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Distribution and Abundance of Fallow Deer Leks at Point Reyes National Seashore, California

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Abbreviations

cm, centimeter
ESRI, Environmental Systems Research Institute
GIS, Geographic Information System
ha, hectare
km, kilometer
m, meter
m^2, square meter
PDA, Personal Digital Assistant
UTM, Universal Transverse Mercator

Distribution and Abundance of Fallow Deer Leks at Point Reyes National Seashore, California

By Gary M. Fellers and Michael Osbourn

Introduction

Only two species of ungulates (hoofed mammals) are native to Marin County, tule elk (*Cervis elaphus nannodes*) and Columbian black-tailed deer (*Odocoileus hemionus columbianus*). In the 1940s, European fallow deer (*Dama dama*) obtained from the San Francisco Zoo were released at Point Reyes. When Point Reyes National Seashore was established in 1962, fallow deer were well established within the boundaries of the National Seashore. The fallow deer population was estimated to be 500 in 1973 (Wehausen, 1973) and that number increased to 860 by 2005 (National Park Service, unpub. data).

Fallow deer have an unusual mating system. During the fall mating season (or rut), male fallow deer establish areas known as leks where they display to potential mates (Hirth, 1997). This behavior is unique among deer and elk, but it is similar to breeding systems used by grouse and a few other birds and mammals. Formation of leks in ungulates decreases the number of aggressive encounters in which dominant males are involved when the local male density becomes too high, because the spatial stability of territories in leks reduces the number of aggressive encounters between males (Hovi and others, 1996; Pélabon and others, 1999).

A fallow deer lek is typically an area of about 100–150 m^2 and typically includes two to five males. Using their hooves and antlers, each male clears away most or all of the vegetation and digs a rutting pit that he defends throughout the breeding season.

Stenström and others (2000) described rutting pits in a Swedish population of fallow deer:"Pits are large patches of bare soil found at the center of mating stands where most of the rutting activities take place. . . . Scrapes are small patches of bare soil found throughout the areas of deer activity. Only bucks showed any interest in scrapes. Within a 10 day period half the scrapes were rescraped at least once. Larger scrapes were more frequently rescraped than smaller ones. Frayings, i.e., removal of bark and subsequent scent marking on bushes and small trees close to scrapes, also had a positive effect on the frequency of rescraping. . . . fallow deer bucks in our study do not seem to mark territorial boundaries, rather the intensity of markings tends to decrease with distance from the rutting pit suggesting that scraping may instead be used in male status signaling."

Establishing and defending a rutting pit is energetically expensive. Apollonio and others (1989) concluded that: "Body condition appears to be an important determinant of male copulatory success, because only males in superior condition could defend a lek territory for up to two weeks. Males do not feed while defending lek territories. Foraging ability during the year probably determines condition at the onset of the rut. Females appear to choose mates at least partially on the basis of location, preferring males located near traditional routes. Females may ultimately select mates in the best body condition."

In the fall of 2005, we initiated a study of the leks in two study sites at Point Reyes National Seashore. The goal of this work was to determine the distribution and size of fallow deer leks, and to evaluate the impact of both the leks and the associated rutting pits on the soil and vegetation.

Study Areas

Our study was conducted in two areas of Point Reyes National Seashore, the northern portion of the Olema Valley and an area around the Estero trailhead (*fig. 1*). The two study areas were selected to represent areas of high fallow deer density, and medium density.

The Olema Valley was selected because it was typical of areas within the Seashore that have a high density of fallow deer, based on combined aerial and ground counts conducted in January 2001 (Gates, 2001). Initially, we intended to survey the entire high density area, but it quickly became obvious that the number of leks and the time required to document each lek site would preclude a complete survey. Hence we restricted our work to an area that was bounded by features that were readily discernable in the field (e.g., Olema Creek, Bear Valley Road, fence lines). The areas surveyed included Divide Meadow, Bear Valley, and portions of the pasture and riparian habitat along Olema Creek. The Olema Valley study area was 147.2 ha (363.7 acres) in size (*fig. 2*). The predominant vegetation was coast live oak (*Quercus agrifolia*) and California bay (*Umbellularia californica*) woodlands; red alder (*Alnus rubra*) and willow (*Salix sp*.) riparian zones; and grassy meadows and pastures.

Once field work was completed in the Olema Valley, a similar size area was delineated near the Estero trailhead for surveys in the moderate density area. As with the Olema Valley study area, the Estero trailhead area was defined by using a combination of fence lines, roads, and natural features. The Estero trailhead area was selected as representative of an area with low-to-moderate densities of fallow deer (Gates, 2001). The Estero study area was 151.6 ha (374.6 acres) in size (*fig. 3*), roughly equal to the Olema Valley study area. The primary vegetation was coastal scrub dominated by coyote

