# Survival of fishers in the southern Sierra Nevada region of California 

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Fishers in the western United States were recently proposed for listing under the U.S. Endangered Species Act because of concerns for loss of suitable habitat and evidence of a diversity of mortality risks that reduce survival. One of 2 remnant populations of fishers in California is in the southern Sierra Nevada region, where we studied them at 2 research sites in the Sierra National Forest. Our objectives were to evaluate whether survival was lower for male fishers and dispersal-aged individuals or if survival varied seasonally. We captured and monitored 232 radiocollared fishers from March 2007 to March 2014 and used model analyses to identify important predictors of survival. Fifty-two percent $(n=120)$ of the radiocollared fishers died, and survival varied by sex and season, but not by age or between study sites. There was no evidence that dispersal-aged fishers experienced lower survival than older fishers. Annual survival trended lower for male ( 0.62 [95\% CI 0.54-0.70]) compared to female fishers ( 0.72 [ $95 \%$ CI $0.67-0.78]$ ), was lowest in the spring to mid-summer season ( 0.83 [ $95 \%$ CI $0.78-0.87]$ ), and highest in late fall and winter ( 0.92 [ $95 \%$ CI $0.89-0.94]$ ). Lower survival among male fishers appeared linked to males moving over large areas to locate mates, while lower survival for females was potentially related to high energetic cost of reproduction. It was possible but unknown if lower survival among all fishers in spring was linked to secondary exposure to toxicants dispersed around illicit marijuana grow sites. Six-month survival of juvenile fishers was 0.85 for females and 0.79 for males, but lower at 0.62 for females and 0.57 for males when adjusted for deaths before late September. Annual survival among adult female fishers was $20 \%$ lower than 0.90 , a value that prior modeling suggested was required for population expansion in the overall southern Sierra Nevada. Survival data from our study imply a greater challenge for maintaining self-sustaining fisher populations in the southern Sierra Nevada region, and resource managers are working to mitigate several of the human-associated factors that limit population growth.

Key words: California, fisher, MARK, Pekania pennanti, Sierra Nevada, survival
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Understanding survival is fundamental for insight into the population biology of any species and crucial for identifying the limits to population growth and recovery for rare or endangered wildlife. Historical loss and fragmentation of important habitats, combined with overexploitation, are the most common drivers of endangerment of wildlife (Lande 1993), all of which contributed to decline in abundance and range extent of fishers (Pekania pennanti) in North America (Lewis and Zielinski 1996; Powell et al. 2003; Raley et al. 2012). There is concern for the conservation status of fishers in many parts of their range, but particularly in the western United States (Lofroth et al. 2010) where information on population-level survival is needed to assist management efforts to conserve them (U.S. Department of the Interior Fish and Wildlife Service 2014a).

Fishers are a medium-sized mammal with a historical distribution encompassing the boreal forest zone of Canada, the Great Lakes region and northeastern United States, a portion of the Rocky Mountains in the United States, and mountainous areas of Washington, Oregon, and California (Gibilisco 1994). In western North America, fishers appear dependent on latesuccessional mixed conifer forests (Raley et al. 2012), which provide habitat for a diversity of prey (Zielinski and Duncan 2004), and where cavities in older trees and snags provide fishers with secure den and rest sites (Weir et al. 2012; Zhao et al. 2012; Aubry et al. 2013; Schwartz et al. 2013). Fishers are considered likely to be negatively affected by logging and other forest management activities in mixed conifer forests (Truex and Zielinski 2013) because loss of mature forests was at least
partly responsible for a significant reduction in their range and abundance in the 20th century (Grinnell et al. 1937; Zielinski et al. 2005). Moreover, recent research indicates that fishers are exposed to many natural and human-associated factors that reduce survival (Chow 2009; Thompson et al. 2013; Wengert et al. 2014). For these reasons, fishers in the west coast states of Washington, Oregon, and California, an area referred to as the West Coast Distinct Population Segment by the U.S. Fish and Wildlife Service, have been the focus of conservation interest from when they were first petitioned for listing under the U.S. Endangered Species Act in 1990 (Zielinski 2013).

In the West Coast Distinct Population Segment (West Coast population segment), fishers currently exist in 3 remnant populations ( 1 each in southern Oregon, northern California, and the southern Sierra Nevada, California), and 3 reintroduced populations in western Washington, southern Oregon, and northeastern California (U.S. Department of the Interior Fish and Wildlife Service 2014a). The 2 remnant fisher populations in California are currently separated by 400 km , and this contemporary distribution was likely produced by the combination of habitat loss after the early 1900s that broadened a preexisting gap (Spencer et al. 2015a), and prior presence of biophysical barriers that limited dispersal and contributed to development of genetic differentiation between fishers in the southern Sierra Nevada and those in northern California, Oregon, and elsewhere (Wisely et al. 2004; Knaus et al. 2011; Tucker et al. 2014).

Population-level survival of fishers may vary by age, sex, or season depending on life history events, and when different types of mortalities are most likely to occur. Field studies of fishers in the western United States report that survival of individual fishers is challenged by exposure to infectious disease (Keller et al. 2012; Gabriel 2013), attacks by larger predators (Lewis 2014; Wengert et al. 2014), collisions with vehicles on highways (Chow 2009; Lewis 2014), and exposure to rodent poisons and other toxicants at trespass marijuana grow sites on public forest lands (Gabriel et al. 2012; Thompson et al. 2013). Female fishers are about $50 \%$ smaller than males in the West Coast population segment and may be more vulnerable to predator attacks than male fishers as a result (Wengert et al. 2014). Reproducing female fishers require nearly 3 times the energy of non-reproducing females associated with extensive foraging movements to support energetic costs of reproduction (Powell and Leonard 1983). Frequent forays away from the security of tree cavities expose denning female fishers to predation (Matthews et al. 2013; Sweitzer et al. 2015a), which is higher in spring than in other seasons (Sweitzer et al., in press). Adult male fishers may die at higher rates in spring when they undergo expansive movements associated with locating and mating with receptive females (Powell et al. 2013; Lewis 2014). Fishers typically disperse before they attain sexual maturity, and the tendency for both males and females to disperse away from familiar natal areas (Arthur and Paragi 1993; Matthews et al. 2013; Sweitzer et al. 2015b) may place dispersal-aged fishers at greater risk of mortality than resident adults (Chepko-Sade and Halpin 1987). Fishers may experience lower survival during fall and winter from the combined effects of higher energetic
costs (Powell 1979) and prey limitation when several species of their rodent and reptile prey are in torpor (Zielinski and Duncan 2004). Gabriel et al. (2013) and Thompson et al. (2013) suggested that the timing of use of toxicants at trespass marijuana grow sites might contribute to lower survival among fishers during spring because more chemicals are spread around the newly emergent and vulnerable plants at that time than later in the growing season.

