ASSESSING THE FEASIBILITY OF RELEASE TECHNIQUES FOR CAPTIVE-BRED BURROWING OWLS

Authors: Poulin, Ray G., Danielle Todd, L., Wellicome, Troy I., and Mark Brigham, R.

Source: Journal of Raptor Research, 40(2) : 142-150

Published By: Raptor Research Foundation

URL: https://doi.org/10.3356/0892-1016(2006)40[142:ATFORT]2.0.CO;2

J. Raptor Res. 40(2):142–150

ASSESSING THE FEASIBILITY OF RELEASE TECHNIQUES FOR CAPTIVE-BRED BURROWING OWLS

RAY G. POULIN[1] AND L. DANIELLE TODD[2]
Biology Department, University of Regina, Regina, Saskatchewan S4S 0A2 Canada

TROY I. WELLICOME
Canadian Wildlife Service, Room 200, 4999-98th Avenue, Edmonton, Alberta, T6B 2X3 Canada

R. MARK BRIGHAM
Biology Department, University of Regina, Regina, Saskatchewan, S4S 0A2 Canada

ABSTRACT.—We tested two methods of releasing endangered, captive-bred Burrowing Owls (*Athene cunicularia*) in Saskatchewan, Canada. The first technique involved releasing pairs of captive-reared, adult owls. Twelve of 26 pairs remained together using this technique, while another six individuals paired with wild owls. Pairing/nesting success was poor when enclosures were left in place for only 3 d prior to release; success improved when enclosures remained for 5 d or until clutch initiation. At least 19% of released adults died during the breeding season, compared to only 3.7% for wild owls. At least five released adults failed to migrate. None of the captive-release adults returned to the study area in subsequent years, whereas 19% of banded wild owls returned during the same period. One of 62 offspring from released pairs returned to breed in a subsequent year; this recruitment rate was not different than that of offspring produced by wild adults. The second release technique involved fostering captive-hatched owlets into wild nests. We fostered 54 owlets at three different ages. Fostered chicks were accepted by wild owls; their growth, survival, and behaviors did not differ from their wild siblings'. Our results suggest that adults raised in captivity can breed successfully in the wild, but there are questions about their ability to migrate successfully. Fostering captive chicks into wild nests showed some success, but also had some limitations.

KEY WORDS: Athene cunicularia; *Burrowing Owl*; *captive-bred*; *fostering*; *reintroduction*; *release techniques*; *endangered species.*

EVALUACIÓN DE LA FACTIBILIDAD DE TÉCNICAS DE LIBERACIÓN DE BUHOS CRIADOS EN CAUTIVERIO

RESUMEN.—Pusimos a prueba dos métodos de reintroducción de individuos cautivos de la especie en peligro *Athene cunicularia* en Saskatchewan, Canadá. La primera técnica involucró la liberación de parejas adultas criadas en cautiverio. Doce de 26 parejas permanecieron juntas usando esta técnica, mientras que 6 individuos formaron parejas con individuos silvestres. El éxito en la formación de parejas y el éxito de nidificación fueron bajos cuando los individuos cautivos permanecieron en el sitio de liberación por sólo 3 días antes de ser liberados; el éxito incrementó cuando los individuos permanecieron por 5 días o hasta el inicio de la eclosión. Al menos el 19% de los adultos liberados murieron durante la temporada reproductiva, comparado con sólo el 3.7% de los individuos silvestres. Al menos cinco adultos liberados no migraron. Ninguno de los adultos cautivos que fueron liberados regresó al sitio de estudio en años subsecuentes, mientras que el 19% de los individuos silvestres que fueron anillados regresaron durante el mismo periodo. Una de las 62 crías producidas por las parejas liberadas regresó a criar en años subsecuentes; esta tasa de reclutamiento no fue diferente a la de crías producidas por adultos silvestres. La segunda técnica de liberación involucró el dar en adopción pichones eclosionados en cautiverio a parejas silvestres con nidos. Dimos en adopción 54 juveniles de tres diferentes edades. Los pichones fueron aceptados por las parejas silvestres. El crecimiento, sobrevivencia y comportamiento de los pichones

---

[1] Present address: Department of Biological Sciences, University of Alberta, Edmonton, AB, T6G 2E9 Canada; email address: rpoulin@ualberta.ca
[2] Present address: Canadian Wildlife Service, Room 200, 4999-98th Ave., Edmonton, AB, T6B 2X3 Canada.

adoptados no fue diferente al de sus hermanos silvestres. Nuestros resultados sugieren que los adultos criados en cautiverio pueden criar exitosamente en la naturaleza, pero permanecen dudas acerca de su habilidad para migrar exitosamente. Dar polluelos en adopción a parejas silvestres mostró cierto éxito, pero también tuvo algunas limitaciones.

