Upper San Joaquin watershed deer herd delineation, migratory behavior, and population dynamic telemetry project final report

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The California Department of Fish and Wildlife (Department) captured 50 mule deer (*Odocoileus hemionus*) in the San Joaquin River watershed from April 2013 through April 2015. We placed Global Positioning System (GPS) collars on 40 adult or yearling does and radio telemetry collars using very high frequency (VHF) transmitters on eight adult and yearling does, and one yearling buck; one buck fawn was ear tagged and released. We defined a primary winter range and three migratory corridors for deer using that watershed. We identified five holding areas along the migration corridors. Summer range habitat was evaluated. We compared current data to that from previous research to develop a better understanding of deer behavior and biology in the watershed as well as changes over time. We discuss major habitat changes, particularly those that occurred during the study period, and provide management and research recommendations.

Key words: mule deer (*Odocoileus hemionus*), Sierra Nevada, migration, telemetry, seasonal range use.

The San Joaquin watershed is one of the dominating geographic features in the Central Sierra Nevada. Mule deer (*Odocoileus hemionus*) are a common wild ungulate in the upper watershed. The upper San Joaquin watershed encompasses 265,215 ha, about half of the D-7 deer hunt zone.

In the mid-twentieth century, the California Department of Fish and Wildlife (Department) divided the state into regions, units and sub-units for the purpose of deer management (Longhurst et al. 1952). For migratory herds they used interviews with local experts to map herd boundaries "in a general way". "In most instances the criterion for defining a management sub-unit was that it should contain one major deer herd, using one particular area of winter range..." Therefore, in most cases, sub-unit and herd designations are interchangeable. Deer herd is the term in common usage and we refer to sub-units as herds hereafter. The San Joaquin watershed lies in the center of the "Madera unit" and the five herds described within the "Madera unit" are either wholly within or overlap portions of the watershed. The migratory herds are, the Oakhurst, San Joaquin, Huntington, and North Kings, and the non-migratory herd is the Friant or South Sierra Foothill (Longhurst et al. 1952).

In addition to the previously mentioned herds, deer from the Round Valley herd migrate westward over the Sierran crest into the upper San Joaquin Watershed (Kucera 1988, Kucera 1992; Pierce 1999, Monteith et al. 2011).

Sierran migratory deer have both winter and summer home ranges (Leopold et al. 1951). During the early 1980s, the Department wrote deer herd management plans, in which it described herd boundaries, winter ranges, summer ranges and migration corridors for each herd. The Oakhurst herd's range lies within the Fresno River watershed and includes the Willow Creek watershed, which flows into the San Joaquin River (Peabody 1984). The boundary between the

Oakhurst and San Joaquin herds runs along Chiquito and Whiskey Ridges. The San Joaquin herd's range is most of the San Joaquin watershed west of the main stem of the San Joaquin River and the area North of Kaiser Ridge to the east (Peabody 1983). The Huntington herd lies south of Kaiser Ridge and includes the Big Creek and Tamarack Creek watersheds, it's southern boundary runs along Tamarack Ridge, at Musick Mountain it curves westward around Shaver Lake and then south to Tollhouse (Rempel 1984). The North Kings herd range is largely in the North Fork of the Kings River watershed, its northern boundary follows the southern boundary of the Huntington herd but its range includes a portion of the San Joaquin watershed north of Pine Ridge, near Shaver Lake (Winter 1970, Chapel and Rempel 1981).

Later wildlife managers investigated deer movement within the watershed and their findings did not always correspond to early perceptions recorded by Longhurst et al. (1952) and subsequently repeated in the various herd plans. Hjersman et al. (1957) included the upper San Joaquin watershed north of Pine Ridge, Foster Ridge, and the Le Conte Divide as a portion of the San Joaquin herd's range. This area includes all of the range Longhurst et al. (1952) attributed to the Huntington Herd and the area around Shaver Lake as well. Rempel (1984) referred to the Huntington Herd as a segment of the San Joaquin herd, separated for outdated management reasons rather than biological ones.

Historically, the Department considered the non-migratory deer in the watershed a distinct population, designating them the South Sierra Foothill herd (Walker 1984). There has always been a lack of clarity over exactly what constituted the range of the South Sierra Foothill herd (Peabody 1984, Walker 1984). The South Sierra Foothill herd is generally described as lower in elevation then the migratory herds and extending west. However, Department biologists recognize non-migratory animals reside well into the study area, most notably in the area ascribed to the Oakhurst herd.

Deer research in the San Joaquin watershed dates back to the early 1950's and there is a wealth of data for comparative purposes. Initially researchers used physical markers on deer including, earmarks, ear tags and bells, as well as field observations to track deer movements and delineate migration and key use areas (Hjersman et al. 1957, Jordan 1967). During the late 20th century, the Department used VHF telemetry collars to monitor deer in the study area and reported some of the results (Sommer 2004). Recent advancements in technology provide opportunities to gather more and better data than previously possible.

Habitat conditions in the watershed have changed over the last half century. Human infrastructure in the watershed is widespread and includes residential, water control, hydroelectric power, and recreational use developments. Longhurst et al. (1976) claimed historic land management practices including, logging, burning, and grazing, resulted in early successional habitat conditions throughout the western states, which benefited deer. He further claimed changes in those practices such as fire suppression and a shift from sheep to cattle grazing starting in the last half of the 20th century resulted in habitat changes, which led to a continuing decline in the deer population. Hjersman et al. (1957) believed the San Joaquin deer herd was in decline in the 1950's following a peak population in 1939. He argued the decline was the result of range degradation caused by a deer population that had expanded beyond carrying capacity. Further, Hjersman argued that without a severe reduction in the deer population, habitat condition would deteriorate beyond recovery, causing further population declines.

Two factors highlight the need for continued research in this area. Habitats within the watershed have continued to change, often drastically and the deer population appears to have declined further.

MATERIALS AND METHODS

Study area.—The project was conducted on the upper San Joaquin River watershed in Fresno and Madera counties, California (N $37^{0}.14'$, W $119^{0}.10'$) (Figure 1). Elevations range between 600 and 3,800 m. The majority of the study area is on the Sierra National Forest, but there is also private and state ownership. Although deer occur at lower elevations along the San Joaquin River, the Department chose this elevation range because the majority of the deer in the watershed exist there.

Captures.—We used free range darting as the primary capture method, largely following procedures outlined by Casady and Allen (2013). Department staff used various models of Pneu-dart Inc.®, cartridge fired and pneumatic dart projectors and proprietary barbed 2 ml disposable darts to deliver immobilization drugs to the deer. Immobilization was by a 1:1 mixture of Telazol® and xylazine at about 2.4 mg per kg and reversed with Tolazine® at 4.4 mg per kg. Where conditions made free range darting difficult, we used Clover traps (Clover 1954, 1956) to augment the primary capture method. Capture and handling of all deer followed Department guidelines (Wildlife Investigations Lab 2012).

