

**The effects of release techniques on the reproductive performance and post-fledging  
juvenile survival of captive-bred Western Burrowing Owls (*Athene cunicularia hypugaea*)  
in the Nicola Valley, British Columbia**

**by**

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## **ABSTRACT**

Reintroduction of captive-bred Western Burrowing Owls (*Athene cunicularia hypugaea*) in the Nicola Valley, British Columbia, has had limited success in increasing the local breeding population. Traditionally, yearling captive-hatched Burrowing Owls that were paired and released into artificial burrows in the field, held overnight, and provided with supplemental food throughout the breeding season (hard release) have had high post-release dispersal and mortality. In 2005 and 2006, I used an alternative soft-release technique to test for an improvement upon the hard-release technique. The soft release followed the same procedure as the traditional hard release but also included enclosures around burrow entrances to contain the owls for a 2-week period in the field prior to release. I compared immediate post-release dispersal, seasonal survival, and reproductive success for 37 hard-released and 30 soft-released pairs. I radio-tagged 39 of these released owls in order to accurately monitor their activities, regardless of whether they remained at release sites or dispersed. The soft-release technique led to 20% more owls remaining at the release sites, 14% more owls surviving the breeding season, and 20% more owl pairs fledging juveniles.

In addition to investigating adult survival and reproductive success, I examined post-fledging juvenile survival, local recruitment, and habitat use, and adult prey consumption behaviour in order to assess the potential of these aspects to limit the success of the reintroduction. Survival and local recruitment rates of the juveniles of captive-bred adults released with two different techniques were similar to that of juveniles of wild adults in the same study area or in other parts of the Burrowing Owl's range. Juvenile habitat-selection analyses identified the importance of rangeland, and comparisons of prey consumption revealed the rapid development of foraging abilities by captive-bred Burrowing Owls. I concluded that these aspects of the owl's ecology were not negatively affected by a captive upbringing, and therefore not likely limiting the success of the reintroduction.

Overall, the use of an enclosure-based soft-release technique addresses major limitations to the success of releases, and shows promise for increasing the breeding population in this region. This approach can also be applied to recovery efforts throughout the Burrowing Owls' range, and provide guidelines for other species' reintroduction programs.

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## **CO-AUTHORSHIP STATEMENT**

I identified and designed the majority of the research project, conducted the research, analyzed the data, and prepared the manuscript. As co-authors on the two manuscript chapters, Troy Wellicome and Kim Cheng provided direction in the experimental design on some portions of the project, advised on data analyses, and reviewed the manuscript in great detail.



## **CHAPTER ONE. Introduction**

### **RESEARCH TOPIC**

A main goal of most reintroduction programs is to create self-sustaining populations that display behaviours expected of wild populations (Meretsky et al. 2001). An increased emphasis on reintroduction has provided opportunities to improve its effectiveness via research, but relatively few programs include monitoring to identify the key causes of failure (Bright and Morris 1994, Mathews et al. 2005, Seddon et al. 2007). To date, most failed reintroduction programs identify problems with a released animal's ability to adapt rapidly to wild conditions, including predation, disease, and competition. To contribute to self-sustaining populations, released animals must survive long enough to leave offspring that breed (Mathews et al. 2005). Studies thus far indicated that demographic factors, such as low post-release survival, breeding success, and recruitment, reduced the success of reintroduction efforts (Kleiman 1989, Snyder et al. 1994, Balmer et al. 2000, Ellis et al. 2000, White et al. 2005). Several characteristics of reintroductions are already known to influence these parameters and, thus, to limit the success of recovery projects.

### **Age and seasonal movements**

Two factors that can contribute to poor success in reintroductions include age of released individuals and seasonal movement patterns of the species being reintroduced. Reintroductions that have used sexually mature animals, which have the potential to breed soon after release, have shown better results than releases that have used immature animals (Griffon Vultures *Gyps fulvus fulvus*, Sarrazin et al. 1994; Aldabra Rails *Dryolimnas [cuvieri] aldabranus*, Wanless et al. 2002). Small populations, which are typical in most reintroductions, are particularly vulnerable to extinction or lack of re-establishment when reproductive success is low. Even one season of poor breeding success in small populations (e.g., island raptor populations) can be sufficient to significantly reduce recruitment, and eventually cause extinctions, in part, by increasing the likelihood of permanent emigration in a migratory species (Hunt and Hunt 1974). In other words, animals that migrate without breeding in the release area are less likely to return the following year to become part of the local breeding population than ones who do breed before migrating. In addition, the lack of breeding at release sites limits the number of young that would have the potential to become new recruits.

## **Source of animals**

One important factor determined early in a reintroduction program is the source of release animals. Source-animals used in any reintroduction effort can be either translocated wild-caught or captive-bred. Because the main focus of reintroductions is to quickly boost species populations, little attention has been paid to assessing the influence of the source of the animals (Snyder et al. 1994), and in some cases animals from both origins are used in the same reintroduction (De Smet 1997).

The term “translocation” has been used to refer to releasing animals of either origin into the wild to establish, re-establish, or supplement a population (Bright and Morris 1994, Wolf et al. 1996). Because of this, it has become difficult to determine for many reintroductions how results were affected by the source of animal used. In one of the few comparisons made (Wolf et al. 1996), there was no relationship between reintroduction success and source of animals used, suggesting the two sources performed similarly. However, in another case, there was an indication that the use of “translocated” (wild-caught) animals instead of “captive-bred” animals may have reduced the success of the reintroduction effort (Morris et al. 1993).

Translocated animals can have higher initial success than released captive-bred animals in some releases (Griffith et al. 1989); however, appropriately released captive-bred animals often perform better than translocated animals, and just as well as wild animals, within a few weeks of release (Bright and Morris 1994, White et al. 2005, Poulin et al. 2006). Translocated animals, particularly those that do not breed at their release site, also typically show higher immediate and future dispersal than captive-bred ones (Bright and Morris, 1994). Recovery planning for reintroductions using translocated animals can also be challenging because it is often uncertain how many animals can be captured and relocated.

When captive-bred animals are used, reintroduction programs typically have more control over the number of animals to be released. This enables the development of better modelling approaches and experimental designs. The initial goal for many captive breeding programs is to provide the maximum number of animals for release. Increasing the productivity of a captive population aids in providing a stable resource from which to draw individuals. However, it does not address the major management problems, defined by Meretsky et al. (2001) as a lack of stability in the wild population and the behavioural problems of released animals that are present in many reintroductions of captive-bred animals. Because of this, it is important to place emphasis on improving the success – here measured in terms survival, reproduction, and subsequent recruitment – of animals once they are released. A limited number of studies have

been conducted to improve the use of captive-bred animals in reintroductions (Seddon et al 2007).

### **Release methods**

Despite other factors having important impacts, evidence suggests that the most significant contributor to the low survival, low breeding success, and low recruitment rates observed in reintroductions is the manner in which animals are released (Kleiman 1989, Bright and Morris, 1994). Release methods include hard release, in which animals receive no aid prior to or after release, and soft release, which involves some assistance with adjusting to post-release conditions. This assistance may include pre-release training, supplemental feeding, and temporary housing at the release site.

Results from behavioural comparisons between translocated and captive-bred animals are similar to those from comparisons made between hard-released and soft-released animals. As with translocated animals, hard-released animals often have high dispersal and frequent mortality occurring soon after release (O'Bryan and McCullough 1985, Morris et al. 1993). Similar to what has been noted with captive-bred animals, soft-released animals may take a few weeks to become established, but then often show performance and survival comparable to wild populations (Kleiman 1989, White et al. 2005, Poulin et al. 2006).

Previous research suggests that the use of captive-bred animals that are soft released often works better, particularly for reintroduction of avian species. Reintroductions of avian species have more commonly used captive-bred animals (Fischer and Lindenmayer 2000). Typically, some form of the soft-release technique is used because of the consequences of captivity for avian species: the energetic cost of learning to fly, the necessity to learn to feed in the wild, and behavioural problems for most imprinted birds (Sarrazin et al. 1994).

Many carnivorous bird species, including Peregrine Falcons *Falco peregrinus*, Bald Eagles *Haliaeetus leucocephalus*, and California Condors *Gymnogyps californianus*, have been soft released with the method referred to as "hacking." This method involves providing food at release sites where individuals are free to come and go (Meyers and Miller 1992, Tordoff and Redig 2001, Woods et al. 2007). Young birds that are hacked are hatched in captivity, often released in juvenile groups, and provided with food while learning to hunt.

For these species, hacking with juvenile birds has had some success. However, high mortality from predation is typically a more pressing concern than mortality from inefficient food-acquisition skills when reintroducing many species that are vulnerable to predation (Griffin

et al. 2000). Indeed, soft-release techniques that have temporally included predator protection, through pens or aversion training, in addition to supplemental food have benefited many avian reintroductions (Mallards *Anas platyrhynchos*, Gatti 1981; Thick-billed Parrots *Rhynchopsitta pachyrhyncha*, Snyder et al. 1994; Sandhill Cranes *Grus canadensis*, Ellis et al. 2000; Aldabra Rails, Wanless et al. 2002).

## **Summary**

Based on prior evidence, it appears that a promising method to improve the success of reintroductions, especially for avian species, would be to use captive-bred animals that are capable of breeding in the year released. However, most critical to maximizing the success of reintroductions is the use of a soft-release method of introducing animals to a novel environment. The information suggests that a strategy that utilizes a soft-release method would best accomplish the goals of increasing the number of released animals that remain, survive, and breed at the release sites, and of increasing the number of animals (both released and wild-hatched) that return to breed. Accomplishing these goals would ultimately aid in creating a self-sustaining population of a threatened or an endangered species in the region where reintroduction is taking place.

## **STUDY SPECIES**

The Western Burrowing Owl (*Athene cunicularia hypugaea*) is a small raptor that lives in the abandoned burrows of fossorial mammals, or in man-made burrows (De Smet 1997, Leupin and Low 2001). Fossorial mammals such as Black-tailed Prairie Dogs (*Cynomys ludovicianus*), American Badger (*Taxidea taxus*), Ground Squirrels (*Spermophilus spp.*), and Yellow-bellied Marmots (*Marmota flaviventris*) typically provide burrows for Burrowing Owls in Canada (Haug et al. 1993, Environment Canada 2008). Pipes, culverts, and artificial burrows are examples of man-made structures that Burrowing Owls also use to nest or roost (D. Brodie, Burrowing Owl Conservation Society, pers. comm., Haug et al. 1993).

This owl species has brownish plumage, bright yellow eyes, a rounded head, and noticeably long legs (Environment Canada 2008). In addition to grasslands, steppes, prairies, and desert regions, the Burrowing Owl has been known to frequent open, short-grass areas of agricultural lands, airports, golf courses, jetties, spits, and coastal sand dunes littered with logs (Campbell et al. 1990, Commission for Environmental Cooperation 2005).

The life history strategy of Burrowing Owls consists of high fecundity and a short average life span of 1-6 years (Todd and Skilnick 2002, Poulin 2003, Environment Canada 2008). A Burrowing Owl clutch averages 9 eggs, but can range from 6 to 12 in Canada. Incubation lasts approximately 30 days, and hatching occurs asynchronously (Wellicome 2000, Wellicome 2005). Hatchlings are altricial, but within 10-15 days become mobile enough to venture outside their burrow entrances (Wellicome 2005). At 5-6 weeks of age juvenile Burrowing Owls are capable of sustained flight, and often begin to disperse from their natal burrow (Wellicome 1997, Todd 2001). However, they may also remain near their natal burrow until just prior to migration (Todd 2001)

In Canada, both juvenile and adult Burrowing Owls leave the breeding grounds for migration some time between late summer and early fall. However, some individuals, particularly males, are resident year round in the southern United States (U.S.) and Mexico (Commission for Environmental Cooperation 2005). Although there is a lack of information on complete migration patterns, recovery and sighting records have indicated owls from Canadian provinces travel to the southern U.S. and venture as far as central Mexico to overwinter (Commission for Environmental Cooperation 2005, COSEWIC 2006).

## **SPECIES STATUS**

The Western Burrowing Owl has been experiencing an overall population decline and retraction of its range throughout Canada (Wellicome and Haug 1995). The breeding range of Burrowing Owls in Canada has shrunk in recent years to less than one-half of the range occupied in the 1970s, and only one-third of the range occupied in the early 1900s (COSEWIC 2006). This decline was considered dramatic enough in 1995 to cause the Committee on the Status of Endangered Wildlife in Canada to change the national designation of the species to Endangered (COSEWIC 1995).

Burrowing Owls have declined in other parts of their North American range. In the U.S., Burrowing Owls continue to decline in many states (Holroyd et al. 2001). The Burrowing Owl is a U.S. Fish and Wildlife Service Bird of Conservation Concern in all three regions that contain grasslands and deserts. It has also been state-listed as Threatened, Endangered, or a Species of Special Concern in 18 U.S. states. In Mexico, the Burrowing Owl is listed as Threatened (McIntyre 2004, Commission for Environmental Cooperation 2005).

There is no singular cause that has led to the decline of Burrowing Owls. A variety of factors such as habitat destruction and loss, burrow loss from decreased fossorial mammal

populations, decreasing prey populations, and increasing predation pressures all likely contribute to the overall decline. Additional factors, including poor weather conditions, collisions with vehicles, and environmental contaminants, have also been implicated in declines (Environment Canada 2008).

## **THESIS OVERVIEW**

### **Background**

Several attempts have been made to reintroduce or release Burrowing Owls to supplement small wild populations within historical ranges (Table 1.1). Reintroduction efforts have employed a variety of techniques. Although both translocated (wild-caught) and captive-bred owls have been used in these reintroduction efforts, the use of the latter has increased. Reintroduction efforts involving translocated owls have been discontinued in all areas because of low reproductive output and low return rates (De Smet 1997, Leupin and Low 2001, Martell et al. 2001). Despite some success using translocated family groups to re-establish breeding owls in the South Okanagan Valley in British Columbia, this program was discontinued and monitoring activities ceased in 1994 (Dyer 1991, Leupin and Low 2001).

With the establishment of a captive-breeding program in British Columbia in 1989, subsequent reintroduction efforts have been able to rely on this local source of owls for release. Because Burrowing Owls readily breed in captivity, captive propagation of the species has not limited the success of recovery programs (Poulin et al. 2006).

Although traditionally-released captive-bred owls have been provided with supplemental food, the immediate appearance of hunting ability in released owls has been noted (Leupin et al. 1999). This gives some indication that the ability of captive-bred Burrowing Owls to forage in the wild probably has not limited reintroduction success.

Released captive-bred Burrowing Owls have survived at release sites, raised broods, successfully over-wintered or migrated, and returned to breed (Leupin and Low 2001, Poulin et al. 2006). However, high mortality following release has significantly affected the success of the British Columbia recovery effort (Leupin and Low 2001).

Other programs and studies have provided valuable insights about release techniques of captive-bred Burrowing Owls that could aid in reducing post-release mortality and improving breeding success. In particular, enclosure-based soft releases already have shown some benefits for Burrowing Owls (Dyer 1991, De Smet 1997, Poulin et al. 2006). In trials with this type of soft-release technique in Saskatchewan, owls were more likely to complete a clutch and stay at

the release site (Poulin et al. 2006). In Manitoba, higher success rates were also observed when released owls were held for approximately 1 week, rather than being released without an enclosure (De Smet 1997). Although not compared directly with a hard-release technique, the moderate success of releases in British Columbia from 1983-1988 (Dyer 1991) may be explained, in part, by the use of soft-release pens.

**Table 1.1.** Burrowing Owl release and reintroduction efforts throughout North America from 1983 to 2004.

| Release study                                    | Source of owls   | Release method               | No. released | No. offspring (per released adult) | No. recruited (prop. of released owls) |
|--|--|------------------------------|--------------|------------------------------------|--|
| Manitoba<br>De Smet<br>1987-1991                 | translocated family groups/hatch-year young from ORRF (ON), SK, and ND | enclosure-based soft release | 176          | 0                                  | 1 (<1%)                                |
| Manitoba<br>De Smet<br>1992-1994 and 1996        | captive-bred yearlings from ON and AB                                  | enclosure-based soft release | 62           | 9 (0.1)                            | 1 (1.6%)                               |
| Manitoba<br>De Smet<br>1995                      | captive-bred yearlings from ON and AB                                  | hard release                 | 7            | 0                                  | 0                                      |
| Minnesota<br>Martell<br>1986-1990                | translocated hatch-year young from SD                                  | enclosure-based soft release | 105          | 0                                  | 0                                      |
| Saskatchewan<br>Poulin<br>1997-2000 and 2002     | captive-bred yearlings and ASY from ON, AB, and SK                     | enclosure-based soft release | 52           | 74 (1.4)                           | 1 (1.9%)                               |
| Okanagan Valley, BC<br>Dyer<br>1983-1988         | translocated family groups from WA                                     | enclosure-based soft release | 257          | 25 (0.5)                           | 27 (10.5%)                             |
| Nicola Valley, BC<br>Leupin and Low<br>1992-1997 | captive-bred yearlings in BC   | hard release                 | 108          | 28 (0.3)                           | 6 (5.5%)                               |
| Nicola Valley, BC<br>Brodie<br>2001-2004         | captive-bred yearlings in BC   | hard release                 | 201          | 164 (0.8)                          | 34 (16.9%)                             |

In a Saskatchewan experiment, pairs of mature owls were placed in enclosures that were left over nests for varying amounts of time depending on the year (3 days, 5 days, or until clutch initiation; Poulin et al. 2006). Highest success was observed in 2002, when enclosures were left until clutch initiation, perhaps because the breeding pair then had a significant investment and was more likely to stay to raise a brood. The enclosures may also have provided a period of adjustment, and therefore increased the likelihood of owls remaining at release sites. The release of birds capable of immediately breeding, rather than the release of pre-bred adults or of hatch-year juveniles, also presumably contributed to the nesting success observed.

### **Thesis Objectives**

The overall goal of my study was to maximize reintroduction success, and thus improve the chances of Burrowing Owl population recovery in British Columbia. The primary objective was to test a potentially superior release technique (Chapter 2). For this objective, the parameters in which I was most interested were the numbers of captive-bred owls remaining at release sites after release, their survival, their nesting and fledging success, and their subsequent local recruitment. Furthermore, I studied the survival of post-fledging juvenile owls to ensure that any reproductive benefits of using the soft-release technique for captive-bred adults were not countered by differential juvenile survival (Chapter 3). The secondary objective of my study was to determine if other behaviours and activities might be reducing the potential for success of reintroductions, and then to make management recommendations for further maximizing reintroduction success. To accomplish this, I assessed the hunting ability of released owls by making a formal comparison of prey consumption by captive-bred and wild owls (Appendix A), and studied the habitat-use patterns of post-fledging juvenile owls (Appendix B).

