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IMMEDIATE EFFECTS OF WILDFIRE ON ISLAND FOX SURVIVAL AND PRODUCTIVITY

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Abstract—Island foxes (*Urocyon littoralis*) exist as six endemic subspecies, one on each of the six largest California Channel Islands. All six subspecies are listed as threatened by the California Department of Fish and Game; four of these, including those on Santa Catalina Island, are also listed as endangered under the federal Endangered Species Act. Six wildfires have been documented on the east end of Catalina Island since the endemic fox (*U. l. catalinae*) population underwent a precipitous decline in 1999. An extensive island-wide trap/mark/recapture effort had been carried out annually on Catalina Island from 2001 through 2008 to monitor island fox population status. We compared pre- and post-burn data from foxes captured in traps within and surrounding the burn areas of the two largest fires—the Empire Fire, a 1063-acre lightning-ignited fire on July 22, 2006, and the Island Fire, a 4760-acre accidentally ignited fire on May 10, 2007. Individual survival and pup presence were the main indicators used to measure the immediate effects of each fire. Though overall fox numbers have increased on the east end of the island, a slight decrease in total foxes captured post-fire was observed in both the Empire Fire (18 pre-fire, 16 post-fire) and the Island Fire (42 pre-fire, 37 post-fire) sampling areas. The ratio of pups to adults captured in the Empire Fire sampling area remained similar pre- and post-burn (1:3 and 1:4 respectively) and consistent with the overall ratio observed on the entire east end of the island (1:4). The ratios of pups to adults observed in the Island Fire sampling area pre- and post-burn (1:2 and 1:17 respectively) suggest a possible decrease in fox productivity in the Island Fire zone. A fire event that occurs while pup mobility is limited (April–June) may alter productivity in the affected area by disrupting parturition and weaning, or causing direct mortality, yet may be less critical during other times of the year.

INTRODUCTION

Island foxes (*Urocyon littoralis*) exist as six endemic subspecies, one on each of the six largest California Channel Islands (Gilbert et al. 1990; Wayne et al. 1991). Due to precipitous fox population declines, four of these six subspecies, including the Catalina Island fox (*U. l. catalinae*), have been listed as endangered under the federal Endangered Species Act. Research has suggested that an outbreak of canine distemper virus in 1999 was the probable cause of the fox decline on Catalina Island (Timm et al. 2000). An extensive island-wide trap/mark/recapture and vaccination effort was initiated in response to the decline and had been carried out annually on Catalina Island from 2001 through 2008 to monitor the status of the population recovery. The Catalina Island fox population was estimated at only 784 animals in 2008 (King and Duncan 2008), therefore evaluation of all potential risks to fox survival is necessary to direct ongoing management decisions and assist in setting recovery goals for all four endangered Channel Island fox populations. The potential immediate effects of wildfire on island foxes has not been well documented and though fire is not considered a major threat on its own, information from this study may be useful in determining cumulative risks and modeling population viability.

Fire affects animals at the individual, population, and community levels. The ecological relationship between fire and animal communities is poorly understood, and there is little known about fire effects on the majority of species existing in California (Shaffer and Laudenslayer 2006). Most research into the effects of wildfire on wildlife has focused on mainland populations of small mammals, reptiles, and birds. For relatively small vertebrates, fires can and do cause substantial mortality, and can result in local declines or

extinctions in areas following a fire (Wirtz 1974; McClure 1981; Peek 1986; Patton 1992). Despite these potential population impacts for small vertebrates, most researchers agree that at the regional population level, mortality effects are very small if not negligible (Wirtz 1977; Quinn 1979; Patton 1992). Although there is a potential for a significant local mortality for some species of small animals, a number of species such as the closely related gray fox (*Urocyon cinereoargenteus*), are capable of retreating from oncoming flames, even if they remain within the immediate burn area (Peek 1986; Patton 1992).

Of all fire regime attributes, seasonality of fire may have the greatest potential for affecting individual animal populations. Island fox parturition and rearing takes place during the spring and early summer (April–June), prior to the general California fire season occurring in late summer and early autumn (August–November) (Laughrin 1977; Shaffer and Laudenslayer 2006). Pups emerge from their natal den at 3–4 weeks of age with the majority being seen in early June. By late summer, pups are highly mobile and abandon their dens to forage with their parents daily in preparation for dispersal by autumn (Laughrin 1977).