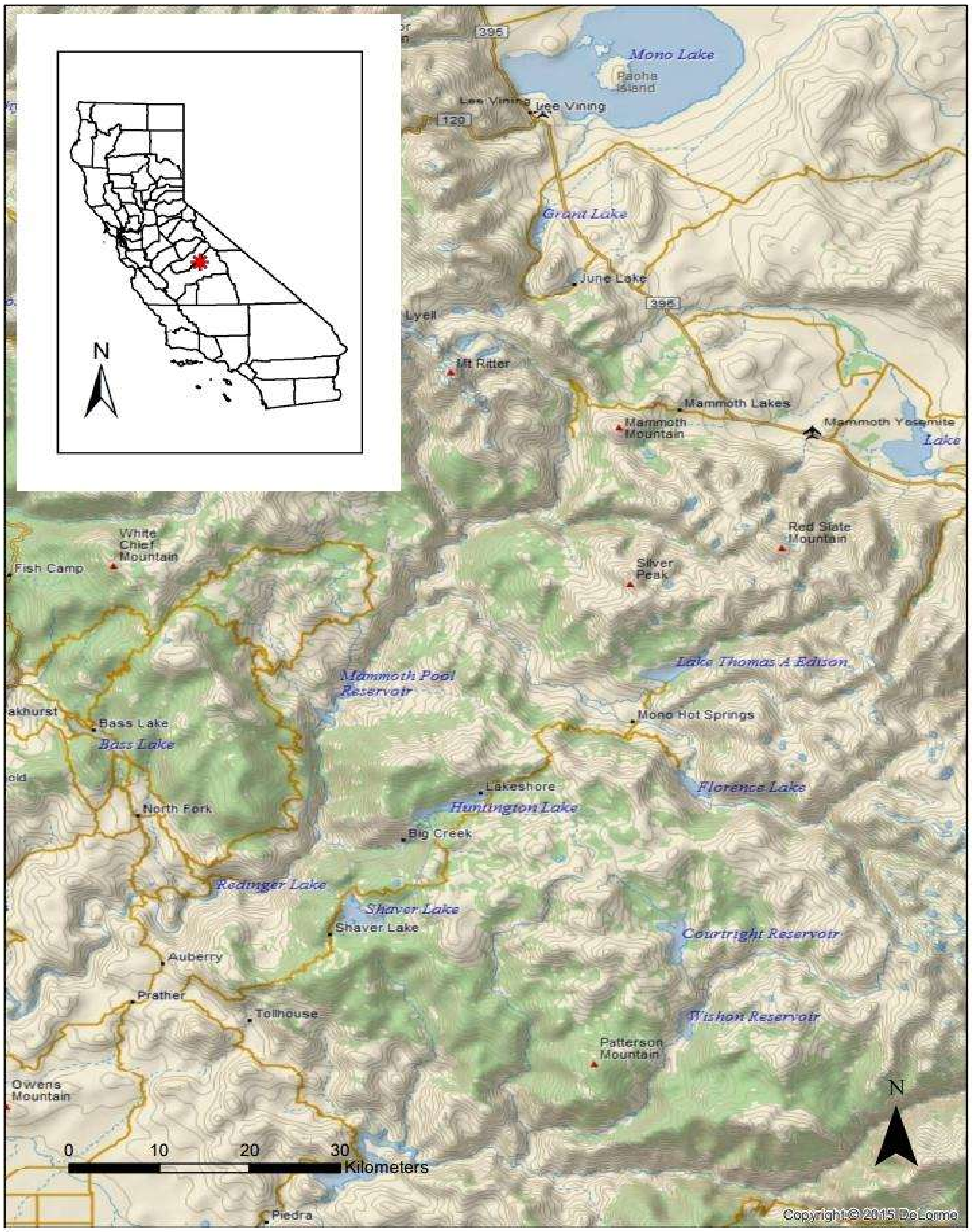

FIGURE 1.—Study area map, San Joaquin River watershed, Fresno and Madera counties California, 2013-2016.

The primary capture area was the lower elevation portion of the study area, where deer are concentrated during the winter. To facilitate even distribution of telemetered animals across the study area we divided the lower elevation areas into seven zones and attempted to direct capture effort equally in each zone. In addition to public land, we also secured access to three large ranches and several smaller parcels of privately owned land for capture purposes. We also directed capture effort to accessible areas of the summer range and captured 20% of our study animals on the summer range.

We subjected captured deer to an examination process, including aging, physical measurements, blood sampling, and examination for external parasites (Appendix I).

Telemetry equipment.—Deer were equipped with a mixture of telemetry collar types, with most receiving Global Positioning System (GPS) transmitters. We used different collar models and compared utility (Appendix II). Advanced Telemetry Solutions (ATS) Iridium LITE/GPS model G2110L collars, with Sure*Drop* collar break off mechanisms were placed on 22 deer; Tellus small iridium collars equipped with Tellus RL-Drop off, were placed on 16 deer. Data from iridium type GPS collars was received through satellite downlink service provided through the collar vendors.

We placed ATS GPS G2110 store on board collars with a standard release mechanism on two deer. We placed ATS VHF transmitters, model M2510B on standard collars, or model M4230B on expanding collars on nine deer.

Monitoring and mapping.—Monitoring of VHF and store on board GPS collars was conducted with Communications Specialists Inc. R1000 receivers and hand held yagi antennas. We estimated deer locations with telemetry using triangulation and recorded these locations on paper maps and data sheets. We handled monitoring data for one store on board GPS collar as a VHF collar when that transmitter failed and was lost. Locations for deer visually observed were marked with Garmin© 60 CSx GPS units.

We used waypoints from GPS telemetered deer, two per day, morning and evening, to identify seasonal home ranges and movement patterns. We used isopleths at 50 and 90 percentile developed from winter range positions of GPS telemetered deer, processed with bivariate plug-in bandwidth selection ($h_{plug\text{-}in}$) (Walter et al. 2011), and the positions of VHF telemetered deer, along with field observations to identify the primary winter range. We mapped migration paths using ArcMap and the ArcMET Trajectory Path Tool, ESRI©. Holding areas were identified by GPS locations collected during migration and mapped by processing through the Kernel Density tool (Walter et al. 2011) in Arc Toolbox, ArcMap v. 10.3.1 ESRI©.

We identified summer ranges through telemetered deer locations during that season and examined fawning areas as a sub-set of summer range habitat more closely. We identified fawning areas by first defining the neo-natal care period as the 30 days following the approximate length of gestation (Nichol 1938) from the beginning of the rut in this watershed. For these deer, that was the 30-day period from 15 June - 14 July. We utilized GPS data clusters, two per day (morning and evening) from telemetered adult female deer to map fawning areas with ESRI® ArcMap.

We made site visits to individual deer's fawning areas and typified them according to the California Wildlife Habitat Relationships System (Mayer and Laudenslayer 1988). During the site visits, we also recorded environmental influences and the presence and use of browse species.

RESULTS

Captures.—We did not attain even distribution of telemetered animals across the study area. Steep topography and dense vegetation limited capture success on portions of the range. Road-less areas or extensively developed private property limited access in other areas. Deer were more prevalent in some areas and therefore easier to capture. However, our methods did secure a sampling of telemetered animals from across most of the watershed (Figure 2) (Appendix I).

Winter range.—The winter range in the lower watershed is contiguous (Figure 3) and shared by deer from throughout the watershed. Winter range locations of telemetered deer and isopleths created from GPS locations overlap visually observed concentrations of deer. All of the winter captured deer from this project stayed within the watershed, as did telemetered deer captured in the watershed during the late-20th century (Peabody unpublished data, Sommer 2004).

The majority of telemetered deer wintered north and west of the San Joaquin River. Seven deer, 23% of our study animals, wintered south or east of the San Joaquin River. One female deer captured on the upper elevation portion of the summer range migrated eastward over the Sierran crest to Goodale herd winter range south of Big Pine Creek.

The majority of individual telemetered deer utilized winter home ranges characterized by slopes or flats with some southern exposure. Habitat types for winter home ranges included Blue Oak Foothill Pine, Montane Hardwood Conifer and Mixed Chaparral.

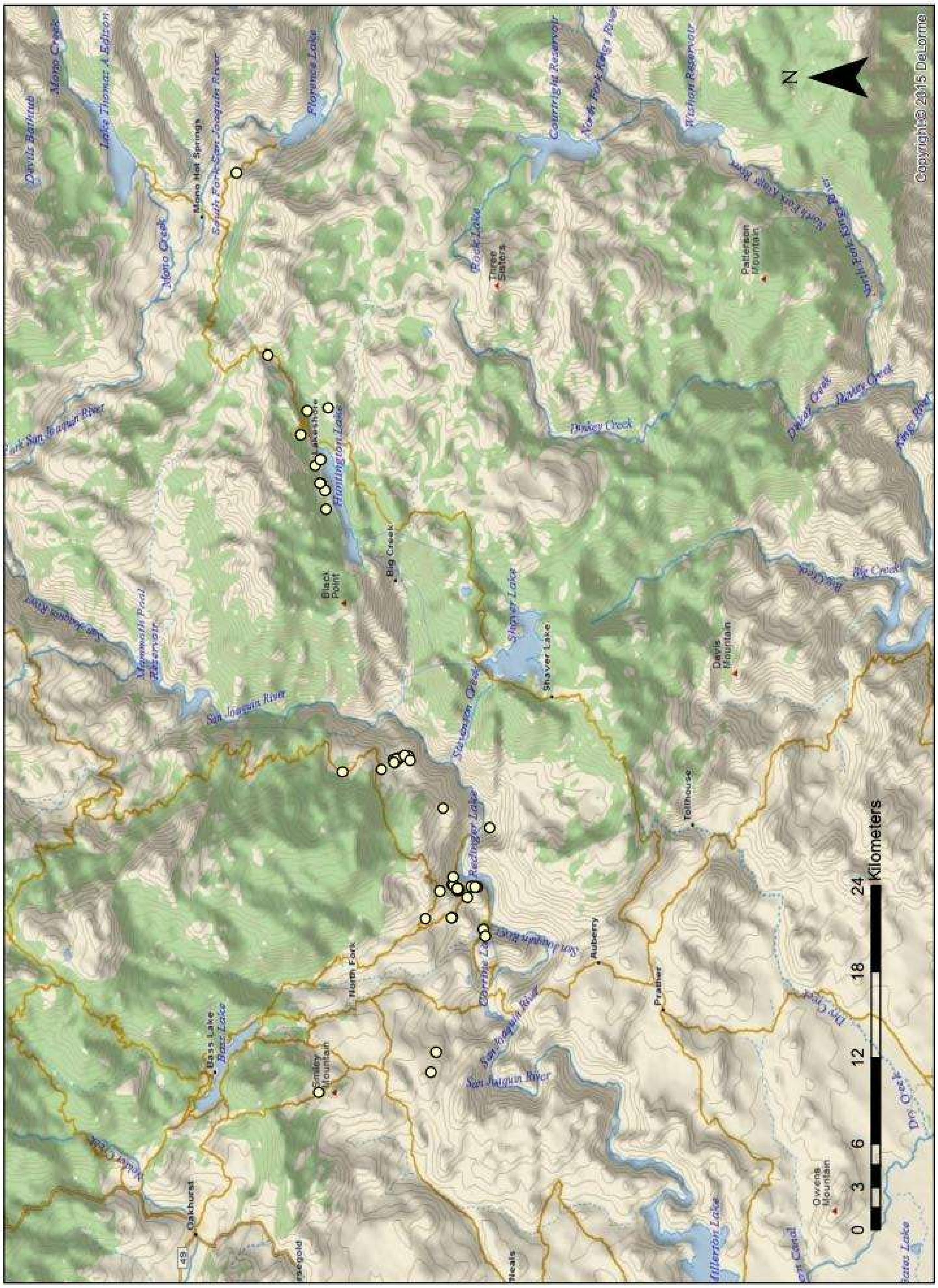

FIGURE 2.—Capture locations of 50 deer within the San Joaquin River watershed, 2013-2015.

