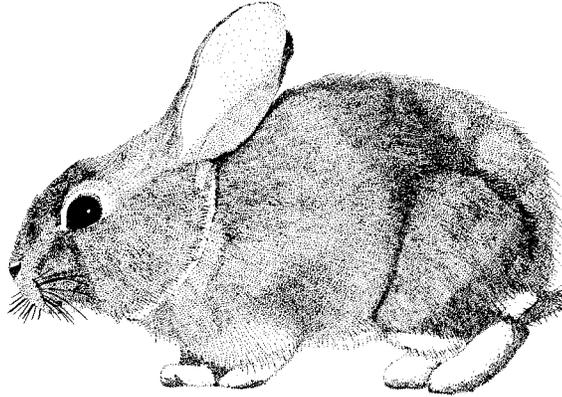


**ECOLOGY AND MANAGEMENT OF THE RIPARIAN BRUSH RABBIT
IN CASWELL MEMORIAL STATE PARK**



FINAL REPORT

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ABSTRACT

Studies of the ecology and management of the riparian brush rabbit (*Sylvilagus bachmani riparius*) were undertaken in Caswell Memorial State Park (CMSP) between July 1986 and April 1988; and other properties on the lower San Joaquin River system managed by the California Dep. of Parks and Recreation were assessed for presence of brush rabbits and their habitat. Riparian brush rabbits occur only in CMSP, ranging over approximately half of its 104.5 ha area in 1988, with an estimated total population of 88 to 452. By the end of the reproductive season after flooding in February and March 1986, riparian brush rabbits were mostly confined to an area of about 3.6 ha with an estimated population of 6 to 31. Habitat for riparian brush rabbits consists of a mix of woody vines and shrubs in patches greater than about 460 m² in areas providing refuge from floodwaters, an open canopy (< 50% closure), a mix of small, shrubby trees and tall, leaning trees, and small openings in the shrub cover supporting grasses and forbs. Downed logs and limbs were also a common component of areas of high use by riparian brush rabbits. Brush and litter clearing operations in CMSP resulted in cessation of use of cleared areas by rabbits. The site of a wildfire in 1981 in the undeveloped oak forest at CMSP had not been occupied by riparian brush rabbits by April 1988. High canopy cover there probably retarded development of a shrub and vine understory. Areas cleared for camping, parking, and recreation in CMSP generally are not used by rabbits. However, densities of riparian brush rabbits were moderate-to-high around picnic and campground areas, suggesting that these activities were compatible with occupancy by rabbits. The greatest threats to riparian brush rabbits probably are fire and flooding. Much of CMSP is overgrown with decadent, flammable shrubs and accumulation of woody litter is great. This fuel poses a great risk from wildfire to the only known population of riparian brush rabbits. At the same time, shrubs and litter are essential components of the habitat for riparian brush rabbits. Recommendations for reduction of fuel levels, renewal of growth of decadent shrubs, and enhancement of habitat for riparian brush rabbits involve creation of additional fire trails, experimental pruning and removal of decadent shrubs, and creation of artificial cover and refuges for rabbits. Recommendations for creating higher ground with cover as refuges from flooding involve acquisition and manipulation of adjacent cultivated property. Other CDPR properties within the study area currently are unsuitable as habitat for riparian brush rabbits. Other potential threats to riparian brush rabbits are predation by feral cats and dogs, foxes, coyotes, and raptors, competition with desert cottontails (*S. audubonii*), and disease.

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ECOLOGY AND MANAGEMENT OF THE RIPARIAN BRUSH RABBIT IN CASWELL MEMORIAL STATE PARK

INTRODUCTION

The brush rabbit (*Sylvilagus bachmani*) ranges along the Pacific Coast of North America from the Columbia River on the north to the Cape region of Baja California Sur. The Pacific slopes of the Cascade, Sierra Nevada, and southern California mountains form the eastern boundary of its range on the north; on the south it is found at scattered sites along both coasts of the Baja California peninsula (Figure 1; Hall 1981).

Sylvilagus bachmani riparius was described by Orr (1935); the type locality is the west side of the San Joaquin River, 2 mi northeast of Vernalis, Stanislaus County, California. Historically, the riparian brush rabbit was recorded from two sites in a small area in the northern San Joaquin Valley, California, in riparian communities along the lower portion of the San Joaquin River (Figure 2). Orr (1935, 1940) collected riparian brush rabbits only from the type locality and reported seeing them nearby, along the west side of the San Joaquin River immediately north of the San Joaquin County boundary. Williams (1986) reported on the population in Caswell Memorial State Park (CMSP), and remarked that there were probably small colonies along the lower Stanislaus river between CMSP and the San Joaquin River. Later Williams and Basey (1986) found only desert cottontails (*S. audubonii*) in the area downstream from CMSP. Based on surveys conducted in 1985 and 1986 in all potential habitat along the Merced, San Joaquin, Stanislaus, and Tuolumne rivers, riparian brush rabbits are found only within CMSP along the Stanislaus River in San Joaquin County, California (Environmental Science Associates [ESA] 1986, Williams and Basey 1986). The extent of the historic distribution of the riparian brush rabbit is unknown.

Habitat for brush rabbits generally consists of dense shrubs. They rarely venture more than 1 or 2 meters from cover (Chapman 1974, Orr 1940). Williams and Basey (1986) found that sites inhabited by riparian brush rabbits usually had a mix of roses (*Rosa californica*), blackberries (*Rubus vitifolius*), coyote bushes (*Baccharis douglasii*), and grape vines (*Vitis californica*), and that the volume of roses and coyote bushes were high in comparison to uninhabited sites. They found significantly more ground litter and surface area of roses and significantly fewer willows in the canopy and understory (none) at sites inhabited by riparian brush rabbits than at sites occupied by desert cottontails. Presence of more surface litter and lack of willows in the understory signified areas of higher ground that were not flooded regularly or heavily.

Brush rabbits have small home ranges compared to other cottontails (*Sylvilagus* spp.; Chapman and Willner 1978, Chapman et al. 1982, Dixon et al. 1981). Size and shape of home ranges were found to conform to size and shape of clumps of shrubs, and clumps smaller than about 460 m² were uninhabited (Chapman 1971). Because of their small home ranges and dependence on dense cover, brush rabbits have lower vagility than other species such as the desert cottontail. Brush rabbits displaced from 16 to 350 m returned to their home areas, but Chapman (1971) noted that homing time increased logarithmically with increasing distances of displacement.

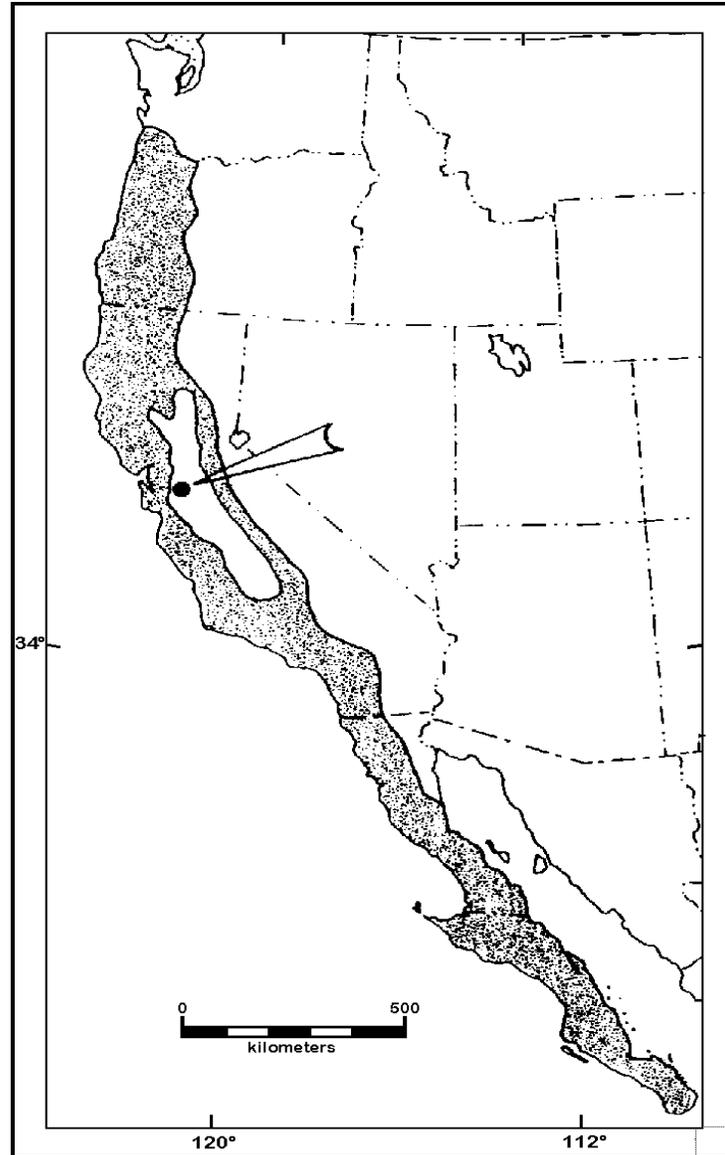


Figure 1. Distribution of the brush rabbit (*Sylvilagus bachmani*). Within this broad area, brush rabbits are found only in dense shrubs and chaparral, so occurrence is spotty. The distribution of the riparian brush rabbit (*S. bachmani riparius*) is shown at the point of the arrow. Based on Williams and Basey (1986).

Chapman (1974) remarked that brush rabbits could not home from distances as great as those reported for other small mammals.

Life history information for the brush rabbit was reviewed by Chapman (1974). Williams and Basey (1986) summarized information on the riparian brush rabbit; little specific information was available. Brush rabbits eat a variety of herbaceous and woody plants. Orr (1940) believed that grasses were the most important food for brush rabbits, but shrubs such as California wild rose (*Rosa californica*), Douglas' coyote bush (*Baccharis douglasii*), and Pacific blackberry (*Rubus vitifolius*) were also eaten. When available, green clover (*Trifolium involu-cratum*) was preferred over all other foods.

