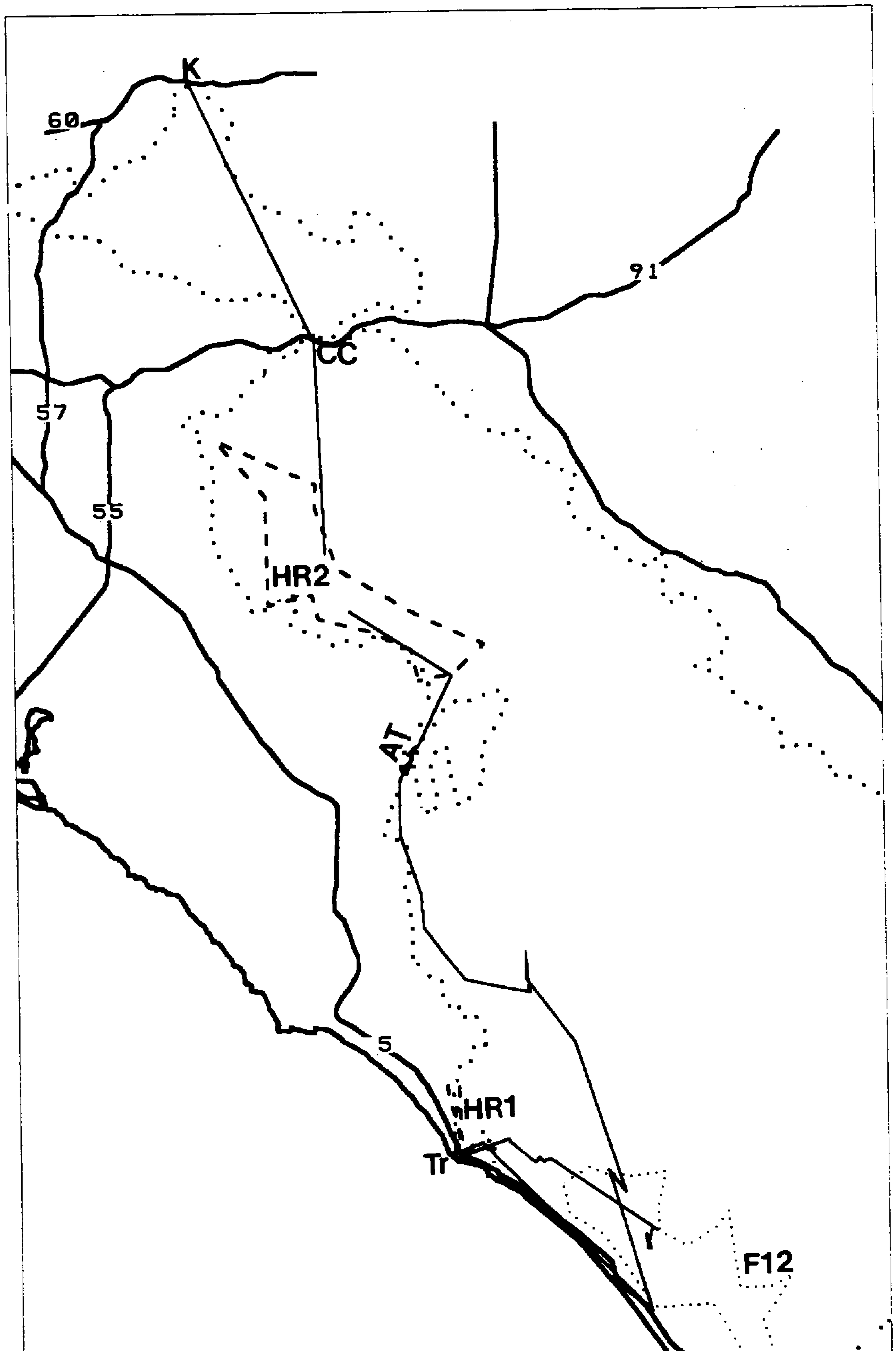

Figure 15: Dispersal Movements of M8. Dotted polygon indicates home range of his mother (**F12**). Heavy dotted line indicates limits of cougar habitat. His initial dispersal movements brought him to a small transient home range (**HR1**) in and near Trestles Beach (**Tr**). After a brief visit back to his natal range, he moved rapidly north, intensively exploring the Arroyo Trabuco Corridor (**AT**) and then using a new transient home range (**HR2**) along Loma Ridge during Feb-Mar 1991. In April he moved into the Chino Hills via the Coal Canyon Corridor (**CC**) and about April 30 was killed (**K**) on SR-60.

January 20, M8 left his daybed in Trampas Canyon and slowly explored or hunted in the upper basin of that canyon for 1½ hours. At 2000, he reached the basin's south rim, and quickly moved west along the rim, then north along the west rim for 800 m before turning west and heading down an unnamed canyon toward the San Juan Capistrano Landfill in Prima Deshecha Canyon. About halfway down, the canyon opened out into a broad grassy slope with no woody vegetation. At this point M8 moved north, quickly crossing 2 small, west-flowing, sparsely-shrubbed drainages; from the intervening ridges he doubtless saw the lights of San Juan Capistrano spread out to his west. The 3rd west-flowing canyon was much larger and contained good woody cover; he stopped there for about 40 minutes. At 2300 he resumed his rapid walk, heading down this wooded canyon all the way to La Pata Avenue. He reached La Pata Avenue (the paved access road for the landfill, which receives no night-time traffic) about 700 m south of the Ortega Highway, walked quickly north 350m along La Pata, turned NE through the nursery at the SE corner of La Pata and Ortega Highway, and crossed the Ortega into San Juan Creek just after midnight. M8 stayed in San Juan Creek for 4 hours, moving very little. At 0415 he walked up San Juan Creek about 400 m, returned downstream to the mouth of Cañada Chiquita and then quickly moved north on the west slope of Cañada Chiquita, staying east of the ridgeline. At 0545 he stopped and daybedded in a wooded canyon west of the Sea Tree nursery, northwest of the Santa Margarita sewage plant.

Although at least 6 radio-tagged cougars used Trampas Canyon, only dispersing animals (M8, M12) used the canyons west of Trampas Canyon. Their rapid pace suggested that they were not comfortable in the area's open grassland.

On the following night (January 21-22), M8 moved another 8 km, discovering and entering the Arroyo Trabuco corridor. He daybedded near the San Francisco Solano site, between the cities of Mission Viejo and Rancho Santa Margarita. During overnight monitoring on the nights of January 22-23 and January 23-24, he spent both nights in local movements (within about 800 m of the San Francisco Solano site), suggesting that he was hunting in the area and exploring small side canyons. Each morning at dawn the ridgetops came alive with earth movers and M8 daybedded near the Arroyo bottom.

On the night of Sunday January 26-27 we monitored the movements of M8. F2 had entered the Arroyo from the south the previous night and was daybedded < 1 km south of M8. We hoped to learn how F2 would react to a juvenile male in her home range. Trespassers traveling by foot, pickup truck, and dirt bike passed near both cats until dusk. Shortly after sunset, both cats started moving slowly towards each other, passing with 250 m (width of the Arroyo bottom at that point) without pause. We presume the cats were aware of each other, but we were not close enough to hear vocalizations. After this non-encounter, F2 continued north and M8 continued south at about 1km/hour. At 2000, a low-flying helicopter shone a spotlight at the radio-tracker (50m from the cougar) and M8 stopped moving for about 30 minutes. At 2130, M8 passed through the Oso Bridge construction site, an area of bare compacted ground with bulldozers, huge steel I-beams and construction debris on the ground, huge steel scaffolds, and a half-complete road bed above. A trespassing vehicle that had earlier broken its radiator was parked under the bridge, and a steamy windshield suggested that its driver was spending the night there.

M8 continued south to the mouth of Corridor Canyon (the large brushy canyon at the south edge of the site of the proposed Las Flores Planned Community). He promptly turned east into Corridor Canyon and walked halfway up the canyon; his unhesitating move into this canyon suggests that he probably used this route when he first entered the Arroyo on the night of January 21-22. After stopping for less than an hour halfway up the canyon, at 2330 he backtracked to and up the Arroyo. He stopped just north of the Oso Bridge site and spent 5 hours exploring 3 small grassy canyons on the Mission Viejo side of the Arroyo. On several occasions he reached the ridgetop, from which he could see the lights of Mission Viejo < 1 km to the west, but he apparently never walked west of the ridgeline. Two of the 3 side canyons he explored had no woody vegetation, and only about 3 inches of new green herbaceous growth. He spent 2 full hours in the smallest of the 3 canyons, in which a dozen Russian thistles were the largest plants. We presume he was hunting for gophers, voles, and ground squirrels there; a few badger holes were also present. At 0500, M8 returned to the Arroyo and moved north, bedding near his starting location.

On the night of January 28-29, M8 left the Arroyo and resumed his northward travel. He was in Joplin Canyon on January 29, just NE of Cooks' Corner on January 31-February 1, across Santiago Canyon Road in Round Canyon on February 3, and in the Villa Park impoundment (willow forest) on February 8. He had traveled 56 km (35 mi) north of the north edge of his mother's home range.

During February 9-April 10 1991, M8 used an elongate home range pressed against the western edge of cougar habitat, mostly along Loma Ridge and its associated canyons, with occasional forays into Santiago Canyon above Modjeska (Figure 15: HR2). During April 8-10, he moved abruptly north, crossing the Riverside Freeway into the Chino Hills. We were unable to locate him with intense aerial telemetry searches south of the Freeway on April 12, April 15, April 26, and April 30, but on May 3 1991, a motorist stalled in traffic found M8's carcass on the north edge of the Chino Hills, in weeds along State Route 60 between Phillips Ranch Road and Diamond Bar Boulevard in Pomona (Figure 15). He had been struck by a westbound vehicle 3-5 days earlier as he tried to cross to the north side of the freeway. He had no doubt spent his last 3 weeks in the Chino Hills. Lack of tracks in any culvert under SR-91 indicates that he reached the Chino Hills via the Coal Canyon vehicle underpass.

In all his dispersal movements, M8 consistently moved north, hugging the western edge of cougar habitat and occasionally attempting to explore further west, only to find that there was no habitat to the west. This pattern was evident in his use of Trestles Beach, his travel through the grasslands west of Trampas Canyon, his exploration of the west ridge of the Arroyo Trabuco, his temporary home range along Loma Ridge, and his eventual death on SR-60.

Dispersal of M10

M10 (sibling of M8) began dispersal during March 22-April 4 1991, 3 months after his mother's death. He first moved about 16 km (10 mi) north of his mother's home range and stayed near a sheep grazing operation in San Mateo Creek during April 4-16, eating several sheep (Figure 16: HR1), then moved 51 km (32 mi., straight-line distance) north in 16-20 days, reaching upper Coal Canyon by May 6. His northward path was east of that taken by his brother.

On the night on May 6-7, we followed M10's movements down Coal Canyon. He started moving well before sunset and moved 3 km down the canyon at a brisk pace, following the main ridge between Gypsum and Coal Canyon. He approached the Riverside Freeway at 2100, stopping at the debris catchment before the main wash enters the culvert under the Freeway. From the catch basin, M10 had a clear view of the Freeway and the twin box culverts but not of the vehicle underpass < 100m to his east. After pausing there for 10 minutes, M10 moved west 200 m to a small hill overlooking the freeway.

After 30 minutes, M10 moved west a short distance crossing one tiny canyon and stopping in the second small, parallel dry wash flowing toward the freeway. He spent the rest of the night at the lip where the wash dropped over a cut bank, from where he could see the freeway (200m away) and the darkness of the Chino Hills beyond the freeway. By dawn he could see that the dark area was suitable habitat. Just after the next sunset, at 2100 on May 7 1991, M10 was struck by an eastbound vehicle on the Riverside Freeway, breaking his left femur. He was photographed sitting in the median strip, but soon ran back into the tiny canyon from which he had come.

After a rapid recovery (Chapter 4: highway injuries) in a small post-accident home range (Figure 16: HR2), in mid-June M10 moved south, encountering and traveling the Arroyo Trabuco corridor from north to south, and continuing through Cañada Chiquita and Christianitos Canyon to Horno Creek (Camp Pendleton) at the north edge of his natal home range. He thus moved at

