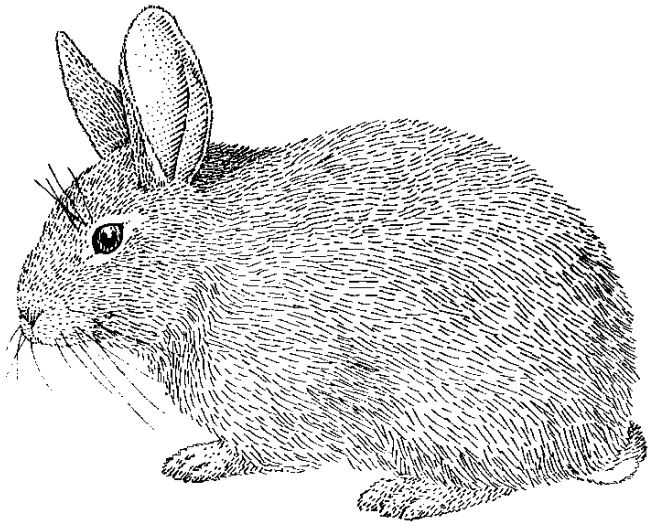
POPULATION CENSUSES OF RIPARIAN BRUSH RABBITS AND RIPARIAN WOODRATS AT CASWELL MEMORIAL STATE PARK DURING JANUARY 1993



by

Daniel F. Williams

San Joaquin Valley Endangered Species Recovery Planning Program
California State University Stanislaus Foundation
2727 N. Grove Industrial Dr., Suite 125
Fresno, California 93727

POPULATION CENSUSES OF RIPARIAN BRUSH RABBITS AND RIPARIAN WOODRATS AT CASWELL MEMORIAL STATE PARK DURING JANUARY 1993

Final Report

California Department of Parks and Recreation
Inland Region
730 South Beckman Road, Suite A
P. O. Box 1450
Lodi, California 95241-1450

by

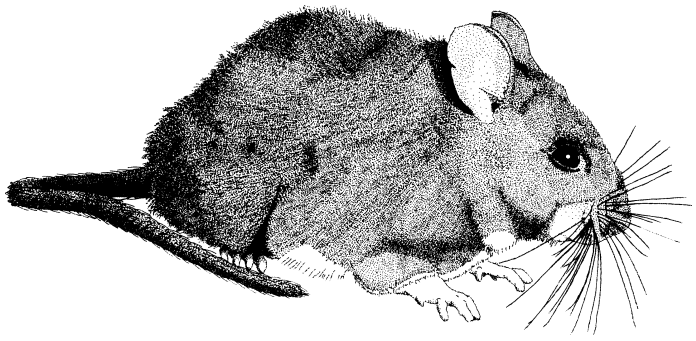
Daniel F. Williams

San Joaquin Valley Endangered Species Recovery Planning Program
California State University Stanislaus Foundation
2727 N. Grove Industrial Dr., Suite 125
Fresno, California 93727

28 June 1993
(reissue 16 April 1997)

TABLE OF CONTENTS

TABLE OF TABLES AND FIGURES



Riparian woodrat (drawing by Wendy Stevens, © CSU, Stanislaus Foundation)

ABSTRACT

Population sizes of riparian brush rabbits (*Sylvilagus bachmani riparius*) and riparian woodrats (*Neotoma fuscipes riparia*) in Caswell Memorial State Park (MSP) were estimated using capture-recapture models. Three areas of the Park were trapped separately for 7- to 9-day periods in January 1993. Estimated naive densities were: 3.0 ± 1.1 brush rabbits/ha, for 241 brush rabbits in 81 ha of the Park (95% confidence interval 170-608), and 4.8 ± 3.7 woodrats/ha, for 437 woodrats in 91 ha of the Park (95% confidence interval 218-2011). The density of woodrat houses was 8.3/ha. Thirty-one sites with three groups of four or more fresh rabbits pellets (deposited on top of recently-fallen leaves) were permanently marked in areas throughout the Park. These sites can be assessed in January of future years and compared with the data for 1993 to calculate an activity index for population monitoring. Several assumptions of this monitoring protocol are untested and it is recommended that a 7- to 10-day livetrapping program be used with or in lieu of the pellet assessment. Livetrapping would provide a better brush rabbit population index, allow detection of pathologies, test the efficacy of the pellet assessment method, and simultaneously assess the woodrat population. Recommendations for management actions, should population levels fall to threshold values below the 1993 level, include quarterly or monthly population monitoring by livetrapping, habitat assessment, testing for pathogens, and developing provisions for temporary removal of the populations to captivity, depending upon the threshold level surpassed. Also recommended are genetic studies to assess the levels of inbreeding and genetic diversity and to determine the relationships of the Caswell MSP populations to the geographically closest populations of brush rabbits and dusky-footed woodrats.