In late 2014, the U.S. Fish and Wildlife Service proposed to list the West Coast population segment of fishers as threatened under the Endangered Species Act (U.S. Department of the Interior Fish and Wildlife Service 2014b). The basis for the proposed listing included risk to fisher habitats from wildfire and fuel reduction-based forest management (Truex and Zielinski 2013), exposure to rodenticides and other poisons, and the cumulative and synergistic effects of these and other stressors acting on small populations (U.S. Department of the Interior Fish and Wildlife Service 2014a). Stressors reduce survival, and our primary objective in this study was to evaluate survival among fishers at 2 study sites in the southern Sierra Nevada region of California. We hypothesized that fisher survival would be (1) lower for male compared to female fishers, (2) lower among dispersal-aged fishers than adult fishers, and (3) that survival might vary among ecologically relevant seasons of the year related to breeding season movements, exposure to toxicants, or reduced availability of prey in winter.

## Materials and Methods

Study area and site description.-The study was conducted on the west slope of the southern Sierra Nevada at 2 different study sites, one in the Bass Lake Ranger District (northern site) and the second in the High Sierra Ranger District (southern site) in the Sierra National Forest, California (Fig. 1). The climate at the study sites was Mediterranean with cool, wet winters and warm, dry summers. Precipitation typically occurs from October to mid-May and rain during summer to early fall is rare. Average annual precipitation in the mid-elevation forests most frequently occupied by fishers $(1,364-1,970 \mathrm{~m}$ elevation) is about $100-120 \mathrm{~cm}$. Most precipitation at $1,650 \mathrm{~m}$ elevation (optimum elevation occupied by fishers in the study area-Sweitzer et al., in press) between late November and early March is snow, which accumulates and persists into April. The long-term mean minimum and maximum temperatures at 1,516 m elevation at Fish Camp, California (near the center of the northern site) were $-4^{\circ} \mathrm{C}$ and $8^{\circ} \mathrm{C}$, respectively.

Our study sites are topographically complex, bisected by steep river and stream canyons (Fig. 1), and field work was carried out between $1,000 \mathrm{~m}$ and $2,400 \mathrm{~m}$ elevation. Other carnivores that co-occurred with fisher in the Sierra National Forest were bobcat (Lynx rufus), coyote (Canis latrans), mountain lion (Puma concolor), gray fox (Urocyon cinereoargenteus), and black bear (Ursus americanus). Primary tree species in approximate order of abundance for conifers and then hardwoods are incense cedar (Calocedrus decurrens), white fir (Abies concolor), ponderosa pine (Pinus ponderosa), sugar pine (Pinus


Fig. 1.-Location of the northern site (A) and southern site (B) study areas in the Sierra National Forest, California.
lambertiana), California black oak (Quercus kelloggii), mountain dogwood (Cornus nuttallii), white alder (Alnus rhombifolia), and quaking aspen (Populus tremuloides). Giant sequoia (Sequoiadendron giganteum) was present but restricted to remnant populations in a few areas. Common shrubs and treelike shrubs in the study area include willow (Salix sp.), whiteleaf manzanita (Arctostaphylos viscida), greenleaf manzanita (Arctostaphylos patula), mountain misery (Chamaebatia foliolosa), blue elderberry (Sambucus mexicana), bush chinquapin (Chrysolepis sempervirens), mountain whitethorn (Ceanothus cordulatus), Sierra gooseberry (Ribes roezlii), and hoary coffeeberry (Rhamnus tomentella cuspidata).

Trapping and radiotelemetry monitoring.-We captured fishers in steel mesh traps (model 207; Tomahawk Live Trap Company, Tomahawk, Wisconsin) modified to include a wood cubby to provide refuge and to minimize injury prior
to processing and release (Wilbert 1992). Our livetrapping effort was typically focused during the fall and winter seasons each year from October 2007 to March 2013 (Sweitzer et al. 2015a). Traps were baited with venison or chicken and checked by late morning each day. Captured animals were restrained in a handling cone and sedated by intramuscular injection of Ketamine hydrochloride ( $40 \mathrm{mg} / \mathrm{kg}$ ) and Diazepam $(0.25 \mathrm{mg}$ / kg ) or Ketamine hydrochloride $(40 \mathrm{mg} / \mathrm{kg})$ and Midazolam $(0.10 \mathrm{mg} / \mathrm{kg})$. Sedated fishers were weighed, classified by age and sex based on examination of teeth, genitalia, and sagittal crest (Matthews et al. 2013), and measured for a variety of standard morphological features. Ages assigned upon capture were young of the year juvenile (6-11 months), subadult (1223 months), and adult ( $\geq 24$ months). Fishers were fitted with Holohil (28-33g) or ATS VHF radiocollars (40-42 g; Holohil Systems Model MI-2M, Ontario, Canada; Advanced Telemetry

Systems Model 1930 or 1940, Isanti, Minnesota) and received subcutaneous passive integrated transponder tags (Biomark, Boise, Idaho) for permanent identification.

Reproducing females typically cease localizing to den structures in mid- to late June but support trailing offspring until late August or early September (Matthews et al. 2013; Sweitzer et al. 2015a). We avoided placing live traps in areas with known reproductive females in the summer and did not fit radiocollars to any juveniles that were captured until after mid-August because of small body size (Facka et al. 2013). Custom breakaway devices were inserted into radiocollars affixed to juvenile fishers on the northern site and for all fishers on the southern site to allow for growth and to avoid injury between recaptures. When we lost contact with radiocollared fishers because of radiotransmitter malfunction, expended battery life, or when collars were shed because of loose fit or separation of the breakaway inserts, efforts were made to recapture those animals. After handling, we placed animals back into the cubby box and released them once they recovered from anesthesia. Capture and handling procedures followed American Society of Mammalogist guidelines (Sikes and Gannon 2011) and were approved by the Institutional Animal Care and Use Committees of the University of California, Berkeley (protocol R139) and the University of California, Davis (protocol 16302).