[Traducción del equipo editorial]

Burrowing Owl populations have undergone a severe decline in Canada for more than 25 yr. In 1995, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) changed the Burrowing Owl's national status from threatened to endangered (Wellicome and Haug 1995). This downward trend has not been limited to Canada; Burrowing Owl populations have declined over most of their North American range (Sheffield 1997, Holroyd et al. 2001, Wellicome and Holroyd 2001).

To attempt to counter the decline in Manitoba, over 260 translocated and captive-bred Burrowing Owls were released between 1987 and 1996 (De Smet 1997). During that time, the provincial population fell from an estimated 35 nests to a single nest, and reintroduction efforts were halted. Burrowing Owls have been essentially extirpated in Manitoba since 2000 (K. De Smet pers. comm.). In British Columbia, 106 captive-bred Burrowing Owls were released into their former range between 1992 and 1997 (Leupin and Low 2001). Additional reintroductions were conducted in this area between 1997 and 2004 (J. Surgenor pers. comm.); however, these efforts have yet to establish a self-sustaining, wild breeding population of Burrowing Owls. Reintroduction efforts were also attempted in Minnesota between 1986 and 1990, by hacking 105 pre-fledging-aged chicks translocated from South Dakota (Martell et al. 2001). Reintroductions were discontinued because no owls were found after leaving their hack sites, and none ever returned to breed in years following the releases.

In 1997, experimentation with various captive-release protocols began in Saskatchewan. Unlike the reintroduction efforts in Manitoba, British Columbia, and Minnesota, the primary aim in Saskatchewan was not to recover the dwindling wild population. Rather, the goal was to test protocols for captive-releases in order to aid Burrowing Owl recovery programs that are using or considering reintroductions as part of their conservation strategy. This project was made possible by the existence of captive Burrowing Owls in facilities located in Alberta, Saskatchewan, and Ontario. Our project also benefited from ongoing studies of wild Burrowing Owl populations in southern Saskatchewan (James et al. 1997, Wellicome 2000, Todd 2001, Poulin 2003). By experimenting with releases while simultaneously studying a wild Burrowing Owl population in the same area, we were able to quantitatively assess the relative success experienced by released birds.

In this paper, we describe the results of two techniques for releasing captive-bred Burrowing Owls: (1) releasing pairs of 1-yr-old, captive-reared adults at the start of the breeding season and (2) fostering captive-hatched owlets into wild nests.

METHODS

Study Area. This project was conducted within the moist mixed-grassland ecoregion (Harris et al. 1983) of southern Saskatchewan, within the core of the historical Burrowing Owl range in Canada (Wellicome and Holroyd 2001). Our study area was intensively cultivated for cereal crop production (ca. 90% of the overall land base) with small and highly fragmented native grassland patches intermixed throughout the cropland matrix (Gauthier et al. 2002). The majority of Burrowing Owl nests in our study area were located in moderately- to heavily-grazed cattle pastures. Wild Burrowing Owls have been continuously monitored in our study area since 1986 (James et al. 1997, Wellicome 2000, Poulin 2003, Todd et al. 2003).

Technique No. 1: Releasing Pairs of Captive-reared Adults. During the springs of 1997–2000 and 2002, we released pairs of captive-reared, adult Burrowing Owls. These owls (48 Second-Year [SY], 4 After-Second-Year [ASY]) were the offspring of non-releasable owls permanently housed at the Owl Foundation (Vineland, ON Canada), the Alberta Birds of Prey Centre (Coaldale, AB Canada), and the Saskatchewan Burrowing Owl Interpretive Centre (Moose Jaw, SK Canada). The number of owls released each year varied because we depended on the number available from these facilities. Unfortunately, the small number of release birds returning precluded us from examining the effects of annual variation; we therefore pooled the data from 1997 through 2002 for our analyses.

The release protocol consisted of choosing pairs of non-related owls and placing them within wire-cage enclosures positioned over a nest box burrow in the spring (April or May), when wild owls were beginning to return from migration. Enclosures consisted of a wooden frame (2-m × 1.2-m × 1.2-m) covered with plastic 1-cm × 1-cm mesh. Each enclosure was placed over the entrance of a nest box burrow (Fig. 1) and the bottom frame was buried approximately 10-cm underground to stabilize the structure and to discourage digging by owls and potential intruders. Once installed, enclosures allowed release-owls access to their underground burrow and protection from predators. The underground nest box system protected