INTRODUCTION

Riparian brush rabbits (*Sylvilagus bachmani riparius*) and riparian woodrats (*Neotoma fuscipes riparia*) occupied extensive riparian forests on the floor of the San Joaquin Valley, California, before its settlement. Concomitant with settlement came forest clearing, land cultivation, and damming and diversion of the Valley's rivers, reducing, degrading, and fragmenting habitat for riparian species. Both subspecies are known to exist today only in and immediately next to Caswell Memorial State Park (MSP), San Joaquin County, on the Stanislaus River. The riparian brush rabbit has not been recorded outside the Park in the last 40 years (Williams and Basey 1986, Williams 1988). Besides the population of riparian woodrats known to inhabit the Park (Williams and Basey 1986), their houses have been observed on private property directly across the Stanislaus River from Caswell MSP, in Stanislaus County (Cook 1992).

Because of their restricted distributions, small extent of occupied habitat, and high risks of extinction from flooding, wildfire, disease, and demographic stochasticity, both taxa are listed as federal Category-1 candidate species (U.S. Fish and Wildlife Service 1991), and a draft proposal for listing as endangered is undergoing agency review. The riparian brush rabbit also is a candidate for listing as endangered by the California Fish and Game Commission (unpubl. data), and the riparian woodrat is treated as a Species of Concern by the California Department of Fish and Game (Williams 1986).

Caswell MSP is 104.4 ha (258 acres) in size and is vegetated with shrubs and trees characteristic of valley floor riparian and floodplain communities: valley oak (*Quercus lobata*), box elder (*Acer negundo*), Oregon ash (*Fraxinus latifolia*), blue elderberry (*Sambucus caerulea*), Fremont cottonwood (*Populus fremontii*), willows (*Salix* spp.), wild roses (*Rosa* spp.), California wild grape (*Vitus californica*), currents (*Ribes* spp.), coyote bushes (*Baccharis* spp.), blackberries (*Rubus* spp.), several other woody species, and a variety of introduced trees and shrubs, most notably black locust (*Robinia psuedoacacia*) and tree of heaven (*Ailanthus altissima*). The shrubby vegetation in the Park is generally decadent, with many dead branches, and a large quantity of downed woody material litters the ground. These features provide good habitat for both brush rabbits and woodrats, but also create a high risk of wildfire that could jeopardize their only known populations.

Estimated population size of riparian brush rabbits varied from a low of about 10 or less following severe flooding in winter of 1985-1986, to an estimated range of 88-452 rabbits in 1988 based on capture-recapture using the Schnable estimator (Williams 1988) and 320-540 rabbits using the Monte Carlo estimator of Minta and Mangle (1989; Basey 1990). Cook studied the mammals of Caswell MSP in 1992. Though she did not use traps of a size that would capture cottontails (*Sylvilagus* spp.), she observed them throughout the Park, and plotted locations of sightings of 9 brush rabbits and 17 desert cottontails; 20 other sightings of rabbits were not identified to species. This differed notably from the situation found in previous studies, based on trapping (Williams and

Basey 1986, Williams 1988, Basey 1990), where only a single desert cottontail was captured at the northwestern edge of the Park.

Cook (1992) estimated a mean density of 6.6 woodrat houses/ha on 13.3 m transects along major roads and trails in the Park. She extrapolated this to an estimated total population of 673 ± 428 woodrats for the Park (subtracting 2 ha from the 104 ha total for nonhabitat).

Before developing plans for securing populations of riparian brush rabbits and woodrats, information on their current population statuses is needed Population estimates using different techniques are highly desirable because capture-recapture estimators often perform poorly due to varying behavioral responses of animals to trapping. For brush rabbits and woodrats, capture-recapture models provide one method for estimating population size (White et al. 1982). For woodrats, a second, nontrapping method is to locate and count all houses in measured areas. However, determining occupancy of houses by woodrats would require efforts as great or greater than trapping. Thus house counts are most useful as an index of potential maximum adult population size, a value that rarely may be attained. A second method for estimating population size of rabbits consists of capturing and marking animals with reflective tape, with subsequent resightings using spotlights, and using capture-resight models for population estimation (Minta and Mangle 1989, McWherter 1991). Rabbit pellets deposited on low-lying logs, runways, and clipped sedges (best determined in winter) were used to rank use of portions of the Park by riparian brush rabbits (Williams 1988, Basey 1990) . While good for determining one-time relative-use levels of different habitats, the ranks could not be directly associated with a range of population densities because most of the Park was not trapped. Also, the subjectiveness of ranking and the irregularity in location of some kinds of sign make their use undesirable for population assessment by several people in different years. Needed is a simpler method of assessing major changes in population size.

Sites with several clusters of rabbit pellets appear to be "communal toilets," used by all of the rabbits in that area (Williams unpubl. data). Assessing these sites shortly after leaf-fall would assure that pellets were recently deposited, and could provide a population index for year-to-year comparisons. Future inventories of pellet groups at these sites could be compared to the initial index developed simultaneously with a population assessment based on capture-recapture.