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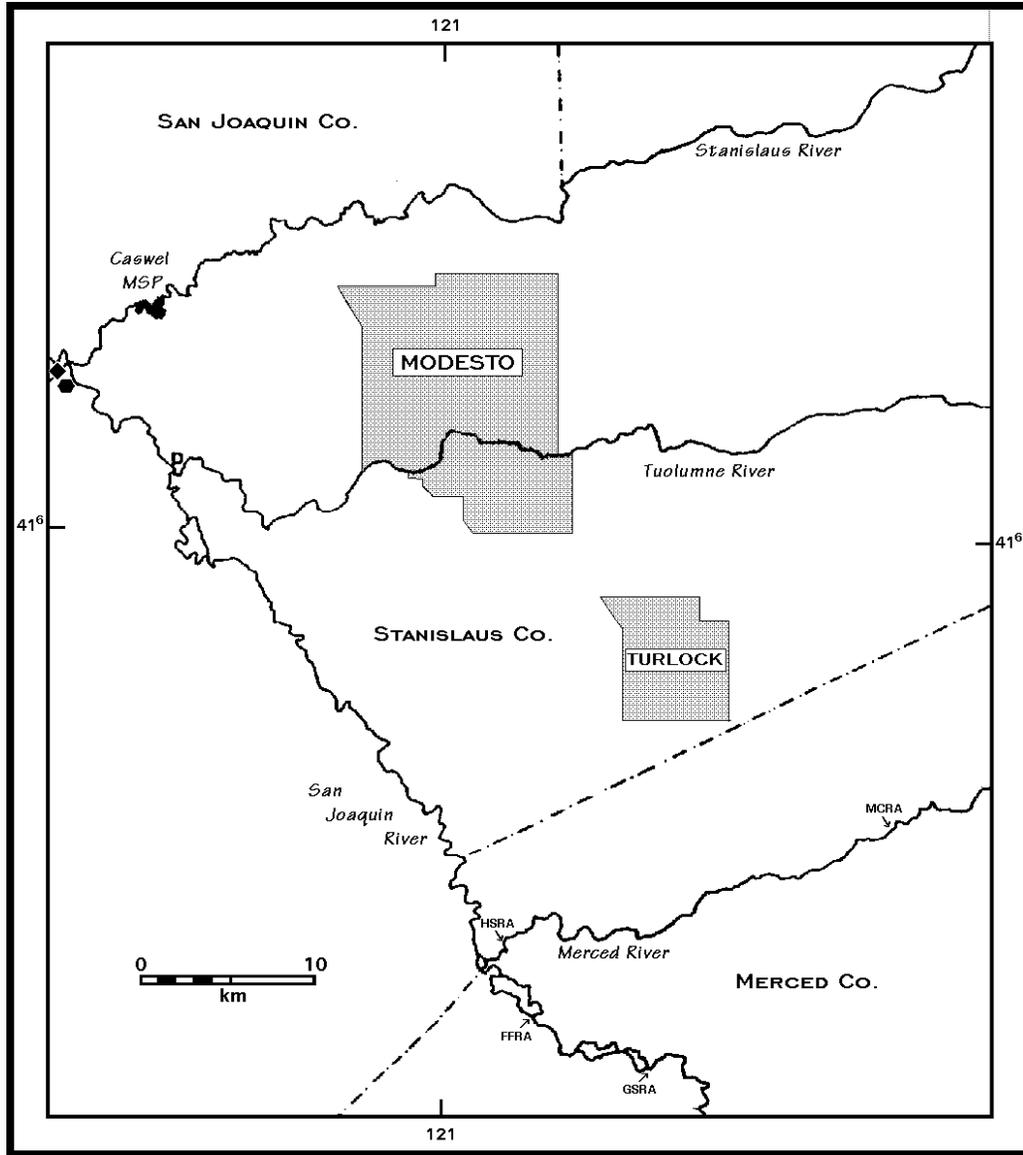


Figure 2. Distribution of *Sylvilagus bachmani riparius*. The polygon indicates the type locality and the triangle depicts the sight record from Orr (1940). The only extant population is found in Caswell Memorial State Park (CMSP). Other California Department of Parks and Recreation properties indicated are Fremont Ford SRA (FFRA), Grasslands State Project (GSRA), Hatfield SRA (HSRA), and McConnell SRA (MCRA).

In California, brush rabbits breed between about December and May or June (Mossman 1955). Chapman (1974) reported that three litters per reproductive season were likely. Mean litter size probably varies between about 3 and 4 in northern and central California (Mossman 1955, Orr 1940). It takes about 4 to 5 months for brush rabbits to mature. Brush rabbits probably do not breed until the winter following their birth. Chapman and Harman (1972) stated that *S. bachmani* did not have as high a reproductive potential as other *Sylvilagus* species.

Williams (1986) listed the riparian brush rabbit in the highest category for concern among mammalian species in California without Threatened or Endangered Species status. *S. bachmani*

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riparius is also listed as a Category-2 Species by the U.S. Fish and Wildlife Service (Dodd et al. 1985). Potential threats of extinction stem primarily from the small size and single location of the its population, and the fact that CMSP is flooded periodically during the winter wet season. Floods probably drown a portion of the population, temporarily eliminate foraging habitat and shelter, and expose the brush rabbits to increased predation by concentrating the population on high ground and in areas with little or no cover. Other potential threats to the population are wild fire, habitat alteration for park management, use of rodenticides for control of California ground squirrels, epidemic diseases, and predation by hawks, owls, coyotes, foxes, feral cats and dogs, and dogs belonging to park users. Brush clearing and burning operations for mosquito abatement and fuel control during winter 1984-85 destroyed habitat for riparian brush rabbits in the Park and demonstrated another threat to this species.

To reconcile conflicts in management goals of fuel and fire control, recreation enhancement, and wildlife conservation, the California Department of Parks and Recreation (CDPR) funded this investigation of the population ecology and habitat requirements of riparian brush rabbits in Caswell Memorial SRA and assessment of other CDPR property in central California for their potential to support this species.

The objectives of the investigations reported here were to: (1) determine distribution and relative density of riparian brush rabbits within the Park; (2) determine structure and composition of the plant community associated with brush rabbits; (3) assess suitability of different sectors of the park for brush rabbits; (4) assess impacts of brush removal, fire control, and park users on brush rabbits; (5) make recommendations on fuel and fire control practices most beneficial to brush rabbits; (6) recommend ways to minimize adverse impacts on brush rabbits and their essential habitat; (7) recommend ways to enhance habitat for brush rabbits should that be needed; and (8) survey State Parks and Recreation properties within the lower San Joaquin River watershed to determine if brush rabbits are found on other properties and to assess the potential of those properties for supporting populations.

METHODS

Studies commenced on 26 June 1986. Size and configuration of study plots was dictated by size and shape of patches of habitat occupied by brush rabbits and the need to locate plots away from areas used by park visitors. Three grid plots and four linear transects (10-m spacing) were trapped using Tomahawk and Havahart livetraps (Figure 3 and Table 1). Trapping effort is the sum of trap-days at a given site. One trap day equals one trap set for a 24-h period.

Riparian brush rabbits were tagged with numbered metal ear-tags, weighed, and released at the capture site. Sex and reproductive condition were noted each time an animal was captured. Data from captures on grids were used to calculate densities using the modified Schnabel method of continuous mark/recapture and the Lincoln/Peterson method, as appropriate (Blower et al. 1981).

Methods for analysis of structure and composition of the plant community were similar to

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Table 1. Plot type and size (meters), number of traps, and trapping effort in Caswell Memorial State Park, San Joaquin County, California. Locations of plots are shown in Figure 3. Sessions are trapping periods listed in tables 2 and 3. See text for additional details.

Plot	Type	Plot Size (m)	Grid Cell Size	Number of Stations	Number of Sessions	Total Effort
1	grid	54 x 37	7 x 9	18	10	666
2	grid	25 x 25	5 x 5	25	1	175
3	grid	25 x 25	t x 5	25	1	175
4	transect			5	1	25
5	transect			8	1	40
6	transect			10	1	59
7	transect			5	1	15

those developed by Warner (1984) for comparison of riparian communities in central California. Twenty-five aspects of plant-community composition and structure were measured on 10 30-m transects in CMSP and compared to 20 sites not supporting brush rabbits outside of CMSP (Williams and Basey 1986; see Appendix).

During August 1987, 30 transects 30-m in length were established at sites throughout the park that were representative of habitat supporting different densities of brush rabbits (Figure 4). On each transect the number of runways crossing the transect line were recorded. Additionally, sightings of rabbits were noted. Data from these transects gave a qualitative rating of levels of use by brush rabbits for different areas of the park. During March and April 1988, the park was divided into 33 units based upon physiographic and anthropomorphic features (Figure 4). Each unit was thoroughly inspected and numbers of clumps of sedges clipped by brush rabbits, runways, and groups of fecal pellets were recorded. Composition and structure of the plant community were described and subjective ratings of abundance of rabbits were made (see data sheet in Appendix for list of features measured). Upon completion of this inventory, 40 sites representing no, low, moderate, and high use by brush rabbits were selected. Open areas maintained by CDPR for recreation and low oxbows that are typically flooded in winter and periodically cleared of shrubs for efficient control of mosquitoes were not included in these assessments because they were not considered to be habitat for riparian brush rabbits.

A 15-m transect at each site was established and the following were recorded: width and height of woody understory (≤ 2 m above ground) by species; width and height of herbaceous ground cover by species; canopy cover by species, determined from 30 points along transect; width and height of logs (≤ 7.6 cm diameter); and width and height of woody litter (≤ 7.6 cm diameter). Numbers of runways, fecal pellets and pellet groups, and clipped sedges were recorded (see Appendix).

Quantitative data on structure and composition of the plant community and occurrence of brush rabbits were summarized using univariate statistical procedures. Because previous anal-

yses of plant structure at inhabited and uninhabited sites (Williams and Basey 1986) and results of univariate analyses of measurements on the 40 transects showed high variance and few significant differences among sites with different quantities of signs of brush rabbits, other analyses were not performed.

Information on controlled burning and wildfires in CMSP between 1975 and 1987 was obtained from CDPR files. Historical information on flooding and use of pesticides within CMSP was obtained from interviews with park personnel.

RESULTS

Captures and population estimates of riparian brush rabbits on plots 1 and 2 are shown in Table 2. Table 2 also lists captures on four line transects. Population estimates using the Lincoln/Peterson method are 3 rabbits on each 625 m² plot. Effective sampling areas are unknown, but were probably between 1 and 2 hectares (see below).