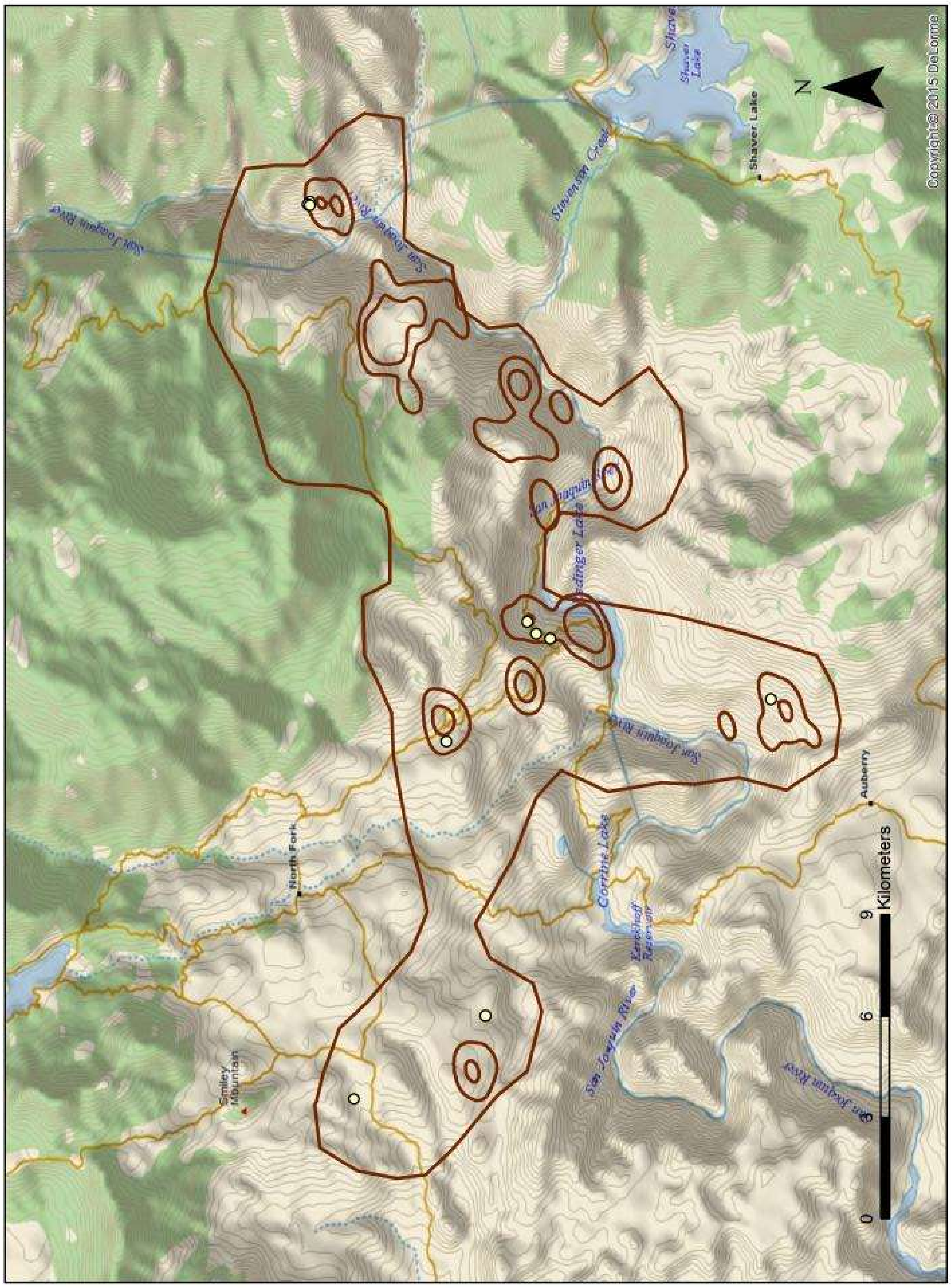

FIGURE 3. —Winter range displayed as a polygon drawn from a composite of telemetry data, and current observations of wintering deer. Concentrated use areas for GPS telemetered deer represented by isopleths at 50 and 90 percentile developed from winter range positions of 18 telemetered deer, processed with bivariate plug-in bandwidth selection (hplug-in) (Walter et al. 2011) and estimated winter home range centers of 10 VHF telemetered deer indicated.

Movements of deer within the winter range were easily detectable for GPS telemetered deer. Five of forty GPS telemetered female deer used distinctly different areas one to eight km apart at some time during the winter. Three of those used a distinct area during the rut, roughly between 25 November and 1 January, compared to the rest of the winter. Other deer made trips a few km away from their primary winter home range of a shorter duration. Previous research also noted location shifts during the winter. Jordan (1967) believed some deer delayed complete migration to the lowest elevation portions of their winter range until January or February.

We note the following major differences in winter use areas since 1957. The construction of Mammoth Pool Dam inundated the majority of the wintering area north of the confluence of Daulton creek and the San Joaquin River. We observed few deer or signs of deer north of Fish Creek. Deer used Source Point throughout the winter. The wintering area extends much farther west than previously believed, to Long Ridge in the south, and west of North Fork at the northern end.

Migration.—Telemetered deer were monitored throughout migration over the three-year period to determine migratory habits (Table 1). We identified three major migratory corridors (Figure 4). Deer also used trails between the major corridors during migration.

We named the major migration corridors, the Huntington, Shaver and Madera corridors. Sixty-nine percent of our telemetered deer used the Huntington corridor. Most of these deer winter west of the San Joaquin River but some winter on the slopes above Chawanakee Flat. The Huntington corridor crosses the river near Mammoth Pool Powerhouse, continues up the slopes above Chawanakee Flat past Mushroom Rock, and Black Point, then along either side of Huntington Lake, across Kaiser Pass and into the South Fork of the San Joaquin watershed. Deer established summer home ranges along the corridor from near Big Creek below Huntington Lake and upwards.

TABLE 1.—Distribution of GPS data sets from 30 deer, by season, used to develop migration corridors over three years. The number of migrations for each deer ranged from one to four.

Corridor	2013		2014		2015		2016
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
Shaver			1	1	4	3	
Huntington	2	6	6	2	12	9	1
Madera	2	1	1		3	1	1

A smaller proportion of our sample used the other two major migratory corridors. The Shaver corridor lies south of the confluence of Stevenson Creek and the San Joaquin River and leads to Shaver Lake. This is a broad corridor but many deer use trails, which lead upslope from the winter range towards Flume Peak and then south towards the summer range between Shaver Lake and Pine Ridge. The Madera corridor lies east of Whiskey and Chiquito Ridges. These deer summered just east of those ridges or crossed the San Joaquin River at or above Mammoth Pool and summered in the South Fork of the San Joaquin River's watershed.

The onset and duration of migration varied between year, migration corridor, and individual deer. Deer on the Huntington corridor took 1-25 days to migrate in the spring, and 1-34 days in the autumn. Deer using the Madera corridor took 3-12 days to make the spring migration, and 1-8 days in the autumn. Those deer using the south Shaver Lake corridor made the relatively short trip in 1-3 days in both the spring and autumn.