We undertook studies in Caswell MSP to obtain population estimates of woodrats and brush rabbits based on capture-recapture, and locate several communal rabbit toilets to be used for assessing future changes in population size.

METHODS

Livetrapping was conducted between 9 January and 3 February 1993. Tomahawk

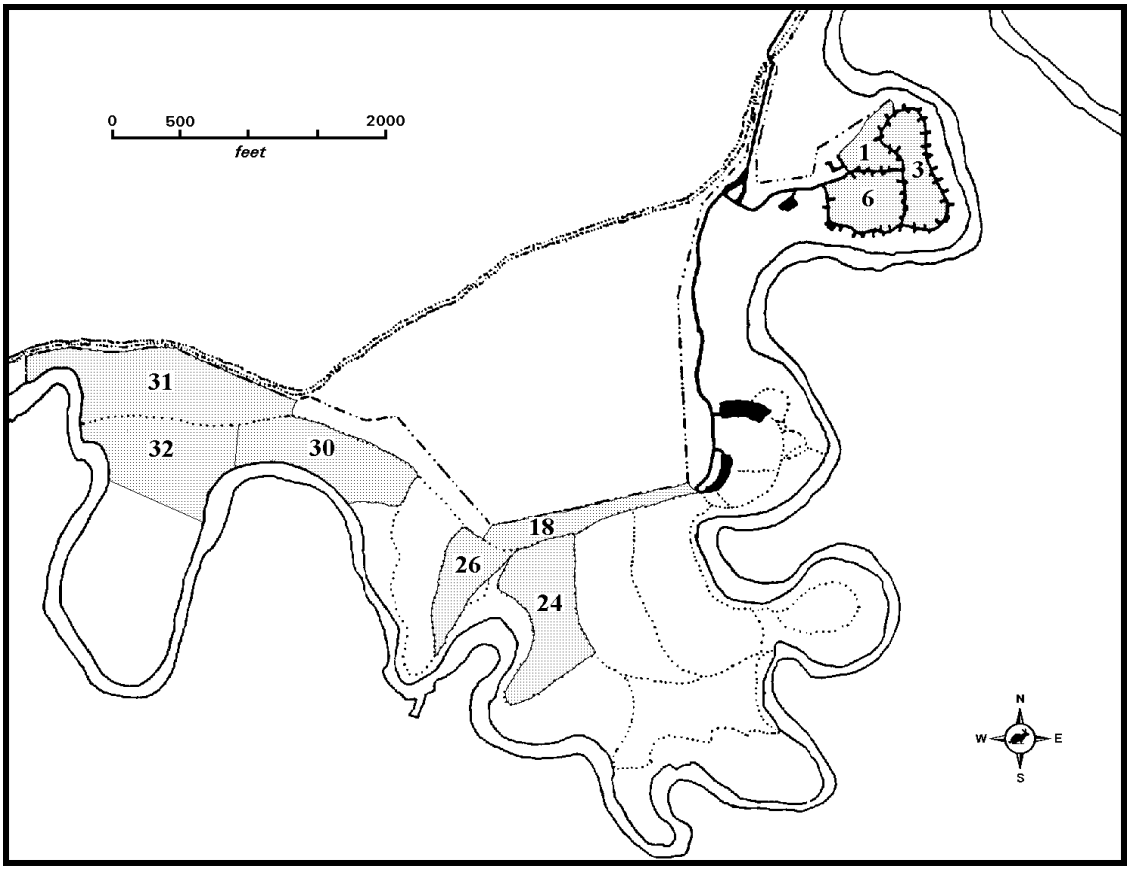


Figure 1. *Caswell Memorial State Park, San Joaquin Co., California (the southern boundary of the Park is the Stanislaus River). Numbers identify arbitrarily designated units for prior assessments of populations of riparian brush rabbits (Williams 1986). Shaded areas are the sites of the three population assessments for brush rabbits and woodrats in January 1993.*

brand, double-door wire-mesh livetraps (61 cm long by 15.2 cm high and wide) were used to capture brush rabbits and woodrats. Traps were baited with a combination of fresh apple slices and a mix of rolled oats and walnut meats. The walnuts were ground into small pieces and mixed with the oats. Traps were positioned in runways or near woodrat houses. We attempted to place traps to cover each area where sign of rabbits or woodrats were found, rather than array them in a grid or other standard pattern in areas of equal size. Traps were not placed closer than 5 m apart, nor in clearings and areas under full canopy without understory or evidence of use by rabbits or woodrats. Three areas of the Park were trapped in different sessions. Each area consisted of three of the units inventoried and ranked by Williams (1988) and Basey (1990) as low, moderate, and high use by brush rabbits (Figure 1). The first area (units 1, 3, and 6, Figure 1), located in the campground, was trapped with 99 traps for 9 nights between 9 and 18 January 1993. This area was approximately 4.76 ha in size, excluding roads. The second site, located in the undeveloped area (units 18, 24, and 26, Figure 1), was trapped for 7 nights between 20 and 26 January 1993. One hundred thirteen traps covered the area of approximately 7.35 ha. The third site in the western-most part of the undeveloped area (units 30, 31,

and 32, Figure 1) had 103 traps covering about 10.38 ha. It was trapped for 7 nights between 28 January and 3 February 1993. Because of cold, wet weather and risk of injury of captives by fighting the trap and from predators, traps were not left open all night except two nights during the first session. Traps were open approximately 4 hours per evening, starting about 1 hour before dark.