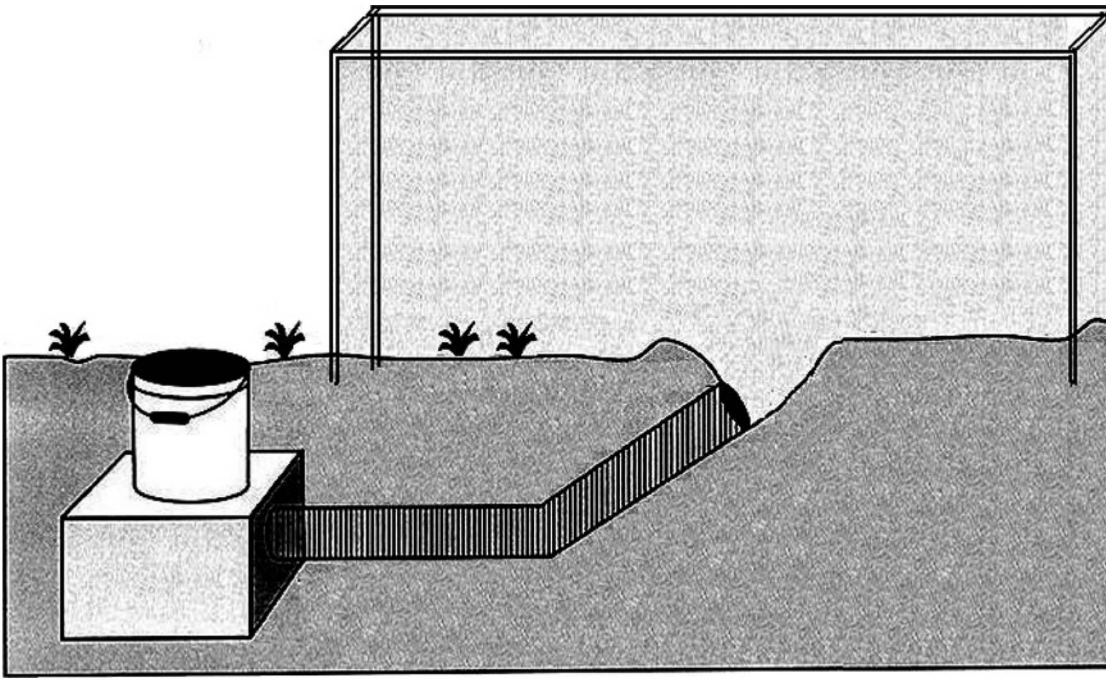

Figure 1. Diagram (not to scale) of underground nest box and release enclosure system used for releasing pairs of captive-bred Burrowing Owls within the Saskatchewan study area. Access to the underground nesting chamber was possible through the removable bucket system. The release enclosure (1.8-m × 1.2-m × 1.2-m from 1997–2000, 2.4-m × 1.2-m × 1.2-m in 2002), used to contain the owl pair at the nest for the first few days before release, is shown over the burrow entrance.

owl nests from fossorial predators, while allowing us access to nest chambers to monitor reproductive parameters and to capture juveniles for banding and radio-tagging (Wellicome et al. 1997, Poulin et al. 1998). Because Burrowing Owls often nest in clusters (e.g., Desmond et al. 1995), release sites were selected where there was always at least one other owl nest in the vicinity. In addition, we selected release sites that had been occupied by wild owls within the previous 3 yr, assuming that sites that were recently inhabited by wild owls would provide appropriate nesting conditions.

The length of time enclosures were left in place varied among years to attempt to increase pairing success. In 1997–99 enclosures were left in place for 3 days and nights; in 2000, enclosures were left in place for 5 days and nights, and in 2002 the enclosures were removed only after clutches had been initiated. While this change in experimental protocol was not ideal, we believe our results were unambiguous because reproductive parameters, other than pairing success, appeared to be unaffected.

While inside the enclosures, owls were provided with food (1–4 lab mice/owl/d) and monitored daily for nest initiation. After the enclosures were removed, we continued to provide supplemental food until wild-caught prey items were found inside the nest chamber.

At each release-nest, we recorded clutch-initiation date, clutch size, hatch date, number of eggs hatched, and number of nestlings fledged. The relationship between clutch-initiation date and clutch size was compared between wild and released owls by using Student's *t*-tests to compare the slopes and elevations of the regression lines (Zar 1996). Approximately 20 d post-hatch, we captured all nestlings and banded them with uniquely-numbered aluminum and colored leg-bands.

In 1997, 1998, and 2000, we monitored the post-fledging survival and dispersal of the offspring using 6 g necklace-style radio-transmitters (Holohil Systems Inc., Carp, Ontario, Canada). During these 3 yr, we also used transmitters to follow the dispersal and survival of wild juveniles as part of another study (Todd 2001, Todd et al. 2003), making it possible to compare survival rates and post-fledging dispersal activities between wild-raised juveniles and those raised by captive-bred adults. Distance from nest and status (alive or dead) of all juveniles was determined every 2–3 d from the time of transmitter attachment (35–40 d post-hatch) until migration or death of the individual. Differences in post-fledging activities between wild and released owls were assessed with two-tailed *t*-tests. Transmitters were not used on adult owls; therefore, adult survival (released and wild owls) could only be estimated from observations made throughout the summer and from the opportunistic recovery of leg bands or carcasses.

We used chi-square tests to compare ratios (e.g., mortality rates, fledging success, return rates) between wild and released owls. For all statistical tests, differences were considered significant at $\alpha < 0.05$.

Table 1. Pairing success of captive-raised adult Burrowing Owls released during the breeding season in Saskatchewan between 1997 and 2002. Release-enclosures remained in place for 3 d in 1997–99, 5 d in 2000, and until egg-laying began ($\bar{x}$ = 16.5 ± 5.2 d [SE]) in 2002.