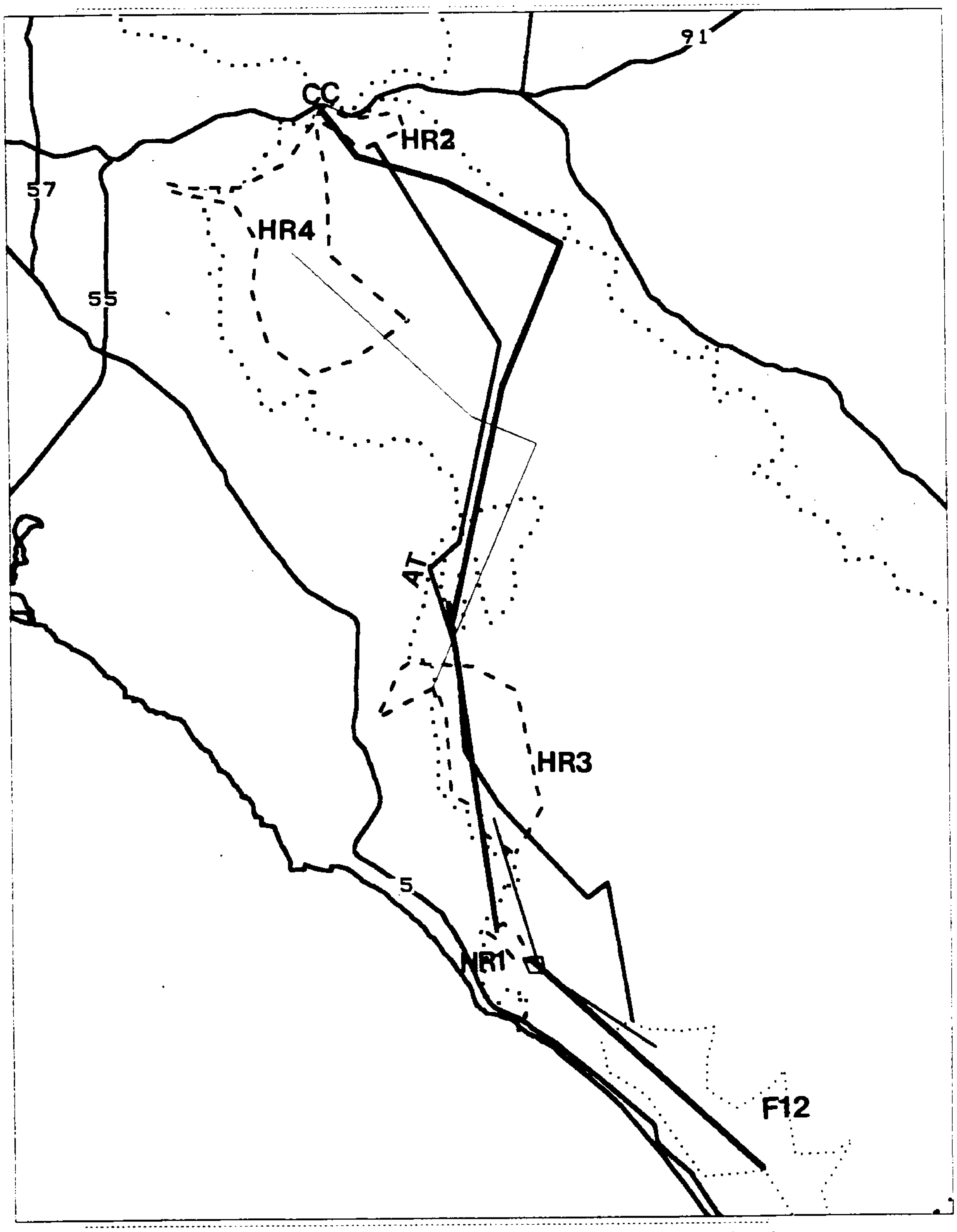

Figure 16. Dispersal movements of M10. Dotted polygon indicates home range of his mother (**F12**). Dashed polygons indicate his transient home ranges; heavy dotted line indicates limits of cougar habitat. The sequence of M10's travels are indicated by progressively thinner lines. After a brief stay in **HR1** (April 4-16 1991), M10 rapidly moved north to Coal Canyon, where he was struck on SR-91 (**CC**) on May 7. After a brief stay in a small post-accident home range (**HR2**), and despite a broken femur, M10 rapidly moved south, using the Arroyo Trabuco Corridor (**AT**) and returning to his natal home range (**F12**). 10 days later he moved north to **HR3**, which he used for 5½ months before moving to **HR4**, which he occupied for 8 months until he died in a second accident.

least 64 km (40 mi) in 14-19 days. He spent 10 days in his natal home range, and then established a transient home range (Figure 16: HR3) that included the area from upper Christianitos Canyon to Cañada Chiquita. After 5½ months in this area, he abandoned it in late January 1992, traveling north for 10 days and establishing another transient home range (Figure 16: HR4) along Loma Ridge and lower Santiago Creek. He remained in that home range until his death in a second vehicle accident on Santiago Canyon Road in September 1992.

Dispersal of M3

In fall 1990 M3 and his brother M4 spent increasingly long periods of time apart from their mother (F2), but they always traveled together within her home range. The longest such period away from their mother lasted for 10 days in early October 1990. Sometime during June-September 1990, M3 received a severe injury to his palate (Chapter 4). M4 died in early November 1990 and was fed upon (and possibly killed by) M3 and F2 (Chapter 4).

M3's dispersal was atypical in that he seemed reluctant to move off his mother's home range, making 2 brief excursions to the east before finally dispersing to the west. During November 26-29, M3 and F2 consumed a deer in the central part of their home range, but 2 days later F2 moved to the western edge of her home range where she spent 2 days near adult male M2 in the Arroyo Trabuco at the west edge of her range, an area she had not visited for over a year. M3 remained where F2 had left him in Bell Canyon.

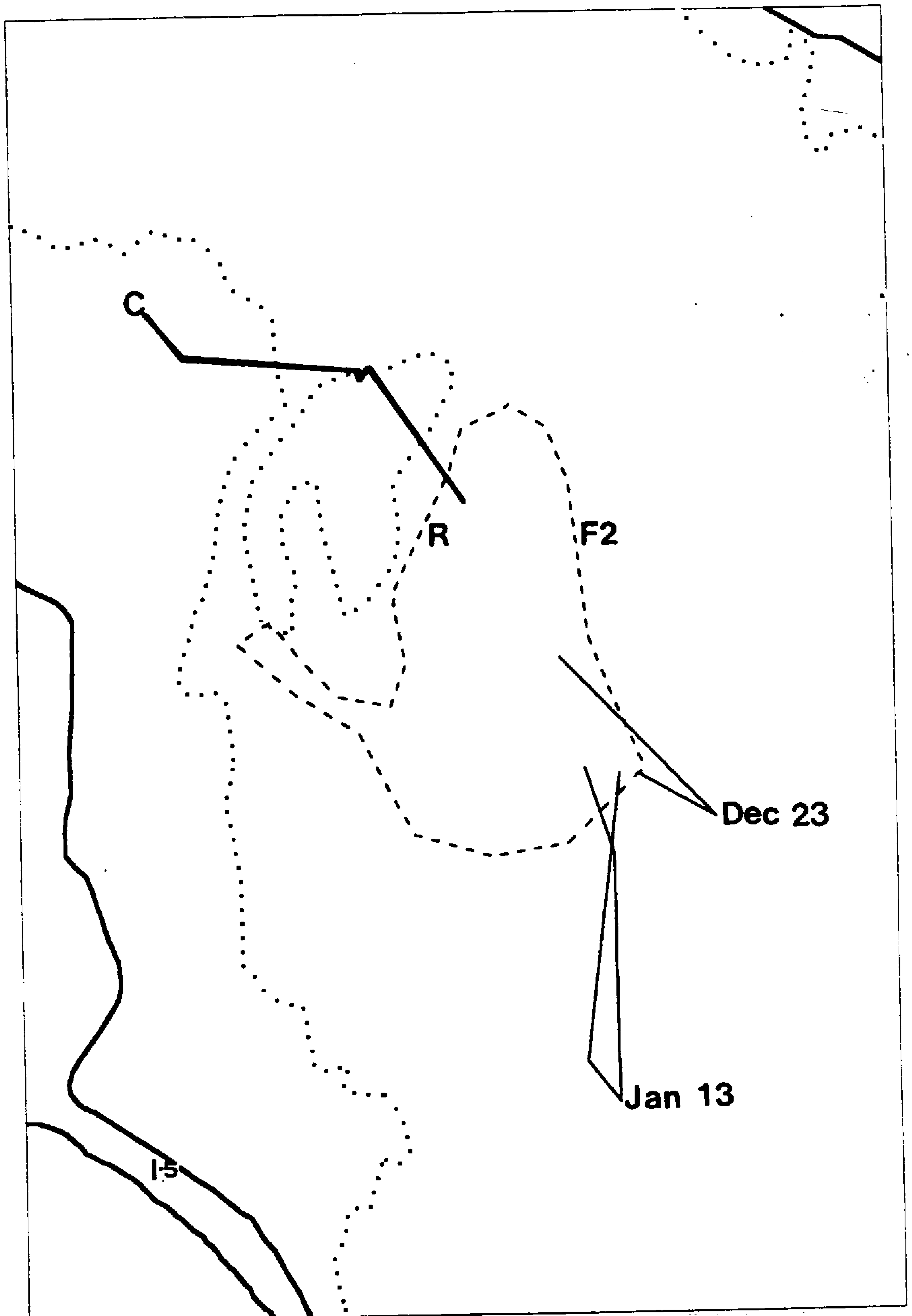

Figure 17: Dispersal Movements of M3: Thinner dated lines indicate M3's predispersal explorations outside his mother's home range; thicker line segments show his short dispersal into Irvine. He was captured in a residential area on 8 Feb 1991(C) and was released at R, where he died 1 week later. The dashed polygon indicates the home range of his mother (F2).

On December 4, F2 returned to her son's location for 1 day and then moved 2.4 km off the southwest edge of her normal home range. There she killed a deer (December 10) and fed on it for 3 days. She then moved back to Arroyo Trabuco. Meanwhile M3 slowly moved eastward within and then beyond her home range (Figure 17: Dec 23). Up to this point, the dispersal pattern and timing was typical except that F2 had abandoned M3 near the center, instead of the edge, of her home range.

However after less than a week away from home, M3 returned to the eastern part of his mother's home range on December 28-29. F2, after a month in the southwest parts of her home range, moved east and encountered M3 in her home range on January 7. M3 immediately moved east again, a bit farther this time (Figure 17: Jan 14). However, by January 16 he again returned to the eastern and northern portions of F2's range. F2 remained far to the west and did not encounter her son.

On January 30 1991, M3 moved off again, this time to the northwest (Figure 17). He moved into the north end of the Arroyo Trabuco where he killed and ate a coyote. During February 4-7, M3 continued dispersing northwest, moving along the wildland-urban edge and through areas interspersed with orchards. As he moved from the Oso Lake area into Serrano Creek, a motorist saw him run north across El Toro Road at the sign marking the future crossing of the Foothill Transportation Corridor (6:00 AM, February 5). On February 8 he had moved into avocado orchards further northwest, and was located about 1 km west of Siphon Reservoir, just east of the intersection of Jeffrey Road and Irvine Boulevard. Early on the night of February 8, M3 moved 1 km west, penetrating 2 blocks into a residential area adjacent to the orchards. There he was treed by a German shepherd dog in a yard at 50 Hunter St. in Irvine shortly after dark. At 2100, Animal Control officers tranquilized M3 and released him back into his mother's home range. He remained near the release site and died there 1 week later (Chapter 4: Disease).

Dispersal of M7

M7 left the home range of his mother (F10) in April 1-4 1991, moving slowly northeast while F10 moved to the southern part of her home range. He initially moved northeast from his mother's range to the Mesa de Burro area. This area immediately became the nucleus of a transient home range (Figure 18: HR1).

After 4 weeks he began to enlarge his transient home range. In May he expanded to include the peaks and canyons west of Lake Elsinore (16 km north), and in July to include the upper Santa Margarita River area several km south. On several occasions, M7 was very close to the I-15 bridge and he doubtless encountered this entrance to the Pechanga Corridor. However, we have no evidence that he ever crossed I-15. In mid-September 1991, M7 made a 65-km excursion to the northern edge of the range, reaching Hagador and Main Street Canyons near Corona, and quickly returned to his transient range (Figure 18: thinner line segments).

In late January 1992, after almost 10 months in this transient range, M7 abandoned it for a new home range (Figure 18: HR2). The south edge of his new home range abutted the north edge of his old range, and he had passed through much of this new range in his September foray. As with most transient ranges, both M7's ranges were elongate and had 1 long edge along the wildland edge (Figure 18). In his movements within each home range, M7 often stayed in 1 canyon for 3-8 days and then moved to another canyon. This was very different from the pattern of adults M2, M9, and M6, who rarely stayed in 1 locality for more than 3 days. As of January 1993, M7

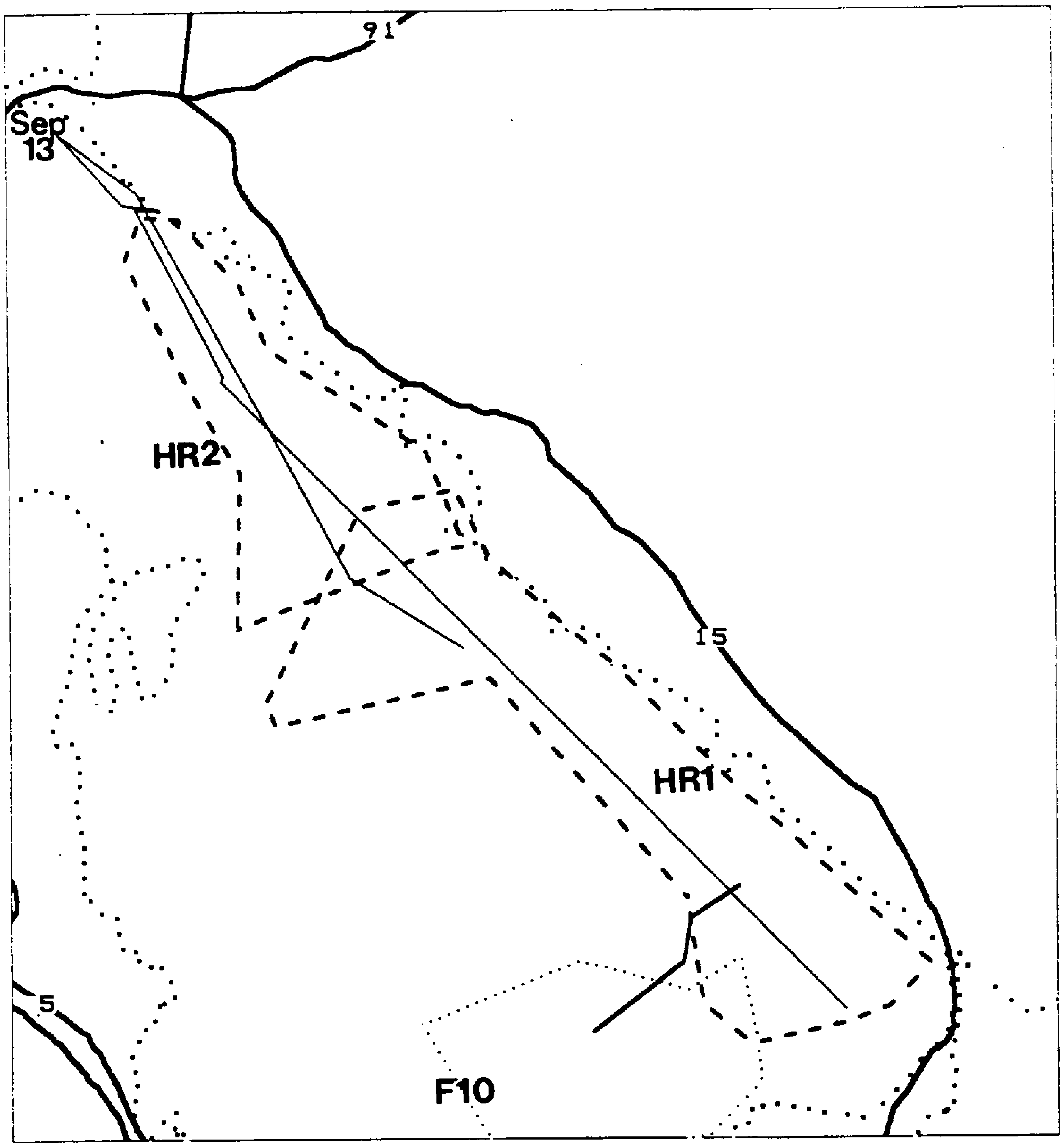

Figure 18: Dispersal Movements of M7. M7 moved a short distance (heavy line) from his mother's home range (**F10**) to a transient home range (**HR1**) which he occupied for 10 months. Thinner line segments indicate a long excursion from HR1 during September 1991. In January 1992 he abandoned HR1 for a second home range (**HR2**) that will probably become the nucleus of his adult home range if he survives. Heavy dotted line indicates limits of cougar habitat.

still occupied this second home range. This area was not overlapped by M6, M2, or M9, and if he lives we suspect it will form the nucleus of his adult home range. However, his movement patterns, and the relatively small size of this home range, suggest that it was not yet a true adult territory.