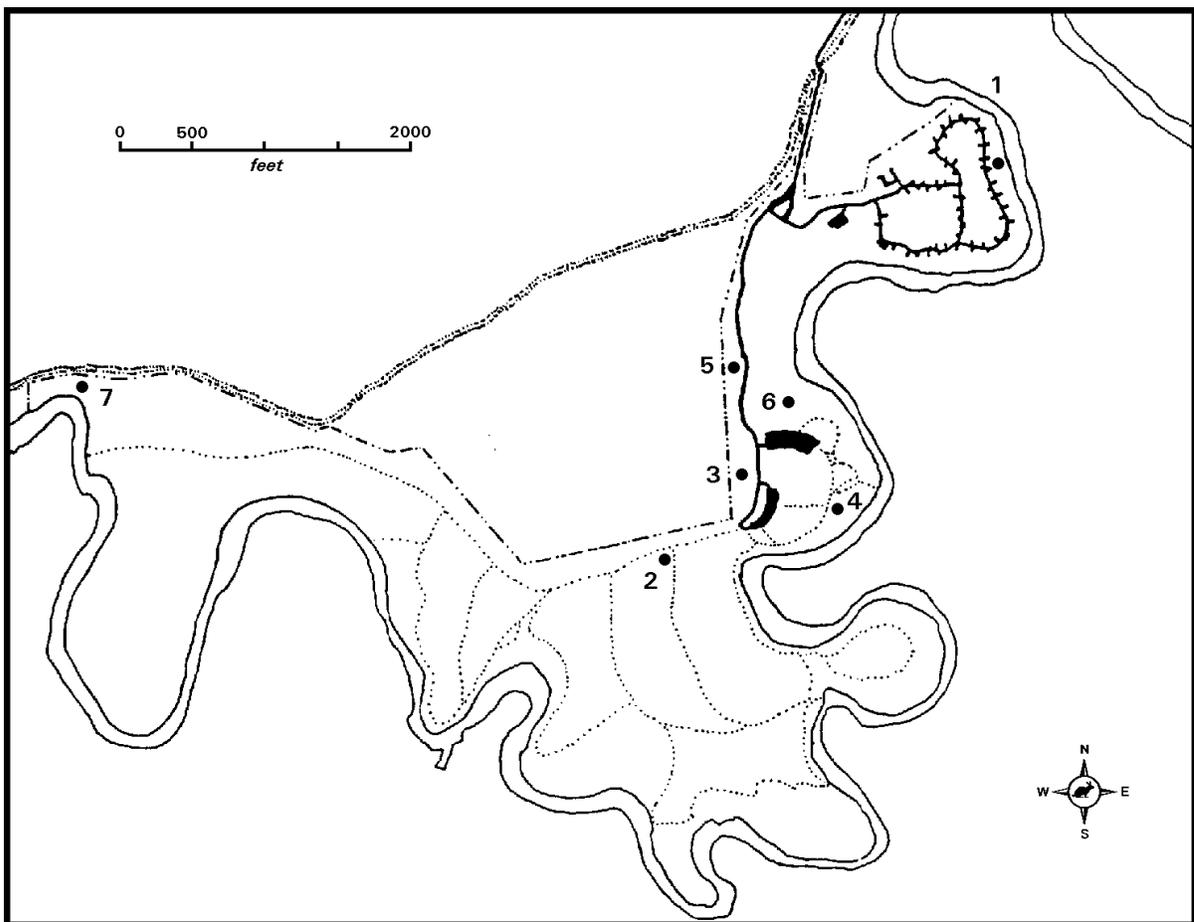


Figure 3. Locations of trapping plots and transects in Caswell Memorial State Park. Sites correspond to numbers in Table 1. Dark lines are roads and parking areas; dotted lines are trails. Park boundaries are dashed line on north and Stanislaus River (double line) elsewhere. The northern river levee is shown as a double dotted line.

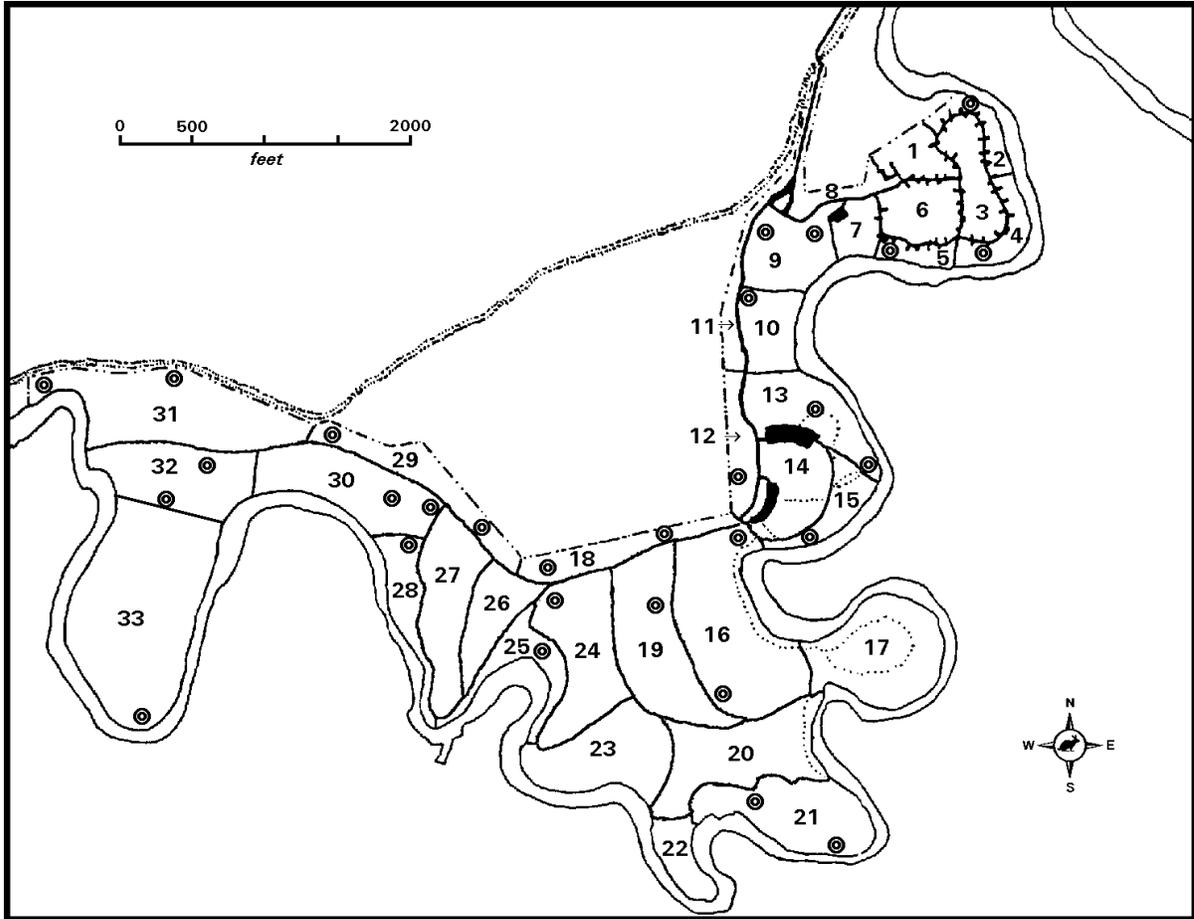


Figure 4. Location of 33 units and 30 transects inventoried for relative abundance of sign of riparian brush rabbits. Numbers correspond to units given in Table A2 (Appendix). Double circles are the approximate sites of transects within units (Table A3, Appendix).

Line transects yielded few captures (Table 2), suggesting that densities of riparian brush rabbits were low in autumn of 1986. The desert cottontail (*S. audubonii*) was captured in the western section of the park in 1986 (unit 33) and was observed in unit 31 in February 1988.

Captures on the main study plot and population estimates of *S. bachmani riparius* are presented in Table 3. Details of captures are given in Table 4. Between 25 June 1986 and 6 July 1987 the population estimates using continuous capture-recapture increased from 5 ± 3 to 13 ± 2 . However, no previously marked individuals were recaptured after 20 March 1987. Thus, the resident population known to be alive on the plot in July 1987 was about 5 animals, the same as the July 1986 estimate.

Because of the small size of the areas that could be effectively sampled and the low density of rabbits, statistically valid methods of estimating populations were not possible. Under these circumstances, the number known to be alive probably is the best measure of population size. In the following discussions, the ranges of estimates of population numbers probably are within the correct order of magnitude, and the true numbers probably are toward or somewhat greater

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Table 2. Summary of captures and population estimates on secondary plots in Caswell Memorial State Park, San Joaquin County, California; \pm is 95% confidence interval for Lincoln/Peterson estimate. *F* and *M* are female and male, respectively. See Table 1 for size of plots.

Plot	Session		Captures			Population
	Dates	Species	M	F	Total	Estimate
1	13–18 Jan 1987	<i>Sylvilatus bachmani</i>		3	3	3 \pm 3
2	21–26 Jan 1987	<i>Sylvilagus bachmani</i>	2	1	3	3 \pm 1
		<i>Neotoma fuscipes</i>			2	
		<i>Rattus rattus</i>			1	
		<i>Didelphis virginiana</i>			1	
4	22–25 Oct 1986	<i>Neotoma fuscipes</i>			2	
5	03–06 Nov 1986	<i>Sylvilagus bachmani</i>	1		1	
		<i>Neotoma fuscipes</i>			1	
6	20–23 Nov 1986	<i>Neotoma fuscipes</i>			2	
7	19–22 Aug 1986	<i>Sylvilagus audubonii</i>		1	1	
		<i>Neotoma fuscipes</i>			4	

than the upper estimated values (Otis et al. 1978).

The effective sampling area for traps on the main plot is not known but was probably between 1.5 and 3 ha. This range of estimates is based on the size and configuration of the study area and the known movements of marked animals. The longest distance moved by an individual on the plot was 54 m. Another animal marked on the plot was captured on plot 2, having moved a minimum distance of 85 m to the southeast. A third animal marked on the study plot was subsequently captured on Plot 5, a distance of approximately 120 m to the northeast. Because the plot was located at the boundary of an agricultural field to the west and a paved road to the east, regular movements by rabbits on and off of the plot were probably restricted by absence of appropriate cover. A shrubless area to the north and a road and parking lot to the south probably contributed to isolating the study plot. The total area containing the study plot was about 6 ha.

Population turnover was rapid. The longest time between first and last captures of an animal was 235 days and the average time for all captures was 35.7 days (Table 4). Excluding first captures in the last trapping session, average duration between first and last captures was 51.7 days. No adults first captured in June and July 1986 were known to be alive after 22 February 1987.

Table 5 gives only a partial reproductive schedule because of the small number of individuals captured and because no brush rabbits were captured during some months. The reproductive season appears to extend from about December to May. Adults were defined on the basis of weight as those weighing over 500 g. Subadults were between about 350 and 500 g, and juveniles were less than 300 g. Both reproductive (scrotal testes) and nonreproductive (testes not

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Table 3. Summary of captures and population estimates on main plot (plot 3) in Caswell Memorial State Park, San Joaquin County, California for trapping sessions between 26 June 1986 and 6 July 1987. New is number of animals not marked in previous sessions. F and M are female and male, respectively. Population Estimate is number of brush rabbits on the plot \pm 95% confidence interval using the Schnabel method.

