Recovering the Endangered Riparian Brush rabbit (*Sylvilagus bachmani riparius*): Reproduction and Growth in Confinement and Survival after Translocation

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Introduction

The Brush rabbit (*Sylvilagus bachmani*) is distributed from sea level to about 2,200 m along the Pacific Coast of North America from the Colombia River in the north to the southern tip of the Baja California peninsula (Fig. 1). There are 13 described subspecies (Hall 1981). All subspecies occupy dense, shrubby communities, many of which are fire adapted. The Riparian Brush rabbit (*Sylvilagus bachmani riparius*) occupies a range disjunct from other Brush rabbits, near sea level on the floor of the northern San Joaquin Valley, California, USA. Riparian Brush rabbits live both in old-growth riparian forest (primarily valley oak, *Quercus lobata*), and riparian communities dominated by thickets of willows (*Salix* spp.), wild roses (*Rosa* spp.), blackberries (*Rubus* spp.), California grape (*Vitis californica*), and other successional trees and woody plants. When available, they also use dense, tall stands of herbaceous plants adjacent to patches of riparian shrubs or woody vines. Most activity is near the edges of large patches of shrubs or vines (Williams and Basey 1986). These communities in the San Joaquin Valley have been reduced and degraded to less than 1% of their historical extent, primarily by clearing natural vegetation, irrigated cultivation, and impoundment and canalizations of rivers. Consequently, many riparian-dependent species have been jeopardized, including the Riparian Brush rabbit. This rabbit is listed as endangered by California and the US Fish and Wildlife Service (Williams and Basey 1986; US Fish and Wildlife Service 1998, 2000).

Remaining populations of Riparian Brush rabbits exist today in two areas of San Joaquin County: Caswell Memorial State Park (MSP, about 105 ha) along the Stanislaus River, a major tributary of the San Joaquin River, and an estimated 125 ha in several small, isolated and semi-isolated patches along the channels of the San Joaquin River in the southern portion of its delta leading into San Francisco Bay (Williams et al. 2002; Fig. 1).

Annual censuses at Caswell MSP between 1997 and 2003 captured 0 to 12 rabbits. In a 1993 census, we captured 43 rabbits and estimated a population

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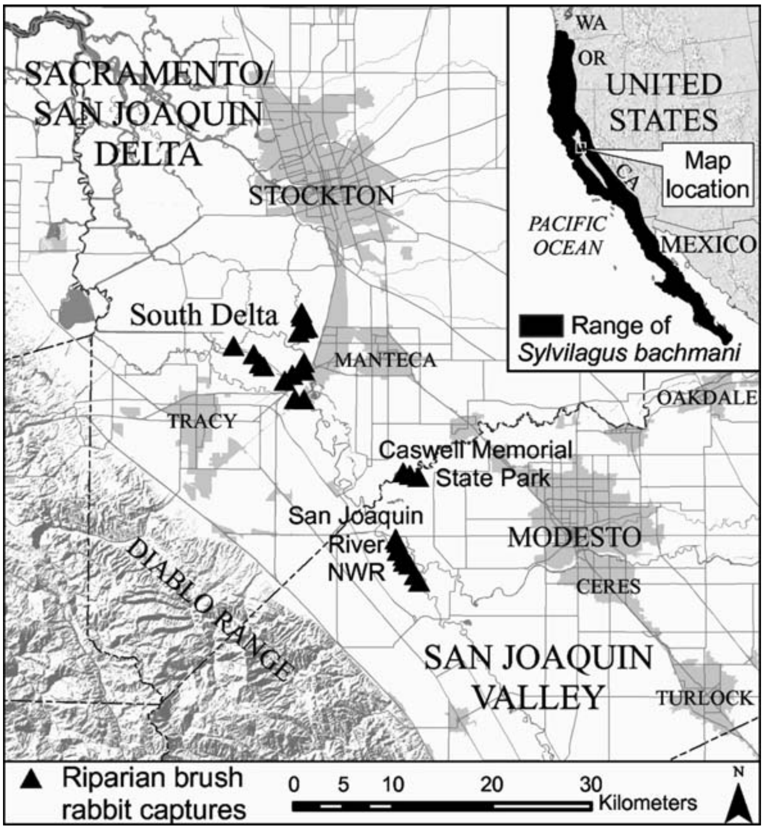