Monitoring and analyses of survival.-We monitored the status (alive, dead, or missing; all radiocollars were equipped with mortality sensors) of all captured and radiocollared fishers from time of 1st capture until death, censorship (dropped or failed collars), or the end of monitoring for the data set (17 March 2014). Regular monitoring was initiated the week of 18-25 March 2007 at the southern site and the week of 23-29 December 2007 at the northern site. Individual fishers were relocated and assessed for status $1-3$ times/week by ground triangulation at the southern site and 4-6 times/week by fixedwing aerial radiotelemetry (Cessna 185, Cessna Aircraft Co., Wichita, Kansas; Piper PA-18 Super cub, Piper Aircraft Inc., Vero Beach, Florida) at the northern site. We developed weekly encounter histories from the monitoring data that identified live/dead or missing status for all individual fishers (Murray 2006). Fishers that were missing for more than 2 consecutive weeks were censored even when they were recaptured $\geq$ 3 weeks later (Murray 2006), and they were added back to the data set if they were subsequently recaptured. Short duration censoring was relatively common when breakaway inserts separated and radiocollars were shed. There were 73 censor events at the northern site and 91 censor events at the southern site, but targeted livetrapping of missing fishers was usually successful for re-collaring them. For example, we noted 51 censor events with subsequent recaptures at the northern site and 70 censor events with subsequent recaptures at the southern site. We had no reason to suspect that fishers that were censored and not recaptured were likely to have died because we often recaptured and resumed monitoring individual fishers that had been missing > 52 weeks; 11 fishers that had been missing more than a year were recaptured and added back to the monitoring data set (range 383-833 days). Finally, survival assessments
typically assume that livetrapping and radiocollars do not influence survival of study animals, and records from necropsies and pathological tests performed by licensed veterinarians on carcass remains of 109 dead fishers indicated that no fisher mortalities were directly attributable to capture- or radiocollarrelated injuries (Gabriel et al., in press).

We used information on 1st initiation of reproductive behavior from 5 prior studies of fisher populations in western North America to define the population year as starting the week of 18-25 March and ending the week of 10-17 March the next year (Sweitzer et al. 2015a). We used known-fate modeling analyses in Program MARK (White and Burnham 1999) to evaluate survival of radiocollared fishers based on weekly encounter histories starting 18 March 2007 and ending 17 March 2014. Known-fate modeling in Program MARK is used to estimate survival when the fate of radiocollared individuals can be determined with certainty. The procedure accommodates staggered entry (e.g., individuals captured after the 1st week can be added to the data set) and censoring based on the same methodology as the Kaplan-Meier staggered entry procedure (Pollock et al. 1989; Cooch and White 2013). Survival estimates can be biased when sample sizes are small, or become small due to early period mortality events prior to recruitment of multiple subjects (Woodroofe 1985; Murray 2006), and we therefore pooled weekly counts of animals within each study site for all years (Koen et al. 2007; McCann et al. 2010). Survival varied among the 52 weeks of the year and may have also varied among years, but we focused our assessment on potential seasonal and sexor age-related variation relevant to the known life history and population biology of fishers (Powell 1993; Matthews et al. 2013; Sweitzer et al. 2015a). Our a priori hypotheses were that fisher survival would vary by sex, be lower for dispersalaged fishers than for adults, and would likely vary among 3 ecologically relevant seasons of the year. Survival could also vary between research sites related to differences in habitats or abundances of prey or larger predators that kill fishers in the region (Wengert et al. 2014), so we included a location variable (site) in the analyses. Fishers were grouped into 3 age classes (age3; previously defined) or 2 age classes (age2) for model assessment. Age2 age classes were 6-23 months for dispersalaged fishers or $\geq 24$ months for adult fishers. The 3 seasons (season) we defined for the analyses were spring to mid-summer (18 March to 21 July; season 1), late summer to mid-fall (22 July to 21 November; season 2), and late fall through winter (22 November to 17 March; season 3). Season 1 encompassed the denning season when adult females were localized to den structures and foraging more frequently to support the high energetic costs of lactation, when males exhibited expansive movements seeking mating opportunities, and when growers begin dispersing poisons around trespass marijuana grow sites in our study area (Thompson et al. 2013). Season 2 included the period when young rodents, birds, and other prey consumed by fishers were increasingly abundant. Season 3 encompassed most of the cool, wet season when snow accumulates as persistent snow cover, and when reptiles and several species of rodent prey are in torpor (Zielinski and Duncan 2004).

Modeling approaches for assessing survival are recommended over univariate tests that do not consider multiple factors influencing mortality risk in free-ranging animals (Murray 2006). Moreover, Burnham and Anderson (2002) recommend that individual candidate models should be biologically relevant and link to specific research hypotheses. Therefore, we used 2 different known-fate model assessments to evaluate our hypotheses on fisher survival. Known-fate assessment 1 included candidate models with the variables age3, sex, site, and season and was used to evaluate the hypotheses that survival varied seasonally, that survival was lower for male compared to female fishers, and that survival varied between the 2 study sites. Known-fate assessment 2 included candidate models with the variables age2, sex, and site and was used to evaluate the hypothesis that survival would be lower for dis-persal-aged fishers compared to adult fishers. We used AIC $_{c}$ (Akaike Information Criterion adjusted for small sample sizeBurnham and Anderson 2002) to rank the candidate models and followed an information-theoretic approach for evaluating them. We considered the candidate model with the smallest $\mathrm{AIC}_{\mathrm{c}}$ and largest AIC weights $\left(\mathrm{AIC} \omega_{\mathrm{i}}\right)$ the "top" model, and candidate models within $2 \Delta \mathrm{AIC}_{\mathrm{c}}$ units of the top model to have support for understanding population-level survival in our study area (Burnham and Anderson 2002). We used relative importance values to identify the subset of variables that were most valuable for understanding variation in fisher survival (Burnham and Anderson 2002), where variables with relative importance values $\geq 0.75$ were considered highly predictive of fisher survival, and those with lower relative importance were less predictive of fisher survival. Relative importance for each variable was estimated as the sum of $\mathrm{AIC} \omega_{\mathrm{i}}$ for all candidate models including the variable (Burnham and Anderson 2002). Data on weekly survival from the top model were transformed (projected) to season-specific survival rates based on the product of weekly survival rates. We used estimates of weekly survival from other candidate models to project to annual survival for subadults, adults, and 6-month survival for juveniles for the purpose of reporting and comparing our data to other reports for fishers in the West Coast population segment. We used the delta method (Powell 2007) to calculate variance and 95\% confidence intervals (CIs) for season-specific, annualized, and 6-month survival rates. We used Z-tests to compare annual or seasonal survival rates for the subset of variables identified as highly predictive of survival from the known-fate model assessments.

