Reintroduction of Western Bluebirds to San Juan Island (2007-2011):

TRANSLOCATION METHODOLOGY AND EVALUATING SUCCESS

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INTRODUCTION

Addressing the loss of biodiversity due to anthropogenic impacts is a central focus of conservation efforts in ecosystems across North America. The most established formula for successful avian conservation is to increase the quantity and quality of habitat for species of conservation concern. In some cases, however, this strategy does not ensure that the desired species will inhabit these areas, especially if it requires expansion of the population back into their former range. Conservation practitioners are increasingly turning to reintroductions when habitat is sufficient to support a population and the factors that led to a species' extirpation have been eliminated or reduced, yet natural recolonization does not occur (Scott and Carpenter 1987, Griffith et al. 1989).

In the prairie-oak (*Quercus garryana*) ecosystem of the Pacific Northwest, American Bird Conservancy (ABC) and its partners have worked extensively to protect and restore this threatened ecosystem and its bird communities through its international *Quercus* and Aves program. Prairie-oak ecosystems deserve attention because they support high levels of biodiversity and generally occur over a limited area - valley floors and foothills – and those areas are attractive for development and population growth. In the Puget lowlands of Washington State, habitat loss, fragmentation, and degradation has had a profound negative impact on birds in prairie-oak habitats; in particular, three cavity-nesting species - Western Bluebird (*Sialia mexicana*), Slender-billed White-breasted Nuthatch (*Sitta carolinensis aculeata*), and Lewis' Woodpecker (*Melanerpes lewis*), have exhibited range contractions and local extirpations (Chappell et al. 2001, Altman 2011). While numerous habitat management and restoration projects have increased the extent and quality of prairie-oak habitats in many parts of the region, these cavity-nesting species of concern have not returned.

ABC and its partners have reached a point where the use of reintroductions was believed to be a necessary step in restoring the full complement of avian biodiversity to prairie-oak habitats in this region. In 2007, ABC, Ecostudies Institute, and others initiated a reintroduction of Western bluebirds to San Juan Island, Washington State, a site where they were formerly considered common but have been extirpated since 1964 (Lewis and Sharpe 1987). The reintroduction of bluebirds on San Juan Island was considered appropriate and timely for several reasons. First, the likelihood of bluebirds reestablishing a population on San Juan Island without assistance appeared low. The long distance (165 km) and large area of unsuitable habitat (i.e., urban Seattle and Puget Sound) between San Juan Island and the closest source population of breeding birds in south Puget Sound apparently hindered dispersal, as there was no evidence of successful colonization in the three decades since the species was extirpated. Second, a pre-project assessment indicated that sufficient habitat was available in north Puget Sound, centered on San Juan Island, to support a bluebird population. In addition, local conservation organizations (e.g., San Juan Preservation Trust, San Juan County Audubon Society) promoted the protection and restoration of the prairie-oak ecosystem, ensuring that habitat would be available in the future. Third, the cause of their extirpation was considered to be the loss of a particular habitat element, cavities for nesting, rather than a more complex set of issues unable to be addressed through management. Nest boxes, however, have been used as management tool to increase the availability of cavities for many cavity-nesting species and they have played a critical role in the recovery of Western bluebird populations in the Willamette Valley in Oregon (e.g., Keyser et al. 2004) and in south Puget Sound (Jim Lynch, Department of Defense, personal communication). Finally, successful translocation methodologies had been developed for Eastern bluebirds in Florida (Slater 2001, Lloyd et al. 2009) and these methodologies were believed to be transferrable to a reintroduction of Western bluebirds.

This final report documents the activities of the 5-year reintroduction program conducted by project partners on San Juan Island. The goals of the project were to: 1) establish a viable, self-sustaining population of Western bluebirds, and 2) use the reintroduction as a public-outreach effort aimed at advancing the conservation of prairie-oak habitats. To our knowledge, this is the first reintroduction of Western bluebirds and the first reintroduction of a migratory landbird species in North America. In this report, we detail independent aspects of the project in four sections. In the first section, we document the reintroduction methods employed in the effort and investigate factors associated with successful methodologies. In section two, we evaluate the progress made towards establishing a viable, self-sustaining population through population monitoring and comparisons of demographic rates in the reintroduced population with other bluebird populations in the Pacific Northwest. In the third section, we report on the outreach and education activities achieved and their importance in defining the integral role of the public in ensuring long-term success of the project. Finally, we summarize how the project directly resulted in the protection of prairie-oak habits, which will benefit not only the reintroduced population of bluebirds but the full spectrum of prairie-oak biodiversity.

1. Reintroduction of Western bluebirds to San Juan Island: translocation methodology and factors associated with successful establishment

Introduction

Reintroduction is a conservation action that intends to reestablish populations of extirpated species in portions of their former range through the release of wild-caught or captive-bred individuals (IUCN 1995). Although the use of reintroductions has a long history in conservation, only recently has thorough documentation and monitoring become standard components in reintroduction efforts. Calls for better-documented reintroductions were triggered by researchers and international organizations following a period in the 1970s when many reintroduction efforts apparently failed and little knowledge was gained regarding how to improve reintroduction success.

Although increased documentation has advanced the field of reintroduction biology, significant information gaps still remain. For example, most avian reintroductions have focused on raptor and game birds; landbird reintroductions have been substantially underrepresented (Seddon et al. 2005). The lack of documented landbird reintroductions hinders progress in improving the value and efficacy of landbird reintroduction as a conservation tool. As a result, conservation practitioners or funding agencies may be reluctant to initiate such a project without examples that such a strategy would be successful.

The success or failure of a reintroduction is proposed to be a function of two separate events, population establishment and population persistence, each associated with a different temporal scale (Armstrong and Seddon 2008). Population establishment is the initial period when released individuals establish a founder population and population size increases from low numbers following the cessation of releases, whereas population persistence is the ability to maintain, on average, a non-negative rate of population growth once carrying capacity has been reached. Evaluating success during each period is important because independent factors can influence success. For example, success during the population establishment phase may be related to implementing successful release strategies to establish the founder population, whereas population persistence may be a function of the quantity and quality of habitat available to the reintroduced species. Monitoring during each periods is critical to evaluate reintroduction outcomes and the factors associated with successful reintroductions (Seddon et al. 2007).

In this section, we report on the methodologies used to reintroduce the Western bluebird to San Juan Island, Washington during the population establishment period. The specific objectives of this section are to: 1) document reintroduction methodology, and 2) investigate factors associate with the successful establishment of translocated individuals. Information on the population dynamics of the reintroduced population is reported in the next section. Our goal was to safely translocate and release > 90 adult individuals over a five-year period. We targeted this number based on a review of reintroductions which indicated that reintroduction programs that translocated > 80 individuals had a higher probability of success; however, there was no benefit to releasing more than 120 individuals (Griffith et al. 1989). We are unaware of any other reintroductions of Western bluebirds, and the information reported here will contribute to the growing body of literature on landbird reintroductions.