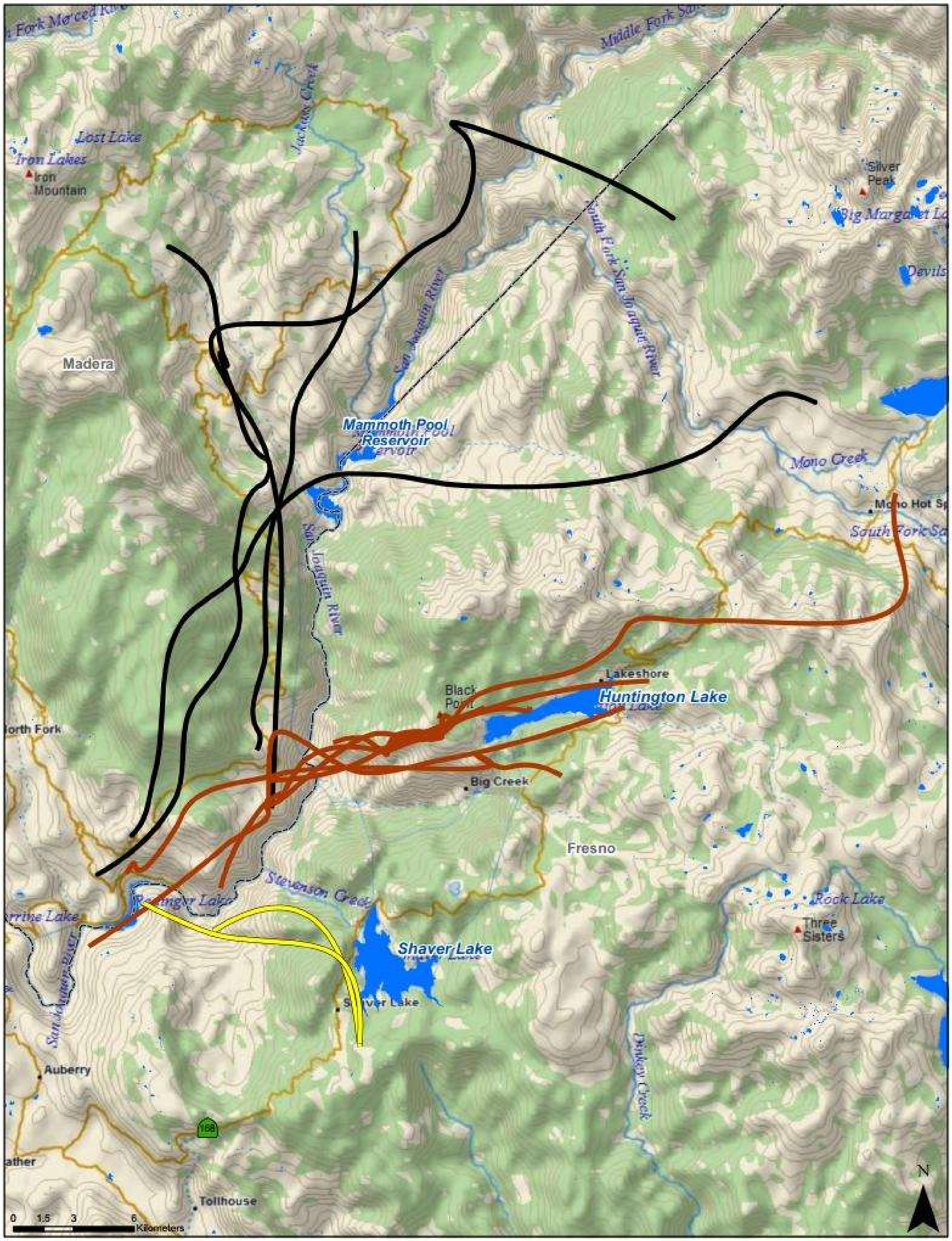

FIGURE 4.—A selection of migratory paths taken by GPS equipped deer using the three migratory corridors. Corridors identified from locational data of deer during migration using ArcMap and the ArcMET Trajectory Path Tool, ESRI©.

In 2015, we had the most telemetered deer available to evaluate migration specifics. During spring migration 2015, there were 12 deer in the Huntington group, 4 in the Shaver group and 3 in the Madera group. During that migration, the Huntington group deer left their winter home range between 28 March and 30 May, arriving on the summer range between 29 March and 1 June. The Shaver deer left their winter home range between 31 March and 17 April arriving on the summer range between 1 April and 17 April. Madera group deer left the winter range between 28 March and 9 April arriving on the summer range between 6 April and 28 April.

During autumn migration 2015, there were nine telemetered deer in the Huntington group, three in the South Shaver group and one in the Madera group. During that migration, deer from the Huntington group left their summer home range between 18 October and 2 November, arriving at their winter home range between 28 October and 10 November. Individual deer took one to two weeks to make the transition. By comparison, during the same autumn deer from the Shaver group left between 24 November and 14 December typically making the trip in one day and occasionally returning to the summer range for a few days before settling on the winter range. The one Madera group deer active that autumn migrated between 2 November and 10 November.

Over the course of the study, the Shaver group of deer typically arrived on the winter range later than deer from the other two corridors. Mean arrival date for GPS telemetered deer was Huntington and Madera groups 29 October (*n* 17); Shaver group 2 December (*n* 4).

Spring migration for individual deer, even within the same year, was highly variable and arrival on the summer range for individual deer ranged from 29 March – 8 July over the course of the study. Weather effects on plant phenology and in the case of snow, actual impediment of migration appear to be the most influential factors on spring migration (Bertram 1984). Although all of the study occurred within a drought, weather effects on plant phenology may still have played a role in migration timing between years or even between destinations across the watershed in the same year.

In addition to winter and summer home ranges, individual migratory deer may also use holding areas, which are an important segment of an individual's home range on the migration corridor (Bertram and Rempel 1977). Our telemetered deer used five holding areas during their transition between winter and summer ranges (Figure 5). Holding areas for individual deer were usually adjacent to, or overlapping those of other deer. The most used holding area is along the Huntington corridor. It covers about 2,700 ha between Chawanakee Flat and Huntington Lake with Mushroom Rock near its center. Late season deer hunters are well aware of this area. We located four other holding areas, one on Rancheria Creek near the upper end of Huntington Lake, the second located north west of Huntington Lake at Coarse Grass Meadow, and one east of Whiskey Ridge. Kinsman Flat functions as both wintering and holding area for deer. Of the 20 telemetered deer that used Kinsman Flat, nine wintered on Kinsman Flat, three spent a portion of the winter on Kinsman Flat but ranged lower for the bulk of the winter, and eight additional animals migrated through or visited at some point.

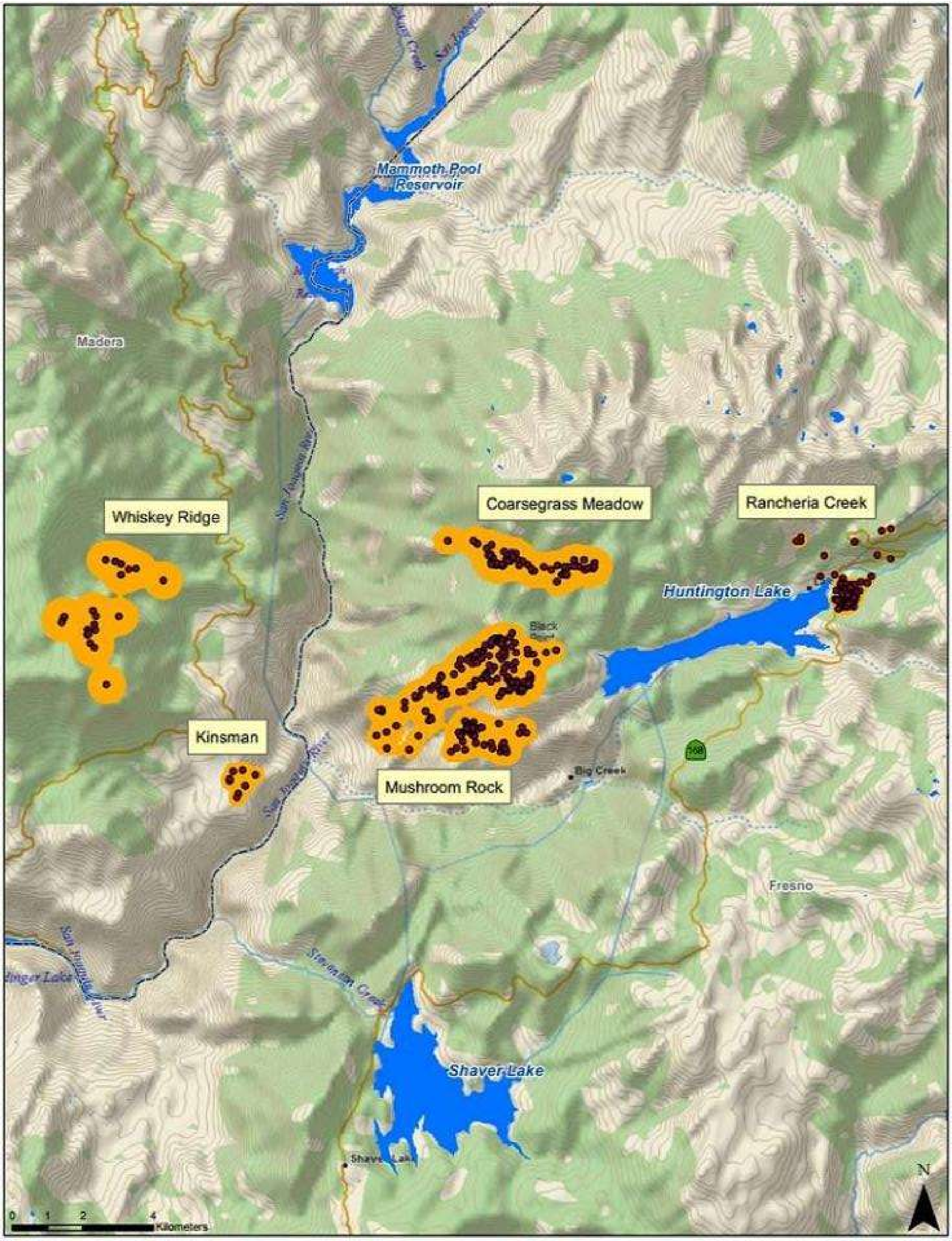

FIGURE 5.—Holding areas represented by isopleths at 50 percentile developed from transition range positions of 26 telemetered adult female deer processed with bivariate plug-in bandwidth selection (hplug-in) (Walter et al. 2011), with GPS data points of deer indicated.