With the continued increase in island residents, visitors, and interior activities on many of the California Channel Islands, there is a greater potential for human-caused fires to become ignited outside of the traditional fire season. This may result in significant pup mortality if fires occur during a time when pups are in dens and are unable to flee from oncoming flames. Non-seasonal fires may also negatively impact native plant species and local vegetation communities, thereby producing considerable short-term and long-term wildlife displacement due to habitat alteration (Shaffer and Laudenslayer 2006).

The recent (ca. 100 years) fire history on Catalina Island is relatively well documented. Based on personal interviews, newspaper articles, and Los Angeles County and Catalina Island Conservancy records, current information suggests that approximately 40 fires larger than 0.02 km^2 (5 acres) have been documented on Catalina Island between 1915 and 2007. Only one of these fires was ignited naturally via lightning. More recently, six fires have been documented in the interior of the island since the fox decline in 1999. Two of these fires, the Empire Fire, a 4.3-km^2 (1063-acre) lightning-ignited fire on July 22, 2006 and the Island Fire, a 19.26-km^2 (4760-acre) accidentally ignited fire on May 10, 2007, collectively burned 23.56 km^2 (5823 acres), or approximately 12% of Catalina Island (Catalina Island Conservancy, unpublished data 2007).

A significant advantage of this study was that we were able to monitor marked foxes both before and after a fire event within the fire-affected areas (local level) as well as at a population level. This was fortuitous and resulted from a unique set of circumstances. The timing of the two fire events examined in this study also allowed us to compare the immediate effects of fire on foxes during the sensitive parturition season and compare the results to those from a less vulnerable time of the year.

Using annual island-wide trapping data and capture trends, our objectives were to: (1) assess the abundance of marked foxes before and after each fire event at the local and population levels; (2) compare the abundance of fox pups and the ratios of pups to adults before and after each fire event at the local and population levels; (3) compare the ratios of males to females before and after each fire event at the local and population levels; and (4) attempt to assess apparent survival of specific marked adults based on their recapture post-fire.

MATERIALS AND METHODS

Study Area

Santa Catalina Island (approximately 194 km^2) is located approximately 32 km from the mainland (Palos Verdes Peninsula, CA), is 34 km long, and ranges from 1 km wide at the Two Harbors Isthmus to 13 km wide near the center of the island. The isthmus geographically separates Catalina into two distinct sides, the east end and west end. The island is quite mountainous with elevations ranging from sea level to 670 m. Catalina Island has a mild and dry climate with infrequent storms occurring mainly between November and April. Annual precipitation in the city of Avalon averages 314 mm (12.36 inches) with average daytime temperatures ranging from 17 C to 23 C. Predominant vegetation types include coastal sage scrub, coastal bluff scrub, island chaparral, island woodland, riparian

woodland, and coastal grassland (Schoenherr et al. 1999).

The two largest fire events selected for this study included the Empire Fire, a 4.3-km^2 (1063-acre) lightning-ignited fire that occurred from July 22–25, 2006, and the Island Fire, a 19.26-km^2 (4760-acre) accidentally ignited fire that occurred from May 10–15, 2007. The total area burned during the Empire Fire was calculated by walking the burn area perimeter while collecting line function data using a Trimble Geo Explorer 3 GPS unit (D. Knapp, unpublished data). Line data were post-corrected using Pathfinder software from base files accessed through a local base station. Data were exported as a shapefile and total area was calculated using ArcView 3.2. The Island Fire perimeter was digitized from aerial photographs taken on June 7, 2007 by I.K. Curtis Services, Inc., at a scale of 1:30,000. Data were converted to a shapefile and total area was calculated using ArcGIS 9.1.