Upon first capture, animals were removed from traps to cloth bags. They were weighed, sexed (reproductive condition noted), and tagged with monel fingerling tags (National Tag and Brand Co., Newport, KY) in one ear. Brush rabbits received size-3 tags to which a 1.3-cm wide strip of red, reflective tape about 7.5 cm long had been attached by folding its adhesive sides together. The hind foot and ear of brush rabbits were measured. Woodrats and roof rats (*Rattus rattus*) were tagged with size-1 tags. Their weight, sex, and reproductive condition were noted on first capture. On subsequent capture, an animal's tag number was read and it was released without further handling. Individuals of other species captured were released without marking. Population estimates were computed using the 1993 version of the program Capture (White et al. 1982). The population estimation model used for each session was that selected in the Model Selection Procedure of Capture. This resulted in using three different models for different sessions, though the estimates from the three models for the same session did not differ significantly.

Thirty-one sites were marked where there were concentrations of more than three groups of rabbit pellets within a 2.5-m radius. A group was arbitrarily defined as four or more pellets closely clustered (i.e., in contact or only a few mm apart). Sites were marked with a metal stake (see appendix for location, compass bearing, and distance from trail markers to assessment stations).

RESULTS

Because of the type of trap used, only relatively large animals were captured. Some roof rats escaped from the traps by squeezing between the door and the side of the trap. Non-target species of mammals taken included 56 roof rats (six escaped before tagging and were not included in totals in Table 1, though some may have been recaptured and tagged later) and seven opossums (*Didelphis virginiana*). Western gray squirrels (*Sciurus griseus*), striped skunks (*Mephitis mephitis*), gray foxes (*Urocyon cinereoargenteus*), and coyotes (*Canis latrans*) were seen or heard, but not trapped. No desert cottontails (*S. audubonii*) were seen or trapped in the Park during these studies.

Brush Rabbits

Forty-three brush rabbits were captured and marked during the study (Table 1; two animals were captured in unit 1 after the population census and are not included in the

Table 1. *Estimated population sizes for three species captured in 7-9-day trapping sessions in Caswell Memorial State Park, San Joaquin Co., California. Model refers to the model for population estimation based on capture-recapture data: h = heterogeneity model where capture probabilities vary by individual; o = constant capture model where capture probabilities do not vary (White et al. 1982).*

	Trapping Session								
	9-18 Jan 1993			20-26 Jan 1993			28 Jan - 3 Feb 1993		
Species	***n***	**Pop. Estimate ± SD**	**Model**	***n***	**Pop. Estimate ± SD**	**Model**	***n***	**Pop. Estimate ± SD**	**Model**
S. bachmani	17	18 ± 2.81	*h*	4	7 ± 4.81	*o*	20	57 ± 11.84	*h*
N. fuscipes	30	51 ± 9.39	*h*	15	19 ± 3.39	*o*	10	12 ± 2.45	*o*
R. rattus	28	45 ± 8.22	*h*	7	13 ± 6.58	*o*	15	17 ± 2.09	*o*

table). Attempts to census brush rabbits by capture-resight using spotlights to illuminate reflective-tape tags (McWherter 1991) were unsuccessful because the rabbits typically stayed in such dense brush that their marks usually were not visible. The capture-recapture population estimate for all three sessions combined (dropping the first and last day of the first session—no rabbits were caught on the first night) was 67 ± 25.33 rabbits, with an approximate 95% confidence interval from 47 to 169, using the constant-probability removal population estimator (M_b). Naive density (population estimate 3 area trapped) for the three sessions was 3.0 ± 1.13 rabbits/ha (95% confidence interval = 2.1 to 7.5 rabbits/ha). For unknown reasons, relatively few animals were captured in the second session. Four unmarked rabbits were seen simultaneously in this area, and unmarked rabbits were seen nearly every day, despite low trapping success. The low capture-recapture population estimate for session two is probably offset by a relatively high estimate for the third session, where sign and sightings would lead us to believe there were fewer rabbits than the estimated number (Table 1).