Summer range.—Telemetered deer dispersed to summer ranges between altitudes of 1,500 and 2,800 m throughout the watershed (Figure 6). Twenty-three summered between Kaiser and Tamarack Ridges. Five summered in the South Fork of the San Joaquin watershed. Five summered on that portion of the watershed south of Shaver Lake. Four summered east of the Middle Fork of the San Joaquin River.

Restricted movement during the neo-natal care period, June 15-July 14, defined fawning areas within an individual deer's summer home range (Figure 7). The primary habitat type for fawning areas was usually Sierran mixed conifer. Secondary habitat types typically included wet meadow or montane riparian (Table 2). Presence and use of preferred browse species was variable between sites (Table 3). Grazing by livestock occurred at less than 20% of the sites and its effects were light to moderate. Therefore, we believe utilization of browse species to be primarily deer related. We estimated disturbance by fire or logging to have occurred over 20 years earlier at most sites. Habitats were typically dense and multilayered, but some also included large open areas. Altitudes of individual fawning areas ranged from 1,650 and 2,800 m with a mean altitude of 2,200 m.

Deer movements between June 15 and July 14 lead us to believe this timeframe is generally but not exclusively indicative of neo-natal care. Although movements of most deer were restricted within a larger summer range during that period, several deer made large-scale movements, some deer traveled back to holding areas or made multiple short duration side trips 2-10 km away from their core area. Two deer did not arrive on the summer range until well within the neonatal period. One of the two left the winter range on 22 June, arriving on the summer range on 24 June. The second deer had such odd movements during the designated

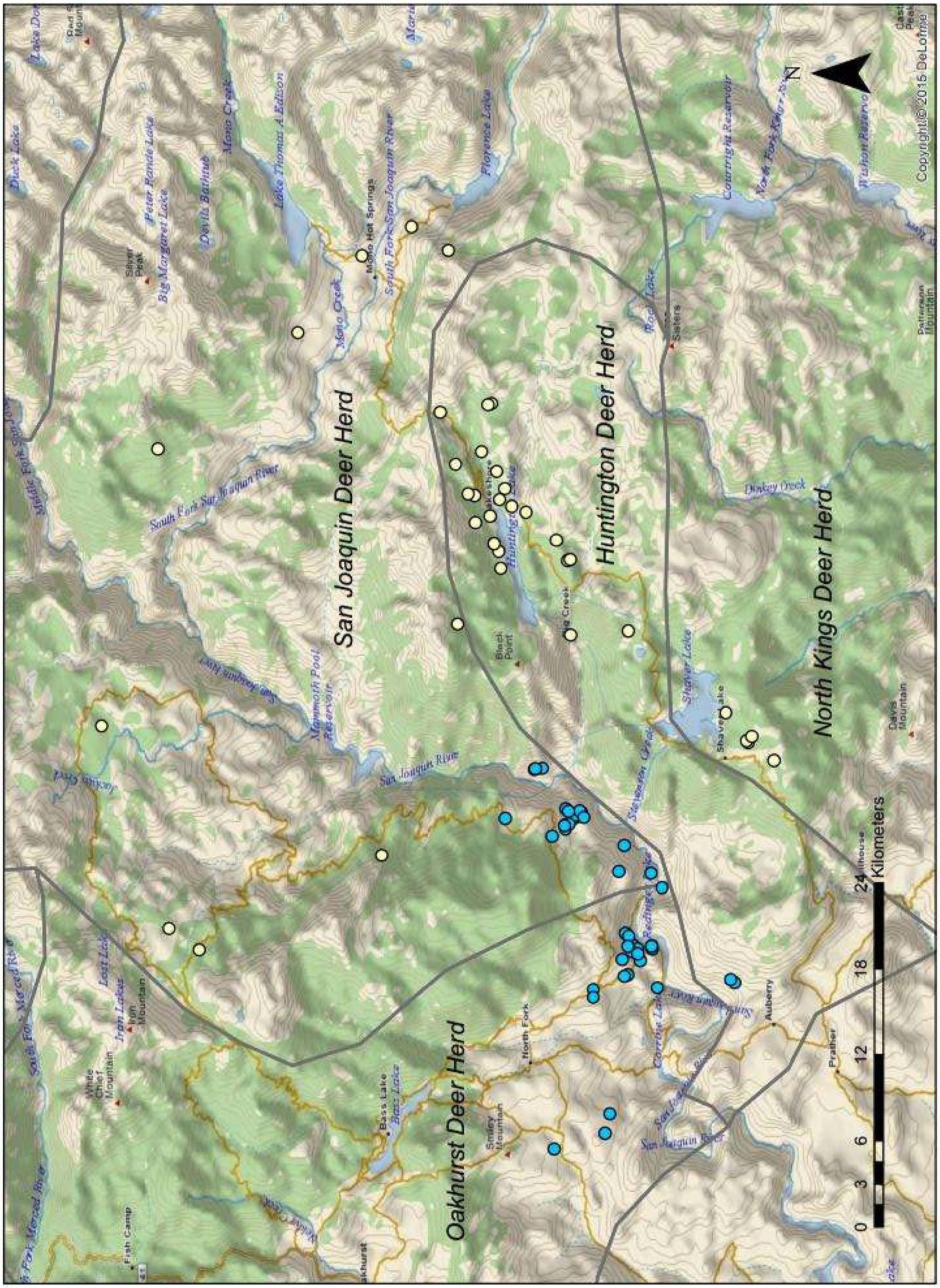

FIGURE 6.—Dispersal of telemetered deer from concentrated winter range locations near the San Joaquin River to summer range locations at higher elevations. Map overlaid with deer herd boundaries, caldeerNAD83.shp from Department archives.