YEAR	PAIRS RELEASED	PAIRS REMAINING TOGETHER	FLEDGLINGS FROM RELEASED PAIRS	PAIRINGS BETWEEN RELEASE-WILD OWLS	FLEDGLINGS FROM RELEASE-WILD PAIRS	SUCCESSFUL NESTS[a]	FLEDGLINGS PRODUCED[a]
1997	8	3	10	2	11	5	21
1998	6	0	0	4	20	4	20
1999	4	1	0	0	0	0	0
2000	4	4	18	0	0	2	18
2002	4	4	15	0	0	3	15
Total	26	12	43	6	31	14	74

[a] Includes release-release pairs and release-wild pairs.

Technique No. 2: Fostering Captive-hatched Nestlings into Wild Broods. During July and August of 2001–03, we fostered captive-hatched nestlings from the Saskatchewan Burrowing Owl Interpretive Centre into wild nests. The Interpretive Centre was located within our study area, and its close proximity to wild owl nests allowed us to minimize travel time (and associated risks to the owls) during transfers. To minimize potentially fatal interactions between siblings (Wellicome 2000), we fostered chicks only into wild broods of comparable ages and chick body masses. The number of owls we fostered depended on the number of owls produced in the captive facility, and the selection of wild nests was limited to those nests of a comparable age to the fostered chicks.

In 2001, we fostered chicks at fledging age, and used radio-transmitters to compare the survival of fostered juveniles with that of a wild sibling from each foster-nest. Each fledgling was banded, mass measured, and fitted with a necklace-style radio-transmitter. The status and location of each radio-tagged juvenile was then recorded every 2–3 d until migration or death.

In 2002 and 2003, we fostered owlets at three different ages; 2–4 d post-hatch, 3 wk post-hatch, and 6 wk post-hatch. Nestlings that were too small to band were marked on their legs and chest feathers with a permanent, non-toxic marker to distinguish them from their wild siblings until we could attach a leg band. To reduce the burden on the wild parents and nestlings, we provided supplemental food (one lab mouse/fostered chick/d) to all foster-nests until fledging. Marti (1973) calculated that adult Burrowing Owls require a mean of 26 g of food per day (in captivity); our lab mice were 20–30 g each, and thus, should have been sufficient to meet the energy needs of a single chick. All nests that received fostered juveniles were in nest boxes; therefore, we were able to capture and measure the mass of fostered and wild juveniles to compare growth rates and body mass gain. We used a paired *t*-test to compare the growth rate of fostered chicks with comparably-sized, wild siblings over the first 24 hr after release. To minimize the amount of disturbance to the nestlings, we measured only during the first 24 hr of nestling growth because we felt this was long enough to indicate whether the introduced chicks were accepted and fed by the foster parents. We were unable to use radio-transmitters to monitor juvenile survival in 2002 and 2003; therefore, survival estimates could only be made by repeated nest visits and visual observations of fostered owls.

In 2002, we also used miniature video cameras (see Poulin 2003 for details on video system assembly) at three release nests to determine if there were any apparent behavioral differences (e.g., begging, feeding, emerging from burrow, predator avoidance) between fostered and wild chicks, and to determine if fostered chicks were accepted by wild parents and nestlings. Fostered chicks were identified on-camera from the mark on their feathers.

RESULTS AND DISCUSSION

Technique No. 1: Releasing Pairs of Captive-reared Adults. *Pairing success and fate.* We released 26 pairs of adult captive-bred owls between 1997 and 2002. Twelve pairs remained together and initiated nests, eight of which fledged young successfully (Table 1). Pairing success appeared to improve with the length of time that enclosures were left in place. When enclosures were left in place for 3 d (1997–99), pairing success ranged from 0% (0 of 6 pairs) to 38% (3 of 8 pairs), with an overall success rate of 22% (4 of 18; Table 1). When enclosures were left in place for 5 d (2000), 4 of 4 pairs remained together. When enclosures were removed only after clutch initiation (2002; $\bar{x}$ = 16.5 ± 5.2 d, N = 4), all four pairs remained together and three pairs successfully raised young.

Six owls (five females, one male) abandoned their release sites immediately after enclosures were removed, but later paired with wild owls in the area. If these pairs are included, pairing success was 58% (30 breeding individuals of 52 owls originally released). However, the formation of the six ''extra'' pairs required the presence of unpaired wild owls in the study area. If this release technique were being used to repopulate an area from which wild owls had been extirpated, pairings of released birds with wild birds obviously would not have occurred.