### **Thesis Predictions and Implications**

I predicted that adults released with the soft-release technique would be more likely to remain on site and survive the breeding season, and would experience higher current reproductive output. I predicted that this increased probability of remaining to successfully breed would lead to an increased probability of adults returning in subsequent years and, thus, increase future local reproductive output. Although post-fledging juvenile owl survival had not been studied in this area before, previous anecdotal observations did not indicate higher than expected mortality. Therefore, I did not expect juvenile survival to be at a level that would reduce the improved success resulting from the use of the soft-release technique. I predicted that the soft-release



technique would increase the success of reintroductions overall, and therefore would be incorporated into owl-releasing practices in British Columbia.

My study provides a more rigorous, multi-year test of the enclosure-based soft-release technique described in Poulin et al. (2006), and assesses additional potential limits to the success of Burrowing Owl reintroductions. The information gathered in my study has important implications, not only for the future of reintroduction efforts in British Columbia, but also for Burrowing Owl populations throughout their historical range. The development of a tested and successful release technique adds to the field of reintroduction research by being applicable in other parts of the Burrowing Owl's range to aid in recovery, and by providing guidelines for other species recovery programs considering reintroductions.

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## **CHAPTER TWO. Influence of release techniques on survival and reproductive performance of captive-bred Burrowing Owls in British Columbia<sup>1</sup>**

### **INTRODUCTION**

The Western Burrowing Owl (*Athene cunicularia hypugaea*) has declined dramatically within its former range in western North America, resulting in its extirpation from some provinces and states, and has been recognized by the tri-national Commission for Environmental Cooperation (2005) as a species at risk. Releases of Burrowing Owls to reintroduce or augment wild populations have been attempted in Manitoba, Minnesota, and British Columbia (Dyer 1991, De Smet 1997, Blood and Low 1998, Leupin and Low 2001, Martell et al. 2001), usually involving the capture and translocation of owls from stable populations to release sites within the historical range. In most of these cases, wild families of adults and young, pre-flying juveniles, or families from rehabilitation centres were translocated (Dyer 1991, De Smet 1997, Martell et al 2001). In each case, however, poor reproduction and low return rates lead to the discontinuance of Burrowing Owl translocations.

Despite this lack of success in Burrowing Owl translocation, there are some examples of translocated animals being re-established (Kleiman 1989, Bright and Morris 1994, Wolf et al. 1996). However, evidence from other reintroduction efforts suggests that translocating juveniles and family groups where adults have already bred (as done in Burrowing Owl translocations), may reduce reintroduction success (Morris et al. 1993, Sarrazin et al. 1994, Wanless et al. 2002).

Because of the low success observed in the reintroduction of translocated owls, and the increasing difficulty of obtaining wild owls from other locations, current reintroduction efforts typically rely on captive-bred birds to restore Burrowing Owl populations (e.g., Leupin and Low 2001). Burrowing Owls breed readily in captivity (Poulin et al. 2006), but post-release mortality (typically within a few weeks post-release) and poor productivity have limited the contribution of released owls to the wild population (Leupin and Low 2001).

In addition to using different sources of animals (translocated wild-caught or captive-bred), various release techniques have also been attempted in reintroductions of Burrowing Owls. Many Burrowing Owl reintroduction attempts have placed owls at their release site with immediate access to their release environment, while providing supplemental food (De Smet 1997, Leupin and Low 2001). This technique of “hacking” often has been used in the release of carnivorous birds, such as Peregrine Falcons *Falco peregrinus* (Tordoff and Redig 2001), Bald

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<sup>1</sup> A version of this chapter will be submitted for publication. Mitchell, A. M., T. I. Wellicome and K. M. Cheng. Influence of release techniques on the survival and reproductive performance of captive-bred Burrowing Owls.

Eagles *Haliaeetus leucocephalus* (Meyers and Miller 1992), and California Condors *Gymnogyps californianus* (Woods et al. 2007). However, high mortality from predation is typically a more pressing concern than mortality from inefficient food acquisition when reintroducing a species, like the Burrowing Owl, that is vulnerable to predation (Griffin et al. 2000).

Burrowing Owl reintroduction attempts that, in addition to hacking confined owls in the field for some time after release often had higher success (more owls breeding or recruiting to the population; Dyer 1991, DeSmet 1997, Martell et al. 2001). In a Saskatchewan experiment, pairs of mature owls were placed in enclosures that were left over nests for varying amounts of time depending on the year (3 days, 5 days, or until clutch initiation; Poulin et al. 2006). Highest success was observed in 2002, when enclosures were left until clutch initiation, perhaps because the breeding pair then had a significant investment and was more likely to stay to raise a brood.

Because the small wild population in British Columbia now relies on annual reintroductions of owls from local captive-breeding facilities, the use of enclosures would probably improve the success of current reintroduction efforts in British Columbia. My study further investigated effects of release technique on captive-bred Burrowing Owls to provide recommendations for maximizing reintroduction success. I accomplished this by placing a subset of paired yearling owls in enclosures until midway through their laying cycle (the soft-release method), while the remaining pairs were released without an enclosure (the hard-release method). The main objectives of my study were to 1) determine if a soft-release technique was an improvement on a traditional hard-release technique by examining the post-release activities, survival, and productivity of captive-bred yearling Burrowing Owls, and by making comparisons with other released and wild owls, and 2) compare the return and overwintering rates of captive-bred Burrowing Owls and their progeny from the two different release techniques with the rates of other released and wild owls.

## **STUDY AREA**

The study area was located in the Nicola Valley in the Southern Interior Ecoprovince of British Columbia (BC Ministry of Forests 1992). This valley is in the Thompson basin vegetation zone (Parish et al. 1996), between Merritt and Kamloops, near Highway 5A which follows the valley bottom. There is a gradual transition from very hot and dry lower grasslands to cool and moist upper grasslands. Shrub-steppe communities, dominated by big sage and bluebunch wheatgrass, occur at the lowest elevations in this region (biogeoclimatic unit BGxh2; Grassland Conservation Council of BC 2004).

Within the Nicola Valley, release sites were in a variety of grassland habitat types, typically on private lands. Sites were grazed and often contained introduced, weedy plant species (Parish et al. 1996). The planting of forage grass and cereal crops, such as crested wheatgrass, alfalfa, and barley (Ministry of Agriculture, Food and Fisheries 2002), has created a fragmented landscape (Leupin 2004), with natural grassland areas remaining largely on sloped land where planting or mechanized alteration of vegetation is difficult.

## **METHODS**

### **Pre-release preparation**

I attempted to determine the sex and identity of any returning wild owls in late-March, and used the sex and location of returning owls to determine the number of singles (to potentially pair with returning wild birds) and pairs to be released in each release site. Returning owls were previously released adults, wild-hatched juveniles, or occasionally unbanded owls of unknown origin. I defined all returning owls as “wild owls” because they had survived at least one year in the wild. I waited until later in the season (after hatching, between late-June and early-July) before attempting to band owls of unknown origin to avoid disturbing their settlement.

Owls at the two existing breeding facilities in British Columbia (Leupin et al. 1999) were raised as family groups, in isolated pens, until juveniles reached at least 4 weeks old. After this time, all families were allowed to use a communal flyway. Prior to spring, juvenile owls at breeding facilities were captured, bled for sexing, and separated into male and female communal pens. Based on genetic sexing, owls were paired immediately in advance of release, mixing birds from the two facilities.

To prepare them for placement in the field, I banded each yearling owl with one U.S. Fish and Wildlife Service aluminium band and one coloured Acraft band for individual identification. In 2006, I affixed harness-style radio-tags (Holohil Systems Limited, Carp, Ontario, Canada, Model BD-2) to 39 adults prior to their release. With elastic attachment material included, radio-tags weighed approximately 3 g, which is ~2% of average adult body weights. I attached two-thirds ( $n = 28$ ) of the radio-tags to hard-released birds and approximately one-third to soft-released birds. I placed twice as many tags on hard-released birds because results in 2005 showed that hard-released birds were twice as likely to leave the study site and thus have unknown fates. I also evenly distributed radio-tags between males ( $n = 18$ ) and females ( $n = 21$ ) and among the different release sites. I paired owls just prior to transport to the release sites, and placed all pairs in the field on the same day (the third weekend in April) in both



years. All procedures in my study were approved by the Animal Care Committee of the University of British Columbia (Protocol # A05-0470) (see Appendix C).

## **Release techniques**

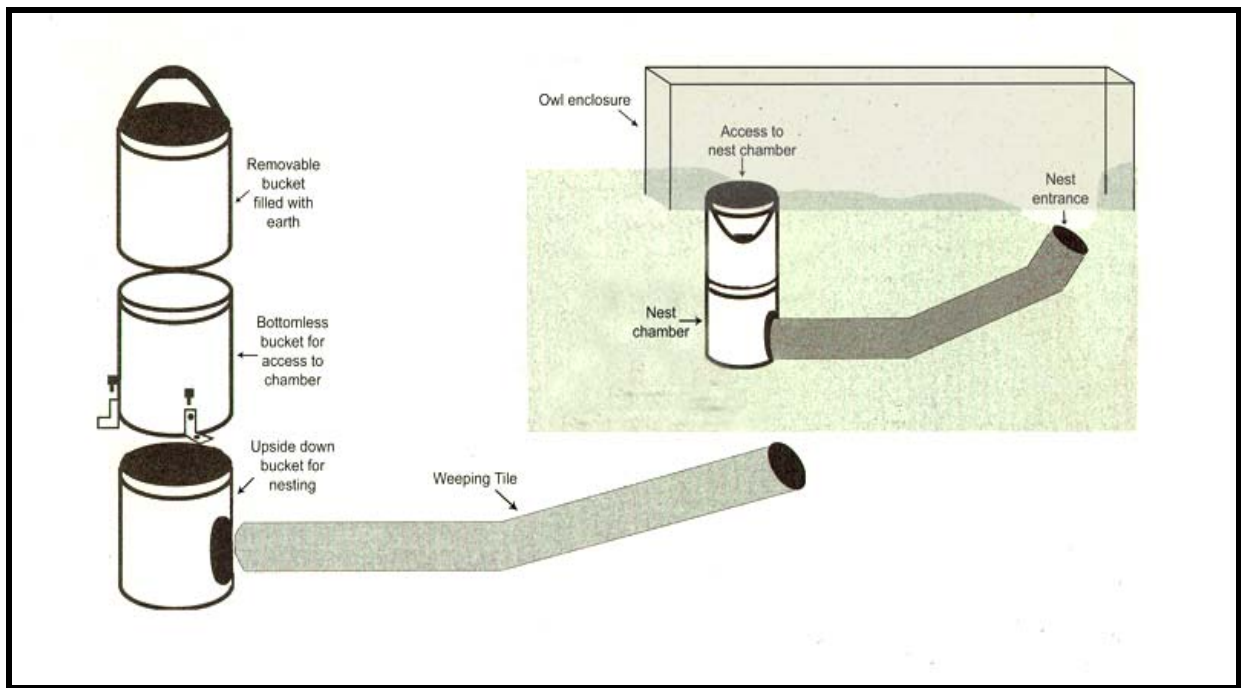
### Hard release

I hard released yearling owl pairs by placing them inside nest chambers of artificial burrows with blocked outer entrances and held them overnight, as had traditionally been performed in releases in British Columbia (Leupin and Low 1999 and 2001, D. Brodie, Burrowing Owl Conservation Society, pers. comm.). Artificial burrows consisted of 2- to 3-m plastic tunnels attached to a nest bucket, all of which was buried underground. Only the entrance to the tunnels and the top of an investigator-access chute that lead to the nest chamber were visible above ground (Figure 2.1).

### Soft release

I installed predator-proof enclosures, built using 1.2×1.2×2.0-m wooden frame covered with strong nylon mesh, over randomly-selected artificial burrows immediately prior to the placement of owls at the release sites in the middle of April. Because some enclosures were destroyed by cattle in 2005, I used electric fencing in 2006, set back approximately 1 m from the enclosure, in fields that contained cattle at the time of release. Electric fencing proved to be a safe and effective cattle deterrent (Figure 2.1). I released owls in the same manner as in the hard release, but placed pairs inside artificial burrows with the enclosures already installed. I attempted to use both hard-release and soft-release techniques equally among the varying release sites, ensuring that the two treatments were entirely interspersed in space (Table 2.1).

In 2005, I attempted to remove enclosures from burrows housing soft-released pairs during mid-clutch, after 4 to 5 eggs had been laid, to ensure a true breeding attempt. Enclosures were removed at this time rather than clutch initiation (i.e., the appearance of 1 egg) because some captive-bred females in British Columbia have been known to be gravid prior to release and subsequently dump their eggs (P. Williams BC Wildlife Park, and D. Brodie pers. comm.). However, waiting for mid-clutch resulted in several enclosures being left on unnecessarily for pairs that did not successfully lay eggs. In 2006, I removed all enclosures at approximately 2 weeks ( $\bar{x} = 17.7 \pm 1.4$  d, for 5 eggs to be laid in 2005) after placement in the field. Removing the enclosures required approximately 15 minutes. I disturbed hard-released and wild pairs for an equivalent amount of time on the same days to keep disturbance consistent between treatments.



**Figure 2.1.** Enclosure used in British Columbia in 2005 and 2006 and placed over artificial nest tunnel opening. Investigator access to nest chamber, via removable bucket system, was located outside enclosure (see Poulin et al. 2006). Only the entrance to the tunnels and the top of an investigator-access chute that lead to the nest chamber were visible above ground. Electric fencing surrounded enclosure for protection from cattle disturbance.

**Table 2.1.** Numbers of Burrowing Owl pairs released with 2 techniques in British Columbia.

| Release site  | 2005              |                   | 2006              |                   |
|---------------|-------------------|-------------------|-------------------|-------------------|
|               | No. hard-released | No. soft-released | No. hard-released | No. soft-released |
| Beresford     | 6                 | 0 <sup>a</sup>    | 5                 | 3 <sup>b</sup>    |
| Haughtons     | 2                 | 2                 | 1                 | 2                 |
| Deleeuws      |                   |                   | 1                 | 3                 |
| Guichon ranch | 2                 | 3                 | 5                 | 5                 |
| Quilchena     | 4                 | 2                 | 6                 | 5 <sup>c</sup>    |
| Hamilton      | 5                 | 6                 |                   |                   |
| <b>TOTAL</b>  | <b>19</b>         | <b>13</b>         | <b>18</b>         | <b>18</b>         |

<sup>a</sup> 3 soft-releases were started here, but cattle destroyed cages before pairs could be released

<sup>b</sup> Cattle present in this year, but cages were protected with electric fencing

<sup>c</sup> Owl pair in one cage confirmed to be two males, and therefore excluded from productivity comparisons

### Supplemental feeding

I supplemented the owls with the equivalent of 1.5 food items (frozen laboratory mice, *Mus musculus*, and domestic chicks, *Gallus gallus domesticus*, averaging 42.5 g) per owl per day, from immediately after the release through to fledging, which was defined as 28-35 days-post-hatch. After fledging, I provided only one food item per bird observed at each visit. Although the pairs not housed in enclosures, including wild owls, were free to hunt for natural prey items, I still provided all groups with equivalent amounts of supplemental food so that all conditions were similar between the treatment groups.

### **Post-release monitoring**

I referred to “release” as the time the block on the burrow entrance was removed for hard-released birds, and to the time the enclosure was removed for soft-released birds. I considered immediate post-release actions of adult owls to be either: 1) remained or 2) absent. Birds “remained” if I detected them alive at a study site for 2 or more consecutive nest visits ( $\geq 8$  days) within the first 2 weeks of release. Owls did not need to stay at the exact burrow or release site to be considered ‘remained’. I also considered owls to have remained if I found them dead at a study site at any time. No owls that remained for the first 2 weeks left the study sites after this period. Owls were “absent” if I did not detect them at any study site under the same conditions in this time period or found them dead outside the release sites (i.e., >300 m away). I determined the causes of mortality by the appearance of remains: 1) individually-plucked feathers indicated avian predation and 2) whole body with broken bones or head trauma (e.g., smashed beak) indicated collision with a vehicle.

I monitored nests of all owls twice per week and checked nest chambers at 10-day intervals until clutch completion. I estimated the date of clutch initiation (day the first egg was laid) by calculating back 1 egg laid every 1.5 d (Wellicome 2005). I also recorded the number of eggs laid and number of chicks hatched. To minimize disturbance once eggs hatched, I did not check the nest burrows again until juveniles reached fledging age. When juveniles reached fledging age (28-35 d post hatch), I inspected the nest burrow and any surrounding roost burrows (i.e., burrows habitually used by Burrowing Owls as a roost or prey-cache site, Environment Canada 2008). I then captured all juveniles inside the accessible artificial burrow chambers and banded each one with a U.S. Fish and Wildlife aluminium leg band, and coloured Acraft leg band for individual identification. I considered the number banded at this age to be the number of fledglings produced.

### **Tracking radio-tagged adults**

In 2006, I began ground surveying for radio-tagged adults 3 days after the release of hard-released owls. I attempted to locate the signals with a handheld YAGI antennae and Communications Specialist R-1000 receiver, and attempted to visually observe each adult twice per week on foot at the study sites. I checked signals of soft-released birds while they were still in their enclosures to test the functioning of their radio-tags.

For any signals that were undetected using the above protocol, I conducted further surveys, radiating out from the release sites by vehicle, which had an aerial car-top antennae (36" high Radiall/Larsen, MAXRAD), at least once per week for the entire season (late-April to late-September). I conducted vehicle ground surveying largely from the major highways throughout all grassland regions in southern British Columbia, and I surveyed the secondary or gravel roads whenever they were accessible.

I also conducted 2 aerial surveys, the first beginning 1 week after the release of hard-released owls. In the initial flight, I covered all grassland regions within the Nicola Valley and a 20-km radius of Kamloops. While in flight, I tested radio signals from both the Kamloops Airport and from owls of known location to determine the maximum distance signals could be detected (~10 km). One week after enclosures were removed from the burrows of soft-released owls, I performed another aerial survey.