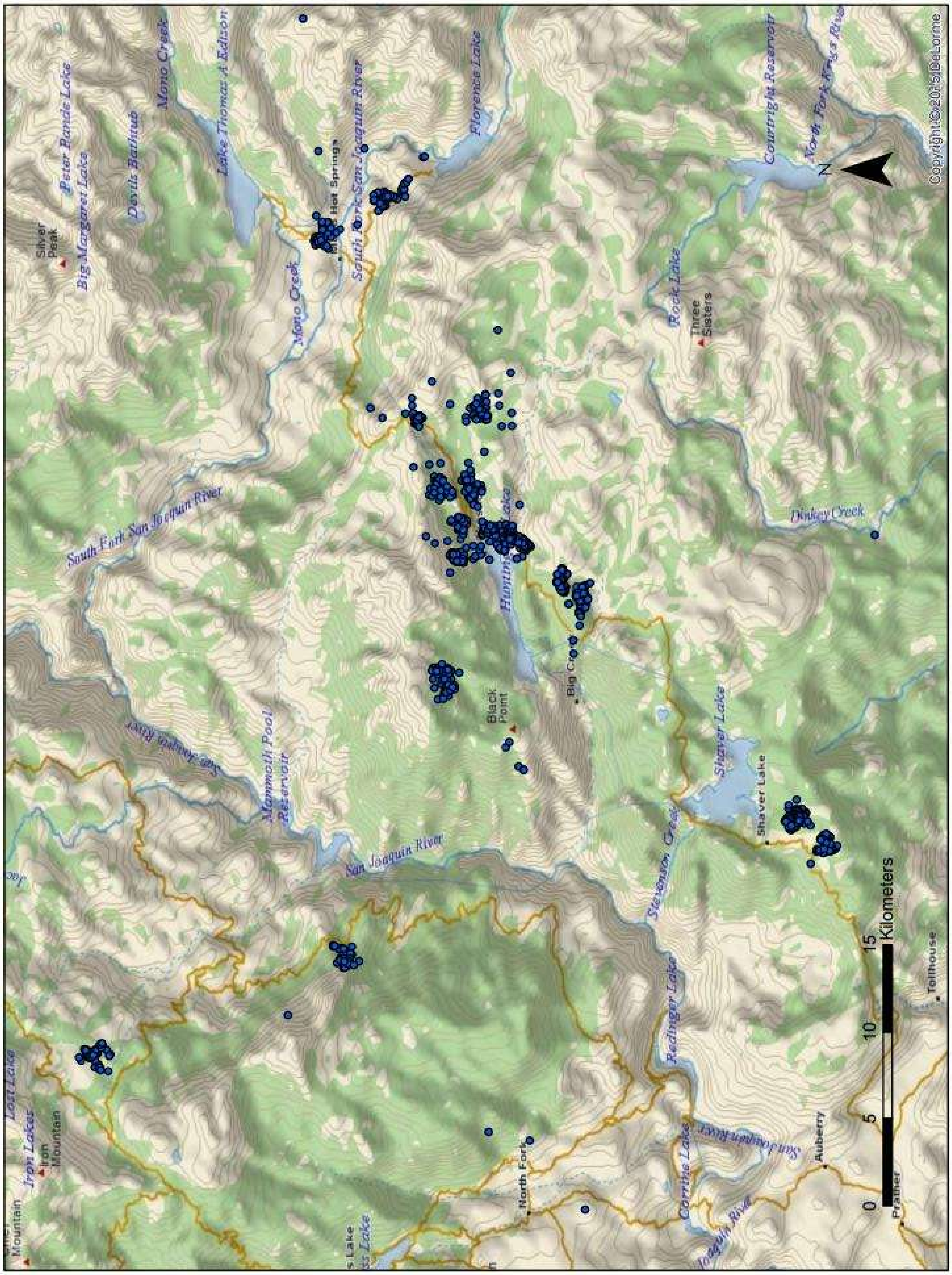

FIGURE 7.—Data clusters of 22 GPS telemetered deer collected over the 30-day neo-natal care period.

TABLE 2.—summer range characteristics of 22 GPS telemetered female deer developed from site visit of waypoint clusters collected in fawning areas. Habitats typed utilizing the WHR system and its abbreviations [a] (Mayer and Laudenslayer 1988).

		Primary Habitat		Secondary Habitat	
Frequency	Elevation	Type	Stage	Type	Stage
160.180	2,150 m	SMC		SCN/WTM	
160.194	1,750 m	SMC	5D		
160.213	2,300 m	SMC	4M	WTM	
160.224	2,500 m	RFR	5D	LPN	5M
160.230	1,750 m	SMC	6D		
160.240	1,750 m	SMC	4D	WTM	
160.270b	2,300 m	SMC		WTM	
160.290	2,300 m	SMC	6	MRI	
160.300	2,700 m	LPN	5S	MRI	
160.343	2,050 m	SMC	5D	WTM	
160.354	2,200 m	SMC	6D	MRI	
160.370	2,700 m	WFR		WTM	
160.394	2,150 m	SMC	5M	WTM	
160.414	2,150 m	SMC	6D	WTM	
160.420	2,250 m	RFR	5		
160.445	2,200 m	SMC	6D	MRI/WTM	
160.510	2,250 m	SMC	6D	SMC	5S
160.584	2,700 m	RFR	4D	WTM	
160.592	1,750 m	SMC	4D	WTM	
160.628	1,700 m	SMC	4D		
160.643	2,300 m	RFR	5D	MRI/WTM	
160.654b	2,350 m	WFR	6	WTM	

[a] SMC= Sierran Mixed Conifer, MRI= Montane Riparian, WTM=Wet Meadow, WFR=White Fir, RFR=Red Fir, LPN= Lodgepole Pine, SCN=Subalpine Conifer

period we removed it from the neo-natal care data set; it located in an upper elevation holding area from 22 May to 8 July then located slightly upslope from 8 July to 21 July, on which date it migrated 16 km downslope. Our methods could not determine when, or if parturition occurred or if an individual doe had lost its fawns.

Many deer utilized fawning areas associated with human development. A two-lane highway bisected over half of the fawning areas. Ten deer choose fawning areas either in, or within 500 m of some type of development, including residential areas, summer cabins, busy campgrounds, summer camps, or some portion of China Peak ski resort. Eight fawning areas however were out of the way of any large development.

Mortality.—Twelve telemetered deer died during the study. When possible we examined deer remains to determine cause of mortality. Specific causes of mortality were, mountain lion (*Puma concolor*) predation five, unknown five, vehicle strike one, and poaching one. Predation is suspected in four of the five, which died of unknown causes. A member of the public found the other one floating in Huntington Lake and removed the collar. Comparatively, an earlier study in the watershed recorded the cause of mortality for 37 of 52 VHF telemetered deer (Sommer 2004). (Table 4).

TABLE 3.—preferred browse species of central sierra deer (Bertram 1984) present on fawning areas of 22 GPS telemetered female deer, developed from summer site visits of waypoint clusters collected during the 30-day period beginning 15 June.

		Level of browsing observed			
	Present	None	Light	Mod	Heavy
Abies concolor, white fir reachable saplings	12	9	2	1	-
Arctostaphylos sp. Manzanita species	17	7	10	-	-
C. cordulatus, Mt. whitethorn	14	1	3	8	2
C. integerrimus, deer brush	6	-	1	2	3
Chamaebatia f., bear clover	1	1	-	-	-
Prunus emarginata, bitter cherry	1	-	1	-	-
Prunus subcordata, sierra plum	2	-	-	-	2
Ribes sp., Currant, goose berry	18	1	6	8	3
Rosa sp., Wild roses	4	1	1	2	-

TABLE 4.—Comparison of mortality causes between telemetry studies in the San Joaquin River watershed separated by two decades.

Study Period	Lion	Unknown	Poaching	Vehicle	Drowning	Other
2013-2015	5 (42) [a]	5 (42)	1 (8)	1 (8)	0	0
1987-1994	13 (35)	10 (27)	11 (30)	0	1 (3)	2[b] (5)

[a] ( ) percent of total, [b] In the earlier study one deer died from each of the following causes, dogs, capture related injuries.

Environmental changes.—California entered a prolonged severe drought starting in the fall of 2011 and continuing through the fall of 2015. Statewide precipitation improved through spring of 2016 and statewide snowpack was 87% of average by 1 April 2016. All of the GPS data collected during this study represent movements and behavior under conditions of severe drought stress. It is unknown to what extent this drought effected deer movements or habitat use patterns. The extremely dry conditions contributed to multiple environmental factors, which altered landscapes in the San Joaquin watershed.

During the study period, five major wildfires occurred within the San Joaquin River watershed (Figure 8). The Aspen Fire 2013, 9,200 ha, the French Fire 2014 5,600 ha, the Courtney Fire 2014, 129 ha, the Corrine fire 2015, 370 ha, and the Willow Fire, 2015, 2,300 ha. The three largest fires occurred primarily on transitional range, although they also effected winter and summer range habitats.

Pine tree mortality resulting from pine bark beetle *Dendroctonus* sp. infestations began in 2010. Drought stress during the following years lead to higher susceptibility to attack. Tree mortality continued through 2017. Drought stress independent of bark beetle killed numerous incense cedar and oak trees as well. As of December 2017 an estimated 31,812,000 trees had died on 307,500 ha within the Sierra National Forest. (U.S. Forest Service 2017).