Methods

Study Areas

Reintroduction site. San Juan Island is the second-largest of the San Juan Islands with a land area of 142.6 km² and is located 30 km off the northwest Washington coast in Puget Sound (48° 32' N, 123° 05' W; Figure 1-1). The San Juan Islands receive less rainfall than elsewhere in western Washington due to their position in the rain shadow of mountains on the Olympic peninsula and Vancouver Island; mean annual precipitation is 51 cm (Western Regional Climate Center 2010). The terrain varies from rocky, undulating hills reaching 329 m in elevation to narrow lowland valleys to rocky shorelines and beaches. Vegetation communities are diverse, varying with slope, aspect, and elevation. Most upland forests are dominated by a single coniferous species, Douglas-fir (*Pseudotsuga menziesii*), with scattered Western hemlock (*Tsuga heterophylla*) and Western redcedar (*Thuja plicata*), but oak (*Quercus garryana*) and grassland communities occur on most southwest-facing slopes (e.g., American Camp, Mt. Young). Agriculture and residential developments dominate most of the lowland valleys. Historically, these areas were characterized by open oak and prairie habitats intermixed with wetlands; scattered oaks still remain, especially on rocky outcrops and valley ridges. San Juan Valley was the largest lowland area (~ 500 ha), and prior to settlement was called “Oak Prairie” due to the groves of oaks that covered it (Custer 1859). We focused pre-release management efforts (nest boxes, landowner contacts) in lowland areas with remnant patches of oaks because historic records indicate that is where bluebirds occurred (Miller et al. 1935, Bakus 1965, Lewis and Sharpe 1987). During the study, we placed > 500 nestboxes in appropriate habitat on San Juan Island.

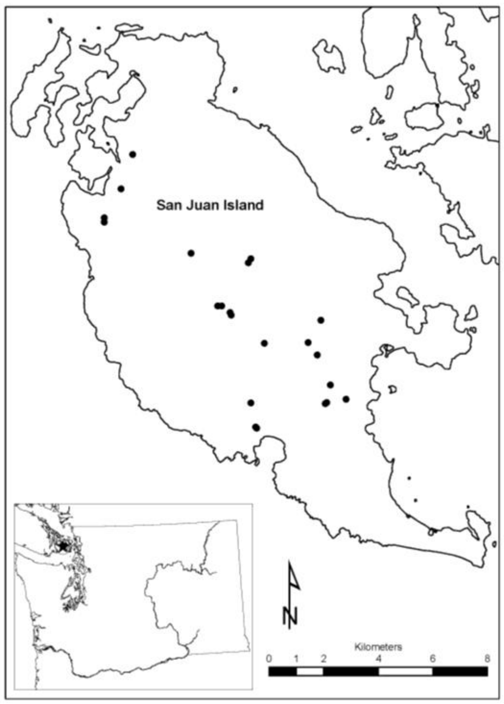


Figure 1-1. Map of San Juan Island, Washington. Dots represent locations of Western bluebird releases from 2007 to 2011.

Donor sites. Joint Base Lewis-McChord military base (JBLM; 47° 01' N, 122° 37' W) is approximately 165 km from the reintroduction site and served as the primary donor site for the reintroduction. JBLM contains the most extensive area of prairie-oak habitat in the Puget lowlands (Chappell et al. 2001) and supports the largest bluebird population in the South Puget Sound. A long-term nestbox program, initiated in the 1980s in prairie-oak habitats, has increased the population size from only a couple pair in the 1980s to current estimates of > 300 individuals (Jim Lynch, Dept. of Defense, pers. comm.). Bluebirds were only captured on the Fort Lewis Unit. In addition to captures at JBLM, a small number of bluebirds were captured from the southern Willamette Valley, Oregon (44° 39' N, 123° 14' W), with the intention of providing another genetic source into the reintroduced population. Donor sites in Oregon were approximately 450 km from the reintroduction site.

Study Species

A non-excavating cavity nester, the bluebird breeds in a variety of open habitats where nest cavities, low perches, and an open understory are present (Szaro 1976, Germaine and Germaine 2002). In the Pacific Northwest, the bluebird is considered a short-distance migrant (Guinan et al. 2008). The Western bluebird was extirpated from the San Juan Islands archipelago, Whidbey Island, and adjacent mainland sites (e.g., Olympic peninsula, Whatcom county) during the mid-1900s (Lewis and Sharpe 1987, Buchanan 2005) and was last observed on Vancouver Island, British Columbia in 1995 (Campbell et al. 1997). Because the species occupies a broad array of open habitats, the primary cause of their decline was apparently the loss of a critical habitat element, nesting cavities. Nest cavities were eliminated by the felling of large oak trees, in which cavities were most abundant (Gumtow-Farrior 1991), and management practices that removed snags. The arrival of the European starling (*Sturnus vulgaris*) to Washington in the mid-1950s likely exacerbated the decreasing availability of nest cavities (Herlugson 1978, Buchanan 2005). Currently, its northernmost population occurs in south Puget Sound, centered on JBLM.

Translocations

We translocated bluebirds to release sites on San Juan Island in each breeding season (March – July) from 2007 to 2011. We used four translocation strategies: 1) adult pairs placed in 1 x 1 x 2 m aviaries (small; Figure 1-2) and held for short time periods, 2) adult pairs placed in 2 x 2 x 2 m aviaries (large; Figure 1-2) and held for long-time periods, 3) adult pairs with dependent young placed in large aviaries, and 4) adult single females placed in small aviaries. The first strategy, used exclusively in 2007, involved capturing pairs early in the breeding season, the first three weeks of March, as they established breeding territories. Pairs were placed in small aviaries and held for four to five days. We discontinued this strategy after Year 1 because of its poor success rate.

Figure 1-2. Two types of aviaries used to hold Western bluebirds on San Juan Island, prior to release. Small aviary used in 2007 and for single females is on the left; large aviary used from 2008-2011 for pairs and pairs with juveniles is on the right.

The majority of translocations consisted of the second strategy, in which breeding pairs were placed in large aviaries at the reintroduction site. This strategy, implemented from 2008 to 2011, involved capture events of breeding pairs over the entire breeding season from March to June. Pairs were kept in the aviary until we observed evidence of nest-building or other breeding behavior, unless no activity was seen after three weeks, in which case they were released at the end of the three week period. From 2008 to 2011, we also moved a few bluebird pairs with their nestlings later in the breeding season. In this strategy, the pair and their nestling were placed in a large aviary. Nestlings were set in an artificial nest in a nest box attached to the wall with the top removed so adults would quickly observe begging, stimulating them to feed. The family group was released after the young had fledged and were capable of sustained flight ($\geq$ seven days), except in 2011 when young were released at 1-2 d old. Finally, in 2010 and 2011, we translocated a small number of single females, captured either as floaters or removed from an established territory at the donor site, because we observed a higher ratio of males to females in the reintroduced population. Females were placed in a small aviary and held for 2-5 days. They were released in the presence of a free-living male.