Trapping

Data gathered during multiple annual island-wide trapping events were used to determine fox abundance, individual fox presence, apparent survival, and pup to adult ratios during periods before and after each fire event. The capture and handling methods used annually on Catalina Island were originally established and implemented in 2000 by the Institute for Wildlife Studies (IWS) while contracted by the Catalina Island Conservancy and have been continued by the Catalina Island Conservancy since the IWS contract concluded at the end of 2005. For the purposes of this study, fox ID, sex, and age class were selected from capture history data associated with the 604 trap sites used each year during 2003–2008. The annual trapping effort was divided into 12 to 13 separate trap lines, consisting of 30 to 60 trap sites and occurred from mid-July through mid-October. Foxes were captured with single-door live traps (Model #106, 23 x 23 x 66 cm; Tomahawk Live Trap Co., Tomahawk, WI) baited with dry cat food, wet cat food, and a loganberry lure (Knobb Mountain Fur Co., Berwick, PA). Captured foxes were weighed (± 25g), sexed, and aged. Age was determined by the relative wear of the first upper molar (Wood 1958; Collins 1993) and foxes were placed in one of five age classes: pups (age class 0), juveniles/young adults (age class 1), adults (age class 2), mature adults (age class 3), and older adults (age class 4). All foxes which had not been previously captured as well as those which had been caught previously and only marked with ear tags, were permanently marked with a passive integrated transponder tag (PIT tag; Biomark Inc., Boise, ID). PIT tags were inserted under the skin between and just anterior to the scapulae using a sterile single-use syringe (King and Duncan 2008).

Isolating Fire-Affected Traps

Geographic information system (GIS) software (Environmental Systems Research Institute, Redlands, CA) was used to create a 500-m buffer around each trap site used annually on the east end of Catalina Island (454 of 604 trap sites). We assumed an "effective trap radius" of 500 m (Schmidt et al. 2005) based on the approximate mean home range size for island foxes on San Clemente Island, California (Schmidt et al. 2004b) and a cursory analysis of home ranges of translocated foxes on Santa Catalina Island (Schmidt et al. 2004a). All trap sites used annually on the east end of the island were collectively placed into the East End category. To quantify potential population impacts resulting from the fires and compare those to the impacts at the local level, the capture history for all trap sites used during annual trapping efforts on the entire east end of Catalina Island were assessed. The remaining 150 of 604 trap sites located on the west end of the island were not included in this study.

Trap sites were placed into either the Empire Fire or Island Fire category if a trap buffer overlapped with, or was located within, the burn area perimeter of either fire event. A history of fox captures occurring between 2003 and 2008 at each trap site was assessed to identify the number of uniquely marked foxes that may have been present within the fire-affected areas before and after each fire.

We calculated the sampling area within the Empire Fire and Island Fire perimeters as the entire area covered (minus overlap) by the 500 m buffers placed around all traps then clipped to the perimeter of each fire, leaving only the buffered area lying inside the appropriate fire perimeter to be calculated. The area sampled for the entire East End was calculated as the area covered (minus overlap)

by the 500-m buffers placed around all 454 trap sites used annually on the East End of Catalina Island.

Adult and Pup Abundance and Ratios

Fox abundance was calculated as the number of individual foxes, pups and adults, captured in each category of traps (Empire Fire, Island Fire, East End) in the years preceding and following each fire event. The ratios of pups to adults within each category post-fire were also calculated and compared to pre-fire ratios using chi-square analysis (GraphPad software 2002–2005). The timing of the annual trapping effort, mid-July through mid-October, was valuable in this comparison because pups continue to remain in close proximity to their parents during the summer and do not disperse until the fall (Laughrin 1977; Fausett 1982).

To evaluate whether the behavior of nursing mothers (e.g., potentially staying with their dependent young versus fleeing, or returning to their young while hazards remained) would affect their immediate survival in the event of a fire, the ratio of adult females to adult males captured in each category of traps annually was calculated and compared using a chi-square analysis against an expected ratio of 1:1.

Apparent Survival of Marked Foxes

Apparent fox survival within the burn areas was estimated by the post-fire recapture of marked foxes that had been captured in these areas prior to the fire event. Because the number of years that annual trapping was conducted after each fire event differed, only foxes recaptured during one subsequent trapping year were compared to the annual recapture results found during non-fire years.

