CONTROLLED PROPAGATION AND TRANSLOCATION OF RIPARIAN BRUSH RABBITS:

ANNUAL REPORT FOR 2003

PREPARED FOR THE U.S. BUREAU OF RECLAMATION
MID-PACIFIC REGION
2800 COTTAGE WAY
SACRAMENTO CA 95825

U.S. FISH AND WILDLIFE SERVICE
ENDANGERED SPECIES DIVISION
2800 COTTAGE WAY, ROOM W-2605
SACRAMENTO, CA 95825

AND

CALIFORNIA DEPT. OF FISH AND GAME
SPECIES CONSERVATION AND RECOVERY PROGRAM
1416 9TH STREET, SUITE 1341
SACRAMENTO, CA 95814

Prepared by:

Daniel F. Williams[1], Matthew R. Lloyd, Laurissa P. Hamilton,
Elizabeth Vincent-Williams, James J. Youngblom,
Kirsten Gilardi[2], and Patrick A. Kelly

Endangered Species Recovery Program
Department of Biological Sciences
California State University, Stanislaus
801 W. Monte Vista Ave.
Turlock, CA 95382
(209) 667-3446

July 14, 2005

[1] dwilliams@esrp.csustan.edu
[2] Wildlife Health Center, School of Veterinary Medicine, University of California, Davis, 95616.

ABSTRACT

We report on activities and gathered information related to the controlled propagation and release of captive-born, riparian brush rabbits (*Sylvilagus bachmani riparius*) to the wild during federal Fiscal Year 2003, and combine and interpret information from this and the prior year's propagation and release of rabbits. In December 2002, nine rabbits of each sex were trapped in the wild in the South Delta, San Joaquin County, California, and released into one of three 1.24-1.70 acre (0.5-0.7 ha) pens that contained natural vegetation. In April 2003, an additional male and female were captured in the wild and were released into one of the pens to replace two rabbits that had died (total number of breeder rabbits = 20). Subsequent monitoring of the confined population provided information on reproduction, survivorship, growth, and health. The first three offspring were captured on 10-13 February 2003, and weighed 60, 115, and 180 g. One female died before breeding and was replaced; all nine remaining females exhibited evidence of producing young. There was a total of at least 97 pregnancies by 53 females that resulted in 284 young that lived long enough to be trapped and marked. The mean number of young per pregnancy surviving beyond the first few weeks after birth was 2.9. There was evidence of pregnancies into mid October and evidence of lactation into mid November. Mean weight at first capture was 220.6, 288.9, and 323.0 g in the three pens, respectively, and the overall mean estimated age at first capture was 31 days. Geneotyping using seven polymorphic microsatellites demonstrated that nine females and eight males contributed to the first cohorts of offspring. In 2003, four males and one female were returned to their original capture sites in the South Delta. The remaining breeders died, or are believed to have died, at the propagation facility. We were unable to monitor repatriated rabbits due to access restrictions. Health exams, necropsy of dead rabbits, and tests for diseases showed that the riparian brush rabbit population in the South Delta, including rabbits in confinement at the controlled propagation facility, was for the most part robust and healthy. There were five cases of neurologic disease, which was likely caused by larvae of *Baylisascaris* sp. , and resulted in the mortality of five breeders. Rabbits did well in captivity, gaining weight and reproducing sooner and at a rate greater than we have witnessed in the wild. Between July 2003 and February 2004, 214 captive-born rabbits were released at the San Joaquin River National Wildlife Refuge. During this period, 152 of the translocated rabbits died—mostly of predation or unknown causes. While still remaining higher than originally expected, the overall survival of the 2003 cohort was significantly lower than the 2002 cohort (Cox's F-Test, $F = 1.908$, $p = 0.046$). In analyzing the movements of 77 individuals, males had larger home ranges and core areas than females regardless of the season. However, in contrast to studies of brush rabbits in other regions, female riparian brush rabbits had larger home ranges during the breeding season than during any other time of the year. In January 2003, we censused the wild populations of riparian brush rabbits and woodrats (*Neotoma fuscipes riparia*) at Caswell Memorial State Park. Traps were operated sequentially for 8 days in each of three sections of the Park. Trapping followed protocols established in earlier years. Fourteen riparian brush rabbits and 41 riparian woodrats were captured in 2003. This represented the highest number of woodrats captured in any year since 1993, and the second highest number of brush rabbits captured since 1993, down only 2 individuals from 2002. Both values, however, were insufficient to reliably estimate population sizes when partitioned among separate census areas. In February and April 2003, we conducted a presence/absence survey at Mossdale Oxbow in the South Delta. Over a combined 2 nights of trapping, we captured 15 riparian brush rabbits, and consequently identified another native population utilizing the fragmented habitat in the South Delta. This report also details the laboratory analyses conducted on rabbit blood samples and outlines the guidelines for managing vegetation at the controlled propagation facility.

CONTROLLED PROPAGATION AND TRANSLOCATION OF RIPARIAN BRUSH RABBITS:

ANNUAL REPORT FOR 2003

TABLE OF CONTENTS

TABLE OF TABLES

LIST OF FIGURES

CONTROLLED PROPAGATION AND TRANSLOCATION OF RIPARIAN BRUSH RABBITS:

ANNUAL REPORT FOR 2003

Daniel F. Williams, Matthew R. Lloyd, Laurissa P. Hamilton, Elizabeth Vincent-Williams, James J. Youngblom, Kirsten Gilardi[1], and Patrick A. Kelly

Endangered Species Recovery Program
Department of Biological Sciences
California State University, Stanislaus
Turlock, CA 95382

INTRODUCTION

The riparian brush rabbit (*Sylvilagus bachmani riparius*) is California- and federally-listed as an endangered species (U.S. Fish and Wildlife Service 2000). It also was identified as a *Critical Needs Species* under terms and conditions of the *Friant Biological Opinion* (U.S. Fish and Wildlife Service 1991). It occupies riparian communities dominated by thickets of willows (*Salix* spp.), wild roses (*Rosa* spp.), blackberries (*Rubus* spp.) and other successional trees and shrubs, and when available seasonally, dense, tall stands of herbaceous plants adjacent to patches of riparian shrubs in the northern San Joaquin Valley (Figure 1). Such communities in the San Joaquin Valley have been reduced to less than 1% of their historical extent, primarily by clearing natural vegetation, irrigated cultivation, impoundment of rivers, and stream channelization.

Today, the only known populations of riparian brush rabbits are confined to Caswell Memorial State Park (MSP) on the Stanislaus River, and the South Delta area of the San Joaquin River, including Paradise Cut and Tom Paine Slough (Williams and Basey 1986, Williams and Hamilton 2002, ESRP unpubl. data). The Park is 104.4 ha in size. The South Delta population is located on private land, mostly along Paradise Cut. Paradise Cut's streambed is private property and the waterway is managed for flood control, not wildlife habitat. The South Delta population exists on an estimated 109.3 ha, spread linearly over several miles in discontinuous patches, mostly only a few meters between developed ground or developed ground and water. An additional population of riparian brush rabbits was discovered on private property in February 2003 (Lloyd and Williams 2003). The 10.9 ha parcel is approximately 2.4 km southwest of the city of Lathrop. As far as is known, all other historical habitat along the San Joaquin River and its tributaries has been lost or degraded beyond use by irrigated agriculture, livestock grazing, and impoundment and channelization of streams (Williams and Basey 1986, Williams and Kilburn 1984, Williams 1993, ESRP unpubl. data).

Both populations of riparian brush rabbits are under significant, proximate threats of extinction. The population in Caswell MSP faces threats from random demographic events in small populations, inbreeding and loss of genetic diversity, wildfire, flooding,

[1] Wildlife Health Center, School of Veterinary Medicine, University of California, Davis, 95616.

disease, and predation exacerbated by high numbers of feral cats (Williams and Basey 1986, Williams 1988, 1993, U.S. Fish and Wildlife Service 1998). The South Delta population faces threats from stochastic demographic and genetic events, flooding, disease, predation, competition, and habitat conversion on private land.

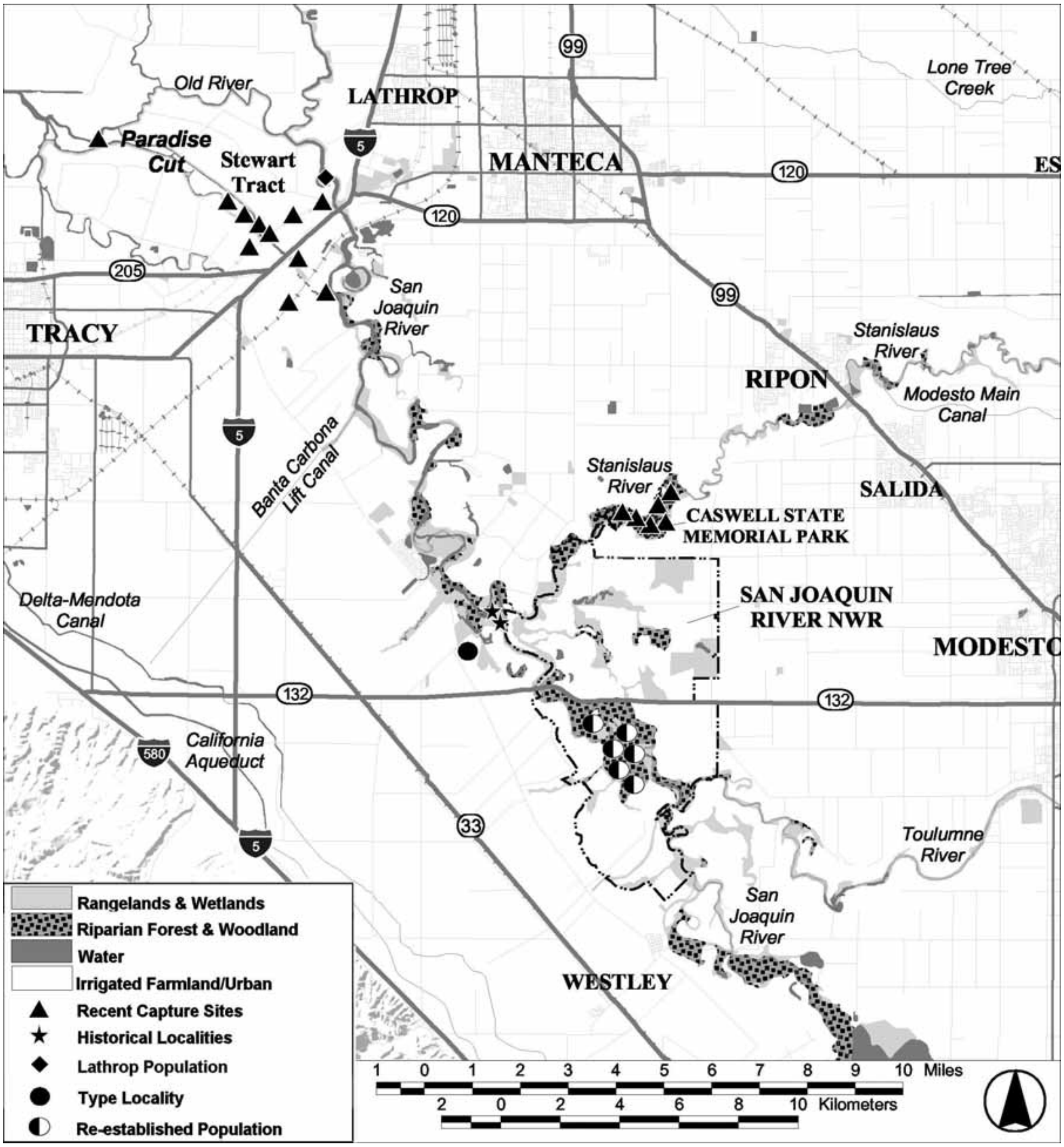

Figure 1. *Distribution map for the riparian brush rabbit based on data current through December 2003.*

The Recovery Plan for the riparian brush rabbit lists the establishment of three additional self-sustaining, wild populations outside of Caswell MSP and within the historical range of the species as being necessary for recovery (U.S. Fish and Wildlife Service, 1998, p.169). Because the extant populations at Caswell MSP and the South Delta are isolated from other suitable sites that currently are uninhabited, reintroductions of individuals derived from existing populations is required to achieve this goal (U.S. Fish and Wildlife Service, 1998). The Caswell MSP population is too small and nonproductive to serve as a source of wild-born rabbits for translocation. For these reasons, breeding in confinement to provide a source of animals for reintroductions is called for in the Recovery Plan. To that end, efforts to initiate a controlled propagation program were undertaken in 1999. Subsequently, the U.S. Fish and Wildlife Service, California Department of Fish and Game, and U.S. Bureau of Reclamation decided not to pursue studies of controlled propagation on a surrogate subspecies of brush rabbits, but rather to take advantage of a newly discovered population of riparian brush rabbits in the South Delta.

To avoid the problems that could arise from confining a rare species in small cages when little is known about its husbandry and mating behaviors, the necessity for offspring to learn about habitat, food, and predator avoidance, and to become acclimated to weather at the translocation site, the Riparian Brush Rabbit Recovery Working Group decided not to confine and breed rabbits in small cages. Instead, animals were placed in fenced enclosures larger than their typical home ranges (0.33 ha; Dixon et al. 1981) and populated with natural vegetation that provided suitable habitat (Williams and Basey 1986, Williams et al. 2002).

This document reports results of efforts directed to recovering the riparian brush rabbit during the federal fiscal year 2003. It includes descriptions of the location and structure of the controlled propagation facility; activities directed at populating and operating the facility; results of observations on the confined population; activities involving the translocation and release of captive-bred animals to the wild; preliminary results of monitoring the newly established population; and other, related activities.

PART 1: CONTROLLED PROPAGATION AND TRANSLOCATION OF RIPARIAN BRUSH RABBITS

The principal objectives for holding and breeding riparian brush rabbits in confinement are to conserve a portion of the South Delta population at risk of extinction; produce offspring that will be reintroduced to restored, historical habitat; maintain confined populations until new populations are established in restored habitat; and produce individuals to supplement and invigorate the extant population at Caswell MSP.