In the second survey, I expanded the search area to include grassland areas 20 km on either side of the Nicola Valley. I tracked adults for a total of 723 radio-days from release until prior to migration, which was from late-April until late-September. I removed all radio-tags from adults that were alive at the end of the season ( $N = 17$ ) just prior to the expected expiration of battery life (~16 weeks). Despite small sample sizes, radio-tagging during the breeding season did not appear to affect an adult's ability to migrate and return the following year (see Appendix D).

### **Data analysis**

I used log-likelihood ratios ( $G^2$ ) (Sokal and Rohlf 1981) to test for differences in the number of remaining and surviving owls, and in reproductive parameters (proportion of owl pairs that initiated a clutch, hatched at least one chick, and produced at least one juvenile of fledging age). Separately, I also used log-likelihood ratios to test for differences in the number of remaining and surviving radio-tagged owls. To compare the productivity (number of eggs, chicks, and fledged juveniles produced per individual) of soft-released females to that of hard-released ones

I used Wilcoxon signed-rank tests (Wilcoxon 1945) because the data were non-normally distributed. Because comparisons of soft-released and hard-released owls were made in one direction (i.e., tested for improved results with the soft-release technique), I used the one-tailed results (Zar 1974). To calculate survival probabilities of nests and of radio-tagged owls, I used maximum likelihood estimation (MLE) with the binomial model (White and Burnham 1999, Shaffer 2004) in Program MARK (White 2007). I used both SAS 9.1.3 and JMP 5.1.2 statistical packages with a significance level ( $\alpha$ ) of 0.05 for all of the tests.

## RESULTS

### Nesting activities

In 2005 and 2006, I monitored owls from 37 hard-released and 30 soft-released pairs (Table 2.2.). Soft-released pairs initiated clutches 44% more often ( $G^2 = 15.6, P < 0.01$ ), hatched young 25% more often ( $G^2 = 4.0, P = 0.023$ ), and fledged juveniles 20% more often than hard-released pairs ( $G^2 = 2.8, P = 0.048$ ). Despite there being fewer soft-released pairs, soft-released pairs contributed 11% more juveniles ( $n = 71$ ) to the population than did hard-released pairs ( $n = 57$ ).

**Table 2.2.** Post-release actions of captive-bred Burrowing Owls in British Columbia in 2005 and 2006.

| Post-release actions     | Hard-released | Soft-released |
|--------------------------|---------------|---------------|
| Individual owls          | $n = 74$      | $n = 62$      |
| Remained                 | 64% (47)      | 84% (52)      |
| Survived breeding season | 47% (35)      | 61% (38)      |
| Owl pairs*               | $n = 37$      | $n = 30$      |
| Initiated clutch         | 46% (17)      | 90% (27)      |
| Hatched chicks           | 32% (12)      | 57% (17)      |
| Fledged juveniles        | 27% (10)      | 47% (14)      |

\*These include only owls who remained as a pair with an owl of the same release technique, mixed paired owls (e.g., soft-hard release pairs, hard-wild pairs) were excluded.

Though there was an effect size of 2.1 in the number of eggs laid, 0.9 in the number of chicks hatched, and 0.8 in the number of juveniles fledged, all in the predicted direction. However, because of small sample size and large variation among females, a

statistically-significant effect in productivity was only detected in the eggs laid per female (Table 2.3.). There was no difference in nest survival probabilities between release techniques ( $0.59 \pm 0.03$  and  $0.54 \pm 0.03$  for hard-released and soft released, respectively).

**Table 2.3.** Productivity of released captive-bred female Burrowing Owls in British Columbia in 2005 and 2006 combined.

| Productivity measure         | Hard-released<br>( <i>n</i> = 37) |     | Soft-released<br>( <i>n</i> = 30) |     | <i>P</i> |
|------------------------------|-----------------------------------|-----|-----------------------------------|-----|----------|
|                              | $\bar{x}$                         | SE  | $\bar{x}$                         | SE  |          |
| Eggs laid per female         | 3.9                               | 0.5 | 6.0                               | 0.7 | 0.04     |
| Chicks hatched per female    | 2.3                               | 0.5 | 3.2                               | 0.6 | 0.13     |
| Juveniles fledged per female | 1.7                               | 0.5 | 2.5                               | 0.5 | 0.09     |

### Breeding season survival

The number of owls remaining did not differ between years for either soft-released ( $G^2 = 0.1$ ,  $P = 0.82$ ) or hard-released pairs ( $G^2 = 0.2$ ,  $P = 0.68$ ). Over both years, 20% more soft-released birds remained at the study sites than hard-released ( $G^2 = 7.3$ ,  $P < 0.01$ ) and 14% more soft-released birds survived the breeding season than hard-released birds ( $G^2 = 2.7$ ,  $P = 0.049$ ) (Table 2.2). I confirmed 28 deaths of released adult owls with 43% of these deaths occurring within the first week, and 71% occurring within the first 4 weeks of release. Avian predation accounted for 79% of deaths, and collision with a vehicle accounted for the remaining 21%. Causes of death differed between release techniques ( $G^2 = 3.5$ ,  $P = 0.03$ ), with a higher proportion of hard-released owls being killed by avian predators (17 of 20; 85%) than soft-released owls (4 of 8: 50%).

### Monitoring with radio-tags

Using radio-tags, I monitored a subset (39 of 91; 43%) of released adults in 2006. During my study, signals from 6 owls were lost (censored). Five of these censored owls were hard-released owls whose signals were lost within the first week following release. Of the 33 owls of known fate, 61% remained at the study sites and 39% became absent. Radio-tagged soft-released owls remained 90% of the time while hard-released owls remained 39% of the time ( $G^2 = 9.6$ ,  $P < 0.01$ ). Sex had no influence on the proportion of remaining owls ( $G^2 = 0.1$ ,  $P = 0.83$ ). Although,

larger percentage (65%) of radio-tagged remaining owls survived than those that became absent (38%), no significant difference was detected. The survival probabilities of radio-tagged owls were similar between release techniques ( $0.55 \pm 0.11$  and  $0.55 \pm 0.18$  for hard-released and soft-released, respectively).

### **Annual returns**

Recruitment rates for adults ( $G^2 = 0.1$ ,  $P = 0.35$ ) and juveniles ( $G^2 = 2.0$ ,  $P = 0.08$ ) were similar between release techniques. One adult and 5 juveniles of 62 soft-released adults (2% and 8%, respectively), and 2 adults and 2 juveniles of 74 hard-released adults (3% for both) returned in 2006 and 2007. A mean of 28% (3 of 10 in 2006, 4 of 15 in 2007) of wild adults from a given year returned to the study sites in the subsequent year. In 2006 and 2007, 6 released adults and 23 wild-hatched juveniles returned, yielding a mean return rate of 2% for all released adults (including all adults released as singles) and 7% for all wild-hatched juveniles (including progeny of mixed and wild pairings). Over the 2-year period of my study, only 1 wild, 1 soft-released, and 1 hard-released (1% of released adults,  $N = 172$ ) owls were known to have made an attempt to overwinter (the wild owl was not observed after December, and the released owls were found deceased inside burrows the following spring).

## **DISCUSSION**

### **Reproductive success**

My study indicates that higher success in reintroductions is achieved using an enclosure-based soft-release technique for captive-bred Burrowing Owls, rather than using hard-release methods. It was also a more effective use of the soft-release technique, which was demonstrated by having improved results over previous releases of Burrowing Owls, as reported in Saskatchewan, Manitoba, Minnesota, and British Columbia (Dyer 1991, De Smet 1997, Leupin and Low 2001, Martell et al. 2001, Poulin et al. 2006). My results also suggest that a key factor affecting the breeding success of released birds was whether they remained long enough at the release site to initiate a clutch. My use of ready-to-breed, young captive owls hatched near release areas also may have improved the results over other studies.

Fledging success was lower (31%,  $N = 26$ ) with enclosure-based soft releases in Saskatchewan (Poulin et al. 2006) than was observed in my study. However, when only considering releases where enclosures left until after clutch initiation ( $\bar{x} = 16.5 \pm 5.2d$ ), their success rate was significantly improved (75% success in raising young,  $N = 4$ ), and comparable

to my study. Low success was experienced when enclosures were left on for only a few days after owls were released into burrows (Poulin et al. 2006). Because success was improved in Saskatchewan when enclosures were left for 5 days or until clutch initiation instead of only 3 days, a further increase in success in my study could be because enclosures were left on until mid-clutch. The latter practice may have provided even more incentive for pairs to remain together and maximize nesting success, while enclosing pairs in the field for only a short period during the breeding season. This enclosure time did not appear to interfere with the owls' ability to improve their flying condition, or to develop effective hunting after the removal of the enclosures. This was not only shown by their improved nesting success, but also by their rapid acquisition of natural prey items (Appendix A).

In Manitoba, there was 11% fledging success ( $N = 73$ ) when enclosures were used (De Smet 1997). Lower success was observed when yearling Burrowing Owls were released by hacking: all owls disappeared overnight and none were seen in following years. For these releases, having enclosures placed over burrows for only 1 week (De Smet 1997) was likely not enough time to ensure maximum probability of improved survival and productivity. Researchers in Minnesota (Martell et al. 2001) had the least success using an enclosure-based soft-release technique with no owls ever being observed after release from their enclosure. In this case, and in the releases conducted in the Okanagan Valley in British Columbia, the use of translocated pre-flighted juveniles and previously bred adults probably contributed to the low reintroduction success observed (Dyer 1991, Martell et al. 2001).

Results of my study lend support to the hypothesis that release methods that promote breeding in the year of release greatly increase the probability of a viable population becoming established (Bright and Morris 1994). My study also suggests that extended time periods for confinement are necessary to instill site-fidelity in released animals (Franzreb 2004). My study revealed not only how a soft-release technique can improve reintroduction efforts, but also how choosing appropriate confinement time frames, as well as ages and pairings of released animals, can significantly reduce dispersal and improve breeding success.

### **Breeding season survival**

In my study, soft-released birds had a breeding season survival rate that appeared to be lower than previously reported. In Saskatchewan, seasonal mortality rate (19%,  $N = 52$ ) was estimated by counting the number of released adults confirmed dead during the breeding season. Birds with unknown fates (33%) were not included, and therefore, the mortality rate reported



represented a minimum value (Poulin et al. 2006). The lower survival rate of soft-released adults in my study may have been because of the close monitoring of birds with radio-telemetry that resulted in fewer unknown fates.

I recorded higher post-release survival of owls that had left the study sites than had been recorded during telemetry studies in the Nicola Valley in British Columbia in 1996 and 1997, but my results were similar to the estimated mean mortality rate from 1992-1997. Studies in 1996 and 1997 showed that 92% ( $N = 13$ ) of owls that disappeared from their release sites were killed by predators (Leupin and Low 2001). When it was assumed that this rate was representative of other years, the estimated mean mortality rate for released birds from 1992-1997 was 34%. The percentage of mortalities (85%) that occurred within the first four weeks of release reported by Leupin and Low (2001) was similar to my study. These similarities indicate that mortality rates in the years of my study were representative of what has been previously observed.

Causes of mortality in my study were consistent with what have been previously reported. Avian predation is often the most common cause of death throughout the Burrowing Owl's range in Canada (Wellicome and Haug 1995, Shyry 2005, Poulin et al. 2006). Leupin and Low (2001) also reported that released Burrowing Owls suffered heavy predation from Northern Harriers (*Circus cyaneus*), Great-horned Owls (*Bubo virginianus*), and Red-tailed Hawks (*Buteo jamaicensis*). Wellicome and Haug (1995) suggested that cultivation and fragmentation of grassland habitat in Canada have allowed populations of predators that prey on Burrowing Owls to increase. Leupin (2004) also suggested that the creation of nesting and perching structures like trees and fences in grassland systems has drastically increased predator populations, such as red-tailed hawks (*Buteo jamaicensis*), and so has hampered Burrowing Owl reintroduction efforts in British Columbia.

Although directly reducing predator populations is not a feasible management option, use of the soft-release method significantly reduced predation pressure. Because predation with the hard release in the years of my study were similar to other years and other Burrowing Owl populations, my results further indicate the overall improved success I observed is a direct result of the use of the soft-release technique.

### **Annual returns**

Return rates reported in my study were higher for released adults and their offspring than there were in other Burrowing Owl releases, but were similar to wild birds elsewhere (De Smet 1997, Hoyt et al. 2001, Martell et al. 2001, Conway et al. 2006). In Saskatchewan, none of the soft-

released captive-adults returned to the study area in subsequent years and only 1 of 62 (2%) offspring from released pairs returned to breed in a subsequent year (Poulin et al. 2006). In the Saskatchewan study, it was suggested that because the captive owls were hatched and raised in Alberta and Ontario, their origins may have affected their ability to navigate successfully back to Saskatchewan once they became wild.

Wild-hatched juveniles typically made up the majority of owls that returned to my study sites in 2005 and 2006. Clearly, captive-bred owls and, even more so, their offspring are capable of contributing to the population in British Columbia in subsequent years. Also, given that soft-released birds recruitment rates (of both adults and the juveniles they produced) were as high or higher than rates for hard-released birds, soft-released birds are apparently not disadvantaged by being enclosed. By increasing the survival and nesting success of captive-bred adults through the soft-release technique, I not only increased the opportunity for return of adults with a successful nesting attempt, but I also increased the number of juveniles with the potential to return to the location in which they were hatched.

In general, return rates underestimate survival rates because many adults and juveniles typically disperse from breeding and natal areas (COSEWIC 2006). The difficulties in calculating accurate measures of adult and juvenile survival rates, and the consequent lack of accuracy in predictions of local population viability, have been highlighted by McDonald et al. (2004). Because this problem is consistent throughout the Burrowing Owl's range wherever they are migratory, a fair comparison between rates observed in my study and rates observed in other areas can be made. However, due to the geographical and burrow limitations in British Columbia, return rates may be higher because of the potentially lower degree of annual dispersal, thus resulting in higher annual site-fidelity.

### **Overwintering**

It has been postulated that being held captive their first winter may hinder a released adult's ability to migrate (Mata et al. 2001). However, overwinter rates of released yearling captive-bred owls in my study area were very small and comparable to those of wild owls in the same study site and in nearby Washington State, where winter conditions are more similar to conditions in British Columbia grasslands than to those on the Canadian prairies. With rates in urban and agricultural areas of Washington pooled, an average of 5% of all birds (males, females, and juveniles) overwintered (Courtney et al. 2006). Overwinter rates of captive-bred owls were also lower in my study than those reported in Saskatchewan (Poulin et al. 2006), where at least 5 of

42 (12%) released owls that survived the season failed to migrate. There were no indications in my study that the captive upbringing or release technique of owls in British Columbia increased their tendency to overwinter or hampered their ability to migrate.

### **MANAGEMENT IMPLICATIONS**

Given that the number of owls remaining and surviving at release sites and the number of pairs producing fledglings were increased in my study through the use of the soft-released technique, it would be logical to implement this well-tested technique for releasing captive-bred Burrowing Owls whenever possible. A few weeks at the beginning of the season is a relatively short investment of time to significantly improve the survival and nesting success of released owls, when compared to the cost and time required to produce more owls in captivity. So, in order to maximize reintroduction success, I recommend placing at least an equal focus on increasing the survival of released owls as is placed on producing more owls in captivity for release. In fact, releasing captive-bred owls without providing some post-release protection would be exposing a significant portion of these owls to a high rate of mortality when this danger can be mitigated. The benefits of being enclosed (e.g., predator protection, encouragement of site-fidelity) outweigh the potential risks of feather damage and reduced flying condition, because neither of these risks were evident in my study given the increased nesting success of the birds that were enclosed. My results suggest that more fledglings with the potential to become recruits can be produced using the soft-release technique and that over time this will lead to increase in the local wild breeding population.

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## **CHAPTER THREE. Post-fledgling survival of wild-hatched offspring from captive-bred Burrowing Owls in British Columbia<sup>2</sup>**

### **INTRODUCTION**

The Western Burrowing Owl (*Athene cunicularia hypugaea*) currently has status as endangered, threatened, or a species of special concern throughout much of its range in North America (Commission for Environmental Cooperation 2005, COSEWIC 2006). Because of this, repeated reintroduction efforts have been attempted in Minnesota, Manitoba, and British Columbia (De Smet 1997, Leupin and Low 2001, Martell et al. 2001; see also Chapter 2). However, reintroductions were not considered successful in both Minnesota and Manitoba, and consequently efforts at these two locations have ceased (De Smet 1997, Martell et al. 2001). Reintroduction attempts in British Columbia have had limited success, with post-release mortality of captive-bred adults identified as significantly hindering efforts (Leupin and Low 2001).

A “soft-release” technique that involved placing enclosures around paired captive-bred yearling owls in the field was used in 2005 and 2006 in British Columbia, to try to improve the success of the reintroduction (see Chapter 2). In this study, and in a pilot project in Saskatchewan, higher proportions of owls remained at release sites, survived the breeding season, and successfully nested when enclosures were left on until at least clutch initiation than when released with a hard-release technique (Poulin et al. 2006, see also Chapter 2). However, even with increased adult survival and productivity from soft-releases, improvements to reintroduction efforts could be in vain if juvenile survival and recruitment in this area are typically low.

Thus far, studies attempting to determine causes for the decline of wild Burrowing Owl populations have examined reproductive performance, survival, return rates, and habitat use of adults (Wellicome et al. 1997, Clayton and Schmutz 1999, Hoyt et al. 2001, Sissons et al. 2001, Holmes et al. 2003). These studies have yielded important insights, and have significantly improved our understanding of Burrowing Owl populations (Todd et al. 2003). However, information on juvenile survival and its impact on subsequent years’ populations has been limited (Todd et al. 2003, Shyry 2005).

The particular life history strategy (i.e., high fecundity and short life span) of Burrowing Owls (Todd and Skilnick 2002, Poulin 2003) may also make survival of adults less of an

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<sup>2</sup> A version of this chapter will be submitted for publication. Mitchell, A. M., T. I. Wellicome and K. M. Cheng. Post-fledgling survival of wild-hatched offspring from captive-bred Burrowing Owls in British Columbia.



influence on population growth than the survival of young owls from hatching until first-migration (Franken and Wellicome 2003). Shyry (2005) suggested that evaluating juvenile survivorship would allow us to determine whether high mortality of immature birds is the limiting factor in population growth and recovery.