Of the remaining 22 released owls, 17 abandoned their release sites and were never seen again, three remained alone near the release site and did not breed, and two were killed immediately following release. Of the four ASY owls released, one bred successfully, one failed to breed, and two abandoned their release sites. Over the course of the summers, 10 of the 52 (19%) release-adults were found dead. Sources of mortality included avian predation ($N = 3$ deaths), vehicle collision ($N = 1$), starvation ($N = 2$), and unknown causes ($N = 4$). As transmitters were not used on adults, deaths were discovered opportunistically by finding remains, and therefore, the 19% mortality rate represents a minimum value. The apparent mortality rate of wild adult owls in this area during the breeding season averaged only 3.7% (range = 0–12%, N = 29/780 between 1992–98; T. Wellicome unpubl. data). We can only speculate that the elevated mortality rate we observed ($\chi^2_1 = 26.3$, $P < 0.001$) in released owls may be related to the time spent in captivity, possibly hindering their ability to detect or avoid hazards (Griffin et al. 2000). A similarly high mortality rate (34%, range 10–54%; Leupin and Low 2001) was observed in 1-yr-old Burrowing Owls released in British Columbia after being held in captivity their first winter.

Being held captive for their first winter may also hinder the released adults' ability to migrate successfully (e.g., Mata et al. 2001). In British Columbia, five of 106 1-yr-old, captive-bred and released birds did not migrate, and remained at their release sites throughout the winter (Leupin and Low 2001). In our study, at least five of the 42 released individuals that survived throughout the summer failed to migrate in the fall. Over-wintering in Saskatchewan is not a viable option for Burrowing Owls, because months of snow cover and intense cold make burrows and prey unavailable. It is unclear whether the other released adults in this project migrated successfully; however, over the course of our study 19% (19 of 101) of wild adult Burrowing Owls returned to breed in a subsequent year (L. Todd and R. Poulin unpubl. data), whereas none of the 42 released adult owls ever returned ($\chi^2_1 = 9.1$, $P = 0.003$). Based on the return rate of the wild adult owls, we expected to find between three and 12 released adults returning (chi-square test; $P > 0.05$).

There are many possible explanations for our inability to relocate released owls in subsequent years. Because the owls were in captivity and were prevented from migrating in their first year, perhaps they lost the ability or willingness to migrate. Alternatively, because many of the owls were hatched and raised in Ontario and Alberta and then released in Saskatchewan, they may have migrated south for the winter but then were unable to navigate back to Saskatchewan. Experiments with other species have shown that some displaced birds will migrate back to their location of birth regardless of where they were displaced (e.g., Mewaldt 1964). The above explanations assume that the birds did not migrate successfully, but it is also feasible that the owls did migrate successfully but continued to experience higher than normal mortality during migration and on the wintering grounds. There are few data on the between-year dispersal patterns of Burrowing Owls (e.g., Duxbury 2004); it is possible that our released adults simply relocated. Further studies are required to provide a definitive answer to this question.

Clutch size and productivity. Wild Burrowing Owls exhibit a seasonal decline in clutch size, whereby clutches laid earlier in the season are generally larger than those initiated later (Wellicome 2000). Clutch sizes of released pairs followed this same trend (Fig. 2). Neither the slopes (t-test; $t_{91} = -0.64$, $P > 0.50$) nor the elevations (t-test; $t_{92} = 0.75$, $P > 0.40$; Zar 1996) of the regression lines of seasonal clutch size decline differed between wild and release pairs. Similarly, fledging success (calculated as the proportion of eggs producing a fledgling) did not differ between wild and release pairs (release-release pairs + release-wild pairs compared to wild-wild pairs: $\chi^2_1 = 0.42$, $P = 0.52$; release-release pairs compared to wild-wild pairs: $\chi^2_1 = 2.81$, $P = 0.09$; Table 2).

Post-fledging survival and recruitment of release pair offspring. In 1997, 1998, and 2000, we affixed a radio-transmitter to an offspring from each of eight different release nests (five in 1997, one in 1998, and two in 2000). Radio-transmitters were also placed onto juveniles from wild nests (12 in 1997, 32 in 1998, and 13 in 2000) to compare survival and dispersal behaviors between offspring of wild versus

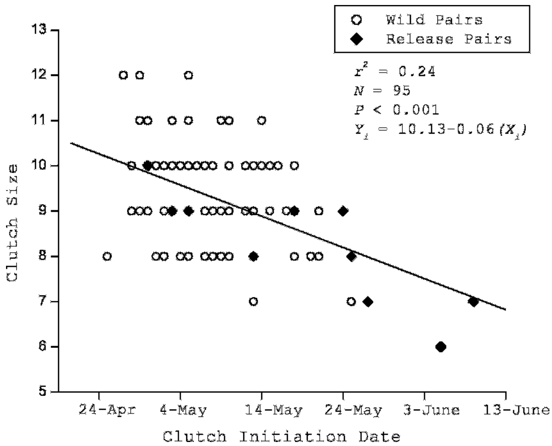

Figure 2. Seasonal decline (common regression equation: Y = 10.13 − 0.06X (r^2 = 0.24, N = 95, P < 0.001) in clutch sizes for wild and captive-released Burrowing Owls. There is no difference in the slope (t_{91} = −0.64, P = 0.5) or elevation (t_{92} = 0.75, P = 0.4) of the regression lines between wild and released owls.

captive-bred adults. Three of the eight (37.5%) juveniles from released parents died before migration; 18 of the 57 (31.6%) juveniles raised by wild parents died over that same period (χ^2_1 = 0.11, P = 0.74). Avian predators were the main cause of mortality for both wild and release juveniles. The similarity in mortality rates and causes suggest that the offspring of captive-bred adults were not affected negatively by their parents' captive upbringing.