Fig. 1 Distribution map for the Riparian Brush rabbit (*Sylvilagus bachmani riparius*)

size of 67 ± 25.3 rabbits and a density of 3.0 ± 1.13 rabbits/ha (Williams 1993; Williams et al. 2005). Excluding developed areas of the park, Williams (1993) estimated 81 ha with natural communities contained 241 rabbits (approximate 95% confidence interval 170-608). The South Delta metapopulation is larger, probably because of frequent disturbances from farming and flood control that maintains early successional communities. Yet this population is highly fragmented and located entirely on unprotected private properties, many of which are planned for urban developments within 0 to 5 years. Most property owners have allowed access to confirm presence or absence and to capture individuals for captive breeding, but not for estimating population size. We believe that there are at most a few hundred rabbits in the South Delta metapopulation (Williams et al. 2002).

The recovery plan for the Riparian Brush rabbit set a goal of maintaining or establishing three self-sustaining, wild populations outside of Caswell MSP and within the historical range of the species (US Fish and Wildlife Service 1998). To that end, a controlled propagation and reintroduction program was initiated to re-establish populations in suitable historical habitat (Williams et al. 2002) on the San Joaquin River National Wildlife Refuge (NWR) and elsewhere where landowners were willing.

There were between 275 and 325 ha of natural communities on the existing San Joaquin River NWR prior to 1997 (Williams et al. 2002). Following extensive flooding along the San Joaquin River in 1997, the US Fish and Wildlife Service purchased over 530 ha of frequently-flooded private farmland adjacent to the refuge. Levees on the refuge have not been repaired and the former farmland is being actively restored to riparian vegetation. The intent is to allow a return of the normal floodplain and flood dynamics to this area, lowering the flood level so that existing levees could be vegetated and serve as refugia from flooding. Additionally, a mound was constructed next to but higher in elevation than the flood levee bordering the best habitat for Riparian Brush rabbits. The mound is meant to serve as a refuge for rabbits from the highest anticipated flood level. As of 2004, approximately 325 ha of the former farmland had been planted with riparian trees and shrubs. More than 200 ha are scheduled for restoration in 2005 and acquisition of additional property along the river is in progress (Sacramento River Partners 2002).

There has been no information published on survivorship of Brush rabbits. Annual survival of cottontails can vary substantially. For example, annual survival of adult, radio-collared Eastern cottontails (*Sylvilagus floridanus*) was 15% (Trent and Rongstad 1974) and 21% in two areas (Rose 1977).

There has been little information on reproduction reported for Riparian Brush rabbits. Breeding extended from February to May or June for Riparian Brush rabbits in one study (Basey 1990) and from December to May for other brush rabbits in coastal California (Mossman 1955). Breeding by young-of-the-year has not been observed, but breeding by females greater than about 90 days old has been reported for some other *Sylvilagus* species (e.g., Powers and Verts 1971; Chapman et al. 1980).

Based on numbers of embryos, mean litter sizes varied from 2.7 to 3.4 over 2 years in Oregon brush rabbits (Chapman and Harman 1972) and from 3.5 to 4.0 in two areas of coastal California (Orr 1942; Mossman 1955, respectively). Mean annual production of young by female brush rabbits in Oregon was estimated at 15.3 (Chapman and Harman 1972). Mean number of young born typically is fewer than the number of embryos for cottontail rabbits (Chapman et al. 1977).

Herein we report survival, causes of mortality, reproduction, and growth of Riparian Brush rabbits during the first 2 years of operation of the propagation program.