Juvenile survival.-The weekly survival rate determined from known-fate analyses for juvenile fishers that were monitored in the 6 months from 30 September to 17 March corresponded to when we typically captured young of the year fishers in the study. The 6-month survival rate projected from weekly survival for juveniles did not account for fisher mortalities that may have occurred between birth in late March and 30 September. We therefore followed Sweitzer et al. (2015a) when estimating an adjusted rate for juvenile survival based on the product of kit survival in the denning season (late March to mid-June, 0.823 —Sweitzer et al. 2015a) $\times$ survival of adult
females with trailing kits from 10 June to 1 September estimated using Kaplan-Meier models (0.880—Sweitzer et al. 2015a) $\times$ the 6-month survival rates for radiocollared juvenile female and male fishers from 30 September to 17 March. An alternative would be to project the weekly survival rate for juveniles from 30 September to 17 March for the 40 weeks from 10 June to 17 March, but that method precludes the potential for higher summer survival when juveniles are trailing their mothers and being protected and provisioned.

## Results

We radiocollared 113 fishers at the northern site and 119 fishers at the southern site during the study (Table 1). Radiocollared fishers were monitored for 55,525 radio days at the northern site, while those on the southern site were monitored 60,676 radio days (Table 1). Individual radiocollared fishers were monitored an average of 497 radio days (range $9-1,807$ ) at the northern site and an average of 505 radio days (range 4-1,910) at the southern site. Sixty-three ( $56 \%$ ) of the individual fishers captured and radiomarked on the northern site were known to have perished, compared to $57(48 \%)$ of fishers captured on the southern site (Table 1). Thirty-five (55.5\%) of the known mortalities among radiocollared fishers at the northern site occurred in season 1 (spring to mid-summer), compared to 15 (23.8\%) in season 2 (summer to mid-fall), and 13 (20.6\%) in season 3 (late fall and winter; Table 2). Twenty-two (38.6\%) of the known mortalities among radiocollared fishers at the southern site occurred in season 1, compared to 18 (31.6\%) in season 2, and $17(29.8 \%)$ in season 3 (Table 2). Overall, the highest percentage of known mortalities in the study occurred within season $1(47.5 \%)$, and the lowest percentage occurred within season 3 ( $25 \%$; Table 2).

Our known-fate model assessment 1 identified a single top model for understanding fisher survival at our study sites that included the variables sex and season, and there were no other candidate models with support (Table 3). Based on relative importance values of 0.85 for sex, 0.99 for season, 0.19 for age 3 , and 0.01 for site, sex and season were highly predictive of fisher survival, whereas age and study site were of low predictive value (Table 3; Fig. 2). The high relative importance of sex was due to an estimated $13 \%$ lower annualized survival for male fishers ( 0.62 ) compared to female fishers ( 0.72 ) in our study populations $(Z=-2.54, P=0.062$; Table 4 ; Fig. 2). Weekly survival projected for each season was lower in season $1(0.83)$ compared to in season $2(0.90 ; Z=-2.54, P=0.006)$ and lower in season 1 compared to in season $3(0.92 ; Z=-3.53$, $P=0.0002$; Table 4). Fisher survival was similar between season 2 and season $3(Z=-0.85, P=0.197$; Table 4). These results supported suggestions that fisher survival would be lower in the spring to mid-summer period compared to other seasons, while further indicating that fisher survival was high in winter rather than low (Fig. 2).
Survival among male fishers was lower in season 1 (0.76) compared to season $2(0.92 ; Z=-3.48, P=0.0005$; Table 4) and lower in season 1 compared to season $3(0.88 ; Z=-2.61$,

Table 1.-Information on radiocollared fishers that were captured and monitored for survival in 7 population years (18 March to 17 March) at a northern site and southern site in the Sierra National Forest, California, from 18 March 2007 to 17 March 2014.

| Site, year | Monitored ${ }^{\text {a }}$ | Individual fishers ${ }^{\text {b }}$ |  | Mortalities ${ }^{\text {c }}$, Long missing ${ }^{\text {d }}$ |  |  | Radio days ${ }^{\text {e }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Female | Male | Female | Male | Missing |  |
| Northern site |  |  |  |  |  |  |  |
| 2007-2008 | 10 | 3 | 7 |  | 1 |  | 586 |
| 2008-2009 | 41 | 24 | 10 | 3 | 5 | 2 | 7,259 |
| 2009-2010 | 51 | 11 | 9 | 8 | 4 | 4 | 9,581 |
| 2010-2011 | 55 | 10 | 8 | 8 | 5 | 4 | 9,453 |
| 2011-2012 | 59 | 11 | 10 | 6 | 3 | 11 | 9,767 |
| 2012-2013 | 52 | 5 | 3 | 5 | 3 | 8 | 11,985 |
| 2013-2014 | 35 | 1 | 1 | 4 | 8 | 12 | 6,894 |
| All year totals | 113 | 65 | 48 | 34 | 29 | 41 | 55,525 |
| Southern site |  |  |  |  |  |  |  |
| 2007-2008 | 25 | 13 | 12 | 3 | 3 |  | 4,091 |
| 2008-2009 | 41 | 15 | 7 |  | 3 | 2 | 8,377 |
| 2009-2010 | 49 | 7 | 6 | 5 | 4 | 6 | 9,563 |
| 2010-2011 | 48 | 8 | 7 | 8 | 2 | 8 | 10,036 |
| 2011-2012 | 45 | 9 | 5 | 6 | 3 | 4 | 8,408 |
| 2012-2013 | 46 | 8 | 6 | 2 | 4 | 2 | 9,677 |
| 2013-2014 | 53 | 9 | 7 | 11 | 3 | 10 | 10,524 |
| All year totals | 119 | 69 | 50 | 35 | 22 | 32 | 60,676 |

${ }^{a}$ Number of individual fishers monitored for $\geq 1$ day in the population year, or during all years of the study.
${ }^{\mathrm{b}}$ Number of previously unmarked fishers captured in the population year, or during all years of the study.
${ }^{\text {c }}$ Number of known fisher mortalities in the population year, or during all years of the study.
${ }^{\mathrm{d}}$ Number of individual fishers with dropped or failed radiocollars in the population year that were not subsequently recaptured. Represents those fishers that were permanently censored in the weekly encounter histories used for analyses of survival.
${ }^{\mathrm{e}}$ Number of days that radiocollared individual fishers were known alive and monitored for $\geq 1$ day within the population year, or during all years of the study.