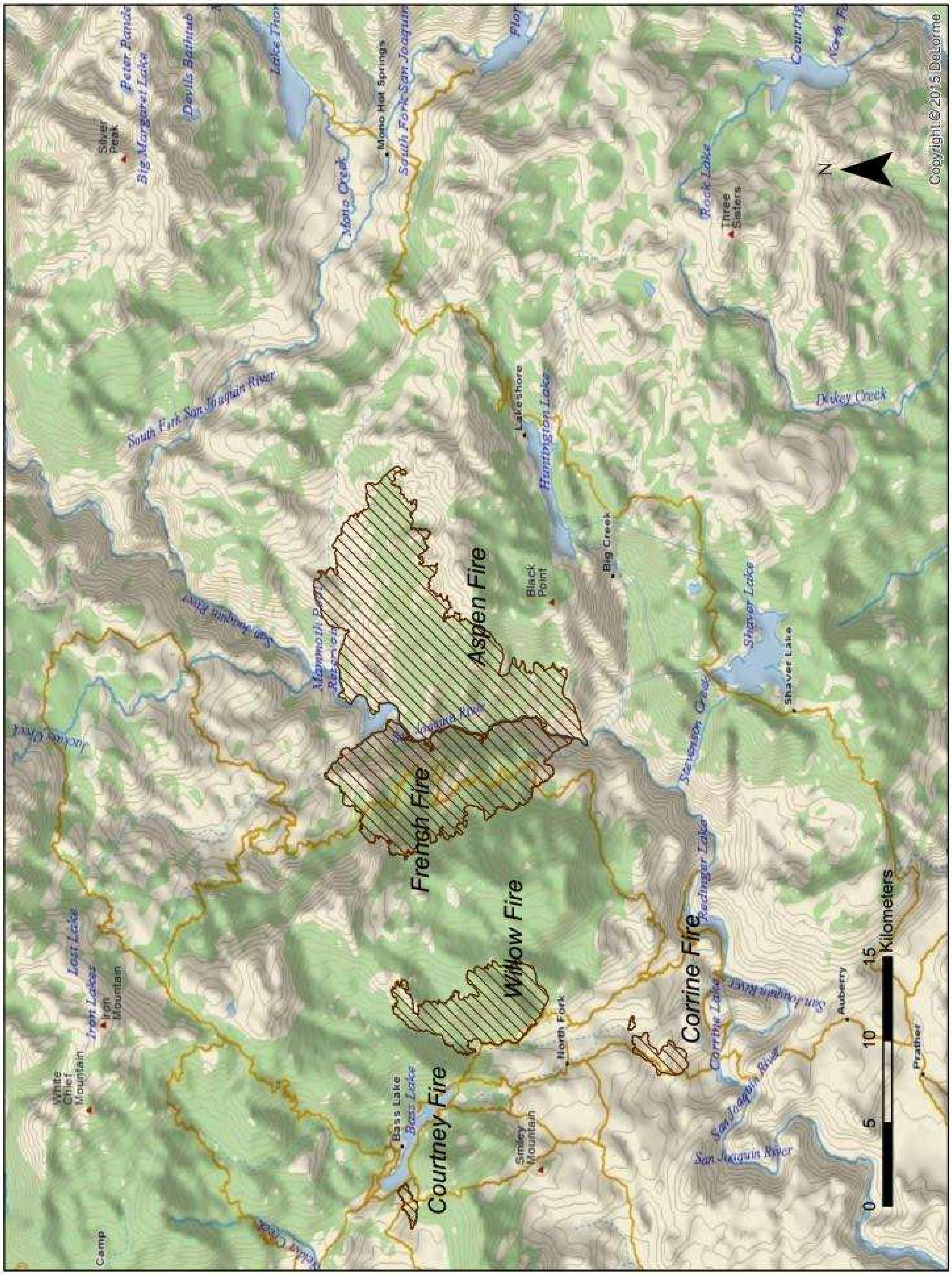

FIGURE 8.—Footprints of five major fires, which occurred over the course of the study, shapefiles from US Forest Service archives.

Discussion

Deer herds.—Position of an individual deer's seasonal home range within the key winter range did not usually predict the direction of its migration or location of its summer home range. For example, the primary winter range in the study area is located near the intersection of four deer herd range boundaries (Longhurst et al. 1952; Peabody 1983, 1984; Rempel 1984, Walker 1984). Although those authors attribute just under half of the winter range in the study area to the Oakhurst deer herd, none of our telemetered deer migrated outside the watershed to summer range attributed to that herd. Of 21 telemetered deer that wintered on the lower Willow Creek or "Oakhurst" portion of the winter range, two did not migrate. The others migrated to locations spread across the watershed. The only clear link between winter home range and summer destination was the relatively small area near Chawanakee Flat, which is winter range for some animals on the Huntington corridor as well as a part of the corridor. Deer from across the upper elevation portions of the watershed spend the winter on a common winter range, including during the rut. Biologically, they form a single population. Site fidelity to a common winter range and to the watershed during migration are two distinctions, which define this population.

Other researchers in California have demonstrated that site fidelity and matrilineal philopatry affect behavioral patterns in black-tailed deer (Bose et al. 2017). Site fidelity to the shared winter range and matrilineal philopatry to summer range location and migration corridor explain the variation between migratory patterns of individual deer within the population. Those two factors also explain non-migratory behavior in a segment of the population.

The segment of the population that uses the Huntington corridor is composed of deer from across the winter range and the corridor continues beyond the range attributed to the Huntington herd. There is no justifiable biological, behavioral, or management reason for a

Huntington herd designation. The lower Willow Creek watershed between its confluence with the San Joaquin River and the town of North Fork is contiguous with the rest of the winter range; the deer, which winter there, migrate into the upper San Joaquin watershed. Biologically, behaviorally, and using criteria defined by the authors of the current herd system, the west slope migrants in the San Joaquin watershed are a single “deer herd”.

In regards to the other herd designations within the watershed, the primary distinction of a herd is its association with a single winter range (Longhurst et al. 1952). The deer, which winter in the lower elevation portions of the study area, are a single population. Shared summer ranges with other groups of deer on the periphery of the watershed notwithstanding; the San Joaquin herd is the primary herd in the watershed.

Habitat use concerns.—Differences in onset of migration and length of time spent during migration between the corridors may indicate dissimilarities in habitat quality. Other researchers have demonstrated the importance of autumn and spring holding areas. Holl, (1975) found use of high quality forage in autumn holding areas important for improving body condition in deer and overwinter fawn survival. Bertram and Rempel, (1977) viewed high quality spring and autumn holding areas as important for maintaining body condition and reducing overuse on both winter and summer range. Poor quality diets of mature browse on holding areas contribute to a decline in the body condition of does during the last trimester of gestation (Salwasser et al. 1978, Holl et al. 1979). Lomas and Bender (2007) found that poor nutritional condition in does results in poor condition and low survival in neonates. The Department should investigate the condition and use of holding areas in this watershed more closely and encourage management of those areas to maintain them in optimal condition.

Our research documented fewer deer on the winter range south of the San Joaquin River compared to the north side. Hjersman et al. (1957) also noted this but did identify deer concentration areas there. Habitat improvement projects on this underused portion of the winter range could help augment population numbers in this watershed.

Environmental changes.—Environmental stressors of drought, wildfire, and insect infestation are acting as a catalyst for habitat change across the watershed. These stressors effected most of the habitat within the watershed over the course of this project, particularly the transitional ranges and lower elevation summering areas. The action of these stressors are dynamic and long-term effects are not yet evident. However, we have observed changes that benefit deer including seral stage reset and rejuvenation of mature browse plants.

The Aspen fire caused a major change to habitat in the watershed. The area impacted by the Aspen Fire on the eastern side of the San Joaquin River extended from the winter range to summer range elevations. The area burned was probably of only minor importance to migrating deer prior to the fire. Three telemetered deer moved quickly through it during migration. Post fire evaluations of deer use in this area could improve our knowledge of how fire changes habitat use along migration corridors. Four telemetered deer used a lower elevation segment of the burn near Chawanakee Flat for winter range. Stands of rejuvenated white thorn *Ceanothus cordulatus* were located in this area at about 1,000 m in elevation, and these showed heavy use by deer. Other browse species rejuvenated by the fire and showing some use included mountain mahogany *Cercocarpus ledifolius*, Mariposa manzanita *Arctostaphylos mariposa,* buck brush *Ceanothus cuneatus*, and deer brush *Ceanothus integerrimus*.

On the western side of the river, the French fire reset dense stands of young conifers and brush to an earlier seral stage. While Hjersman et al. (1957) considered this area important for migrating deer, our telemetered animals moved quickly through it prior to the fire. By the time, browse-species had rejuvenated after the fire, all of our telemetered animals in that area, had died or dropped their telemetry collars.

It is unclear to what extent tree mortality resulting from drought and insect infestation will change habitats and influence deer populations. Several factors contribute to this uncertainty. Trees are continuing to die and the duration, and extent, of this event is unknown. Forest managers have concentrated on removing hazard trees, leaving the majority of dead trees standing. The dead trees, either standing or downed, may contribute to increase susceptibility to wildfire with subsequent habitat change. Extensive fields of fallen dead trees on migration corridors may hinder deer during migration (Gerstenberg pers. comm.).

Research recommendations.—The Department should investigate how wildfire and tree mortality in the watershed effect deer. Questions include: do habitat changes resulting from these stressors benefit deer, how do changes along migration corridors effect deer use of holding areas, and what effect if any does tree mortality have on deer movement and susceptibility to predation? Migration corridors and holding areas may well be the least understood portions of deer range. A critical question is how have recent wildfires effected oak trees and their vital mast? Monitoring, including telemetry research, habitat typing, investigations in habitat productivity and nutritional analysis of forage along migration corridors will provide important information to direct forest management recommendations.

There are still unanswered questions related to herd dynamics in the watershed as well as the rest of the "Madera unit". Although the Department has periodically initiated research for both the San Joaquin and North Kings deer herds, there are still portions of their range, which they never fully investigated. Evaluating telemetry data collected between 1988 and 1994 with up to date mapping software could provide additional insights into deer movement in the watershed. Further telemetry research based on summer captures between Pine Ridge near Shaver Lake and the Dinkey Lakes Wilderness would help us understand summer range use and interactions for the two herds. Summer captures along both sides of Chiquito Ridge would help define linkages and holding areas for both the San Joaquin and Oakhurst herds.