Materials and Methods

Animals selected for breeding were placed in fenced enclosures (0.50–0.57 ha) larger than their typical home ranges (0.33 ha, Dixon et al. 1981). Large patches of Himalayan blackberries (*Rubus discolor*; Fig. 2) and ruderal grasses and forbs provided food and cover within enclosures. No supplemental

Fig. 2 Pen for controlled propagation of Riparian Brush rabbits measuring 162 m long, 30.5 m wide and with side fencing of 2.14 m in height. The top is covered with netting to prevent raptors from entering and the sides are covered with sheet metal (shown on the *left*) but not yet installed on the *right* (photo by L.P. Hamilton)

food was provided. In 2001–2002, only one pen was completed for use. It was populated with six rabbits (3M, 3F) in November–December 2001. These rabbits were initially fitted with radio collars consisting of a cable within Tygon tubing (Holohil); the collars were removed in March because the rabbits were catching their forelegs and jaws under the collar. The pen was emptied of rabbits in November 2002. All three pens were populated with six rabbits each (3M, 3F), newly captured from the wild, in December 2002. We captured breeders from the South Delta, selecting individuals from as far apart as possible to ensure low kinship values. Straight-line distances between capture points of rabbits chosen for captive breeding in 2002 varied from 1.1 to 6.1 km. Distances between capture points of animals selected for breeding in 2003 were shorter, ranging from 0.1 to 4.6 km, but animals of opposite sex placed in the same pen had capture points >0.25 km.

We operated traps in pen 1 at 2-week intervals in 2002, starting 22 February. In 2003, we trapped twice weekly in pen 1 and once weekly in pens 2 and 3. Upon capture, we assessed general health and appearance, visible reproductive condition, weighed adults and offspring, and measured offspring. To calculate gain in mass and estimate age of young rabbits, animals heavier than 600 g were not included because their weights probably were influenced by reproductive condition. To estimate age using mass, we assumed

4-day-olds weighed 28 g (Davis 1936) and used mean gain in mass/day calculated for all young between first capture and last capture when they weighed <600 g. The difference in mass at first capture between years and pens was compared using Student's *t*-test, assuming unequal variance.

Parentage of rabbits born in captivity was determined using eight polymorphic microsatellite loci: (Surridge et al. 1998; Williams et al. 2005). Parental genotypes were determined and compared with the first 15 offspring in 2002 and the first 40 offspring in 2003. Parentage of other offspring was not determined because of problems identifying parents of potential F2 and F3 matings and of backcrosses between generations.

Surviving breeders (3) were removed from the pen in July 2002 and repatriated to their original capture points after attaching a radio transmitter. Additionally, three radio-collared rabbits born in confinement were released at the capture sites of the dead brood stock. These rabbits were monitored by radio-telemetry biweekly through 15 Feb 2003. We were unable to monitor repatriated rabbits in 2003 because of access restrictions on private property.

Young rabbits produced in the pens were released at the San Joaquin River NWR after they had attained adulthood (>500 g). They were fitted with a radio transmitter with a mortality signal and a neoprene-strap collar (ATS model M1750). They were released into soft-release pens (about 0.5 ha in size) that were placed in suitable habitat on the refuge. After acclimation periods of 1–20 days (most were held for 5 days), the pen was opened and the rabbits were allowed to disperse. While in the holding pen, and for 1 week immediately after introduction, the rabbits were monitored daily by radio telemetry. The rest of the year, animals were monitored for status twice weekly. The remains of dead rabbits were located and cause of death was assessed.

Survival of translocated rabbits was calculated from date of introduction to the soft-release pen 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 from 31 July 2002 through 12 June 2004 (682 days). For comparisons of survival between years, deaths were grouped in 14-day intervals for rabbits released before November each year and tracked through February of the ensuing year (maximum of 208 days of exposure). Survival and life table analyses were performed on data with censoring using Statistica, version 6.1 (2002). We used Cox's *F*-test to compare survivorship between years.

Results

We captured 340 captive-born young (62 in 2002, 278 in 2003, Fig. 3). Mean mass at first capture was 272.2 g (Table 1) and did not differ by year for pen 1 ($P = 0.79$) or between rabbits in pens 2 and 3 in 2003 ($P = 0.44$), but rabbits in pens 2 and 3 differed significantly from rabbits in pen 1 in 2003 ($P > 0.001$). The first offspring of 2002 were captured on 22–23 February, and weighed 140