Bluebirds were captured using playbacks and mist-nets positioned next to nest boxes where individuals had exhibited breeding behavior. All translocated individuals were banded with a unique combination of a single aluminum U.S. Fish and Wildlife Service band and color-bands. Birds were transported to San Juan Island in a small (0.5 m x 0.5 m x 0.5 m) bird cage, supplied with perches and food (mealworms), via vehicle or plane. During transport, the cage was covered with a lightweight cloth to minimize stress by reducing the amount of light into the cage, yet allowing air circulation (Bocetti 1994). Translocated nestlings were not placed in cages and were fed every 30 min.

Release and monitoring

Initial releases were conducted in the San Juan Valley, almost exclusively on private land. Release sites were selected based on the presence of suitable habitat (e.g., proximity to oaks, appropriate foraging habitat), the willingness of landowners to host an aviary and place nest boxes on their property, and, upon establishment, the proximity of bluebird territories. As territories became established, we also released individuals outside of the San Juan Valley in open habitats where an oak component was present (e.g., Cady Mountain, Beaverton Valley). Release sites for single females were selected based on the presence of a single territorial male.

Bluebirds were placed in outdoor aviaries at the release site. Aviaries were constructed with plywood and hardware cloth, which allowed for open views of the surrounding area, yet provided protection from the sun, rain, and wind. A one-meter skirt of hardware cloth was placed on the ground along the outside of the aviary to deter entry by predators. In each aviary, various-sized branches were positioned to provide multiple perch choices, and a nest box was provided for roosting. Food (mealworms and crickets) and water were provided ad libitum.

Upon release, we monitored individuals if they remained near the release site, but did not chase individuals if they flew out of sight. We then searched the release site and adjacent areas of suitable habitat daily for at least one week or until the birds were located and established a territory. If individuals were not found after this time, we searched for birds as part of our regular systematic searches. We also established a bluebird hotline, providing a means for private landowners to report bluebird sightings.

In each year of the project, we surveyed previously used capture sites and adjacent areas at JBLM to detect bluebirds that returned to the source population. These surveys were conducted throughout the breeding season, typically when we were looking for individuals and pairs to translocate, although at least one full day each season was dedicated towards surveying for returning birds.

Translocation success

For the translocation strategies in which pairs were translocated, we considered an event successful if at least 1 individual of the pair established at a territory and initiated breeding activity (e.g., nest-building). For pairs released with juveniles, we also considered the return of juveniles to San Juan Island as evidence of success on an individual basis. For translocations of single females, an event was considered successful if the female paired with a male and initiated breeding activity.

With the exception of translocation strategy 2, sample sizes were too small to conduct statistical analyses investigating factors associated with success. For translocation strategy 2, we conducted a series of univariate analysis comparing successful versus unsuccessful events. We used *t*-tests to compare data of capture (using Julian date), percent nest complete at the donor site at capture, and number of days in the aviary. To examine variation in success due to categorical variables - year and age composition of the translocated pair - we used a chi-square goodness-of-fit test. Age composition was broken into 4 categories: 1) both adults = second year (SY; first breeding season), 2) male = SY and female = after second year (ASY; 2^{nd} or later breeding season), 3) male = ASY and female = SY, and 4) both adults = ASY. We considered significance at the $P < 0.05$ level. Analyses were conducted using R (version 2.12.0; R Development Core Team 2010) and SPSS. Unless otherwise noted, means and SE are reported.

Results

We conducted 54 translocation events during the course of the 5-year project, 8 in 2007, 10 in 2008, 11 in 2009, 13 in 2010, and 12 in 2011. In 2007, we only captured pairs and placed them in small aviaries for 4 or 5 days (Strategy 1). During the period from 2008-2011, we conducted 33 translocations in which pairs were placed into large aviaries (Strategy 2) and 8 translocations in which pairs and their dependent young were placed into large aviaries (Strategy 3). In 2010 and 2011, we conducted 5 translocations in which a single adult female was placed into a small aviary and released after a resident male was observed at the aviary in successive days (Strategy 4). In total, 101 adults and 36 juveniles were captured and placed into aviaries on

San Juan Island. Except for 4 pairs captured from the Willamette Valley, all individuals were captured from JBLM.

Two adults and one juvenile died while in their aviaries. Their deaths appear unrelated to methodological issues, rather they appear due to random factors outside of our control. One mortality event occurred in 2008, when an adult female and a juvenile were found dead inside their aviary on their 17th day of captivity. They were scheduled for release the next day. There were no obvious signs of trauma to either individual. However, the adult male was found outside the aviary, having apparently escaped or been released by an unknown individual. The two birds may have died from stress related to the male outside the aviary. The remaining 5 juveniles were moved to another large aviary and held until they were able to forage on their own. The other mortality event occurred in 2011, when an adult male was killed by a predator on the 2nd day of captivity. We found remains both inside and outside the aviary, suggesting the bird had been attacked from outside the aviary, perhaps by a forest raptor, which were regularly seen at the site. The female of the pair was subsequently moved to a different aviary and a single male from the reintroduced population was captured and introduced into the aviary with her. Overall, 125 individuals, 99 adults and 35 juveniles, were translocated and released in good condition (Table 1-1).

In 2007, when paired adults were placed in small aviaries and held for three to four days, 13% (1 of 8) of the pairs were subsequently found on a breeding territory (Table 1-1). Thereafter, we used Strategy 2 to translocate breeding pairs. This technique was more successful than Strategy 1, with 41% (13 of 32) of translocation events (e.g., not including the event in which the male was killed in the aviary) resulting in the successful establishment of a breeding territory. Except for two cases, pairs maintained their pair bonds following release. In the two instances when pair bonds were not upheld, the breeding female joined a resident male and established a territory and the translocated male was never observed on a territory. The average length of time that pairs were held in the aviary was 19 days (S.E. = 1.2, range = 6 - 32 days). Six pairs initiated nest-building in the aviary, of which 4 (67%) established a breeding territory after release.

Translocations of pairs with dependent young resulted in the success establishment of a breeding territory in 43% (3 of 7) of the cases (e.g., not including the event in which the adult female and one juvenile died). In all cases, pairs maintained pair bonds. Thirty-five juveniles

Table 1-1. Number of individuals (pairs in parentheses) released from aviaries on San Juan Island under the four translocation techniques and their subsequent fate.