The northern “Madera unit”, which includes the South Fork of the Merced River, the Fresno River and upper Willow Creek watersheds has numerous research needs. Development has fragmented the Oakhurst herd’s winter range. The construction of the Crane Valley Dam in 1910 flooded Crane Valley and created Bass Lake in its center. Much of the rest has been developed for residential and recreational use. Mature montane hardwood-conifer forests dominate undeveloped portions of the winter range. The Department has not identified specific holding areas for these deer. Wildfire, bark beetle infestation and drought have effected habitat across this area. In addition to the Oakhurst herd, non-migratory deer also reside here. Over the last five years, 25 percent of annual buck harvest for the Oakhurst herd occurred on the winter range prior to migration (unpublished data).

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APPENDIX I: MEASUREMENTS TAKEN AT TIME OF CAPTURE

TABLE 1.—Deer capture locations in chronological order, Fresno and Madera counties, California 2013-2015.

Collar Frequency	Latitude	Longitude	Capture Date
160.170	37.16639	-119.43917	3 April 2013
160.939	37.14872	-119.46862	8 April 2013
160.949	37.16576	-119.43895	8 April 2013
160.230	37.18270	-119.55400	9 April 2013
160.280	37.14975	-119.46453	9 April 2013
160.908	37.17962	-119.54160	9 April 2013
160.370	37.20435	-119.33749	10 April 2013
160.180	37.20430	-119.35750	23 April 2013
160.300	37.24902	-119.13768	5 September 2013
160.330	37.24902	-119.13740	5 September 2013
160.420	37.26058	-119.13908	5 September 2013
160.290	37.25539	-119.17327	6 September 2013
160.240	37.15733	-119.43757	9 January 2014
160.270	37.16006	-119.44437	3 February 2014
160.470	37.20280	-119.35724	5 February 2014
160.250	37.18602	-119.45769	6 February 2014
160.400	37.25309	-119.56669	6 February 2014
160.440	37.20465	-119.35794	13 February 2014
160.695	37.17720	-119.44043	19 February 2014
160.705	37.20324	-119.35688	24 February 2014
160.424	37.21367	-119.36401	27 February 2014
160.654	37.16935	-119.43646	27 February 2014

160.654b	37.16871	-119.43655	22 April 2014
160.434	37.23845	-119.36556	24 April 2014
160.270b	37.20610	-119.35778	28 April 2014
160.510	37.30498	-118.98978	10 September 2014
159.598	37.25228	-119.16964	10 September 2014
160.247	37.24863	-119.20072	10 September 2014
160.157	37.26445	-119.15401	11 September 2014
160.888	37.24938	-119.18899	11 September 2014
160.920	37.25230	-119.18430	12 September 2014
159.636	37.25229	-119.18431	12 September 2014
159.875	37.16609	-119.43993	16 December 2014
160.394	37.20540	-119.35974	8 January 2015
160.633	37.16880	-119.43169	8 January 2015
160.354	37.20314	-119.35683	13 January 2015
160.224	37.19704	-119.35593	15 January 2015
160.592	37.14584	-119.40050	15 January 2015
160.445	37.20436	-119.35749	21 January 2015
160.584	37.17521	-119.38817	27 January 2015
160.604	37.19939	-119.35532	28 January 2015
160.643	37.19580	-119.35830	28 January 2015
160.414	37.43405	-119.73601	3 February 2015
160.684	37.20591	-119.35962	23 February 2015
160.628	37.15530	-119.43785	25 February 2015
160.204	37.16948	-119.45698	25 February 2015
160.194	37.15379	-119.43781	26 February 2015
160.213	37.16624	-119.43899	3 March 2015
160.343	37.16995	-119.45722	4 March 2015

Although adult does were targeted for capture by free-range darting, younger animals were occasional captured. We aged captured animals by evaluation of tooth replacement and wear (McLean 1936, Severinghaus 1949) (Table 2).

TABLE 2.—Age of deer at capture in years, Fresno and Madera counties 2013-2015.

Age	YOY	1	2	3	4	+4
Number Captured	1	8	5	8	8	10

We took physical measurements of captured deer including weight, girth, length (tip of nose to base of tail) and neck (behind the jaw, mid cervical and base of neck). Complete data sets were available for 37 adult females and 7 yearling females (Table 3).

TABLE 3.—Summary of mean physical measurements in kg and cm for deer captured in Fresno and Madera counties, California 2013-2015.

	Yearling doe	Range	Adult doe	Range
Weight	41 ± 5.0[a]	(34-48)	50 ± 5.1[a]	(41-59)
Length	132 ± 9.3[a]	(121-153)	138 ± 5.3[a]	(127-150)
Girth	84 ± 2.5[a]	(79-87)	89 ± 4.0[a]	(82-98)
Neck behind jaw	31 ± 3.1[a]	(28-35)	33 ± 2.7[a]	(28-38)
Neck mid-cervical	33 ± 2.4[a]	(30-36)	35 ± 3.1[a]	(28-40)
Base of neck	43 ± 5.2[a]	(34-49)	46 ± 5.7[a]	(37-60)

[a] Standard deviation

We collected whole blood samples from captured animals and tested them for selenium content (California Animal Health and Food Safety Laboratory System). Adequate selenium content is considered to be between 0.08 and 0.5ppm (Dargatz and Ross 1996). Selenium deficiency can lead to muscle damage (white muscle disease), ill thrift, poor production (including reproduction), and decreased resistance to other diseases (Hefnawy and Tortora-Perez 2010). Of 45 animals tested 29 (64%) had in-adequate levels of selenium. Of the 11 tested deer which died during the study, 9 (81%) had in-adequate selenium levels at capture.

Hair loss and high mortality rates in deer have been associated with infestation by exotic fallow deer louse (*Bovicola tibialis*) in central Washington (Washington Department of Fish and Wildlife. 2010). Exotic fallow deer louse and African blue (*Linognathus africanus*) lice are known to occur in Central California and were associated with hair loss there in 2009 (Gerstenberg 2013). Department staff have collected fallow deer lice from deer adjacent to the San Joaquin watershed in Madera County, and a few deer have been observed with mild hair loss there (unpublished Department records). We examined captured deer for the presence of lice and submitted samples of external parasites to USDA National Veterinary Services Laboratories, Ames Iowa for identification. The only lice identified from our samples were native sucking lice *Solenopotes ferrisi*.

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APPENDIX II: TRANSMITTER AND COLLAR SERVICEABILITY

We employed a variety of collar and transmitter types over the course of the study. Construction, function and serviceability varied between types. We compare the transmitters here.

Tellus small iridium transmitters were heavier at 600 g and the collars bulkier and stiffer than other types used. The one outstanding capability for this collar type was two-way communication. Satellite uplink provided the capability of changing programmed collar functions such as frequency of data gathering, or drop off command after we had deployed the collar on a study animal.

A few collar failures occurred with this type. One Tellus GPS collar failed to transmit data. The deer wearing this collar was located twice after its capture and the observer noted the blinking light indicating it was in service; however, it never transmitted a location. Another collar of this type deployed prematurely. We suspect the drop off mechanism malfunctioned while the deer was swimming. This particular deer crossed the San Joaquin River multiple times and we found the collar on the bank of the river. One other collar made a series of errors, which recorded false locations for the collar about 80 km from its actual location for a period of days prior to resuming accurate positioning.

ATS Iridium LITE/GPS model G2110L collars, with Sure*Drop* collar break off mechanisms were smaller at 425 g, and the collars were made of flexible neoprene. These collars were difficult to program through the ATS PC/GPS Wildlink module, PN 1762, a wireless system that provided ephemeral communication between PC and collar at best. While we were able to program a majority of the transmitters, we returned several collars to the manufacturer who programmed them. Customer service at ATS was very good.

There were several failures in the Iridium LITE/GPS model G2110L, which resulted in incomplete data sets. The most common failure was the result of a “software bug”. ATS became aware of the bug during the study and replaced all of the effected collars. However, we deployed five collars prior to learning of the “bug” and the batteries in those collars eventually failed. Three collars of this type dropped off early when screws backed out of the plastic housing on the drop off mechanism. One collar stopped transmitting data a few weeks prior to the scheduled drop off date.

ATS GPS model G2110 store on board GPS collars are slightly smaller than the G2110L at 410 grams, and easy to program. GPS data is stored on board rather than sent regularly via satellite uplink. These collars require regular monitoring for mortality.

The two ATS G2110 store on board collars exhibited reduced VHF transmission capabilities over time. One of these collars was lost due to this failure. We recommend programming these collars to drop off no later than one-year post deployment to minimize this type of problem.

All of our GPS collars were equipped with VHF transmitters with unique frequencies at least .01MHz apart, to aid in finding mortalities and detached collars. We selected unique frequencies to avoid interference from other nearby collars. These transmitters proved invaluable; in several instances, collars were not at the last reported GPS location due to imprecise locations or having been moved by predators or scavengers.

ATS model M2510B, and M4230B VHF transmitters proved to be a solid lightweight telemetry device at about 340 g. These devices performed as expected.