Specific to the British Columbia recovery program, monitoring juvenile survival allows for understanding of as many life-history stages as possible and can help ensure efforts to improve the population status of owls are being applied at the most appropriate life stages. The objective of my study was to compare post-fledging survival, mortality, and recruitment of the offspring of captive-bred owls released with two different techniques with those of offspring from wild adult owls in the same study sites in British Columbia, and with those of wild populations elsewhere in North America. Making these comparisons would then allow me to determine whether any parameters in the post-fledging life-history stage were limiting the re-establishment of a population in British Columbia.

## **STUDY AREA**

The study area was located in the Nicola Valley in the Southern Interior Ecoprovince of British Columbia (BC Ministry of Forests 1992). This valley is in the Thompson basin vegetation zone (Parish et al. 1996), between Merritt and Kamloops, near Highway 5A which follows the valley bottom. There is a gradual transition from very hot and dry lower grasslands to cool and moist upper grasslands. Shrub-steppe communities, dominated by big sage and bluebunch wheatgrass, occur at the lowest elevations in this region (biogeoclimatic unit BGxh2; Grassland Conservation Council of BC 2004).

Within the Nicola Valley, release sites were in a variety of grassland habitat types, typically on private lands. Sites were grazed and often contained introduced, weedy plant species (Parish et al. 1996). The planting of forage grass and cereal crops, such as crested wheatgrass, alfalfa, and barley (Ministry of Agriculture, Food and Fisheries 2002), has created a fragmented landscape (Leupin 2004), with natural grassland areas remaining largely on sloped land where planting or mechanized alteration of vegetation is difficult.

## **METHODS**

### **Juvenile tagging**

I inspected nest burrows in late-June to mid-July, when juveniles reached fledging age (28-35 days post-hatch). I also inspected surrounding roost burrows, or burrows habitually used by

Burrowing Owls as roosts or prey-cache sites, as defined by Environment Canada (2008). I then captured juveniles inside burrow chambers, and banded them with U.S. Fish and Wildlife Service aluminium bands and coloured Aircraft leg bands for unique identification. At the time of banding I randomly selected 1 juvenile from any nest that produced at least 2 fledglings and fit the selected juvenile with a collar-style radio-tag (Holohil Systems Limited, Carp, Ontario, Canada, Models PD-2, and RD-2). I radio-tagged 39 juveniles of 235 juveniles that were banded (Table 3.1.). I radio-tagged only juveniles that weighed at least 135 grams to ensure they were not carrying more than the suggested maximum percentage of their body weight (3%). Two different weights of radio-tags were available (4 and 6 g), so I distributed the tags evenly among the study sites, allowing for an examination of radio-tag effects (see Appendix D).

**Table 3.1.** Radio-tagging of juveniles each year in British Columbia in relation to study sites.

| Study site   | No. radio-tagged |           |           |          |
|--------------|------------------|-----------|-----------|----------|
|              | 2005             |           | 2006      |          |
|              | 4 g              | 6 g       | 4 g       | 6 g      |
| Beresford    | 1                | 2         | 2         | 1        |
| Haughtons    | 1                | 1         | 2         | 2        |
| Deleeuws     |                  |           | 1         |          |
| Guichon      | 3                | 3         | 5         | 4        |
| Quilchena    | 2                | 2         | 2         | 2        |
| Hamilton     | 1                | 2         |           |          |
| <b>TOTAL</b> | <b>8</b>         | <b>10</b> | <b>12</b> | <b>9</b> |

I considered the post-fledging period to commence at 40 days post-hatch and end at migration, which typically occurs between early September and early October in British Columbia. I recorded which of the following three nest types fledglings originated from: hard-releases, soft-releases, or wild nestings (see Chapter 2). I made an attempt to have at least 1 juvenile from each nest type represented at all study sites, and I equally distributed the 2 different models of radio-tags among the various nest types. After fledging, I provided 1 food item (frozen laboratory mouse, *Mus musculus* or domestic chick, *Gallus gallus domesticus*) per owl observed at each visit every 3 days. All procedures were approved by the Animal Care Committee of the University of British Columbia (Protocol # A05-0470).

## **Diurnal tracking of survival**

Tracking of post-fledging survival began early in July. I checked signals for radio-tagged juveniles every 3-4 days from the time of tagging until September/October, for a total of 692 tracking days. I used a handheld YAGI antenna and Communications Specialist R-1000 receiver, and determined the maximum range of radio-tags on the ground to be 2.0 km. I followed signals until 1) it was determined that the juvenile was inside a burrow, 2) there was visual confirmation (i.e., radio-tag was clearly visible when the owl was sitting or flying), or 3) there was evidence of mortality.

I determined cause of mortality by the appearance of remains: 1) individually-plucked feathers indicated avian predation, 2) chewed feathers and remains in large pieces indicated mammalian predation, and 3) whole body with broken bones or head trauma (e.g., smashed beak) indicated collision with a vehicle. When there were no obvious signs, I categorized the death as an unknown cause. I estimated the date of mortality as the mid-point between the date recovered and the date of last observation when alive unless the condition of remains indicated a more accurate date of death. For example, when tissues or blood were not yet dry, I estimated that death was on the day recovered. I recorded the locations of deceased owls with a hand-held Global Positioning System (GPS) unit (EtrexVista®, Garmin International) with <15 m error in both years.

If I detected juvenile signals inside the same burrow for 2 consecutive visits, I opened and inspected the burrow to ensure that the juvenile was not dead inside. When a given transmitter signal was undetected at the natal study site, I attempted to detect the signal at all other study sites. For any owl signals that were still undetected, I conducted further surveys that radiated out from the study sites, by vehicle with an aerial car-top antennae (36" high Radiall/Larsen, MAXRAD). These surveys were conducted at least once per week for the entire field season. When I did not detect signals again by the end of the season, I considered the censoring date to be the day after the last live observation. Beginning in early September, just prior to migration, I attempted to capture and remove radio-tags from any surviving juveniles for which a complete set of habitat-use points had been gathered (see Appendix B).

I considered juvenile fate to fall into three categories: 1) alive - confirmed survived until prior to migration, 2) dead, or 3) unknown fate - signal lost or radio-tag recovered without a carcass and no signs of predation or damage to tag, indicating the owl may have gotten the collar off. If the signal from a radio-tag began to fail, I attempted to recapture the juvenile and replace the radio-tag (2 of 3 failing radio-tags were successfully replaced).

## Data analysis

To calculate and compare survival probabilities of radio-tagged juveniles, I used maximum likelihood estimation (MLE) with the binomial model (White and Burnham 1999, Shaffer 2004) in Program MARK (White 2007). I used two-way ANOVAs to compare differences in mean weight and age of radio-tagged and untagged juveniles between years. I used log-likelihood ratio tests ( $G$ ) (Sokal and Rohlf 1981) and multiple logistic regression (Hosmer and Lemeshow 1989, Agresti 2002) to test for effects of year, study site, nest type, and radio-tag model (weight) on juvenile fate (alive or dead). I used multiple linear regression to test whether weight and age at banding were associated with time of death. To test whether weight and age at time of capture influenced survival (alive or dead) I used two-tailed t-tests. I used both SAS 9.1.3 and JMP 5.1.2 statistical packages with a significance level ( $\alpha$ ) of 0.05 for all tests.

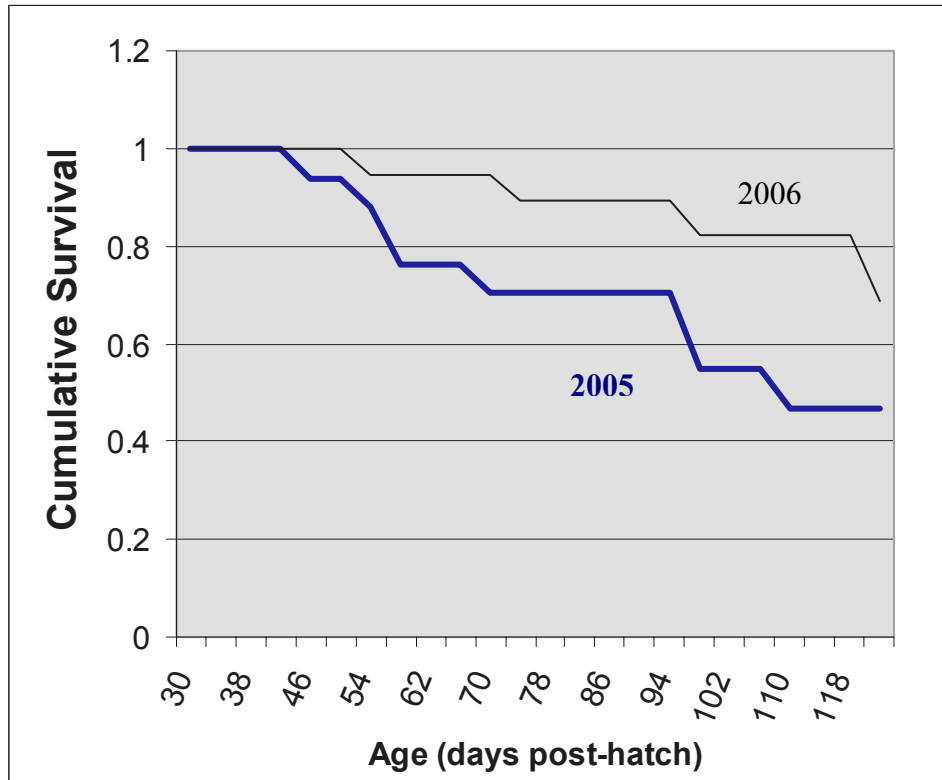
## RESULTS

### Post-fledgling survival

Over the 2-year period of my study, 35% of all radio-tagged juveniles died before migration. Thirty-two percent more juveniles survived to migration in 2006 (15 of 19; 79%) than in 2005 (7 of 15; 47%) ( $G^2 = 4.2$ ,  $P = 0.049$ ). Although survival probabilities were higher in 2006 ( $0.69 \pm 0.15$ ) than in 2005 ( $0.47 \pm 0.13$ ), this difference was not significant (log rank = 2.2,  $P = 0.14$ ) (Figure 3.1.). While juveniles were on average 2.7 d younger ( $F = 34.9$ ,  $P < 0.01$ ) at the time of banding in 2006 than in 2005, the 4.2 g heavier weight in 2006 was not significant ( $F = 3.8$ ,  $P = 0.05$ ). I observed no differences in the mean age of radio-tagged and untagged juveniles. However, radio-tagged juveniles were on average 6.2 g heavier ( $F = 4.6$ ,  $P = 0.03$ ) (Table 3.2.).

I observed no difference in the number of juveniles that died prior to migration wearing the heavier radio-tag versus the lighter version, or in their survival probabilities (see Appendix D). Weight and age at time of capture of radio-tagged juveniles (Table 3.2.) did not influence survival throughout the post-fledging period ( $t_{28} = -0.35$ ,  $P = 0.73$  and  $t_{28} = -0.55$ ,  $P = 0.58$ , respectively). Juveniles from parents of soft releases (9 of 13; 69%) survived at a similar proportions and had those from hard releases (5 of 10; 50%) ( $G^2 = 0.8$ ,  $P = 0.38$ ). Their survival probabilities were also similar ( $0.66 \pm 0.16$  for soft-released and  $0.58 \pm 0.17$  for hard-released, log rank = 0.03,  $P = 0.86$ ). The proportions of juveniles that survived until migration were similar for juveniles from wild parents (8 of 11; 73%) and from captive-released parents (14 of 23; 61%) ( $G^2 = 0.4$ ,  $P = 0.49$ ). Survival probabilities also did not differ (log rank = 0.24,  $P = 0.63$ ) between juveniles of these origins ( $0.53 \pm 0.14$  and  $0.71 \pm 0.14$ , release and wild

respectively). Most (25 of 34; 74%) radio-tagged juveniles remained close (within 300 m) to their natal burrow until migration.



**Figure 3.1.** Annual cumulative survival probabilities for radio-tagged juvenile Burrowing Owls in British Columbia. For 2005,  $n = 18$  owls and for 2006,  $n = 21$  owls

**Table 3.2.** Mean weight  $\pm$  SE and age  $\pm$  SE of juvenile Burrowing Owls in British Columbia at time of capture in each year and category of radio-tag status.  $n =$  number of individual juveniles.

| Year | Untagged        |                |     | Tagged          |                |     |
|------|-----------------|----------------|-----|-----------------|----------------|-----|
|      | Weight          | Age            | $n$ | Weight          | Age            | $n$ |
| 2005 | 147.8 $\pm$ 1.9 | 31.4 $\pm$ 0.4 | 84  | 154.5 $\pm$ 2.9 | 32.2 $\pm$ 0.9 | 17  |
| 2006 | 152.2 $\pm$ 1.5 | 28.8 $\pm$ 0.3 | 78  | 157.9 $\pm$ 3.2 | 28.8 $\pm$ 0.6 | 16  |

### Post-fledging mortality

In both years, predation was the main cause of mortality of radio-tagged juveniles that were found dead (7 of 12; 58%). Avian predation had a higher impact in 2005, accounting for 50% of deaths; however, it did not account for any deaths in 2006. Coyotes accounted for the majority (2 of 3; 67%) of deaths by mammalian predators, with the remaining death probably caused by a member of the weasel family. Collision with motor vehicles resulted in 33% of deaths. Causes of death were distributed somewhat evenly among nest types. Thus, causes of death did not appear to be influenced by their parents' origin, though sample sizes were too small to allow statistical testing of this relationship with adequate power (Table 3.3.). I did not detect any influence of study site, nest type, or radio-tag weight on juvenile fate. However, year had a significant influence, with juveniles more likely to experience mortality (be dead) in 2005 ( $P = 0.02$ ).

**Table 3.3** Fate of radio-tagged juvenile Burrowing Owls in British Columbia. Causes of death are separated into predation by raptors and mammals, collision with vehicle, and unknown death. Values given for each fate-category are proportions of all individuals, and values in parentheses indicate numbers of juveniles from wild, hard-released, and soft-released parents.

| Year  | Survive         | Predation       |                 | Collison with vehicle | Unknown death   | Unknown fate    |
|-------|-----------------|-----------------|-----------------|-----------------------|-----------------|-----------------|
|       |                 | Raptor          | Mammal          |                       |                 |                 |
| 2005  | 0.39<br>(1,3,3) | 0.22<br>(2,0,2) | 0.06<br>(0,1,0) | 0.11<br>(0,2,0)       | 0.06<br>(1,0,0) | 0.16<br>(1,2,0) |
| 2006  | 0.70<br>(7,2,6) | 0.00<br>(0)     | 0.10<br>(0,1,1) | 0.10<br>(0,1,1)       | 0.00<br>(0)     | 0.10<br>(0,1,1) |
| TOTAL | 0.56<br>(8,5,9) | 0.10<br>(2,0,2) | 0.08<br>(0,2,1) | 0.10<br>(0,3,1)       | 0.03<br>(1,0,0) | 0.13<br>(1,3,1) |

Failure of radio-tags occurred infrequently (3 of 39; 8%), and all of these failures were of the lighter tags. I was able to replace 2 of these failed tags before complete failure occurred, and thus only one individual's fate remained unknown because of tag failure. The unknown fate of the other 4 birds was probably because radio-tags were removed by the owls, and fate could not be able determined through regular visual monitoring (e.g., re-sighting or capture in burrow).

Fifty-eight percent ( $N = 12$ ) of mortality occurred over the first 19 d of the post-fledging period (40 to 59 d post-hatch) ( $\bar{x} = 67.4 \pm 7.3$  d). Older juveniles died at distances that were no further from their nests than younger juveniles ( $r_s = 0.17$ ,  $P = 0.18$ ). All dead juveniles were recovered <2.5 km from their nest ( $\bar{x} = 529 \pm 195$  m). I did not detect any difference in age of death between year, study site, nest type and radio-tag weight.

## **Annual returns**

The proportion of banded juveniles returning did not differ between 2006 (8 of 105; 8%) and 2007 (8 of 131; 6%) ( $G^2 = 0.2$ ,  $P = 0.65$ ). Juveniles that were radio-tagged during the breeding season returned (1 of 22; 5%) at a similar rate as untagged juveniles (15 of 197; 8%) ( $G^2 = 0.2$ ,  $P = 0.64$ ). Recruitment rates were not significantly different between release types with 5 juveniles from 62 soft-released adults (8%), and 2 juveniles from 74 hard-released adults (3%) returning in 2006 and 2007 ( $G^2 = 2.0$ ,  $P = 0.16$ ). Juveniles of captive-released parents (11 of 157; 7%) returned at the similar rate as those of wild parents (5 of 78; 6%) ( $G^2 = 0.02$ ,  $P = 0.86$ ). Nesting success (success = raising at least 1 young until 28 d post hatch) of returning juveniles was high (5 of 8; 63% in 2006 and 6 of 8; 75% in 2007) compared to release adults.

## **DISCUSSION**

### **Juvenile survival**

Post-fledging juvenile survival in British Columbia was comparable to survival in other areas of the Burrowing Owl's range. Survival probabilities over the 2 years in my study were also higher than in a terminally declining population in Saskatchewan (0.55, 95% CI 0.44 – 0.70,  $N = 64$ ) (Todd et al. 2003), but similar to an approximately stable population in Alberta (pooled survival function =  $0.62 \pm 0.11$  SE) (Shyry 2005), and in nearby Washington state (61% survival,  $N = 83$ ) (Conway et al. 2004). Although this population of owls was supplementally fed during the nesting period, the level of feeding was dramatically reduced at the beginning of the post-fledgling period, and probably did not have significant influence on survival during that period (as observed by Todd et al. 2003).

Similar to the release study in Saskatchewan (Poulin et al. 2006), juvenile survival did not differ between progeny of released birds and progeny of wild birds in British Columbia, suggesting juveniles of released birds are not negatively affected by their captive-bred parents. Survival also did not differ between release methods, indicating the reproductive benefits of using the soft-release technique for captive-bred adults were not countered by differential juvenile survival. This lack of evidence of lower survival of juveniles from soft-released parents further supports the importance of the implementation of the soft-release technique to increase the success of reintroduction efforts. Compared with other regions, juvenile survival in my study more closely followed patterns observed in relatively stable populations and is not likely limiting the success of the reintroduction effort.