RESULTS

Isolating Fire-Affected Traps

The number of traps included in each trap category (Empire Fire, Island Fire, and Entire East End) was 34, 69, and 454 respectively (Fig. 1). Using the 500-m buffers clipped with the fire perimeters, approximately 58% of the area burned

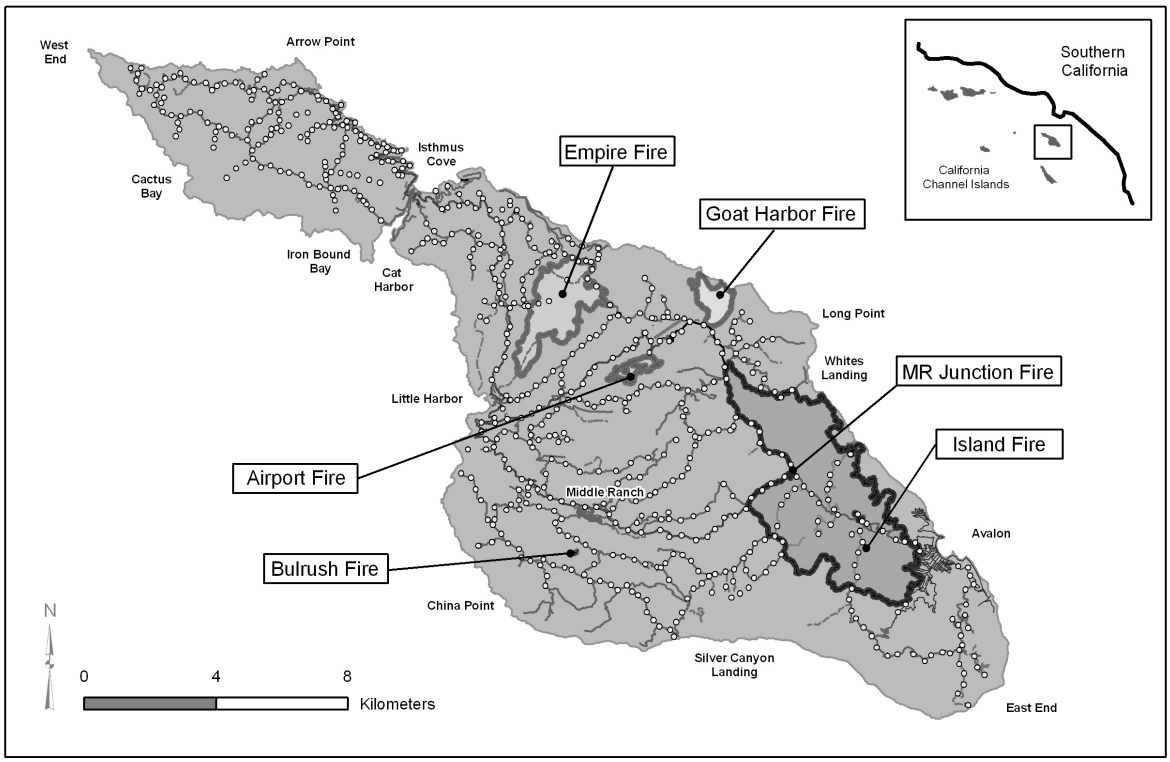

Figure 1. Locations and area of six interior island fires documented on Santa Catalina Island, California between 1999 and 2008. Annual island-wide trap sites maintained from 2003 to 2008 represented by open dots.