Dispersal of M12

M12, his brother M11, and their mother F6 had spent 2 weeks traveling together, when F6 and M11 abandoned M12 in a small brushy canyon on September 3 1991. M12 stayed in and near this canyon for 17 days, while his family ranged widely without him, mostly to his north. Tracks indicate that he used nearby dirt roads regularly. Finally, during September 20-22, he started dispersal movements to the south (Figure 19: thickest line segments).

During overnight monitoring on October 1-2 1991, M12 was moving steadily south through previously unvisited terrain when he encountered the noisy and well-lit California Silica Products factory and its adjacent open quarries. His first several attempts to pass by led to parts of the quarry or factory, and it took him 2 hours to select a route that skirted the east edge of the facility. Once past the plant, he rested on a ridge top for 2 hours and then moved west toward Trampas Lake but turned back before reaching the lake. Although M10 was also at the lake, the 2 cats did not meet each other; M12 may have detected M10's scent. M12 returned to his previous resting place, spent another hour there, and then continued southward, crossing into the Christianitos Creek watershed, and walking another 2 km south along the ridge just west of Christianitos Road.

On this initial move south, M12 travelled over 40 km (25 mi), reaching

Margarita Peak on October 17. He then moved rapidly back north and established a transient home range immediately south of this mother's home range (Figure 19: HR1). He spent almost 3 months in this transient range, killing at least 5 domestic goats in at least 3 incidents. In December 1991, he took a second exploration to the south.

This excursion (Figure 19: medium-width line segments) began during December 6-13, when M12 moved to La Paz Canyon, quickly finding the only domestic goats in south Orange County. He killed several goats in a single night before moving west to Trampas Lake. At the start of overnight monitoring on December 23-24, M12 and M13 were both at Trampas Lake (the 2 animals apparently did not encounter each other). About 2 hours after sunset, M12 started moving rapidly west. At 2000 he entered the San Juan landfill in Cañada Prima Deshecha, and spent about 2½ hours exploring heavily-grazed grasslands near the dump. This was the only time we documented a cougar exploring Prima Deshecha and the landfill area. But an even more unusual exploration followed. M12 skirted north of the landfill and moved further west, exploring the big grassy ridge that separates the cities of San Juan Capistrano and Capistrano Beach. M12 walked over 6 km through this 2-km-wide peninsula of marginal habitat fringed by homes. This area is so open and treeless, and so fringed by urban uses, that we had never obtained gate keys to these parcels; our limited access made it impossible to determine his exact travel path. At 0400, he reached an oak grove alongside I-5 between the exits for Camino Las Ramblas and San Juan Creek Road, and he daybedded there on December 24 (Figure 19: W). Tens of thousands of motorists passed within 200m of the cougar on the clogged freeway that Christmas Eve. There were no reported cougar

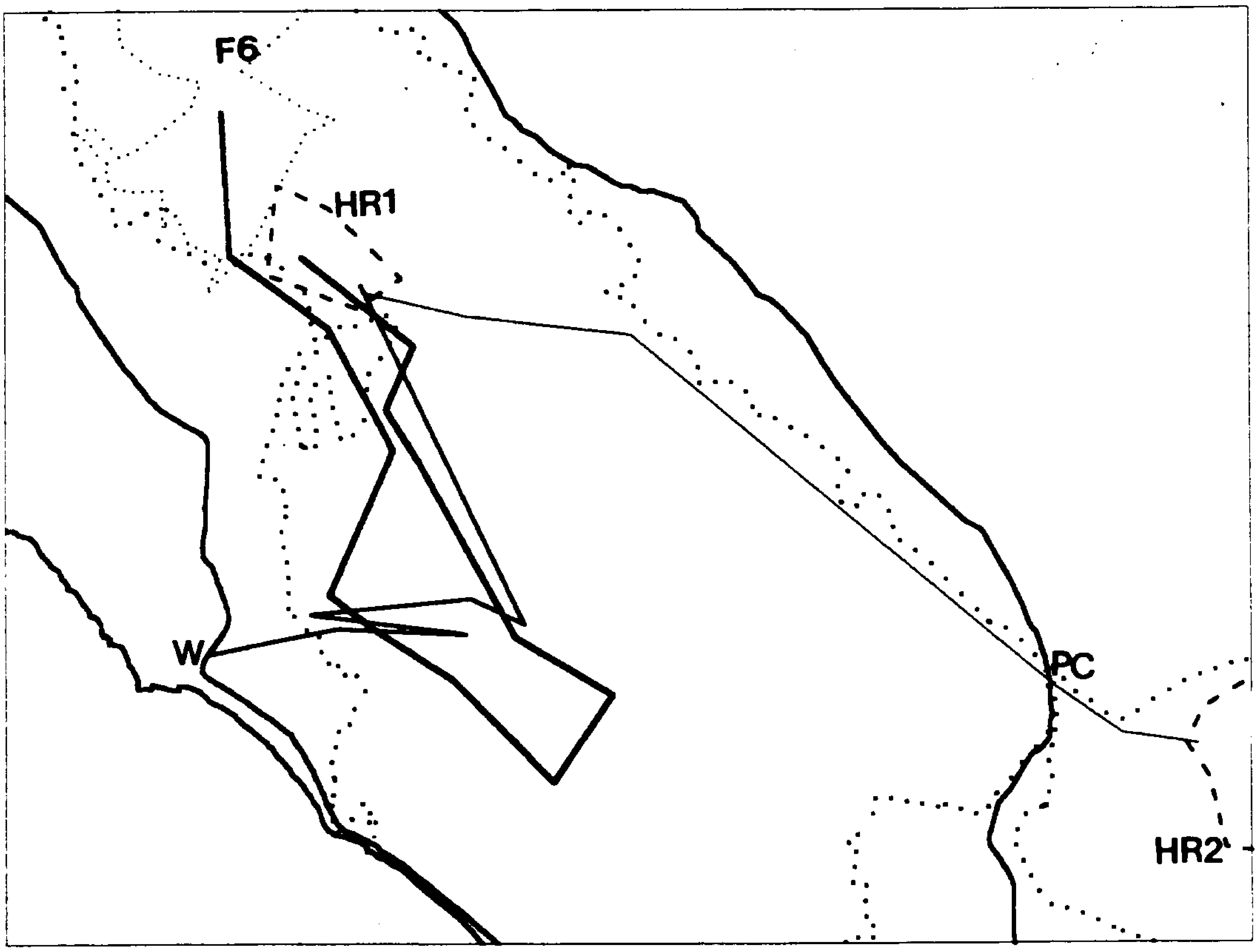

Figure 19: Dispersal Movements of M12. Dashed polygons indicate his transient home ranges; heavy dotted line indicates limits of cougar habitat. The sequence of M12's travels are indicated by progressively thinner lines. His first transient home range (**HR1**) abutted that of his mother (**F6**). On the foray to the west (**W**) (Dec 23-24 1991), M12 moved from Trampas Canyon through open terrain to within 100m of I-5 in San Juan Capistrano; he returned to **HR1** within 48 hours. M12 took less than 8 days to travel from HR1 to **HR2** in the Palomar Range, using the Pechanga Corridor (**PC**) to cross I-15 (see Figure 7 for detail).

sightings. Within 48 hours M12 returned 29 km (18 mi) back to his transient home range. Although this foray did not lead anywhere, it attests to the remarkable ability of dispersing cougars to explore habitat peninsulas and corridors without detection by humans.

On January 13 1992, M12 left his transient home range for the last time (Figure 19: thin line segments). Eight days and 59 km (37 mi) later, he became the first cougar in our study to move into or out of the Santa Ana Mountain Range, crossing I-15 via the Pechanga Corridor into the Palomar Range. We first located him east of I-15 on January 22; he was then in upper Pechanga Creek on the Pechanga Indian Reservation. On the morning of January 23 his tracks leading up to I-15 were fresh enough to be tracked visually and scent-trailed by hounds. M12's eastbound tracks left the Santa Margarita River about 400 m before the I-15 bridge. Although he could not have directly viewed the lights of Temecula from the river channel at that point, he could see the glow of city lights in the sky, and perhaps he gained elevation to better see what lay ahead. He climbed until he reached a dirt road about 50 vertical m above and parallel to the river, and he continued to walk east. As he got closer to the freeway, he left the road and moved southeast and then south, until he was roughly parallel to the freeway. His path took him away from the city lights. Perhaps using darkness as a cue to judge where appropriate habitat might be, he moved away from the bridge that offered the only good crossing under the freeway. Cliffs to his right gradually pinched him closer to the freeway, and where the cliffs met the road, he turned and crossed I-15 at grade about 800 m south of the bridge. On the east side he walked down the embankment 50 m to a paved golf course service road. At this point we lost his scent, suggesting that he traveled south along this road for at least 300m. There were no tracks in the dusty road and sandy stream bed to the north of the crossing point, in Pechanga Creek at several points along the golf course, nor in Pechanga Creek 400 m upstream from the uppermost housing tract. Thus he must have traveled southeast across a series of low wooded ridges for 2-4 km before dropping further east into upper Pechanga Creek where he spent the next few days.

M12 then established a large transient home range north and east of Mount Palomar from January 20 until he died there in late March 1992, apparently of natural causes (Chapter 4).

Dispersal of M11

M11 began to disperse in early January 1992. His pattern of separation was similar to M12's: He and his mother had spent several days together within F6's home range. Then F6 moved about 16 km away toward the northern part of her range (Gypsum Canyon) and left M11 in Round Canyon on Loma Ridge. M11 stayed there, moving little, for about 7 days, and then suddenly began moving south (Figure 20: thick line segments). Within 5 days he had moved 40 km (25 mi). Like many dispersers, he spent several days along Trampas Ridge near San Juan Capistrano.

From the Trampas Lake area, M11 continued south into Camp Pendleton, where he was struck by a vehicle on Basilone Road on the evening of February 4 1992. His injuries apparently were minimal, as he spent only about 48 hours within 1 km of the accident site, and then resumed his exploration of Camp Pendleton (Figure 20: dashed polygon). His period of post-accident recovery was far shorter than that of other accident victims (Chapter 4).

In late February, apparently fully recovered, M11 continued southeast and became the first radio-tagged cougar to move across the open grassland at the south edge of Camp Pendleton to reach the San Luis Rey River (Figure 20: thin line segments). This remarkable movement again illustrates the ability of cougars to move across marginal habitat in their dispersal explorations. However, the San Luis Rey River is too impacted by urbanization to function as a corridor. M11 moved down the River, crossing under I-5 into the City of Oceanside. At 0230 on February 29, M11 was sighted near the River in central Oceanside, about 3 blocks from the Pacific Ocean. At 0600, after about 3½ hours of pursuit through 8-12 residential blocks south of the river, M11 was shot at least 9 times by police officers near the intersection of 6th and Pacific Streets. Although we do not have data showing exactly how M11 reached the San Luis Rey River from Camp Pendleton, the most probable

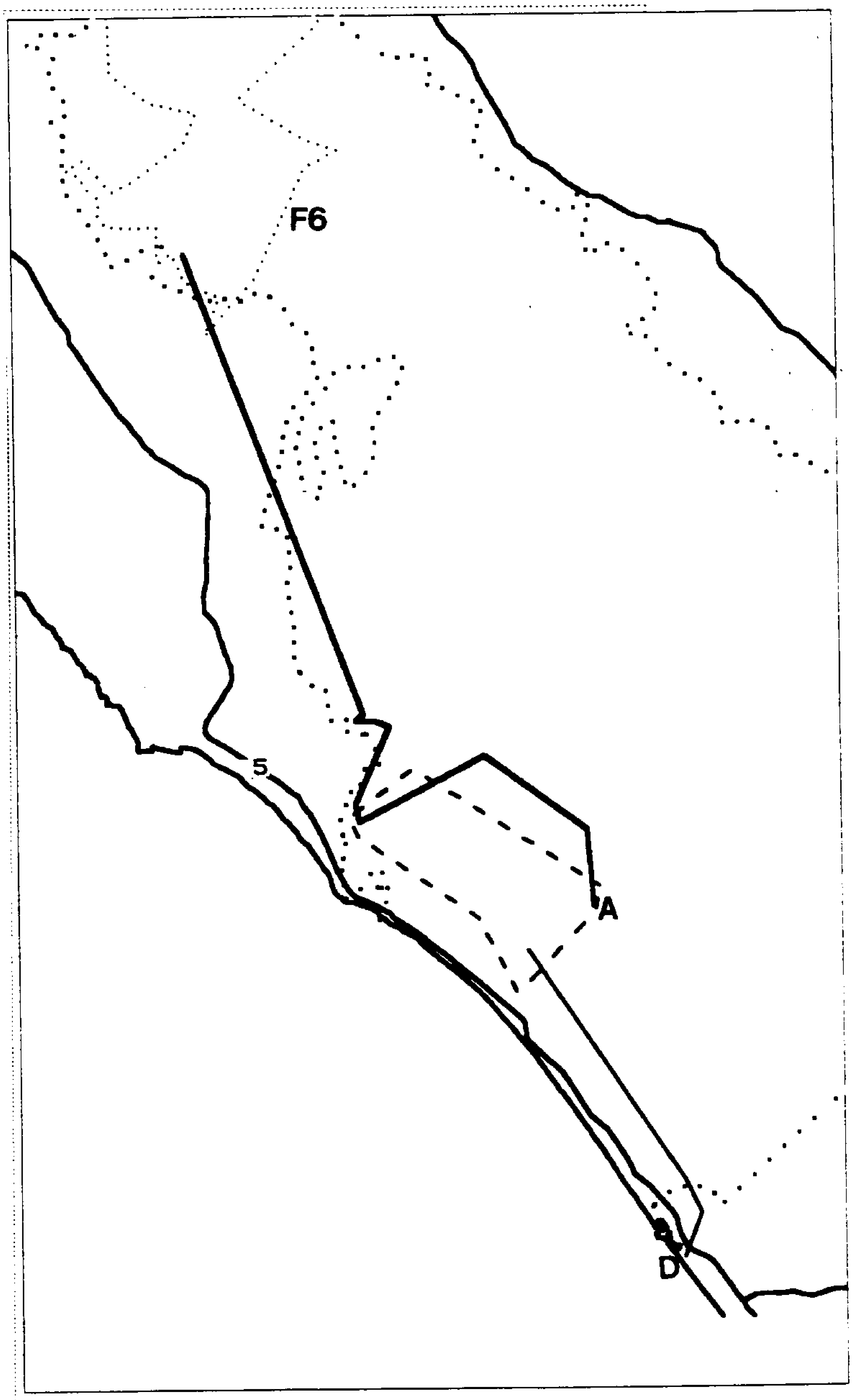

Figure 20: Dispersal Movements of M11. Dotted polygon indicates home range of his mother (**F6**). The thick line segments indicate his movements from Jan 16 1992 until his automobile accident (**A**) on Feb 4. The dashed polygon indicates his post-accident home range (3 weeks). The thin line segments indicate his travels into the San Luis Rey River. He died in Oceanside (**D**) on Feb 26 1992. Heavy dotted line indicates limits of cougar habitat.

routes were Tuley Canyon or Pilgrim Creek.