The Department of Water Resources' property known as Pond 6, in San Joaquin County, was chosen as the location to construct three controlled propagation enclosures (Williams et al. 2000). Vegetation at the site includes willows, Fremont cottonwood (*Populus fremontii*), Himalayan blackberry (*Rubus discolor*), Baltic rush (*Juncus balticus*), salt grass (*Distichlis spicata*), poison hemlock (*Conium maculatum*), and stinging nettle (*Urtica dioica*), among others. The parcel's riparian characteristics make this site especially attractive for the project because there is a well-established shrub component that the rabbits can use for cover.

CONSTRUCTION AND PREPARATION OF THE PROPAGATION ENCLOSURES

Only one enclosure (Pen 1) was built in time for the first year of controlled propagation in 2002; however, three enclosures were completed in time for the second year of controlled propagation in 2003. The enclosures are 1.24-1.70 acres (0.5-0.7 ha) in size. Each is fenced with hardware cloth and has a 2-ft band of sheet-metal flashing at the top. The sides stand 7 ft high. The interior is covered with netting, which is supported by cables strung from the long sides of the enclosures (Figure 2). The netting allows songbirds and quail to enter and exit, but not without some difficulty. Raptors, however, are excluded.

Prior to introducing brush rabbits into the two new enclosures, we conducted periodic trapping totaling 21 days to remove animals that could adversely affect the captive breeding population (e.g. weasels, other rabbit species, rodent species). Pen 1 still contained brush rabbits from the 2002 effort, and was therefore not trapped, having been emptied of other species in 2001.

We used extended length, folding Sherman™ traps (30.48 cm long × 9.53 high × 7.62 cm wide) and double-door, wire-mesh Tomahawk™ traps (Model 203; 61cm long × 15.2 cm high and wide). Half were baited with canned cat food and half with a mix consisting of apples, oats, walnuts, and molasses. Traps were checked twice a day and captives were released outside the enclosure.

Over the 21 days of trapping in Pen 2 we caught and removed 11 desert cottontails (*Sylvilagus audubonii*), 11 California voles (*Microtus californicus*), 32 house mice (*Mus musculus*), 12 deer mice (*Peromyscus maniculatus*), 1 black rat (*Rattus rattus*), and 41 California ground squirrels (*Spermophilus beecheyi*) . We removed 23 desert cottontails, 38 California voles, 15 house mice, 6 black rats, and 4 California ground squirrels from Pen 3. Re-entry of ground squirrels into Pen 2 during the initial days of trapping contributed to the high number of ground squirrels captured; therefore, the number "removed" is greater than the number of individuals. When the problem was realized, burrows around the perimeter of the enclosure were filled, which led to a decrease in ground squirrel captures.

We constructed six artificial nests with 8-inch PVC pipe for Pens 2 and 3, and placed them into openings carved into the blackberry thickets. We used gasoline-powered hedge trimmers to carve openings for nests and tunnels of pipe. Various lengths (approximately 2-3 ft) of 6 and 8-inch PVC pipe were placed along the edge of the blackberry bushes to serve as the initial runways in and out of the thickets. In addition, various lengths and widths of concrete and terra cotta pipe were placed throughout the enclosure to provide refugia from climatic elements. Piles of concrete pipe and rubble were placed in cleared areas near the fence on the short-sides of the pen to serve as refugia in case the vegetation in the pens caught fire.

Figure 2. *Photo of a portion of a pen for controlled propagation of riparian brush rabbits at Pond 6. The pen is approximately 530 feet long, 100 feet wide, and the side fencing is about 7 feet high. The top is covered with netting to prevent raptors from entering. Sides are topped with sheet metal, shown on the left, but not yet installed on the right. For scale, two vehicles are parked near the centerline (photo by L.P. Hamilton).*

INTRODUCTION OF RABBITS TO THE PROPAGATION ENCLOSURES

In December 2002, we trapped at six general locations in the South Delta area of the San Joaquin River in an effort to capture rabbits for relocation to the controlled propagation enclosures. Our objective was to capture 18 individuals (3 males and 3 females for each of the 3 enclosures) from distinct areas of suitable habitat to allow for low kinship values and, presumably, maximum genetic heterozogosity, thereby reducing the effects of inbreeding depression.

We searched closely in potential habitat for sign of rabbits (fecal pellets, runways, fur, clipped sedges). Where sign was found, we set Tomahawk™ traps baited with a combination of walnut meats, rolled oats, molasses, and sliced apple. Number of traps used and length of time trapped varied by location, but in total we trapped for 274 trap days (number of traps × number of 24-h days of trapping). Traps were set in the afternoon or early evening, checked about 2 hours after dark and again in the early morning. Traps were left open around the clock unless weather conditions threatened the health of the rabbits. Captured brush rabbits were permanently marked with metal ear tags and PIT tags, weighed, and measured. Two 3-mm diameter plugs of ear tissue were taken with a biopsy punch from brush rabbits and preserved in 95% ethanol (reagent grade). Animals that were not selected for propagation were released at the site of capture.

Twenty-six riparian brush rabbits were captured during this effort (Table 1). The distance between the two furthest captures was 4.5 km, with other captures dispersed in between. Access restrictions and failure to capture rabbits at more distant locations decreased the geographic range, and therefore genetic diversity, we had hoped to incorporate. However, having 3 enclosures allowed us to place rabbits of higher possible kinship values in different enclosures to reduce the possibility of inbreeding (Table 2).

Physical examinations and blood sample collections for complete blood counts and serum chemistries (detailed in Appendix A) were performed on 24 of the brush rabbits captured at Paradise Cut. Exams were performed at the University of California, Davis Wildlife Health Center by Drs. Kirsten Gilardi and Deanna Fritcher, with assistance from ESRP biologists. For six rabbits, abnormal findings on physical exam and/or results of blood analyses precluded translocation of those rabbits to Pond 6; they were subsequently returned to their capture sites. Abnormalities included low white blood cell counts, increased white blood cell counts, oral mucosal lesions (areas of reddening or mild ulceration), and in one case, abnormal lung sounds on thoracic auscultation (the act of listening for sounds made by the heart and lungs).

The 18 rabbits selected for propagation were fitted with ATS™ radio-collars so they could be monitored for movement and mortality inside the enclosures. After being released into the enclosures, rabbits were monitored for mortality by radio telemetry approximately two times per week. Within the first 3 months of captivity, 3 of the 18 rabbits had died (one probably by predation and two that were disease-related). In December 2002, following the possible predation in Pen 1, we conducted 7 days of predator trapping using 89 Tomahawk™ traps and 78 Sherman™, extended-length traps. Traps were baited with wet cat food, scent tabs, and/or chicken livers. During this effort, we captured and removed 12 California voles and 44 house mice. Since we did not capture any predatory species, we assumed the enclosure was safe to continue brush rabbit propagation.

Trapping at Mossdale Oxbow in April 2003, led to the capture and introduction of two additional breeder rabbits to replace the two that had died in Pen 2 due to health problems (see Part 3). Pre-translocation physical examinations and blood collections of these rabbits were performed in the field by an ESRP biologist. Abnormal findings on the physical exam of one of the rabbits precluded her immediate translocation to the propagation facility. She was kept in captivity pending a second attempt to obtain a blood sample. While in captivity, she gave birth to a litter of four kittens on 06 April 2003. All the kittens died within approximately 48 h of birth. A blood sample obtained from the female post-partum on 09 April 2003 revealed no abnormalities and she was subsequently translocated to the propagation facility.

Table 1. *Results of the South Delta trapping effort to relocate brush rabbits to the propagation enclosures in 2002.*

Location	Days Trapped	# of Traps	Male	Female	Total	# Relocated for Propagation
A	1.5	35-50	6	9	15	11
B	2	10	0	0	0	N/A
C	2	20	3	2	5	2
D	1	20	1	3	4	3
E	2.5	10-20	2	0	2	2
F	2.5	18-49	0	0	0	N/A
Total	--	--	12	14	26	18

Table 2. *Distribution of 2003 brood-stock rabbits in the three enclosures by location of capture and sex.*

Location	Enclosure #1		Enclosure #1		Enclosure #1		Total
	Male	Female	Male	Female	Male	Female	
A	2	2	2	1	2	2	11
C	0	0	0	1	1	0	2
D	0	1	0	1	0	1	3
E	1	0	1	0	0	0	2
Total	3	3	3	3	3	3	18

RADIO COLLARS

To monitor survival in captivity, the 20 breeder rabbits were fitted with radio collars prior to their transfer to the controlled propagation facility. Advanced Telemetry Systems (ATS; Isanti, MN), model M1750, with neoprene-impregnated cotton-duck belting collars, had been found to be effective during the 2002 season. These units weighed approximately 13 grams, with a battery life of 7 months to 1 year. The strap-type collar of fixed size and placement of holes was secured by a nut and bolt.

During trapping to assess reproduction in the spring of 2003, abrasions from the radio collar straps were noted on the necks of 10 of 20 breeders. One individual had a wound that required treatment. The other nine rabbits were treated and released on-site; collars were removed, wounds were cleaned with diluted betadine, and antibiotic ointment was applied. Subsequent trapping sessions indicated that the rabbits fully recovered from the injuries.

REPRODUCTION AND DEVELOPMENT OF CAPTIVE RABBITS

The controlled propagation enclosures were trapped at regular intervals to recapture the brood stock and their offspring. Our objectives included assessment of the general health and appearance of all captured individuals, reproductive condition of the breeders, numbers of offspring present in the enclosures, and growth and development of captive-bred offspring.

In 2002, Pen 1, the only propagation enclosure in use, was trapped at biweekly intervals between 22 February and October. The first offspring were captured on 22-23 February, and weighed 140 and 179 g. The total known productivity in 2002 was 64 offspring (34 female, 28 male, 2 unsexed). The unsexed individuals were very small and still nursing, and were not recaptured, so presumably died. The overall sex ratio was 1:0.82, female to male. In 2002, we captured many more females in the early part of the summer and more males in August and September (Figure 3).

In 2003, Pen 1 was trapped twice weekly using 89 permanently situated Tomahawk™ traps. Pens 2 and 3 were trapped once weekly between 10 February and 17 December using 76 permanently situated Tomahawk™ traps in each pen. The first offspring were captured on February 10-13, and weighed 60, 115, and 180 g. Given the approximate 30-day gestation period for brush rabbits, conception of the offspring weighing approximately 180 g probably occurred in late December, a few weeks prior to date we projected for the beginning of mating season based on field observations (Williams 1988).

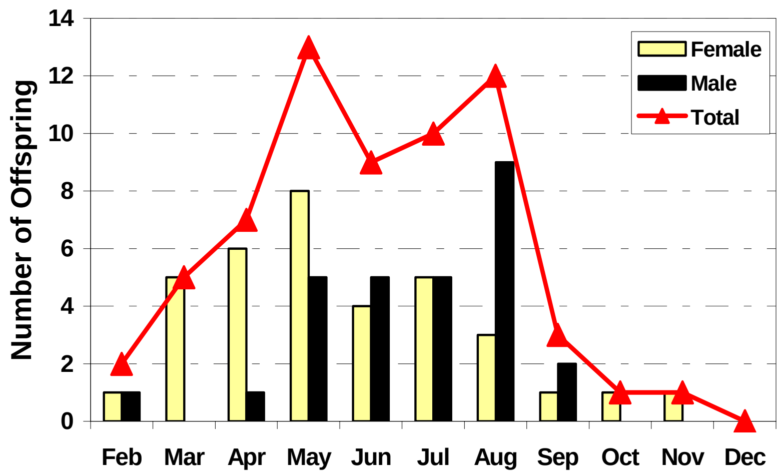

Figure 3. *Number of young rabbits newly trapped and marked in the controlled propagation enclosure each month during 2002.*

In 2003, 122 (59 males, 63 females) offspring were produced in Pen 1. The numbers of offspring produced in Pens 2 and 3 were 79 (38 males, 41 females) and 84 (49 males, 35 females), respectively. The total number of offspring produced at the controlled propagation facility was 285 (146 males, 139 females). The overall sex ratio in 2003 was 1:1.05, female to male. Unlike in 2002, the monthly sex ratio remained relatively even throughout the breeding season; however, the breeding season in 2003 extended into the fall, whereas in 2002 breeding essentially finished at the end of summer (Figure 4).

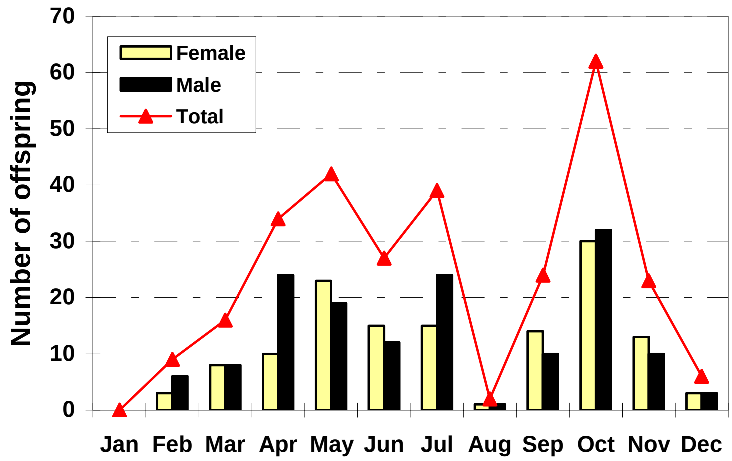

Figure 4. *Total number of young rabbits newly trapped and marked in the controlled propagation enclosures each month during 2003.*

***Pen 1.*—**We conducted 100 trap sessions in Pen 1 during 2003. The smallest individual captured weighed 50 g, was probably no more than about 9-10 days old, and probably had not been weaned (Davis 1936, Mossman 1955, Chapman and Harman 1972, ESRP unpubl. data). Mean mass at first capture for 122 young was 220.5 (*s* = 95.3 g). Least and greatest mass at first capture were 50 g and 580 g, respectively. The distribution of weight classes for mass at first capture is shown in Figure 5. The majority of rabbits weighed less than 300g when first captured—the modal weight class was 151-200 g.