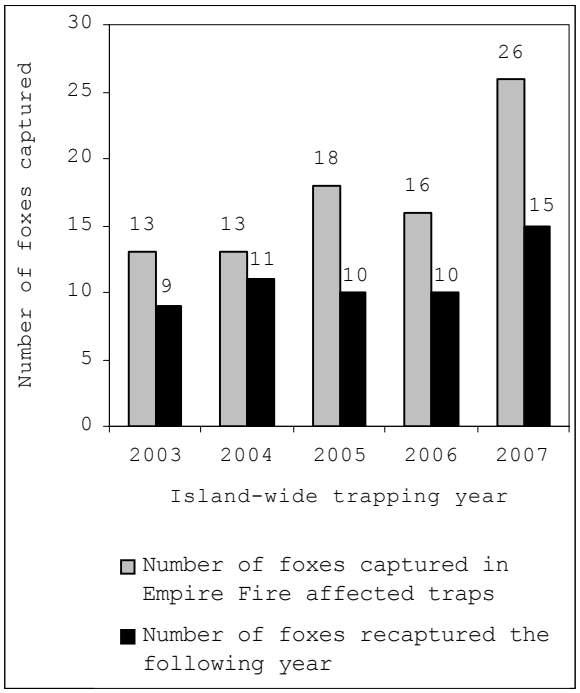

Figure 2. Number of adult foxes and pups captured each year in traps affected by the Empire Fire, on Santa Catalina Island, California from 2003 to 2007. The grey bars indicate the number of foxes captured during the target year and the black bars are the number of those marked foxes captured the following year. The Empire Fire occurred in 2005.

by the Empire Fire and 67% of the area burned during the Island Fire were sampled during each annual island-wide trapping effort. By utilizing the same method of surrounding all 454 East End traps with a 500-m buffer (minus overlap), approximately 71% of the Entire East End of Catalina Island was sampled annually from 2003 through 2008.

Adult and Pup Abundance and Ratios

The total number of foxes captured in Empire Fire-affected traps during annual island-wide trapping decreased slightly from pre-fire sampling (n = 18) in 2005 to post-fire sampling (n =16) in 2006 (Fig. 2). Of the 16 foxes captured within these traps 1 month post-fire, only 7 were from the original 18 detected in this area prior to the Empire Fire. The other 9 foxes detected included 5 new animals (3 pups, 2 yearlings) and 4 marked adults that had either been captured previously during 2004 in those traps, or had been captured during 2005 in a trap immediately adjacent to a fire-affected trap along the fire perimeter line. No previously marked adult foxes were documented to have moved in from outside areas. The ratio of pups to adults captured post-Empire Fire (1:4) did not differ significantly from pre-fire sampling (1:3) ($\chi^2 = 0.22, P = 0.64$) (Table 1). The ratio of adult females to adult males captured after the Empire Fire did not differ significantly from 1:1 ($\chi^2 = 0.078, P = 0.78$).

The total number of foxes captured in Island Fire-affected traps also decreased slightly from pre-fire sampling (n = 42) in 2006 to post-fire (n = 37) sampling in 2007 (Fig. 3). Only 20 of the foxes detected post-fire were from the original 42, while the additional 17 of 37 foxes captured in Island Fire-affected traps during 2007 included 2 new pups, 9 new unmarked adults that had been undetected previously, and 6 marked adults previously captured in traps immediately adjacent to fire-affected traps along the fire's periphery during 2006. Despite an increase in adult foxes present, the number of pups captured in Island Fire-affected traps decreased substantially from pre-fire (n = 14)

Table 1. Number of pups and adult foxes captured in each category of traps during the annual island-wide trapping effort on Santa Catalina Island, California from 2003 to 2008.

		Sampling year					
Area		2003	2004	2005	2006	2007	2008
Empire Fire affected traps (n = 34)	Pups	4	7	4	3	3	19
	Adults	9	6	14	13	23	18
Island Fire affected traps (n = 69)	Pups	0	0	1	14	2	43
	Adults	5	10	12	28	35	33
East End traps (n = 454)	Pups	21	25	42	45	50	157
	Adults	48	89	104	162	196	185