Roads, paved parking lots and camp sites, maintenance yard, house and grounds occupy about 3 ha of the Park. Periodically flooded oxbow areas occupy about 10 ha. Other areas not used or seldom-used include closed canopy forest without understory and open areas without cover, estimated to be about 20 ha. Excluding structures (roads, parking areas, building sites) and other areas that may not be habitat provides a range of population estimates depending upon the combination of areas excluded. The extremes of estimated population sizes were 213 and 312 rabbits, with extreme minimum and maximum 95% confidence intervals of 149 to 780, depending on the number of ha that were habitat (Table 2). During January 1993 many oxbow areas showed some use by brush rabbits—most had been continuously dry since the last flood in 1986. Including oxbows as temporary habitat, but not the areas occupied by structures and others without shrub cover, yields an estimated habitat area of 81 ha and an estimated population size of 241 rabbits (approximate 95% confidence interval = 170-608, Table 2).

Table 2. *Estimated population sizes and 95% confidence intervals for riparian brush rabbits and woodrats in Caswell Memorial State Park, San Joaquin Co., California, based on different assumptions about hectares of habitat. Structures are buildings and associated yards, roads, and parking areas. Oxbows are low areas that often flood during winter, and which do not provide permanent habitat for either species. Many of these sites are periodically cleared of vegetation to expedite mosquito control.*

	Method for Estimating Habitat Area				
	All of Park	**Excluding Structures**	**Excluding Structures & Oxbows**	**Excluding Structures & Closed Forest**	**Excluding Structues, Oxbows & Closed Forest**
Habitat (ha)	104	101	91	81	71
		Sylvilagus bachmani riparius			
Population Size	312	303	273	241	213
Range	218-780	212-758	191-682	170-608	149-532
		Neotoma fuscipes riparia			
Population Size	499	485	437	—	—
Range	250-2,298	242-2,232	218-2,011		

Several of the 31 sites with concentrations of rabbit fecal pellets had more than 10 large clusters of pellets within the 2.5-m radius, but some groups were dispersed over a larger area (see Appendix). These sites typically had sparse or no ground cover of shrubs or herbs in January 1993, but had an overstory canopy. A few were in openings between shrubs and lacked a canopy. All pellets had been deposited in late December or early January after the end of leaf fall. Plastic flagging and a stake were placed to mark the approximate center of each area. These sites will serve to assess future population trends (see Discussion).

Weights and measurements for 34 of the riparian brush rabbits captured in Caswell MSP during January 1993 are listed in Table 3. One or more measures were missing for the other seven rabbits because they escaped before measuring was completed, mostly because several field workers were inexperienced with handling rabbits. We lacked a reason to suspect, however, that any of the rabbits captured were desert cottontails.

Woodrats

Fifty-five woodrats were marked during the three population censuses (Table 1). Estimated naive densities of woodrats/ha for the three sessions in sequence were, respectively, 10.7, 2.58, and 1.2. Estimated population size, using the variable-probability

Table 3. *Sex, weights, and measurements of riparian brush rabbits captured in Caswell Memorial State Park, San Joaquin Co., during January 1993.*

			Measurements	
Tag	**Sex**	**Weight (g)**	**Hind Foot (mm)**	**Ear (mm)**
1	M	610	74	68
4	F	590	74	64
5	F	690	74	68
6	M	600	68	66
7	M	575	81	64
8	&	625	70	72
10	M	530	76	68
13	F	580	79	66
19	M	635	76	69
20	M	570	80	68
21	M	550	70	68
22	F	615	78	68
23	M	660	77	71
24	M	670	72	69
26	F	310	77	70
27	F	550	72	66
35	F	670	82	65
36	M	610	80	66
37	F	630	82	64
49	F	650	80	62
50	M	590	74	66
52	M	550	70	71
53	F	650	70	68
56	M	550	77	72
57	F	600	76	68
59	F	590	78	69
60	M	565	77	70
61	F	570	78	70
63	F	700	78	70
64	M	660	82	68
65	M	550	76	67
67	F	655	72	65
68	F	650	72	65
73	M	630	76	67
Mean		609.7	75.8	67.6

Table 4. *Numbers of woodrat houses (nests) and riparian woodrats trapped, and estimated nest denisty/ha in three areas of Caswell Memorial State Park, San Joaquin Co., during January 1993.*

Units	Nests	Individuals Captured	Nest Density/ha	Mean Density/ha
1, 3, 6	28	30	5.88	
18, 24, 26	73	15	9.92	8.32
30, 31, 32	95	10	9.15	

removal estimator (M_o) for the combined sessions was 109 ± 83.7 (approximate 95% confidence interval = 55-497), for a mean naive density of 4.8 woodrats/ha. We counted 196 nests in the same areas (Table 4), for a mean density of 8.3 nests/ha. The estimated naive densities of woodrats and their houses were significantly different (adjusted log-likelihood $G = 10.109$, $P = 0.0067$, d.f. = 2) when comparing densities of woodrats and houses in the three areas trapped during sessions 1-3. The estimated population size was only about 56% of the number of nests. We did not attempt to distinguish occupied from unoccupied nests—several were in disrepair, suggesting abandonment, but a few others, located above ground in hollows in trees, may have gone undetected.