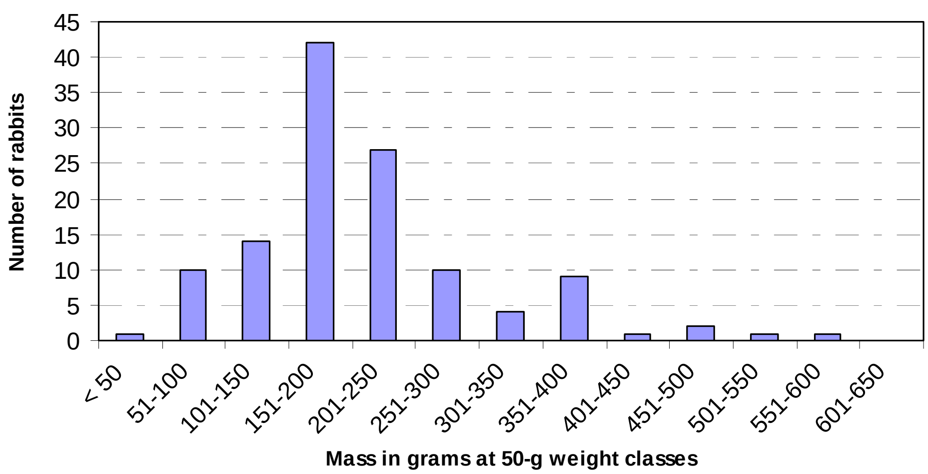

Figure 5. *Distribution of mass (g) at first capture of 122 young in 50-g weight classes for rabbits born in controlled propagation Pen 1 in 2003.*

***Pen 2.*—**We conducted 58 trap sessions in Pen 2 during 2003. The smallest individual captured weighed 100 g. Mean mass at first capture for 79 young was 292.7 (*s* = 124.4 g). Least and greatest mass at first capture were 100 g and 570 g, respectively. The distribution of weight classes for mass at first capture is shown in Figure 6. More than half of rabbits weighed less than 300 g when first captured.

Pen 3.**—**We conducted 63 trap sessions in Pen 3 during 2003. The smallest individual captured weighed 80 g and was probably no more than about 3 weeks old (Davis 1936, Mossman 1955, Chapman and Harman 1972, ESRP unpubl. data). Mean mass at first capture for 84 young was 323.0 g (*s* = 158.8 g). Least and greatest mass at first capture were 80 g and 800 g, respectively. The distribution of weight classes for mass at first capture is shown in Figure 7. A little more than half of rabbits weighed less than 300 g when first captured.

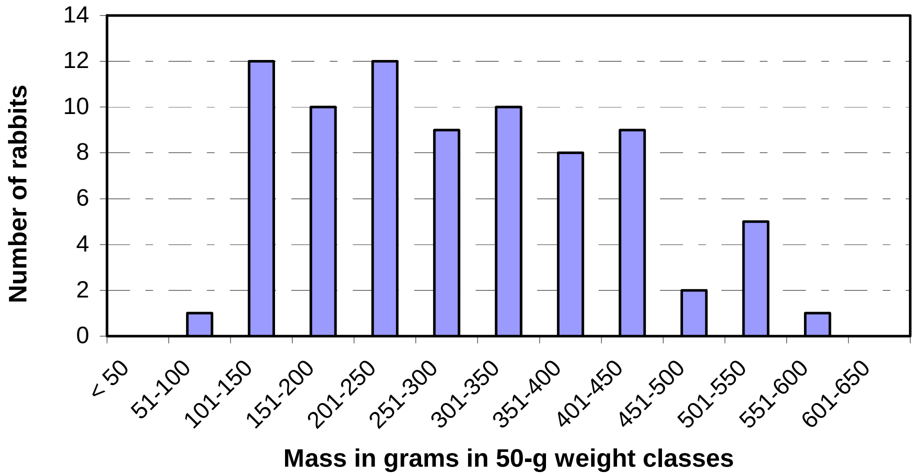

Figure 6.. *Distribution of mass (g) at first capture of 79 young in 50-g weight classes for rabbits born in controlled propagation Pen 2 in 2003.*

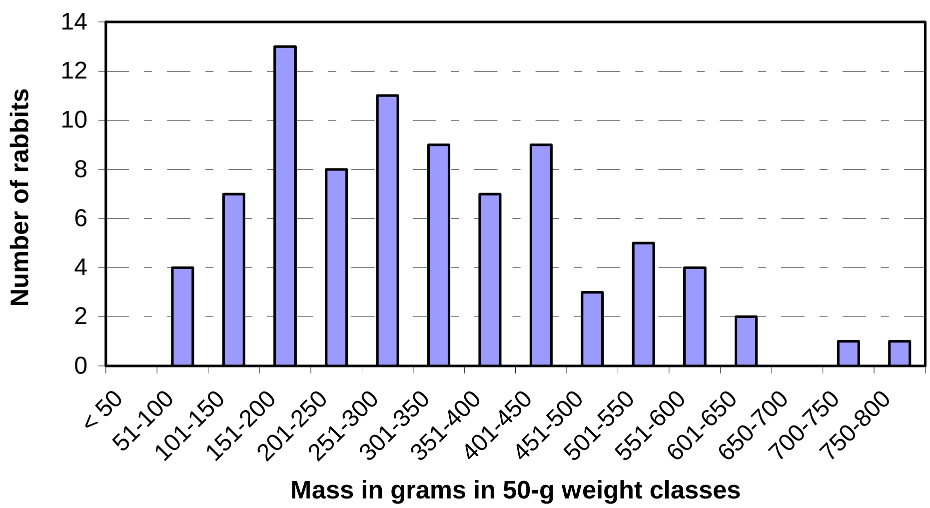

Figure 7. *Distribution of mass (g) at first capture of 84 young in 50-g weight classes for rabbits born in controlled propagation Pen 3 in 2003.*

In 2002 and 2003 a total of 347 young were captured and marked—62 in 2003 and 285 in 2004.

We have weights for a few offspring that were born in captivity. These newborns all died shortly after birth. Their mass ranged from 15.2 to 30.7 g. The mean mass of the eight newborn and aborted, near-term fetuses was 21.8 g.

In 2002, all three of the adult females exhibited evidence of producing young; two probably had three or four litters each. Though five litters was considered the upper number that might be produced by females, we had expected only two or three (Mossman 1955). Twelve juvenile females exhibited evidence of reproduction such as estrus, lactation, or pregnancy. Of these, two individuals likely had two litters. As a conservative estimate, there were 22 pregnancies by 15 females producing 64 young. The mean number of young per pregnancy surviving beyond the first few weeks after birth was 2.9. We found no evidence of estrus or pregnant females after 19 September. We removed all the males from the pen that we could capture and which were of sufficient size to radio-collar, beginning on 31 July.

In 2003, one female died before breeding and was replaced; all nine remaining females exhibited evidence of producing young. There were a total of at least 97 pregnancies by 53 females that resulted in 284 young that lived long enough to be trapped and marked. As in 2002, the mean number of young per pregnancy surviving beyond the first few weeks after birth was 2.9. There was evidence of pregnancies into mid October and evidence of lactation into mid-November. Potential reproduction was interrupted starting on 03 July when we began translocating offspring that passed health exams, were not lactating or obviously pregnant, and weighed > 500 g.

Our data on growth of young and the calculated relationship between age and mass suffer from lack of robust data on change in mass between birth and weaning. Mossman (1955) reported that near-term embryos weighed 24.3 to 32.2 g, and that there was a post-partum weight loss the first few days. Davis (1936) calculated a mean mass of 28 g for 4-day-old brush rabbits. We calculated a mean weight of 21.8 g for live-born and aborted near-term fetuses and the Y-intercept for the regression of change in mass by time was 21.8 g, assuming a linear relationship (Figure 8). Yet we believe that our data were skewed by inclusion of aborted fetuses and a nonlinear growth curve, so instead used Davis's estimate, 28 g at 4 days of age, to estimate age from mass. Mean gain in mass was 6.62 g/day for rabbits weighing 60 g or more initially. The smallest, live-trapped individual we captured (50 g) was estimated to be about 8 days old, and the mean age at first capture was 31 days. Young at weaning weighed about 94-101 g, assuming that weaning was at about 14-15 days of age, as found for other *Sylvilagus* species (Chapman 1974, Chapman 1975, Chapman and Wilner 1978, Chapman et al. 1980). Young attained reproductive maturity when about 83-90 days old (550-600 g).

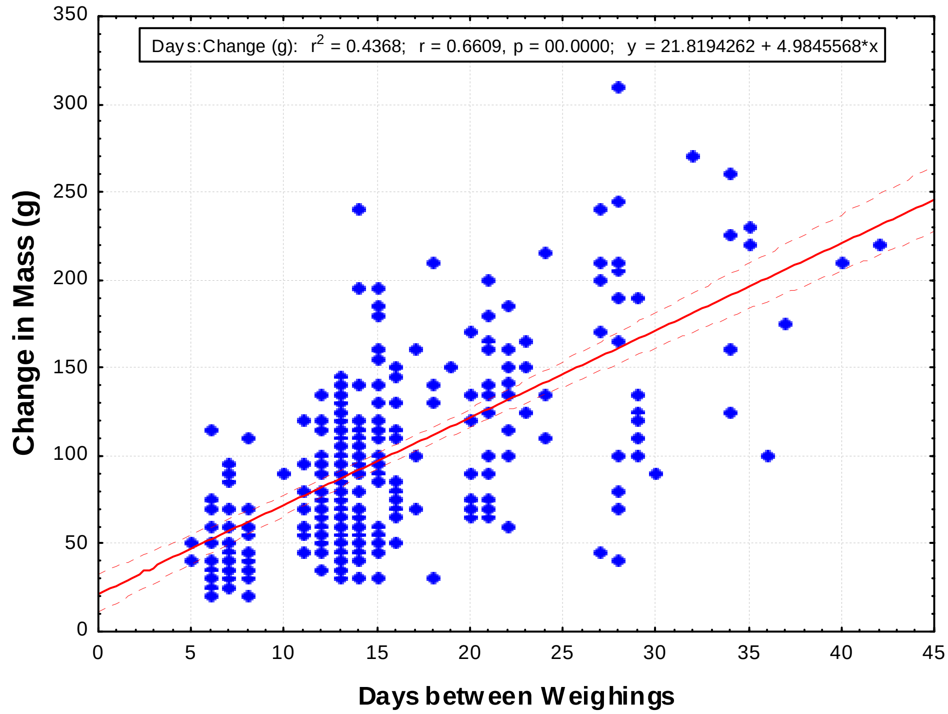

Figure 8. *Scatter plot depicting increase in mass between weighing periods in days for 123 young riparian brush rabbits born at the controlled propagation facility in 2002 and 2003.*

GENEALOGY OF YOUNG RABBITS PRODUCED IN CONFINEMENT

The genetic variability of the rabbit populations was determined using seven polymorphic microsatellite loci (Table 3). Each reverse primer carried a TET fluorescent tag. Extracted DNA was amplified in a 20 µl PCR [3 µl DNA, 4 µl dNTPs (1.25 mM each), $MgCl_2$ (Table 4), 1 x PCR buffer, Taq DNA polymerase (1 unit), 0.4 µl each primer (50 µM)]. PCR conditions were optimized for each primer by varying the $MgCl_2$ concentration and annealing temperature (Table 4). In addition, primer, Sol-44, required higher concentrations of Taq DNA polymerase (2 units/20 µl reaction). The following thermocycler program was used for each reaction: 5 minute denaturation at 95°C; 8 cycles of 94°C for 30 seconds, primer specific annealing temperature for 30 seconds, and 72°C for 30 seconds; 26 cycles of 89°C for 30 seconds, primer specific annealing temperature for 30 seconds, and 72°C for 30 seconds; 10 minute final extension at 72°C, hold at 4°C.

Following PCR, proper amplification was affirmed by examining the samples after electrophoresis on a 2% agarose mini-gel. Aliquots of amplified samples were sent to the Iowa State University DNA Sequencing and Synthesis Facility for genotyping on an ABI Prism 377 DNA sequencer (high resolution gel electrophoresis system). Images of gels were downloaded from Iowa State Univ. and analyzed locally using Genographer 1.2 genotyping software (Benham et al. 1999).

Table 3. *Base sequences for seven polymorphic microsatellites isolated from riparian brush rabbits.*

Microsatellite	F-Strand	R-Strand	Authors
SOL-8	5'GGATTGGGCCCTTTGCTCACACTTG3'	5'ATCGCAGCCATATCTGAGAGAACTC3'	Rico et al. 1994
SOL-30	5'CCCGAGCCCCAGATATTGTTACCA3'	5'TGCAGCACTTCATAGTCTCAGGTC3'	
OCBGLX	5'TCTAGGAAGAAGCTTTATCCCTC3'	5'GTTTTCTCATCAGAAATCCACC3'	Van Haeringen, et al. 1996/97
OCLS	5'ACTGCTATATCAAAGGCATGACCC3'	5'TCAGGTATTTGGAAAGTGAATCCC3'	
SOL-44	5'GGCCCTAGTCTGACTCTGATTG3'	5'GGTGGGGCGGCGGGTCTGAAAC3'	Surridge, et al. 1997
SAT-7	5'GTAACCACCCATGCACACTC3'	5'GCACAATACCTGGGATGTAG3'	Mougel, et al. 1997
SAT-16	5'AATCAGCCTCTATGAATTCCC3'	5'AATGCTACATGGTAACCAGGC3'	

Table 4. *Magnesium chloride concentration and annealing temperature (TA) for each primer.*

Primers	$MgCl_2$ (mM)	T_A
SOL-8	3.0	55
SOL-30	2.5	54
OCBGLX	2.5	56
OCLS	3.5	62
SOL-44	4.0	58
SAT-7	3.0	59
SAT-16	3.5	56

Parental genotypes (Table 5, Table 7) were determined and compared with the corresponding offspring (for each pen) that were captured and marked (Table 8, Table 10). Only seven of the original eight microsatellites were used for this analysis because one (OCR-4) was non-variable in the brood-stock population. Analyses of F2 offspring were not done because it would be to many uncertainties in to determining the parents of the offspring with two or three generations potentially interbreeding.