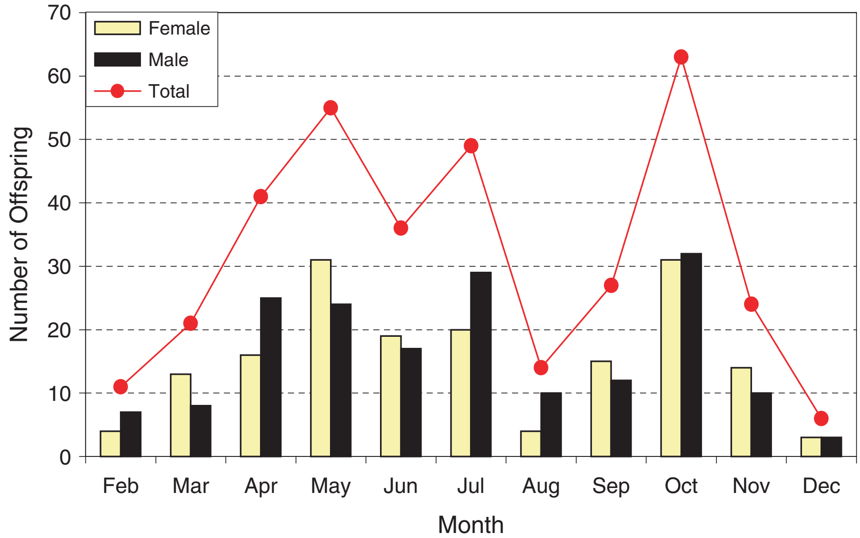

Fig. 3 Number of young rabbits newly trapped and marked in the controlled propagation pens by month in 2002 and 2003 combined

Table 1 Number of young Riparian Brush rabbits captured and mass at first capture in the controlled propagation facility in 2002 and 2003

	n	Mass (g) at first capture $\bar{x}$ (*sd*)	Min	Max
Pen 1 - 2002	62	236.3 (90.17)	110	480
Pen 1 - 2003	111	258.6 (112.71)	70	580
Pen 2 - 2003	80	308.7 (158.22)	105	570
Pen 3 - 2003	87	330.4 (171.84)	80	800
Total	340	272.2 (141.72)	70	800

and 179 g. In 2003 (10–11 Feb), the first-captured offspring weighed 115 and 180 g. The Y-intercept for the regression of change in mass by time for 123 young, non-reproductive rabbits was 21.8 g (Fig. 4). Mean gain in mass was 6.8 (±2.80) g/day for rabbits weighing 70 g or more initially.

The sex ratio was 1.08M:1F (Yates corrected Chi-square 0.39, $P = 0.53$). In 2002, all three of the adult females exhibited evidence of producing young; two had three or four litters each. There was no evidence of females producing more than four litters. Twelve juvenile females reproduced in 2002. Of these, two had two litters. Minimally, there were 22 pregnancies by 15 females producing 62 live young. The mean number of young per pregnancy surviving to a trappable age was 2.8. We removed all the males from the pen that we could

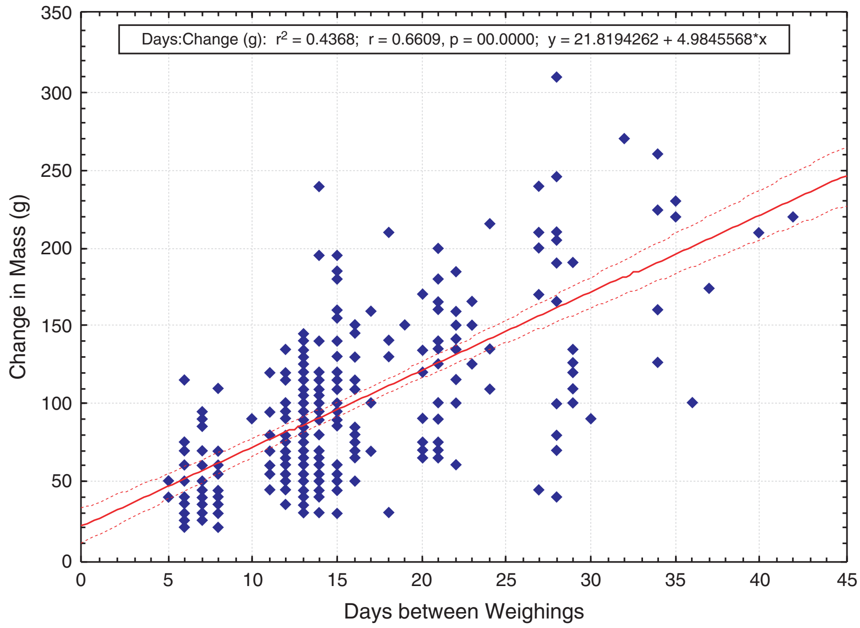

Fig. 4 Scatter plot depicting increase in mass between weighting periods in days for 123 young Riparian Brush rabbits born at the Controlled Propagation facility in 2002–2003