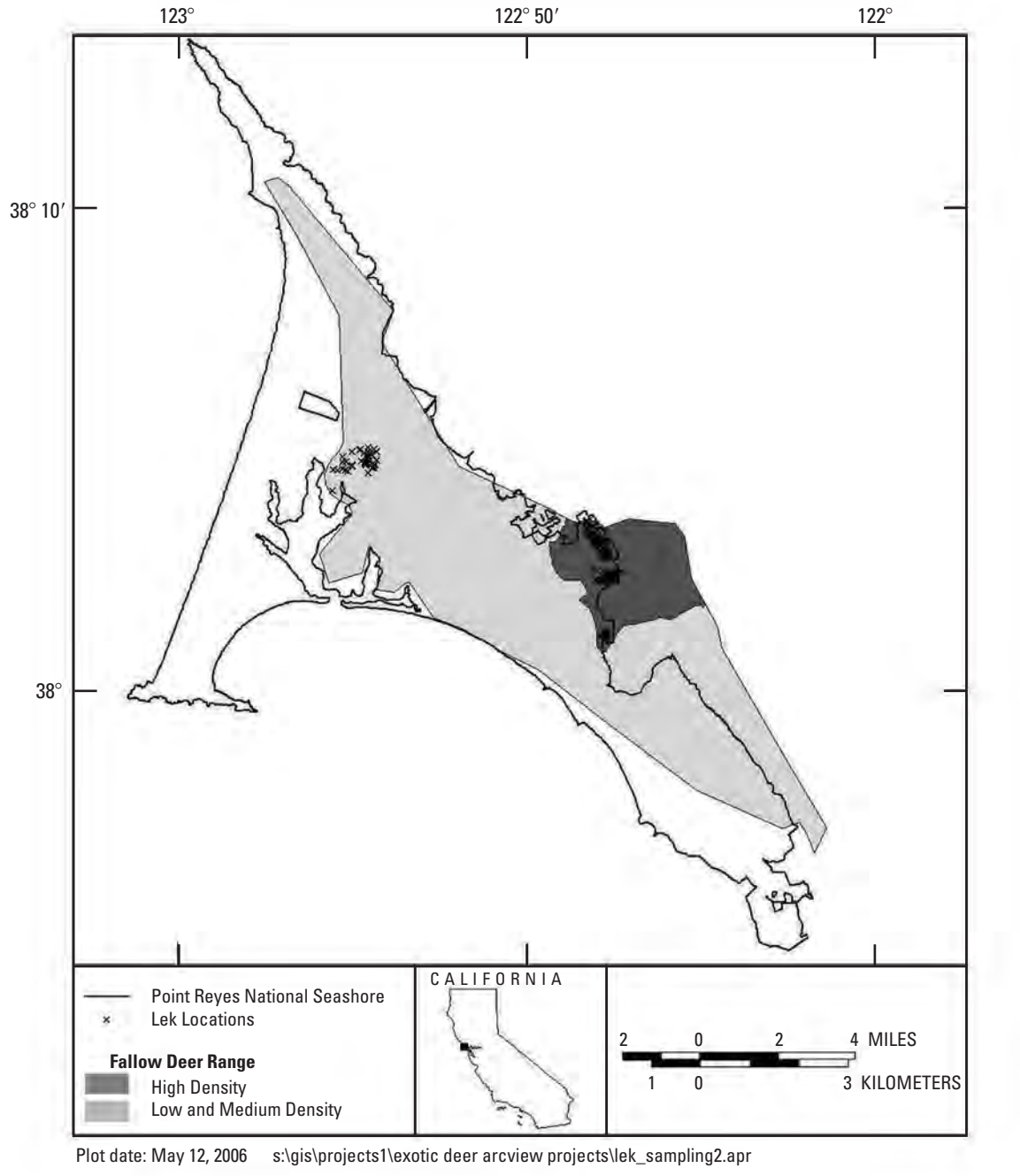

Figure 1. Distribution of high and medium/low density areas for fallow deer at Point Reyes National Seashore, California. Triangle symbols (see figures 2 and 3) mark the location of leks within the Olema Valley and Estero trailhead study areas.

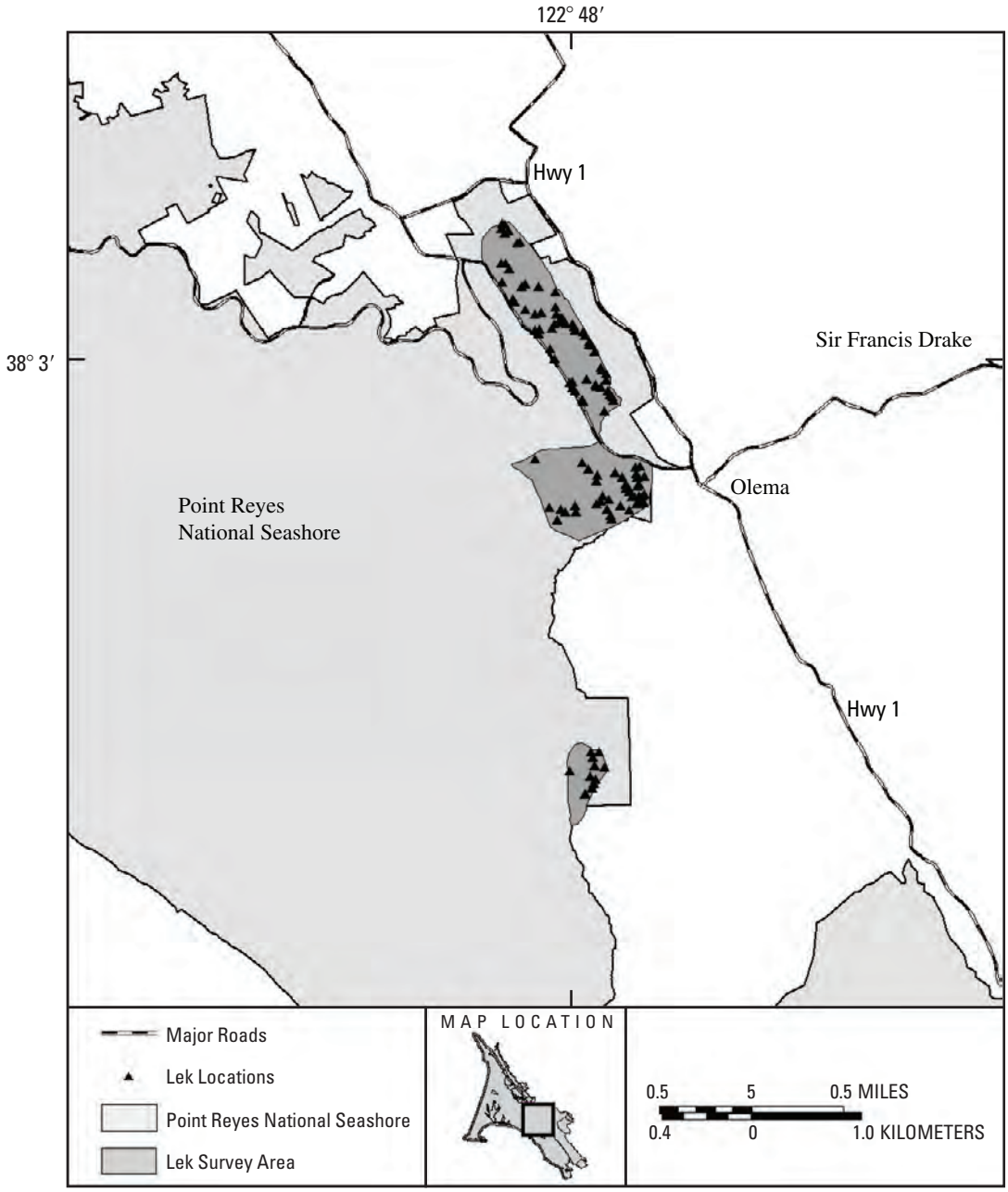

Figure 2. Fallow deer lek sites in the Olema Valley study area, Point Reyes National Seashore, California.