Table 5. *Genotypes for seven microsatellites for six adult riparian brush rabbits comprising the brood stock for the controlled propagation program for Pen 1 in 2003.*

ID/sex	Parental Genotypes						
	OcBGLX	Sat-16	Sol-8	Sat-7	Sol-44	Sol-30	OCLS
676 male	243, 235	141, 133	120, 116	196, 196	213, 203	159, 155	165, 157
630 male	233, 233	141, 129	120, 116	198, 198	205, 000	161, 161	165, 157
684 male	233, 233	139, 129	120, 112	200, 196	213, 207	161, 155	173, 165
634 female	233, 233	141, 141	120, 112	198, 196	205, 203	163, 155	173, 157
253 female	235, 233	139, 129	120, 116	196, 184	209, 207	169, 159, 155	169, 157
198 female	243, 235	139, 139	120, 116	198, 196	203, 000	161, 153	169, 157

Table 6. *Genotypes for seven microsatellites for six adult riparian brush rabbits comprising the brood stock for the controlled propagation program for Pen 2 in 2003.*

ID/sex	Parental Genotypes						
	OcBGLX	Sat-16	Sol-8	Sat-7	Sol-44	Sol-30	OCLS
626 male	235, 233	139, 135	120, 116	198, 196	205, 201	155, 153	157, 157
682 male	235, 233	141, 129	120, 116	196, 196	207, 203	169, 161	173, 157
678 male	233, 233	139, 139	120, 112	200, 196	205, 203	161, 161	173, 165
627 female	233, 233	139, 129	120, 116	198, 196	207, 201	155, 153	173, 173
629 female	243, 235	141, 139	120, 116	196, 196	209, 203	159, 159	173, 165
631 female	233, 233	141, 129	120, 116	198, 196	213, 207	159, 153	165, 157

Table 7. *Genotypes for seven microsatellites for six adult riparian brush rabbits comprising the brood stock for the controlled propagation program for Pen 3 in 2003.*

ID/sex	Parental Genotypes						
	OcBGLX	Sat-16	Sol-8	Sat-7	Sol-44	Sol-30	OCLS
676 male	243, 235	141, 133	120, 116	196, 196	213, 203	159, 155	165, 157
630 male	233, 233	141, 129	120, 116	198, 198	205, 000	161, 161	165, 157
684 male	233, 233	139, 129	120, 112	200, 196	213, 207	161, 155	173, 165
634 female	233, 233	141, 141	120, 112	198, 196	205, 203	163, 155	173, 157
253 female	235, 233	139, 129	120, 116	196, 184	209, 207	169, 159, 155	169, 157
198 female	243, 235	139, 139	120, 116	198, 196	203, 000	161, 153	169, 157

***Pen 1*.—**Twenty-two offspring were genotyped for each of seven microsatellites (~95% confirmed). Both male and females parent were confirmed in 19 cases (Table 8). One female parent gave birth to 11 offspring; two of the female founders gave birth to 4 young each. One male fathered 13 offspring; the other two male founders each produced 3 young.

***Pen 2*.**—Eight offspring were genotyped for each of seven microsatellites (~95% confirmed; Table 9). The male and female parents were confirmed in all cases. One female gave birth to four offspring; and the other two females each gave birth to two young. One male fathered five offspring; another male produced 3 young, and one male did not successfully reproduce. The data may represent the surviving young of one litter from each female founder. In both cases where the females produced two surviving young, the young were fathered by the same male. However the group of four young produced by one female, had two fathers—three fathered by one male, and one by another male.

***Pen 3*.**—Ten offspring were genotyped for each of seven microsatellites (~90% confirmed). The male parent was confirmed in five cases and the female parent was confirmed in seven cases (Table 10). One female founder gave birth to three offspring whereas the other two females each gave birth to two young. Two males each fathered two offspring and the other male produced one young. There were two alleles present among the offspring that were not present among the six founders. In both young with these genes, the mother was identifiable—the most likely explanation is that one of the females was pregnant when captured in the wild.

Table 8. *Genotypes of 22 offspring tested in the controlled propagation Pen 1, 2003, and their presumed genealogy.*

ID	Offspring Genotypes							Parents
	OcBGLX	Sat-16	Sol-8	Sat-7	Sol-44	Sol-30	OCLS	M/F
691	243, 235	139, 133	120, 116	198, 196	213, 203	159, 153	165, 157	676/198
697	235, 233	141, 141	120, 120	198, 196	203, 203	163, 155	165, 157	676/634
1162	235, 235	141, 129	120, 116	196, 196	209, 203	169, 159	169, 157	676/253
6E76	243, 235	139, 133	120, 120	196, 196	203, 203	155, 153	169, 157	676/198
5318	233, 233	141, 129	120, 112	198, 196	205, 203	161, 155	165, 157	630/634
1933	233, 233	139, 139	120, 112	196, 196	207, 203	161, 159	173, 165	684/253
0D24	243, 235	141, 139	120, 116	198, 196	203, 203	155, 153	169, 157	676/198
123C	233, 233	129, 129	116, 112	0	205	169, 161	165, 157	630 or 684/253
1246	233, 233	141, 129	120, 116	198, 196	0	161, 155	157, 157	630/634 or 253
050A	233, 233	141, 129	116, 112	198, 196	207, 207	161, 155	169, 157	630/634 or 253
432D	243, 235	139, 133	120, 116	198, 196	203, 203	155, 153	165, 157	676/198
3F0F	235, 233	139, 129	116, 112	198, 196	207, 203	161, 161	165, 157	684/198
376E	235, 233	141, 141	120, 120	198, 196	213, 205	163, 155	173, 157	676/634
176A	235, 235	139, 133	120, 116	196, 196	203, 203	155, 153	169, 157	676/198
2C09	235, 233	139, 129	120, 120	196, 196	207, 201	161, 153	173, 169	684/198
1313	243, 235	141, 139	120, 116	198, 196	203, 203	161, 155	165, 157	676/198
4F2F	235, 233	141, 139	120, 112	198, 198	207, 203	161, 153	165, 157	630/198
3666	243, 235	141, 139	120, 116	198, 196	203, 203	161, 159	169, 157	676/198
1B34	243, 233	139, 129	120, 112	198, 198	205, 203	161, 153	169, 157	630/198
3730	235, 233	133, 129	120, 116	196, 184	207, 203	159, 159	169, 157	676/253
1169	235, 233	141, 129	120, 116	196, 184	207, 203	169, 155	157	676/253
180C	235, 233	141, 133	120, 112	196, 196	213, 203	155, 155	173, 157	676/634

Table 9. *Genotypes of eight offspring tested in the controlled propagation Pen 2, 2003, and their presumed genealogy. Male rabbit 685 did not produce any offspring.*

ID	Offspring Genotypes							Parents
	OcBGLX	Sat-16	Sol-8	Sat-7	Sol-44	Sol-30	OCLS	M/F
OB11	233, 233	139, 129	120, 118	198, 196	213, 201	169, 161	169, 157	677/632
5624	243, 233	129, 129	120, 118	196, 196	207, 201	155, 155	0	677/683
684D	243, 233	129, 129	120, 118	196, 196	207, 201	169, 155	169, 157	677/683
5526	233, 233	141, 129	120, 116	196, 194	209, 207	161, 153	157, 157	679/223
704F	235, 233	139, 139	120, 118	196, 196	213, 201	169, 161	169, 169	677/632
4310	233, 233	139, 129	120, 118	196, 196	203, 201	169, 161	165, 157	677/632
5301	233, 233	141, 129	120, 116	198, 196	207, 205	161, 153	173, 157	679/223
1B1D	233, 233	133, 129	120, 116	196, 196	209, 203	161, 153	169, 157	679/632

Table 10. *Genotypes of 10 offspring tested in the controlled propagation Pen 3, 2003, and their presumed genealogy*

ID	Offspring Genotypes							Parents
	OcBGLX	Sat-16	Sol-8	Sat-7	Sol-44	Sol-30	OCLS	M/F
1E1C	243, 235	139, 139	120, 116	198, 196	203	159, 155	175, 165	*/629
5355	233, 233	141, 139	116, 112	198, 196	213, 205	161, 153	165, 157	678/631
5627	235, 233	141, 139	120, 116	196, 196	201	159, 153	165, 157	626/631
6B6A	235, 233	141, 139	120, 116	196, 196	207, 203	159, 159	165, 165	--/629 or 631
2223	0	139, 139	120, 120	198, 196	207, 201	161, 153	157, 157	626/--
734A	233, 233	141, 141	120, 116	198, 196	207, 207	161, 155	165, 157	682/631
6860	235, 235	139, 139	120, 116	196, 196	205, 205	159, 157	175, 165	*/629
0D51	235, 233	139, 129	116, 116	196, 196	207, 205	161, 155	173, 173	682/627
7140	233, 233	139, 139	120, 112	200, 198	213, 203	161, 153	173, 165	678/631 or 627
4A5B	233, 233	139, 139	120, 116	196, 196	205, 201	161, 155	173, 165	--/627

* alleles not present in parental brood stock
-- parentage not resolved

Genetic data presented here probably represent only a portion of the offspring produced by the wild-caught brood stock. We have not attempted to identify parents for a majority of the offspring produced using microsatellites because it would be impossible to resolve genealogy for many young in subsequent generations because of F2 and F3 matings and possible backcrosses. The data are clear in showing that all nine of the wild-caught females successfully reproduced and that eight of the nine males also were successful. Similar to the findings for the 2002 cohort, one male appeared to dominate breeding in each pen, and females typically bred with more than one male, either during the same estrus or for sequential litters.

MORBIDITY AND MORTALITY OF CAPTIVE RABBITS

The following information summarizes the information presented in detail in Brush Rabbit Captive Propagation and Reintroduction Program Health Updates produced in May 2003, October 2003, and March 2004 (covers October – December 2003; Gilardi in litt.).

December 2002 – April 2003.—During this reporting period we dealt with two cases of severe corneal ulceration due to intracorneal foreign bodies (believed to be plant material). We did not see eye injuries during the 2001-2002 translocation season. These corneal injuries were not new/recent at the time they were discovered, and therefore very likely caused these rabbits to decline in condition due to the stress of chronic pain and ongoing infection, inability to forage adequately, etc. By the time we had these rabbits under treatment, their health was quite poor, making the prognosis for full recovery very guarded. During this reporting period, we also dealt with births in captivity for the first time, with unfortunate outcomes (all either stillborn or died shortly after birth due to inattentive mothers). Hand-raising newborn rabbits is not easy, so it was decided that every effort should be made to return late-term females to SJRNWR or the propagation enclosures to whelp in a more natural situation. If necessary, kittens can be hand-raised following protocols established and used by the wildlife rehabilitation community. One other noteworthy case among the captive riparian brush rabbit population at the propagation pens was a dead rabbit that exhibited a mild enteritis in the small intestine, and possible lymphoma in the caecum; however, due to the marked autolysis, it was not possible to evaluate this lesion further. There was no evidence of abundant lymphoblasts in the other tissues available for examination. Also during this reporting period, we trapped five rabbits with fur abnormalities (thin, "undercoat"-like fur in places, grayer in color). We also had a neurologic case during this period.

May – October 2003.—During this period we dealt with several cases of neurologic disease, which prompted us to review neurologic disease cases since the inception of the project. At this time, there had been five rabbits (and one woodrat from Caswell Memorial State Park) exhibiting neurologic disease clinically. Of the five rabbits, four were breeders and one was born in Pen 2. Clinical signs included: obtunded mentation, nystagmus, head tilt, moderate to extreme ataxia, exophthalmos, progression to lateral recumbency, seizures, and death. Ante-mortem diagnostics (clinical hematology, radiographs) were unrewarding in determining a cause, and hospitalization with therapeutics (primary supportive care only: fluids, tube feeding, antibiotics in some cases, sedatives in some cases) have not significantly alleviated clinical signs or prevented spontaneous death or the decision to euthanize. Histologic lesions in the brains of four of the rabbits and the wood rat were the same. A portion of a cross-section of a nematode larvae was seen on histosection of the brain of the woodrat. This larvae appears to be either a *Angiostrongylu*s larvae or a *Baylisascaris* larvae: it cannot be positively identified from this particular section because the section is not whole. At the time, our working hypothesis was that these rabbits were infected with a nematode. As aberrant, non-definitive hosts for these nematodes, these rabbits are susceptible to migration of the larvae out of the gastrointestinal tract and into the brain. The infection is not diagnosable ante-mortem; it is a post-mortem diagnosis, at best. During this period, we also had two confirmed cases of rabbits that died due to severe, acute, necrotizing typhlitis (inflammation of the caecum). A *Clostridium* bacterium was cultured from one and was the likely cause of typhlitis in this rabbit; culture results were unrewarding for the other due to autolysis, and were unavailable for the third rabbit. A single point source of contamination for these rabbits seems unlikely, given the separation in space and time of the cases. However, it remains possible that rabbits were exposed to contaminated feed or water at these different times. As well, we treated two rabbits with eye injuries.

November – December 2003.—In this reporting period we had two additional neurologic disease cases in which there were mild lesions in the brain that looked similar to other rabbits with *Baylisascaris*, but we cannot say for sure that these rabbits had infections. We had one more confirmed case of typhlitis, for a total of three cases of severe, acute, necrotizing typhlitis. Given the spatial and temporal distribution of these cases, a single point source of contamination for these rabbits seems unlikely. Also of note: a first case of amyloidosis (insoluble protein fibers deposited in renal tissues), two cases of conspecific mortality, and two cases of trap trauma. We also treated a rabbit with eye trauma.

Repatriation of Brood Stock

In 2003, four males and one female (of the 20 rabbits used as brood stock) were returned to their original capture sites in the South Delta. A goal of the controlled propagation program was to monitor repatriated rabbits to assess the impacts of capture, confinement, and repatriation on the brood stock. Unfortunately, in 2003 we did not have frequent access to the capture/release locations, and were therefore unable to monitor repatriated rabbits.

In 2003, thirteen of the 20 breeder rabbits died while in captivity. Causes of mortality included neurologic encephalomalacia, likely due to the parasite *Baylisascaris procyonis*, lymphoma, and eye lesions/infections (Table 11). As of 01 July 2004, two breeders (both female) have yet to be removed from the propagation enclosures. One rabbit was last captured on 17 February 2004 and the other was last captured on 19 November 2003. We presumed that both were dead.

Table 11. *Causes of mortality and frequency among brush rabbit breeders in 2003.*

Cause of mortality	Male	Female	Total
Neurologic encephalomalacia	2	3	5
Lymphoma	0	1	1
Eye lesions/infections	2	2	4
Unknown	2	1	3
Total	6	7	13

An important goal of the program is to have no net negative effect on the naturally occurring populations. In 2002, we replaced three breeders that died at the propagation facility with three of the offspring. However, all three offspring lived less than 2 months before dying. Considering the poor results in 2002, and without regular access to the release sites for monitoring, we chose not to replace the 13 dead and 2 unaccounted for breeder rabbits. We hope that additional animals can be released into the source populations to compensate for losses from those populations.