Table 2.-Data on seasons within the population year (18 March to 17 March) when radiocollared female and male fishers were confirmed as mortalities at a northern site and a southern site in the Sierra National Forest, California, from 18 March 2007 to 17 March 2014.

| Season ${ }^{\text {a }}$ | Northern site |  | Southern site |  | All fishers (\%) |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Female | Male | Female | Male |  |
| Season 1 (18 Mar. to 21 Jul.) | 17 | 18 | 12 | 10 | 57 (47.5\%) |
| Season 2 (22 Jul. 17 Nov.) | 9 | 6 | 14 | 4 | 33 (27.5\%) |
| Season 3 (18 Nov. to 17 Mar.) | 5 | 8 | 9 | 8 | 30 (25\%) |
| Totals | 31 | 32 | 35 | 22 | 120 (51.7\%) ${ }^{\text {b }}$ |

${ }^{\text {a }}$ Season 1 was described as spring to mid-summer, season 2 was late summer to mid-fall, and season 3 was late fall and winter.
${ }^{\text {b }}$ The value in parentheses represents the percentage of all 232 radiocollared fishers ( $n=113$ at the northern site, $n=119$ at the southern site) that were known to have died before 17 March 2014.
$P=0.009$; Table 4). Survival among male fishers was similar between season 2 and season $3(Z=1.07, P=0.285$; Fig. 2). Survival among female fishers was similar between season 1 (0.86) and season $2(0.88 ; Z=-0.49, P=0.624)$ and lower between season 1 and season 3 ( $0.94 ; Z=-2.48, P=0.013$; Table 4). Survival among female fishers trended lower between season 2 and season $3(Z=1.90, P=0.057)$.

Our known-fate model assessment 2 identified a single top model including the variable sex, but no other candidate models with support for understanding fisher survival. Variable age2 was not included in the top model and had a low relative importance of 0.18 , which indicated lack of support for the hypothesis that dispersal-aged fishers experienced lower survival than adult fishers in our study area (Tables 3 and 4). Moreover, considering the low relative importance values for the age 3 and age 2 variables in the known-fate models (Table 3), there was
no evidence for age-related differences in fisher survival in our study populations. Variable site also had low predictive value in both model assessments (Table 3), indicating that fisher survival was similar at the 2 study sites.

Model-determined weekly survival for juvenile fishers projected for the 6 months from 30 September to 17 March was 0.86 for females and 0.79 for males (Table 4). The product of kit survival in the denning period, adult female survival during summer, and 6-month juvenile survival (e.g., adjusted juvenile survival) was 0.62 ( $95 \%$ CI $0.56-0.68$ ) for females and 0.57 ( $95 \% C I 0.52-0.62$ ) for males $(Z=1.23, P=0.22)$.

## Discussion

Our study provides new information on population-level survival for fishers in the southern Sierra Nevada, California,

Table 3.-Candidate models used in known-fate analyses in Program MARK to evaluate hypotheses on survival of fishers at 2 study sites in the Sierra National Forest, California, from March 2007 to March 2013. Predictor variables in Model 1 included sex, site (northern or southern), age3 (juvenile [6-11 months], subadult [12-23 months], adult [ $\geq 24$ months]), and season (season 1 [18 Mar. to 21 Jul.]; season 2 [22 Jul. to 17 Nov.]; season 3 [ 18 Nov. to 17 Mar.]). Predictor variables in Model 2 included sex, age2 (juvenile + subadults [6-23 months], adult [ $\geq 24$ months]), and site.

| Model, candidate models | AIC $_{\mathrm{c}}{ }^{\mathrm{a}}$ | $\Delta \mathrm{AIC}_{\mathrm{c}}$ | $\omega_{\mathrm{i}}^{\mathrm{b}}$ | $K^{\mathrm{c}}$ | Model <br> likelihood |
| :--- | ---: | ---: | ---: | ---: | :---: |
| Model 1 variables: age3, sex, site, season ${ }^{\mathrm{d} e}$ |  |  |  |  |  |
| Sex + season | $4,229.7$ | 0.00 | 0.68 | 6 | 1.00 |
| Age3 + sex + season | $4,232.7$ | 3.06 | 0.15 | 15 | 0.22 |
| Season | $4,233.4$ | 3.78 | 0.10 | 3 | 0.15 |
| Age3 + season | $4,235.1$ | 5.50 | 0.04 | 8 | 0.06 |
| Sex + site + season | $4,237.7$ | 8.03 | 0.01 | 12 | 0.02 |
| Sex | $4,239.6$ | 9.91 | 0.00 | 2 | 0.01 |
| Site | $4,242.8$ | 13.11 | 0.00 | 2 | 0.00 |
| Sex + site | $4,243.4$ | 13.74 | 0.00 | 4 | 0.00 |
| Age3 + sex + site + season | $4,245.1$ | 15.42 | 0.00 | 28 | 0.00 |
| Age3 | $4,245.1$ | 15.42 | 0.00 | 3 | 0.00 |
| Age3 + sex | $4,247.4$ | 17.78 | 0.00 | 6 | 0.00 |
| Age3 + sex + site | $4,257.6$ | 27.99 | 0.00 | 12 | 0.00 |
| Model 2 variables: age2, sex, site |  |  |  |  |  |
| Sex | $4,239.6$ | 0 | 0.60 | 2 | 1 |
| Site | $4,242.7$ | 3.19 | 0.12 | 2 | 0.20 |
| Age2 | $4,243.2$ | 3.59 | 0.10 | 2 | 0.17 |
| Sex + site | $4,243.4$ | 3.82 | 0.09 | 4 | 0.15 |
| Age2 + sex | $4,243.5$ | 3.97 | 0.08 | 4 | 0.14 |
| Age2 + sex + site | $4,251.4$ | 11.81 | 0.002 | 8 | 0.003 |

aDifference between model's Akaike Information Criterion corrected for small sample size.
${ }^{\mathrm{b}}$ Akaike weight $\left(\omega_{\mathrm{i}}\right)$ provides evidence of model likelihood.
${ }^{\mathrm{c}}$ Number of parameters estimated.
${ }^{\text {d }}$ Weekly encounter histories used to assess survival for juvenile fishers for variable age 3 started 30 September to 6 October and ended 10-17 March, which represented 24 weeks ( 6 months).
${ }^{\text {e }}$ Relative importance values for variables in Model 1 were 0.99 for season, 0.85 for sex, 0.19 for age 3 , and 0.01 for site.
${ }^{\mathrm{f}}$ Relative importance values for variables in Model 2 were 1.0 for sex, 0.21 for site, and 0.18 for age 2 .
which is important because these types of data have been lacking and needed for an understanding of the long-term prospects for fishers in the region after it was determined that they were being exposed to direct mortality from disease, predation, roadkill, and exposure to toxicants at trespass marijuana grow sites (U.S. Department of the Interior Fish and Wildlife Service 2014a). While we anticipate future analyses evaluating whether survival of fishers is depressed by forest management activities that could impinge on fisher habitats (Truex and Zielinski 2013), our results herein provide evidence for lower survival in the male segment of the population, and indications of seasonal variation in survival that was not entirely congruent for females and males. Our analyses did not provide evidence for a cost of dispersal on survival of young age fishers, which we will also discuss below.