trap and which were of sufficient size to radio-collar, starting on 31 July. We found no evidence of oestrus or pregnancy after 19 September.

In 2003, one female died before breeding and was replaced; nine remaining females reproduced, as did 44 young-of-the-year. We detected 97 pregnancies by 53 females that resulted in 278 young that lived long enough to be trapped. The mean number of young per pregnancy surviving beyond the first few weeks after birth in 2003 was 2.9. There were pregnancies into mid-October and lactation into mid-November. Potential reproduction of offspring was slowed starting 3 July by translocating to the wild those offspring that passed health exams, were not lactating, and weighed >500 g.

All six breeders contributed to producing the first 15 offspring in 2002 based on analyses of parental and offspring genotypes. Seven (of eight) microsatellites were variable in this set of adults. Paternity was not resolved by microsatellites for two young. One male fathered eight of the 15 young while another fathered from four to six, and the third male from one to three. One female produced six young, another produced eight, and the third, which died of a collar-related accident on 1 March, produced only one. In 2003, parentage was determined for 33 and unresolved for seven young born early in the year. In pen 1, where more genotypes were analyzed, a single male dominated breeding (13 young from three females), but one other male also mated with all three females (5–6 young), whereas the third male mated with only two females, producing 2–3 offspring. The three females produced 11, 4–6, and 4–6 young. Similar patterns of parentage were seen in the other pens although 1 male did not produce any of the young we tested.

Forty-nine of the rabbits born in captivity in 2002 were released at the San Joaquin River National Wildlife Refuge (SJRNWR) between 31 July and 31 October 2002. Three others were released in the South Delta to replace adult breeders that died in captivity. For the cohort raised in 2003, 194 had been released on the refuge by 1 March 2004; of these, 156 had been released between 3 July and 31 October 2003, a period comparable to 2002.

In 2002, three of the six breeders survived over 7 months in the pen (196 days) and then were repatriated to their original capture sites in July. One repatriated rabbit left his original capture site and was located ~270 m and ~545 m away on two different dates. The next time we located him, he had returned to his capture site, all within 1 month of release. On subsequent sessions we could not pick up his radio signal. The other two were alive until we lost contact with one on 20 January 2003 and the other on 19 March 2003. Of three young released at the sites of capture of the adult breeders that died while in the pens, we lost contact with one immediately, and within 1 month contact with the other two was lost.

In 2003, 13 of 20 adult breeders died while in the pens (35% survival, 272 days maximum exposure). The seven that were repatriated to their original capture sites were not monitored, and no young were released to replace the ones that died in captivity.

Survival statistics of captive-born rabbits while in the breeding pens and after release to the wild are listed in Table 2. Young unaccounted for in Table 2 in 2003 were still in the breeding pens at the cut-off date for this report. The percentage of marked young surviving while in captivity in 2003 compared to 2002 was not significantly different (Yates corrected Chi-square, 1.21, $P = 0.272$). Survival during comparable at-risk intervals from release (Fig. 5) was significantly higher for the 2002 cohort compared to the 2003 cohort (Cox's F-test, $F = 1.908$, $P = 0.046$). By 1 March 2003, 30 of 49 rabbits translocated

Table 2 Survival rates of Riparian Brush rabbits involved in controlled propagation and translocation to the San Joaquin River National Wildlife Refuge

Captive born rabbits	2002	2003
Number	62	278
Died in pen	13	40
Survival rate in captivity (days exposed[a])	0.79 (298)	0.86 (450)
Number translocated	49	196[b]
Died after release	23	152[b]
Survival rate after release (days exposed[a])	0.23 (673)	0.22 (317)[b]