Selection and Preparation of Release Sites

In 2002, 49 riparian brush rabbits were translocated from the controlled propagation facility to the San Joaquin River National Wildlife Refuge (SJRNWR) between 31 July and 19 October. The release site at SJRNWR was adjacent to a dirt mound that was created by the U.S. Bureau of Reclamation to provide rabbits with a refuge above flood level (D. Woolington, S. Frazier, USFWS, pers. comm.). Contiguous to the mound, along the streamside of the levee, were approximately 7.5 acres (3.04 hectares) of patches of tall, dense herbaceous annuals, rose, blackberry, willow, and mugwort (*Artemisia vulgaris*; Griggs 2000) that were distributed more or less continuously. Other clumps of suitable habitat, covering between about 100-200 acres, were located at various distances from the mound and readily accessible to dispersing rabbits. Christman Island, an area between 600-700 acres in size, also was available to dispersing rabbits when sloughs connected to Hospital Creek had little or no agricultural drain-water or storm runoff.

Prior to moving young to SJRNWR in 2002, a soft-release enclosure (Release Pen 1) was built to provide translocatees with moderate protection from predation while becoming acclimated to their new surroundings (Figure 9). The enclosure consisted of 1-inch poultry netting attached to steel T-posts, standing 5 feet above ground level and extending 1 foot below ground level (Figure 10).

The enclosure encompassed approximately one acre of suitable habitat consisting of willows, blackberries, mugwort, coyote brush (*Baccharis* spp.) and various grasses and forbs. We hypothesized that by confining the rabbits for a few days they would become more familiar with places to shelter and retreat, and would become better acquainted with the other individuals released during the same time period. We expected that this would provide them additional protection from predators. In July 2003, a second release enclosure was constructed approximately 0.8 miles (1.3 km) NW of Release Pen 1 (Figure 9). Release Pen 2 was constructed using the same materials and design as Pen 1, and also encompassed approximately one acre of suitable habitat with a flora similar to Pen 1. By using a second release site on the Refuge, we expected to introduce the translocated population into areas that were not regularly reached by rabbits dispersing from release Pen 1.

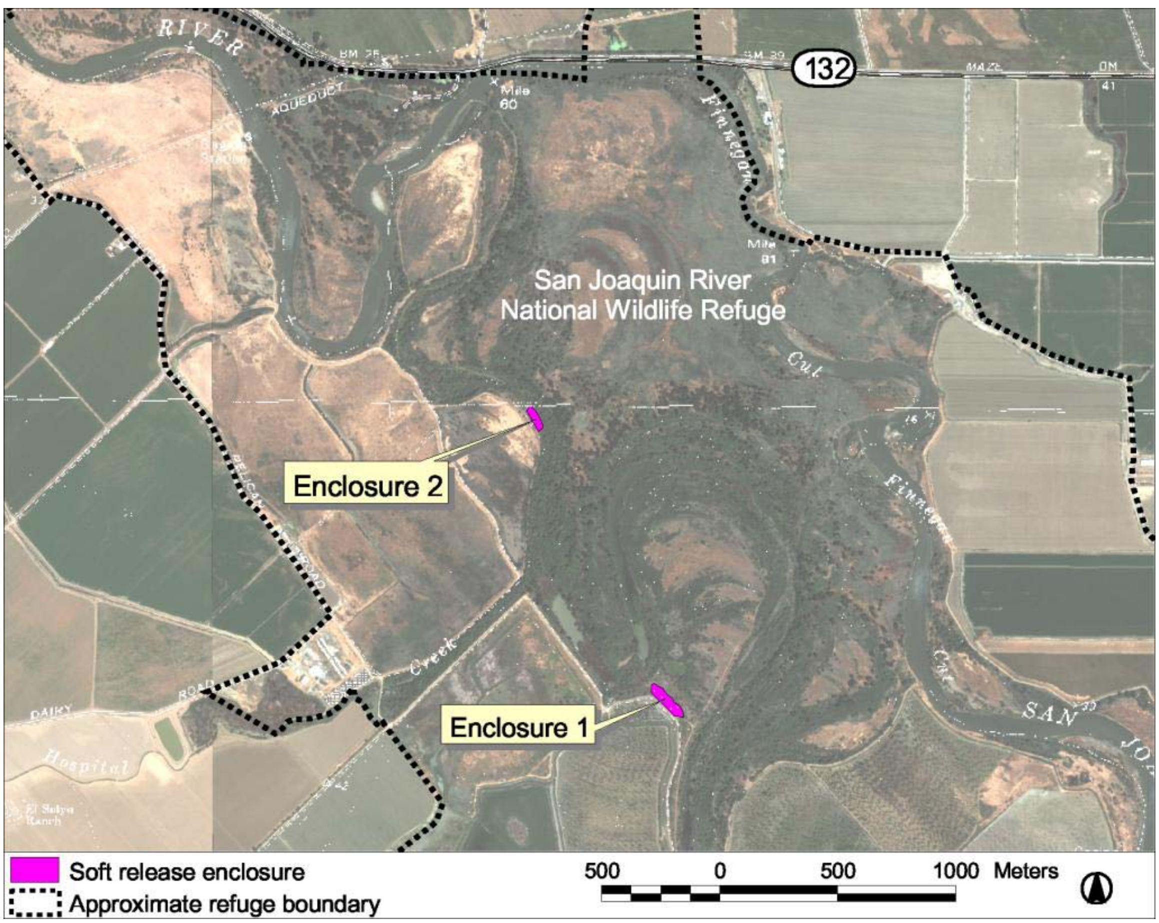

Figure 9. *Locations of the soft-release (pre-release) enclosures for riparian brush rabbits at the San Joaquin River National Wildlife Refuge.*

Figure 10. *Soft-release (pre-release) enclosure for riparian brush rabbits at the San Joaquin River National Wildlife Refuge (photo by D.F. Williams).*

During 12-15 August 2003, we conducted daily predator trapping throughout Release Pen 2. This effort involved setting 75 Tomahawk™ double-door, wire-mesh traps, 37 of which were baited with a combination of walnut meats, rolled oats, molasses, and sliced apple, and 38 traps were baited with chicken liver. Fresh bait was prepared each day of trapping. Traps were set in the evening, checked approximately 1 hour after sunrise, and were closed during the daytime hours. A spotlight survey was conducted each evening concurrent with the trapping sessions. Spotlighting was conducted from the levee road, and encompassed the areas one mile to the north and to the south of the Release Pen 2. This route was driven twice to maximize coverage and to increase the possibility of sightings.

During this trapping, we captured 2 desert cottontails (*Sylvilagus audubonii*) and 3 California voles (*Microtus californicus*). The cottontails were released outside of the soft release enclosure to reduce conspecific pressure. During spotlighting, we observed 1 raccoon (*Procyon lotor*), 2 striped skunks (*Mephitis mephitis*), 2 coyote (*Canis latrans*), 1 domestic cat, and had numerous sightings of barn owls (*Tyto alba*). The owl sightings were likely repeat sightings of a pair, residing 0.5 miles to the south of the translocation site. Throughout the area, coyote scat was very common, and raptors were regularly present during daylight hours. Furthermore, we assumed that predators, such long-tailed weasels and snakes, were present in the area, but went undetected. Although the presence of owls, hawks, and coyotes presented risks of predation on translocated rabbits, the situation was similar to our observations at Release Pen 1 prior to the initial rabbit translocations in 2002. Because the rate of predation on these rabbits was lower than anticipated, we believed that the predation risks at Release Pen 2 were sufficiently low to confine and later release rabbits at this site.

TRANSLOCATION AND RELEASE OF RIPARIAN BRUSH RABBITS

Offspring captured in the propagation enclosures weighing ≥ 500 grams were given a physical exam under general anesthesia and blood was collected and tested to ensure general overall health prior to translocation. These examinations were conducted either by an attending veterinarian or trained ESRP biologists. Specifically, health-screened rabbits were anesthetized with Isoflurane™ gas anesthetic (via mask) in the field, physically examined, and bled (0.5 – 1.0 cc blood from either an ear vein or the jugular vein). Blood samples were submitted to an analytical laboratory for complete blood counts, serum chemistries, and any remaining serum was saved frozen (for more detail, see Appendix A). Upon completion of physical exams and blood collection, rabbits were transferred to pet carriers for recovery from anesthesia and for holding until translocation. Dr. Kirsten Gilardi, the project veterinarian, assessed the physical examination findings and laboratory results for each rabbit and authorized the translocation of only those rabbits whose physical states were within normal limits, and whose laboratory results also were within reference ranges. In 2003, there were two cases in which abnormal results of lab work prevented the translocation of the respective rabbits. In one case, lab work detected an elevated white blood cell count; and in the other, a decreased white blood cell count. For both rabbits, these hematological abnormalities resolved themselves by the next veterinary check, and both rabbits were translocated at that time. The only physical examination finding during these pre-release health screens that has prevented same-day translocation has been palpable evidence of pregnancy or lactation.

Between 3 July and 4 December 2003 187 rabbits were translocated from the controlled propagation facility to SJRNWR. We alternated translocations between the two release pens; and in all, 102 rabbits were released into Release Pen 1 and 85 were released into Release Pen 2. These rabbits were confined to the soft-release enclosure for 2 to 7-day intervals, and were monitored daily by radio-telemetry and direct observation to ensure that they remained alive during the acclimation period. The enclosure was then opened in up to seven separate sections, to allow the rabbits to leave at their will.

Five rabbits died while in Release Pen 2, prior to it being opened. These mortalities occurred from 22 August to 10 November 2003—one from raptor predation, one from disease, and the causes of the other three mortalities are unknown. Eleven rabbits died in Release Pen 1 prior to it being opened. These mortalities occurred from 6 September 8 December 2003, with 4 of the 11 deaths occurring between 6 and 8 September 2003—of the 11, 3 were from raptor predation, 1 from mammal predation, 1 from disease, and the causes of the other 6 mortalities are unknown. This spike in mortalities of undeterminable causes at release pen #1, prompted predator trapping around the release pen from 18 to 23 September. A feral cat was caught on 21 September and removed from the area.

MONITORING OF RELEASED RABBITS

Monitoring after release from the enclosure had multiple objectives, including measuring dispersal distance, patterns of dispersion of rabbits over the colonized area, survivorship, and causes of mortality. The first two cohorts of translocated rabbits were monitored daily for 5-day periods upon opening of the enclosure. Rabbits in subsequent translocations were monitored a minimum of twice per week every week. Initially, radio-collared rabbits were hand tracked using 2-element "H" style directional antennas and portable receivers. Signals were followed to determine which patch/clump of brush each individual was using. The animal's position was then estimated to within a few meters and recorded in UTM coordinates with a global positioning system (GPS). The time, weather conditions, signal quality, and habitat patch in which the rabbit was located were recorded.

As additional individuals were released it became impractical to locate each by hand tracking. The rabbits dispersed more widely than expected and we determined that they occasionally were disturbed when approached. Consequently, survival and movements were monitored via radio telemetry from fixed stations consisting of 5-element precision direction finding arrays (Model RA-NS, Telonics; Figure 11).

Initially, tracking occurred during one of four monitoring stages (0400-1000 h, 1000-1600 h, 1600-2200 h, and 2200-0400 h). These stages were used to determine periods of peak activity. Due to staffing limitations, tracking was restricted to a 6-h period in the evenings (starting 1-2 hours prior to sunset and extending until 4-5 hours after dark), beginning in September 2003.

To acquire location information, bearings were taken simultaneously by each researcher on radio-collared rabbits. Synchronous collection of bearings was achieved by communication via hand-held radios. Each researcher carried an active radio-collar or beacon. For each location fix, a total of four bearings were collected, one from each researcher to the rabbit and one from each researcher to the other. Time, weather conditions, and signal quality were recorded by each researcher for every location fix. Readings on collared individuals were separated by at least 1 h to minimize autocorrelation of the data. Bearing information was recorded on Dell Axim handheld computers to facilitate data entry and interpretation. Paper data sheets also were maintained to prevent accidental data loss. An ArcView® (Environmental Systems

Figure 11. *Five-element precision direction finding arrays (Model RA-NS, Telonics). ESRP photo.*

Research Institute, Redlands, CA) program extension was used to calculate rabbit locations (Jenness Enterprises, 2002). Home ranges and core areas were determined with the ArcView extension Animal Movement (Hooge and Eichenlaub 1998). Home ranges were estimated using a fixed kernel home range utilization distribution (95% and 50%) (Worton 1989) as a grid coverage and with least-square cross validation (Silverman 1986) as the smoothing parameter. Differences in home ranges and core area size between genders and breeding seasons were tested with analysis of variance (ANOVA). Seasons were defined as breeding (1 December – 31 May) and non-breeding (1 June – 30 November). The data were examined for homoscedasticity and normality, and home range and core area sizes were log transformed to ensure that they met the assumptions of ANOVA. Treatment effects, least squared means, and confidence intervals were estimated with the general linear model Statistica (release 6).

To evaluate researcher error, location fixes were taken by triangulation on carcasses prior to their collection. Once the carcass was located, a GPS reading was taken at the site to allow the calculated position to be compared with the known location (Bond 2001). Dead rabbits were collected following the procedures outlined by Gilardi (2002) and available remains were collected and transferred to Dr. Karen Terio, Diagnostic Pathology, Veterinary Medical Teaching Hospital; UC, Davis.

Dispersal.—Rabbits that moved a distance greater than 250 m were defined as dispersing. Of the 49 individuals translocated in 2002, 16 (10F, 6M) remained within 250 m of the soft release enclosure. However, 21 (8F, 13 M) made long, one-way movements greater than 250 m (Figure 12). The remaining individuals did not survive long enough to provide detailed spatial information. The maximum dispersal distance was 1.1 km for females, and 2.5 km for males. Mean dispersal distances were 578 m (*se* 109 m) for females, and 897 (*se* 181 m) for males, but did not differ significantly by gender ($p = 0.079$). No individuals from either translocation cohort were observed returning to the soft release enclosures after dispersing.