Dispersal of F17

During August 22-25 1991, F17's mother (F18) moved 16 km northeast of her home range, abandoning F17 in San Mateo Canyon in the center of their home range. After waiting there alone for 2 weeks, F17 started dispersing northwest about September 3. F18 returned during September 3-10.

For the next 123 days, F17 ranged widely over the northern 2 thirds of the mountain range, staying north and west of her mother's home range (Figure 21). During that time she never occupied a transient home range. She traveled a minimum distance of 342 km (214 miles), ricocheting off the east, west, and northern edges of suitable habitat several times (Figure 21).

During September 25-27, F17 spent 3 days in the area where Main Street Canyon leaves the steep mountainous terrain and opens into the alluvial plain, now bearing avocado orchards, on the outskirts of Corona. Curiously, M7 (on a foray from his first transient home range) also spent 2-3 days in the same location on September 17-18 (10 days earlier). During overnight monitoring there September 26, F17 walked near 2 rural houses to enter an abandoned avocado orchard where she killed and ate 2 opossums.

On the night of October 21, F17 moved into a finger of natural vegetation at the extreme northwest corner of the remaining

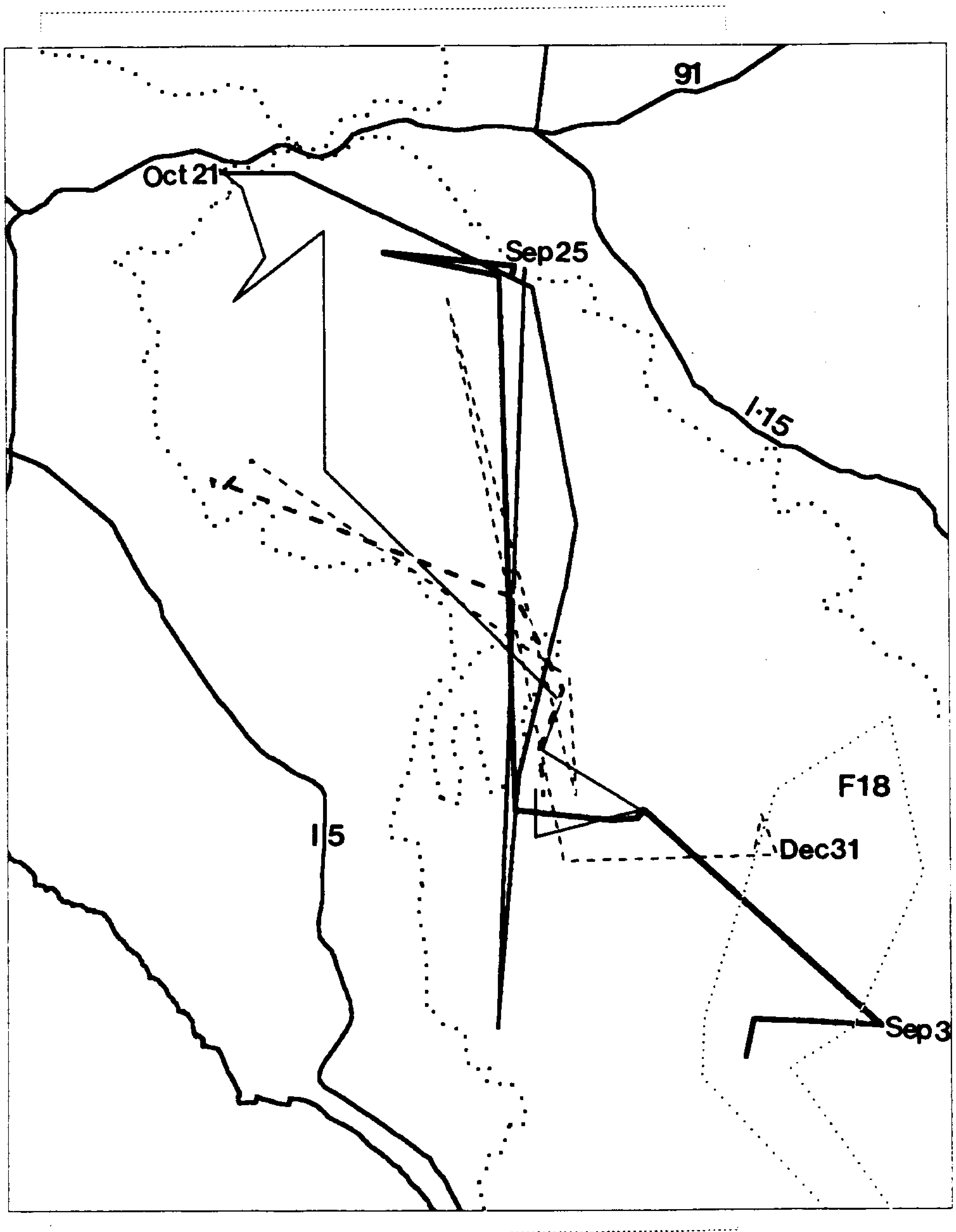

Figure 21: Dispersal Movements of F17. Dotted polygon indicates home range of her mother (**F18**). Heavy dotted line indicates limits of cougar habitat. The sequence of F17's travels are indicated by progressively thinner solid lines, then by progressively thinner dashed lines.

habitat, surrounded by the encroaching urban growth of the Anaheim Hills. She daybedded in the small canyon that contained a small horse stables and The Garden Church, sandwiched south of these facilities and north of a huge area where graders were ripping the terrain for new housing tracts. The Riverside Freeway was 400 m north at the mouth of the canyon. On the ridge to her west carpenters were framing houses on Star View Street. F17 had been exploring the urban edge that night, and had to wait until dark to extricate herself. Dozens of people and machines surrounded her all day long. This is yet another example of the remarkable ability of cougars to explore marginal habitat, habitat peninsulas, and habitat corridors without being detected by humans.

On about December 31 1991, F17 returned to her mother's home range for the first time since her dispersal began. On that date F17 and F18 were located together at the north edge of F18's home range. By January 6 1992, F18 had moved south into the interior of her home range, but F17 was still near her December 31 location. She died there during January 6-9 1992, apparently of natural causes (Chapter 4).

Dispersal of M5

M5 was captured and radio-tagged on August 3 1990 after he was treed by domestic dogs in a Temecula back yard. The capture site was near the tip of the "Temecula cul-de-sac" of the Pechanga Corridor (Figure 7: M5; Figure 22: C). M5 was a dispersing yearling and his presence there was our first evidence that dispersers were attempting to use that corridor. His tracks confirmed that he had moved up Temecula Creek from its confluence with Pechanga Creek, but we could not determine if he had reached that confluence from the west (Santa Ana Mountain Range) or the east (Palomar Range).

M5 was released 22 km (14 miles) west

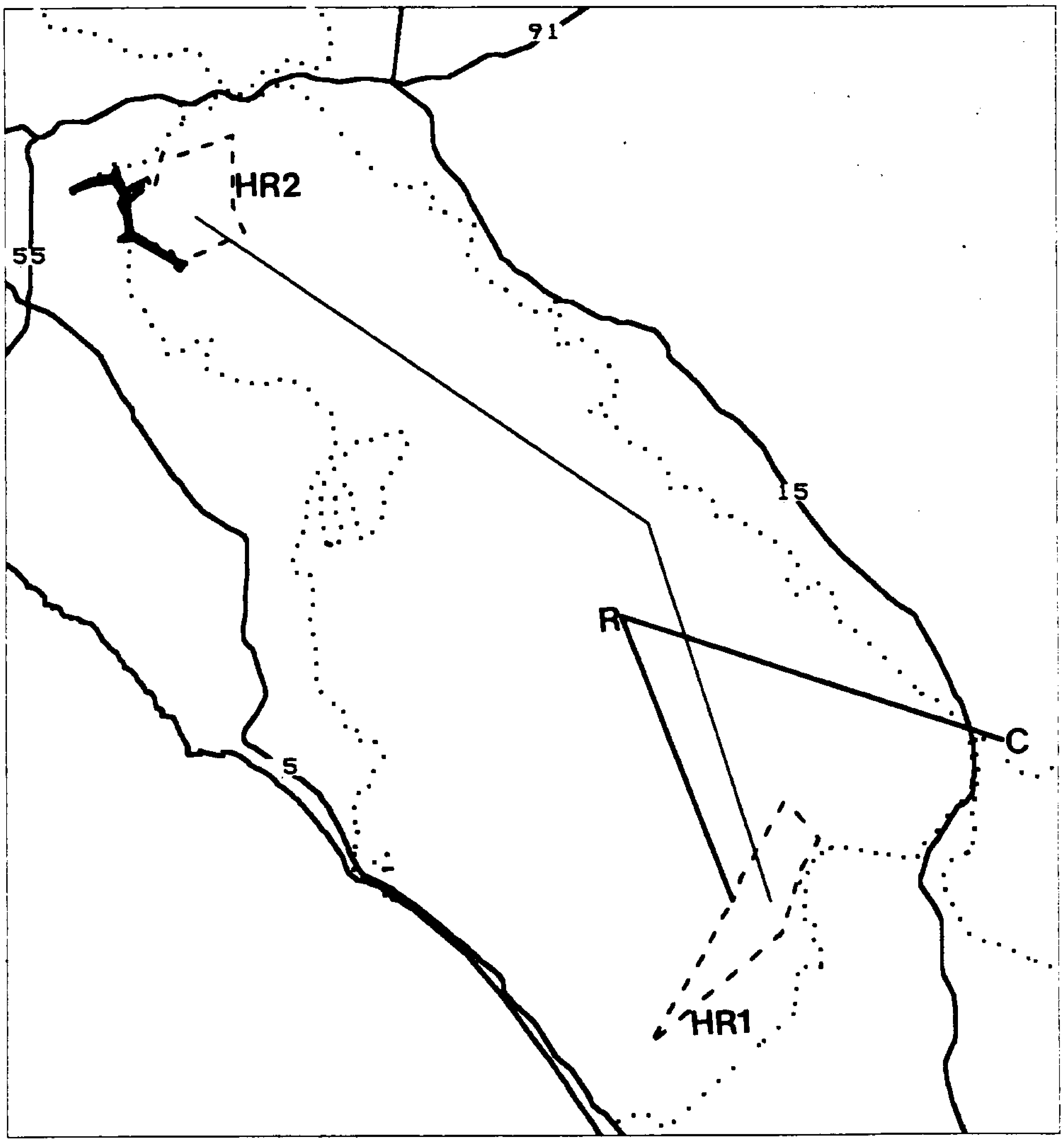

Figure 22: Dispersal Movements of M5. M5 was captured as a disperser in Temecula at **C** and released at **R**, from which he promptly moved to **HR1**. After 6 weeks there, he moved to **HR2** in less than 15 days. After M5 was crippled in an auto accident, he used a very small area (thick solid-edged polygon at west border of HR2) until his death 5 months later. The heavy dotted line indicates limits of cougar habitat.

of his capture site (Figure 22: R). By August 12, he had moved to the Santa Margarita River, another 22 km south of the release site. He used a transient home range there for the next 6 weeks (Figure 22: HR1). Like other transient ranges, this was elongate along the habitat edge. After exploring the southern habitat edge, and finding no route further south, M5 rapidly moved north, covering at least 32 km (20 mi) in a 5-day interval, and at least 40 km (25 mi) in the next 10-day interval. By October 7, he had reached Peters Canyon Reservoir, and thus in less than 15 days had moved from the extreme southeast to the extreme northwest edges of habitat in the Santa Ana Mountain Range.

M5 established a medium-sized home range (Figure 22: HR2) in this area, with a favorite daybed in the large willow forest in the Villa Park Dam impoundment area in Irvine Park. This area was adjacent to housing tracts or the developed areas of Irvine Park along nearly half of its periphery. On November 15, we treed M5 and he appeared to have gained about 15 pounds since initial capture. During diel monitoring on December 10-11, M5 began and ended his night movements in the willow forest, but spent most of the night hunting in nearby Weir Canyon, never approaching the housing tracts or the developed parts of the park.

After 6½ months in this home range, M5 was severely injured in an a vehicle accident and died 5 months later (Chapter 4). During his last 5 months he used an extremely small home range pressed up against the urban edge (Figure 22: thick dashed polygon along west edge of HR2). Despite being crippled and within a stone's throw of tract homes for most of those 5 months, M5 was never a threat to human property or safety (Chapter 9).