[a]Indicates the maximum days of exposure for an event
[b]All animals translocated from July 2003 through February 2004

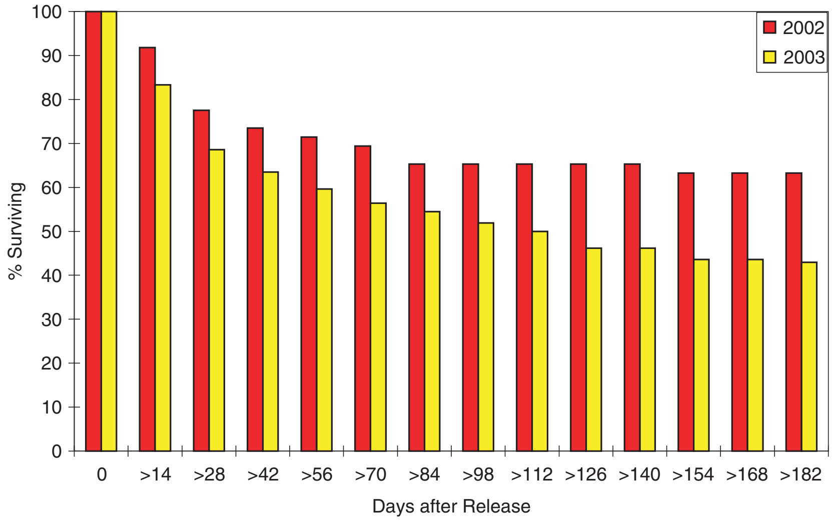

Fig. 5 Survival of two cohorts of captive-breed Riparian Brush rabbits released on the San Joaquin River National Wildlife Refuge in 2002 and 2003. Data for each group span a period from July through February of the ensuing year

in 2002 were alive (61% survival), and of the 2003 cohort (156), 69 were alive on 1 March 2004 (44% survival).

After 682 days of monitoring the 2002 translocation cohort, five rabbits were alive, we had lost radio contract with 18, and 26 were known to have died. The cumulative survival rate for this period was 23.1% (±7.6%). Median life expectancy of 376 days peaked at 99 days (SE>97.9 days) after release. The survival rate 1 year after release was 49% (±7.6%) for the 2002 cohort, based on life table analysis.

Cause of mortality (Table 3) was unknown for the largest number of deaths. In the propagation pens most deaths due to unknown causes were of rabbits that were not recaptured and no remains were found (these animals were not radio-collared). 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 to be the likely cause, *Baylisascaris* sp. was most often implicated. Other diseases implicated in deaths were necrotizing typhlitis, and intestinal lymphoma. Predation, including presumptive predation, was the greatest cause of deaths in translocated rabbits. We noted problems with loss of collars and catching legs or jaws in cable-tubing-type collars, either because of improper crimping of the cable or inability of some crimps to hold under the force exerted by the forefeet of the rabbits. One adult breeder died by catching its lower jaw under the cable of the collar. After this incident, we removed the collars from the confined rabbits. All the translocated rabbits had strap collars, which were the source of several non-lethal injuries as well as one known mortality.

Table 3 Number of mortalities by cause for Riparian Brush rabbits in the controlled propagation and translocation program

	Predation			Accident				
Group	Mammal	Avian	Probable	Collar	Trap	Disease	Newborn	Unknown
Propagation Pens								
2002	0	0	0	1	1	3	1	8
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

Discussion

In both years of captive propagation, reproduction of Riparian Brush rabbits started earlier (December versus February) and extended much later (October versus May; Mossman 1955; Williams 1988; Basey 1990) than had been seen in the wild for this or other subspecies. For the breeding season, successful production of young per breeding female (5.3) was much lower than the production of 15.2 newborns per female estimated by Chapman and Harman (1972) based on number of embryos. Our productivity estimates are for young living to independence or beyond. Further, the successful productivity per female included substantial contributions from rabbits born earlier in the same breeding season, something that neither Mossman (1955) nor Chapman and Harman (1972) observed in the wild. Three factors could have led to lower productivity than the theoretical estimates for adult breeders: having fewer live young per litter than the mean number estimated by counting embryos; having one or more young, on average, die before reaching a trappable age; and having fewer than expected litters. We have not tried to determine the numerical contributions of each factor, but only about a third of the brood-stock females had more than one or two litters instead of the four to five predicted by Chapman and Harman (1972). Yet, the realized production of rabbits living to be translocated from the three pens was between two and three times greater than the minimum we had estimated *a priori* (Williams et al. 2002), due mostly to the reproduction of young females whose contribution was unexpected.