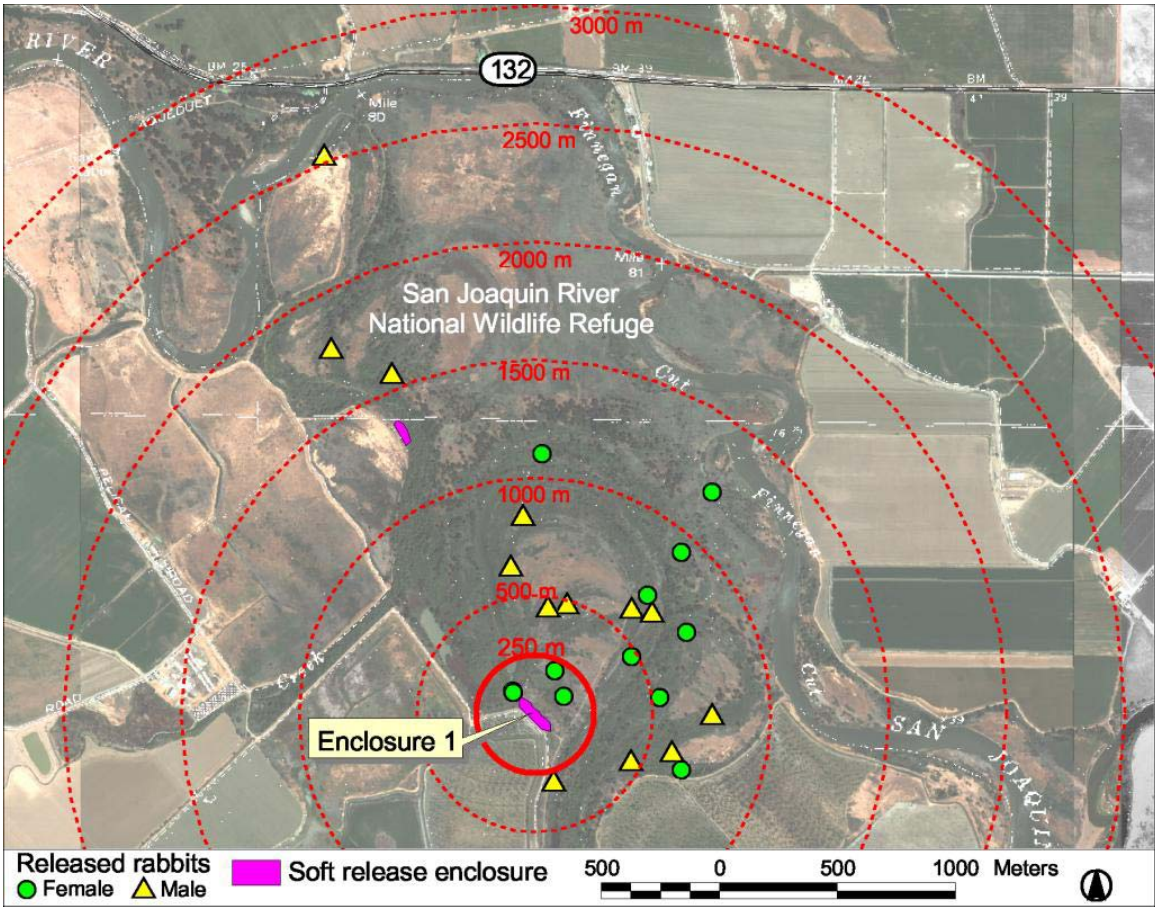

Figure 12. *Locations of rabbits that dispersed from soft release enclosure #1. The dashed lines indicate distances of 500 m.*

Home range and core area.—Average home ranges and core area sizes by gender and season are provided in Table 12. We used 2,169 locations to calculate home ranges and core areas for 77 individuals that were monitored between 1 December 2002 and 31 May 2004. The home ranges and core areas of male rabbits were larger than those of females, regardless of season (Table 12). In contrast to observations reported by Shields (1960), female home ranges were larger during the breeding season than during the remainder of the year, however this difference was not statistically significant (p = 0.45).

Home range size was significantly different for rabbits by gender but not by season. The gender-by-season interaction was significant, however (Table 13). Size of core area also was significantly different for rabbits by gender and by season, but the interaction between gender and season was not significant (Table 14). Post hoc analysis with the Tukey HSD test indicated that the difference in home range size was attributable to the larger home range size of male rabbits during first two seasons following the initial translocations to SJRNWR. The home range size of male rabbits was significantly larger than that of females in 2003 during the breeding and non-breeding seasons (Table 15; Figure 13).

Table 12. *Mean (± SE) home range (HR) and core area (CA) in hectares for translocated male and female brush rabbits at San Joaquin River National Wildlife Refuge. Points are the average number of locations taken per rabbit per season.*

Season	Sex	HR	CA	N	Points
Breeding 2003	M	6.89 ± 2.01	2.01 ± 0.82	7	43
	F	2.30 ± 0.72	0.42 ± 0.12	9	48
Non-breeding 2003	M	2.98 ± 0.44	0.57 ± 0.12	14	22
	F	1.79 ± 0.41	0.33 ± 0.99	10	26
Breeding 2004	M	2.57 ± 0.39	0.50 ± 0.08	17	24
	F	2.44 ± 0.32	0.54 ± 0.08	20	23

Table 13. *ANOVA results for the effect of gender, season, and the interaction of sex*season on the home range size of riparian brush rabbits at the San Joaquin River National Wildlife Refuge. Significant effects are in bold font.*

	df	Sum of Squares	Mean Square Error	F	P
Gender	1	1.3419	1.3419	12.279	**0.000797**
Season	2	0.1792	0.0896	0.820	0.444523
Gender*Season	2	0.8959	0.4480	4.099	**0.020665**
Error	71	7.7588	0.1093		
Total	76	9.5281			

Table 14. *ANOVA results for the effect of gender, season, and the interaction of gender*season on the core area size of riparian brush rabbits at the San Joaquin River National Wildlife Refuge. Significant effects are in bold font.*

	df	Sum of Square	Mean Square Error	F	P
Gender	1	0.95837	0.95837	6.8805	**0.010630**
Season	2	1.01898	0.50949	3.6578	**0.030693**
Gender*Season	2	0.83099	0.41549	2.9830	0.056936
Error	71	10.02870	0.13929		
Total	76	12.06576			

Table 15. *Tukey HSD test results of sizes of home ranges by gender of riparian brush rabbits. Approximate probabilities for Post Hoc Tests Error: between MS = .10928, df = 71. Significant results are denoted by bold font.*

	Gender	Season	{1}	{2}	{3}	{4}	{5}
1	Female	Breeding 2003	--	--	--	**--**	--
2	Female	Non-breeding 2003	0.998116	--	--	**--**	--
3	Female	Breeding 2004	0.754734	0.947284	--	--	--
4	Male	Breeding 2003	**0.006930**	**0.017801**	0.050324	--	--
5	Male	Non-breeding 2003	0.390273	0.653097	0.964084	0.267574	--
6	Male	Breeding 2004	0.621640	0.868511	0.999614	0.103153	0.996144

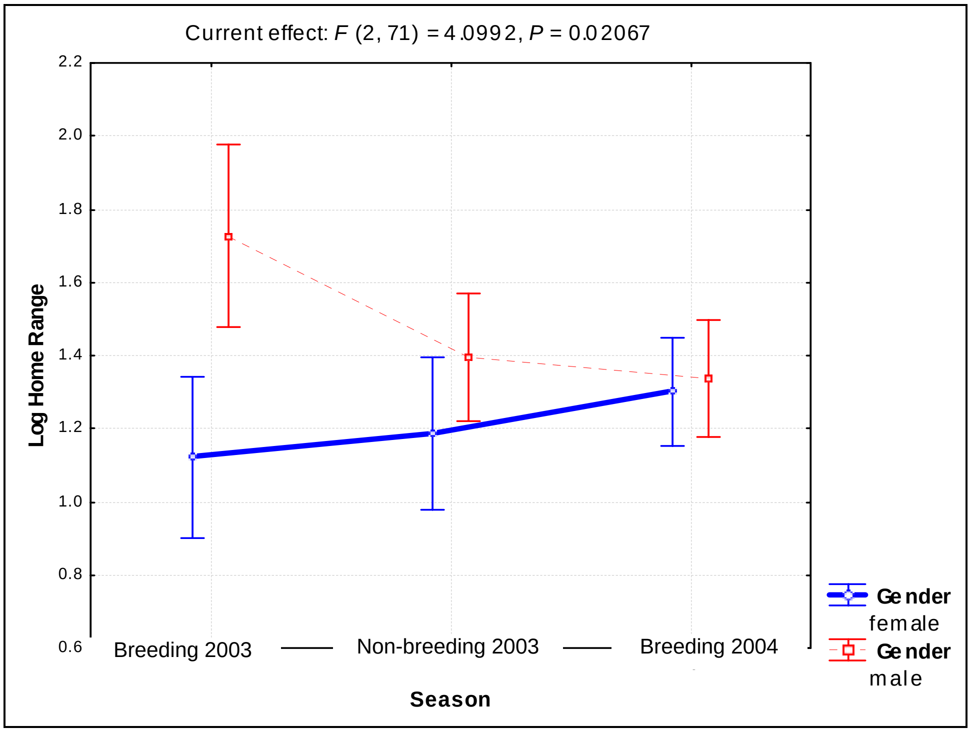

Figure 13. *Log transformed home range sizes of translocated male and female rabbits by season. Vertical bars denote 95% confidence intervals.*

The results of home range monitoring contrast with the observations of other researchers. Previous studies of brush rabbits have suggested that the species maintains small home ranges. For example, in chaparral habitat near Berkeley, California, Connell (1954) recorded home ranges of 0.34 and 0.38 ha for male and female brush rabbits, respectively. Shields (1960) noted average home range diameters of 88 and 51 m for male and female brush rabbits in the Humboldt Bay area of northern California, and Chapman (1971) documented average home range diameters of 37 m for males and 33 m for females during studies of brush rabbits near Corvallis, Oregon.

Studies of eastern cottontails, *S. floridanus*, in Mississippi by Bond et al. (2001) indicated that home ranges and core areas of male rabbits were larger during the breeding season than during non-breeding. They also noted that home ranges and core areas of males were larger than those of females during the breeding season, but male and female home ranges and core areas were approximately equal during non-breeding periods. In studies of *S. floridanus* in Wisconsin, Trent and Rongstad (1974) observed an increase in the home range size of males during the breeding season, whereas female home ranges decreased. In contrast, riparian brush rabbit home ranges were considerably larger than those that had been recorded previously. Furthermore, male riparian brush rabbits exhibited large home ranges in comparison to females during the first two seasons (breeding and non-breeding 2003) following the initial translocations to the San Joaquin River NWR. Additionally, about half of the rabbits of each gender made long one-way movements prior to settling in a location. Several researchers have noted that cottontail rabbits are capable of long one-way movements (Shields 1960, Forays and Humphrey 1996, J. Rachlow, pers. comm.). Thus, it is likely that male rabbits may have spent the initial seasons following the translocation in search of suitable habitat and potential mates. As additional males were introduced to the refuge, suitable habitat might have been occupied by prior individuals and their offspring, resulting in smaller home ranges and core areas among all individuals.

Survival.—Survival times of rabbits were calculated from date of release to date of mortality signal or other evidence of death. For life table analyses of the 2002 cohort, deaths were summed per 28-day period. For comparisons of survival between years, data for only those rabbits released before November each year and tracked through February of the ensuing year were used. Deaths were grouped in 14-day intervals for comparisons between years. Survival and life table analyses were performed using the computer program, Statistica (release 6). We used Cox's F test to compare survivorship between years.

The numbers of animals at risk and deaths are listed in Table 16. In 2001-2002, 64 young were known to have been produced, some by young rabbits born in captivity. In 2002-2003, there were 284 known young. Most young were a few to several weeks old when first encountered, though a few very young rabbits, such as those born in a trap and dying quickly or being found dead on the ground, are included. Young unaccounted for in Table 16 were still in the breeding pens at the cutoff date for this report and were subsequently translocated to SJRNWR. Survival during 14-day intervals for animals translocated to the refuge in 2002 and 2003 are depicted in Figure 14. Data include comparable intervals for translocation and being at risk (July through February). Survival was significantly lower for the 2003 cohort compared to 2002 (Cox's F-Test, F = 1.908, p = .046). By 1 March 2003, 19 of 49 translocated rabbits had died (61% survival), and of the 2003 cohort (214), 91 died by 01 March 2004 (42% survival).

Table 16. *Numbers of rabbits that died during activities of controlled propagation and translocation and their survival rates. Repatriated rabbits in 2003 were not monitored.*

	2002	2003
	Number	**Number**
Brood Stock	6	20
Died in Pen	3	13
Survival rate (days exposed[1])	0.50 (196)	0.35 (272)
Died after Repatriation	1	—
Young	64	284
Young died in pen	13	21
Survival rate (days exposed[1])	0.80 (298)	0.93 (450)
Young Repatriated	3	—
Died after Repatriation	3	—
Young Translocated	49	214
Died after Release	23	152
Survival rate (days exposed[1])	0.23 (673)	0.29 (317)

[1] indicates the maximum days of exposure for an event

After 673 days of monitoring the 2002 translocation cohort, 5 rabbits were alive, we had lost radio contract with 18 others, and 26 were known to have died. The cumulative survival rate for this period was 23.1% (*se* 7.6%). Median life expectancy of 376 days peaked at 99 days (*se* 98 days) after release. The survival rate 1 year after release was 49% (*se* 7.6%) for the 2002 cohort, based on life table analysis.