Translocation method	2007	2008	2009	2010	2011	Total
1) Adult pairs in small aviaries	16 (8)					16
Established territory	2 (13%)					2 (13%)
Returned to capture site[b]	6					
Unknown fate	8					
2) Adult pairs in large aviaries		16 (8)	18 (9)	16 (8)	15 (7)[a]	65
Established territory		10 (63%)	6 (33%)	8 (50%)	2 (13%)	26 (40%)
Returned to capture site[b]		3	4	2	*[c]	
Unknown fate		3	8	6	13	
3) Adult pairs with nestlings		3 (1)[d]	4 (2)	4 (2)	4 (2)	15
Established territory		0 (0%)	2 (50%)	0 (0%)	4 (100%)[e]	6 (40%)
Returned to capture site				2	0	
Unknown fate		3	2	2	0	
Nestlings		8	10	8	9	26[f]
Returned to San Juan Island		1 (13%)	2 (20%)	2 (25%)	*	5 (19%)
Unknown fate		7	8	6	*	
4) Single females				3	2	5
Established territory				2 (66%)	1 (50%)	3 (60%)
Returned to source population				0	*	
Unknown fate				1	1	

[a] A female whose mate was killed in the aviary was released with a resident male placed in the aviary.
[b] Some individuals were not located until the subsequent year.
[c] * Signifies that results will not be determined until 2012.
[d] At one aviary, a breeding female and one juvenile died; the male escaped from the aviary, and the five remaining juveniles were moved to a new aviary and held until they were capable of independent foraging.
[e] Both pairs established a territory and began nestbuilding, but the female subsequently disappeared.
[f] Totals only included translocations from 2008-2010, which includes . Results of 2011 translocations will not be determined until $\geq$ 2012.

were successfully released. Not including the 9 juvenile released in 2011, whose success will not be determined until 2012 or later, 5 of 26 juveniles (19%) returned to San Juan Island the following year. The average number of days that pairs with juveniles were held was 14 days (S.E. = 1.2, range = 5-19 days).

Of all the translocation strategies, the release of single females had the highest success rate, as 3 of 5 (60%) single females joined a resident male and established a breeding territory. In all cases, females were visited within 24 hours by a single male. Average time in the aviary of single females was 5 days (S.E. = 1.6, range = 1-11).

In each year, we found translocated individuals release on San Juan Island that returned to the source population at JBLM. In most cases, returning individuals were not found until the following year. Not including those individuals release in 2012, 17 of 78 (22%) translocated individuals returned to JBLM. We also had 3 cases in which translocated individuals bred on San Juan Island in the year they were translocated, and the following year were found nesting at JBLM.

For the statistical analysis investigating factors associated with success for translocations under Strategy 2, we removed the two events in which only the female established a territory. We did this because the predictors that we used were measured at the pair level and not based on individual characteristics. Thus, the data set upon which analyses were conducted included 30 translocation cases of which 12 were successful.

Overall we found no statistically significant differences between successful and unsuccessful translocations of pairs in large aviaries, but several interesting patterns did emerge. Annual variation in success of Strategy 2 did not differ significantly (Figure 1-2; chi-squared = 4.03, df = 3, $P = 0.26$) even though we observed relatively large differences between years. The lowest success rates occurred in 2011 when only 14% (1 of 7) pairs successfully established a breeding territory. In contrast, 63% (5 of 8) pairs successfully established a territory in 2008. In 2009 and 2010, translocation success was 33% (3 of 9) and 50% (4 of 8), respectively. Capture date was marginally significant with successful events conducted earlier in the breeding seasons (Figure 1-3; mean = 10 April $\pm$ 5 days) than unsuccessful events (mean = 27 April $\pm$ 6 days; t = 2.0, df = 28, $P = 0.06$). No translocation events conducted after 7 May, of which there were 5, were successful. The number of days held in the aviary did not differ between successful (Figure 1-3; mean = 16 $\pm$ 2 days) and unsuccessful events (mean = 19 $\pm$ 2 days; t = 1.2, df = 28, P = 0.25). The percentage of a complete nest at the donor site at capture did not differ between successful events (mean = 30.1% $\pm$ 11.7) and unsuccessful events (mean = 40.1% $\pm$ 10.8, t = 0.65, df = 28, $P = 0.52$). We observed slight, but not significant variation in age composition of successful pairs versus unsuccessful event (Figure 1-2; chi-square = 4.8, df = 3, $P = 0.19$). Pairs comprised of SY birds (i.e., their first breeding season) were most successful (75%, 3 of 4), followed by pairs composed of both ASY birds (50%, 6 of 12). Second year females paired to ASY males (18%, 2 of 12) and ASY females paired to SY males (33%, 1 of 3) were less successful.

Although, we could not statistically analyze data related to pairs translocated with juveniles, due to the small number of translocation events. One small pattern emerged. The three successful events had release date from 19 June to 24 June, while the four failures had release dates from 28 June to 4 July. In addition at the three successful releases juveniles were younger than at the releases that failed. Juveniles had fledged 1, 2, or 8 days before release compared to unsuccessful events, where juveniles had fledged 9-13 days before release.

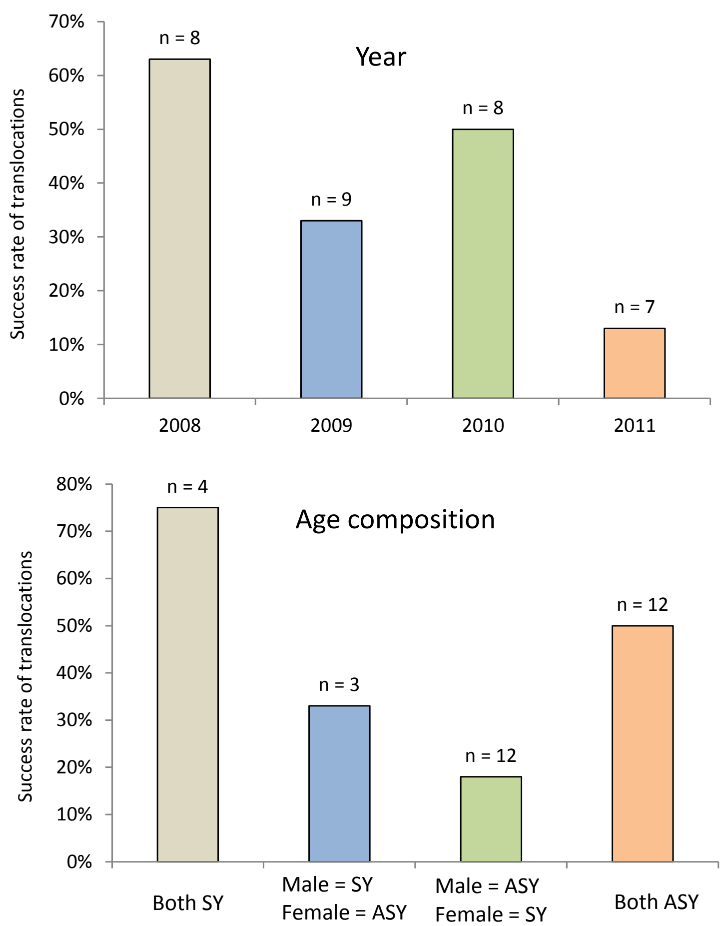


Figure 1-2. Proportion of translocated pairs under strategy 2 in which $\geq$ 1 individual successfully established a territory with respect to year (top) and age composition (bottom).