That mean mass at first capture was significantly greater in pens 2 and 3 compared to pen 1 probably is explained by the less frequent trapping in pens 2 and 3. Our understanding of growth of young and the calculated relationship between age and mass suffers from lack of data on the change in mass between birth and weaning, data that could not be obtained because nests were inaccessible in large clumps of blackberry vines. We recognize that growth is not linear and our method probably underestimates age by a few days. We estimated the smallest, live-trapped individual (70 g) to be about 10 days old—eastern cottontails were thought to be capable of leaving the nest when 12–16 days old (Chapman et al. 1980). Mean estimated age at first capture of all young was 40 days. Young at weaning weighed about 96–103 g, assuming that weaning was at about 14–15 days of age, based on other *Sylvilagus* species (Chapman 1974, 1975; Chapman and Wilner 1978). Young Riparian Brush rabbits attained reproductive maturity when about 77–84 days old (550–600 g).

Based on the results of geneotyping, Riparian Brush rabbits in the controlled propagation pens exhibited a polygynous mating system, with one male dominating mating of females but not to the exclusion of all other males. Females exhibited promiscuity in that some litters were fathered by more than one male.

The relatively large number of translocated rabbits with which we lost contact probably had dead transmitter batteries. Our resources were not sufficient to locate and trap all rabbits and replace failing batteries because of the large area over which they had dispersed. Mortalities attributed to radio-collars (two of 286, Table 3) were few, but are major concerns in any study (Bond et al. 2000). More deaths than we detected may have been associated with radio-collars because of neck abrasions and other injuries from radio-collars that were found on several rabbits when trapped. Strap-type radio-collars eliminated most accidents with legs or jaws becoming caught under the collar, but were a worrisome cause of abrasions and wounds. Trap accidents included two rabbits being caught simultaneously in the same trap, with subsequent injuries from fighting, broken cervical vertebrae from collision within the trap, and accidentally leaving a trap set when unattended. All were exceedingly rare considering the number of times rabbits were trapped.

Repatriation of the wild-caught brood stock after 7 months in captivity was a limited success (2 of 3 surviving from July to beyond January), but releasing captive-reared young at the capture site of their dead progenitors was not successful the first year and was not done the second year for logistical reasons. We believe it is important in situations such as this that the captive-propagation program not significantly impact the natural populations that are the sources of breeders (Williams et al. 2002). Unfortunately, access and activity restrictions on private property precluded us from measuring possible impacts.

There was no evidence from health exams, which included blood chemistry for several captive rabbits, or from necropsy of rabbits that died in captivity, that any rabbits were undernourished or malnourished (Williams et al. 2005). We also saw no evidence that vegetation within the propagation pens was being over-browsed or otherwise adversely impacted by rabbits. We conclude that providing adequate space and abundant natural, live vegetation for rearing brush rabbits were successful in avoiding potential problems of husbandry in captivity related to diet.

That 61% and 44% of the translocated rabbits survived from release through February of the ensuing year, when the females could have had two or more litters, exceeded our expectation of less than 20% survival through what we predicted would be the breeding season (Williams et al. 2002). That survival was so high for the 2002 cohort may have been due to an absence of predators cued into brush rabbits at the release site. Perhaps survival was significantly lower for the second (2003) cohort because more predators had been attracted by the population of rabbits established in 2002. Some females in the cohort translocated in 2002 were pregnant when translocated, others bred soon after, and survivors and offspring bred during the next breeding season. These rabbits may have occupied much of the most suitable habitat, forcing more rabbits released in 2003 into poorer-quality habitat where they were more vulnerable to predation. This suggests that perhaps the best 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. We plan to use and assess different reintroduction strategies on other properties that are expected to become available for repopulation of Riparian Brush rabbits, and compare them with the population on the San Joaquin River NWR. When sufficient data are available, we also will compare survival of rabbits held for various periods in the soft-release enclosures.