Dispersal of M6

M6 (like M5) was captured as a disperser and thus we do not know his natal home range. He was captured in lower San Mateo Creek on August 27 1990, weighing 80 pounds and in excellent condition. After release he moved steadily southeast along the coastal hills and coastal plain of Camp Pendleton for 10 days, moving a net distance of 4-6 km per day until he reached the lower Santa Margarita River September 8 or 9 (Figure 23: thick line segments). He used a small home range centered on the river delta for about 2 weeks (Figure 23: HR1), and then moved back northwest along the coastal plain. When he reached the north edge of Camp Pendleton on October 7, M6 began a rapid move north (Figure 23: thin line segments).

Between October 10 and October 15 1990, M6 moved 27 km (17 mi) north to the highlands of O'Neill Regional Park near Oso Lake. He had left this vicinity by October 17 and we were unable to locate him again despite intense ground searches and weekly air searches of all areas wouth of SR-91. M6 suddenly reappeared near the mouth of Gypsum Canyon on May 6 1991. On the night of May 26-27, he moved north across the Riverside Freeway using the Coal Canyon culvert to cross under SR-91. Over the last 1½ years of the study, M6 moved between the Chino Hills and the Santa Ana Mountain Range at least 22 times (Figure 8). Because we searched the lands south of SR-91 so thoroughly during October 1990-May 1992, we conclude that M6 spent that 6½ months in the Chino Hills.

Over the last 1½ years of the study, M6 spent increasingly longer periods of time south of the Riverside Freeway, with increasingly shorter stays in the Chino Hills. On each of 18 crossings, we found M6's tracks in the Coal Canyon culverts. On the other 4 crossings, there were no tracks in any culvert, and we conclude that he used the vehicle underpass at Coal Canyon. The frequency with which M6 crossed the freeway is precisely the intensity with which that corridor must be used by an adult male to insure that female cougars in the Chino Hills are bred. These data provide yet another striking example of the ability of dispersing cougars to find and use corridors.

The size of M6's home range (Figure 23: HR2) approached that of M2 and M9, both fully territorial adult males. His pattern of movement and his occasional associations with adult females suggest that he was an adult male at the end of the study. However, if he lives, we expect that his home range will continue to increase in size.

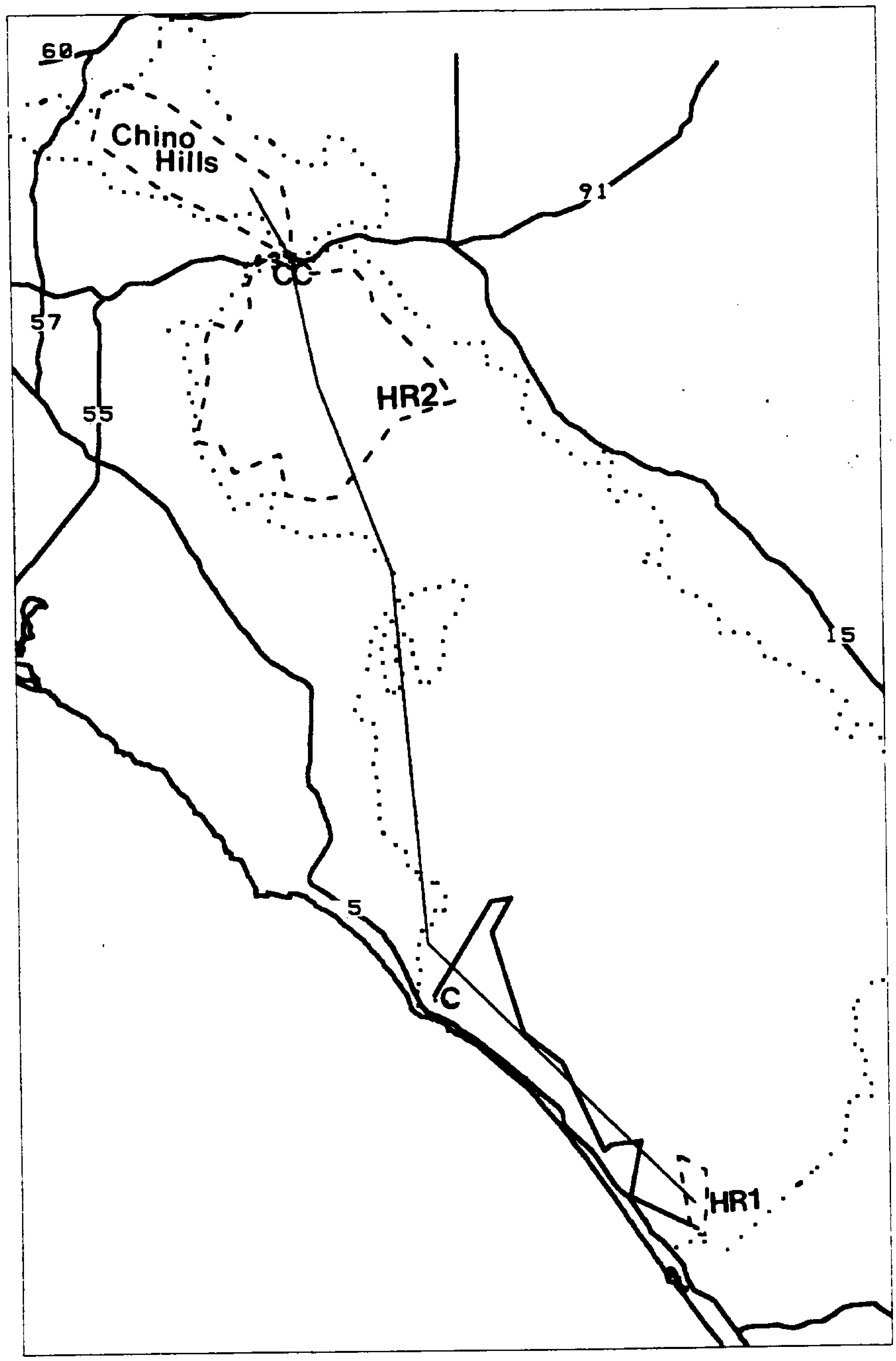

Figure 23: Dispersal Movements of M6. M6 was captured as a disperser at **C** and then he travelled (thick line segments) to **HR1**. After 2 weeks there, he moved rapidly (thin line segments) to the **Chino Hills** where he spent 5½ months before expanding this area into an hourglass-shaped home range (**HR2**). The 2 lobes of HR2 are connected by the Coal Canyon Corridor (**CC**). The heavy dotted line indicates limits of cougar habitat.

CHAPTER 7. PREY RELATIONSHIPS

Prey use based on prey remains

In the course of our routine monitoring activities, we examined 145 cougar-killed prey carcasses. About 59% of these carcasses were deer, and the main secondary prey were coyotes and opossums (Figure 24). Deer were also the largest prey item regularly taken (calves were larger but rarely taken). In terms of mass, the prey carcass data suggest that deer were 78% of the prey biomass eaten, followed by calves (8%), coyotes (3%), and all other species at less than 3% each (using approximate live weights listed in Encyclopedia of Mammals, Fact on File Inc., New York, 1984).

All 3 common species of livestock were taken by cougars. The 4 calves taken were all young animals, and all were killed by male cougars. The chart excludes about 12 killed goats that we learned about when livestock owners reported the losses to state or county authorities. Including these goats would have greatly inflated the apparent importance of goats to cougars because these livestock losses were much more detectable than other carcasses. Only 1 goat and no sheep were present in 176 cougar scats (see below)

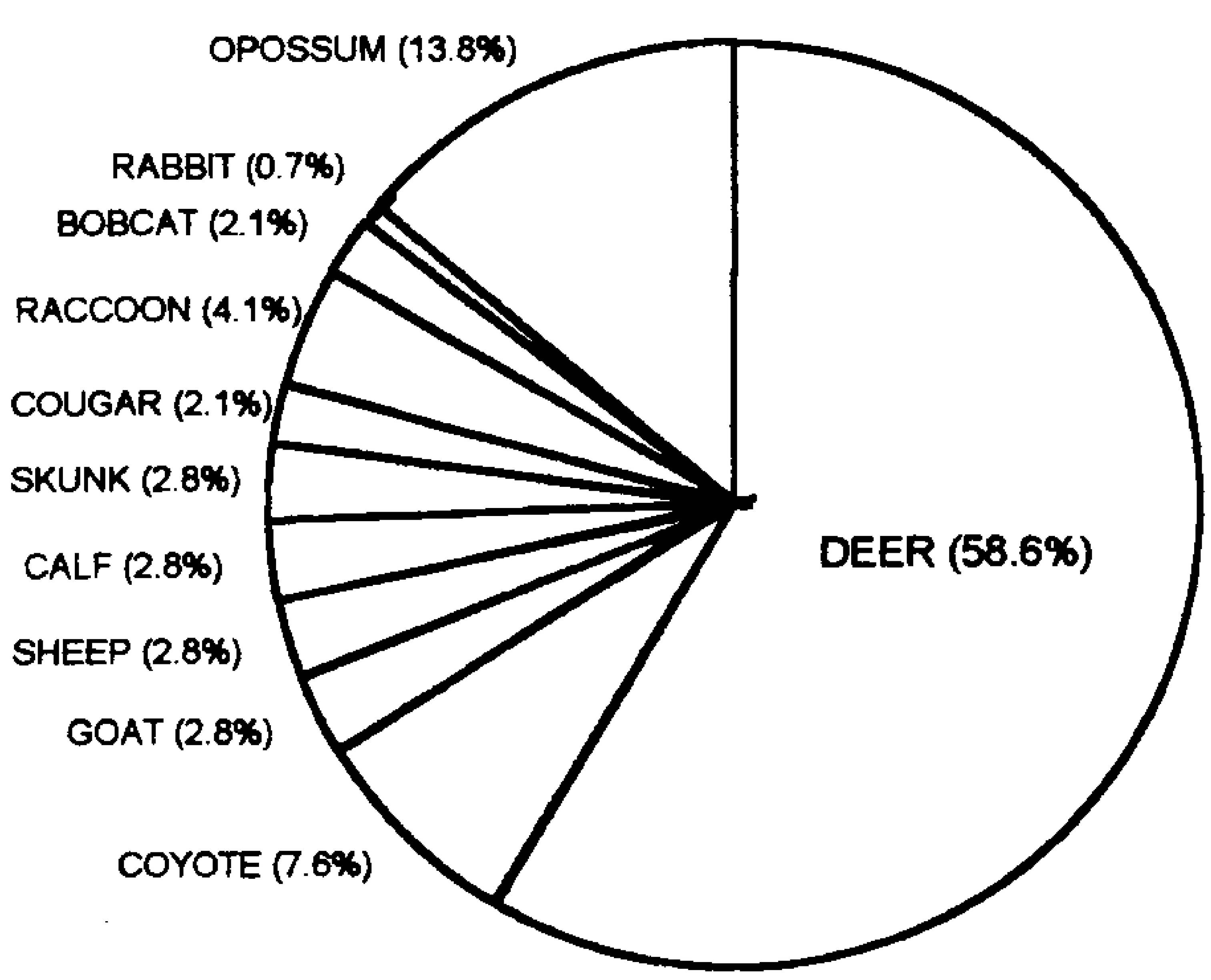

Figure 24. Cougar food habits as determined by examination of 145 prey carcasses. Each prey item = 0.7% of the sample.

suggesting that there is a strong detectability bias even for those livestock carcasses we found without reports. Nonetheless, the impact on the livestock owner is greater than our data indicate, because in many depredations, several goats and sheep would die in addition to the 1 or 2 animals eaten. Most of these surplus victims were killed by the cougar; a few others died with no apparent injury, perhaps due to shock.

The 3 cougar carcasses (F6, M4, and a cub of F3) were consumed almost completely, and 2 of them (F6 and the cub) showed clear evidence that they were killed by a cougar. M4 may have died of other causes, but his fresh carcass was eaten by his mother and brother. In addition, a 4th cougar (F1) died of cougar-inflicted injuries but is not included here because she was not fed upon. These data greatly overestimate the importance of cannibalism because the radio-collars made cougar carcasses 100% detectable. The 160 scats we collected (see below) contained small amounts of cougar fur, apparently from grooming, but no scats contained enough cougar fur to suggest cannibalism.

Almost ¼ the 85 deer carcasses were fawns (table below). Because many fawns, especially those only a few days or weeks old, were consumed completely and left no carcass for us to find, cougars prey much more heavily on fawns than these data suggest. Of the 63 deer carcasses for which we could determine sex, 36 (or 57%) were males. In contrast, adult males comprised only about 20% of live deer in our spotlight surveys (see below: "Deer density estimates and deer herd composition"). Clearly male deer were more susceptible than female deer to predation by cougars. Although capturing the relatively larger male deer yields more food energy per kill, we do not believe that cougars actively select males for that reason. It is more likely that the behavior of male deer (e.g., wide-ranging movements, or lowered vigilance while scouting female deer and sparring with other males) makes males more vulnerable to predation.

Table 9: Age and sex composition of 85 cougar-killed deer in the Santa Ana Mountain Range, 1988-1992.

Sex of deer	Age of Deer (years) 0	1	2	3-10	Adult (age unknown)	Total
Females	2	1	2	12	10	27
Males	4	7	4	17	4	36
Sex unknown	14	0	1	1	6	22
Total	20	8	7	30	20	85

For 12 deer killed by cougars in the dry season (Jun-Dec), the average fat content of the femur marrow was 41%, with a standard error of 7%. For 3 deer killed by cougars in the wet season (Jan-May), the average fat content was 49%, with a standard error of 8%. These fat contents indicate fair to poor condition. However, this does not necessarily indicate that cougars are taking weaker deer, because these fat levels may be typical for deer in this mountain range.

Of the 145 cougar-killed prey carcasses, we examined 130 carcass within a few hours or days of the kill. We found that cougars generally followed a very predictable pattern of prey consumption:

1. Cougars usually spent 3-4 days consuming a deer, and usually ate the entire carcass, often including the brain and some bone marrow. Generally the heart, lungs, and liver were eaten immediately after the kill, and major muscles were eaten over the next few days.

2. Deer were usually dragged a short distance from the kill site to the site where they were consumed; these sites were generally cool canyon bottoms with good hiding cover.

3. Prey consumption was almost entirely at night. Deer carcasses were usually covered with leaves and twigs at dawn and left covered all day. The deer's rumen (major stomach) was almost always buried in a separate leaf mound several feet away from the rest of the carcass; the rumen was never consumed.