### **Juvenile mortality**

Observed causes of post-fledging juvenile mortality were not unusual compared to those found in other areas of the Burrowing Owl's range. Similar to my results in 2005, studies in Alberta and Saskatchewan (Clayton and Schmutz 1999, Todd 2001, Shyry 2005) reported that avian predators caused most deaths in post-fledging juveniles. However, in my study avian predators were not responsible for any juvenile deaths in 2006, which likely explains the higher survival reported in that year. Mortality due to mammalian predation and anthropogenic causes in my study were similar to what has been reported in other populations of Burrowing Owls (Todd et al. 2003, Shyry 2005). Causes of mortality also did not differ between release methods, indicating the use of the soft-release method does not influence the causes of mortality of juveniles of captive-bred parents.

Most measures associated with mortality in my study also showed similarities to wild populations. The age for the greatest risk of death of juveniles and the distance of carcass recoveries from the natal burrow in my study were similar to those reported in Alberta ( $56.1 \pm 2.7$  d post hatch and  $\bar{x} = 680 \pm 226$  m, respectively) (Shyry 2005). Though age at death and the distance from the natal burrow were positively correlated ( $r_s = 0.65$ ,  $P = <0.01$ ) in the 2005 Alberta study, these 2 variables were uncorrelated in my study. In British Columbia most juveniles that died were within 1 km of their natal burrow. This trend more closely resembles observations by Clayton and Schmutz (1999), where most juveniles (72%) were killed near the nest during the post-fledging dependency period. The most likely reason for the differences observed is that in my study most juveniles remained near the nest until migration.

### **Juvenile recruitment**

Juvenile recruitment (of both released and wild parental origins) in my study more closely resembles recruitment in areas with wild populations (Todd et al. 2003, Conway et al. 2006, Shyry 2005) than in other areas in which releases have taken place. Juvenile recruitment in areas where reintroductions have been attempted has been quite low (De Smet 1997, Martell et al. 2001, Poulin et al. 2006). Recruitment of offspring of soft-released owls was equal to that of hard-released owls, indicating the recruitment of juveniles of soft-released parents was not influenced by the method of release of their parents. There was no indication that recruitment in my study areas was limiting the success of the reintroduction effort.



## **MANAGEMENT IMPLICATIONS**

Juvenile survival in the Nicola Valley does not appear to be limiting the success of Burrowing Owl reintroduction in British Columbia. Juvenile survival rates, causes of mortality, and annual return rates reflect what is observed in most other parts of the Burrowing Owl's North American range. In addition, juveniles of captive-released adults in my study tended to exhibit recruitment more similar to that of juveniles of wild Burrowing Owls, than to juveniles of captive-released adults in previous studies. Because released-adult survival and productivity in this region typically have been shown to be low, while juvenile survival is not, increasing survival and nesting success of captive-released adults may be the most appropriate way of currently maximizing the success of reintroduction efforts in this region. Producing more juveniles hatched at study sites will increase the number of owls available to return, and have a successful breeding attempt in this region.

On the other hand, similar factors that affect juvenile survival (e.g., increased predator populations, habitat fragmentation) in other Burrowing Owl sites may exist in British Columbia. These factors may still threaten to reduce juvenile survival to a level that impedes reintroduction efforts. The Nicola Valley is experiencing a high degree of new developments, thus increasing roads and fragmentation. Current and future development locations must be taken into account when deciding on where to release owls in the future.

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## **CHAPTER FOUR. Summary and Conclusions**

### **RELEASE TECHNIQUE EFFECTS ON REINTRODUCTION SUCCESS**

In this study, I assessed potential limits to the success of the reintroduction of Burrowing Owls in British Columbia, and used the results to make management recommendations for maximizing success. These limits included high immediate post-release dispersal and mortality, inadequate hunting ability, low juvenile survival, and available habitat. Unique to my study were the direct comparison of the soft-release technique to the hard-release technique, and the comparison of the post-release movements and fates of soft-released and hard-released radio-tagged owls (Chapter 2). An extended study on the offspring of captive-bred Burrowing Owls was also carried out in order to examine juvenile survivorship and recruitment (Chapter 3). In addition, my study systematically compared the diets of released owls with that of wild ones (Appendix A), and assessed habitat availability (Appendix B) in British Columbia.

With this testing of an enclosure-based soft-release technique, I demonstrated that increasing the number of owls remaining at release sites enhanced survival and reproductive performance. My study confirmed the positive effects soft releases with enclosures can have, as observed in other reintroductions of the same and different species (Ellis et al. 2000, Wanless et al. 2002, Poulin et al. 2006), by employing a rigorous experimental design. The higher success rates in my study than in other Burrowing Owl soft releases, were likely influenced by use of captive-bred animals capable of breeding in the season released, rather than the use of translocated ones (Dyer 1991, DeSmet 1997, Martell et al. 2001).

Juvenile survival and recruitment in this study were similar to the same measures in a stable population (Shyry 2005) rather than in a terminally declining one (Todd et al. 2003) (Chapter 3), and indicated that the study area has sufficient resources for juvenile owls to survive to successfully migrate. Juvenile recruitment had a more significant impact on the local breeding population than recruitment of previously released adults, further indicating the importance of improving productivity (Chapter 2) in this area.

The investigation of other potential limits to reintroduction success, such as adult foraging ability and juvenile habitat selection, provided novel, detailed information. The seasonal similarity in the diet between captive-bred released and wild owls in my study suggested innate hunting and foraging abilities of Burrowing Owls (Appendix A). The more immediate appearance of wild prey at the nests of soft-released owls and their higher survival and reproductive success showed that soft-released owls (Chapter 2) are likely able to better

adapt to their new environment than hard-released owls. Results from my study showed the importance of rangeland (tame pasture), and indicate that the availability of this habitat in this region of British Columbia benefits post-fledging juvenile Burrowing Owls. This is valuable information, as there are often concerns about introducing a species back into an environment that historically supported them when there is uncertainty in the suitability of the current environment (IUCN 1998).

Through investigation of potential limits to a successful reintroduction, some factors (e.g., low juvenile survival, inadequate foraging ability, and insufficient available habitat) were able to be excluded as being concerns. Because of this, more focus can now be directed towards the application of a proven reintroduction method, the enclosure-based soft-release technique.

## **FUTURE RESEARCH**

Because released captive-bred Burrowing Owls in my study experienced some post-release mortality (Chapter 2), even when released with the enclosure-based soft-release technique, it suggests that the owls may benefit from pre-release training in predator avoidance. Predator avoidance training has benefited other reintroduction efforts (Griffin et al. 2000, White et al. 2005). Any study involving predator avoidance training, however, should not be treated as an alternative to the soft-release protocol. It is likely that the stressful events of being captured, banded, and shipped to the field just prior to release increase post-release mortality (Hartup et al. 2005). In addition to increasing the likelihood of birds staying because of initiating a clutch, enclosures may allow owls to lower their stress level before having to cope with avoiding hazards. Predator avoidance training would not address this problem like the soft release, but would aid the owls in adapting to their new environment.

Although some examples of successful translocation and re-establishment of animals exist (Kleiman 1989, Bright and Morris 1994, Wolf et al. 1996), the more positive results in my study compared with translocations (Chapter 2) indicate that method of reintroduction is not the best method for Burrowing Owls. These results highlight the importance of distinguishing between sources and age of animals used in reintroductions, something that has seldom been done when reviewing successes and failures (Bright and Morris 1994, Sarrazin et al. 1994, Wolf et al. 1996). Future research focusing on this distinction will lead to a further understanding of which factors enable a successful reintroduction effort for a particular species.

Significant differences were observed in the available habitat among study sites (Appendix B), but no differences in productivity or survival (Chapter 2 and 3) among study sites

were detected in my study. Therefore, I would recommend further research into correlations between habitat composition and prey abundance and availability, and their impacts on survival and breeding success in this region. This would allow for more detailed information on the habitat and prey requirements of Burrowing Owls in this region, and aid in future release-site selection.

Despite the proven ability of some released captive-bred owls to successfully produce the same clutch sizes as wild owls (21 of 67 released pairs or 37% in 2005 and 2006 in this study produced 8-10 eggs), pre-release egg laying in this reintroduction effort likely reduced average clutch sizes in the field (Dawn Brodie, Burrowing Owl Conservation Society, pers. comm.). Formal research into the triggers of egg laying (e.g., light regimes, male calling) in the captive-bred population of owls could provide methods for reducing pre-release egg laying. Reducing the energy expended and stress of producing additional eggs might aid in increasing productivity of the captive-bred owls once they are released.

Although release and wild Burrowing Owls in this region of British Columbia had diets that were proportionally equivalent to each other and to owls in other parts of the Burrowing Owl's range (Appendix A), this comparison was only based on the relative proportions of prey categories. An experiment testing quantity of prey acquired would provide information on whether wild birds acquire significantly more food than released birds.

Despite the fact that many aspects in the post-fledging stage (survival, Chapter 2 and habitat selection, Appendix B) did not appear to be limiting in my study, any research reviewing the limits to the reintroduction success should still consider as many life stages as possible. Research into the post-fledging period is especially important, considering factors such as the continued loss of owl habitat to development will likely affect habitat available to juvenile owls and ultimately their survival in the future.

Finally, although it was determined that juvenile and adult recruitment of owls from the Nicola Valley are not low in comparison to wild populations elsewhere (Chapter 2 and 3), there is a lack of information available on yearly (rather than just seasonal) mortality and movements of Burrowing Owls. Information gathered on how mortality in wintering grounds and during migration is affecting return rates throughout the Burrowing Owl's range would have important management implications. Although a net loss of 'Canadian' owls to the northern United States has been reported (Duxbury 2004), it is unclear whether this is a result of high emigration from Canada or low immigration from the U.S., when compared to historical rates (Environment Canada 2008). Therefore, further research in these areas is highly recommended.

## **MANAGEMENT IMPLICATIONS**

Given the relative success of the enclosure-based soft-release technique and the limited resources available for reintroduction efforts, this method for releasing captive-bred Burrowing Owls has proven to be a worthwhile investment. Although there are costs associated with the construction, placement, and removal of enclosures, there must be consideration of the cost of producing additional Burrowing Owls in captivity to produce the same number of surviving released adults and wild-hatched juveniles that result from the use of the soft-release technique. For any reintroduction effort, I would recommend using young, captive-bred animals that are capable of breeding in the year they are released in order to minimize their time in captivity while simultaneously maximizing the opportunity to breed in the wild, and their potential to return in the future. Such protocols should be implemented to facilitate meeting the recovery goals for Burrowing Owls in British Columbia and other parts of the Burrowing Owl range where reintroductions are required. With appropriate modifications, this protocol can also be applied in recovery efforts for other endangered or threatened species.



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**APPENDIX A.**

## **APPENDIX A. Comparison of prey consumption between released and wild Burrowing Owls in British Columbia**

### **INTRODUCTION**

Direct behavioural comparisons between captive-bred and wild animals are useful for determining the ability of captive-bred animals to persist once released (Mathews et al. 2005). The ability of captive-bred animals to exhibit behaviours (e.g., foraging, predator avoidance, and reproductive) similar to their wild counterparts is typically the primary factor affecting the success of reintroduction efforts (Meretsky et al. 2001, White et al. 2005). Foraging behaviour, in particular, has been identified as one limitation for naïve, captive-bred animals that are establishing themselves in the wild after release (Bright and Morris 1994, Touchton et al. 2002, Mathews et al. 2005).

The primary objectives of my study were to conduct 1) a monthly comparison of diet between released and wild Burrowing Owls, and 2) a temporal days-post-release comparison of diet between Burrowing Owls released with 2 different release techniques. These comparisons were completed in order to assess how the abilities of released captive-bred owls to acquire natural prey might be affecting the reintroduction effort, and to make recommendations on how to maximize the success of the reintroduction.

### **STUDY AREA**

See Chapters 2 and 3

### **METHODS**

#### **Supplemental feeding**

See Chapter 2

#### **Pellet collection and analyses**

To monitor intake of natural prey, I collected pellets and inspected prey remains and caches at nest and roost burrows of a subset of hard-released, soft-released, and wild breeding Burrowing Owl pairs until just prior to migration. I attempted to collect a minimum of 4 pellets every 3 days for the first 3 weeks following release, and 2-3 times per month throughout the breeding season from released and wild pairs from all study sites. I first teased apart pellets by hand to identify and isolate any hair and feathers. I soaked the remaining portions of the pellet in 2.5 molar NaOH solution (Marti et al. 1986) that dissolves integument, such as hair and feathers. After

soaking the samples in NaOH solution, I dried the remaining bones and chitin, and carefully examined them to isolate key components for identification. I used the maximum number of left and right lower mandibles in combination with skulls and upper mandibles to enumerate mammal species. I excluded any unknown mammalian components from analyses.

I also counted small mammals (rodents and shrews), bird species and toads present in the prey remains and in caches to estimate the dietary make-up. I used the small mammal identification guide (The Royal BC Museum; Nagorsen 2002), and sample collections in the Cowan Vertebrate Museum at the University of British Columbia (UBC) to ensure correct identification of vertebrate prey items. I used the invertebrate field guide of North America (Knopf 1980) and sample collections at the Scudder Entomology Museum at UBC to ensure correct identification of invertebrate specimens. Domestic mice skulls and bones of young chickens from supplemental feeding were easily distinguished from natural prey items.

I summed prey item data for nests of all wild and released pairs in the seasonal comparison, and data from nests of hard-released and soft-released pairs in the days-post-release comparison. The seasonal comparison was summarized by month during the breeding season to allow for a detailed analysis and comparison with results reported in previous studies in this region (Leupin and Low 1999, Rankin 2006), and with study results from other areas (Sissons 2003, Shyry 2005). However, April was excluded because soft-released pairs were still enclosed and not available for comparison in that month. For the days-post-release comparison, I reviewed data at 3-day intervals post-release (beginning at 3-days and ending at 21-days) in order to determine the length of time before released birds acquired natural prey. Post-release began after the block was removed from burrows for hard-released pairs (~24 hrs after placement in the field) and after enclosures were removed from covering burrows for soft-released pairs (~2 wks after placement in the field) when the pairs were free to hunt.

I identified a total of 1,860 prey items in 2005 and 3,934 items in 2006 (Table A1). I used the full collection of pellets and prey items for the seasonal comparison, but used a subset of pellets (numbers in parentheses) for the days-post-release comparison. Pellets and prey remains were analysed from 12 hard-released, 12 soft-released, and 4 wild pairs. I analysed prey categories in terms of percent frequency and percent biomass (mean weights) (Table A2).

I used Mann-Whitney U tests to compare average percent frequency and biomass because the data was non-normally distributed, and were not transformed to fit a parametric test because of small sample size (<10 categories). I tested seasonal average percent frequencies and biomasses for each prey category between released and wild birds, and post-release temporal

frequencies and biomasses for each prey category between hard-released and soft-released birds. Because there was no detectable difference between years, I pooled the data. I used JMP 5.1.2 statistical package for all comparisons.

**Table A1.** Burrowing Owl pellet collection in British Columbia in 2005 and 2006. Days-post-release pellet subset in parenthesis.

| Pellet collection                                  | 2005      | 2006      |
|--|-----------|-----------|
| # of pellets                                       | 431 (152) | 774 (171) |
| # of items identified from pellets                 | 1,707     | 3,746     |
| # of items identified from prey remains and caches | 153 (81)  | 188 (104) |

**Table A2.** Prey body weights used to calculate biomass component of prey categories identified in Burrowing Owl pellets, prey caches and remains in British Columbia in 2005 and 2006.

| Prey Category   | Mass (g) | Source   |
|---|----------|--|
| <b>MAMMALS</b>  |          |  |
| <i>Microtus pennsylvanicus</i>                                | 33.2     | Nagorsen 2002                                    |
| <i>Thomomys talpoides</i>                                     | 90.7     | Nagorsen 2002                                    |
| <i>Peromyscus maniculatus</i>                                 | 21.7     | Nagorsen 2002                                    |
| <i>Sorex sp</i>   | 6.1      | Nagorsen 2002                                    |
| <b>AVES</b>   |          |  |
| Passeriformes   | 30.0     | Marti 1974                                       |
| <b>ANURANS</b>  |          |  |
| Average of <i>Bufo boreus</i> and<br><i>Spea intermontana</i> | 43.3     | Matsuda et al 2006<br>Högland and Säterberg 1989 |
| <b>INSECTS</b>  |          |  |
| Coleoptera  | 0.3      |  |
| Carabidae   | 0.2      | Marti 1974                                       |
| Scarabidae  | 0.3      | Marti 1974                                       |
| Silphidae   | 0.3      | Marti 1974                                       |
| Tenenebrionidae   | 0.6      | Marti 1974                                       |
| Histeridae  | 0.2      | Estimated from Knopf, 1980                       |
| Brentidae   | 0.2      | Estimated from Knopf, 1980                       |
| Cicindelidae  | 0.3      | Estimated from Knopf, 1980                       |
| Unknown coleoptera  | 0.3      | Estimated  |
| Orthoptera  | 0.5      | Marti 1974                                       |
| Hymenoptera   | 0.1      | Estimated from Knopf, 1980                       |
| Diptera   | 0.1      | Estimated from Knopf, 1980                       |
| Unknown Insects   | 0.3      | Estimated  |
| <b>SUPPLEMENTAL FEED</b>                                      |          |  |
| <i>Gallus domesticus</i>                                      | 34.0     | This study                                       |
| <i>Mus musculus domesticus</i>                                | 22.0     | This study                                       |

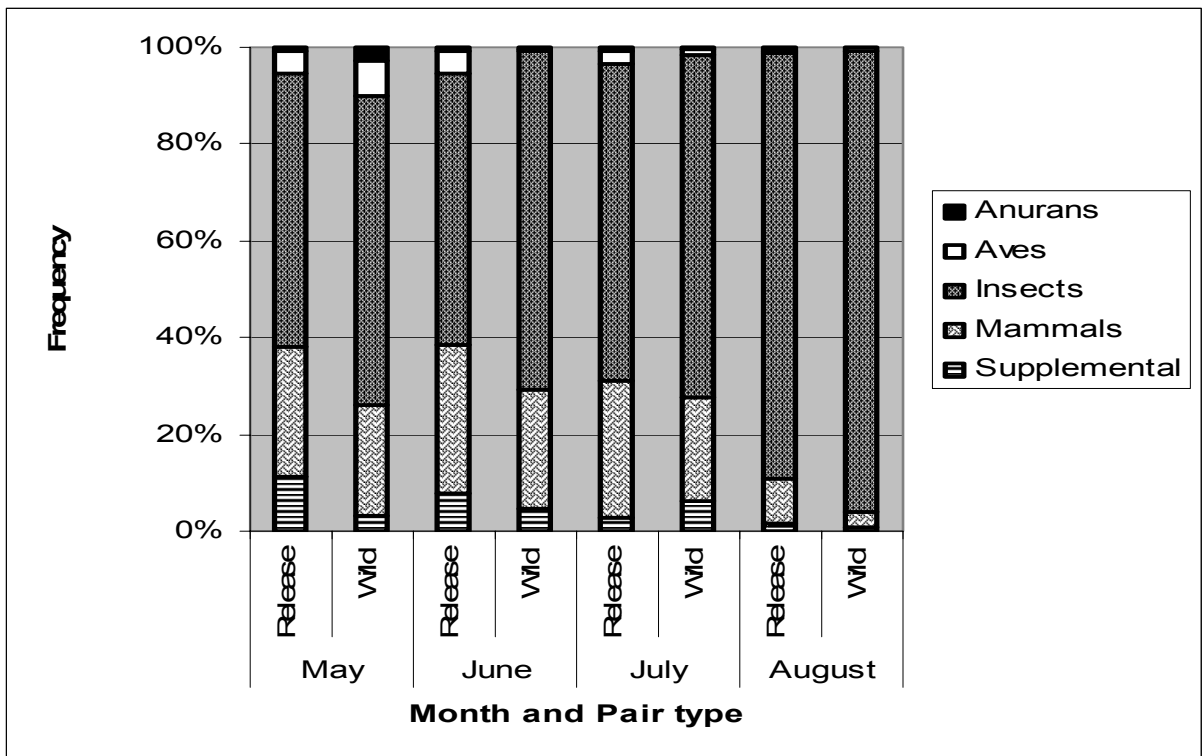
## RESULTS AND DISCUSSION

Prey items were classified into five categories: mammals, aves, anurans, insects, and supplemental food (Figure A1a and b and Figure A2a and b). The mammals identified were largely cricetine rodents, which accounted for the largest biomass component (~64%) for both released and wild owls. In order of abundance, they were Meadow Voles (*Microtus pennsylvanicus*), Deer Mice (*Peromyscus maniculatus*), and Northern Pocket Gophers (*Thomomys talpoides*). Shrews (*Sorex sp.*) were also observed in small amounts in both years.