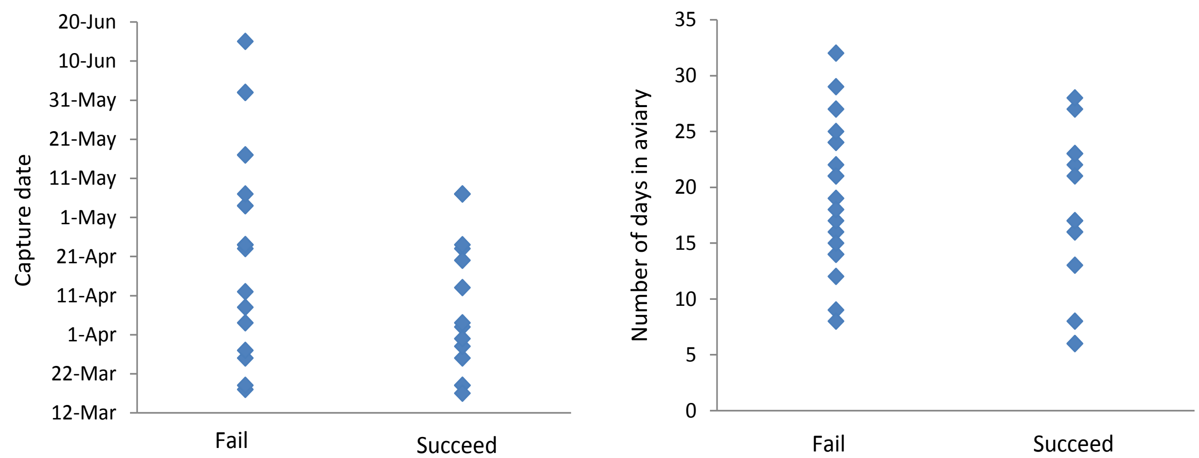


Figure 1-3. Scatterplot of translocation events of pairs placed in large aviaries from 2008-2011 with success or failure shown with respect to capture date (left and number of days in the aviary (right).

Discussion

Using four translocation strategies, we established a founder population of Western bluebirds on San Juan Island, Washington. In doing so, we also gained important information about methodological factors associated with the successful establishment of breeding territories by released individuals, which can be considered in future landbird reintroductions. Over the five-year period of the project, we released 125 bluebirds, of which 99 were adults, surpassing our goal of releasing > 90 adult bluebirds, a level found to be correlated with reintroduction success (Griffith et al. 1989). Although three deaths occurred while individuals were inside their aviary prior to release, the deaths appear unrelated to methodological issues. Of the 99 adults released on San Juan Island, 37 (37%) established a breeding territory. The exact founder population size of the reintroduced population will not be known until 2012 when released juveniles from 2011 return. Through, 2011, 5 of 26 (19%) juveniles have returned, making the minimum size of the founder population 42 individuals.

Post-release monitoring is an important component of reintroductions because it allows practitioners to revise methodologies if outcomes are not as expected (Ostermann et al. 2001). In this reintroduction, the primary translocation approach was to capture and translocate pairs that had established territories in the source population, but had not yet initiated breeding (i.e., egg-laying). This approach was successful in a translocation of Eastern Bluebirds in Florida (Slater 2001). In the first year of the project, we investigated a simpler and more cost-effective release strategy (small aviary, short holding period) for moving pairs, rather than the more labor- and cost-intensive methods (large aviary, long holding period) used in Florida (Slater 2001). The success rate of the simpler, cost-effective strategy was poor (13%), and hence we reverted to using larger aviaries and a longer holding period, which improved our success rate to levels found in other projects.

We also initiated a new translocation strategy later in the reintroduction program in response to unexpected problems revealed through our population monitoring (See section 2). In 2010, the reintroduced population showed an increasingly male sex-bias sex ratio due to the presence of unpaired males. In response, we conducted releases of single females in proximity to single male territories. This technique was very effective, as 60% of released females paired with a male.

After discontinuing our first translocation strategy, the proportion of adult bluebirds that established a territory using our three other strategies fell very near the range of other landbird reintroductions. The most successful strategy was moving single females, although this technique alone is clearly not a viable option for a reintroduction program. The two remaining translocation strategies, in which pairs or pairs with juveniles were placed in large aviaries, each resulted in the successful establishment of 40% of released individuals. In Florida, 57% (n = 47) of released Eastern bluebirds established breeding territories (Slater 2001), and, in Hawaii 43% (n = 14) of puaiohi (*Myadestes palmeri*) established breeding territories (Tweed et al. 2003).

The slightly lower success rate in this study compared to other reintroductions may be a function of the migratory status of the Western bluebirds, compared to the resident species translocated in other studies. Through 2011, we documented 17 of 78 (22%) individuals returning 165 km to their capture site. Several authors have reported landbirds returning > 20 km to release sites (Clarke and Schedvin 1997, Fancy et al. 1997), but we found no studies reporting the number of returning individuals when the distance between capture and release sites was large (> 20 km; e.g., Armstrong 1995, Armstrong and Craig 1995). In Florida, only two (4%) Eastern bluebirds returned 35 km to the donor site (Slater 2001). The Western bluebird's status as a migratory species may explain their capacity to successfully return such a long distance, in comparison to a resident species such as the Eastern bluebird, which may not be as well-adapted to long-distance movements. If this pattern generally holds true in reintroductions of other migratory landbird species, the number of individuals necessary to establish a founder population may be larger than for non-migratory species because many migrants could choose to return to their capture site.