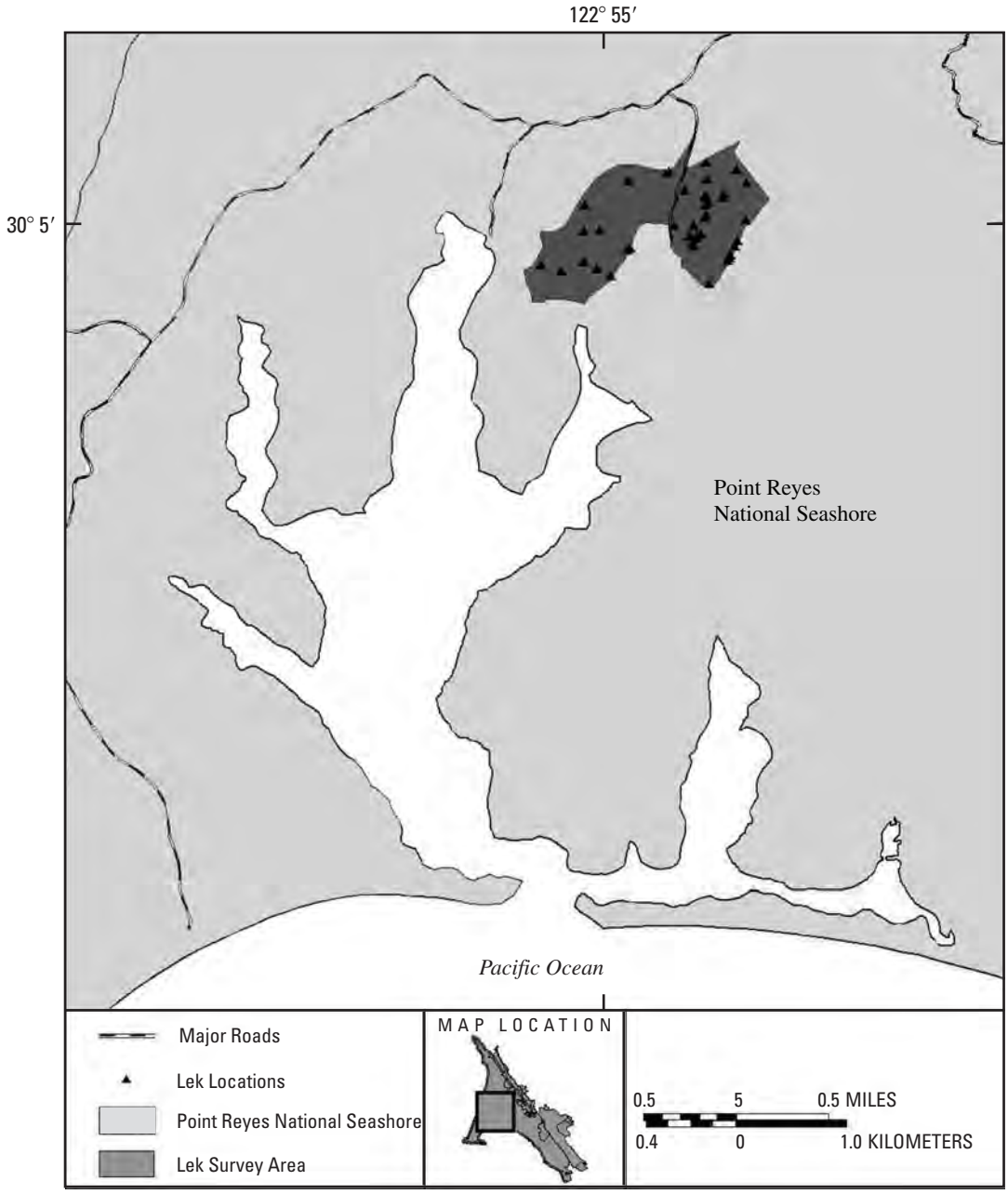

Figure 3. Fallow deer lek sites in the Estero trailhead study area, Point Reyes National Seashore, California.

brush (*Baccharis pilularis*), riparian zones with red alder, and pasture grasslands.

Methods

Leks were located by conducting visual surveys for fallow deer during, and shortly after, the fall lekking season (Oct. 3–Dec. 6, 2005). A total of 202 hours were spent conducting surveys. Fallow deer surveys were carried out at dawn from hilltop vantage points. Treelines and grasslands were scanned with binoculars to locate congregations of fallow deer, damaged vegetation, or bare ground. These areas were subsequently investigated to determine whether or not a lek was present. By repeatedly surveying the entire study area, we were confident that few, if any, leks were overlooked.

Leks were documented by noting the predominant vegetation, recording the condition of the soil and vegetation, measuring the length and width of the lek, and measuring each individual rutting pit. Leks and rutting pits were photographed, and data were recorded with a PDA (Personal Digital Assistant) for later input into a Microsoft Access database.

Delineating Leks

Only areas with disturbed ground or rutting pits were recorded as leks. Pits ranged from shallow depressions where the vegetation had been scraped away to trenches over 50 cm deep. Areas that showed only vegetation damage and lacked ground disturbance were not scored as leks. Areas with obvious cattle impacts or sites with no discernable deer signs (hoof prints, feces, urine stains, antler scrapes, or deer present) were not counted as leks, resulting in a conservative estimate of lek density.

Leks tended to be concentrated linearly along the treelines at margins of fields. Since many of these areas had a nearly continuous band of disturbance, it was difficult to define individual leks. We marked the end of a lek when there was at least 20 m of undamaged ground between lek areas. The length and width of the disturbed ground was measured with a digital range finder (Bushnell Yardage Pro). These measurements were used to calculate the area for each lek.

Measuring Rutting Pits

Within a lek, fallow deer bucks excavate numerous rutting pits. The length and width of each pit was measured with a fiberglass tape. Pit depth was measured with a ruler. These measurements were used to determine the total area of excavated ground and the depth of the pits.

Vegetation Condition

In addition to recording the predominant vegetation associated with each lek site, vegetation condition was evaluated. Disturbed ground, damaged foliage, damaged bark, and exposed roots were all noted. Disturbed ground occurred where the herbaceous cover had been scraped away, resulting in bare soil or excavated rutting pits. Damaged foliage included leaves, twigs, or branches that had been shredded or broken. Damaged bark was noted where fallow deer had used their antlers to break, tear, or scrape off the bark of trees or shrubs. Exposed roots were found in some of the deeper pits where the roots of trees were damaged and exposed to the air.

Damaged vegetation that was not closely associated with a lek was ignored, even though it might have been caused by fallow deer. Native black-tailed deer will feed on buds, twigs, sprouts, leaves, fruit, and flowers of woody plants. We never observed these deer in or around fallow deer leks, probably because fallow deer tend to be behaviorally dominant. Beef cattle were present in all of the Estero trailhead study area and part of the Olema Valley study area. While cattle will sometimes rub on vegetation and cause discernable vegetation damage, we did not observe this behavior at fallow deer lek sites. Additionally, most of the vegetation damage we observed was in riparian areas where cattle had been excluded by fencing.

During our initial surveys, we did not quantify vegetation condition at each lek, so we revisited 22 randomly selected leks in the Olema Valley to record the condition of both the soil and vegetation in more detail. We used a scoring system (Cole 1989a, 1989b) to evaluate the impacts of fallow deer (*table 1*). At each lek site, we scored ground surface disturbance, percent vegetative cover, damage to live trees, and presence of exposed roots. No attempt was made to quantify damage to individual trees or to assess likelihood of tree death resulting from the lek damage.

Table 1. Codes used to evaluate ground surface disturbance, vegetation cover, tree damage, and root exposure at fallow deer leks in the Olema Valley, Point Reyes National Seashore, California.

	Surface disturbance
0	No surface disturbance
1	Little disturbance to ground cover, whether cover is vegetation or litter
2	Noticeable disturbance to litter or vegetation
3	Moderate disturbance and bare ground
4	Ground surface highly disturbed, extensive areas of bare ground

	Vegetation cover
1	50–100 percent
2	15–50 percent
3	5–15 percent
4	0–5 percent

	Live tree damage
0	No tree damage
1	A few small broken branches
2	Several broken branches and/or scraping of bark
3	Extensive bark gouging or scraping; broken branches may be present

	Root exposure
0	No exposed roots seen
1	One to two roots are up to 10 percent exposed (in cross–section) for <1 m
2	Some roots 10–50 percent exposed for up to 1 m
3	Some roots >50 percent exposed and/or exposed 10–50 percent for > 1 m

Photo Documentation

A digital camera was used to document leks, rutting pits, and damaged vegetation. Bucks displaying and actively digging or shredding foliage were also photographed, as were groups of does. Photographs were also taken of deer feces, hoof prints, and urine stains as evidence of deer use.