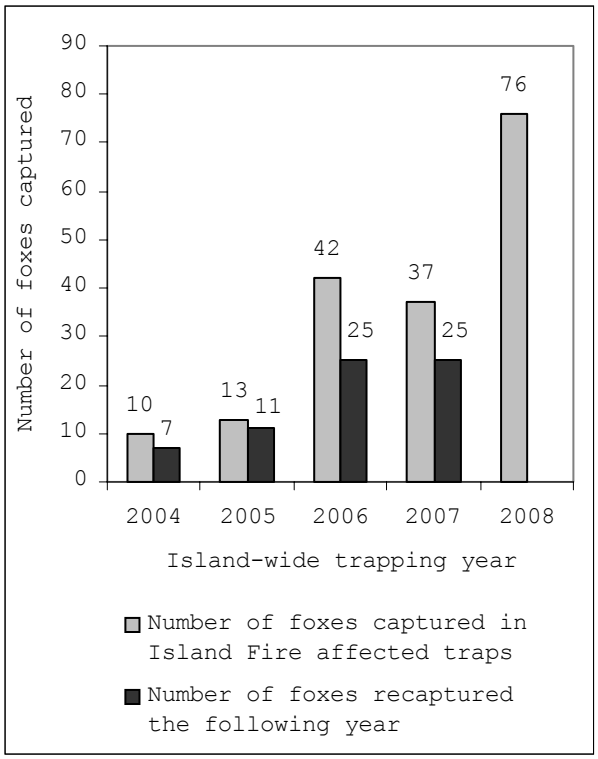

Figure 3. Number of adult foxes and pups captured each year in traps affected by the Island Fire, on Santa Catalina Island, California from 2004 to 2008. The grey bars indicate the number of foxes captured during the target year and the black bars are the number of those marked foxes captured the following year. The Island Fire occurred in May 2007, prior to that year's trapping effort.

in 2006, to 4 months post-fire ($n = 2$) in 2007. This was followed by a substantial increase in the number of pups documented in 2008 ($n = 43$) (Table 1). The ratio of pups to adults differed significantly 4 months post-fire (1:17) compared to ratios documented both before the Island Fire event (1 : 2) ($\chi^2 = 12.33$, $P = 0.0004$) and 1 year following the fire (1:1) ($\chi^2 = 29.43$, $P<0.0001$). The ratio of adult females to males following the Island Fire in 2007 (18F : 17M) did not differ significantly from those ratios documented prior to the fire in 2006 ($\chi^2 = 1.05$, $P = 0.31$) or 1 year after the fire in 2008 ($\chi^2 = 0.12$, $P = 0.73$).

At the population level, the number of adult foxes captured in East End traps during annual island-wide trapping increased each year from 2003 to 2007 despite the Empire and Island Fire events. The number of pups captured in East End traps also increased each year through 2007, but at a slower rate (Table 1). The ratio of adult females to adult males captured on the East End of the island after each fire event did not differ significantly from 1:1 (Empire Fire $\chi^2 = 2.0$, $P = 0.16$; Island Fire $\chi^2 = 0.18$, $P = 0.67$).

The annual variability observed in pup to adult ratios on the East End may best be explained by annual rainfall. The majority of precipitation received on Catalina Island occurs between November 1 and April 30. We found the average ratio of pups to adults significantly lower during dry years (2004, 2006, 2007) when less than 178 mm (7 inches) of rain were recorded, than during wet years (2003, 2005, 2008), when annual precipitation exceeded 305 mm (12 inches) ($\chi^2=25.67$, $P<0.0001$) (Table 2.).

Apparent Survival of Marked Foxes

Of the 18 uniquely marked foxes captured within the Empire Fire-affected traps during 2005, the sample year prior to the Empire Fire, 10 adults

Table 2. Ratio of Catalina Island fox pups to adults captured during annual island-wide trapping on the island's East End. Ratios shown in relation to average annual rainfall received at three weather stations located at Avalon, Middle Ranch, and Airport in the Sky, on Catalina Island, California during 2002–2008.

Rain date range	Pup year	Average rainfall (inches)	Number of pups to adults	Ratio Pups : Adults
November 1, 2002–April 30, 2003	2003	15.24	21/48	1 : 2.3
November 1, 2003–April 30, 2004	2004	6.37	25/89	1 : 3.5
November 1, 2004–April 30, 2005	2005	23.38	42/104	1 : 2.5
November 1, 2005–April 30, 2006	2006	6.84	45/162	1 : 3.6
November 1, 2006–April 30, 2007	2007	3.56	50/196	1 : 4.0
November 1, 2007–April 30, 2008	2008	12.26	157/185	1 : 1.2