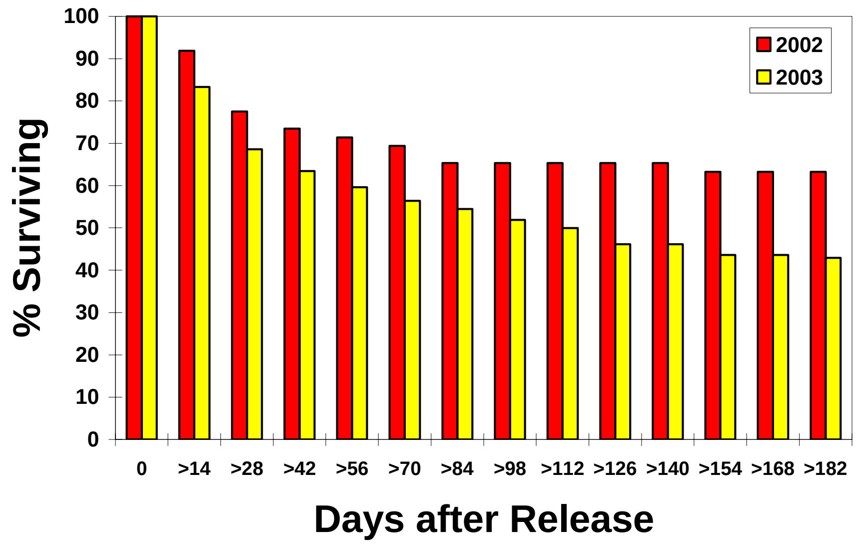

Figure 14. *Survival of two cohorts of captive-breed riparian brush rabbits released on the San Joaquin River National Wildlife Refuge in 2002 and 2003. Data for each group span a period from July through February of the ensuing year.*

Mortality causes.—Causes of mortality are listed in Table 17. Cause was unknown for the majority of deaths. In the propagation pens most of unknown causes were rabbits that were marked but not recaptured later and no remains were found. Likewise, for translocated rabbits, either no remains were found (except the radio-collar) or the remains were too few to determine cause. Where disease was determined as the likely cause, *Baylisascaris* sp. was most often implicated, but only in rabbits reared in Pens 2 and 3 in 2003. Other diseases implicated in deaths were necrotizing typhlitis and intestinal lymphoma. Predation, including presumptive predation, was the greatest known cause of deaths in translocated rabbits.

Table 17. *Numbers of mortalities by cause for rabbits in the controlled propagation and translocation program.*

	Predation			Accident				
Group	Mammal	Avian	Probable	Collar	Trap	Disease	Newborn	Unknown
Prop. Pens								
2002	0	0	0	1	1	3	0	6
2003	0	0	1	0	5	16	7	11
Translocation								
2002	1	1	9	1	0	0	0	20
2003	9	9	22	0	0	4	0	59

Mortalities related to radio-collars (2 of 286, Table 17) were few, but are major concerns in any study (Bond et al. 2000). We suspect that many more deaths may have been associated with radio-collars because we found non-lethal abrasions and other injuries from radio-collars on several rabbits. We noted collar loss and catching legs or jaws in cable-tubing-type collars—one adult breeder died by catching its lower jaw under the cable of the collar. All the translocated rabbits had strap collars, which also were a source of several non-lethal injuries as well as mortality. Trap accidents included two rabbits being caught simultaneously, with subsequent injuries from fighting, broken vertebrae from collision within the trap, and leaving a trap open when unattended.

That 61% and 43% of the translocated rabbits survived through February, when the females could have had two or possibly three litters, exceeded our expectation of less than 20% survival through what we predicted would be the breeding season. Annual survival rates for adult *S. floridanus* was 20% (Trent and Rongstad 1974)—we assumed that naïve, captive-reared rabbits would have a lower rate of survival. That survival was much higher both years and even higher for the 2002 cohort may have been due to an absence of predators cued in to brush rabbits at the release site. We believe that survival was significantly lower for the second cohort (2003) because more predators had been attracted by the population of rabbits established in 2002. They and their progeny probably had occupied much of the most suitable habitat, forcing more rabbits released in 2003 into portions of the biotic community where they were more vulnerable to predation. This suggests that the better conservation strategy for repopulating unoccupied habitat is to make the largest and most genetically diverse release the first or only release instead of releasing smaller numbers in two or more years.

RECOLLAR TRAPPING

The ATS™ radio transmitters that were employed had a guaranteed battery life of 7 months. In order to monitor this population beyond the transmitters' expected battery life following their release, rabbits needed to be captured and their radio collars replaced. Between 25 February and 4 December 2003, we conducted irregular trapping in areas where targeted individuals were known to reside. The process began by pinpointing the individuals equipped with collars that were approaching the 7-month failure date. The general areas of residence were plotted using null telemetry data, and based on the plotted locations, we were able to determine the actual locations using hand-held, "H" style antennae, while in the field. In these locations, we set Tomahawk™ double-door, wire-mesh live-traps baited with a mix of fresh apples, rolled oats, and molasses. Traps were typically opened in the evening, checked approximately 1 hour after dark, and checked again in the morning. After the morning check, traps were closed during the daytime hours. The numbers of traps used at each location varied. Typically, we focused on 3-4 rabbits at a time and used an average of 54 total traps.

Detailed trapping results are provided in Table 18. In summary, we trapped for a total of 2,428 trap days (trap days = number of traps × number of 24-h days of trapping). Of the 49 brush rabbits that were translocated in 2002, 30 were still alive when we began trapping. Of those 30, we were able to capture and recollar 23 individuals (76.7%). The 7 non-recollared rabbits were trapped for with no success for periods extending well past the collar failure dates. Eventually, we could no longer rationalize expending the effort because our time and resources were needed elsewhere. In addition, we captured 21 brush rabbits that were members of the 2003 translocations, and therefore not in need of replacement collars. These animals also were processed according to standard protocol, which included measuring foot length, ear length and weight, and checking sexual reproduction.

Table 18. *Numbers and capture rates[1] of individual brush rabbits captured at SJRNWR in an effort to replace radio collars between 25 February and 04 December 2003.*

Group	Male	Female	Total	Capture Rate (%)
2002 translocatees	12	11	23	0.95
2003 translocatees	13	8	21	0.86
Native to SJRNWR	16	14	30	1.24
Total	41	33	74	3.05

[1] captures divided by trap days multiplied by 100—in this case trap days is equal to 2428

During the same trapping effort, we captured 30 riparian brush rabbits that were unmarked and therefore native to SJRNWR (offspring of the original translocated population). These rabbits were processed according to standard protocol, were given an ear and a PIT tag, and had tissue and hair samples taken for genetic analysis. The weights of the rabbits at the time of original capture varied, ranging from 120-725 grams, and many exhibited signs of sexual reproduction (scrotal males and pregnant and/or lactating females). Nine of the native rabbits that weighed ≥ 500 grams were fitted with radio collars so that their activities could be compared to those of the translocated population. As of 1 July 2004, we know that two of the collared natives have died, five are no longer being monitored due to our inability to replace their collars prior to transmitter failures, and two rabbits that have been recollared still are being monitored.

PART 2: RIPARIAN BRUSH RABBIT AND WOODRAT CENSUS AT CASWELL MEMORIAL STATE PARK—2003

Beginning in January 1993, ESRP began periodic monitoring of the riparian brush rabbit population at Caswell MSP by trapping and marking individuals (Williams 1993). The Park, covering about 253 acres of riparian forest, is located in the San Joaquin Valley of California, along the Stanislaus River, approximately 6 miles west of the city of Ripon. Monitoring objectives included obtaining population numbers from capture-recapture of marked individuals for year-to-year comparisons and obtaining tissue or hair samples for genetic studies.

We set Tomahawk™ traps directly in runways, natural paths, and other sites with sign of rabbits or woodrats, and around potential woodrat houses. Traps were baited with a combination of walnut meats, rolled oats, molasses, and sliced apple. Traps were set in the afternoon or early evening, checked about 2 hours after dark and again in the early morning. Traps were left open around the clock unless it rained. We did not trap during heavy rains. Captured brush rabbits, woodrats, and black rats were permanently marked with metal ear tags (all three species) and PIT tags (rabbits and woodrats), weighed, and measured (rabbits only). Two plugs of ear tissue was taken with a biopsy punch from brush rabbits (3 mm punch) and woodrats (2 mm punch) and preserved in 95% ethanol (reagent grade, not denatured). Animals were released at the site of capture. These procedures followed the protocol established by Williams (1993), except that we did not trap the middle section of Caswell MSP where rabbits were previously found to be scarce and little or no sign was found in more recent censuses and surveys. Instead, the Crow's Loop area (Figure 15), which was added in 1998, was trapped. Number of days trapped varied from year to year because of rainstorms some years, and because of extra efforts made to capture rabbits in others. Number of traps also varied based on amount of sign where traps were placed.

The census at Caswell MSP, in January 2003, yielded captures of 14 riparian brush rabbits. All 14 rabbits were captured in the Fenceline Trail and Crow's Loop census areas (Figure 15). Sign of rabbits elsewhere were scarce or absent. Brush rabbit and woodrat populations were found to be high in 1993, but very low in 1997 through 2003 (Table 19). This is especially apparent when comparing capture rates (Figure 16). The capture rate of rabbits in 2003 was lower than the capture rate in 2002, but higher than any other year since 1993. The capture rate of woodrats in 2003 was higher than any year since 1993. Unfortunately, current population numbers are still too low to allow for a meaningful statistical estimate of population size. A desert cottontail also was captured in the Park in February 2000, the first since the mid 1980's. No additional desert cottontails were captured during the 2001-2003 censuses.

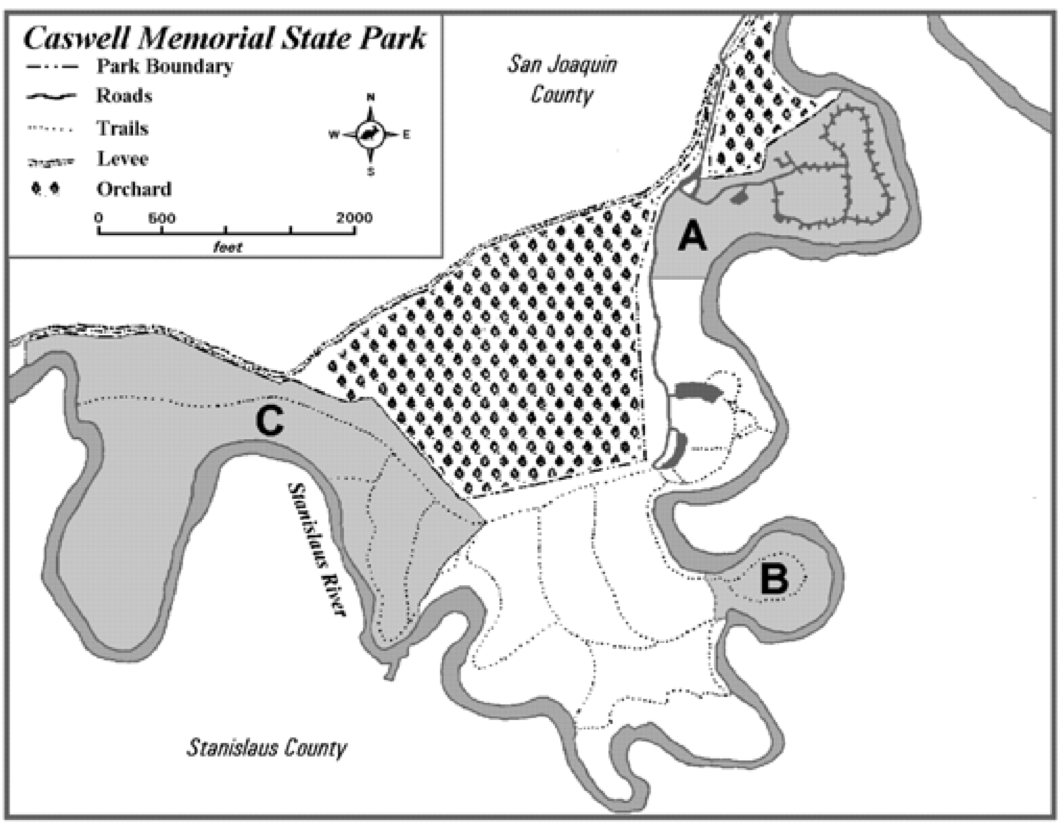

Figure 15. *Map of Caswell MSP depicting the three regularly surveyed areas (lighter shading): A – Campground; B – Crow's Loop; C – Fenceline Trail. The levee on the southern side of the Stanislaus River is not shown.*

Only during January 1993 were captures and recaptures of brush rabbits and woodrats great enough to estimate population sizes using closed population models. The population of riparian brush rabbits was estimated to contain 241 rabbits with a 95% confidence interval of 170-608 rabbits. The population of riparian woodrats (*Neotoma fuscipes riparia*) was estimated to be 437 with a 95% confidence interval of 170-608 woodrats. The populations of both species probably were at or near the carrying capacity of the Park (Williams 1993). In 2002 and 2003, there were increases in rabbit sign and capture rates for both rabbits and woodrats, suggesting that the populations might be recovering from lows in their fluctuating population cycles.

Table 19. *Numbers of individual riparian brush rabbits, riparian woodrats, and desert cottontails captured (capture rate[1] in parenthesis) at Caswell MSP each year starting in 1993. Traps equal the average number of traps used each night.*

Year	Days Trapped	Traps	*S. b. riparius*	*N. f. riparia*	*S. audubonii*
1993	21	105	41 (1.86%)	55 (2.49%)	0
1997	28	99	0	6 (0.22%)	0
1998	29	78	6 (0.27%)	11 (0.49%	0
1999	16	58	2 (0.22%)	8 (0.86%)	0
2000	14	124	5 (0.29%)	12 (0.69%)	1 (0.06%)
2001	21	123	2 (0.07%)	15 (0.50%)	0
2002	21	122	16 (0.62%)	31 (1.21%)	0
2003	21	143	14 (0.47%)	41 (1.37%)	0

[1] captures divided by trap days—trap days is the number of traps multiplied by the number of 24-h days of trapping

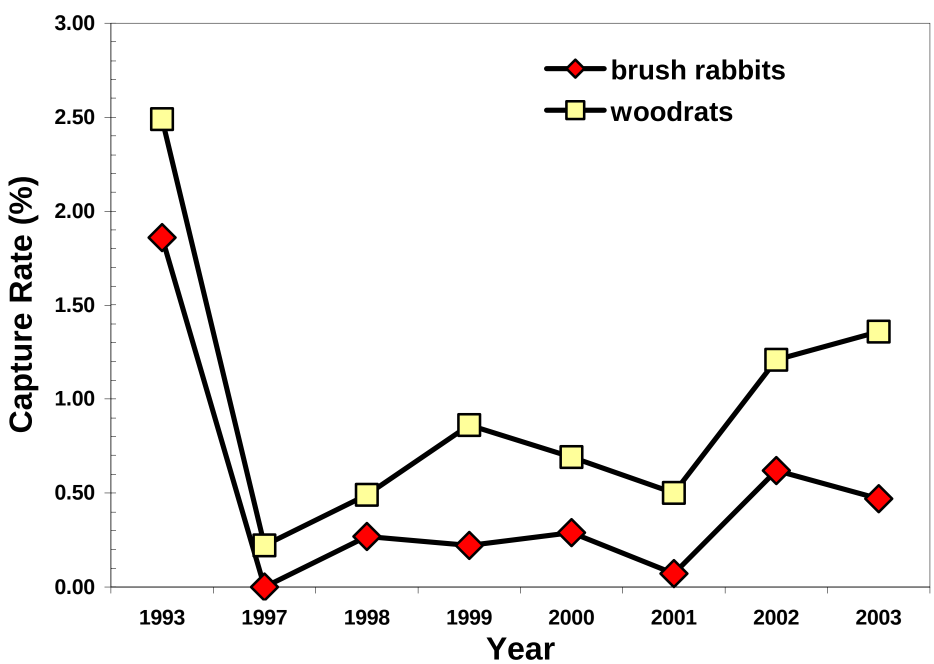

Figure 16. *Capture rates of riparian brush rabbits and woodrats for annual censuses during January between 1993 and 2003.*

PART 3: RIPARIAN BRUSH RABBIT SURVEY AT MOSSDALE—2003

In February and April 2003, ESRP biologists conducted “presence/absence” surveys at Mossdale Oxbow, which is privately owned property along the east bank of the San Joaquin River, southwest of the city of Lathrop, San Joaquin County, California. The site is approximately 27 acres in size, and supports a successional riparian forest community dominated by Fremont cottonwoods, Valley oaks (*Quercus lobata*), wild rose, blackberry, and annual grasses. There were many occurrences of rabbit sign (e.g. fecal pellets and runways), as well as numerous downed logs. The study site is approximately 0.5 mile from a known population of riparian brush rabbits that is located along a railroad right-of-way just west of the San Joaquin River.