Mapping

UTM coordinates were recorded using a Garmin XL GPS unit. ArcView 3.3 software (ESRI, *http://www.esri.com/software/arcgis/arcinfo/index.html*) was used to plot lek locations and to determine the size of the two study areas.

Results

Leks and Rutting Pits

A total of 159 fallow deer leks were located within the 298.8 ha (738.3 acres) surveyed at Point Reyes National Seashore (*table A1*, *appendix*). In the Olema Valley, there were 116 lek sites compared with 43 leks in the Estero trailhead area. The mean dimensions of a lek site were 13 × 7 m with an area of 115 m^2 (SD = 132). The total area of the leks in the Olema Valley was 16,188 m^2, while the area at the Estero trailhead was 2,136 m^2 for a combined total of 18,324 m^2 (4.5 acres). This was 0.6 percent of the 298.8 ha surveyed. There was a notably higher proportion of the Olema Valley study site that was part of a lek, 1.1 percent compared to 0.1 percent at Estero trailhead. In the Olema Valley, there were 0.8 leks per ha, while the Estero trailhead area had 0.3 leks per ha (*table 2*).

Table 2. Number of fallow deer leks and rutting pits in two study areas at Point Reyes National Seashore, California.

[Numbers in parentheses are Standard Deviations. cm, centimeter; ha, hectare; m^2, square meter]

	Olema Valley	Estero trailhead	Combined
Study area size (ha)	147.2	151.6	298.8
Number of leks	116	43	159
Leks per ha	0.8	0.3	0.5
Mean lek area (m^2)	140 (±142)	50 (±60)	115 (±132)
Total lek area (m^2)	16,188	2,136	18,324
Percent lek area (m^2)	1.1 percent	0.1 percent	0.6 percent
Number of rutting pits	598	107	705
Total pit area (m^2)	1,463	358	1,821
Percent study area as pits	0.1 percent	0.02 percent	0.6 percent
Mean number pits/lek	5.1 (±5.1)	2.5 (±1.9)	4.4 (±4.6)
Mean pit depth (cm)	10 (±9)	6 (±5)	9 (±9)
Maximum pit depth (cm)	60	15	60

A total of 705 rutting pits were found in the two study areas, with an average size of 1 × 2 m, and an area of 2.6 m (SD = 3.0) for each pit. The mean number of pits per lek was 5.1 in the Olema Valley and 2.5 for Estero trailhead. The total combined area of excavated ground in rutting pits was 1,821 m^2, or 0.6 percent of the total area surveyed. Eighty-five percent (598) of pits were found in the Olema Valley study area. Though fewer in number, the pits at the Estero trailhead study area were larger (3.3 m^2) than the pits in Olema Valley (2.4 m^2).

Vegetation Condition

There was vegetation damage at 110 (69.2 percent) of the lek sites (*table A2, appendix*). Damaged foliage was present at 102 (64 percent) of the lek sites. During initial surveys for leks, sites were often located by broken live oak or California bay branches that were visible from considerable distances. Low branches and bark adjacent to rutting pits were often heavily damaged. On several occasions, bucks were observed thrashing vegetation with their antlers, digging in the rutting pits, and displaying at their lek. Bark damage was recorded at 72 (45 percent) of the leks. Exposed roots were documented for 30 (19 percent) of the lek sites. In addition to having nearly three times as many leks, the Olema Valley study area had a higher percentage of sites with damaged foliage and a higher percentage of sites with damaged bark, but the result was not statistically significant when using an $\alpha = 0.05$ for evaluating level of significance ($X^2 = 3.16$, df = 2, $p = 0.206$).

Riparian Impacts

Vegetation damage was greater in riparian areas (compared with non-riparian) for both the damaged foliage and damaged bark categories (*table 3*). In riparian areas, willows and alders were the trees most often observed with damage. Several alders were completely girdled. Less commonly, there were exposed roots, especially in the Estero trailhead area (*table 3*). Overall, there was more damage in riparian areas, but the result was not statistically significant ($X^2 = 5.74$, df = 2, $p = 0.057$). A larger sample size would quite likely result in a statistically significant difference.

Vegetation and Soil Condition Scores

In our quantitative evaluation of the vegetation and soil at 22 random sites, surface disturbance ranged from 0 (no disturbance) to 4 (ground surface highly disturbed with extensive areas of bare ground) with a mean score of 1.6 and a median of 2 (*table 4*). The mean score corresponds to a damage level between “Little disturbance to ground cover” and “Noticeable disturbance to litter or vegetation.” Both vegetation cover and live tree damage had a mean and median score of 1 (50–100 percent cover, and a few small broken branches). There were no roots exposed in the sample plots.

Table 3. Vegetation damage at fallow deer lek sites at Point Reyes National Seashore, California.

[The numbers under each study area are the number of leks in each category; the percents are the proportion of leks in that category]

	Olema Valley		Estero Trailhead		Combined	
Riparian	17	15 percent	8	19 percent	25	16 percent
Damaged foliage	15	88 percent	7	88 percent	22	88 percent
Damaged bark	14	82 percent	8	100 percent	22	88 percent
Exposed roots	1	6 percent	3	38 percent	4	16 percent
Non-riparian	100	86 percent	34	79 percent	134	84 percent
Damaged foliage	71	71 percent	8	24 percent	79	59 percent
Damaged bark	45	45 percent	6	18 percent	51	38 percent
Exposed roots	20	20 percent	6	18 percent	26	19 percent

Table 4. Vegetation data from randomly selected fallow deer leks in the Olema Valley, Point Reyes National Seashore, California.

[See table 1 for a description of the codes]

Lek	Surface disturbance	Vegetative cover	Live tree damage	Root exposure	Species composition
22	4	2	1	0	Oak, grass, hedge nettle, geranium
25	2	1	0	0	Bay, forget-me-not, nettles, cow parsnip, currant, sword fern
27	0	0	0	0	Oak, blackberry, nettles, Australian fireweed, hazelnut, grass, sedge
29	2	1	2	0	Bay, grass which is mostly purple velvet, oak, coffeeberry
33	2	2	2	0	Oak and littler, bay seedlings, grass, Italian thistle, nettles
34	2	1	2	0	Oak, litter, grass
40	2	1	1	0	Oak, grass, Italian thistle, mustard
42	3	1	1	0	Oak, grass, Italian thistle, mustard
43	0	0	0	0	Not recorded
46	1	1	0	0	Oak, bay, litter, hemlock, grass
52	2	1	1	0	Oak and litter, grass, hemlock
60	0	0	0	0	Oak, grasses
61	3	2	2	0	Oak, with little vegetation under the canopy.
64	2	1	2	0	Oak and oak litter, blackberry, fern, hazelnut, Italian thistle, poison oak
66	0	0	0	0	Oak and litter, grass (mostly Italian rye and purple velvet), bracken fern, blackberry
67	0	0	0	0	Oak, forbs (didn't record what)
82	2	0	1	0	Oak, grass, thistles, radish, poison oak
85	0	0	2	0	Oak, willow, grass, blackberry, poison oak, dock
90	2	1	2	0	Oak, grass, small forbs, blackberry, hemlock, mint, dock
97	1	3	1	0	Oak and oak litter. Nearby are blackberry, some grass.
100	3	2	1	0	Oak, bay, poison oak, blackberry, Italian thistle, hazelnut.
Mean	**1.6 (±1.2)**	**1**	**1**	**0**	
Median	**2**	**1**	**1**	**0**	