4. The cougar usually bedded down for the day near the carcass, but sometimes up to 1.5 km away.

5. Smaller prey, like opossums, raccoons, and skunks, were usually consumed in 3-5 hours; sometimes these carcasses would also be covered.

In contrast to this general pattern, we occasionally observed unusual behavior with respect to prey carcasses. We present several of these anecdotes below:

1. Six of the 145 prey carcasses were abandoned or only slightly fed upon: (A) F2 killed a pregnant 8-year-old doe at 1AM on March 2 1989 and stayed on the kill until the night of March 7, thus spending 5 nights consuming the carcass. During this time she consumed nearly 100% of the carcass, but left the fully-developed deer fetus virtually untouched and left an opossum carcass, with the head and tail and feet neatly bitten off, but otherwise intact. (B) F7 killed a mule deer fawn on July 9 1989, ate less than half the carcass on the night of the kill, and abandoned it in the morning with no attempt to cover it from the sun's heat or scavengers. She did not return to the kill. (C) During overnight monitoring on April 15-16 1992, M9 killed a doe and 2 fawns at about 10:30 PM. He stayed on the kill until about 06:45AM, when he moved 500 m into a nearby canyon. He had consumed 1 fawn and less than 1/4 of the doe, covering the doe and 1 uneaten fawn as if he intended to return. M9 did not return to these kills. (D) During overnight monitoring on May 26 1992, M13 fed on a large buck all night

long, but left most of the carcass unconsumed. In this case, the carcass had been dragged from an open hillside into a narrow canyon where the carcass became wedged before it could be dragged further downstream to a shady location. Quite likely the carcass was so tightly wedged that M13 could not turn it over for feeding. (E) On January 17-19 1991, M8 killed 2 deer and consumed only 1 of them; this occurred early in his dispersal. (F) On June 15 1989, F1 killed a raccoon and an opossum at the same site. She ate the raccoon, but the intact possum was left buried under grass and covered with ants.

2. Almost all prey carcasses had been freshly killed by the cougar. We documented only 1 clear case of scavenging. On the nights of January 21 and 22 1990, F4 fed upon the badly decomposed carcass of a male fawn that had died 1-2 weeks earlier. F4 buried the carcass carefully with grass and leaves for daytime storage and buried the excised rumen separately. F4 avoided eating the most rotten meat (ribs and backstrap), and fed only on the (moderately rotten and maggoty) major limb muscles. This carcass was also in an unusual location, only 50 m from a golf course fairway in San Clemente.

3. The longest distance we documented

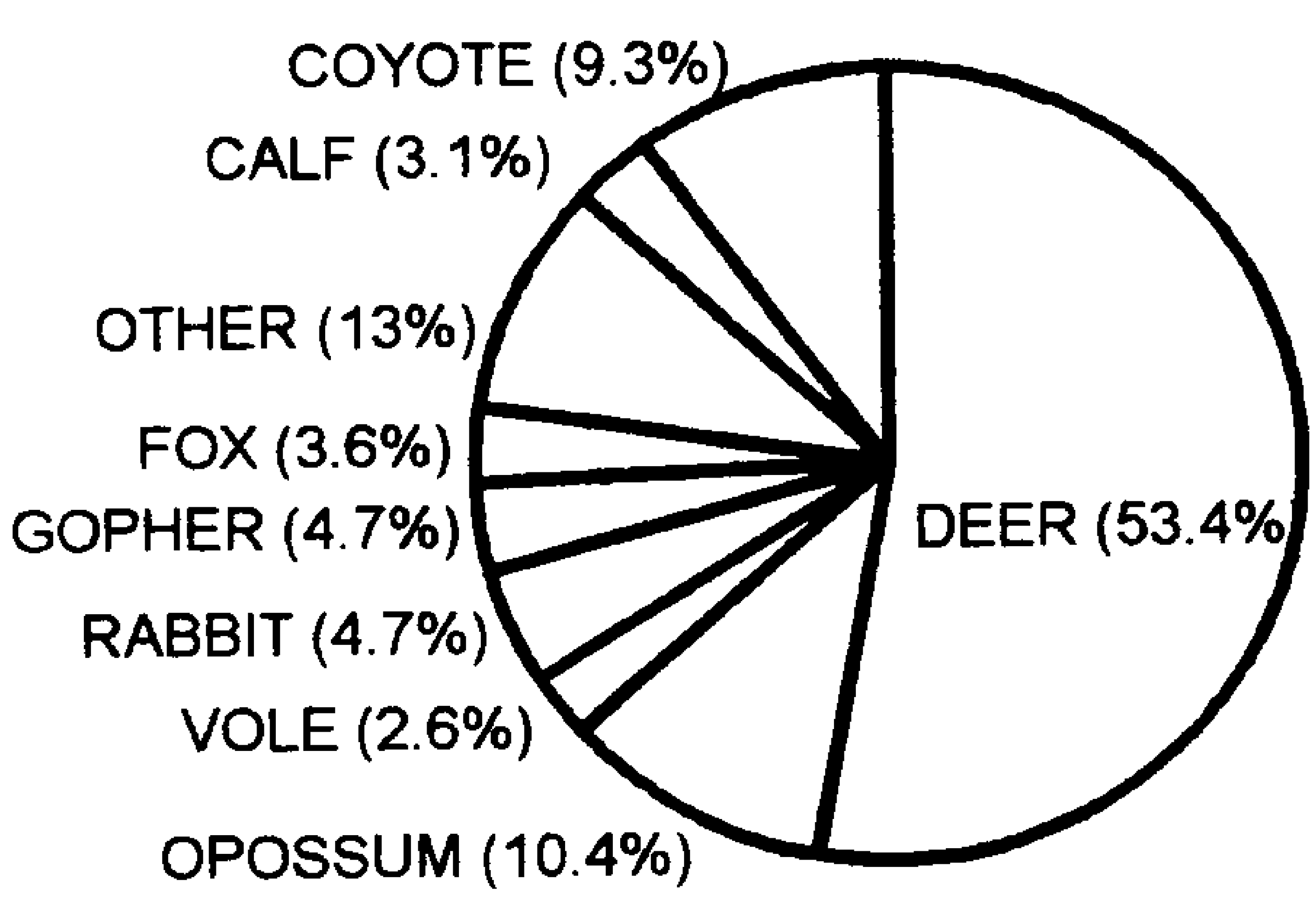

Figure 25. Cougar food habits as determined by frequency of occurrence of fur, claws, and bones in 178 scats (fecal droppings). There were 2 prey in each of 15 scats, for a total of 193 prey items. "Other" prey were raccoons, unidentified canids, domestic cats, unidentified rodents, beavers, badgers, skunks, goats, and moles (each < 2%).

a deer carcass being dragged was 250 m. In that case (F5, 18 Nov 1989), this distance was necessary to get the deer into a canyon with suitable cover. F5 disemboweled the deer after dragging it about 70m, discarding the rumen at that point. The consumption site was in dense chaparral about 4 feet tall, and in the bottom of a minor drainage. Given the low shrubs and grassy openings in the kill area, she had dragged the deer to the nearest good (or at least marginal) consumption site. In this case F5 daybedded next to the carcass.

Prey use based on cougar scats

We collected a total of 204 scats (fecal deposits), 28 of which yielded no identifiable cougar prey. Dr. Joel Weintraub of California State University at Fullerton identified 193 prey items in the other 178 scats. Deer were the most common prey item in these scats, comprising just over half the total; the scats contained fur, bones, or claws from 17 other taxa (Figure 25). However, most of these other species weigh a great deal less than deer, and are less important than suggested by the number of animals eaten. In terms of biomass, deer made up 81% of the weight of these 193 prey items. The only other species contributing at least 1% of biomass were domestic cattle (11%), coyotes (3.8%), and opossums (1.0%); the remaining 12 species combined contributed only 3.2% of the total biomass (using approximate live weights listed in MacDonald 1984). All scats containing cow-calf hair were from the early calving season and had reddish short hairs suggesting that young calves were taken.

The data based on prey carcasses are obviously biased toward larger prey items, because smaller prey will often leave no carcass, or only a few tufts of fur that we overlooked in searching for prey remains. Thus scats are a less biased sample of cougar food habits. Nonetheless both sources of data give the same ranking both in terms of prey numbers (deer, opossums, coyotes, and calves) and in terms of biomass (deer, calves, coyotes, opossum). As expected, several smaller prey were found in scats but not as carcasses, namely, voles, gophers, gray foxes, badgers, beaver, moles, domestic cats, and 1 woodrat. Several larger species that were present in the carcass tally were not found in scats, namely bobcats, sheep, goats, and cougars.

Two scats contained remains of domestic cats and 3 others contained remains of unidentifiable canids, which could have been domestic dogs. The geographic locations of these scats suggest that these animals were not backyard pets but were either feral or had been abandoned in the country.

Deer density estimates and herd composition

Deer were clearly the most important prey species for cougars in this study. To better understand cougar-deer relationships, we attempted to estimate deer density and the age-sex composition of the deer population using spotlight transects, data from CDFG helicopter surveys, and data from the deer capture effort carried out by CDFG for the Tollway studies.

Our spotlight surveys for deer covered over 125 km of roads in south Orange County (Rancho Mission Viejo, Starr Ranch, Caspers Park, and adjacent areas) and in north Orange County (Weir, Blind, upper Gypsum, and parts of Fremont and Blackstar Canyons, and Loma Ridge). We repeated these transects on 6 occasions: November 1988, March 1989, June 1989, September 1989, January 1990, and September 1992, covering only the south Orange County areas on the first 2 efforts. Analyses of these data using program TRANSECT (Laake et al. 1979, Burnham et al. 1980) indicated that there were about 1.1 to 2.2 deer per square kilometer (2.8-5.5 deer/mi^2). We believe that these estimates are invalid due to gross violations of the assumptions of the line-transect procedure. Line-transect analysis assumes that detectability of the deer depends mainly on distance from the transect line and that 100% of deer on or near the line are detected. But detectability of deer on our transects depended mainly on topography and vegetation, both of which changed greatly along each transect and were far more important than distance from the transect line. We could have failed to detect deer 5 m from the transect line. As a result, our data yielded a declining function of deer numbers versus distance only after several attempts at reclassifying distance classes, and the resulting detection function was sensitive to these arbitrary classes. In turn, program TRANSECT's estimates are highly sensitive to the shape of the detection function. The line transect estimates are certainly invalid, and we believe they lay far below the true number of deer in these areas.

We suggest that somewhat better estimates are provided by 2 other sets of data: (1) In late October 1990, CDFG observers ran helicopter surveys to determine the age-sex composition of the deer herd in several areas in the Santa Ana Mountains. (2) In January 1990, Blind Canyon (Irvine Ranch) was intensely surveyed from a helicopter just after 14 deer were captured and radio-collared there. Although the surveys were not designed to estimate deer numbers, the observer felt that virtually all deer in Blind Canyon, and at least 70% of the deer in the other areas, were counted. We estimated minimum density by dividing the deer counts by the area surveyed as calculated from maps provided by Esther Burkett (CDFG biologist-observer on all the flights). The Blind Canyon survey was conducted over a period of several hours by a very skilled and aggressive pilot, with more wildlife experience than the pilot on the other surveys. Thus it is quite likely that nearly 100% of the deer in Blind Canyon were seen. The other surveys were conducted in less time per unit area by a less experienced pilot, and it is certain that some deer were not seen.

Our analyses of these data suggest that true deer density was about 5 deer per km^2 (13 deer per mi^2) in the better habitat and about 1.9-2.3 deer per km^2 (5-6 deer per mi^2) in the poorer habitat (Table 10). We feel this is a much more realistic estimate, and one which is more consistent with our estimates of deer mortality rates due to cougars (next section).

The high density estimate for Blind Canyon was not solely a result of survey methods, but probably also reflects the fact that Blind Canyon contained some of the best deer habitat in the Santa Ana Mountain Range (oak trees, coastal sage, chaparral, grasslands, and water well-distributed throughout). Starr Ranch, Caspers Park, the southern parts of Rancho Mission Viejo, Loma Ridge, and Gypsum and Coal Canyons were probably similar to Blind Canyon in habitat quality and deer density, i.e., about 13 deer per square mile. If adults were about 76% of the population (see end of this section), the adult population density was about 9.9 adults/mi^2 on better habitat.

The chaparral-dominated areas at higher elevation in the mountain range probably supported lower deer densities. Although the estimates are very sensitive to assumptions about the number of deer not counted, these areas probably supported about 5.5 deer per square mile, assuming that half the deer were counted. If adults were about 76% of the population (see end of this section), the adult population density was about 4.2 adults/mi^2 on poorer habitat. It is important to note that most of the protected habitat in Orange and Riverside Counties (i.e., the Trabuco Ranger District) lies in these areas of low deer density. Relatively little of the area with the highest deer density (and consequently little of the best cougar habitat) is protected from urban growth.

These deer density estimates are very crude. We would recommend that future efforts should not use spotlight transects, and that any future helicopter counts should use a skilled and aggressive pilot concentrating on a few target areas that can be clearly delineated both from the air and on maps. The results of the Blind Canyon survey suggest that near-total counts are possible.

Although they provided low density

Table 10: Deer density estimates based on intensive helicopter surveys in Blind Canyon (January 1990) and less-intensive helicopter surveys in other areas (October 1990).

Location	Area (mi2)	# deer seen	Deer/mi2 Minimum[a]	Deer/mi2 Estimate[b]
Blind Canyon (Irvine Ranch)	2.33	30	6.0	12.9
upper Blackstar Canyon[c]		0	0	0
Tin Mine Canyon	1.86	6	3.2	6.4
Silverado Burn[d] (Brown, Anderson, and Coldwater Cyns)	12.1	17	1.4	2.8
Cañada Chiquita	5.94	12	2.0	4.0
Wagon Wheel Canyon & west Cañada Gobernadora	3.49	9	2.6	5.2
Average (excluding Blind Canyon and upper Blackstar)			2.25	5.5

[a] based on actual number of deer counted, except for Blind Canyon, which is based on 14 deer captured and collared.

[b] based on the assumption that 50% of the deer present were observed, except for Blind Canyon, which is based on the total number observed in an intense survey.

[c] E. Burkett suspects that overgrazing and poaching in upper Blackstar contribute to this zero count.