Most areas of the Park were habitat for woodrats, including closed canopy forest, but a few ha of open areas and open-canopy woodlands without significant understory lacked sign of woodrats. Habitat area was probably about 85-95 acres. The estimated population size of 437 woodrats, based on a mean density of 4.8 woodrats/ha in 91 ha (Table 2) compares with an estimated 757 houses in the same area.

DISCUSSION

Though invasion of the Park by desert cottontails could have occurred due to temporary circumstances (e.g., seasonal habitat change or habitat disturbance outside the Park), I believe Cook's (1992) visual identification of desert cottontails in the Park were mostly or wholly in error. We too have misidentified cottontails in the area when they were not in hand. In 1993 we trapped in the areas where all her 1992 sightings of this species were made only about 6 months earlier, and neither saw nor captured desert cottontails. Cook probably was unaware that many riparian brush rabbits are as light-colored and have a nape color that is similar to desert cottontails. Coloration alone is not diagnostic unless the animal is in hand and the tips of the ears and the basal segments of white hairs on the underside of the tail can be examined.

Measurements of desert cottontails average substantially larger than those of brush rabbits. Mean weight, hind foot length, and ear length for combined sex samples of *S. a. audubonii* (Orr 1940) were 925 g, 89.4 mm, and 80.6 mm, respectively. Weights of rabbits captured in the Park in January 1993 averaged 65.8% (609.7 g) of those for desert

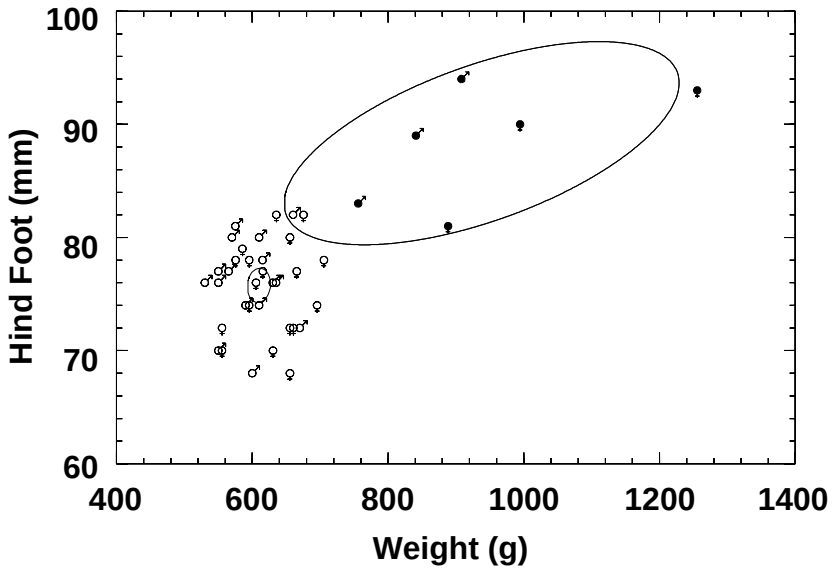


Figure 2. *Bivariate plot (weight and hind foot length) of riparian bursh rabbits (open symbols) captured in Caswell Memorial State Park, San Joaquin Co., during January 1993, and means and extreme values for measurements of desert cottontails (*S. audubonii audubonii*; filled symbols) from Orr (1940). Ellipses encompass the bivariate 95% confidence intervals (see text for further explanation).*

cottontails. Hind foot length averaged 84% (75.8 mm) of the mean for desert cottontails (Table 3; Orr 1940). More importantly, the maximum values for weight and hind foot length of animals captured during this study did not equal or exceed the minimum values for desert cottontails listed by Orr (Figure 2). Plotted values for desert cottontails in Figure 2 were the means and extremes for samples of males and females of *S. audubonii audubonii*, the subspecies that occurs in the area of Caswell MSP. These were the only values available without visiting museums with large collections. Yet plotting only the means forced a 95% confidence ellipse that encompassed most of the variation reported for the subspecies by Orr (1940). Had measurements for individuals been plotted, the ellipse would have been much smaller, similar to that for the animals measured in Caswell MSP (Figure 2). These data provide no evidence that any animals captured were desert cottontails.

The size of the brush rabbit population in January 1993 was as great or greater than previously observed by us (Williams 1988, Basey 1990). I believe that the population estimates for 1993 are reasonable and represent a nonbreeding population near the peak carrying capacity of the Park. Future assessments can be made and compared to this standard by revisiting the 31 sites identified as communal rabbit toilets. It is important to stress that assessments should be made in January, a few weeks after most or all leaves have fallen and covered older fecal pellets. Sites with three or more groups of four or more pellets will be assumed to be occupied by rabbits at numbers similar to January 1993. The number of sites showing this activity level will be compared to the 1993

standard. For example, if 28 stations met the criteria for use, the activity index would be 0.9, or 90% of 1993 use. If only 12 stations met the criteria, the activity index would be 0.39.