Session	Species	Captures			Population	
		M	F	Total	New	Estimate
25 Jun–02 Jul	<i>Sylvilagus bachmani</i>	1	4	5	5	5 \pm 3
	<i>Mephitis mephitis</i>			1		
	<i>Neotoma fucipes</i>			1		
	<i>Rattus rattus</i>			1		
10–12 Aug	<i>Neotoma fuscipes</i>			2		3 \pm 1
21–24 Oct	<i>Neotoma fuscipes</i>			2		
	<i>Rattus rattus</i>			1		
21–23 Nov	<i>Sylvilagus bachmani</i>	2		2	2	7 \pm 8
	<i>Neotoma fuscipes</i>			3		
21–23 Dec	<i>Sylvilagus bachmani</i>	3	1	4	1	9 \pm 5
22–16 Jan	<i>Sylvilagus bachmani</i>	3	1	4	1	9 \pm 2
	<i>Neotoma fuscipes</i>			3		
	<i>Rattus rattus</i>			2		
	<i>Didelphis virginiana</i>			1		
21–23 Feb	<i>Sylvilagus bachmani</i>	2	1	3	0	8 \pm 1
	<i>Neotoma fuscipes</i>			1		
18–20 Mar	<i>Sylvilagus bachmani</i>	2	1	3	1	9 \pm 2
	<i>Neotoma fuscipes</i>			2		
18–20 Apr	<i>Sylvilagus bachmani</i>		1	1	1	9 \pm 1
04–06 Jul	<i>Sylvilagus bachmani</i>	3	2	5	3	13 \pm 2
	<i>Neotoma fuscipes</i>			1		
	<i>Rattus rattus</i>			2		

scrotal) males were found in the November–February period. These may have been adult-sized males of different ages, with younger animals born late in the previous reproductive season not reaching sexual maturity by February.

Summaries of data on plant community structure associated with riparian brush rabbits are presented in Table 6 and in tables A1 and A2 of the Appendix. Sites without signs of rabbits were ranked “none;” sites with less than 10 signs (sum of pellet groups and runways) on a transect were ranked “low,” sites with from 11 to 20 signs were ranked “medium,” and sites with > 20 signs were ranked “high.”

Sites associated with riparian brush rabbits had few or no willows in the overstory when

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Table 4. Sex, age, and dates of first and last capture of riparian brush rabbits on the main study plot, Caswell Memorial State Park, San Joaquin County, California. Duration is number of days between first and last capture.

Number	Sex	Age at First Capture	First Capture	Last Capture	Duration
36	f	Adult	26 Jun 1986	27 Jun 1986	1
37	m	Adult	26 Jun 1986	22 Dec 1986	179
38	f	Juvenile	26 Jun 1986	27 Jun 1986	1
—	f	Adult	02 Jul 1986	(died)	—
39	f	Adult	02 Jul 1986	22 Feb 1987	235
41	m	Adult	21 Nov 1986	21 Nov 1986	0
42	m	Adult	23 Nov 1986	23 Nov 1986	0
43	m	Adult	21 Dec 1986	18 Mar 1987	87
44	m	Adult	22 Dec 1986	26 Jan 1987	35
51	m	Adult	22 Jan 1987	21 Feb 1987	30
52	m	Adult	18 Mar 1987	19 Mar 1987	1
53	f	Adult	19 Apr 1987	19 Apr 1987	0
54	m	Subadult	04 Jul 1987	04 Jul 1987	0
55	f	Subadult	04 Jul 1987	04 Jul 1987	0
56	m	Subadult	05 Jul 1987	05 Jul 1987	0
57	m	Adult	05 Jul 1987	06 Jul 1987	1
58	f	Juvenile	05 Jul 1987	06 Jul 1987	1

compared to sites lacking riparian brush rabbits (Table A1). Sites not supporting riparian brush rabbits also evidenced recent flooding by the lack of ground litter. There was a significantly greater area of roses in the understory than sites unoccupied by either *S. bachmani* or *S. audubonii*, but the differences in area of roses in sites supporting each species were not significant.

Among sites within CMSP, unoccupied sites had significantly fewer logs and grapevines in the understory and greater amounts of annual grasses and forbs in the ground cover than occupied sites (Table 6). Other differences between occupied and unoccupied sites were not significant. This was partly because two contrasting types of sites were not used by riparian brush rabbits: open areas with a ground cover of low grasses and forbs and little or no canopy cover; and areas in oak forest with high canopy cover, little shrub understory, and ground cover of annual grasses and forbs.

Sites ranked low had significantly fewer runways, pellet groups, and clipped sedges than sites ranked high, but ranks were arbitrarily defined on the basis of numbers of pellet groups and runways. Number of clipped sedges was not used in ranking sites, although increasing numbers clipped correspond to increasing rank. There was only one significant difference in community structure between the three ranks. There was less area of coyote bushes in the understory of high-use sites compared to sites of low use. Although not significant, sites ranked high had more

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Table 5. Times of observed reproductive states of adult riparian brush rabbits and presence of juveniles and subadults in samples trapped in Caswell Memorial State Park, San Joaquin County, California. No rabbits were trapped in May, August, September, or October.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Females												
Estrus	██████	██████	██████									
Pregnant			██████	██████								
Lactating						██████						
Non Reprod.	██████			██████				██████	██████			
Males												
Testes Large	██████										██████	██████
Non Reprod.	██████	██████				██████	██████				██████	██████
Juveniles												
						██████	██████					
Subadults												
							██████					

logs and litter, more sedges, and fewer nettles in the ground cover than sites ranked low.

The variance for characteristics of plant community structure and composition was high within ranks, obscuring the significance among sites that might be important to occupancy by brush rabbits. This was mostly due to the lack of uniformity of the plant community among sites of the same rank. One of the two unifying characteristics of sites of medium and high use, based on signs, was their variability, with a mix of low shrubs, tall shrubs or small trees, and patches of open areas with grasses, sedges, or other herbaceous plants. Logs and other woody litter also were commonly associated with medium and high use areas, although areas with a dense cover of low blackberry vines and little woody litter had similar amounts of signs of use. The second characteristic was large patches of shrubs surrounded by roads, trails, campgrounds, or seasonally flooded areas. These edges between dense shrub patches support grasses and other herbs and appear to be heavily used by brush rabbits.

Flooding of the Stanislaus River inundated most of CMSP during February and March 1986. At the onset of population assessments in June 1986, the population of riparian brush rabbits was extremely low; rabbits were confined to parts of the campground (sites 10 to 40's) and group picnic area, and four sites on higher ground along the northern edge of the park (Figure 5). Few pellets or runways were found outside those areas during 1986. By summer, 1987, signs of brush rabbits could be found over virtually the entire park (tables A2 and A3 in Appendix).

Based upon abundance of signs found during inventories in February and March 1988, areas of highest use did not correspond well to areas of occupancy shortly after flooding in 1986 (tables A2 and A3, figures 4 and 5). The latter areas being clustered along the northern edge of the park and on the highest ground, and including sites with a relatively large quantity of coyote bushes which showed little evidence of use in 1988.

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Table 6. Community structure and signs of brush rabbits within Caswell Memorial State Park, San Joaquin County, California. Values are means and standard errors. Length and area (length X height) were measured in m and m², respectively, on 15-m transect lines. Categories are defined in the text.

Variable	none	low	medium	high
% Canopy Cover	68.1 ± 7.3	52.0 ± 6.8	47.3 ± 7.8	57.6 ± 8.0
Ground Cover Length				
litter	9.2 ± 2.8	2.4 ± 1.3	4.1 ± 1.3	6.3 ± 1.3
logs	0.01 ± 0.01*	0.1 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
nettles	2.7 ± 0.9	1.9 ± 0.4	2.3 ± 0.8	0.9 ± 0.1
sedges	0.4 ± 0.2	4.4 ± 1.8	1.6 ± 0.4	2.4 ± 1.4
grasses/forbs	2.8 ± 0.5*	0.6 ± 0.2	0.6 ± 0.3	0.4 ± 0.1
Understory Length				
blackberry	1.7 ± 0.6	2.6 ± 1.2	3.6 ± 1.3	1.5 ± 0.5
coyote bush	1.6 ± 0.7	1.9 ± 0.3 ^a	0.7 ± 0.2	0.5 ± 0.2 ^a
grape	0.3 ± 0.1*	2.3 ± 1.0	2.5 ± 1.3	2.3 ± 1.1
rose	0.9 ± 0.4	2.8 ± 1.3	2.9 ± 0.9	3.1 ± 1.1
currant	2.1 ± 0.9	4.1 ± 1.5	1.8 ± 0.4	2.8 ± 0.8
other	0.8 ± 0.3	0.4 ± 0.1	0.6 ± 0.2	0.5 ± 0.2
Understory Area				
blackberry	0.2 ± 3.7	16.2 ± 4.1	30.6 ± 13.9	18.1 ± 7.5
coyote bush	30.4 ± 14.3	38.0 ± 21.4	13.3 ± 3.8	9.0 ± 4.1
grape	1.8 ± 0.7*	25.3 ± 11.2	22.5 ± 5.7	27.6 ± 13.8
rose	7.7 ± 2.4	23.8 ± 12.5	37.7 ± 14.4	24.8 ± 6.4
currant	25.2 ± 11.6	45.1 ± 28.7	19.8 ± 7.1	35.0 ± 16.1
other	14.4 ± 5.9	6.4 ± 3.0	10.8 ± 3.3	9.5 ± 3.6
Runways	0*	3.6 ± 0.4 ^a	5.5 ± 1.3	10.8 ± 2.2 ^a
Clipped Sedges	0*	5.5 ± 0.9	11.2 ± 3.1	13.8 ± 4.5
Pellet Groups	0*	6.5 ± 1.9 ^a	20.3 ± 5.3 ^a	38.6 ± 5.6 ^a

* differs significantly from occupied sites

^a occupied sites indicated differ significantly

California Department of Parks and Recreation property within the potential historic range of the riparian brush rabbit are listed in Table 7 and shown in Figure 2. Brush rabbits were found only within CMSP. The undeveloped portion of George J. Hatfield State Recreation Area supported a plant community judged to be suitable habitat for brush rabbits, but inspection and trapping there yielded no evidence of use by brush rabbits (Williams and Basey 1986). The suitable area is probably too small and too vulnerable to flooding to support a viable population of brush rabbits.

The campground area of Turlock SRA contains a few large patches of shrubs, but only those west of the campground area were judged to be large enough to be suitable habitat for brush rabbits.

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Table 7. *Properties administered by the California Department of Parks and Recreation within the potential historic range of the riparian brush rabbit. Values are hectares (2.46 ac); SRA = State Recreation Area. Locations are shown in Figure 2, except for Turlock Lake SRA. Grassland State Project is an undeveloped parcel.*

Property	River	Size (ha)	Potential Habitat	Brush Rabbits Present
Caswell Memorial State Park	San Joaquin	104.5	52.0	yes
Fremont Ford SRA	San Joaquin	46.2	0	no
Grasslands State Project	San Joaquin		0	no
George J. Hatfield SRA	Merced	19.0	3	no
McConnell SRA	Merced	30.0	0	no
Turlock Lake SRA	Tuolumne	92.3	0	no

bits. Trapping (Cheryl Johnson, pers. comm.) and inspection showed no evidence of brush rabbits. The area along the river floods too frequently and is too small to support a viable population of brush rabbits. Other properties administered by CDPR are either flooded regularly, or do not have habitat for brush rabbits, or both.