On 3 February 2003, we set 90 Tomahawk™ double-door, wire-mesh live-traps in areas of suitable habitat throughout the oxbow. Traps were baited with a mix of fresh apples, rolled oats, and molasses. Traps were open continuously from the afternoon of 3 February until the morning of 4 February, and were checked after dark (~1900 h) and in the morning (~0700 h). On 1 April 2003, we set 50 Tomahawk™ traps in areas that produced brush rabbit captures during the February survey. Traps were opened in the afternoon during set-up and were closed and removed following the trap check from 1900-1930 h.

A total of 13 riparian brush rabbits (9 females, 4 males) were captured during the February survey (Lloyd and Williams 2003). Each rabbit was given an ear and PIT tag, measured (foot length, ear length), weighed, checked for sexual activity, and ear biopsies and hair samples were taken for genetic analysis. One male and one female brush rabbit were captured during the trapping in April, the purpose of which was to verify the continued presence of brush rabbits on the site and to remove one male and one female to be used as breeders in the controlled propagation program.

This survey is significant in that it was the first confirmation of riparian brush rabbits on the east side of the San Joaquin River. Brush rabbits have been captured at other locations within the South Delta region at a few sites on the west side of the San Joaquin River, along the overflow channels and railroad rights-of-way near Paradise Cut and Tom Pain Slough.

LITERATURE CITED

Benham, J., J. Jeung, M. Jasieniuk, V. Kanazin, and T. Blake. 1999. Genographer: an Graphical Tool for automated fluorescent AFLP and microsatellite analysis. Journal of Agricultural Genomics, Vol. 4, 2 un-numbered pp. http://www.ncgr.org/jag/papers99/paper399/indexp399.html

Bond, B.T., J.L. Bowman, B.D. Leopold, L.W. Burger, Jr., and C.O. Kochanny. 2000. An improved radiocollar for eastern cottontails. Wildlife Society Bulletin 20:565-569.

Bond, B.T., B.D. Leopold, L.W. Burger, and D.L. Godwin. 2001. Movements and home range dynamics of cottontail rabbits in Mississippi. Journal of Wildlife Management 65:1004-1013.

Chapman, J. A. 1971. Orientation and homing of the brush rabbit (*Sylvilagus bachmani*). Journal of Mammalogy 52 (4): 686-699.

Chapman, J.A. 1974. *Sylvilagus bachmani.* Mammalian Species 34:1-4.

Chapman, J.A. 1975. *Sylvilagus nuttallii.* Mammalian Species 56:1-3.

Chapman, J.A., and A.L. Harman. 1972. The breeding biology of a brush rabbit population. Journal of Wildlife Management 36:816-823.

Chapman, J.A., and G.R. Wilner. 1978. *Sylvilagus audubonii*. Mammalian Species 104:1-4.

Chapman, J.A., J.G. Hockman, and M.M. Ojeda C. 1980. *Sylvilagus floridanus*. Mammalian Species 136:1-8.

Connell, J.H. 1954. Home range and mobility of brush rabbits in California chaparral. Journal of Mammalogy 35:392-405.

Davis, W.B. 1936. Young of the brush rabbit, *Sylvilagus bachmani*. The Murrelet 17:36-40.

Dixon, K.R., J.A. Chapman, O.J. Rongstad, and K.M. Orhelein. 1981. A comparison of home range size in *Sylvilagus floridanus* and *S. bachmani*. Pp. 541-548, *in* Proceedings of the World Lagomorph Conference (K. Myers and C.D. MacInnes, eds.). Univ. Guelph, 983 pp.

Forays, E.A., and S.R. Humphrey. 1996. Home range and movements of the lower keys marsh rabbit in a highly fragmented habitat. Journal of Mammalogy 77:1042-1048.

Gilardi, K. 2002. Health plan for the Endangered Species Recovery Program riparian brush rabbit reintroduction program. Wildlife Health Center, School of Veterinary Medicine, University of California, Davis, 15 pp.

Griggs, F.T. 2000. Pre-restoration plan for West Units of the San Joaquin River National Wildlife Refuge. Sacramento River Partners 89 pp.

Hooge, P.N., and W.M. Eichenlaub. 1998. Animal movement extension to Arcview. ver.1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, AK, USA.

Lloyd, M.R., and D.F. Williams. 2003. Riparian brush rabbit survey: Mossdale Landing, San Joaquin County, California, February 2003. Report to Geoff Monk and Associates, ESRP, Turlock, CA, 4 pp.

Mossman, A.S. 1955. Reproduction of the brush rabbit in California. Journal of Wildlife Management 19:177-184.

Shields, P.W. 1960. Movement patterns of brush rabbits in northwestern California. Journal of Wildlife Management 24:381-386.

Silverman, B.W. 1986. Density estimation for statistics and data analysis. Chapman and Hall, London, UK.

Trent, T.T., and O.J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. Journal of Wildlife Management 38:459-472.

U.S. Fish and Wildlife Service. 1991. Biological opinion for the Friant Division water contract renewals. Fish and Wildlife Enhancement, Sacramento Field Office, Sacramento, CA 47 pp. + appendices *As amended by* U.S. Fish and Wildlife Service. 1992. Amendment of Biological Opinion on the Friant Division Water Service Contract Renewals (1-1-91-F-22; issued October 15, 1991); Fish and Wildlife Enhancement, Sacramento Field Office, Sacramento, CA 7 pp. + appended October 15, 1991 opinion.

U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. Region 1, Portland, OR. 319 pp.

U.S. Fish and Wildlife Service. 2000. Endangered and threatened wildlife and plants; final rule to list the riparian brush rabbit and the riparian, or San Joaquin Valley, woodrat as endangered. Federal Register 65:8881-8890.

Williams, D.F. 1988. Ecology and management of the riparian brush rabbit in Caswell Memorial State Park. California Dept. Parks and Recreation, Final Report, Interagency Agreement, 4-305-6108, Lodi, CA 38 pp.

Williams, D.F. 1993. Population censuses of riparian brush rabbits and riparian woodrats at Caswell Memorial State Park during January 1993. Final Report, California Dept. Parks and Recreation, Lodi, CA 15 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., and L.P. Hamilton. 2002. Riparian Brush Rabbit Survey: Paradise Cut along Stewart Tract, San Joaquin County, California, August 2001. Report to Califia LLC, Lathrop, CA, and California Department of Fish and Game, Sacramento, 10 pp.

Williams, D.F., and K.S. Kilburn. 1984. Sensitive, threatened, and endangered mammals of riparian and other wetland communities in California. Pp. 950-956, *in* California riparian systems ecology, conservation, and productive management (R.E. Warner and K.M. Hendrix, eds.). Univ. California Press, Berkeley, 1,035 pp.

Williams, D.F., P.A. Kelly, and L.P. Hamilton. 2002. Controlled Propagation and Reintroduction Plan for the Riparian Brush Rabbit. Endangered Species Recovery Program, California State University, Turlock 75 pp.

Williams, D.F., L.P. Hamilton, J.J. Youngblom, C. Lee, and P.A. Kelly. 2000. Riparian brush rabbit studies, 1997-2000. Report prepared for the U.S. Bureau of Reclamation and Fish and Wildlife Service, Endangered Species Recovery Program, Fresno, CA 13 pp.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

APPENDIX A. LABORATORY ANALYSES CONDUCTED WITH BRUSH RABBIT BLOOD SAMPLES

CBC

Red blood cell count, including nucleated red blood cells
White blood cell count:

- Neutrophils
- Lymphocytes
- Monocytes
- Eosinophils
- Basophils

Hemoglobin
Packed cell volume
Mean corpuscular volume
Mean corpuscular hemoglobin
Mean corpuscular hemoglobin concentration
Platelet count

SERUM CHEMISTRY

Total CO_2
Calcium
Phosphorus
Creatinine
Urea nitrogen
Glucose
Total Protein
Albumin
Globulin
Alanine aminotransferase
Aspartate aminotransferase
Alkaline phosphatase
Total bilirubin
Cholesterol
Gamma glutamyl transferase

Serologic screening for pathogens, fecal parasitology analysis, and nasal swabs for aerobic culture were not conducted routinely on every rabbit.

APPENDIX B. VEGETATION MANAGEMENT GUIDELINES FOR THE CONTROLLED PROPAGATION FACILITY

OBJECTIVES

The objectives are to reduce the possibility of wildfire spreading to pens, give a clear space around pens to inspect integrity of the wire mesh, and prevent climbing vines from encroaching onto the structure sides, cables, supports, and roof. Vegetation control will:

1. Reduce the likelihood of black rats gaining entrance into a pen by climbing onto vegetation.
2. Reduce the likelihood of wildfire spreading into a pen via contiguous vegetation from the outside.
3. Maintain vegetation-free, 3-foot wide footpaths on the outside of the enclosures that will enable inspection for pen integrity.
4. Maintain vegetation-free, 5-foot wide footpaths on the inside of the enclosures that will enable inspection for pen integrity; the inside and outside footpaths will provide a vegetation free firebreak of 8 feet around the pens.
5. Maintain up to 5-foot wide footpaths inside the enclosure, down the middle and at several intervals across the short axis to facilitate researchers' movements.

METHODS

Vegetation will be controlled with a gas-powered trimmer, ATV-pulled mower and tiller, occasional spot application of herbicides, and various hand tools. Every day a log of accomplished tasks will be recorded. Any evidence of predators within the pens or any RBR death that is found should be left in place. Then project leaders should be immediately contacted for procedure on how the situation should be handled.

Outside Enclosure.—Perimeter vegetation will be removed on a regular basis, as needed to meet the following objectives:

6. Three-foot wide footpath around the pen will be maintained in bare state by cutting or tilling vegetation, or selective use of herbicides. Cutting or tilling should be done bimonthly or more often, as needed.
7. The outside and inside perimeter and the netting of the pens should be closely inspected for breaches at the beginning of every week. If breaches are found they should be investigated, reported and repaired immediately.
8. East side: all vegetation to be removed between pen and fence-line of grazed pasture; vegetation must be cut from around poles and wires. This trimming should be done bimonthly or more often if needed to keep the area bare.
9. West side: vegetation will be cut to ground level to least 15 feet from the enclosure. This trimming should be done bimonthly or more often if needed to keep the vegetation at ground level.
10. North and south of the enclosures (50 feet south of pen 1 and 50 feet north of pen 3, all space between pens 1 and 2 and 2 and 3) a 50-ft wide band will have

vegetation mowed and the trimmings removed to facilitate fire control. All vegetation between the pens and around the storage containers must be kept at ground level (a height of 2 inches or less). This trimming should be done bimonthly or more often as needed.

Inside Enclosure.—Vegetation will be removed as needed to maintain the following:

1. Five-foot perimeter around the inside of the fence. This perimeter will be tilled and scraped twice a year at the beginning and end of the growing season. It will be mowed bimonthly, or more frequently as needed. The portion of the perimeter within 1 foot of the fence will be cut with a gas trimmer as needed to remove all vegetation to ground level. All breaches, including ground squirrel holes, will be filled with concrete up to 5 feet from the inside and outside of the fence.
2. Five-foot perimeter paths through the pens. On these footpaths, vegetation will be maintained to approximately 3 inches tall or less. To accomplish this, the vegetation will need to be cut back bimonthly, or more frequently as needed.
3. Existing discreet clumps of vegetation will be maintained by keeping vegetation between them cut down. The sides of these clumps will be trimmed as needed to maintain the general size and shape of the clumps and to keep them from encroaching on permanent trap sites and footpaths.
4. All vines will be prevented from growing on the guy-wires, large support poles, roof netting, and enclosure sides. To accomplish this the vegetation will need to be cut back bimonthly, or more frequently if needed. Vegetation should be kept 4 feet below all roof netting at all times.
5. Nest chamber openings and permanent trap site locations will be preserved by maintaining narrow paths. Non-mechanized hand tools will be used in the immediate area of chambers and trap stations. Trimming to keep the trap stations free of debris will be done by hand clippers bimonthly so that traps and equipment are not damaged and to facilitate locating and operating traps. Vegetation above and beside the traps should be left, creating a tunnel to encourage rabbits to use the artificial runways and to provide shade and protection from wind and rain while confined in traps.

S*afety precautions*.—The following safety precautions and hygiene will be practiced:

6. All tools will be cleaned in a 10% chlorine solution every other month, before using in the pens.
7. Fifteen-yard^2 sections will be pre-scouted before beginning any vegetation removal. This will involve walking slowly in one direction and moving vegetation aside by hand or stick until the bare ground is observed. This will ensure the area is free of rabbits or other animals.
8. Slash will be removed from the enclosure immediately following cutting. This will prevent accumulation of debris that may subsequently be used for nesting sites, and prevent buildup of dry, flammable material that may contribute to the spread of a fire.