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References

Basey GE (1990) Distribution, ecology, and population status of the Riparian Brush rabbit (*Sylvilagus bachmani riparius*). MS Thesis. California State University, Stanislaus, Turlock
Bond BT, Bowman JL, Leopold BD, Burger Jr LW, Kochanny CO (2000) An improved radiocollar for eastern cottontails. Wildl Soc Bull 20:565–569
Chapman JA (1974) *Sylvilagus bachmani*. Mamm Spec 34:1–4
Chapman JA (1975) *Sylvilagus nuttallii*. Mamm Spec 56:1–3
Chapman JA, Harman AL (1972) The breeding biology of a brush rabbit population. J Wildl Manage 36:816–823
Chapman JA, Wilner GR (1978) *Sylvilagus audubonii*. Mamm Spec 104:1–4

Chapman JA, Harman AL, Samuel DE (1977) Reproductive and physiological cycles in the cottontail complex in western Maryland and nearby West Virginia. Wildl Monogr 56:1–73

Chapman JA, Hockman JG, Ojeda MM (1980) *Sylvilagus floridanus*. Mamm Spec 136:1–8

Davis WB (1936) Young of the brush rabbit, *Sylvilagus bachmani*. Murrelet 17:36–40

Dixon KR, Chapman JA, Rongstad OJ, Ohrlein KM (1981) A comparison of home range size in *Sylvilagus floridanus* and *S. bachmani*. In: Myers K, MacInnes CD (eds) Proceedings of the World Lagomorph Conference Univ. Guelph, Ontario, Canada, pp 541–548

Hall ER (1981) The mammals of North America, 2nd edn. Wiley, New York

Mossman AS (1955) Reproduction of the brush rabbit in California. J Wildl Manage 19:177–184

Orr RT (1942) Observations on the growth of young brush rabbits. J Mammal 23:298–302

Powers RJ, Verts BJ (1971) Reproduction of the mountain cottontail rabbit in Oregon. J Wildl Manage 35:605–613

Rose GB (1977) Mortality rates of tagged adult cottontails. J Wildl Manage 41:511–514

Sacramento River Partners (2002) San Joaquin River National Wildlife Refuge Riparian Restoration Plan for Fall 2002 (Project B: Fields H5, H6, H21, H25, and L1-L9). Final Report, Stanislaus County, California

Statistica, Release 6.1. (2002) Statstoft Incorporated, Tulsa, OK, USA

Surridge AK, Bell DJ, GM Hewitt (1998) Using molecular tools to study biogeography of the European wild rabbit (*Oryctolagus cuniculus*) in Britain. Gib Faun Sauv, Game Wildl 15:65–74

Trent TT, Rongstad OJ (1974) Home range and survival of cottontail rabbits in southwestern Wisconsin. J Wildl Manage 38:459–472

US Fish and Wildlife Service (1998) Recovery plan for upland species of the San Joaquin Valley, California. Region 1, Portland, OR

US 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 DF (1988) Ecology and management of the Riparian Brush rabbit in Caswell Memorial State Park. Final Report, Interagency Agreement, 4-305-6108. California Dept. of Parks and Recreation, Lodi, California

Williams DF (1993) Population censuses of Riparian Brush rabbits and riparian woodrats at Caswell Memorial State Park during January 1993. Final Report. California Dept. of Parks and Recreation, Lodi, California

Williams DF, Basey GE (1986) Population status of the Riparian Brush rabbit, *Sylvilagus bachmani riparius*. Contract Final Report. California Department of Fish and Game, Wildl. Management Division, Nongame Bird and Mammal Section, Sacramento, California

Williams DF, Kelly PA, Hamilton LP (2002) Controlled propagation and reintroduction plan for the Riparian Brush rabbit. US Fish and Wildlife Service, Sacramento, California and Endangered Species Recovery Program, California State University, Turlock

Williams DF, Lloyd MR, Hamilton LP, Vincent-Williams E, Youngblom JJ, Gilardi K, and Kelly PA (2005) Controlled propagation and translocation of Riparian Brush rabbits: annual report for 2003. Endangered Species Recovery Program, California State University, Turlock