DISCUSSION

Distribution and Density

Currently, riparian brush rabbits are confined to CMSP (Williams and Basey 1986). They are widely distributed within the park, but there is little or no evidence of their regular presence over about one-half of its area. Large, low areas that are normally flooded during the wet season, open shrubless areas, and parts of the oak forest with a closed canopy and sparse distribution of low shrubs are not used regularly by brush rabbits. Parts of the western end of the park appear to be occupied by desert cottontails; they may be spreading deeper into areas formerly occupied solely by riparian brush rabbits.

Of the 104.5 ha (258 ac) comprising the park, only about 6.2 ha (15.2 ac) in four widely separated areas showed high use by brush rabbits in March and April 1988 (Table A2 and Figure 4). Approximately 32 ha was rated medium-use, but highest activity was concentrated along edges of trails and clearings. The remainder either showed evidence of no use or only low or occasional use by brush rabbits. The latter included 9.9 ha that flood periodically and hold water for part or all of the year, a portion of which is maintained free of shrubs and dense herbaceous cover for control of mosquitoes. Also included is an undetermined amount of land used for buildings, roads, parking areas, and cleared camp and picnic sites.

Based upon movements of individuals on the main study plot and their capture on other transects, the effective sampling area of the 0.14 ha grid was probably between 1.5 and 3 ha. The total area showing use by brush rabbits that contained the study plot was about 6 ha. Using this range of estimated sampling area and the range of population estimates in Table 3 for this unit

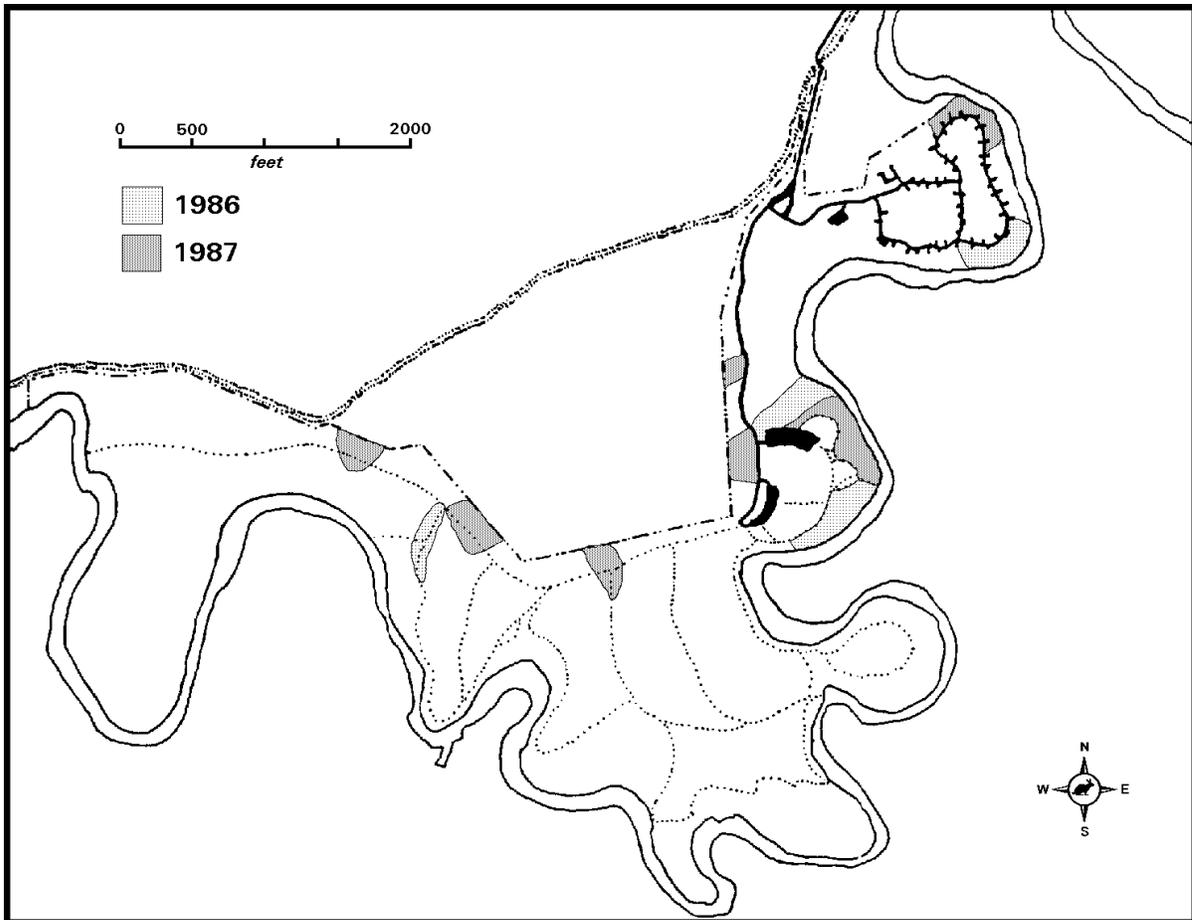


Figure 5. Sites with highest densities of riparian brush rabbits in July 1986 after flooding in February and March, and additional high-use areas one year following flooding (the combined areas shown for 1986 and 1987).

(12, Figure 4), the number of brush rabbits varied from a low of about 10 to 20 to a high of from 26 to 52 rabbits between June 1986 and April 1987. The estimated densities ranged between about 1.7 and 8.7 brush rabbits per ha (0.7 and 3.5 per ac).

Floods in February and March covered nearly all of the park with water. During summer 1986, brush rabbits were absent from most areas of the park and scarce in others (Figure 5). The five small areas evidencing regular use by brush rabbits in summer 1986 covered approximately 3.6 ha. Using the previous range of densities, the population probably consisted of from about 6 to 31 rabbits. These estimates represent the peak population for that year after the annual reproduction, and suggest that the adult female population was reduced to fewer than 15 individuals by flooding in March.

These values are probably conservative because 24 brush rabbits were recorded on a walk along the trails west of the Family Picnic Area on 15 August 1986. This was an ideal day to observe rabbits because the weather changed from hot to overcast and cool, which seemed to stimulate activity by brush rabbits in open areas. The trails were virtually the only open areas

inside the boundaries in this portion of the park. Walking the same route on 10 August and 21 October resulted in 6 and 8 rabbits sighted, respectively. Walks on 20 October and 20 November yielded no sightings.

By summer 1987, areas with evidence of regular use by brush rabbits covered approximately 7.3 ha (Figure 5), with an estimated range from about 12 to 64 rabbits.

In comparison with other units in 1988, Unit 12 had a low-to-medium or average amount of use by brush rabbits. Assuming that the average condition represented by unit 12 prevailed over 52 ha (32 ha of medium, 6.2 ha of high, and 66.3 ha of no or low use) of habitat for riparian brush rabbits, the total estimated peak population by April 1988 was between about 88 and 452 individuals. Although the actual number of riparian brush rabbits is unknown, it probably was within the range of estimates or slightly higher. Assuming the maximum values are closest to the true numbers, the populations varied from a low of about 20 immediately after relatively mild flooding, in 1986, to a high of about 450 after two successive winters without floods.

Habitat

Habitat evidencing highest use by riparian brush rabbits is found in areas with large clumps of shrubs with a mix of low-growing vines and some tall shrubs or small, shrubby trees such as coyote bush, elderberry, and box elder. Logs and large tree limbs litter the ground and some are covered with a low growth of blackberry or grape vines. According to Chapman (1971), some clumps of shrubs should be greater than 460 m² (about 21 x 22 m). High-use sites for riparian brush rabbits also include some blackberry vines and rose bushes. Small clearings or trails supporting sedges or grasses and forbs surround or extend through shrub thickets. Essential habitat includes high ground that is not regularly flooded.

Tall shrubs or bushy trees and large, leaning snags or trees may be essential for riparian brush rabbits to refuge from floods. Low, exposed logs surrounded by low-growing vines and litter are favorite resting or observation sites for riparian brush rabbits. Fecal pellets on logs are testament to their frequent use. Logs higher than about 46 to 61 cm (18 to 24 in) above the substrate rarely had deposits of fecal pellets.

Hollows in logs with openings of less than about 6.4 cm (2.5 in) provide places for riparian brush rabbits to refuge from larger predators such as gray foxes, coyotes, and feral cats, but are not an essential component of their habitat.

Trails and roads bordered by thickets of shrubs show evidence of greater use by brush rabbits than clearings supporting dense, weedy grasses or tall patches of nettles. Most roads and trails support a mix of annual and low-growing perennial grasses and forbs which may be preferred foods for riparian brush rabbits (Orr 1940).

Population Threats

The entire population of riparian brush rabbits is clearly vulnerable to flooding. The only refuge from high water is the levee to the north of the park which is kept free of vegetation by regular use of herbicides and provides no cover for rabbits to refuge from floods. The most recent episodes of flooding occurred in 1980, 1983, and 1986, when virtually the entire park was inundated. Brush rabbits apparently survived by clustering on small areas of high ground and climbing into bushes and trees. Rabbits were rescued from large, leaning oak trees and moved to high ground by the Park Ranger Ken Martin during the floods in the 1970's.

Riparian brush rabbits are threatened by wildfire. Much of the park is overgrown with decadent shrubs; they and large quantities of woody litter represent a dangerous amount of fuel. Between 1975 and 1987, 10 wildfires were reported within CMSP (Table 8). All were quickly extinguished; the largest burned only 0.2 ha (0.5 ac). The potential remains great, however, for a wildfire of devastating proportions. If a fire started in the undeveloped, western part of the park and went undetected for more than a few minutes, it would probably burn many acres before it could be controlled.

Wildfires destroy habitat for brush rabbits and pose a proximate threat of death by fire. Unfortunately, the areas most vulnerable to fire are particularly important as habitat for brush rabbits. Large, decadent clumps of coyote bush, elderberry (*Sambucus mexicana*), and toyon (*Heteromeles arbutifolia*) may provide refuges from flooding, and downed limbs and logs provide a framework for vines which create essential cover and a place to hide and nest.

A third threat of unknown significance is epidemic disease. No information on diseases has been reported for *Sylvilagus bachmani* (Chapman 1974), but rabbits, including cottontails, are known to be susceptible to a variety of diseases that sometimes reach epidemic proportions (Chapman et al. 1982, Myers and MacInnes 1981). Common diseases in rabbits in California are tularemia, plague, myxomatosis, silverwater, California encephalitis, equine encephalitis, listeriosis, Q-fever, and brucellosis (Robert Schmidt, pers. comm.). Because brush rabbits range over the whole park, a virulent pathogen could quickly spread and jeopardize the entire population.