Photograph documentation

Typically, leks were found at the edge of a woodland or at the edge of the low-hanging part of the canopy of isolated trees. *Figure 4* shows a large area of bare ground at the edge of a coast live oak. Some rutting pits were more than 50 cm deep (*fig. 5*), often surrounded by an even larger area cleared of all vegetation. Other leks had only a modest depression and were identified by the lack of vegetation along with associated fecal material, hoof prints, and damage to woody vegetation (*fig. 6*). Rutting pits in close association with bushes and trees were often associated with significant damage to the woody vegetation, including broken branches, stripped bark, and sometimes, girdled trees (*fig. 7*). Fallow deer were observed using their antlers to clear vegetation, rub the trunk of trees, break limbs, and dig pits. Vegetation was sometimes caught in their antlers (*fig. 8*).

Figure 4. Typical location for a fallow deer rutting pit, at the interface between a tree and the adjacent grassland or the edge of the low-hanging canopy, Olema Valley, Point Reyes National Seashore, California.

Figure 5. Rutting pit and bare ground associated with a fallow deer lek in the Olema Valley, Point Reyes National Seashore, California.

Figure 6. Rutting pit and bare ground associated with a fallow deer lek in the Olema Valley, Point Reyes National Seashore, California.

Figure 7. Broken willow branches at a fallow deer lek in the Olema Valley, Point Reyes National Seashore, California.

Figure 8. Fallow deer buck with vegetation caught in his antlers, Olema Valley, Point Reyes National Seashore, California.

Discussion

Fallow deer are one of the few mammals that use a lek breeding system where males gather in groups and display to potential mates. As part of the display, male deer dig rutting pits with their hooves and antlers, and scrape bushes and trees adjacent to the pits. This results in soil disturbance, loss of vegetation, and occasionally damage to the trunks and limbs of nearby vegetation. The extent of the impacts was related to the density of fallow deer. This density was higher in the Olema Valley (Gates, 2001) and lek impacts were greater in that area, as would be expected. The Olema Valley had a greater mean lek area, total lek area, percentage of total area as leks, mean number of rutting pits per lek, percentage of total area as rutting pits, and mean pit depth (*table 2*). In the Olema Valley study area, more than 1 percent of the total land area surveyed was impacted by lek damage, with riparian areas being disproportionately affected. For example, in riparian areas of the two study areas, there was bark damage at 88 percent of the leks and 84 percent of the leks had damaged foliage (*table 3*).

The primary habitat impact of leks at Point Reyes was caused by the digging of rutting pits that resulted in a loss of soil and vegetation. At the peak of the rut, pits were commonly found in Olema Valley, especially at the woodland/grassland interface where fallow deer tend to congregate. The density of rutting pits was less in the Estero trailhead study area due to the smaller fallow deer population there.

Our research shows that fallow deer are having a measurable impact on the soil and vegetation at Point Reyes. In the Olema Valley, there were 0.8 leks per ha, while the Estero trailhead area had 0.3 leks per ha (*table 2*). The total number of rutting pits was 705 with a total area of 1,821 m^2. Pélabon and others (1999) have shown that the formation of leks in ungulates is “a mating tactic that aims at decreasing the number of aggressive encounters in which dominant males are involved when the local male density becomes too high.” If the fallow deer population continues to increase, the number of leks, the number of rutting pits, and the associated habitat damage will likely increase.

Acknowledgments

Wende Rehlaender conducted the detailed soil and vegetation evaluations and provided those data to us for analysis. Patrick Kleeman provided assistance in data management. Kan Dhillon assisted with the initial surveys for fallow deer leks and with general advice on the location of fallow deer within the seashore. Dave Schriokaurer and Amelia Ryan provided GIS mapping assistance. Natalie Gates helped offered advice throughout the development and implementation of the project. Rick Golightly, Dale McCullough, Kurt Jenkins, Patrick Kleeman, and Joan Fellers provided comments on an earlier draft of this report. We greatly appreciate the assistance of all of the above.

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Appendix

Table A1. Locations of fallow deer leks at Point Reyes National Seashore, California.

[m, meter; km, kilometer]

	Lek Site	UTME	UTMN
Olema Valley sites			
2	Cluster of Douglas Firs on Knob ~200 m SSW of Morgan Ranch house, Bear Valley	517496	4209939
3	Lone pit at base of small bay	517535	4209914
4	SE edge of grove of live oaks, Douglas Fir, and bay along Woodpecker and Bear Valley Trails	517625	4209915
5	Within grove of live oaks, Douglas Fir, and bay along Woodpecker and Bear Valley Trails	517620	4209967
7	Top of Knob at edge of field, along Bear Valley Trail	517460	4209845
8	At base of Douglas Fir next to meadow behind Morgan Horse Ranch	517273	4210372
9	At forest edge adjacent to Woodpecker Trail, 15 m from Morgan Trail	517390	4209948
10	Near large bay in meadow at Bear Valley between Earthquake Trail and Vadanta	517934	4209851
11	Near base of live oak in meadow at Bear Valley between Earthquake Trail and Vadanta	517924	4209878
12	Grove of bays in meadow in Bear Valley, south of Earthquake Trail	517894	4209936
13	In groove of bays ~100 m SE of SE corner of Bear Valley parking lot	517807	4209980
14	Edge of grove of bays ~100 SE of Bear Valley parking lot	517842	4210007
15	10 m S of Earthquake Trail, adjacent to bay tree	517857	4210053
16	East edge of Divide Meadow	517776	4207778
17	SE corner of Divide Meadow	517759	4207823
18	East edge of Divide Meadow, next to live oaks	517785	4207705
19	Small open area east of tree line, SE corner of Divide Meadow	517829	4207822
20	At edge of live oaks along edge of Divide Meadow	517872	4207694
21	Base of live oak at NE corner of Divide Meadow	517750	4207615
22	Edge of NE corner of Divide Meadow, live oak	517800	4207587
23	Under live oak at tree line of edge of Divide Meadow	517781	4207548
24	Inside forest edge, under bay trees, NE corner of Divide Meadow	517769	4207516
25	Forest edge under bay and alders, Divide Meadow	517706	4207462
26	Under alder at N end of Divide Meadow	517708	4207459
27	Under live oak, west of Bear Valley Trail, across from Divide Meadow	517571	4207660
28	20 m N of Earthquake Trail, at edge of meadow and bays in Bear Valley	517916	4210024
29	Base of bay between Earthquake Trail and Rift Zone Trail	518012	4209969
30	20 m from Rift Zone Trail in clearing at edge of Bear Valley meadow	518087	4209925
31	20 m N of Rift Zone Trail on knob SE of Bear Valley, under live oaks	518174	4209983
32	On knob 75 m N of Rift Zone Trail, under live oak	518217	4209989
33	Adjacent to live oak, on knob, 75 m N of Rift Zone Trail	518207	4210015
34	Under live oak, ~100 m N of Rift Zone Trail on W side of knob	518206	4210053
35	Under live oak, ~125 m from Rift Zone Trail on knob	518219	4210070
36	Under live oak, 20 m N of Rift Zone Trail	518178	4210049
37	Under live oak, 30 m N of Rift Zone Trail on knob	518150	4209982
38	At large bay, ~40 m N of Rift Zone Trail on knob	518138	4210048
39	Under bay tree, ~50 m N of Rift Zone Trail on knob	518111	4210048
40	Under lone live oak in meadow near top of knob N of Rift Zone Trail	518086	4210124
41	Area at base of large oak and bay trees, on knob near Rift Zone Tail and Earthquake Trail	518062	4210116
42	Near top of knob N of Rift Zone Trail at forest edge, ~20 m E of Earthquake Trail	518061	4210150
43	At forest edge on knob N of Rift Zone Trail and E of Earthquake Trail	518087	4210094
44	On slope 40 m NE of Earthquake Trail and 150 m SE of Red Barn parking lot	517970	4210251
45	Area around small live oak on top of knob, NE of Earthquake Trail	518025	4210213
46	Field at base of knob between Rift Zone Trail and Bear Valley Rd., ~100 m SW of BV Road	518183	4210311