and 0 pups (56%) were recaptured during the subsequent post-fire island-wide trapping effort in 2006 (Fig. 2). These foxes may have been captured in any available East End trap to determine apparent survival. This recapture success was not significantly lower than the recapture rates documented in this area prior to the fire in 2003–2004 ($\chi^2 = 0.33$, $P = 0.56$), or 2004–2005 ($\chi^2 = 1.29$, $P = 0.25$), nor after the fire in 2006–2007 ($\chi^2 = 0.15$, $P = 0.69$). An additional 5 (3 pups, 2 adults) of the original 18 foxes captured during 2005, yet not detected during 2006, were recaptured the second year (2007) resulting in 15 of 18 (83%) foxes known to have survived at least 1 year after the Empire Fire event. The remaining 3 foxes (1 pup, 2 adults) were undetected during all 3 years of trapping following the fire.

Of 42 individual foxes captured in Island Fire-affected traps during 2006, the sample year before the Island Fire, 25 (60%) were recaptured during the subsequent post-fire island-wide trapping effort in 2007 (Fig. 3). This was significantly lower than recapture results (85%) from trapping efforts in this area during 2005–2006 ($\chi^2 = 23.53$, $P = <0.0001$), yet not different than the 70% documented from 2004-2005 ($\chi^2 = 2.195$, $P = 0.14$). Six of the original 42 foxes captured in 2006 were not detected in 2007, yet were recaptured during 2008. Of the remaining 11 foxes not captured in traps during 2007 or 2008, 1 had been radio collared and monitored weekly during 2006 until the collar malfunctioned in June 2007, while a second fox was euthanized in May 2008 due to severe injuries; evidence that these two foxes also survived at least 1 year post-fire. A total of 33 of 42 (79%) foxes therefore were known to have survived at least one year following the Island Fire. The other 9 foxes, (3 pups, 4 new 1-year-olds, and 2 mature adults) were not detected during the 2 subsequent years of post-Island Fire trapping.

Of 146 marked foxes captured on the entire East End of the island during the 2005 annual island-wide trapping effort (before the Empire Fire), 111 (77%) were recaptured the following year (2006). Similarly, of 207 marked foxes captured on the East End during the 2006 island-wide trapping effort (before the Island Fire), 141 (68%) were recaptured during island-wide trapping in 2007 after the Island Fire, suggesting that fire effects were minimal at the population level (Fig. 4). During 6 years of systematic trapping, 2003–2008, we observed a 67% average annual recapture rate of marked foxes on the East End of Catalina Island.

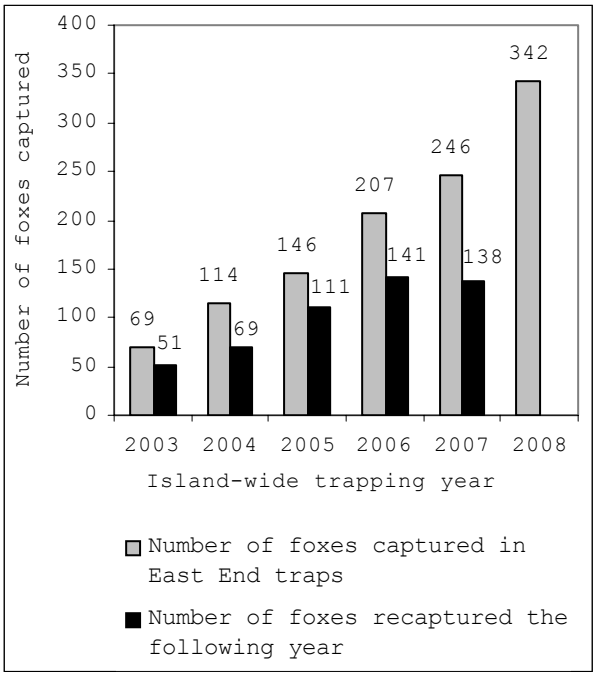

Figure 4. Number of adult foxes and pups captured each year in traps on the East End of Santa Catalina Island, California from 2003 to 2008. The grey bars indicate the number of foxes captured during the target year and the black bars are the number of those marked foxes captured the following year.