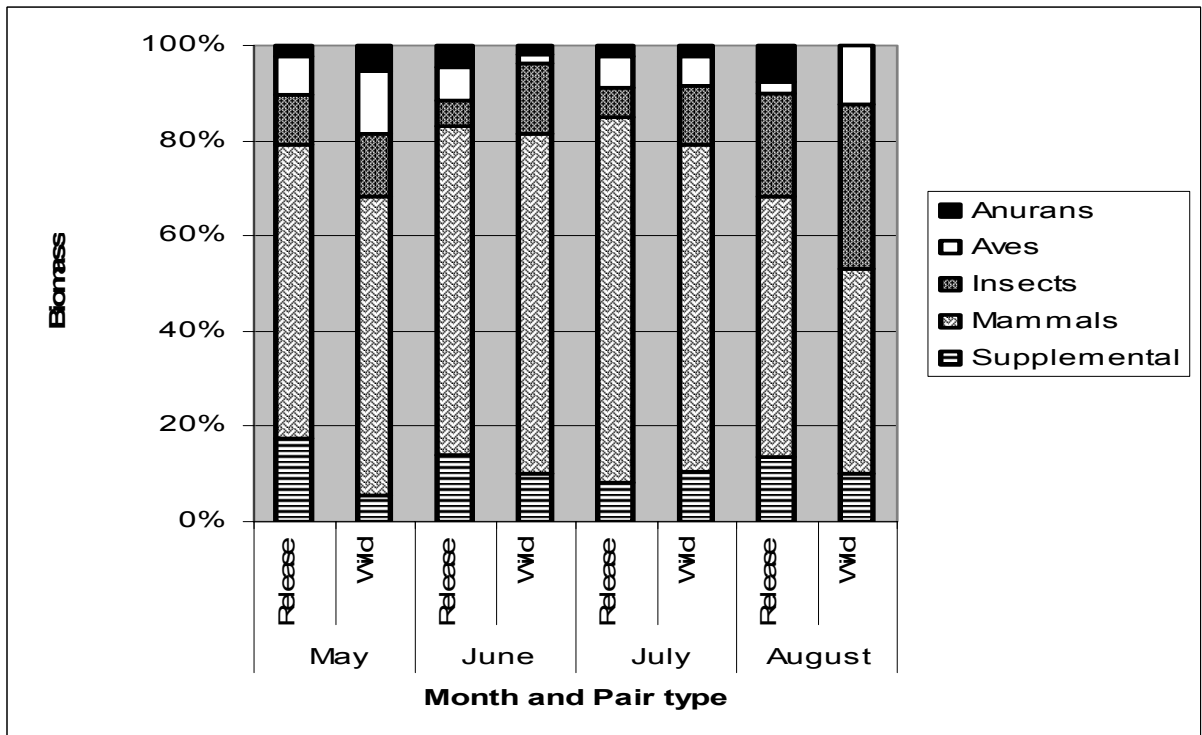
Mammals were the most consistent part of both the released and wild owls' diet (21% mean frequency) throughout the season, and this was comparable to what has been previously reported for wild owls in Canada (Sissons 2003, Shyry 2005). I detected no difference between released and wild owls in the proportional consumption of mammals throughout the season. Within 3 days of release, soft-released owls were consuming mammalian prey in similar proportions as the average seasonal % frequency and % biomass (22% and 56%, respectively). However, hard-released owls consumed mammalian prey at a lower % frequency and % biomass until 12 days post-release (average 11% and 32% respectively, prior to this time).

Aves components in pellets were not identifiable in my study to species; however, information from prey remains identified four species or species types. Western Meadowlark (*Sturnella neglecta*) was most commonly encountered, and accounted for 50% of my observations. Mountain Bluebird (*Sialia currucoides*), Vesper Sparrow (*Pooecetes gramineus*), and various other sparrow species (*Passer sp.*) accounted equally for the rest. Similar to other reports on the Burrowing Owl's diet, aves made up a small proportion (<10%) of both frequency and biomass. I detected no difference between released and wild owls in the consumption of this prey category seasonally. Soft-released owls demonstrated the ability to acquire avian prey within 3 days of release, while avian prey did not appear at nests of hard-released owls until 6 days of release.

Reptiles were not included as a prey category because they occurred very infrequently. Garter Snakes (*Thamnophis sp.*) were only observed on four separate occasions during my study. Western (*Bufo boreus*) and Great Basin spadefoot (*Spea intermontana*) toads were observed equally in prey remains and caches. The presence of anurans has been previously noted but not quantified in British Columbia (Leupin 2004), and the majority of anurans in my study were found from sites close to Kamloops at higher elevations.

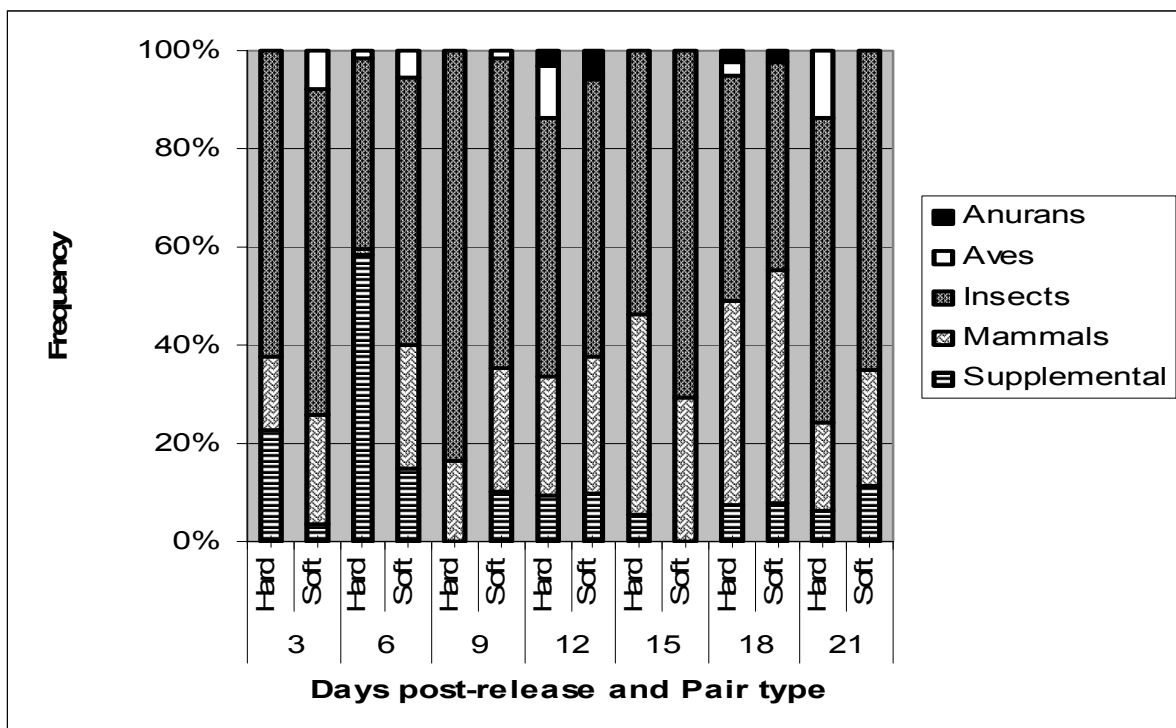


**Figure A1a:** Seasonal changes in percent frequency in the diets of released and wild Burrowing Owls in British Columbia in 2005 and 2006.

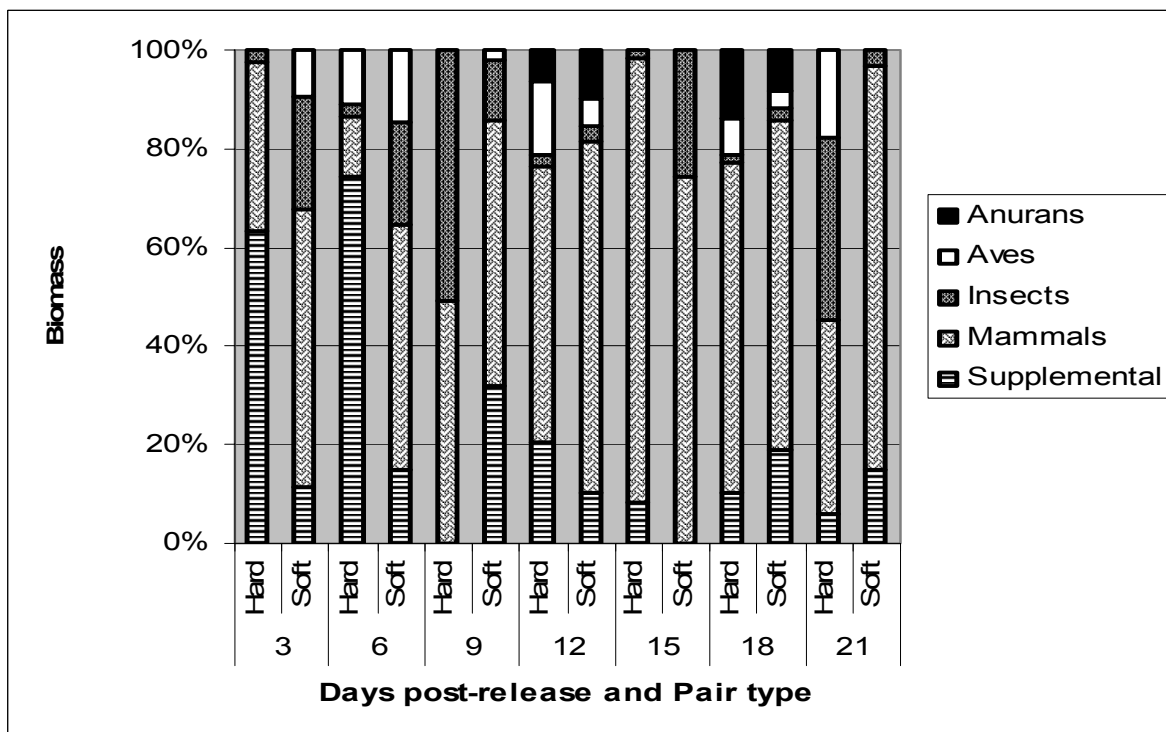


**Figure A1b:** Seasonal changes in percent biomass in the diets of released and wild Burrowing Owls in British Columbia in 2005 and 2006.





**Figure A2a:** Post-release temporal changes in percent frequency in the diets of hard-released and soft-released Burrowing Owls in British Columbia in 2005 and 2006.



**Figure A2b:** Post-release temporal changes in percent biomass in the diets of hard-released and soft-released Burrowing Owls in British Columbia in 2005 and 2006.

Anurans accounted for the lowest percentage of mean frequency (<1%) and biomass (3%) among all categories seasonally, and were distributed equally between released and wild owls. Both hard-released and soft-released owls demonstrated the ability to acquire anuran prey within 12 days of release.

The most diverse group of prey items were insects (71% frequency and 15% biomass seasonally for all owls). Insects were further separated into five classes based on Order (also in order of abundance): coleoptera (average 70% of observations), orthoptera (16%), hymenoptera (6%), diptera (4%), and unknown insects (4%). Because head capsules and elytra were easily separated out from pellets, I also identified many families of insects.

Most insect families identified were in the order coleoptera. In order of abundance, insect families included: carabidae (ground beetles), including genus carabus; scarabaeidae (scarab beetles); silphilidae (carrion beetles), including the genus nicophorus; tenebrionidae (darkling beetles), including the genus coelochemis; cicindelidae (tiger beetles), including genus cicindela; brentidae (weevils); histeridae (hister beetles); and lucanidae (stag beetles). The significant contribution of coleopteran to Burrowing Owl diets has also been previously reported (Leupin and Low 2001, Sissons 2003, Shyry 2005).

I was able to further divide hymenoptera into several different groups (in order of abundance): ants (formicidae), wasps (all from family ichneumonidae), and bees (all from family apidae). The common occurrence of hymenoptera (in my study) has not been reported in previous Burrowing Owl diet studies (Leupin and Low 2001, Sissons 2003, Shyry 2005). Identification of orthoptera mandibles to family or genus was more challenging. However, I was able to identify several species from whole field samples: Spur-throated and Band-winged Grasshoppers (*Acrididae spp.*) and Crickets (*Gryllidae spp.*).

Insects became an increasingly important part of released and wild owl's diet as the season progressed. I also recorded a shift from a higher reliance on beetles (coleopteran) early in the season to grasshoppers (orthoptera) later in the season, which has been previously reported for wild Burrowing Owls in other regions (Sissons 2003, Shyry 2005). Both hard-released and soft-released owls were consuming insects at similar frequencies (62% and 66%, respectively) of the seasonal average percent frequency within 3 days of release.

The supplemental diet, as revealed by pellet analysis, was composed of 55% laboratory mice (*Mus musculus domesticus*) and 45% domestic chicks (*Gallus domesticus*). This was representative of the proportions fed, which was a 50-50 split between the two supplemental food items. I detected no difference in the overall contribution of supplemental food to the diet

of released or wild birds seasonally. However, hard-released birds had a higher reliance on supplemental food (average 19% frequency and 33% biomass) within the first 15 days of release than did soft-released ones (average 8% frequency and 14% biomass).

The seasonal similarity in the diet between captive-bred released and wild owls suggests that hunting and foraging abilities of Burrowing Owls may be largely innate. This is supported by previous observations of the immediate appearance of hunting ability in released owls (Leupin et al. 1999). My study now provides the experimental data that indicates foraging behaviour of captive-bred owls is not limiting the success of reintroductions in British Columbia.

There is also evidence that release techniques can have a larger influence on captive animals' dependence on supplemental food than their past captivity (Bright and Morris 1994). This was supported in my study with the soft-release method appearing to aid owls in acquiring hunting abilities sooner after release than owls released with the hard-release method. Having a delayed release potentially allowed more time for the owls to assess the foraging areas in the vicinity of their nest, while simultaneously reducing their stress levels to allow for the faster development of hunting ability once they were released.

## **MANAGEMENT IMPLICATIONS**

Release and wild Burrowing Owls in this region of British Columbia demonstrated proportional diets equal to each other, and to owls in other parts of the Burrowing Owl's range. There is no indication currently that foraging behaviour is limiting reintroduction success, but release techniques do appear to affect how quickly released birds acquire some natural prey items. Therefore, I would recommend that any future attempts to maximize the success of Burrowing Owl reintroductions should focus on increasing post-release survival and reproductive performance through the enclosure-based soft-release technique (see Chapter 2), as opposed to any pre-release prey acquisition training. However, because this comparison only reviewed proportions of prey categories in diet, an experiment testing quantity of prey acquired would provide information on whether wild birds acquire significantly more food than released birds. Although this population of Burrowing Owls is provided with supplemental food, results from my study have shown that it constitutes only a small proportion of the owl's diet. Future research could test how different levels of supplemental feeding affects nesting success and productivity. Finally, I would also recommend further investigation into relationships between Burrowing Owls, rodent populations, and prey habitat management in this area. The information gathered

from these additional studies will allow for management decisions that further maximize reintroduction success, while minimizing resources needed.

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**APPENDIX B.**

## **APPENDIX B. Habitat use by post-fledging juvenile Burrowing Owls in British Columbia**

### **INTRODUCTION**

Identifying available habitat and its use is the first step towards maintaining, increasing, and enhancing breeding and foraging habitat, a goal that has been recognized as an important component of the recovery effort for Burrowing Owls (Environment Canada 2008). I studied habitat availability and use by juveniles to help identify ways to improve the program to reintroduce captive-bred Burrowing Owls in British Columbia. Information on what habitat types juvenile Burrowing Owls are selecting can be used to make management recommendations on how to maximize success of the reintroduction.

### **STUDY AREA**

See Chapters 2 and 3

### **METHODS**

#### **Juvenile tagging**

See Chapter 3

#### **Nocturnal habitat-use tracking**

I tracked nocturnal habitat-use with a handheld YAGI antenna and a Communications Specialist R-1000 receiver. For a total of 546 tracking days, I tracked each juvenile twice per week, from post-fledging until there was evidence of mortality or the signal was lost. Because juveniles were being tracked diurnally for survival (see Chapter 3), I knew their current status (within 1-2 days) and location. I scheduled tracking by study site in 30-60 minute intervals for each juvenile, and rotated the intervals each tracking session. Depending on the target intervals, and time needed to travel between study sites, I tracked 5-8 juveniles per night. Points were taken by two observers taking simultaneous points while in constant radio contact (Springer 1979).