Table A1. Locations of fallow deer leks at Point Reyes National Seashore, California—Continued.

[m, meter; km, kilometer]

	Lek Site	UTME	UTMN
47	In grove of live oaks at base of knob ~100 m SW of Bear Valley Rd	518146	4210301
48	Grove of live oaks on East side of top of knob, 250 m SW of BV Rd. and 220 m N of Rift Zone Trail	518178	4210152
49	Area surrounding live oak in field on top of knob, 0.5 km W of Olema	518158	4210140
50	Edge of field at grove of live oaks, ~0.5 km E of Red Barn and 0.5 km W of Olema	518163	4210218
51	Grove of live oaks and bays on NE corner of knob, ~0.5 km W of Olema	518154	4210245
52	Grove of oaks near base of NE corner of knob, 0.5 km W of Olema	518220	4210221
53	Edge of meadow in grove of oaks	517544	4211545
54	At edge of live oak grove on SW edge of hills between BV Rd. and Hwy 1	517522	4211568
55	In grove of live oaks in pasture between BV Rd. and Hwy 1	517512	4211590
56	Grove of willows and live oaks at base of east-facing slope between BV Rd. and Hwy 1	517592	4211546
57	Edge of pasture and treeline, 390 m N of Headquarters	517684	4210871
58	Edge of pasture 410 m N of Headquarters	517682	4210887
59	Near live oak on SW-facing slope of hill NE of BV Rd., 1.15 km NNW of Headquarters	517310	4211503
60	Stewart's pasture at base of two live oaks, 1.4 km NNW of Headquarters	517438	4211544
61	Under live oak, 1.0 km NNW of Headquarters	517420	4211507
62	Base of live oak in Stewart's pasture NE of Bear Valley Rd., 1.17 km NNW of Headquarters	517487	4211564
63	Under live oaks in grove at NE edge of Stewart's pasture, 1.2 km NNW of Headquarters	517492	4211601
64	Under live oaks on NE side of hill in Stewart's Pasture NE of Bear Valley Road, 1.22 km NNW of Headquarters	517452	4211635
65	Underneath live oak tree, 550 m N of Headquarters	517721	4211065
66	Grove of live oaks, 550 m NNE of Headquarters	517803	4211003
67	Under live oaks at base of hill on east facing slope, 550 m NNE of Headquarters	517796	4211020
68	Stand of willows at east-facing slope of hill, 510 m NE of Headquarters	517844	4210995
69	Under alders along creek, 510 m NE of Headquarters	517903	4210968
70	Alders along Olema Creek, 600 m NNE of Headquarters	517887	4211061
71	Adjacent to Olema Creek on gravel bar in stand of alders, 560 m NNE of Headquarters	517886	4211111
72	Edge of pasture and stand of willow and alder, along Olema Creek, 580 m NNE of Headquarters	517850	4211143
73	Edge of pasture along fence, creek, and stand of willow and alder, 610 m NNE of Headquarters	517839	4211170
74	Edge of pasture along fence, creek, and willows, 860 m N of Headquarters	517785	4211309
75	Adjacent to creek in stand of willows and alders, 900 m N of Headquarters	517768	4211361
76	Pasture, 910 m N of Headquarters	517739	4211369
77	Border of pasture and riparian, 940 m N of Headquarters	517743	4211393
78	Pasture, 1.0 km N of Headquarters	517706	4211447
79	Pasture, 1.01 km N of Headquarters	517691	4211476
80	Under live oaks at base of E slope of hill, 1.02 km N of Headquarters	517618	4211496
81	Grove of willows, 1.1 km N of Headquarters	517614	4211527
82	Top of hill by lone fallen live oak, 1.25 km NW of Headquarters	517327	4211647
83	Edge of forest under live oak, near top of hill, 1.22 km NW of Headquarters	517267	4211628
84	Grove of oaks and small clearing at forest edge, 1.3 km NW of Headquarters	517185	4211672
85	Edge of treeline in pasture NE of Bear Valley Rd., 1.1 km NW of Headquarters	517268	4211494
86	Treeline 30 m NE of Bear Valley Rd. at pasture edge, 970 m NW of Headquarters	517297	4211458
87	Treeline at edge of pasture NE of Bear Valley Rd., 930 m NW of Headquarters	517405	4211330
88	Under oak in clearing 15 m NE of Bear Valley Rd., 840 m NW of Headquarters	517442	4211244
89	Grove of oak and bay NE of Bear Valley Rd., 600 m NNW of Headquarters	517570	4211039
90	Grove of oaks along Bear Valley Road, 580 m NNW of Headquarters	517594	4211046
91	Grove of oaks bordering Bear Valley Rd., 520 m NNW of Headquarters	517595	4210987
92	Grove of oaks bordering Bear Valley Rd., 480 m NNW of Headquarters	517620	4210966

Table A1. Locations of fallow deer leks at Point Reyes National Seashore, California—Continued.

[m, meter; km, kilometer]