Major assumptions of this assessment method are that: brush rabbits do not randomly deposit all fecal pellets throughout their home range, instead some are deposited at sites in common with other individuals; these toilets are fixed in location and do not vary from year to year; areas inhabited within the park will change as the population increases and decreases, and this will be reflected by presence or absence of pellets at communal sites inhabited in 1993; and the sites identified represent the range of areas that change in occupancy as population size changes. These assumptions have not been tested, but general observations suggest that deposition of fecal pellets at communal sites is true. Reason suggests that if habitat features do not change significantly from year to year, the same sites will continue to be used. The last two assumptions present the most difficulties. The method obviously would not distinguish the numbers of rabbits using a site, and, therefore, a severalfold change in population size might go undetected if all stations showed use at or above the minimum criteria. Our previous work suggests that as population size has changed dramatically, rabbits disappeared from large portions of the Park. Clearly this was true with changes associated with severe flooding. Our assessments since the last flood in winter 1985-1986, however, suggest that this also is true with lesser population changes caused by factors other than flooding (Williams 1988, Basey 1990). I expect that population changes of less than about 0.5 (i.e., change from 300 to 150 or 450) may not be detectable with this few stations and the minimum criteria of three pellet groups. Yet, use of the method is to detect a major population decline, not to estimate population size—this is important to emphasize. The population sizes at which a threshold is surpassed and use of major areas of the Park increases or decreases are unknown, but such changes should be detectable by this method. With the current stations, only a major population decline would be detectable. Bear in mind that we did not attempt to locate all toilets; instead we marked easily relocatable ones in a range of habitat types, and included a number sufficient to detect a major decrease in population size. Had we wanted to detect a major increase in population size compared to January 1993, we would have tried to locate and mark all toilets in the Park. We did not attempt this because the level of labor required was too costly, the population was relatively high, and our objective was to provide a nontrapping method of detecting a major decline from this level that might require action to prevent extinction of the population.

A 7-10-day livetrapping program at many sites (i.e., 100 trap stations operated simultaneously) scattered over the range of habitats and space of the Park would provide a better population index than pellet assessment, and should be considered as a annual population-monitoring tool in place of or in addition to pellet assessment. Such a program would require more people (probably a minimum of four), but would not be too costly nor time consuming. Additionally, a livetrapping program would yield a population index for woodrats, which also require population monitoring.

Suggested levels for management actions are: a decline in the activity (toilet-use) or

livetrapping index to about 0.6 of the 1993 level would trigger a quarterly monitoring program that should include an evaluation of habitat conditions and livetrapping so that population size could be estimated and animals could be handled and inspected for sign of pathology. A decline below about 0.4 of the 1993 level would require a more intensive program of population monitoring by monthly livetrapping, habitat evaluation, and, possibly, emergency removal to captivity. If flooding or fire were not obviously associated with a decline of this magnitude, testing for known diseases (Williams 1986) should be undertaken. Depending upon the outcome of population, habitat, and pathological evaluations, removal to captivity should be considered. In the interim, provisions for removal and maintenance of a population in captivity should be developed by involved agencies.

The greatest numbers of woodrats typically are found in shrubland, woodland, and forest communities with a mix of overstory trees and shrubs. Houses are most often at the bases of trees or against logs in closed woodland or dense shrubs . Houses are seldom located in areas without shrub or tree cover except in rock talus and crevices (Williams et al. 1992). Cook (1992) described microhabitat surrounding woodrat houses in Caswell MSP, based on measurement of plant community structure around 25 houses. Most houses were located in areas with a ground cover high in leaf litter and a light growth of sedges, a moderate understory of vines, seedlings, and shrubs, and a high percentage of canopy cover. A majority were positioned over or next to logs.

Reported densities of woodrats from studies in a variety of habitats ranged from about 0.1 to 8.3/ha; the number of houses is typically greater than the number of woodrats (Williams et al. 1992). Cook's (1992) estimate of 673 woodrat houses in Caswell MSP compares with an estimate of 847 houses using the mean density of 8.3 houses calculated from our study, and her 102-ha habitat estimate. The difference in the estimates is not significant. Inherent in Cook's (1992) estimate was the assumption that houses located along roads and trails were characteristic of the distribution of houses throughout suitable portions of the Park. Woodrats may prefer house locations that are farther from the edge of clearings, on average, than the distance from roads and trails included in her transects, which could explain the differences in our estimates of house density. Regardless of which estimate is used, the most important consideration for assessing the population in Caswell MSP is that there are fewer than 102 ha of habitat for woodrats—probably about 85-95 ha.