Survival in mammalian vertebrates is often lower for males than females and may also have a seasonal component
due to differences in food availability, higher energetic costs of reproduction in spring, or exposure to periods of cold, inclement weather (White et al. 2011; Clark et al. 2014). Both of these general patterns were evident in our study population (Fig. 2). Annualized survival trended lower for male fishers, but a closer examination of the data suggested that this pattern was primarily associated with lower survival among males in the spring period of the year (Fig. 2). Survival among female fishers was lowest in spring and gradually increased as the population year progressed into winter (Fig. 2). We therefore consider that the importance of sex as a predictor of survival was because males encountered more challenges than females in the spring breeding season, which was in agreement with Powell et al. (2013) and Lewis (2014), who suggested that expansive movements by males associated with finding and mating with females in late March to mid-April exposes them to higher risk. Koen et al. (2007) and York (1996) reported lower survival for male fishers in harvest-exposed populations in eastern Ontario, Canada, and Massachusetts, and sex-based differences in survival have also been reported for non-harvested fishers elsewhere within the West Coast population segment. In notable contrast to our study, however, point estimates of survival for 6 of 7 studies in the West Coast population segment suggested that survival among female fishers was about the same or lower than survival of males (Table 5). Lewis (2014) suggested that lower survival among reintroduced female fishers in Olympic National Park may have been due to higher mortality risk in the prolonged period required for them to establish home ranges in suitable habitat. Female American marten (Martes americana) in Maine were also reported as having lower survival than male marten, likely due to higher predation on smaller-size females (Harrison et al. 1997). Adult female fishers (mean body mass $=2.1 \mathrm{~kg}$ ) in our study area are smaller than adult males (mean body mass $=4.3 \mathrm{~kg}$; R. A. Sweitzer, pers. obs.), and Wengert et al. (2014) reported that smaller female fishers were more likely to be killed by bobcats and that mountain lions killed both female and male fishers. It is possible but unknown if some of the variation in survival for female and male fishers among populations in the West Coast population segment (Table 5) is related to differences in predator communities (Wengert et al. 2014). We also note that much of the data summarized in Table 5 were drawn from unpublished reports with relatively smaller sample sizes, and several of the studies were ongoing.

Low survival among female fishers from spring continuing through summer to early fall was consistent with the hypothesis that the combined energetic costs of lactation and extensive movements to support dependent offspring until late summer (Powell and Leonard 1983; Powell 1993) expose them to higher risk and subsequent lower survival in those periods. Sweitzer et al. (2015a) reported multiple deaths of denning female fishers at the northern study site from predator attacks at or near den trees, and data from remote cameras used to monitor denning females included that female fishers spent more time foraging away from den trees late in the den season compared to


Fig. 2.-Survival rates for a) female and male fishers, b) according to season, and c) female and male fishers in 3 different seasons from the start to the end of the fisher population year ( 18 March to 17 March). Survival rates were transformed from weekly survival estimates derived from known-fate analyses of encounter histories for radiocollared fishers in the Sierra National Forest, California, from 18 March 2007 to 17 March 2014.
early in the den season (Sweitzer et al. 2015b). Krohn et al. (1994) reported lower survival for both male and female fishers in Maine during the fall trapping season (late October to early December) compared to outside of that period. Three other ongoing studies of fishers within the West Coast population segment used known-fate modeling to assess potential seasonal variation in survival. Although season for these studies
were defined differently, season was included in the top model set for all 3 studies, with lower survival evident in spring, or in spring and summer compared to other periods of the year (Table 5). Thus, data from our study and 3 other non-harvested populations do not support that survival among fishers is lower in winter because of higher energetic costs or limited availability of prey.

Table 4.-Model determined survival rates, $s(t)$, of fishers for variables included in known-fate survival analyses in Program MARK. Ages were defined as 6-11 months for juveniles, 12-23 months for subadults, $\geq 24$ months for adults, and 6-23 months for "young" fishers. Weekly survival rates were from candidate models in Table 3, and weekly encounter histories for radiocollared fishers from March 2007 to March 2014 at 2 study sites in the Sierra National Forest, California.

|  | Weekly $s(t)(S E)^{\mathrm{a}}$ | Weeks for projection | $\begin{gathered} \text { Projected } \\ s(t)(95 \% C I)^{\mathrm{b}} \end{gathered}$ |
| :---: | :---: | :---: | :---: |
| Season ${ }^{\text {c }}$ |  |  |  |
| Season 1 (18 Mar. to 21 Jul.) | 0.989 (0.001) | 18 | 0.83 (0.78-0.87) |
| Season 2 (22 Jul. to 17 Nov.) | 0.994 (0.001) | 17 | 0.90 (0.86-0.93) |
| Season 3 (18 Nov. to 17 Mar.) | 0.995 (0.001) | 17 | 0.92 (0.89-0.94) |
| Sex and season ${ }^{\text {d }}$ |  |  |  |
| Female, season 1 | 0.992 (0.002) | 18 | 0.86 (0.82-0.91) |
| Male, season 1 | 0.985 (0.003) | 18 | 0.76 (0.69-0.84) |
| Female, season 2 | 0.992 (0.002) | 17 | 0.88 (0.83-0.93) |
| Male, season 2 | 0.995 (0.002) | 17 | 0.92 (0.87-0.97) |
| Female, season 3 | 0.996 (0.001) | 17 | 0.94 (0.90-0.97) |
| Male, season 3 | 0.993 (0.002 | 17 | 0.88 (0.83-0.94) |
| Sex and age ${ }^{\text {e }}$ |  |  |  |
| Females (all ages) | 0.994 (0.001) | 52 | 0.72 (0.66-0.78) |
| Males (all ages) | 0.991 (0.001) | 52 | 0.62 (0.54-0.70) |
| Juvenile female ${ }^{\text {f }}$ | 0.994 (0.003) | 24 | 0.86 (0.75-0.96) |
| Juvenile male | 0.990 (0.004) | 24 | 0.79 (0.65-0.93) |
| Subadult female | 0.993 (0.001) | 52 | 0.71 (0.59-0.83) |
| Subadult male | 0.992 (0.002) | 52 | 0.65 (0.50-0.80) |
| Young female ${ }^{\text {g }}$ | 0.994 (0.001) | 76 | 0.61 (0.48-0.74) |
| Young male ${ }^{\text {g }}$ | 0.991 (0.002) | 76 | 0.52 (0.37-0.67) |
| Adult female | 0.994 (0.001) | 52 | 0.72 (0.65-0.79) |
| Adult male | 0.991 (0.002) | 52 | 0.62 (0.52-0.72) |