Other threats are perceived as of lesser magnitude but are not unimportant, for they could conceivably extirpate a population already reduced by flooding, wildfire, or disease. Included are use of rodenticides; predation by coyotes, gray foxes, long-tailed weasels, feral cats and dogs, hawks, and owls; and brush and litter removal for mosquito and fire control.

Rodenticides were used within the park in the past for ground squirrel control (Glenn Basey, in. litt.) and are used regularly along the river levee north of the park.

Foxes and other ground predators, including a large population of feral cats, were a constant threat to rabbits confined in traps. Three animals were lost to predators in this manner before traps were completely encased in plywood and staked securely to the ground. Evidence of predation on rabbits was frequently noted while working in the park.

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Table 8. *Wildfires within Caswell Memorial State Park reported between 1975 and 1987 (CDPR files).*

Date	Size	Location and Fuel
Jun 1975	0.1 ha	Undeveloped area; brush and grass
Feb 1976	2.3 m ²	Adjacent to office; also 18.3 m of levee; grass
Jul 1977	55.8 m ²	Picnic area; shrubs and grass
Jun 1978	3.3 m ²	Campground site 8; shrubs
Jul 1979	—	Campground site 39; shrubs (spot fire)
Jun 1981	0.2 ha	Oak forest; shrubs and grass
Jul 1983	13.4 m ²	Picnic area; brush and grass
Jul 1984	6.7 m ²	Campground site 55; shrubs and grass
Jun 1987	0.1 ha	Campground site 24; shrubs and grass
Jun 1987	101.3 m ²	North of residence, west of service yard; shrubs

During winter 1985 an unsupervised California Conservation Corps crew cleared large areas for mosquito and fire control. Litter was stacked and burned at numerous sites throughout the cleared areas. One site cleared encompassed the first plot established to study brush rabbits. Brush rabbits immediately disappeared from that plot. By August 1987 the plot showed evidence of low to moderate use by rabbits.

There is no evidence that recreation adversely impacts brush rabbits in CMSP. Relatively high populations were found in the campground and family picnic areas, and parts of these areas were among the sites where rabbits were located shortly after flooding in 1986. Trails and trail-side thickets in the undeveloped portion of the park also showed regular use by rabbits. A common component of these areas is edge; the interface between thickets of brush and small, open areas. Trail and road maintenance through the undeveloped areas results in accumulation of additional logs and limbs near trails, which when covered with vines, leaves, and twigs, provides ideal cover for brush rabbits.

Population Status

With an estimated range in peak population numbers from a low of about 20 (8 - 31) immediately after flooding in 1986, and a high of 88 to 452 during July 1988 following 2 years with no flooding, and probably between 4 to 16 females surviving the last flood, it is clear that the riparian brush rabbit faces an imminent threat of extinction. A high probability of extinction will continue until a portion of the habitat within the park is secured from the highest floodwaters and populations are established in additional areas, reducing the risks of extirpation by wildfire or epidemic disease.

Recommendations for Management

Because CMSP provides the only extant habitat for the riparian brush rabbit, high priority must be given its preservation. Management actions and permitted recreation activities should be compatible with this objective. Fortunately, most recreation activities in CMSP do not impact seriously on brush rabbits, and no significant conflict in management actions is forecast.

Recommended actions necessary for securing and enhancing populations of riparian brush rabbits within CMSP include activities that should be instituted immediately as components of ongoing management of the park, and actions that require commitments of additional resources for research and acquisition of property, and which will take longer to accomplish.

Predator and Pest Control: Control of feral cats by trapping and removal should be an ongoing activity in CMSP. Rodenticides should not be used in CMSP or on levees bordering the park. If introduced rats (*Rattus rattus*, *R. norvegicus*) or California ground squirrels (*Spermophilus beecheyi*) require control, only species-specific methods that do not harm brush rabbits should be permitted. These could include placing poisonous gas in ground squirrel burrows where squirrels have been observed and live trapping and subsequent euthanasia of pests. All temporary and permanent park personnel should be routinely instructed not to undertake pest control measures without review and approval by the regional office.

Fire Lines and Access Roads: The system of existing roads and trails in the undeveloped portions of the park should be expanded to provide ready access to all areas and serve as the nuclei for fire breaks should a wildfire get started. Additional trails running north-south across the narrow sections between units 31 and 29 and extending through unit 32 and 33 to the river (Figure 4) should be established. East-west trails in units 32 or 33; 26, 27, and 28; 16 and 19 are also recommended. Other trails may be needed, as determined by fire-control officers. These and existing trails should be maintained free of logs and other obstructing litter and shrubs, and mowed periodically.

Campground, Picnic, and Recreation Areas: Developed areas should be maintained to minimize the risk of wildfire, as these areas are the sites of origin of most wildfires. Manual reduction of accumulations of small twigs and limbs and dead grasses and weeds around camp and picnic sites is recommended. Large clumps of decadent shrubs and vines should be thinned and pruned, but sufficient cover for brush rabbits must be retained. No open fires should be permitted during the dry season when there is a significant risk of wildfire.

Large clearings and parking lots are not used by brush rabbits, and expansion of camping or recreation areas would reduce their habitat. No such expansion should be considered unless it is accompanied by acquisition of additional property. Should this occur, acquisition and expansion on the existing northeast boundary (Figure 6) is recommended, as this would increase camping and most recreation activities in areas farthest from the undeveloped portions, keeping the

risk of wildfire low in the currently undeveloped part of the park and minimizing any adverse impacts on rabbits by campers.

Vertical pipes placed in the ground to protect access to valves on buried pipelines serve as pitfalls for riparian brush rabbits and other small animals. Two dead brush rabbits were found in such structures. All vertical pipes should be equipped with a cover that cannot be accidentally removed by wind or tipped off by animals or people.

The rules that all pets be kept on a leash at all times should be strictly enforced. Pets of park personnel should also be kept restrained at all times.

Brush and Fuel Control: Decadent, flammable shrubs such as coyote bush, mule fat (*Baccharis viminea*), toyon, and elderberry, and large accumulations of leaves and woody litter present a serious risk of fire. Renewal of growth of young shrubs should also enhance habitat for brush rabbits, and is a desirable goal for the overall maintenance of the riparian community. Conversely, removal of shrubs and litter reduces cover and degrades habitat quality for brush rabbits. Securing and maintaining a viable population of riparian brush rabbits will require establishing a balance between fuel reduction and brush renewal and maintaining optimum habitat.

Available information is not sufficient to determine the best method of achieving these goals. Fuel management in developed areas of the park is critical and should not await the outcome of further research, but must be tempered by the need to maintain cover and other habitat features required by brush rabbits. In undeveloped portions of the park, manual removal of dead fuel, pruning or removal of decadent shrubs, and controlled burns may be required to maintain optimum conditions for brush rabbits. Experiments on manipulation should be designed to determine effective methods that enhance habitat for brush rabbits while achieving fuel reduction and vegetation renewal.

The area burned in 1981 (0.2 ha, oak grove) showed virtually no use by rabbits in April 1988. Nearly complete canopy cover possibly has retarded revegetation of a shrub understory. High percent canopy cover is found over a large portion of the undeveloped park, suggesting a long recovery time for shrubs and other elements of habitat for brush rabbits.

Areas manipulated should be kept small. Narrow strips 1.2 to 2 m in width would provide increased edge and additional fire lines without greatly reducing cover for brush rabbits. Some large and some tall

patches of shrubs or shrubby trees should be maintained throughout the area. Manipulated strips should be separated by sufficient unaltered vegetation to maintain optimum conditions for brush rabbits.

Periodic monitoring of treated areas to determine rates of regrowth and level and nature of use by brush rabbits will be needed in order to establish a maintenance schedule. A strip-rotat-

tion schedule that results in repeated treatment of strips every 15 to 25 years may be required if habitat for brush rabbits is not to be reduced significantly.

Mosquito Abatement: Approximately 10 ha (24.6 ac) of low spots representing former river channels (Figure 6) periodically flood and, in the past were cleared of brush and herbaceous growth and treated with insecticides. Other, smaller channels and low spots were cleared on a more irregular basis and are not shown in Figure 6 or included in the 10 ha total. Only areas around the campground are now targeted for regular maintenance for mosquito control. Some low spots receive irrigation wastewater and thus retain water nearly year around. Others are flooded only periodically. In addition, short trails are maintained for access for mosquito abatement operations.

Clearing of one such area within the main study plot in winter 1985 resulted in cessation of its regular use by brush rabbits. It also isolated higher ground on each side of the cleared channel and restricted movements of rabbits across the plot.

These observations demonstrate that mosquito abatement activities reduce habitat for brush rabbits and restrict their movements. However, in wet years with high runoff, these channels fill with water which also reduces habitat and restricts movements of brush rabbits.

Controlling mosquitoes is important to park management and as a public health measure, and should be facilitated as long as it does not jeopardize brush rabbits or other sensitive species. That brush and litter removal is critical to control measures has not been established, however. If these actions are simply to expedite access and application of insecticides, then they should be reduced or halted if control can still be accomplished. Perhaps a longer period between clearing operations or only a partial clearing could facilitate abatement processes and still provide adequate cover for movement of brush rabbits.

Habitat Enhancement: Enhancing habitat by natural means would involve restoration of growth to decadent shrubs by mechanical pruning or fire, and increasing edge in areas with large expanses of decadent shrubs by cutting narrow paths (i.e., < 2 m in width) at 30- to 60-m intervals. The ideal habitat would be managed to maintain many small openings supporting grasses and forbs, a high number of logs from 0 to 1 m above the substrate, a mix of shrub species and ages of shrubs with continuous blocks of shrub cover between 20 and 30 on a side, an open canopy (< 50% closure) with a mix of tree sizes with some large, leaning trees and some small, shrubby species, and provide access to high ground with cover.

Enhancing habitat while simultaneously reducing fuel levels in areas of excess fuel may require use of some artificial cover until natural cover is reestablished. Restoring agricultural land may also require temporary use of artificial cover and dens. Creation of artificial cover and mounds of soil that are less susceptible to flooding would probably allow for more frequent fuel reduction than could be achieved otherwise.