To minimize errors, observers positioned themselves to create as close to a 90° angle as possible with the owl location. Based on the last known location of the owl during the day (typically within 100 m of nest), I would decide in advance where to begin the tracking session. These positions were typically the same for most tracking sessions, but once juveniles began making larger movements, observers would adjust their positions in order to best obtain the desired angle. In cases where owls made too large of a movement in a short time, and the

resulting angle was  $<40^\circ$  or  $>140^\circ$ , I excluded these locations due to the extremely elliptical polygon errors created (4% of readings). If time permitted during other tracking sessions, observers made another attempt to obtain locations for timeslots when points were excluded because of angle error. I still considered points valid even if they were within  $<50$  m of nest because juveniles often spend time foraging for insects in the area immediately surrounding their nest both diurnally and nocturnally (pers. obs. 2004).

Observers recorded time, angle to strongest signal, and observer location (by Global Position System [GPS] in Universal Transverse Mercator [UTMs]) at 7.5-minute intervals, to keep track of juvenile movements. However, I used points only every 15 minutes for analyses to ensure independence. While reviewing data I determined 15 minutes to be ample time for owls to cross the maximum distance of their habitat-use range. I attempted to gather at least 30 points from the period of 2100-0500 for each juvenile, otherwise the juveniles was omitted from habitat-use analysis. I considered a full collection of points to be 64 points each taken every 7.5-minutes, which translated into 32 points when every 15-minute interval was used.

I downloaded and transferred observer locations into a database, and then entered the corresponding angles. I transferred the database into the program Locate III (Nams 2006), where point locations and error polygons were calculated with the in-field calculated error angle of  $5^\circ$ . I imported points into the Geographic Information Systems (GIS) program, ArcGIS 9 with Spatial Analyst. Finally, in order to incorporate error area, I added error buffers to all resulting locations once in ArcGIS.

### **Habitat mapping**

Observers conducted habitat mapping by ground truthing 1: 20,000 orthophotos (courtesy of the BC Ministry of Environment and the Integrated Land Management Bureau Base Mapping and Geomatic Services) as soon as juveniles were collared. After each tracking session, I downloaded observer locations and estimated owl locations with the accompanying Garmin GPS software, MapSource Version 5.4. Observers conducted habitat mapping based on the estimated location of points and the radius of the maximum distance from the nest that was used to define available habitat. Once a complete set of points were acquired for each juvenile, I downloaded the final points, summarized databases, and imported them into ArcGIS. Observers then mapped any areas that were encompassed by available habitat that had not already been surveyed.

I characterized habitat types into 7 categories: 1) bare ground, 2) tame pasture, 3) hayland, 4) disturbed grassland, 5) grassland, 6) meadows, and 7) grazed hayland (Table C1). I classified



habitats guided by descriptions within the “Plants of the Southern Interior British Columbia and the Inland Northwest” (Parish et al. 1996). I described vegetation types associated with moisture, soil regimes, and the degree of grazing, which ultimately affected the distribution and height of vegetation. I mapped forested areas and water, but excluded them from habitat-use analyses because I considered them unsuitable for the owls. Only 4-5 categories were available in significant amounts to juveniles within particular study sites. The majority of nests of juveniles were in tame pasture ( $n = 18$ ) and native grassland areas ( $n = 7$ ), with only one located in disturbed grassland.

To compare results from all study sites, I made final comparisons based on which key similarities were present (e.g., tall or short vegetation, grazed or ungrazed, potential for insect abundance and availability) when I observed statistically-significant preferences or avoidances. I ground-truthed habitat types by recording on printed copies of orthophotos, and then used them to guide digitizing in ArcGIS. I overlaid points with error buffers and habitat available (again created from the radius of the maximum distance each juvenile traveled) on the created habitat type layer. I clipped and summarized both the point-error buffers and habitat available by habitat type and its corresponding area.

### **Data analysis**

I used Chi-square contingency analyses to determine whether habitat types were significantly preferred or avoided and calculated simultaneous confidence intervals using the Bonferroni adjustment ( $\alpha$  level for each test was the equivalent of 0.05 divided by the number of comparisons) (Neu et al. 1974, Zar 1974, Byers et al. 1984). I conducted comparisons on a study site and year basis because habitat available to individuals within study sites in the same year were homogeneous but were heterogeneous (all tests showed significant difference as described in Zar 1974 pp.51-53) in the same study site between the 2 years of my study. In other words, I pooled all individual juvenile data for each study site for each year. I conducted 12 different available habitat-use comparisons based on study sites and year.

**Table C1.** Habitat type classifications of post-fledging juvenile Burrowing Owl available habitat in the Nicola Valley, British Columbia.

| Habitat type        | Description   |
|---------------------|---|
| Bare ground         | Areas of stripped of vegetation (e.g., cattle dugouts) and roads (i.e., paved, gravel, and dirt 2-way tracks).  |
| Tame pasture        | Dominated by introduced crested wheat ( <i>Agropyron cristatum</i> ), to the extent of being a monoculture at times. Vegetation ranges from very thin and sparse, with large sections of bareground, to dense fields of grass, where more moisture is available. Crested wheat is planted as a forage crop, and tends to dominate in those areas. It almost exclusively occurs on flat or rolling fields that have been plowed and seeded. Dry, sandy soils are common. Grazed more heavily in the early season when tender shoots are preferred by cattle.   |
| Hayland             | Irrigated monocultures of alfalfa ( <i>Medicago sativa</i> ) or other introduced hay species which are cut periodically.  |
| Disturbed grassland | Grassland areas significantly disturbed by human activity and grazing. Dominated by introduced and hardy grasses as well as weedy species such as; Kentucky bluegrass ( <i>Poa pratensis</i> ), bromes ( <i>Bromus spp.</i> ), great mullien ( <i>Verbascum thapsus</i> ), dandelion ( <i>Taraxacum officinale</i> ), mustards ( <i>Sisymbrium spp.</i> ), stickseed ( <i>Lappula redowskii</i> and <i>Hackelia micrantha H. jessicae</i> ) and thistles ( <i>Cirsium spp.</i> ). Occurring near roadsides and in depressions with moderate moisture. Because these areas produce more green tender food, cattle tend to concentrate their grazing on these areas. Grass is often grazed down to a few centimeters, leaving only a few tall unpalatable species, such as giant mullien and thistles untouched.  |
| Grassland           | Dominated by Western fescue ( <i>Festuca occidentalis</i> ), bluebunch wheatgrass ( <i>Agropyron spicatum</i> ), and rabbit-brush ( <i>Chrysanthammus nauseosus</i> ). Often includes prickly pear ( <i>Opuntia ployacantha</i> ), cut-leaved daisy ( <i>Erigeron compositus</i> var. <i>glabratus</i> ), needle-and-thread grass ( <i>Stipa comata</i> ), low pussytoes ( <i>Antennaria dimorpha</i> ), and tarragon ( <i>Artemisia dracunculus</i> ). Vegetation is somewhat sparse, with patches of bareground throughout. Vegetation height varies, with rabbit brush and medium tall grasses providing cover for prey. Soil is rocky and well drained and there is very little moisture. Outcroppings of bare rock are common. Although this habitat consists mostly of native prairie species, their distribution has been dramatically altered due to grazing. |
| Meadows             | Areas that receive large amounts of moisture, in depressions, and on the fringes of marshes and ponds and characterized by alkali soils. Common vegetation includes silverweed ( <i>Potentilla anserina</i> ), Baltic rush ( <i>Juncus balticus</i> ), scouring-rush ( <i>Equisetum hyemale</i> ), Nuttall's alkaligrass ( <i>Puccinellia nuttalliana</i> ), hawkweed ( <i>Heiracium spp.</i> ), foxtails ( <i>Hordeum jubatum</i> ), and strawberry ( <i>Fragaria virginiana</i> ). Vegetation usually quite low dense growing, becoming tall quickly when flower spikes grow later in the season.   |
| Grazed hayland      | Hayland (grass <i>sp.</i> ) that had regular grazing occurring (only present in 1 study site) within the post-fledging juvenile period.   |

## RESULTS

### Foraging range

I used the distance of nocturnal travel away from the active natal or roost burrow as a measure of foraging range. Ninety percent of movements by collared juveniles in both years were less than 600 m (577 m in 2005, 518 m in 2006). The mean distance traveled in 2006 (277 m) was higher than in 2005 (207 m) ( $t_{2262} = -8.01$ ,  $P \leq 0.001$ ). However, I detected no between-year difference in the maximum distances traveled by collared juveniles. Mean distances traveled by juveniles of wild parents (230 m) did not differ from juveniles of released parents (278 m). Larger movements (>600 m) tended to occur between 2300 and 0000 hrs and then again between 0400 and 0500 hrs. This indicates distant foraging activities were probably maximized from approximately 1.5-2.5 hrs after sunset and again at 1.5-0.5 hrs before sunrise.

### Habitat use

Of the 12 habitat-use comparisons, all but 3 displayed preferences or avoidances of one or more habitat types (Table C2). I detected clear preferences or avoidances of 4 habitat types. Tame pasture was the most commonly preferred habitat (7 of 9; 78% of significant habitat comparisons). In the one case where tame pasture was not available, grazed hayland, a unique habitat type to that study site, was overwhelmingly preferred. Grassland was the most frequently avoided habitat type (6 of 9; 67%), and was also the only habitat that was available at all study sites. At all study sites where hayland was available ( $n = 5$ ), it was avoided as well.

The remaining habitat types that I mapped were neutral and were only either preferred or avoided in a few comparisons. Bare ground was available in small amounts at most study sites ( $n = 8$ ) but was used in proportion to what was available. In areas where disturbed grassland was available ( $n = 8$ ), it was preferred only once (13% of the time), avoided 3 times (38%), and used in accordance with availability at the remaining 4 sites (50%). Meadow was available in 6 habitat-use comparisons. Although in most cases ( $n = 5$ ) meadow was used at a higher proportion than available, it was only significantly preferred once (20%). Meadow was also significantly avoided on one occasion.

**Tame pasture → Meadow → Bare ground → Disturbed grassland → Grassland → Hayland  
(Grazed hayland\*)**

Preferred ----- --→ Neutral -----→ Avoided -----→

\*On the one occasion where grazed hayland was available tame pasture was not.

**Table C2.** Habitat available-use of post-fledging juveniles Burrowing Owls in British Columbia

| <b>GUICHON</b>      |                     | <b>A 2005</b> ( $N = 2$ ), $X^2 = 58.5$ , $P < 0.001$ |  |                     | <b>A 2006</b> ( $N = 4$ ), $X^2 = 41.1$ , $P < 0.001$          |   |  |
|---------------------|---------------------|---|--|---------------------|--|---|--|
| Nest type           |                     | <b>Tame pasture</b>                                   |  |                     | <b>Tame pasture</b>  |   |  |
| Habitat Type        | Observed Proportion | Expected Proportion                                   | Bonferroni Confidence Intervals                  | Observed Proportion | Expected Proportion  | Bonferroni Confidence Intervals               |  |
| Bare ground         | 0.042               | 0.027   | $0.000^a \leq x \leq 0.100$                      | 0.026               | 0.021  | $0.000^a \leq x \leq 0.062$                   |  |
| Tame pasture        | 0.295               | 0.130   | <b><math>0.162 \leq x \leq 0.429^*</math></b>    | 0.194               | 0.083  | <b><math>0.105 \leq x \leq 0.281^*</math></b> |  |
| Hayland             | n/a                 | n/a   | ----   | n/a                 | n/a  | ----  |  |
| Disturbed grassland | n/a                 | n/a   | ----   | 0.017               | 0.066  | $0.000^a \leq x \leq 0.047^{**}$              |  |
| Grassland           | 0.195               | 0.650   | $0.079 \leq x \leq 0.310^{**}$                   | 0.594               | 0.741  | $0.485 \leq x \leq 0.703^{**}$                |  |
| Meadow              | 0.468               | 0.193   | $0.322 \leq x \leq 0.614^*$                      | 0.169               | 0.089  | $0.085 \leq x \leq 0.252$                     |  |
| <b>GUICHON</b>      |                     | <b>B 2006</b> ( $N = 2$ ), $X^2 = 12.7$ , $P < 0.002$ |  |                     | <b>Stackyard 2005</b> ( $N = 1$ ), $X^2 = 137.2$ , $P < 0.001$ |   |  |
| Nest type           |                     | <b>Grassland</b>                                      |  |                     | <b>Disturbed grassland</b>                                     |   |  |
| Habitat Type        | Observed Proportion | Expected Proportion                                   | Bonferroni Confidence Intervals                  | Observed Proportion | Expected Proportion  | Bonferroni Confidence Intervals               |  |
| Bare ground         | n/a                 | n/a   | ----   | 0.010               | 0.070  | $0.009 \leq x \leq 0.011^{**}$                |  |
| Tame pasture        | 0.203               | 0.095   | $0.086 \leq x \leq 0.320$                        | <b>0.750</b>        | <b>0.230</b>   | <b><math>0.746 \leq x \leq 0.754^*</math></b> |  |
| Hayland             | n/a                 | n/a   | ----   | 0.000               | 0.140  | $0.000 \leq x \leq 0.000^{**}$                |  |
| Disturbed grassland | 0.350               | 0.294   | $0.212 \leq x \leq 0.489$                        | 0.240               | 0.127  | <b><math>0.236 \leq x \leq 0.244^*</math></b> |  |
| Grassland           | 0.447               | 0.611   | <b><math>0.302 \leq x \leq 0.591^{**}</math></b> | 0.000               | 0.340  | $0.000 \leq x \leq 0.000^{**}$                |  |
| Meadow              | n/a                 | n/a   | ----   | 0.000               | 0.093  | $0.000 \leq x \leq 0.000^{**}$                |  |
| <b>BERESFORD</b>    |                     | <b>2005</b> ( $N = 2$ ), $X^2 = 46.1$ , $P < 0.001$   |  |                     | <b>2006</b> ( $N = 2$ ), $X^2 = 17.1$ , $P < 0.002$            |   |  |
| Nest type           |                     | <b>Tame pasture</b>                                   |  |                     | <b>Tame pasture</b>  |   |  |
| Habitat Type        | Observed Proportion | Expected Proportion                                   | Bonferroni Confidence Intervals                  | Observed Proportion | Expected Proportion  | Bonferroni Confidence Intervals               |  |
| Bare ground         | n/a                 | n/a   | ----   | 0.007               | 0.026  | $0.000^a \leq x \leq 0.033$                   |  |
| Tame pasture        | 0.534               | 0.212   | <b><math>0.394 \leq x \leq 0.673^*</math></b>    | 0.506               | 0.328  | <b><math>0.351 \leq x \leq 0.662^*</math></b> |  |
| Hayland             | n/a                 | n/a   | ----   | n/a                 | n/a  | ----  |  |
| Disturbed grassland | n/a                 | n/a   | ----   | 0.000               | 0.075  | $0.000 \leq x \leq 0.000^{**}$                |  |
| Grassland           | 0.378               | 0.701   | $0.242 \leq x \leq 0.514^{**}$                   | 0.308               | 0.431  | $0.164 \leq x \leq 0.451$                     |  |
| Meadow              | 0.088               | 0.087   | $0.009 \leq x \leq 0.168$                        | 0.179               | 0.140  | $0.060 \leq x \leq 0.299$                     |  |

These values are actually for a unique category to Guichon Stackyard = Grazed hayland

**Table C2.** Continued...

**HAUGHTON 2005** ( $N = 1$ ),  $X^2 = 22.8$ ,  $P < 0.001$

**2006** ( $N = 4$ ),  $X^2 = 26.2$ ,  $P < 0.001$

| Nest type           | Tame pasture        |                     |   | Tame pasture        |                     |   |
|---------------------|---------------------|---------------------|---|---------------------|---------------------|---|
| Habitat Type        | Observed Proportion | Expected Proportion | Bonferroni Confidence Intervals               | Observed Proportion | Expected Proportion | Bonferroni Confidence Intervals               |
| Bare ground         | 0.041               | 0.028               | $0.000^a \leq x \leq 0.121$                   | n/a                 | n/a                 | ----  |
| Tame pasture        | 0.470               | 0.217               | <b><math>0.268 \leq x \leq 0.672^*</math></b> | 0.418               | 0.256               | <b><math>0.318 \leq x \leq 0.517^*</math></b> |
| Hayland             | 0.000               | 0.149               | $0.000 \leq x \leq 0.000^{**}$                | n/a                 | n/a                 | ----  |
| Disturbed grassland | 0.197               | 0.125               | $0.036 \leq x \leq 0.358$                     | 0.031               | 0.126               | $0.000^a \leq x \leq 0.066^{**}$              |
| Grassland           | 0.292               | 0.481               | $0.108 \leq x \leq 0.476^{**}$                | 0.551               | 0.618               | $0.451 \leq x \leq 0.651$                     |
| Meadow              | n/a                 | n/a                 | ----  | n/a                 | n/a                 | ----  |

**DELEEUWS 2006** ( $N = 1$ ),  $X^2 = 0.5$ ,  $P = 0.492$

**HAMILTON 2005** ( $N = 2$ ),  $X^2 = 6.3$ ,  $P = 0.052$

| Nest type           | Tame pasture        |                     |                                 | Grassland           |                     |                                 |
|---------------------|---------------------|---------------------|---------------------------------|---------------------|---------------------|---------------------------------|
| Habitat Type        | Observed Proportion | Expected Proportion | Bonferroni Confidence Intervals | Observed Proportion | Expected Proportion | Bonferroni Confidence Intervals |
| Bare ground         | n/a                 | n/a                 | ----                            | 0.053               | 0.020               | $0.000^a \leq x \leq 0.116$     |
| Tame pasture        | 0.816               | 0.792               | $0.717 \leq x \leq 0.915$       | n/a                 | n/a                 | ----                            |
| Hayland             | n/a                 | n/a                 | ----                            | n/a                 | n/a                 | ----                            |
| Disturbed grassland | n/a                 | n/a                 | ----                            | n/a                 | n/a                 | ----                            |
| Grassland           | 0.145               | 0.167               | $0.055 \leq x \leq 0.235$       | 0.589               | 0.674               | $0.449 \leq x \leq 0.728$       |
| Meadow              | n/a                 | n/a                 | ----                            | 0.358               | 0.306               | $0.223 \leq x \leq 0.494$       |

**QUILCHENA 2005** ( $N = 2$ ),  $X^2 = 9.5$ ,  $P = 0.050$

**2006** ( $N = 2$ ),  $X^2 = 52.2$ ,  $P < 0.001$

| Nest type           | Grassland           |                     |                                 | Tame pasture        |                     |   |
|---------------------|---------------------|---------------------|---------------------------------|---------------------|---------------------|---|
| Habitat Type        | Observed Proportion | Expected Proportion | Bonferroni Confidence Intervals | Observed Proportion | Expected Proportion | Bonferroni Confidence Intervals               |
| Bare ground         | 0.066               | 0.057               | $0.003 \leq x \leq 0.130$       | 0.020               | 0.051               | $0.000^a \leq x \leq 0.053$                   |
| Tame pasture        | 0.261               | 0.278               | $0.148 \leq x \leq 0.373$       | 0.636               | 0.335               | <b><math>0.521 \leq x \leq 0.753^*</math></b> |
| Hayland             | 0.279               | 0.364               | $0.164 \leq x \leq 0.394$       | 0.099               | 0.300               | $0.027 \leq x \leq 0.171^{**}$                |
| Disturbed grassland | 0.005               | 0.021               | $0.000^a \leq x \leq 0.022$     | 0.003               | 0.014               | $0.000^a \leq x \leq 0.015$                   |
| Grassland           | 0.389               | 0.280               | $0.265 \leq x \leq 0.514$       | 0.242               | 0.300               | $0.138 \leq x \leq 0.346$                     |
| Meadow              | n/a                 | n/a                 | ----                            | n/a                 | n/a                 | ----  |

<sup>a</sup> The true lower confidence interval was negative

\* Indicates significantly preferred habitat type at alpha level 0.05

\*\*Indicates significantly avoided habitat type at alpha level 0.05

"n/a" Indicates habitat type was not present (or present in insignificant amounts) within available habitat

Nest location (type) did not appear to determine selection of that habitat. Although most study sites with nests in tame pasture selected tame pasture (7 of 8: 88%), no study sites with nests in grassland ( $n = 3$ ) selected grassland. Additionally, at one study site that had nests in grassland, grassland was significantly avoided and tame pasture was selected (although not significantly). The remaining study site had a nest that was located in disturbed grassland. Although in this case this habitat type was selected, another habitat type (grazed hayland) was selected to a much greater degree.