The estimated number of woodrats in January 1993 was significantly less than the number of houses. A population size of from about 500 (slightly greater than the capture-recapture estimate) to 700 (50 lower than the highest estimate of houses/ha in 91 ha) may be the maximum for the Park. While this size probably is sufficient to prevent short-term loss of genetic diversity, the important question that is directly applicable to assessing long-term population viability is what are the population sizes at the low points in periodic fluctuation and after severe flooding? Woodrats probably survive flooding at much higher rates than brush rabbits because they are semiarboreal and eat a great variety of plant material (Williams et al. 1992). Yet, extended flooding probably causes high

mortality from exposure and predation, and it is likely that the Caswell population has been periodically reduced so low that significant genetic diversity has been lost.

Genetic studies of both riparian brush rabbits and woodrats are needed to assess the genetic variation in the Caswell populations, and to determine the extent of genetic similarity to their geographically closest neighbors. This information is needed for conservation planning, and also can used in decision-making about the degree of relationships to other subspecies and the taxonomic identity of other Central Valley riparian populations of these species.

ACKNOWLEDGMENTS

Major funding for this research was provided by contracts with Stanislaus State University Foundation by the U.S.D.I. Bureau of Reclamation (San Joaquin Valley Endangered Species Recovery Planning Program), as part of the assessment of species with critical habitat needs in the San Joaquin Valley, and the California Department of Parks and Recreation. I thank Rosalie Faubion, Gary Waldron, and Joanne Kerbavaz for their support in administering these contracts for their agencies. Andrea Chapman provided logistic support during our field work. Stan Hyer of Recreation on Wheels, Modesto, CA, generously donated the use of a travel trailer. Ron Batie and James Curtis were the principals in the field work. Mike Allenger, Karla Allred, Glenn Basey, Ellen Cyper, Mary Davis, Laurissa Hamilton, Joshua Lerner, Mark McFall, Stephen Myer, Suzanne Nelson, and Terrence Trassatti also participated in the field work. Dena Bos and Rebecca Roth provided the administrative and logistic support to keep the project running smoothly. David Germano assisted in developing the research proposal and permit application. Caryla Larsen developed a Memorandum of Understanding between the California Dep. of Fish and Game and the Recovery Planning Program to permit trapping of riparian brush rabbits and woodrats. Gary Waldron and Patrick Kelly reviewed the draft report and provided suggestions for its improvement.

LITERATURE CITED

Basey, G. E. 1990. Distribution, ecology, and population status of the riparian brush rabbit (*Sylvilagus bachmani riparius*). M.S. Thesis, Calif. State Univ., Stanislaus, Turlock. 76 pp.

Cook, R. R. 1992. An inventory of the mammals of Caswell Memorial State Park. Final Report, California Dept. Parks and Recreation, Lodi, CA, 30 pp.

McWherter, G. R. 1991. Estimating abundance of cottontail rabbits using live trapping and visual surveys. M.S. Thesis, Univ. of Tennessee, Knoxville, 102 pp.

Minta, S., and M. Mangle. 1989. A simple population estimate based on simulation for capture-resight data. Ecology 70:1738-1751.

Orr, R. T. 1940. The rabbits of California. Occas. Papers. California Acad. Sci., 19:1-227.

U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species. Federal Register, 56(225):58804-58836.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, Los Alamos, New Mexico, 235 pp.

Williams, D.F. 1986. Mammalian Species of Special Concern in California. California Dep. Fish and Game, Wildl. Manage. Div., Admin. Rep., 86-1:1-112.

Williams, D. F. 1988. Ecology and management of the riparian brush rabbit in Caswell Memorial State Recreation Area. California Dep. Parks and Recreation, Inland Region, Final Report, Interagency Agreement 4-305-6108, 38 pp.

Williams, D.F., and G.E. Basey. 1986. Population status of the riparian brush rabbit, *Sylvilagus bachmani riparius*. California Dep. Fish and Game, Sacramento, Wildl. Manage. Div., Nongame Bird and Mammal Section, Contract Final Report, 21 pp.

Williams, D.F., J. Verner, H.F. Sakai, and J.R. Waters. 1992. General biology of major prey species of the California spotted owl. USDA Forest Service Gen. Tech. Rep., PSW-GTR-133:207-221.

APPENDIX

Below is a list of distances and compass bearings from trail markers to the survey posts marking the sites of brush rabbits' communal toilets (see map on next page).

Station	Distance (m)	Compass Bearing
1	8	180°
2	30	45° [a]
3	SW Corner in Low area	
4	58	270° [b]
5	Between Campsite Parking Lots 63 & 65	
6	3	170° [c]
7	19	270° [d]
8	20	130°
9	32	310°
10	26	220°
11	16	230°
12	20	195°
13	6	150°
14	13	220°
15	19	200°
16	12	140°
17	9	0°
18	8	150°
19	34	270°
20	9	30°
21	20	90°
22	5	0°
23	12	170°
24	19	210°
25	4	0°
26	5	70°
27	96	180°
28	43	160°
29	7	210°
30	33	0° [e]
31	11	180° [f]

[a] From post 49.
[b] From post 48.
[c] From nature trail.
[d] From 2nd picnic area.
[e] From oak tree; 8 m @ 90° to stake.
[f] From trail's end.