Concrete pipe with openings large enough for brush rabbits but too small for larger predators (probably about 6.5 cm) connected to larger-diameter pipe and provided with more than two

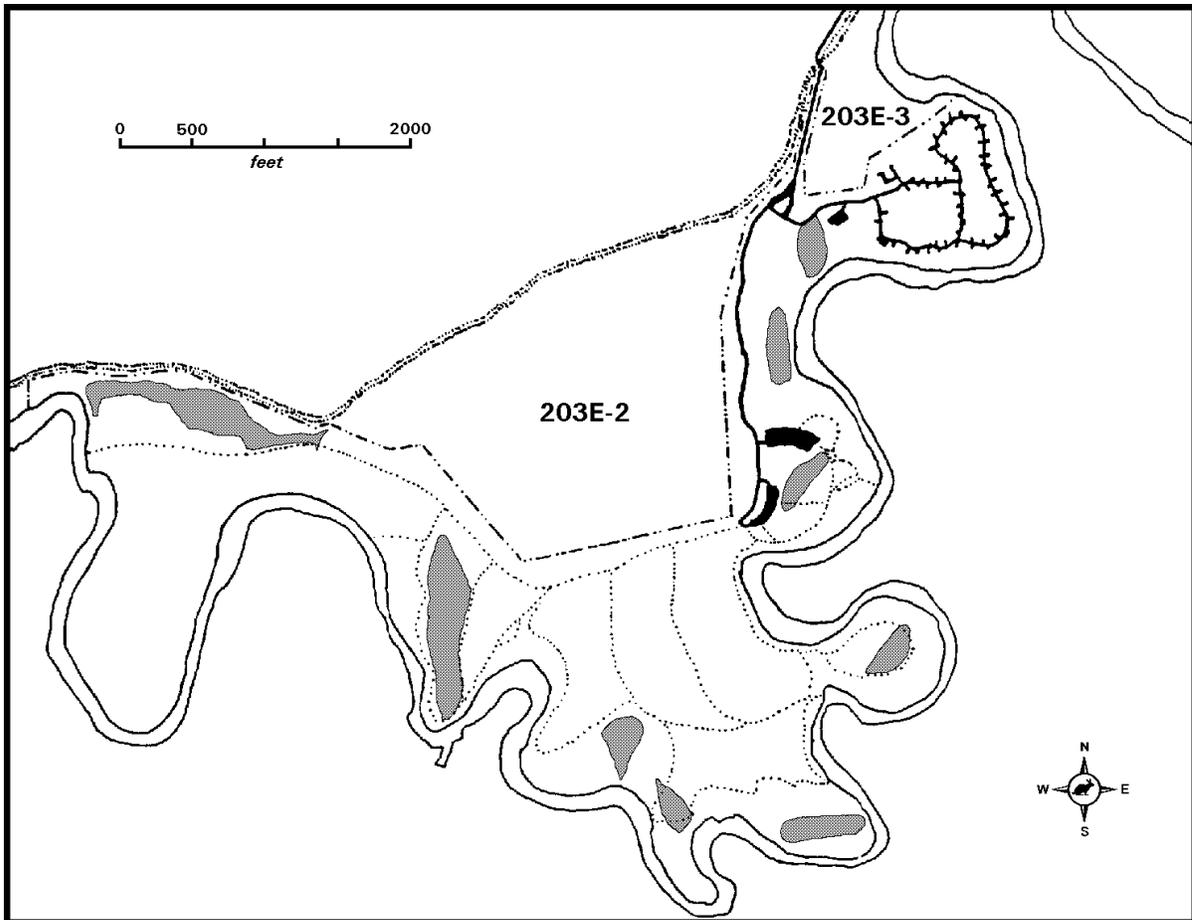


Figure 6. Low sites (shaded areas) in Caswell Memorial State Park that are periodically flooded. Vegetation at some flooded sites is controlled to facilitate control of mosquitoes. Private property recommended for acquisition for inclusion in CMSP are parcels 203E-2 and 203E-3 (partly shown, 203E-1 is located in a narrow band along the west edge of the Stanislaus River in 203E-3).

access points along its length might substitute for logs and limbs in providing refuge from predators and shelter from wet weather. Poultry wire laid over the pipe and held off of the ground would serve as a support for vines and catch leaf and limb litter and provide cover from aerial predators. Experiments should be conducted to determine suitable design and placement of artificial shelters and cover.

Mounding of soil at strategic sites could provide spots to escape from high water. These could be planted with a mix of species known to be used by brush rabbits and provided with artificial refuges and cover until natural cover is established. Piles of limbs and small logs removed from areas requiring fuel reduction or pipes and wire could be used for cover.

Translocate Populations: Populations of brush rabbits should be translocated to areas with potential habitat to reduce the risk of extinction. No existing CDPR property within the potential historic range of the riparian brush rabbit is presently suitable, with the possible exception of Hatfield SRA. However, potential habitat there is probably too small and vulnerable to flood-

Riparian Brush Rabbit Study – Caswell MSP

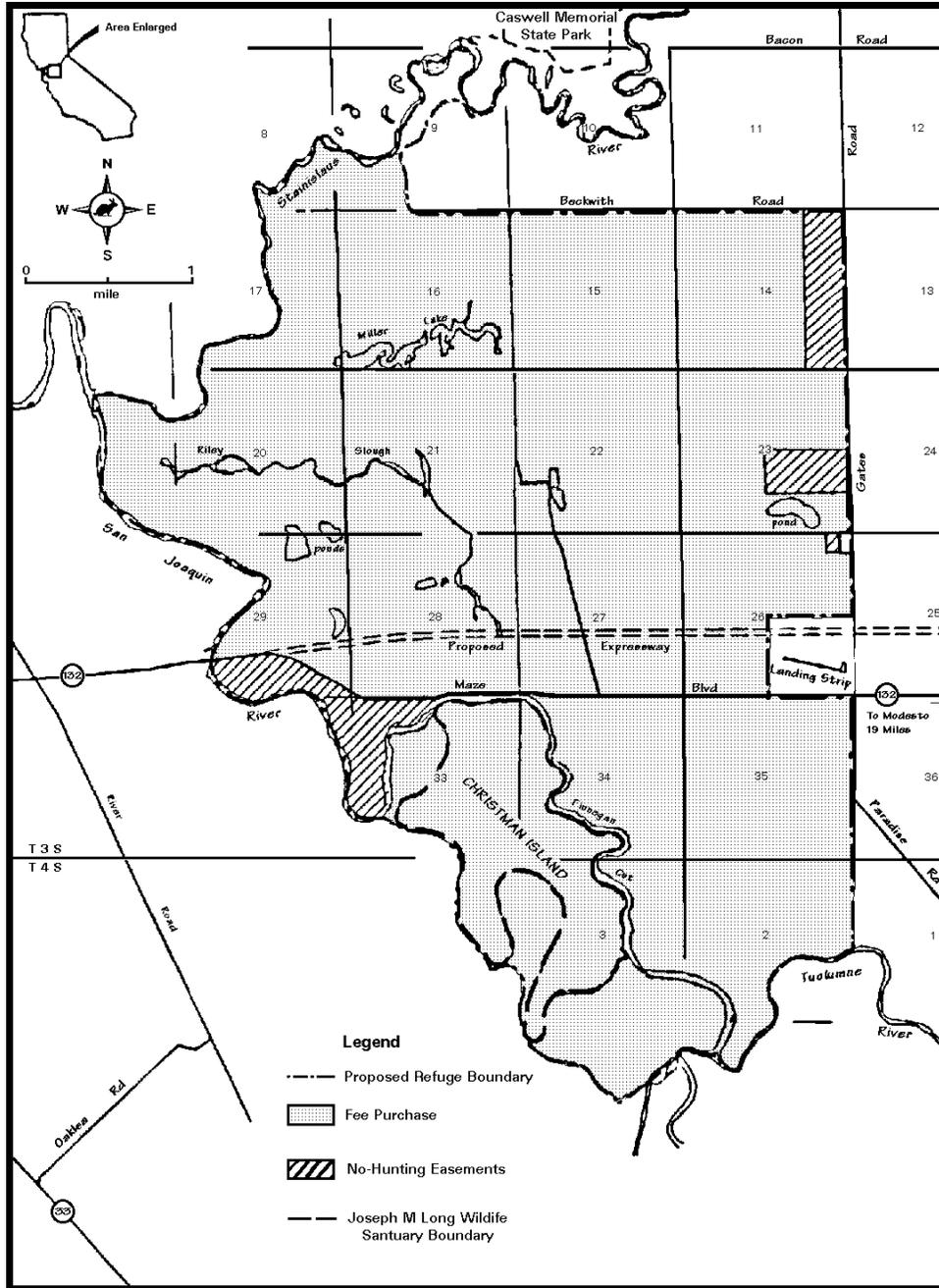


Figure 7. Proposed San Joaquin River National Wildlife Refuge, Stanislaus County, California.

ing to maintain a viable population. Property for the proposed San Joaquin River National Wildlife Refuge (Figure 7) does not presently support habitat suitable for riparian brush rabbits or is not secure from flooding, but it offers the greatest potential to establish and secure additional populations within their known historic range. Other possible sites are Turlock Lake SRA and the Consumnes River Reserve managed by The Nature Conservancy.

Riparian Brush Rabbit Study—Caswell MSP

Actions needed to acquire property and alter it so that it is secure from flooding and furnishes suitable habitat for brush rabbits should proceed as rapidly as possible. Priority should be given to property to be included in the San Joaquin River National Wildlife Refuge. Although this is not a task to be undertaken by CDPR, the Department should facilitate the process wherever possible.

Expansion of CMSP through Acquisition: Two parcels bordering CMSP are considered to be critical to securing the riparian brush rabbit population. Most important is the 33 ha Brocchini property (about 80 acres, parcel 203E-2 of Brocchini Ordinary Flowage Easement, Army Corps of Engineers; Figure 6). The parcel is currently planted to alfalfa. Recent leveling of this parcel and creation of a small dike between the cultivated field and the park might cause increased flooding in CMSP. The dike might also be used by rabbits to refuge from high water, but it is kept bare of vegetation so would provide no cover for rabbits.

Acquisition and addition of this property to CMSP should be given highest priority. Once acquired, its topography should be changed to create high ground for refuging rabbits. The width of the levee on the northern boundary could also be increased so that shrubs and other cover could be established without risk of weakening the levee. Planting of native shrubs and trees and placing artificial shelters and cover for brush rabbits on the property would hasten use by brush rabbits and provide safe refuge from floods.

The second parcel recommended for acquisition is the 8 ha bordering the northeast end of the park (about 20 acres, parcel 203E-3 Brocchini Ordinary Flowage Easement, and Parcel 203E-1 Brocchini Riparian Habitat Easement, COE; Figure 6). It is currently an almond orchard. After manipulation, this parcel could provide additional habitat for brush rabbits on higher ground adjoining the flood levee, and space for expansion of camping and other recreation activities.

ACKNOWLEDGMENTS

All trapping was done by Glenn and Debbie Basey. Glenn also provided information on the sites of use by riparian brush rabbits in 1986 and 1987, and conducted the counts of rabbits on their signs on the 30 transects. Susan Williams and Nancy Nicolai inventoried the park units in 1988 and assisted with measurements of plant community structure. Dan Blankenship and Sandy Harrison of the California Department of Parks and Recreation assisted in obtaining financing and carrying out the contract with CDPR. John Gustafson and Ron Schlorff of the California Department of Fish and Game provided advice and assistance in obtaining collecting permits. Ken Martin provided valuable information on tree-climbing by brush rabbits and the histories of floods and fires within CMSP.