## **DISCUSSION**

### **Foraging range and habitat selection**

As described in my study, foraging distances and activities of post-fledging juveniles indicate that juveniles very rarely forage greater than 1 km from their natal or roost burrow. The only other study that examined juvenile foraging habitats for Burrowing Owls (Shyry 2005) reported average distances traveled of less than 600 m, and is consistent with what was observed in my study.

The differences between years in foraging distances, with larger nocturnal movements I recorded in 2006, may have been related to juveniles being heavier in 2006 (see Chapter 3). Being heavier would indicate a more robust body condition, which might enable individuals to travel further distances when foraging nocturnally. Similar results were observed in dispersal activities of juvenile Burrowing Owls in Saskatchewan (Todd 2001). However, this is contradictory to other studies that have associated heavier body weights and higher prey abundance or supplemental food with smaller movements because of a reduced need to travel to obtain sufficient resources (King and Belthoff 2001, Garcia 2005)

Post-fledging juveniles selected habitats that had low vegetation and conditions that likely supported concentrations of insects. This trend is not unlike previous observations of juvenile habitat selection. Juveniles have been known to select areas, particularly ephemeral wetlands and ditches, where grasshoppers and beetles were most abundant (Shyry 2005). Although ephemeral wetlands were not identified as being an available habitat in the Nicola Valley, meadows were very similar. However, tame pasture was chosen over meadows.

Perhaps tame pastures were selected over meadows because they supported the highest abundance of insects in the area of this study. These insects were likely also more “available” in tame pasture than in meadows. Finally, it is probable that tame pastures supported more insect species that are preferred by juveniles (i.e., grasshoppers). This is relevant because juvenile

Burrowing Owls are typically more dependant on insects than rodents (Leupin and Low 2001, Poulin 2003, Shyry 2005). Grasshoppers and beetles, in particular, typically make up a significant proportion of juvenile Burrowing Owl diets. Furthermore, grasshoppers increase in abundance and make up a larger portion of the juvenile diet in the post-fledging period (Shyry 2005).

The high abundance of preferred insects in tame pasture is supported by other studies. For example, some species of grasshoppers prefer wheatgrass species present in tame pasture over other forage crops and native vegetation, and have also been positively correlated with percent cover of crested wheatgrass (Hinks and Olfert 1999, Kemp et al. 2002). Alkaloids that are present in many grass species (as would be growing in the alkali soils of meadows) have been implicated in inhibiting grasshopper growth (Hinks and Olfert 1999), and might reduce the abundance of grasshoppers in meadows.

Tame pastures are characterized as having areas with sparse vegetation and large sections of bare ground, and areas of dense grass when more moisture is available. Meadows, on the other hand, have taller, denser vegetation later in the season, presumably making it more difficult for inexperienced juvenile owls to catch insect prey in meadows than in tame pasture where more patches were present.

Because tame pasture consists of a planted forage crop (crested wheatgrass) (Ministry of Agriculture, Food and Fisheries 2002), and is grazed consistently, it would have a higher grazing index than meadows. While deer mice have been found to respond negatively to a grazing index of current grazing pressure on a site, beetles and grasshoppers have responded positively (Sissons 2003). Prey items most often observed in grazed areas by Haug and Oliphant (1990) were dung and carrion beetles. Selection for grazed areas appeared to be consistent across sites in British Columbia because in the one case where tame pasture was not available, grazed hayland was clearly selected.

The avoidance of disturbed grassland was somewhat unexpected as this habitat type is characterized by low vegetation, areas of bare ground, and being grazed. However, because of the tendency of cattle to concentrate grazing on these areas, overgrazing may have reduced the selection of this habitat type by juveniles. Severely grazed pastures have been known to be avoided by adult male owls as overgrazing reduces cover for small mammals and feed for grasshoppers in other areas (Haug and Oliphant 1990).

The avoidance of grassland patches was obviously influenced by the preference for tame pasture. This trend has also been noted elsewhere. Burrowing Owls were described as preferring

areas with sparse vegetation and short grass to dense sagebrush in Idaho by King and Belthoff (2001). Re-seeded pastures were also selected over native pastures for roosting in proportion to their respective availability in Alberta (Clayton and Schmutz 1999).

The significant avoidance of hayland was similar to observations in other areas where cropland was present. Hayland and cropland are similar in that they are both monocultures subject to seasonal cutting regimes. Crop was significantly avoided by two male owls in Saskatchewan despite small mammal abundance being highest in crops and right-of-way habitats and typically lowest in pastures (Sissons et al. 2001). Haug and Oliphant (1990) also noted that avoidance of crop could also be related to the Burrowing Owl's tendency to prey heavily on grasshoppers that were predominately found in rights-of-way and uncultivated areas.

Although juvenile owls are known to forage on or near roadways (Shyry 2005, pers. obs. 2005), bare ground (which included roads) was always used within its availability, and in one case bare ground was actually significantly avoided in this study. Higher prey abundances along roadsides may contribute to the tendency for Burrowing Owls to select roadsides over upland native prairie in other areas because prey visibility is not obscured by vegetation on bare roads (Shyry 2005). However, perhaps no selection was observed in my study because of the very low availability of bare ground compared to other habitat types. In most cases, bare ground was used more than available, but with such small amount available overall, confidence intervals often covered the span of the observed use.

## **MANAGEMENT IMPLICATIONS**

Habitat availability and its use by post-fledging juvenile Burrowing Owls in this region do not appear to be limiting the success of the reintroduction effort. The comparable survival rates with juveniles in other areas (see Chapter 3) indicate the available habitat in British Columbia sufficiently supports post-fledging juvenile Burrowing Owls through to migration. The higher occurrence of rangeland (including tame pasture) than hayland, likely benefits juvenile owls in the Nicola Valley. Therefore, any future conversion of rangeland to hayland could affect juvenile survival, and should be considered when selecting release sites. Furthermore, to maximize survival of juvenile Burrowing Owls and the success of the reintroduction, future release-site selection should have rangeland making up a substantial portion of habitat within 600 m of natal burrows. Because habitat availability has not been proven to be limiting but adult survival has been so proven, the most effective way of maximizing reintroduction success appears to be



increasing survival and productivity of captive-bred adults, as I have shown occurs with the soft-release technique (see Chapter 2).

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## **APPENDIX C.**

## APPENDIX C. UBC Animal Care Certificate

The University of British Columbia

### Animal Care Certificate

Application Number: A05-0470

Investigator or Course Director: Kimberly M. Cheng

Department: Land and Food Systems

Animals Approved: 

|                             |
|-----------------------------|
| Owls Athene cunicularia 280 |
|-----------------------------|

Start Date: **May 1, 2005**

Approval Date: **July 25, 2005**

Funding Sources:

**Funding Agency:** World Wildlife Fund Canada

**Funding Title:** The influence of release techniques on survival,

**Unfunded title:** N/A

The Animal Care Committee has examined and approved the use of animals for the above experimental project.

This certificate is valid for one year from the above start or approval date (whichever is later) provided there is no change in the experimental procedures. Annual review is required by the CCAC and some granting agencies.

**A copy of this certificate must be displayed in your animal facility**

Office of Research Services and Administration  
102, 6190 Agronomy Road, Vancouver, V6T 1Z3  
Phone: 604-827-5111 Fax: 604-822-5093

**APPENDIX D.**

## **APPENDIX D. Radio-tagging effects on adult and juvenile Burrowing Owls in British Columbia.**

### **INTRODUCTION**

Radiotelemetry is frequently used to gather specific information regarding species biology and behaviour, and important management decisions are based on the results. Determining radio-tag effects is recommended (Bro et al. 1999, Kenward 2001, Millsaugh and Marzluff 2001) to ensure unbiased conclusions. Reported effects of radio-tags on the survival, behaviour, and reproductive success of avian species vary from directly impeding survival and success or altering behaviour (Horton and Causey 1984, Foster et al. 1992, Garrettson et al. 2000, Cox et al. 2004) to having little or no effect (Hill et al. 1999, Göth and Jones 2001, Hernández et al. 2004). Reported impacts of radio-tags on Burrowing Owls vary in the literature, especially with respect to attachment type. One study indicated negative effects on yearly recruitment from harness radio-tags (Gervais et al. 2006), while another suggested negative impacts on breeding season survival from collar radio-tags (Shyry 2005). However, most studies did not detect any impacts (Todd et al. 2003, Conway and Garcia 2005, Gervais et al. 2006). My study examines potential impacts of radio-tags on adult and juvenile owls by comparing harness and collar styles of attachment, and two different weights of the collar-style radio-tag.

### **STUDY AREA**

See Chapters 2 and 3

### **METHODS**

#### **Banding and radio-tagging**

See Chapters 2 and 3

#### **Survival tracking**

See Chapters 2 and 3

#### **Protocols and methods of comparison**

Based on reports of higher impacts from radios attached by harnesses (Gervais et al. 2006), and the difficulties (more room for error and more time consuming) in attaching radioharnesses in the field (Kenward 2001), I chose collar radio-tags for juvenile owls. Harness radio-tags (harnesses) were placed on captive-bred adults before release because of potential negative

effects (i.e., interference in egg rotation) of collar radio-tags (collars) on nesting female owls (D. Todd, Canadian Wildlife Service, pers. comm.), and because harnesses could be attached in captivity prior to owls being released.

I studied radio-tag effects on juvenile owls by comparing behaviours of juveniles wearing two different weights of collars (4 g and 6 g) during the breeding season. I excluded 7 juveniles ( $N = 39$ ) from the comparison (5 signals were lost and the owls' fates were unknown, and 2 surviving juveniles wore transmitters of both sizes throughout the season because of radio-tag failure and replacement). I also compared the recruitment of juveniles who were leg-banded and had been fit with radio-tags with those that were only leg-banded (untagged). Effects on adult Burrowing Owls were assessed by observed behaviours and return rates. The method I used for measuring radio-tag effects on survival of Burrowing Owls was unique to my study because of the high rate of recovery of radio-tags late in the breeding season, and prior to migration. Effects were studied for the most part within the breeding season because of the 86% recovery from surviving juveniles ( $N = 22$ ), and 100% recovery from surviving adults ( $N = 17$ , excluding 6 lost signals). Therefore, measuring radio-tag effects based on yearly survival and return rates were limited (i.e., these comparisons were based on whether radio-tagging during the breeding season impacted survival throughout migration, even though the owls did not carry the radio-tag during migration)

## **RESULTS AND DISCUSSION**

There was little evidence in my study that radio-tags negatively affected the survival or condition of Burrowing Owls within the breeding season. Similar proportions of banded adults released with and without radio-tags became absent from the study sites after release in 2006 (30%,  $N = 50$  and 33%,  $N = 33$ , respectively). Despite adverse effects having been reported in animals with heavier packages (Kenward 2001), survival probabilities between juveniles wearing the 6 g radio-tags ( $0.62 \pm 0.17$ ) and the 4 g version ( $0.57 \pm 0.12$ ) were similar (log rank = 1.1,  $P = 0.28$ ). I observed no difference ( $G^2 = 0.1$ ,  $P = 0.773$ ) in the number of juveniles that died prior to migration wearing the heavier radio-tag (6 of 18; 33%) versus the lighter version (4 of 14; 29%). When removing radio-tags of either attachment type, I found no evidence of chafing, feather damage, or increased plucking around the neck or wings.

This lack of negative effects of radio-tags on Burrowing Owls is supported by other studies. No effect on within-season survival was observed when collars were used in Alberta (Clayton and Schmutz 1999), or when collars and harnesses were used in Saskatchewan (Todd et

al. 2003). Radio-tags have also been shown not to be associated with any negative physical effects (e.g., feather loss or skin abrasions) when owls were recaptured prior to migration (Todd et al. 2003).

However, negative impacts of collars on juvenile Burrowing Owl breeding seasonal survival have been reported in another study (Shyry 2005) in comparison with harnesses. It was suggested that this negative impact resulted from collars being fitted loosely to provide room for pellet regurgitation, and that the dangling radio-tag affected drag and increased the energy demands on owls (Sissons et al. 2001, Shyry 2005). Although in other studies the difference in radio-tag weight within the range of 4-6 g was not considered different (Sissons et al. 2001, Todd 2001, Shyry 2005, Gervais et al. 2006), I observed an obvious degree of dangle only with the heavier collars in my study. However, all collars in my study had a smaller circumference (2.6 cm rather than 2.8 cm) than previously used (Conway and Garcia 2005). This likely reduced the degree of dangle, the potential for drag, and adverse effects on survival (e.g., getting their legs caught in the collar; Conway and Garcia 2005), while still enabling ample room for pellet regurgitation.

Return rates of Burrowing Owls also appeared not to be affected by the use of radio-tags during the breeding season in my study. One previously harnessed female returned and bred successfully in 2007 – a return rate of 6% of radio-tagged birds known to be alive prior to fall migration ( $N = 17$ ). The return rate of untagged adults was 3% ( $N = 32$ ), with 1 male returning and breeding successfully in 2007. Juveniles that were collared during the breeding season also returned at a similar rate (1 of 22; 5%) as those that were untagged (15 of 197; 8%) ( $G^2 = 0.2$ ,  $P = 0.64$ ).

Similar results were observed in Washington, but with juveniles who remained tagged throughout migration. In this area 5% of collared juveniles and 4% of juveniles that were not collared returned as breeders in subsequent years (Conway et al. 2004). In California, no difference in return rates was detected between collared owls and those that were not collared (Gervais et al. 2006). However, in another subset of owls in the same study, harnessed owls returned at half the rate of owls that were not, indicating significant negative impacts of this type of radio-tag attachment.

Despite the lack of detection of any significant impacts on Burrowing Owls with either attachment type in my study, observations showed that collars were less likely to interfere with natural behaviours and activities. More evidence of radio-tag interference was observed with the harnesses on adults (as observed by Gervais et al. 2006) than was observed with the collars on



juveniles. I observed many adults preening the harness straps and attempting to remove them. In addition, the radio-tags I removed from adults with harnesses were more often altered (antennae coiled and stripped of plastic cover indicating chewing by adult) than the collars worn by juveniles.

Contrary to previous reports (Sissons et. al 2001, Shyry 2005), I found harness attachments to be more accessible, distracting, disruptive to the preening process, and subject to a high degree of destruction by the owl, perhaps because they cover a larger portion of the body. However, because all harnesses installed in my study were placed on the same day in a limited time frame, some harnesses were probably not fit perfectly to every adult, and may have contributed to some of the higher interference observed. Because collars have been noted to interfere in egg rotation (D. Todd pers. comm.) by breeding females, carefully attached harnesses could potentially suite female Burrowing Owls better. However, the concern of interfering in egg rotation was probably the result of the use of heavier radio-tags with a larger than necessary circumference, and a high degree of dangle. The use of lighter radio-tags with a smaller circumference may not result in this negative effect, and in the case of breeding females the use of collars may still be preferred.

Because I was able to remove the majority of collars from juveniles and harnesses from adults in my study by the end of the season, any potential negative impacts on owls migrating and returning to breed were greatly reduced. Although I recognize that the high rate of radio-tag recovery that occurred in my study is not typical, or even possible in many other studies, it does not diminish my findings that there was no significant radio-tag effect on Burrowing Owl survival within breeding season.

## **MANAGEMENT IMPLICATIONS**

Despite the lack of significant impact of radio-tags on survival of Burrowing Owls, my study indicates collars are less likely to negatively affect behaviours than harnesses. Because of this, I would recommend that collars be preferentially used as the method for attachment. There is also an indication that a smaller circumference (2.6 cm) of collar and a lower weight of transmitter reduces potential negative impacts, and therefore should be used in future research. There will always be a need in research to obtain critical information on populations, particularly endangered or threatened ones, which may only be possible to gather through radiotelemetry. Research methodology involving caution and attempts to use the smallest, least obstructive technology should be attempted in cases where the information is critical to obtain.

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