Each year we attempted to determine the band status of all Burrowing Owls within our study area. Between 1997 and 2003, 5.3% (35 returns from 658 banded owls) of all wild fledglings returned. Seventy-four fledglings from release nests were produced throughout the 5 yr of this captive release project (Table 1), 62 of which were allowed to attempt migration and potentially return to breed in a subsequent year. Based on the return rate of wild juveniles, we would have expected zero to six juveniles from release nests to return (chi-square, P = 0.05). As of 2003, one fledgling (1.6%) had returned to the breeding grounds in a subsequent year. This fledgling was the offspring of a pair of release birds. With such a low wild recruitment rate, it is difficult to assess whether juveniles from release nests are any less successful at migration than those from wild nests. Statistically, the rates are comparable (χ^2_1 = 1.64, P = 0.20) and we argue that, because at least one owl did migrate and return, these juveniles do have the potential to contribute to the subsequent years' breeding population.

Post-fledging activities of release pair offspring. We found no significant differences in the dispersal activities of juveniles raised by wild or captive-bred parents (Table 3). The offspring of released adults also departed the breeding grounds at the same time as wild owls were migrating, further strengthening the argument that these owls are capable of migrating successfully.

Technique No. 2: Fostering Captive-hatched Nestlings into Wild Broods. *Survival and behavior of fostered juveniles.* Between 2001 and 2003, we fostered 54 captive-hatched juvenile Burrowing Owls into wild nests; 42 as fledglings (6 wk old), six as 3-wk-old nestlings, and six as newly-hatched nestlings (2–4 d old). In 2001, we used radiotelemetry to monitor the survival and movements of nine fledgling-aged foster owls as well as that of a wild sibling from each of the nine foster nests. Although sample sizes were small (N = 9), survival of the fostered fledglings may have been lower than that of their wild siblings: six of the nine fostered juveniles died prior to migration, whereas only two of the nine wild juveniles in these same nests died during the same period (Fisher exact test: P = 0.15). Predation was the main cause of death for both wild

Table 2. Proportion of eggs that resulted in fledged young from captive-bred and wild pairs of Burrowing Owls. These data are derived only from nests that fledged at least one young successfully (e.g., not depredated) and only from nest boxes, where we were able to determine accurately the number of eggs laid and the number of young fledged.

YEAR	RELEASED-RELEASED	RELEASED-WILD	WILD-WILD
1997	38% (10/26)	100% (7/7)	82% (60/73)
1998		86% (12/14)	41% (15/37)
2000	100% (18/18)		80% (37/46)
2002	58% (15/26)		72% (98/137)
Total	61% (43/70)	90% (19/21)	72% (210/293)

Table 3. Comparison of post-fledging dispersal activities between offspring of wild versus captive-bred Burrowing Owls. Values are presented as means ± 1 SE; ranges and sample sizes are presented below means. Statistical differences were tested using 2-tailed *t*-tests.

VARIABLE	OFFSPRING OF WILD ADULTS	OFFSPRING OF RELEASED ADULTS	*P*
Age at initial dispersal (d post-hatch)	50.7 ± 1.8 (33–63, $N = 24$)	49.6 ± 3.8 (39–60, $N = 5$)	0.80
Date of initial dispersal	31 July ± 1.4 (13 Jul–10 Aug; $N = 23$)	4 August ± 3.8 (24 Jul–17 Aug; $N = 5$)	0.20
Closest used satellite burrow (m)	45.3 ± 9.4 (3–210, $N = 24$)	60.6 ± 22.1 (4.8–130, $N = 5$)	0.51
Number of satellite burrows used	5.0 ± 0.5 (2–11, $N = 24$)	4.2 ± 1.2 (0–7, $N = 6$)	0.44
Farthest distance from nest before migration (m)	950.5 ± 356.9 (10–3586, $N = 14$)	177.7 ± 21.3 (110–230, $N = 5$)	0.22
Age at migration (d post-hatch)	104.7 ± 2.7 (76–124, $N = 24$)	102.7 ± 5.6 (78–116, $N = 6$)	0.73
Date of migration	21 Sept ± 2.1 (1 Sept–6 Oct; $N = 24$)	26 Sept ± 3.4 (11 Sept–3 Oct; $N = 6$)	0.29

and fostered juveniles. Mammalian predators killed three fostered juveniles, avian predators were responsible for two deaths, and one died of unknown causes. Both wild juvenile deaths were attributed to avian predators. Higher mortality experienced by fostered juveniles compared to their wild siblings may have been a result of the age at which they were fostered. Burrowing Owl chicks emerge from their burrows as early as 10–12 d post-hatch, at which time they first become exposed to the anti-predator behavior and alarm calls of their parents. Because fostered chicks were released into wild nests at fledging age, they missed up to 4 wk of learning anti-predator behaviors under natural conditions. In 2002 and 2003, we fostered owlets at three different ages: six at 2–4 d post-hatch, six at approximately 3 wk post-hatch, and 33 at 6 wk post-hatch. Unlike in 2001, we were unable to use transmitters to follow the fate of these fostered owlets; however, we observed no indication of predation at any of the nests through weekly nest visits ($N = 5$–7) until the end of August.