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APPENDIX

Data sheets listing the measurements and observations recorded for unit inventories and vegetation transects are found on succeeding pages. Table A1 presents analyses of plant community structure and composition associated with presence or absence of riparian brush rabbits from Williams and Basey (1986). Table A2 summarizes unit inventories in CMSP, and Table A3 presents results of transect inventories for sign of riparian brush rabbits.

**RIPARIAN BRUSH RABBIT STUDY
CASWELL STATE PARK
Unit Inventory**

Site _____ Name _____ Date _____

Site Description _____

Rabbits Sighted _____

Woodrat Signs _____

No. of Runways _____

No. of Logs Examined _____

	Weathered	Black	Fresh
No. of Pellets: 0	_____	_____	_____
(groups) 1 - 5	_____	_____	_____
6 - 10	_____	_____	_____
> 10	_____	_____	_____

No. Clipped Sedge or Grass _____

Subjective Abundance: None _____ Low _____ Moderate _____ High _____

Overstory: Open _____ < 50% _____ >50% _____ Closed _____

Habitat: Setting _____

Trees _____

Shrubs _____

Ground Cover _____

Amount of Downed Woody Material _____

Litter _____

Other Remarks on Habitat _____

Other Observations _____

Riparian Brush Rabbit Study—Caswell MSP

Table A1. Means, standard errors of means, and ranges for plant community variables at 30 sites: 10 occupied by *Sylvilagus bachmani*, 10 occupied by *Sylvilagus audubonii*, and 10 unoccupied by either species. Canopy cover is by percentage; understory area is in square meters; all other values are linear measures (meters) along a 30-m transect; ground cover and shrub and understory cover were measured separately. Significant differences ($P \leq 0.05$, t-test) in values for sites occupied by riparian brush rabbits and the others are marked with an asterisk (*). Adapted from Williams and Basey (1986).

Habitat variable	Brush Rabbit		Desert Cottontail		Unoccupied Sites	
	Mean \pm se	Range	Mean \pm se	Range	Mean \pm se	Range
Canopy cover	65.1 \pm 8.2	23–94	56.5 \pm 11.5	0–100	79.1 \pm 6.8	26–100
oak	21.4 \pm 8.3	0–71	20.2 \pm 11.2	0–88	18.1 \pm 9.5	0–80
box elder	22.3 \pm 8.9	0–84	16.1 \pm 9.8	0–81	17.5 \pm 8.1	0–65
willow	2.0 \pm 1.3*	0–10	16.9 \pm 6.6*	0–58	23.0 \pm 9.2*	0–87
cottonwood	9.7 \pm 7.2	0–71	1.0 \pm 1.0	0–10	22.1 \pm 9.9	0–77
Herb height	0.7 \pm 0.06	0.4–1.0	0.6 \pm 0.05	0.4–0.8	0.7 \pm 0.2	0–2.0
Ground cover						
herbaceous	17.3 \pm 2.3	1–26	15.9 \pm 3.7	1.2–29.4	13.1 \pm 4.1	0–30.0
downed wood	0.1 \pm 0.1	0–1.0	0.9 \pm 0.4	0–4.2	0.5 \pm 0.3	0–2.8
litter	5.7 \pm 2.6*	0–26.7	0 \pm 0*	0–0	3.6 \pm 2.4	0–18.4
bare soil	7.2 \pm 1.9	0–16.2	13.2 \pm 3.7	0–28.7	12.8 \pm 3.9	0–29.5
Understory cover	20.9 \pm 3.2	0–30.0	20.5 \pm 2.6	1.0–28.2	15.5 \pm 3.1	0–30.0
rose	5.3 \pm 2.2	0–16.0	4.5 \pm 1.8	0–13.1	0.7 \pm 0.4	0–4.1
blackberry	7.2 \pm 2.3	0–21.5	7.0 \pm 0.2	0–19.7	8.4 \pm 3.0	0–29.3
tree seedlings	0.3 \pm 0.1	0–1.4	0.5 \pm 0.3	0–3.0	0.3 \pm 0.2	0–2.0
grape	5.3 \pm 2.7	0–23.6	1.2 \pm 0.7	0–6.1	2.6 \pm 1.6	0–14.1
coyote bush	2.9 \pm 1.4	0–14.4	3.1 \pm 2.1	0–19.7	0.3 \pm 0.2	0–2.0
willow	0 \pm 0*	0	4.3 \pm 2.9*	0–27.1	2.6 \pm 1.4*	0–14.7
Understory area	313.8 \pm 65.4	0–590.2	443.6 \pm 126.4	4.0–1355.0	281.2 \pm 80.4	0–837.5
rose	82.8 \pm 36.9*	0–320.0	72.4 \pm 29.6	0–239.7	14.1 \pm 9.5*	0–92.3
blackberry	100.4 \pm 35.6	0–333.3	66.6 \pm 19.7	0–153.0	77.6 \pm 24.8	0–213.4
tree seedlings	7.8 \pm 4.5	0–39.2	8.9 \pm 5.1	0–48.0	6.9 \pm 5.9	0–60.0
grape	55.4 \pm 25.6	0–228.8	21.6 \pm 14.8	0–136.5	47.3 \pm 29.5	0–282.6
coyote bush	67.3 \pm 39.5	0–394.6	101.7 \pm 67.5	0–531.9	3.6 \pm 2.6	0–24.0
willow	0 \pm 0*	0	172.8 \pm 136.0*	0–1360.0	109.0 \pm 67.1*	0–675.0

Riparian Brush Rabbit Study—Caswell MSP

Table A2. *Summary of abundance of sign of riparian brush rabbits and habitat features of 33 units comprising Caswell Memorial State Park, San Joaquin County, California. Locations of units are shown in Figure 4. Units were not of uniform size, but search times per unit were approximately equal, resulting in more complete inventories of small units.*

Unit	Runways	Pellet Groups	Clipped Sedges	Relative Abundance	Percent Canopy	Comments
1	10	3	9	low	> 50	Around service area; rabbits mostly in area of dense thickets with much litter and next to high ground with grasses and sedges.
2	7	5	6	low	50	Campground next to river; willows in canopy; clumps of shrubs small with much edge; rabbits mostly in currant/grape thickets.
3	4	14	7	medium	50	Campground; some low areas; several thickets of currant/blackberry; many trails; nettles and sedges in open areas.
4	6	13	5	low	> 75	Campground next to river; several low areas; few herbs, ground covered with litter; canopy closed in much of area; willows in canopy; rabbits in blackberry/ currant thickets.
5	8	17	11	medium	50	Campground next to river; several trails; willows in overstory; most signs in tall sedges mixed currants and blackberry with abundant logs and litter.
6	4	19	7	high	50	Campground; numerous trails; large thickets of currant, blackberry and grapes; runways in dense sedges and thickets; no willows in overstory.
7	1	6	2	low	> 50	Group campground; several low, flooded areas; little herbaceous ground cover; large cleared area.
8	0	0	0	none	> 50	Narrow zone between road and edge of park; sparse understory.
9	0	2	8	low	> 50	Large flooded area; large open areas; dense thickets of bamboo, other thickets of rose, blackberry, current, and grape.
10	0	2	12	low	50	Large flooded area; impenetrable thickets of currants, blackberry and rose; sedges and nettles for ground cover; little edge.
11	2	9	6	low	< 25	Large open areas, low areas, few shrubs in understory; low grasses and weeds; little woody litter.
12	7	4	4	medium	< 50	Inhabited area narrow; large low spot without understory; thickets mostly of low blackberry; sedges between thickets in higher spots; main study site.
13	5	10	9	medium	> 50	Group picnic area; low areas with intervening ridges covered with shrubs and herbs; moderate woody litter.
14	4	10	10	medium	< 50	High-use picnic areas; parking lots, low spots and trails create much edge; large thickets of blackberry and currant.
15	5	24	10	high	75	Between picnic area and river; many trails; thick litter; large thickets of blackberry; several flooded areas.
16	6	4	7	low	50	Large thickets of currant; little edge; most signs of rabbits near trails.
17	3	8	5	low	50	Large thickets of currant and rose; open ground or edge; most signs of rabbits near trails.
18	1	3	2	low	< 25	Narrow zone between park edge and road; large thickets of currant and coyotebushes; few herbs.
19	1	21	13	medium	50	Oak forest; several small clearings; low thickets of grape, coyote bush, rose, and currant; little woody litter; moderate amount of edge.
20	4	41	20	medium	> 50	Oak forest with clearings; large thickets of tree samplings, currant, blackberry and grapes; signs most numerous along trails and other edges.
21	0	16	1	low	50	Large low area in middle; patches of willows; most signs near path at edge of blackberry and currant thickets.
22	0	8	0	low	> 50	Low ground with willows; evidence of flooding; small thickets of shrubs.
23	4	18	19	medium	< 50	Large low area and trails create much edge; thickets of blackberry, rose, and currant around edge; sedges in low areas; high amount of woody litter.
24	3	47	5	medium	50	Oak forest with many clearings; moderate number of logs and limbs; low thickets of blackberry, rose, and currant.

Riparian Brush Rabbit Study—Caswell MSP

Table A2 (continued). Summary of abundance of sign of riparian brush rabbits and habitat features of 33 units comprising Caswell Memorial State Park, San Joaquin County, California. Locations of units are shown in Figure 4. Units were not of uniform size, but search times per unit were approximately equal, resulting in more complete inventories of small units.

Unit	Runways	Pellet Groups	Clipped Sedges	Relative Abundance	Percent Canopy	Comments
25	7	17	11	high	> 50	Small area with much edge; high amount of logs and litter; thickets of rose, blackberry, and currant.
26	16	64	13	high	> 50	Small area with much edge; oaks; large low area bordering unit; thickets of rose, blackberry, currant; high number of logs and woody litter.
27	15	25	22	medium	25	Larger area bordering low spot; box elders, maples, and willows; thickets of currant, coyote bush, and blackberry; moderate number of logs.
28	4	15	5	medium	< 50	Small area near river and low spot; sedges in openings and low spots; few logs; thickets of rose, blackberry, coyote bush, and currant.
29	6	13	8	medium	< 50	Narrow area between low spot and park boundary; mostly tangle of low-growing blackberries in understory; low number of logs; small thickets of rose, currant, and coyote bush.
30	4	16	5	medium	< 50	Thickets of rose, blackberry, coyote bush, and currant interspersed with lower ground with sedges; moderate litter.
31	10	26	12	medium	> 50	Cottonwoods and willows along low area; little habitat for rabbits between park boundary and low area and low area and road; mix of shrubs; <i>Sylvilagus audubonii</i> seen here.
32	22	69	13	high	< 50	Mix of young, successional trees and shrubs; sedges common around thickets; woody litter moderate.
33	2	8	10	low	< 25	Cottonwoods and willows along river edge; large thickets in interior; signs mostly along edges; <i>Sylvilagus audubonii</i> caught.