${ }^{a}$ Weekly survival and SEs from known-fate survival analyses. Rates, SEs, and $95 \%$ CIs shown to 3 significant digits, but 7 significant digits were used for seasonal or annual projections.
${ }^{\mathrm{b}}$ Estimated by projecting weekly survival for the number of weeks in each season or time period. Projected rates were reported to 2 significant digits only, and variances used to calculate $C I$ s were estimated using the delta method (Powell 2007).
${ }^{\text {c Parameter estimates from candidate model Season in Table } 3 .}$
${ }^{\text {d Parameter estimates from candidate model Sex }+ \text { season in Table } 3 .}$
${ }^{\text {eParameter estimates from candidate models Sex, age3 }+ \text { sex, and Age2 }+ \text { sex }}$ in Table 3.
${ }^{\text {f }}$ Survival projected for 24 weeks ( 30 September to 17 March) because most young of the year juveniles $(90 \%, n=109)$ were captured in this period. ${ }^{8}$ Survival projection for 76 weeks, corresponding to survival from 30 September when fishers were young of the year juveniles until they were $\approx 23$ months old.

It has only recently been learned that poisons deposited around trespass marijuana grow sites in the western United States can cause both direct and indirect mortality to fishers (Gabriel et al. 2012). Although much is uncertain on the source and rates of application of toxicants used at trespass grow sites in California, we do know that they plant their crops in spring as soon as snow melt permits access to remote areas and that use of toxicants is heaviest in spring when the plants are small and most vulnerable to herbivory (C. M. Thompson, pers. obs.). Further, when the marijuana plants are harvested 3-5 months later, large amounts of toxicants are typically left in the environment (Gabriel et al. 2013). Model-supported patterns in our data were that fisher survival was lowest in spring to mid-summer but increased thereafter, which did not suggest
continuing potential toxicant-related effects on fisher survival in fall and winter. We have not established a direct link, but it is possible that depressed fisher survival in the spring to midsummer was partly from secondary exposure to toxicants when growers were applying poisons at high rates early in their growing season. Other carnivores and nontarget species including bobcats, mountain lions, American badger (Taxidea taxus), red fox (Vulpes vulpes), Great bustards (Otis tarda), little spotted kiwis (Apteryx owenii), and the North Island saddleback (Philesturnus carunculatus rufusater) are known vulnerable to similar toxicants used around trespass grow sites in the Sierra Nevada region of California (Shore et al. 1999; Robertson and Colbourne 2001; Davidson and Armstrong 2002; Riley et al. 2007; Lemus et al. 2011; Proulx and MacKenzie 2012; Thompson et al. 2013). It is likely that the diverse types of poisons spread in the environment at grow sites in the Sierra National Forest are also depressing populations of multiple prey species consumed by fishers (Spencer et al. 2015a), similar to the negative effects rodenticides have on nontarget wildlife in other regions (Ruder et al. 2011; Sánchez-Barbudo et al. 2012). We know that exposure to rodenticides and other toxicants at trespass grow sites directly killed 13 fishers in California (Gabriel et al., in press), and Thompson et al. (2013) reviewed a wide range of sublethal effects of toxicant exposure which can impair normal physiological function and contribute to reduced survival among fishers. Future research that documents the spatial extent of environmental contamination by toxicants and their population-level impacts for species of conservation concern like the fisher is needed.

A significant body of work has focused on the dynamics of dispersal because of the many ways this life history process influences individual fitness, population genetics and demography, and persistence of wildlife population on the landscape (Greenwood 1980; Chepko-Sade and Halpin 1987; Olson et al. 2014; Tucker et al. 2014). Our results did not support the hypothesis that dispersal is costly in terms of reduced survival among dispersal-aged fishers. Arthur and Paragi (1993) and Matthews et al. (2013) described aspects of fisher dispersal in Maine and in northwestern California, respectively. Matthews et al. (2013) suggested that fishers in northern California may have limited dispersal ability, but neither study evaluated the consequences of dispersal on survival. Johnson et al. (2009) evaluated mortality risk and dispersal dynamics among American marten and were able to determine that those that dispersed longer distances and through regenerating forests instead of through uncut forests experienced the lowest survival. Similar, more detailed analyses of the potential survival costs and habitats associated with dispersal movements are needed for fishers in the southern Sierra Nevada region because there are no indications that they are expanding back into suitable historic range north of our study area despite protective management and redevelopment of mature forest conditions in that region (Zielinski et al. 2013a; Spencer et al. 2015a).

Younger carnivores commonly have lower survival than older ones (Krebs et al. 2004; Farias et al. 2005; Clark et al. 2014), but reliable data on survival of juvenile fishers in their 1st full year of life are entirely lacking because researchers generally

Table 5.-Comparative review of point estimates of annual survival for female and male fishers that were determined from monitoring of radiocollared fishers at study sites in the western United States and in areas where fisher were not commercially trapped. The Sierra National Forest location was this study, and annualized survival rates were developed using weekly survival rates from known-fate model assessments for data from radiocollared fishers at 2 study sites.

| Location of research | Female survival |  |  | Male survival |  |  | Source of data |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | All | Adult | Juvenile ${ }^{\text {a }}$ | All | Adult | Juvenile |  |
| Sierra National Forest | 0.72 | 0.72 | $0.866_{\text {month }}, 0.62_{\text {adjusted }}$ | 0.63 | 0.61 | $0.79{ }_{6 \text { month }}, 0.57_{\text {adjusted }}$ | Table 3 |
| Olympic National Park, Washington ${ }^{\text {b }}$ | 0.55 | 0.52 | 0.62 | 0.74 | 0.68 | $0.76{ }^{\text {c }}$ | Lewis (2014) |
| Sequoia National Forest, California | 0.61 |  |  | 0.73 |  |  | Truex et al. (1998) |
| East Klamath region, northern California | 0.73 |  |  | 0.86 |  |  | Truex et al. (1998) |
| North Coast region, northwest California | 0.84 |  |  | 0.84 |  |  | Truex et al. (1998) |
| Hoopa Valley, northern California ${ }^{\text {d }}$ |  | 0.78 |  |  | 0.74 |  | Higley et al. (2012) |
| Northeastern California ${ }^{\text {e }}$ | 0.93 |  |  | 0.96 |  |  | Powell et al. (2013) |
| Rogue River region, southern Oregon | 0.78 |  |  | 0.85 |  |  | Aubry and Raley (2006) |