In 2002 and 2003, we measured the change in body mass of the six 3-wk-old fostered chicks 24 hr after release, and compared this body mass change to a comparably-sized wild sibling in the same nest. We found no difference in body mass gain between wild and fostered chicks (paired *t*-test, $t_5 = 0.46$, $P = 0.67$). We also measured body mass change in the six nestlings that were 2–4 d old, and found that their growth rates were not different than their wild siblings' within the first 24 hr of release ($\bar{x}_{\text{foster}} = 1.4 \pm 0.16$ g; $\bar{x}_{\text{wild}} = 1.5 \pm 0.13$; Mann-Whitney *U*-test $U_{6,4} = 8.5$, $P = 0.45$). These results suggest that parents fed fostered chicks in the same manner as their wild siblings. Videotaping at three nests confirmed these results, as we observed no apparent differences in the behavior of foster and wild chicks, or in the behavior of the adults toward foster or wild chicks. All three foster chicks were observed receiving food from parent owls within 1 hr of release. In addition, foster chicks emerged from their nest burrows with the brood of wild siblings (i.e., as a group), and responded to predator alert calls from parents in the same manner as wild chicks (i.e., retreating as a group).

The ability to produce Burrowing Owls in captivity is unlikely to be a limiting factor for a recovery program because the species breeds so readily in captivity. However, the release of these captive-bred owls is typically a less successful stage in recovery programs. We acknowledge that opportunistically using the products of a variety of captive breeding facilities resulted in inconsistency in our methodologies, but we believe that our results provide an important first assessment of factors that may be influential for the release of captive-reared Burrowing Owls. Our findings suggest that releasing pairs of captive-bred adults had some limited success—reproductive parameters were similar to wild adults' and at least some of their offspring were capable of migrating and joining the breeding population in subsequent years. A significant limitation of this technique was a lack of evidence that captive-bred owls released as adults could migrate successfully and later return to the breeding grounds. We suggest that if this technique is used, enclosures should be left on until clutch initiation, and part of the protocol should include recapturing captive-bred adults that fail to migrate prior to winter.

Fostering captive-hatched chicks into wild nests with similarly aged young also had some success. The foster chicks were readily accepted by the foster parents, but this technique also has limitations. This technique would require that nest boxes are used if very young chicks are fostered (to match the age of the siblings and to place the nestlings into the nest chamber). Foster parents would have to be provided with supplemental food to compensate for the extra burden placed on the wild brood. There is a limit to the number of 'extra' chicks that can be fostered into wild nests, and of course, there would have to be wild nests in the area into which to foster the captive chicks.

Regardless of the release method, an important consideration before any large-scale reintroduction effort is attempted is to determine the cause of the decline in the wild population. Obviously, if factors negatively affecting the wild population have not been adequately addressed, releasing captive-bred individuals may do little to halt the decline.

ACKNOWLEDGMENTS

This project was funded by Wildlife Preservation Trust Canada, and World Wildlife Fund Canada and Environment Canada's Endangered Species Recovery Fund, with support from Science Horizons, Saskatchewan Environment's Fish and Wildlife Development Fund, Nature Saskatchewan, TransCanada Pipelines, TransGas, Interprovincial Pipeline Inc., Foothills Pipelines, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the University of Regina Faculty of Graduate Studies and Research. We thank J. Skilnick, K. Dohms, R. Fisher, and R. Sissons for assistance with fieldwork. Captive owls (adults) were provided by the Owl Foundation and the Alberta Birds of Prey Foundation. Nestlings and fledglings were provided by the Saskatchewan Burrowing Owl Interpretive Centre. The manuscript was improved significantly by the suggestions of D. Hjertaas, S. Sheffield, and anonymous reviewers.

LITERATURE CITED

DE SMET, K.D. 1997. Burrowing Owl (*Speotyto cunicularia*) monitoring and management activities in Manitoba, 1987–1996. Pages 123–130 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the northern hemisphere: second international symposium. USDA Forest Service, Gen. Tech. Rep. NC-190, St. Paul, MN U.S.A.

DESMOND, M.J., J.A. SAVIDGE, AND T.F. SEIBERT. 1995. Spatial patterns of Burrowing Owl (*Speotyto cunicularia*) nests within black-tailed prairie dog (*Cynomys ludovicianus*) towns. *Can. J. Zool.* 73:1375–1379.