[d] The Silverado burn occurred in 1987. The Ortega and San Mateo Burns of 1989-1990 were briefly surveyed and appeared to have very few deer.

Table 11: Deer herd composition in Orange County as determined by spotlight counts. The March 1989 counts are excluded because age and sex of deer were difficult to discern in that season. The total and mean values for fawn:doe ratio excludes the June 1989 counts because most fawns hide during June.

Date	Males	Females	Fawns	Male:Female	Fawns : 100 Females
November 1988	3	18	6	14%:86%	33
June 1989	10	(38)	(8)	21%:79%	(21)
September 1989	10	43	17	19%:81%	40
January 1990	5	23	9	18%:82%	39
September 1992	17	58	28	23%:77%	48
Total	45	180(142)	68 (60)	20%:80%	42
Unweighted mean				19%:81%	40

estimates, the spotlight surveys probably accurately estimated the relative proportions of deer in the fawn, adult male, and adult female classes. Although these numbers varied seasonally and among years, the adult population was about 20% males and 80% females (Table below), and about 76% (187/247) of the population were adults. As mentioned above ("Prey use based on prey remains"), 57% of deer carcasses were males, indicating that males were much more vulnerable to cougar predation.

Estimation of deer harvest rate and cougar kill rate on deer

Thirty (30) deer were radiotagged and monitored in the northwestern part of the Santa Ana Mountain Range during March 1990-December 1991 (Anonymous 1992) and an additional 11 deer were radiotagged and monitored in south Orange County from Fall 1990 through December 1991 (D. Padley, project leader, pers. comm.). From January through December 1992, we continued to monitor these radio-tagged deer, and we investigated deer mortalities to determine cause of death.

To compute the probability of a deer being killed by a cougar during a year, we analyzed these data using 1-month time intervals and the product limit procedure with staggered entry (Pollock et al. 1989). The product of 12 monthly rates yielded an estimate of annual rate of not being killed by a cougar, and the average of these running products yielded a single point estimate. Subtracting this rate from 1.00 yielded a harvest rate. We analyzed the data to provide separate estimates for adult males (through March 1992, at which time only 3 male radiotags were functioning) and adult females (through December 1992, at which time 19 female radiotags were functioning). Following these procedures, cougars annually killed about 10% of adult male deer and 6% of adult female deer. These harvest rates are considerably lower than we had expected. However, harvest rate of fawns is undoubtedly much higher than on adults, and the harvest rate for all age classes is therefore higher than 6-10%.

Twelve (12) radio-tagged deer died during March 1990-December 1992, and 6 of these mortalities were due to cougar predation. Thus cougar predation accounted for about half of adult deer deaths over this period.

In Chapter 6, we noted that cougars killed deer on about 10% of the intensive monitoring sessions. This yields a rate of about 1 deer killed per 10 days, or 36 deer killed per cougar per year.

Inconsistency among our estimates

Finally, it is instructive to evaluate the consistency among our various results. In particular, we have estimated:

- **C** = population density of Cougars = 2.5 adults/100 mi^2
- **K** = the Kill rate, or frequency at which cougars kill adult deer = about 1 deer per 10 days = 36 deer/year
- **D** = population density of adult Deer = 990 adult deer/100mi^2 on better habitat and 420/100mi^2 on poorer habitat, probably about 600/100mi^2 on average.
- **H** = % of adult deer Harvested by cougars per year = 7%, sexes combined

Obviously the number of adult deer killed by cougars per 100 square miles per year should be given by either the quantity $\mathbf{C \cdot K}$ or by the quantity $\mathbf{D \cdot H}$. Thus we can state:

$$\mathbf{C \cdot K = D \cdot H}$$

However, when our estimates are inserted into this identity, we obtain:

$$(2.5)(36) = (600)(0.07)$$
$$90 = 42.$$

Clearly one or more of our estimates is in error. This inequality can be turned into an identity by 1 of the following (or by some combination of changes in the indicated directions):

halving our estimate of cougar density, **C**
halving our estimate of kill rate, **K**
doubling our estimate of deer density, **D**
doubling the harvest rate, **H**

Of these 4 factors, we feel that **D** is based on the weakest data, and that **H** was much lower than we had expected. It would be impossible to halve **C** without going below the numbers radio-tagged in 1991, and our **K** is based on extensive data that agrees closely with other published reports. We believe it is most likely that our estimates of **D** and **H** are too low.

CHAPTER 8. IMPACT OF URBAN GROWTH

Habitat loss and fragmentation

The cougar population is the Santa Ana Mountain Range is clearly in jeopardy of becoming extinct due to habitat loss and fragmentation (Chapters 2, 3, & 4; Beier 1993). Vehicle mortalities associated with increased highway traffic due to urban growth also impact the population (Chapter 4). However, even if vehicle-caused deaths were eliminated, the population will not survive continued massive loss of habitat. If the critical Pechanga corridor is enhanced and most of the other important corridors are preserved (Chapter 3), then considerable areas of cougar habitat can be converted into urban uses without significantly increasing the extinction risk (Chapter 4; Beier 1993). However, if the Pechanga corridor is not protected, every new parcel of habitat lost will add to the risk of extinction (Chapter 4).

There is no evidence that habitat loss and fragmentation cause cougars to become aggressive toward humans, or habituated to humans (Chapters 6 and 9).

Six freeways threaten to fragment habitat

Six major freeway projects have great potential to fragment cougar habitat and induce urban growth that eliminate habitat. Fragmentation could occur due to the physical obstacle provided by the freeway itself, due to the urban growth induced by the freeway, or a combination of these 2 factors. The 3 most important and immediate threats are:

1. The southern half of the Foothill Transportation Corridor (FTC-s) slices deeply through an area with no human residents and only 1 approved urban project. It could potentially isolate several small protected parcels (Arroyo Trabuco, Wagon Wheel Park, the Cañada Gobernadora wetland mitigation area, and the Rancho Mission Viejo Conservancy) from the main block of habitat to the east of the Tollway alignment. The Transportation Corridor Agency (TCA) solicited our comments on these potential impacts. In response to our comments, TCA has planned bridged undercrossings at sites along 5 routes that radio-tagged cougars used to access these smaller parcels. Due to an apparent misunderstanding, our proposed bridge crossing on upper Christianitos Creek northeast of the Rancho Mission Viejo Conservancy was omitted from TCA's modified map in late 1991, but we were assured at that time that this bridge would be added. If no urban growth occurs along FTC-s, these undercrossings would effectively mitigate the impact of the FTC-s on cougar movements. However the Tollway will induce massive urban growth that will block these undercrossings unless further mitigations are implemented. In its EIR for this project, TCA's worst case scenario for predicting impacts presumed that the project area (except 1 parcel) would not be built to greater densities than permitted by the Open Space designation in the general plan.

2. The Eastern Transportation Corridor (ETC) would potentially isolate Irvine Regional Park and the proposed Weir Canyon Regional Park from the main habitat block. We provided comments regarding impacts to wildlife movements on 2 occasions. Our second set of comments reflected our knowledge that the only promised crossing area led into a planned community of 13,000 homes (instead of toward the central habitat block), and newer data indicating that the main cougar crossing area was in upper Blind Canyon. As of spring 1992, the TCA had not modified their plans to reflect these conditions.

3. State Route 91 widening project: CalTrans and a private corporation are co-

operating to add additional lanes to SR-91 (Riverside Freeway) from the Riverside County Line to SR-55. At least 9,500 homes cannot be built or sold without this widening project (City of Anaheim conditions of approval); these homes include the Cypress Canyon project that would occlude the critical Coal Canyon Corridor (Chapter 3). Despite being informed of these impacts at a meeting on February 6 1992, later that same month CalTrans prepared a statement that the project did not require an EIR on the grounds that the widening project would not be growth inducing, and that, moreover, the urban growth in the project area would occur with or without the project.

In addition, 3 other highway projects have potential impacts that are either less severe or less immediate. Carbon Canyon Road (SR-142) has been proposed for widening, and a superstreet has also been proposed to run through Soquel Canyon just south of SR-142. Such roads would probably break the Chino Hills habitat into 2 halves. However, this impact is overshadowed by the potential loss of the Coal Canyon Corridor, which would eliminate cougars from the entire Chino Hills. A freeway proposed by Riverside County and generally referred to as the "Cajalco Road Extension" would cut east-west across the Trabuco Ranger District at Santiago Canyon, just north of Saddleback Mountain. This road is so early in the proposal stage that it is difficult to determine if there is any chance that it would be built. It would have a severe impact on cougars. Finally, there have been several proposals (one version was called the Santa Rosa Expressway) for freeways to run from either Fallbrook or Temecula, around the north side of Camp Pendleton (traversing the San Mateo Canyon Wilderness Area), and into south Orange County. The impact of this road on cougars, other wildlife, federally-designated wilderness, and Camp Pendleton would be so severe that it is difficult to justify.

CHAPTER 9. COUGAR-HUMAN ENCOUNTERS

A history of cougar-human encounters

We have previously summarized the record of cougar attacks on humans in the U.S. and Canada during 1890-1990 (Beier 1991, included as Appendix 2 in this report) and updated these observations for 1991 and early 1992 (Beier 1992, inlcuded as Appendix 3 in this report). These 2 papers should be consulted for details beyond this brief summary. During 1890-1990 (101 years) there were 9 attacks resulting in 10 human deaths and at least 44 nonfatal attacks. Attacks on humans have increased markedly during the last 2 decades, probably because cougar numbers and human use of cougar habitats also increased during this time. Most victims (64%) were children; the modal age class was 5-9 years. Of 37 child victims, 35% were alone, 37% in groups of children, and 22% were accompanied by adults; 11 of 17 adult victims were alone at the time of the attack. We believe these data show that attacks are more likely for children, especially unaccompanied children, and more likely for solitary adults than adults in groups. However, the data also clearly show that children accompanied by adults, and even adults in groups, are at some risk of being attacked.

The data also suggest that aggressive human responses appear to be effective in averting an imminent attack and do not support the notion that one should avoid loud shouting or avoid eye contact with the cougar when attack appears imminent. An aggressive response may also be effective in causing a cougar to retreat after an attack has been initiated. There is no empirical support for the efficacy of "playing dead" once an attack has begun. The data suggest that yearling and underweight cougars were more likely to attack humans, but some attackers were healthy adults.

Finally, although attacks were much rarer in previous decades when cougar prey (deer) were market hunted and cougars were aggressively persecuted, the risk was always greater than zero. There has been at least 1 attack in every decade since 1890. It is impossible to reduce this small risk to zero without eliminating either cougars or humans from cougar habitat.

The habituation hypothesis

One popular hypothesis to explain recent cougar attacks is that cougars have become habituated to humans because they are no longer bountied predators, and because in many areas (e.g., wilderness parks, all of California since 1971) cougars are no longer subject to sport hunting. The hypothesis is that as cougars learn to accept humans as a non-threatening part of their environment, they may be more likely to treat humans as prey. However, hunters and animal control agents annually kill about 6-10% of the cougars on Vancouver Island annually (Hebert 1989), a rate that is probably higher than harvest rates in any western state (see references in Smith 1989). Compared to other North American populations, Vancouver's cougar population may be the least habituated to humans and the most subject to aversive conditioning. Nonetheless Vancouver Island has by far the highest concentration of cougar attacks on humans (Beier 1991). This fact is inconsistent with the habituation hypothesis. There is no substantial evidence that habituation has played a role in any particular attack nor in the general recent increase in attacks.

Our study yielded no evidence to suggest that cougars in the Santa Ana Mountain Range are habituated to humans. Cougars entered urban areas with astonishing rarity and were generally unseen by the thousands of potential human observers in their midst.

The "repeat offender" hypothesis

The data provide weak support for the "repeat offender hypothesis," which speculates that once a cougar has attacked a human, it is more likely to attack again. Beier (1991, 1992) lists 10 cases in which no cougar was removed after an attack. In 3 of these cases there was a subsequent attack within 80 km and 2 years of the initial attack; in the other 7 cases the offending animal did not attack again. Thus when an attacking cougar was not removed, there was a 30% chance of a second attack within 80 km and 2 years. We believe that for a random set of dates and locations in the current range of cougars, there is a far less than a 30% rate of cougar attacks within the same time and distance. Due to small sample size and the lack of a rigorous test (i.e. actually selecting some random dates and locations), this must be considered weak support for the hypothesis.

Use of garbage and artificial food sources

During this study we had no evidence that cougars directly used artificial food sources. Although the cougar killed in Caspers Park after the attack on Laura Small was reported to have aluminum foil in its stomach, no suggestion of anything other than wild prey has been found in any of the scats we collected and examined.

A possible secondary influence of artificial food sources could occur at garbage dumps where raccoons and opossums and coyotes may feed in considerable numbers, thus offering an abundant and reliable prey base for cougars. We have no evidence for this occurring at the San Juan Capistrano or Irvine Lake landfill sites, both of which are accessible to cougars. It is unlikely that such attraction occurred without detection, because many radio-tagged animals lived near these landfills and we monitored these areas frequently both day and night. In both cases, the extremely open terrain around the landfills probably acted as a deterrent to cougars. It is possible that a landfill in or adjacent to wooded areas could attract cougars to feed on the raccoons and opossums.

We documented 4 occasions when cougars fed on raccoons and opossums near the urban edge; these raccoons and opossums probably did feed from nearby trash cans or other human refuse. Shortly before her death F2 spent about 1 week along the Arroyo Trabuco, just north of the I-5 bridge, feeding on opossums and raccoons within 70 m of a residential area. For the several months after breaking both legs in a vehicle accident, M5 relied mainly on opossums and raccoons in Peters Canyon Reservoir and lower Santiago Creek, almost always within 300 m of residential areas, and on the night of November 18 1990, M3 also killed and ate a raccoon just outside the kitchen house of the Lazy W Camp in Hot Springs Canyon. During her dispersal movements, F17 killed and ate 2 opossums in an abandoned avocado orchard (with much more ground cover than in a maintained orchard) in Main Street Canyon near Corona. In all of these cases, unlike the 2 landfills, the kills were consumed (and presumably made) in dense woody cover close to the artificial food sources.

We conclude that cougars are not directly attracted to artificial food sources, but in rare cases they may secondarily be attracted to areas where raccoons and opossums rely on garbage.