	Lek Site	UTME	UTMN
93	Under lone tree at SE end of pasture, 320 m NNE of headquarters	517876	4210789
94	Grove of live oaks adjacent to Olema Creek, 480 m NE of headquarters	517954	4210882
95	Grove of oak and bay at East edge of pasture, along Olema Creek, 500 m NE of headquarters	517945	4210911
96	Grove of oak and bay along Olema Creek, 500 m NE of headquarters	517921	4210928
97	At base of live oak, along treeline at edge of pasture 1.36 km NW of Headquarters	517157	4211873
98	Forest edge of pasture, 1.30 km NW of Headquarters	517188	4211892
99	Forest edge of pasture, 1.40 km NW of Headquarters	517095	4211738
100	Edge of pasture and forest, under oak and bay 1.42 km NW of Headquarters	517079	4211764
101	Under lone live oak in pasture, 1.6 km NW of Headquarters	516983	4211907
102	Open pasture, 1.7 km NW of Headquarters	516974	4212069
103	In open pasture on top of knob, 1.73 km NW of Headquarters	517016	4212074
104	Open pasture on top of knob, 1.7 km NW of Headquarters	517045	4212027
105	Small cluster of willow in field east of Olema Marsh	517004	4212337
106	Patch of invasive plants in field east of Olema Marsh	516974	4212376
107	Edge of willows and field along Olema Creek, east of Olema Marsh	516982	4212418
108	Edge of willows and field along Olema Creek, east of Olema Marsh	517004	4212415
109	Under willows along Olema Creek, east of Olema Marsh	517034	4212360
110	Edge of riparian willows along Olema Creek, 400 m east of Olema Marsh	517136	4212262
111	Next to willow, 400 m east of Olema Marsh	517118	4212252
112	Edge of oak grove and pasture 1.45 km NW of Headquarters	517304	4211868
113	Under live oak at edge of pasture near Olema Creek, 1.37 km NNW of Headquarters	517450	4211826
114	Base of live oak in pasture, 1.27 km NNW of Headquarters	517446	4211695
115	Next to bay tree at NE end of Bear Valley picnic area	517732	4210281
116	Next to bay at edge of Bear Valley picnic area	517809	4210229
117	Edge of treeline at SE end of Bear Valley picnic area	517803	4210182
118	Grassy area at edge of tree line along road, 100 m South of Headquarters	517679	4210336
	Estero Trailhead sites		
119	Open pasture, near Home Ranch, 200 m E of Estero Trail parking lot	507828	4214722
120	Open pasture, near Home Ranch, 200 m E of Estero Trail parking lot	507835	4214696
121	Open pasture, near Home Ranch, 250 m ENE of Estero Trail parking lot	507861	4214769
122	Open pasture, near Home Ranch, 300 m ENE of Estero Trail parking lot	507897	4214811
123	Patch of thistle, near Home Ranch, 260 m ENE of Estero Trail parking lot	507870	4214797
124	Open pasture, near Home Ranch, 220 m ENE of Estero Trail parking lot	507800	4214790
125	Open grassland on ridge top, near Home Ranch, 750 m WNW of Estero Trail parking lot	506885	4214833
126	Open grassland on ridge top, near Home Ranch, 650 m WNW of Estero Trail parking lot	507024	4214838
127	Top of point West of Home Bay, 1.5 km SW of Estero Trail parking lot	506470	4213642
128	Ridge top 1.1 km W of Estero Trail parking lot	506509	4214534
129	Ridge top 1.0 km WSW of Estero Trail parking lot	506692	4214484
130	Open grassland on ridge top 700 m NW of Estero Trail parking lot	507275	4215275
131	Open pasture, near Home Ranch, 200 m ENE of Estero Trail parking lot	507798	4214783
132	Top of Knob, near Home Ranch, 500 m NE of Estero Trail parking lot	507961	4215090
133	Top of Knob, near Home Ranch, 450 m NE of Estero Trail parking lot	507937	4215053
134	Top of Knob, near Home Ranch, 550 m NE of Estero Trail parking lot	507941	4215133
135	Side of Knob, near Home Ranch, 650 m NE of Estero Trail parking lot	508097	4215160
136	Side of Knob, near Home Ranch, 600 m NE of Estero Trail parking lot	508085	4215122
137	Side of Knob, near Home Ranch, 400 m NE of Estero Trail parking lot	507945	4214969
138	Side of Knob, near Home Ranch, 370 m NE of Estero Trail parking lot	507927	4214944

Table A1. Locations of fallow deer leks at Point Reyes National Seashore, California—Continued.

[m, meter; km, kilometer]

	Lek Site	UTME	UTMN
139	Pasture on knob 275 m NE of Estero Trail parking lot	507834	4214889
140	Pasture on NW side of knob 500 m NE of Estero Trail parking lot	507927	4215134
141	Pasture on knob 600 m NNE of Estero Trail parking lot	507950	4215280
142	Pasture 900 m NE of Estero Trail parking lot	508205	4215368
143	Bare ground adjacent to coyote brush 800 m NNE of Estero Trail parking lot	507941	4215429
144	Pasture 500 m NNE of Estero Trail parking lot	507758	4215188
145	Pasture 150 m N of Estero Trail parking lot	507667	4214877
146	Edge of pasture along unnamed stream, 450 m SE of Estero Trail parking lot	507965	4214373
147	Edge of pasture along unnamed stream, 500 m ESE of Estero Trail parking lot	508130	4214576
148	Edge of pasture along unnamed stream, 475 m ESE of Estero Trail parking lot	508144	4214601
149	Edge of pasture along unnamed stream, 510 m ESE of Estero Trail parking lot	508150	4214625
150	Edge of pasture along unnamed stream, 525 m E of Estero Trail parking lot	508190	4214700
151	Edge of pasture along unnamed stream, 550 m E of Estero Trail parking lot	508214	4214747
152	Pasture in saddle 850 m NE of Estero Trail parking lot	508297	4215253
153	Edge of pasture along unnamed stream, 650 m ENE of Estero Trail parking lot	508287	4214922
154	Pasture 600 m N of Estero Trail parking lot	507598	4215337
155	Pasture 650 m N of Estero Trail parking lot	507622	4215353
156	Pasture 400 m W of Estero Trail parking lot	507265	4214667
157	Grove of willows along unnamed creek, 350 m W of Estero Trail parking lot	507290	4214685
158	Pasture on ridge top, 800 m NW of Estero Trail parking lot	506888	4215054
159	Scrub 750 m WSW of Estero Trail parking lot	506884	4214571
160	Scrub 700 m WSW of Estero Trail parking lot	506999	4214505
161	Edge of willows along unnamed creek, 600 m WSW of Estero Trail parking lot	507116	4214443

Table A2. Description of leks and associated ground and vegetation damage at the two study sites at Point Reyes National Seashore, California.

[m, meter; m^2, square meter; —, no data]

	Length (m)	Width (m)	Area (m^2)	Number rutting pits	Ground disturbance	Damaged foliage	Damaged bark	Exposed roots
Olema Valley sites								
2	20	16	320	5	X	X	—	X
3	7	2	14	1	X	X	X	—
4	25	15	375	5	X	X	—	—
5	8	2	16	3	X	—	—	—
7	8	2	16	2	X	X	—	—
8	3	1.5	4.5	1	X	X	—	X
9	25	5	125	4	X	X	—	X
10	2	1	2	1	X	—	—	—
11	3	1.5	4.5	1	X	—	—	—
12	13	10	130	6	X	X	—	X
13	2.5	1.2	3	1	X	—	—	X
14	20	20	400	8	X	X	—	X
15	2	1.4	2.8	1	X	—	—	—
16	25	10	250	4	X	—	—	—
17	10	2	20	2	X	—	X	X
18	20	15	300	4	X	X	X	X
19	10	10	100	4	X	X	X	X
20	4.5	1	4.5	2	X	X	—	X
21	15	10	150	5	X	—	—	—
22	2	1.1	2.2	3	X	—	—	—
23	16	5	80	5	X	—	—	—
24	20	10	200	6	X	—	—	X
25	15	2	30	4	X	—	—	—
26	4	1	4	1	X	—	—	—
27	2.5	1.1	2.75	1	X	—	—	—
28	3	1.2	3.6	2	X	X	X	X
29	4.5	1.5	6.75	3	X	X	—	—
30	17	2	34	2	X	X	—	—
31	20	10	200	4	X	X	—	X
32	5	4	20	1	X	—	—	—
33	17	15	255	8	X	X	—	—
34	16	10	160	4	X	X	—	—
35	5	2	10	2	X	X	—	—
36	10	3	30	3	X	—	—	—
37	20	17	340	16	X	X	—	X
38	20	18	360	7	X	X	—	X
39	5	5	25	1	X	X	—	X
40	20	17	340	2	X	—	—	—
41	10	5	50	5	X	X	X	X
42	16	8	128	9	X	X	—	X
43	10	5	50	3	X	X	X	X
44	10	5	50	1	X	X	X	X
45	8	5	40	1	X	X	—	—
46	17	5	85	6	X	—	—	—

Table A2. Description of leks and associated ground and vegetation damage at the two study sites at Point Reyes National Seashore, California—Continued.