DISCUSSION

A fortuitous set of unique factors provided us with an exceptional opportunity to quantify the potential immediate effects of a wildfire event on island fox survival and productivity. The level of monitoring that was in place before either fire event occurred recorded the status of island foxes in each area. Most investigations into the effects of wildfire on wildlife populations have been limited in this regard, as studies are often only initiated after a fire event has occurred (Whelan 1995). We had the rare opportunity to follow marked individuals from a population in which approximately 71% of the overall study area had been systematically sampled for several years prior to and at least two trapping years following each fire event. The timing of the Island Fire also provided us with the ability to gain knowledge of fire effects during the parturition

season (April–June) when foxes are the most vulnerable; this situation would be extremely difficult to replicate both legally and ethically.

Similar to its mainland relative the gray fox, the island fox only uses a den for parturition and pup rearing, which occurs generally from early April to mid-June (Laughrin 1977; Clifford et al. 2007). Island fox dens usually are simple structures that include brush piles, small caves, rock crevices, manmade structures, hollowed limbs or stumps; or, in the absence of existing structures, a simple tunnel may be dug (Laughrin 1977). Most of these types of simple structures would provide little safety in the event of a fire. Other studies that have investigated fire effects suggest that animals taking refuge in burrows or dens may be more susceptible to fire due to extended periods of elevated temperatures and the increased potential for suffocation (Whelan 1995). Captive adult foxes have been documented carrying their young to new den locations within their enclosures. However, it is unknown what behavioral alterations adult foxes would make in the wild during a fire event that took place when pups were completely dependent and had limited mobility. It is possible that due to pup dependence, adult foxes could have remained in or returned to hazardous areas, increasing their chances of injury or death. Several observations of foxes returning to the burn area while flames were still present were documented during the Island Fire. An injured adult female fox showing signs of nursing was also captured and provided with veterinary treatment. Her injuries included severe burns to all four paws suggesting that she may have returned to a hazardous area, perhaps to search for pups, after initially fleeing. This fox made a complete recovery from her burns after extended treatment and was ultimately released back to the wild.

Our comparison of recapture results between annual trapping efforts conducted during years with large documented fire events and those with no fire activity provided no consistent evidence to suggest that either fire event had any influence on the survival of marked adult foxes at the local or population level. As suspected in this case and documented among similar animals, adult foxes had the ability to retreat from the oncoming flames. This was supported with data from 6 adult foxes (3F:3M) fitted with radio collars prior to the Island Fire, which left the affected area during the fire and later returned. All 6 collared animals were monitored weekly prior to and following the fire event for the remainder of the year. All 6 animals survived the fire without injury. We also did not find a significant difference in the ratio of adult females to adult males compared pre- and post-fire suggesting that the behavior of nursing mothers did not influence their survival. If adult foxes were injured or killed within either fire event, is was not at a level distinguishable from the recapture variability documented over several years. Additional post-fire annual trapping efforts would likely detect additional survivors and strengthen the above statements, but the fate of foxes still undetected could not be linked to the fire events.

The similarities in the relative abundance of pups and ratio of pups to adults documented at the local level before and after the Empire Fire (1:3 and 1:4 respectively) would suggest that at the time of this fire (July), fox pups were sufficiently mobile to avoid the oncoming flames and independent enough not to return to the area before the hazards were extinguished. The timing of the Island Fire event however, coincided with the parturition season. The severe decline in the abundance of pups present after the Island Fire and the ratio of pups to adults documented at the local level before and after the Island Fire (1:2 and 1:17) suggests that approximately 10 pups that we would have expected to have captured that year were lost as a direct result of the fire and productivity at the local level was adversely affected.

Our findings indicate that the seasonality of a fire event appeared to have the most influence on immediate fox survival. Fires that occur during early post-parturition may affect survival of pups resident in the fire areas. The negligible effects of either fire event at the population level reflect stability in the current size and structure of the Catalina Island fox population. In situations of poor population condition, including low abundance, restricted age class distribution, or a precipitous decline, a single fire event or a series of fires, as in this case, may pose a serious threat to an animal species or population (Shaffer and Laudenslayer 2006). Although the assessment of the immediate effects of fire on fox survival is important to determine, the long-term fire effects such as habitat alteration and/or conversion to grassland, individual displacement, and resource availability were not

assessed in this study and may prove to have a much larger effect on population recovery.

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