${ }^{a}$ Weekly survival for juvenile fishers from known-fate survival analyses was projected for 6 months ( 30 September to 17 March; Table 3). Six-month juvenile survival was adjusted used data reported by Sweitzer et al. (2015a) on survival of kits in the den season ( 0.823 ), and summer survival of adult females with trailing kits from June 10 to September $1(0.880)$. The adjusted rates are the product $0.823 \times 0.880 \times 0.856$ for juvenile females, and $0.823 \times 0.880 \times 0.789$ for juvenile males.
${ }^{\text {b }}$ Olympic Fisher Reintroduction Project; point estimates of survival were estimated as the mean of 2nd year post-release survival rates for 3 release cohorts from Table 2.5 (Lewis 2014).
${ }^{\text {c }}$ Lewis (2014) defined juvenile males as 0-23 months old; this survival rate is not directly comparable to this study.
${ }^{\text {d }}$ Hoopa Valley Indian Reservation Fisher Project; survival rates are the average of survival estimates from capture-mark-recapture data and known-fate models described by Higley et al. (2013).
${ }^{\text {e}}$ Stirling Management Area Fisher Reintroduction Project; survival rates reported by Powell et al. (2013) were estimated as the product of April to August survival $\times$ September to March survival (females), or the product of March to May survival $\times$ June to February survival (males).
do not attempt to monitor them before they are $\geq 6$ months old (Facka et al. 2013). Although we found no evidence for agerelated variation in survival among radiocollared fishers in our study populations, we believe this result was partly due to the high 6-month survival rates of 0.86 for juvenile female and 0.79 for juvenile male fishers, which was a consequence of not monitoring them during their first 5 months of life (Facka et al. 2013). We consider it unlikely that juvenile survival would be higher than adult survival (Table 4), and our adjusted survival rates of 0.62 for juvenile females and 0.57 for juvenile males appear more realistic based on the many risks naïve young of the year fishers would encounter in our study area (Chow 2009; Gabriel et al. 2012; Keller et al. 2012; Wengert et al. 2014). We acknowledge some uncertainty for our adjusted survival rates, however, related to whether all kits that are produced in March to early April are weaned from den trees (Matthews et al. 2013) and because of no information on young of the year survival for most of September (Sweitzer et al. 2015a). Nevertheless, we believe that the adjustments we applied provide improved insight on this important demographic parameter, which links to recruitment and how resilient the species will be as resource managers continue efforts to increase their range and abundance in California and elsewhere (Lofroth et al. 2010; Matthews et al. 2013; Spencer et al. 2015b).

Vital rates for wildlife populations occurring in close proximity in multiple use landscapes may vary when predator or prey communities or human pressures from hunting and disturbances to habitat differ (McLellan 2015). Our 2 study populations were in the same national forest but separated by $\approx 40 \mathrm{~km}$ and a major river canyon (San Joaquin River; Fig. 1). We found no evidence for a site effect on fisher survival, however, suggesting that land use, habitats, and predator communities within
our Sierra National Forest study sites were generally similar. This is important for identifying that encounter histories from the northern and southern sites can be pooled and used to generate more precise estimates of survival for region-scale population viability models. For example, Sweitzer et al. (2015a) estimated demographic rates and developed a population model to evaluate the growth trajectory for the fisher population at the northern study site. The deterministic population growth rate ( $\lambda$ ) for fishers within the northern site for the period from 2008 to 2013 was estimated at 0.97 (range $0.79-1.16$ ), which, together with concurrent information on population size and density, suggested the population was basically stable (Sweitzer et al. 2015a). A previous habitat-linked assessment for fishers within the southern Sierra Nevada region suggested that the larger, overall population of around 500 total fishers has the potential to increase and expand, provided annual survival of adult females, subadult females, and juvenile females are in the range of 0.90 , 0.70 , and 0.50 , respectively (Spencer et al. 2011). Both Sweitzer et al. (2015a) and Spencer et al. (2011) reported that population growth for fishers in the Sierra Nevada was much more sensitive to adult female survival than any other demographic rate, and our estimate of annual survival for adult female fishers (0.72) was $20 \%$ lower than 0.90 . Because annual survival of adult female fishers is lower than previously believed, it may be more of a challenge to maintain a self-sustaining fisher population in this part of the West Coast population segment.

Information from this study provide quantitative data on survival patterns and survival rates for fishers at the northern terminus of the small, remnant fisher population in the southern Sierra Nevada, California. Most of these data have been integrated into the Southern Sierra Nevada Fisher Conservation Assessment (Spencer et al. 2015a) and are also being used to
formulate a conservation strategy for fishers in the southern Sierra Nevada region of California (Spencer et al. 2015b). As part of conservation planning for fishers in the southern Sierra Nevada, data from our 2 study sites are being used to update a previous region-scale population viability model and to develop a spatially explicit population model framed around empirically determined demographic and vital rates. We are hopeful that a long-term self-sustaining fisher population in the southern Sierra Nevada can be encouraged as resource managers adapt forest management in the region (North et al. 2009) to emerging insights on habitat use, denning ecology (Zhao et al. 2012), responses of fishers to wildfires (Hanson 2013; Sweitzer et al., in press), and proactive restorative forest management to protect forest habitats used by fishers (Thompson et al. 2011; Aubry et al. 2013; Truex and Zielinski 2013; Zielinski et al. 2013b).

## Acknowledgments

The field effort would not have been possible without help from a dedicated team of staff and volunteers including, J. Ashling, S. Bassing, A. Beaudette, J. Busiek, A. Cellar, T. Day, Z. Eads, T. Gorman, D. Hardeman, D. Jackson, W. Mitchell, B. Nieles, C. O'Brien, M. Ratchford, J. Ruthven, J. Schneiderman, W. Sicard, T. Thein, S. Vogel, R. Wise, T. Watson, and others on the northern site, and J. Garner, T. Brickly, J. Banaszak, C. Indelicato, N. Hebert, Z. Miller, B. Nichols, S. Rossler, T. Smith, Z. Stoll, and G. Watts on the southern site. We thank Forest Service pilots, J. Irving, S. Forkel, B. Bulfer, C. Haney, and especially J. Litton for aviation support. Local support at the northern site was facilitated by B. Persson, A. Otto, and A. Lombardo. We also thank 2 anonymous reviewers for comments and suggestions that helped improve the manuscript. This study was associated with the Sierra Nevada Adaptive Management Project (SNAMP) and is SNAMP publication no. 42. Our research was funded by U.S. Forest Service Region 5, U.S. Forest Service Pacific Southwest Research Station, U.S. Fish and Wildlife Service, California Department of Water Resources, California Department of Fish and Game, California Department of Forestry and Fire Protection, the Sierra Nevada Conservancy, and the California Agricultural Experiment Station.

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Submitted 31 March 2015. Accepted 19 October 2015.

## Associate Editor was Bradley J. Swanson.