Although we failed to identify significant relationships between our independent factors and translocation success (i.e., pairs establish breeding territories), we did observe several patterns of success that appear biologically relevant related to variation in year, capture date, and age composition of pairs. In this study, translocation success dropped substantially in the last year of the project to 13% after ranging from 33% to 63% in previous years. This result was surprising considering population size was at its highest level and released birds should have had increased opportunities to interact with resident individuals. The presence of other conspecifics has been found to increase settling patterns (i.e., conspecific attraction) in some species. Lower translocation success in the last year of the project could have been a function of limited opportunities for individuals to establish territories if access to habitat or nestboxes was limitied; for example, if the population on San Juan Island had reached its carrying capacity. This seems unlikely, however, as > 500 nestboxes have been placed on San Juan Island and many areas of vacant habitat, including on nearby islands, resembled areas where bluebird occurred. A more likely explanation is that environmental conditions played a role in the lower translocation success in 2011. The spring of 2011 was characterized by unseasonably cold and wet conditions. Western bluebirds, and a host of other migratory species, arrived late on the breeding grounds at JBLM and San Juan Island. We suspect that many translocated bluebirds may have not been in adequate condition to initiate breeding following release or that they decided to forgo breeding.

Patterns of success we observed with respect to capture date and age composition have potential management implications and should be evaluated in future translocations efforts, such as those being considered in Canada. No translocations of pairs without juveniles were successful when the capture date was after 7 May. Assuming a two to three-week holding period, these individual were not released until late May to early June, seemingly enough time for individuals to breed. However, pairs captured this late in the season may have already failed or were late in attempting to breed. In both cases, pairs may simply not be in adequate condition to establish and defend a territory and initiate breeding.

Curiously, we found that translocations conducted with the least experienced individuals, those in which the pair was comprised of two first-year breeding birds, had the highest likelihood of translocation success. It is worth noting that sample size was only four pairs. We also found that pairs in which both birds had breeding success had relatively high success. In contrast, those pairs in which one individual had breeding experience and the other did not had a low likelihood of establishing a territory.

Sample sizes were too small to fully evaluate factors associated with successful translocations using other strategies, but we found one potential pattern of success related to translocating pairs with nestlings that should be considered in future translocations. We found that pairs released earlier in the breeding season, before 24 June, were more successful, than releases from 28 June to 4 July. Earlier, more successful, releases were also associated with translocations in which juveniles were much younger and less capable of sustained flight than unsuccessful releases. These results could be due to several reasons. First, pairs released earlier may have more time to establish a territory and begin nesting. Further, if their juveniles are less developed, they may be more likely to stay in the release area and consider nesting rather than prospect new areas because their young are too immobile.

Summary and management recommendations.

Results from this study indicate progress towards the establishment of a reintroduced population of Western bluebirds on San Juan Island and represent an example of how landbird reintroductions can contribute to avian conservation. Future reintroduction of Western bluebirds should continue to focus on translocating pairs, because in most cases pair bonds were maintained. We found that when translocating pairs, the use of large aviaries with a longer holding period (7-21 days) appears more effective than the use of small aviaries with a shorter holding period (4-5 days). However, this success appears time dependent as no pairs captured after 7 May were successful. Practitioner may want to switch to moving pairs with nestlings in May and early June, as this technique is equally effective as moving pairs. When conducting translocations of pairs with nestling, releases should occur within days after nestlings fledge in the aviary. Although juveniles may be more vulnerable to predators, the adults appear to be more likely to remain in the area. In this case, aviaries should be placed near adequate cover for juveniles.

2. Monitoring the reintroduced Western Bluebird population on San Juan Island: evaluating reintroduction progress during establishment.

Introduction

Evaluating success is one of the most challenging aspects in a reintroduction program. Success ultimately requires the achievement of two independent events, each associated with different time scales: population establishment (short-term) and population persistence (long-term; see Section 1). The primary goal of a reintroduction project is to establish a self-sustaining population in the release area. However, this long-term goal can only be measured following the successful establishment of a population. Further, it may require years of demographic data from the target population to estimate population viability, ideally incorporating various dynamic scenarios including catastrophic events. Early in a reintroduction program, for example during the establishment phase when translocated birds are being released into the reintroduction site and the population is expected to grow, short-term benchmarks have been recommended as a means to assess reintroduction progress (Sarrazin and Barbault 1996, Ostermann et al. 2001).

In this section, we report on the progress made in the reintroduction of Western bluebirds to San Juan Island during the 5-year translocation phase of the project. Through population and demographic monitoring, we evaluated reintroduction progress using a combination of simple and robust criteria. Simple criteria included annual increases in population size and successful reproduction by translocated individuals and their offspring. These criteria are important because successful reproduction has a strong influence on population size, and population size is strongly correlated to the probability of persistence by species populations (Jones and Diamond 1976, Soule' et al. 1988). As the reintroduced population grew larger, we considered more robust criteria. We compared several vital rates: clutch size, productivity, and survival in the reintroduced population to rates found in other large, and presumably viable, Pacific Northwest populations. Comparing results of restoration efforts to reference conditions is an ideal approach to measuring restoration success (National Research Council 1992). In addition, population and demographic monitoring may reveal potential threats that may require management consideration.

Methods

Population size and demography

We collected data on population size and demography of the reintroduced Western Bluebird population on San Juan Island, Washington State (48° 32' N, 123° 05' W; for detailed description of study area, see Section 1). Fieldwork was conducted in each of the five breeding seasons (March-July) in which translocations occurred. We determined population size by counting uniquely-identified territorial and non-territorial adults through a combination of systematic and targeted playback surveys at translocation release sites, in areas previously used by bluebirds, in unoccupied but apparently suitable habitat, and where bluebird sightings were reported by private landowners. Most of the habitat available to bluebirds was on private lands, with the exception of two National Park Service properties (English Camp and American Camp) and several properties managed by local conservation organizations. In general, we tried to survey all apparently suitable habitat on the island that could be observed from roads or walked following permission of landowners, acknowledging that some lands areas were not surveyed due to their inaccessibility, particularly large residential properties away from roads and those that contained significant habitat behind buildings and other obstructing structures. Overall, we believe the total area surveyed for bluebirds was relatively consistent among years.

Survey methodology differed slightly in the first year of the project (2007) when a full-time technician was not employed compared to subsequent years when a full-time technician was hired. In the first year of the study, we conducted three systematic island-wide surveys during the breeding season using volunteers; volunteers also conducted weekly roadside surveys in areas assigned as high quality habitat. In following years, we initiated surveys in mid-March, when individuals began establishing territories, and conducted surveys 1 to 2 times per week throughout the breeding season. When we conducted targeted playback surveys along roads, surveyors stopped approximately every 0.5 km and played calls and songs of Western Bluebirds followed by a 1 to 3 minute waiting period to listen for a response. We also conducted several playback surveys on two other islands, Orcas and Lopez, following reports of bluebird sightings.

We considered our measure of adult population size an index rather than a census. Using counts of individuals detected over the breeding season likely underestimated true population size because some unknown number of individuals went undetected either because we failed to detect them in areas we surveyed or they occurred in areas we were unable to survey. While we believe few individuals escaped detection, this index should be viewed as a minimum estimate of population size.