Aversive conditioning was infeasible

Our original contract suggested testing the use of aversive conditioning to make cougars avoid humans. Such work was not practical on wild cougars, because we did not have the sort of control necessary to (a) apply the aversive conditioning, and (b) monitor its efficacy. We reached this conclusion in our first annual report (May 1989) and indicated at that time that we would not make progress on this objective.

In any event, the cougars in our study were remarkably adept at avoiding contact with humans (next section), and it is difficult to imagine that their behavior could have been more reclusive if we had been able to apply aversive conditioning. The experience of being chased by hounds, and then drugged and handled by humans, may have provided some aversive conditioning to our radio-tagged cougars. However, radio-tagged cougars always returned to the capture site, usually within a few days. Thus apparently they did not associate the negative experience with the location.

The aversive conditioning of being chased by hounds is apparently of limited effectiveness on Vancouver Island, where cougar attacks are relatively frequent despite heavy use of hounds to chase cougars (Beier 1991). Also, a yearling cougar attacked a person in Big Bend National Park 4 months after being chased and handled by humans for radio-tagging (Beier 1991). Aversive conditioning (shooting the cougar with rock salt at close range) was tried deliberately on another cougar after a near-attack in Big Bend NP. That animal returned to aggressive behavior 2 weeks later and had to be removed.

Public warnings

Some wildland parks now offer warnings to visitors about the risk of attacks. Such a policy may be appropriate as part of a park's educational program, or for other reasons. We offer 3 observations:

1. There are serious consequences to consider if parks are *required* to post such warnings. If cougars are dangerous enough to merit a warning, then warnings for many other hazards -- from rattlesnakes to cliffs to poison oak -- seem equally appropriate for thousands of square miles of wildlands, including national parks, national forests, and other public lands. This raises the specter of wilderness areas blighted with guardrails and warning signs or, worse yet, wildlands sanitized of all hazards.

2. It is not clear that a warning reduces the risk to wildland visitors. If a visitor is warned that "There are mountain lions in this wildland; they could bite or kill you," the only risk-reducing action he can take, based solely on this warning, is not to enter the area. After several attacks over a decade, Big Bend National Park (Texas) during 1990-91 attempted to warn every person entering their Visitor Center about the potential for cougar attacks. In the first year of this program, the park is unaware of a single visitor who has turned back because of this warning (P. Koepp, Big Bend NP Director, pers. comm., August 14 1991). In 1 case, a cougar walked through the main campground in Big Bend National Park in daylight, confronting a camper briefly before retreating. After the incident, park rangers warned everyone in the campground about cougars and specifically mentioned the recent incident; no camper (except the person involved in the confrontation) left the Park. Similarly, Caspers Regional Park required every visitor during 1988-92 to sign a statement that he or she had been warned of the potential risk of cougar attacks. Our conversations with Park employees indicate that fewer than 10 people in

5 years chose not to enter the Park due to this warning.

3. A broad public education effort is an alternative to simple warnings. Recently several public entities have started to educate the public about cougars in a balanced way that includes mention of the aesthetic and ecological role of cougars, the potential risk of attack, and suggestions for how to respond if one encounters a cougar. Within the past 5 years, Colorado Division of Wildlife, Montana Department of Fish Wildlife and Parks, and Big Bend National Park have produced helpful and accurate brochures on cougars. The first 2 agencies provide information targeted not only at wildland visitors but also at people who live in cougar habitat. California Department of Fish and Game has also prepared a similar brochure which is available for distribution.

Cougar use of areas on the urban fringe

Cougars were remarkably adept at using habitat along the urban-wildland edge. In particular, all 9 dispersing juvenile cougars encountered at least one urban area during their explorations. There were no instances of cougars behaving aggressively to humans or taking pets in any of these urban edge settings. (Cougars did take pet goats near rural homes).

The sections of Chapter 6 dealing with dispersal movements of juveniles offer many anecdotes illustrating cougar behavior at the urban edge. Several additional anecdotes follow:

M5 in East Orange. Probably the most dramatic case is presented by M5. After breaking both hind legs (Chapter 4: highway injuries) in a vehicle collision on Santiago Canyon Road on April 23 1991, M5 used a very small home range, and stayed in very level terrain eating mainly raccoons and opossums until his death 5 months later. During this 5 months, his locations were almost entirely within 300m of the urban edge. His favorite haunts were the Villa Park Dam impoundment area, Peters Canyon Reservoir, Santiago Oaks Regional Park, and Santiago Creek *downstream* from Santiago Oaks Regional Park as far as the small (10-ha) forest on the north side of Santiago Canyon Road at Hewes St.

In overnight monitoring at Peters Canyon Reservoir on June 12-13 1991, and in Santiago Creek near Hewes St. on July 29-30 1991, M5 moved in a manner suggesting that he was feeding on small prey. On neither occasion did he enter the surrounding residential areas. We had only 2 reported sightings of M5 by a human, in both cases brief glimpses of M5 moving away from the human. At death M5 was grossly normal except for the healed leg injuries and being markedly underweight. M5 never behaved in a manner suggesting a threat to public safety.

M10 in the Anaheim Hills. During overnight monitoring on June 23-24, June 25-26, and July 6-7 1992, M10 spent the night in a thin shard of habitat north of Santiago Oaks Regional Park, close to residential areas, and in a heavily-used recreational area. This area consisted of a ridgetop and small canyon, and was mostly grassland with some coastal scrub and a few eucalyptus trees. Although the area had less woody cover than is typical for cougar habitat locally, it contained abundant prey. Nearby to the southwest were new homes along Serrano and Maybury Streets. More new homes and powerlines lay upslope (north) of this habitat fragment, and tanks and powerlines occupied much of the artificially-flattened north-south ridge.

In each of the 3 nights that we monitored M10 in this area, many hikers, bikers, and joggers passed close to him. However, there were no reported sightings of M10 by people, no indication that M10 was interested in humans as prey, and only 1 occasion when he got close enough to a residential area to cause a dog to bark.

In the late afternoon of June 24-25, and continuing into the twilight, many joggers and bikers passed near M10 without incident. Just before 10 PM the Disneyland fireworks show began, and 2 people watched the fireworks from the ridge above (north of) M10. After the fireworks these people walked south passing within 250 m of M10. At 0130, M10 walked into the mouth of the draw and approached Serrano Road, at which point the neighborhood dogs erupted with barking and howling, apparently getting scent of the cat before he entered the residential area. M10 promptly retreated to the draw and apparently hunted there the rest of the night (our followup in the morning did not reveal any prey remains).

Two nights later (June 25-26), M10 started out in the same small canyon and stayed there until about 8 PM, while several joggers and bikers again passed nearby. From 1830-2030 the radio-tracker watched M10 from a nearby rock outcrop. During most of this time M10 was resting in a patch of rather open grassland about 300 m from the observer, semi-hidden by his brown color, laying posture, and immobility. The cat raised his head and looked around in response to nearby barking dogs, singing birds, and perhaps scents carried on the wind (on 2 occasions he sniffed the wind and then looked around). At one point M10 started walking but then stopped when 2 women with 2 small dogs jogged on a trail about 200m away. He sat and calmly watched them pass by, but never crouched or appeared aggressive. During the night, he moved gradually east, and by dawn he had moved into Weir Canyon.

We monitored M10 a third night (July 6-7) in the same area. Once again he hunted close to residential areas, and within 200m of joggers and bikers during the evening hours. He again ended the night in Weir Canyon, far from developed areas.

F2 in San Juan Capistrano. On the night of February 7-8 1991, F2 moved down Trabuco Creek to I-5, and spent the next several days there, north of the Freeway and south of 3 residences (including a small ranch with horses and goats) built right on the creek. This site was 3 km south of that portion of Trabuco Creek that F2 normally uses. This portion of the Creek lay in a channel with cut banks 8-12 feet deep. About 8 homes on the eastern blufftop were less than 200m from F2's daybeds and the large "Village San Juan" housing tract was less than 100 m from the western bluff top.

On February 11, we found remains of 2 raccoons and 2 opossums that F2 had killed along Trabuco Creek. One opossum was extremely large and perhaps it had thrived by raiding nearby garbage cans. There were no reported sightings of F2 from nearby residents, and no indication that she was a threat to the nearby pets, goats, or residents. In 3 visits to the creek we were unable to see or hear her despite approaching to within 10 feet of her, so strong was her determination not to leave the protection offered by the dense bamboo thickets.

M13 in Coto de Caza. During overnight monitoring of M13 on September 25-26 1992, M13 traveled north up Cañada Gobernadora into an area of estate lots at the southern end of Coto de Caza. At about midnight he killed a deer in the creek bottom, near the chain-link fence marking the estate boundary. The kill site was about 50m from the road and a similar distance from a light illuminating the estate grounds. He stayed in this location feeding on the deer until 0530, at which time he traveled south and east about 2 km, skirting the south edge of a freshly graded area and traveling through the northern part of the new Gun Club site, into Bell Canyon to daybed.

Urban intrusion. Most radio-tagged cougars had urban areas abutting part of their home range, and several cougars experienced urban growth within their home ranges during the study. The cougars did a remarkable job of keeping out of areas immediately after the bulldozers removed the native vegetation. In several cases cougars moved into newly-initiated construction sites during the night, and remained bedded near them while heavy machinery operated nearby the following day. For instance, in early January 1990, F2 made her first visit to the lower Arroyo Trabuco in over 2 years, during which time many changes had occurred. On January 11, she was daybedded in a small canyon on the east rim of the Arroyo Trabuco. To her east, a street sign ("Antonio Parkway") stood incongruously in a grassland and bulldozers were busy making a street for the street sign to mark, with the road cut about 150m east of F2. To the north the cat could easily see golfers on the newly-built Rancho Santa Margarita. To the west (across the Arroyo) hundreds of hammers clattered on hundreds of house frames in Mission Viejo. And less than 1 km south bulldozers were scraping the Arroyo to put in footings for the Oso bridge. During all daylight hours the cougar was surrounded by construction activity. Shortly after dusk she quickly moved back east to the central part of her range.

Human structures in rural areas. Cougars in more remote areas also encountered humans regularly. For instance, within F3's home range were Los Amantes Camp (used for large outdoor parties), the TRW ("Star Wars") plant, the Ford munitions testing facility, and a very large sand mining and processing operation. F3 used all of these facilities when human activity was low, and showed no apparent aversion to passing near isolated buildings or vehicles at night. During one overnight monitoring session, she passed within 200m of Los Amantes Camp when a large outdoor party was in progress, showing no apparent interest in the activity.

Cougars also passed close to rural homes and occasionally ate goats there.

Cougars in parks and near wilderness trails

On several occasions, we documented a cougar (on different occasions: F1, F2, M2, M5, M6, M8, and M10) bedded for the day a few feet off of well-used park trails in Caspers Park, O'Neill Park, the Arroyo Trabuco (closed trails regularly used by trespassers), Whiting Ranch Regional Park, Chino Hills State Park, or Santiago Oaks Regional Park. The cougar doubtless was aware of the hikers, the hikers were completely unaware of the cougar and therefore were at risk of being ambushed. The only reported sighting in all these cases was a single incident in which F2 scrambled up a tree as an equestrian approached.

Given the high human use of Santiago Oaks Regional Park, there is a potential for human-cougar encounters in that Park. Although there may be greater risk at other parks that are more regularly used by cougars, park visitors are probably less aware of the potential for encountering a cougar in Santiago Oaks Regional Park. Because most people approach the park from the heavily-urbanized west, many park visitors tend to regard it (despite its oak forest and other wild traits) as a "city park," disregarding any efforts to make them aware of a potential cougar encounter. A similar disparity between public perception and biological reality exists at Irvine Park.

Many County Parks were cougar habitat (Chapter 3), and thus each had the potential for a cougar attack, although this risk is very low. Neither the historical record nor our data on radio-tagged animals provide a basis for assigning a greater degree of risk to a particular park. As long as a park is cougar habitat, it has a small amount of risk.

Management practices related to cougars differed greatly among the above County Parks, from signed warnings and a prohibition on minors in Caspers Wilderness Park, to busloads of school children in Santiago Oaks Regional Park, to a largely unpatrolled Wagon Wheel Regional Park. The Parks as a group also differed from adjacent National Forest lands that were open to all visitors.

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GLOSSARY

adult - a cougar over 24 months of age and exhibiting a stable home range.

carrying capacity - the average number of animals that a given habitat area can support in the long term. For cougars, it is usually expressed in numbers of adults per 100 km^2 or per 100 mi^2.

corridor (wildlife corridor) - a linear habitat used by animals or plants to move between 2 larger habitat areas.

cub - a cougar from birth until dispersing out of its mother's home range at 13-27 months of age

depredation - the killing of domestic livestock or pets by a wild predator

dispersal - Movement of an animal away from its place of birth to establish a new home range elsewhere. For cougars, the process of dispersal takes several weeks to months, during which the animal searches for suitable habitat with minimum risk of conflict with other resident adults of the same sex. Cougars in this population dispersed at 13-27 months of age.

hectare (ha) - hectares, a unit of area equal to 10,000 m^2 (e.g., a square 100 m on a side) or about 2.471 acres. To convert ha to acres, multiply ha by 2.471; to convert acres to ha, multiply acres by 0.4047. see also kilometers

home range - The area used by animal in the course of its normal activities of feeding, breeding, resting, and raising young. Home range excludes rare excursions to locations not later revisited.

intensive monitoring - radio-tracking sessions starting before sunset and continuing until after sunrise. During each session, we determined the location of a single cougar (the focal animal) every 15 minutes. also called "overnight monitoring"

juvenile - a term that includes both cubs and subadults, i.e., any cougar that is not yet adult.

kilometer (km) - a unit of length equal to 1000 meters, or about 0.625 miles. To convert km to miles, multiply km by 0.625; to convert miles to km, multiply miles by 1.6. To convert km^2 to mi^2, multiply by 0.386; to convert mi^2 to km^2, multiply by 2.59.

overnight monitoring - *see* intensive monitoring

parturition - the act of giving birth

Santa Ana Mountain Range - The study area, including the Santa Margarita Mountains, the Santa Rosa Plateau, and the Chino Hills. See Figure 1.

scat - fecal dropping

subadult - a cougar from the age of dispersal until a stable home range is established, usually by 36 months of age

transient (home range) - (a home range) used for several weeks or months by a dispersing juvenile cougar and then abandoned. Transient home ranges were smaller than adult home ranges, and were usually elongate and pressed up against the urban edge.