DUXBURY, J.M. 2004. Stable isotope analysis and the investigation of the migrations and dispersal of peregrine falcons (*Falco peregrinus*) and Burrowing Owls (*Athene cunicularia*). Ph.D. dissertation, University of Alberta, Edmonton, AB Canada.

GAUTHIER, D.A., L. PATINO, AND K. MCGOVERN. 2002. Status of native prairie habitat, prairie ecozone, Saskatchewan. Canadian Plains Research Centre Project 8.65A.IR-01/02. University of Regina, Regina, SK Canada.

GRIFFIN, A.S., D.T. BLUMSTEIN, AND C.S. EVANS. 2000. Training captive-bred or translocated animals to avoid predators. *Conserv. Biol.* 14:1317–1326.

HARRIS, W.C., A. KABZEMS, A.L. KOSOWAN, G.A. PADBURY, AND J.S. ROWE. 1983. Ecological regions of Saskatchewan. SK Parks and Renewable Resources, Tech. Bull. 10.

HOLROYD, G.L., R. RODRÍGUEZ-ESTRELLA. AND S.R. SHEFFIELD. 2001. Conservation of the Burrowing Owl in western North America: issues, challenges, and recommendations. *J. Raptor Res.* 35:399–407.

JAMES, P.C., T.J. ETHIER, AND M.K. TOUTLOFF. 1997. Parameters of a declining Burrowing Owl population in Saskatchewan. Pages 34–37 *in* J.L. Lincer and K. Steenhof [EDS.], The Burrowing Owl, its biology and management including the proceedings of the first international Burrowing Owl symposium. Raptor Research Foundation, Raptor Research Report No. 9.

LEUPIN, E.E. AND D.J. LOW. 2001. Burrowing Owl reintroduction efforts in the Thompson-Nicola region of British Columbia. *J. Raptor Res.* 35:392–398.

MARTELL, M.S., J. SCHLADWEILER, AND F. CUTHBERT. 2001. Status and attempted reintroduction of Burrowing Owls in Minnesota, U.S.A. *J. Raptor Res.* 35:331–336.

MARTI, C.D. 1973. Food consumption and pellet formation rates in four sympatric owl species. *Wilson Bull.* 85:178–181.

MATA, A.J., M. CALOIN, D. MICHARD-PICAMELOT, A. ANCEL, AND Y. LE MAHO. 2001. Are non-migrant white storks (*Ciconia ciconia*) able to survive a cold-induced fast? *Comp. Biochem. Physiol. A Comp. Physiol.* 130:93–104.

MEWALDT, L.R. 1964. California sparrows return from displacement to Maryland. *Science* 146:941–942.

POULIN, R.G. 2003. Relationships between Burrowing Owls (*Athene cunicularia*), small mammals, and agriculture. Ph.D. dissertation, Univ. Regina, Regina, SK Canada.

———, T.I. WELLICOME, R. LONGMUIR, AND D. SCOBIE. 1998. Burrowing Owl nest box construction and installation procedures. Saskatchewan Environment & Resource Management, Fish & Wildlife Branch.

SHEFFIELD, S.R. 1997. Current status, distribution, and conservation of the Burrowing Owl (*Speotyto cunicularia*) in midwestern and western North America. Pages 399–407 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the northern hemisphere: second international symposium. USDA Forest Service, Gen. Tech. Rep. NC-190, St. Paul, MN U.S.A.

TODD, L.D. 2001. Survival and dispersal of juvenile Burrowing Owls (*Athene cunicularia*) during the post-fledging, pre-migratory period. M.S. thesis, Univ. Regina, Regina, SK Canada.

———, R.G. POULIN, T.I. WELLICOME, AND R.M. BRIGHAM. 2003. Post-fledging survival of Burrowing Owls in Saskatchewan. *J. Wildl. Manage.* 67:512–519.

WELLICOME, T.I. 2000. Effects of food on reproduction in Burrowing Owls (*Athene cunicularia*) during three stages of the breeding season. Ph.D. dissertation, Univ. Alberta, Edmonton, AB Canada.

——— AND E.A. HAUG. 1995. Second update of status report on the Burrowing Owl (*Speotyto cunicularia*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON Canada.

———, G.L. HOLROYD, K. SCALISE, AND E.R. WILTSE. 1997. The effects of predator exclusion and food supplementation on Burrowing Owl (*Speotyto cunicularia*) population change in Saskatchewan. Pages 487–497 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the northern hemisphere: second international symposium. USDA Forest Service, Gen. Tech. Rep. NC-190, St. Paul, MN U.S.A.

——— AND G.L. HOLROYD. 2001. The second international Burrowing Owl symposium: background and context. *J. Raptor Res.* 35:269–273.

ZAR, J.H. 1996. Biostatistical analysis, 3rd Ed. Prentice Hall, Upper Saddle River, NJ U.S.A.

Received 21 February 2005; accepted 18 February 2006