[m, meter; m^2, square meter; —, no data]

	Length (m)	Width (m)	Area (m^2)	Number rutting pits	Ground disturbance	Damaged foliage	Damaged bark	Exposed roots
47	15	5	75	4	X	X	—	—
48	17	13	221	9	X	X	X	—
49	14	10	140	11	X	X	X	—
50	10	5	50	3	X	—	X	—
51	33	12	396	12	X	X	X	—
52	20	10	200	8	X	X	X	—
53	20	10	200	8	X	X	X	—
54	18	10	180	8	X	X	X	—
55	10	2	20	2	X	—	—	—
56	25	10	250	4	X	X	X	—
57	25	8	200	8	X	—	—	—
58	20	5	100	4	X	—	—	—
59	15	5	75	2	X	X	—	—
60	35	24	840	22	X	X	X	—
61	20	10	200	6	X	X	X	—
62	18	10	180	6	X	X	X	—
63	10	10	100	2	X	X	—	—
64	5	4	20	2	X	—	—	—
65	13	5	65	9	X	X	X	—
66	24	10	240	9	X	X	X	—
67	20	10	200	15	X	X	X	—
68	10	5	50	3	X	X	X	—
69	10	8	80	1	X	X	X	—
70	10	5	50	1	X	X	X	—
71	15	5	75	5	X	X	X	—
72	5	5	25	1	X	X	X	—
73	4	4	16	1	X	X	X	—
74	20	4	80	9	X	X	X	—
75	10	5	50	3	X	X	X	—
76	8	5	40	1	X	—	—	—
77	27	8	216	12	X	X	X	X
78	10	10	100	2	X	X	—	—
79	1	1	1	1	X	—	—	—
80	34	8	272	5	X	X	X	—
81	20	20	400	4	X	X	X	—
82	15	15	225	6	X	—	—	—
83	8	5	40	2	X	X	—	—
84	20	15	300	9	X	X	X	—
85	10	5	50	2	X	X	X	—
86	8	5	40	1	X	X	X	—
87	27	10	270	18	X	X	X	—
88	16	7	112	3	X	X	—	—
89	20	10	200	5	X	X	—	—
90	15	12	180	11	X	X	X	—
91	32	20	640	24	X	X	X	—

Table A2. Description of leks and associated ground and vegetation damage at the two study sites at Point Reyes National Seashore, California—Continued.

[m, meter; m^2, square meter; —, no data]

	Length (m)	Width (m)	Area (m^2)	Number rutting pits	Ground disturbance	Damaged foliage	Damaged bark	Exposed roots
92	20	12	240	7	X	X	X	—
93	14	10	140	8	X	X	X	—
94	30	17	510	30	X	X	X	—
95	20	15	300	5	X	X	X	—
96	25	10	250	7	X	X	X	—
97	15	13	195	2	X	X	X	—
98	15	10	150	5	X	X	—	—
99	15	10	150	2	X	X	X	—
100	8	5	40	4	X	X	X	—
101	10	5	50	1	X	X	X	—
102	10	5	50	1	X	—	—	—
103	5	3	15	1	X	—	—	—
104	25	10	250	5	X	—	—	—
105	17	5	85	3	X	X	X	—
106	20	10	200	3	X	X	—	—
107	15	10	150	3	X	X	X	—
108	10	5	50	2	X	—	—	—
109	10	4	40	4	X	X	X	—
110	15	5	75	3	X	X	X	—
111	8	3	24	1	X	X	X	—
112	10	3	30	1	X	X	X	—
113	21	5	105	7	X	X	X	—
114	10	4	40	5	X	X	X	—
115	30	5	150	8	X	X	X	—
116	5	5	25	1	X	X	X	—
117	32	15	480	24	X	X	X	—
118	17	6	102	6	X	X	—	—
Estero Trailhead sites								
119	12	7	84	5	X	—	—	—
120	3	3	9	2	X	—	—	—
121	20	7	140	4	X	—	—	—
122	15	7	105	5	X	—	—	—
123	13	10	130	4	X	—	—	—
124	10	5	50	3	X	—	—	—
125	3	2	6	1	X	—	—	—
126	2	2	4	1	X	X	X	—
127	10	10	100	6	X	—	—	—
128	10	4	40	1	X	X	—	X
129	10	3	30	3	X	—	—	—
130	10	4	40	5	X	X	—	—
131	20	10	200	4	X	—	—	—
132	2	2	4	1	X	—	—	—
133	10	2.5	25	2	X	—	—	—
134	2	2	4	1	X	—	—	—

Table A2. Description of leks and associated ground and vegetation damage at the two study sites at Point Reyes National Seashore, California—Continued.

[m, meter; m^2, square meter; —, no data]

	Length (m)	Width (m)	Area (m^2)	Number rutting pits	Ground disturbance	Damaged foliage	Damaged bark	Exposed roots
135	10	3	30	2	X	X	—	X
136	3	2	6	1	X	—	—	—
137	5	2	10	3	X	X	X	X
138	2	2	4	1	X	X	X	—
139	7	4	28	2	X	—	—	—
140	8	3	24	3	X	—	—	—
141	3	2	6	1	X	X	—	X
142	25	10	250	9	X	—	—	—
143	5	5	25	1	X	X	X	X
144	15	2	30	2	X	—	—	X
145	2	2	4	1	X	X	—	—
146	10	8	80	2	X	X	X	—
147	18	8	144	6	X	—	X	—
148	10	4	40	3	X	—	X	—
149	15	10	150	5	X	X	X	X
150	15	5	75	6	X	X	X	—
151	7	5	35	1	X	X	X	—
152	3	2	6	1	X	—	—	—
153	5	2	10	1	X	—	—	X
154	12	4	48	3	X	—	—	—
155	5	1.5	7.5	2	X	—	—	—
156	10	3	30	1	X	X	X	—
157	15	10	150	2	X	X	X	X
158	4	4	16	1	X	—	—	—
159	2	1	2	1	X	—	—	—
160	5	1.75	8.75	2	X	—	—	—
161	10	3	30	1	X	X	X	—
Totals	—	—	18,324	705	159	102	72	30
Mean	13	6.7	115	4.4				
Percentage	—	—	—	—	100	63.5	45.3	18.2

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