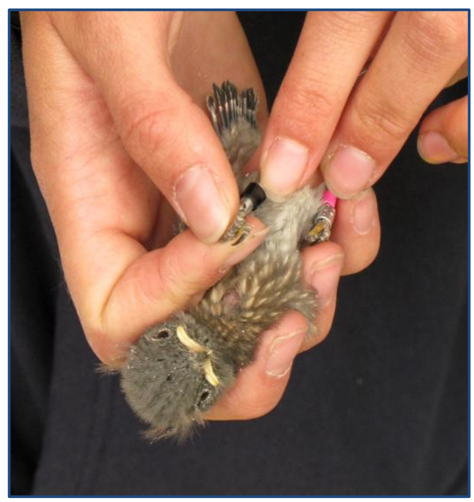
Upon the location of a breeding territory, we identified color-marked individuals, searched for evidence of breeding behavior (e.g., mate feeding, nest-building), and checked nest boxes. Unmarked individuals were captured and banded with USFWS and color bands. We visited territories every three to five days until evidence of nesting was detected, and thereafter monitored nest status every one to three days until nestlings fledged or the nest failed. Nestlings were banded when 10 to 16 days old.

In the latter half of the 2008 breeding season, we began providing supplemental food (mealworms) to birds on established breeding territories. By feeding birds on established

territories we hoped to accelerate population growth via improved fecundity and survival, thereby improving the likelihood of population establishment. In 2008, supplemental food was provided only during periods of cool (< 16° C), windy, and rainy weather, conditions often associated with nest failure (Herlugson 1980). In subsequent years, we expanded supplemental feeding to also include the period from hatching until one to three weeks after fledging, regardless of weather conditions. Supplemental food was typically provided in the morning (0600 to 1100), but was given in the evening during inclement weather, and it amounted to about 20 mealworms per individual in the territory.

We determined nest initiation date (i.e., first date of incubation) and clutch size for each nest. We considered a nest successful if it fledged $\geq$ one nestling. If eggs or young disappeared before the anticipated time of fledging (< 18 days old), we assumed the nest failed and we searched the immediate vicinity for clues to the cause of nest failure. We measured productivity in three ways: 1) the number of young fledged per successful nest, the number of young fledged per nest, and 3) the number of young fledged per breeding female per year, to allow for comparisons with other studies in the Pacific Northwest (See below). We determined the number of young fledged from each nest as the count of nestlings of sufficient age and size that departed the nestbox and that were not subsequently found on the ground. We continued to monitor territories through July to determine whether renesting occurred.

To determine annual survival measures, we attached colored leg bands to translocated individuals, unmarked individuals found on San Juan Island, and as many nestlings as possible in each year of the study. In some years, we did not band all nestlings because some territories were not found until after the nest had fledged. We captured unbanded adults in mist nets, either by luring them to the net with recorded vocalizations, by setting the net in front of their nest box or, if they were harassing birds in an aviary, setting the net adjacent to the aviary.



We used program MARK (version 5.1; White and Burnham 1999) to estimate local (apparent) survival and recapture probability for the reintroduced Western Bluebird population. In this study, local survival rate (φ) is the probability of a bird alive during breeding season *i* to return to the local site and be available for resighting during the breeding season *i* + 1. Recapture probability (*p*) is the probability of a bird in breeding season *i* being observed. Apparent survival rate improves upon annual return rates because it takes into consideration recapture probability; however, mortality and dispersal are still confounded and both processes must be considered when comparing survival rates.

For the survival analyses, we considered any individual captured or resighted during the breeding season (March to July) as alive in that year. Survey data consisted of live recaptures for the period 2007 to 2011, thus for each individual we had an encounter history of 5 occasions. The dataset included nestlings banded and assumed to have fledged, adults banded on San Juan Island, and translocated individuals that established a territory. Translocated birds that were never observed or did not establish a breeding territory were censored because of bias associated with transients. We also removed three translocated individuals that established a territory and nested on San Juan Island, but in the following year were observed nesting near their original capture site at the donor site. Finally, we censored the first survival interval for three translocated juveniles that ultimately returned to San Juan Island even though their parents did not establish a territory. For example, we treated a juvenile banded in 2009 and resighted in 2010 and 2011 as if it had been marked as an adult for the first time in 2010. We considered only evaluating San Juan Island banded individuals in the analyses, but rejected this constraint as overly restrictive, particularly given the sparse dataset. Future analyses could investigate if differences in survival exist between translocated and non-translocated adults. Our goal was to examine the effects of age and sex, and if possible annual variation, on survival in the population, recognizing that our data were sparse, particularly early in the study when the population was small.

To investigate the effects of age, sex, and annual variation, we constructed 10 models that we believed represented reasonable descriptions of Western bluebird survival based on our knowledge of the species' ecology. Our global, or most parameterized, model included annual variation in survival, φ, between adult males and females and constant survival for juvenile males and juvenile females and variation in recapture probability, p, between adults and juveniles. We conducted a Goodness-of-Fit (GOF) test of our global model using the parametric bootstrap test implemented by program MARK. We ran 100 simulations to generate a distribution of deviance values against which to compare the deviance of the fully-parameterized model of the true data. We also estimated values of c (the variance inflation factor or level of overdispersion) in two ways. First, we computed c as the deviance of the true data model by the mean deviance of the simulated models. Second, we computed c as the observed c (model deviance divided by deviance degrees of freedom) divided by the mean of c obtained via simulations. Results indicated good fit (P = 0.26) of the global model, therefore we subsequently attempted to improve model fit by running the additional 9 nested models with reduced numbers of parameters. We evaluated the degree of support for each model using Akaike's Information Criterion (AIC), as corrected for small sample size (AICc; Burnham and Andersen 1998). AIC methods measures how well a model fits, but incorporates a penalty for the addition of parameters, thus providing a satisfactory trade-off between bias and variance (Burnham and Anderson 1998). We obtained estimates of φ and p from the best fit model.

Evaluating progress and data analysis

We evaluated reintroduction progress during the translocation period using two sets of criteria. The simplest criteria were that population size increased annually and that released individuals and their offspring bred successfully. As the population grew, we were able to compare several vital rates: clutch size, productivity, and survival, in the reintroduced population to rates found in other large, and presumably viable, Pacific Northwest populations. We compared demographic measures between the reintroduced Western Bluebird population on San Juan Island with bluebird populations in ponderosa pine (*Pinus ponderosa*) forests on the east slope of the Cascade Mountains (Kozma and Kroll 2010) and residential and agricultural habitats in the Willamette Valley (Keyser et al. 2004). Keyser et al. (2004), using quantitative models, determined that the bluebird population in the Willamette valley had positive population growth rate making that comparison especially useful in evaluating restoration progress. We compared vital rates using means and 95% confidence intervals and viewed measures that did not differ significantly (i.e., overlapping confidence intervals) between the reintroduced and other Pacific Northwest populations as evidence of restoration progress.

Using generalized linear models, we also investigated whether other factors influenced nest initiation date (first attempts only), clutch size, and productivity (young per breeding female/year) in the reintroduction populations to look for any effect of the translocations on reproduction and to improve our understanding of Western Bluebird nesting ecology, which has not been well studied. This information is important in the face of previous extirpations in the region and results may unveil issues that might require management attention. To look for an effect of the translocation on reproduction, we included a fixed effect term for breeding pair composition. In other words, we tested for differences between nesting pairs that included individuals that were translocated in that year (hereafter referred to as translocated pairs) or pairs in which both individuals returned to San Juan Island following migration (hereafter referred to as returning pairs). We also included fixed effect terms for year and attempt (clutch size only). We did not include interaction terms because we had no biological reason to believe they would be important and because preliminary analysis indicated that they were not significant. For nest initation date and clutch size, we initially considered a Poisson distribution, as appropriate for response variables that are integers. However, preliminary results indicated the data were underdispersed (c = 0.2), suggesting less variation than expected under the Poisson distribution. To address this problem we used a Quasi-Poisson distribution, which adjusts the standard error of the parameter estimates to account for the underdispersion. For models of productivity, we used the normal error distribution. Analyses were conducted using R (version 2.12.0; R Development Core Team 2010) and SPSS.

Results

Population size

Annual counts of adults indicated that the reintroduced bluebird population grew in each year of the project, and at the end of the 2011 breeding season the minimum estimate of population size was 38 individuals (Figure 2-1). The rate of population growth was largest from 2008 to 2010, averaging 209%, but slowed to 19% from 2010 to 2011. Beginning in 2009, we found some evidence of an increasing male bias in the population's sex ratio, locating two unpaired males. That number increased to seven unpaired males in 2010, but decreased back to two unpaired males in 2011, perhaps in response to the translocation and release of single females into the population (See section 1).

The number of non-translocated individuals increased in each year of the project, and the number of translocated adults increased in each year except in the final (Figure 2-1). In 2011, non-translocated adults comprised 55% of the population. In each year we found unbanded adults in the population. In 2008, we found two second-year birds that were unbanded. We suspect at least one of these birds was an offspring from the single pair in 2007. In 2010, we found 4 unbanded birds, 3 females and 1 male, and in 2011, we found two unbanded birds, both females. These individuals represent either immigrants from other populations or offspring from territories that were not found in previous years on San Juan Island.

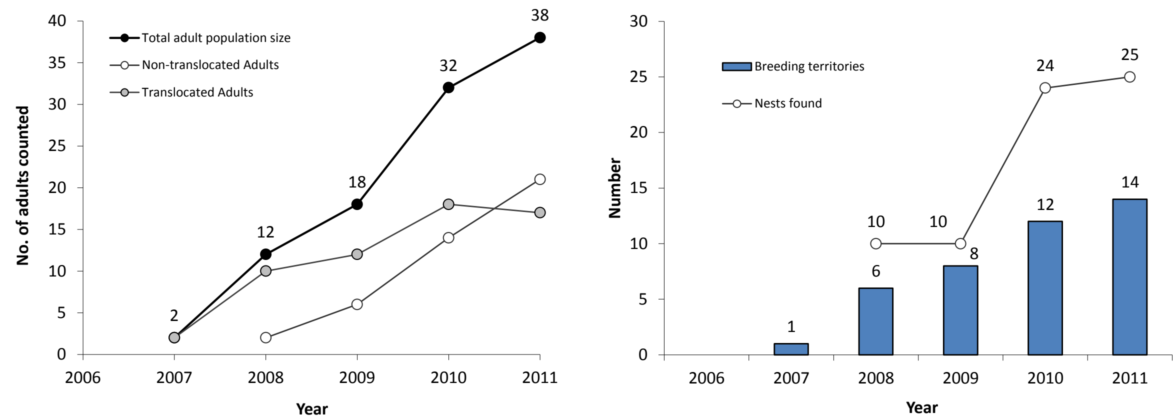


Figure 2-1. Number of Western bluebird adults counted on population surveys (left) and breeding territories and nests found (right) on San Juan Island, Washington, 2007-2011

Reproduction

We found evidence of successful breeding in each year of the project and both translocated individuals and their locally-produced offspring reproduced successfully. In 2007, we did not find a nest, but found one breeding pair with three juveniles. Overall, we monitored the fate of 68 nests on 41 breeding territories from 2007-2011 (Table 2-1.Figure 2-1).

Table 2-1. Mean (+ SE) reproductive measures for the reintroduced Western bluebird population on San Juan Island, Washington during the translocation period, 2007-2011.

	2007	2008	2009	2010	2011	Total
Breeding territories	1	6	8	12	14	41
Monitored nests	0	9[a]	10	24	25	68
Clutch size	-	5.8 (0.3)	5.4 (0.3)	5.3 (0.2)	5.2 (0.2)	5.3 (0.1)
Nest initiation date [b]	-	15 May (5)	12 May (6)	10 May (6)	9 May (4)	11 May (3)
Successful nests	-	7	8	17	14	46
Nest success (%)	-	70%	80%	71%	56%	69%
Nestlings fledged[c]	3	31	42	84	77	236
No. young/nest^{-1} [d]	-	3.6 (0.9) [d]	4.2 (0.8)	3.5 (0.5)	2.9 (0.5)	3.4 (0.3)
No. young/successful nest^{-1}	-	4.6 (0.7)	5.3 (0.4)	4.9 (0.3)	5.2 (0.2)	5.0 (0.2)
No. young/breeding female^{-1}	3.00	5.3 (1.3)	5.3 (1.5)	7.0 (1.2)	5.4 (1.0)	5.8 (0.6)

[a] One nest was not monitored due to access problem.
[b] First attempts only.
[c] Number of nestlings known to have fledged including those in which nests were not found.

Clutch size. The average number of eggs laid per clutch in the reintroduced populations was 5.3 $\pm$ 0.12 (N = 64; Table 2-1) and did not differ significantly from bluebird populations in the Willamette Valley, Oregon (Keyser et al. 2004) or in ponderosa pine forests along the east slope of the Cascades Mountains, Washington (Kozma and Kroll 2010; Figure 2-2). Our generalized linear model indicated that clutch size did not differ between translocated pairs and returning pairs (t-value = -0.14, df = 60, P = 0.89; Figure 2-3) or among years (t-value = -1.01, df = 60, P = 0.32; Figure 2-3). We found marginal variation in clutch size with respect to attempt (t-value = -1.65, df = 60, P = 0.10), with 3rd attempts having nearly one less egg than 1st and 2nd attempts (Figure 2-3).

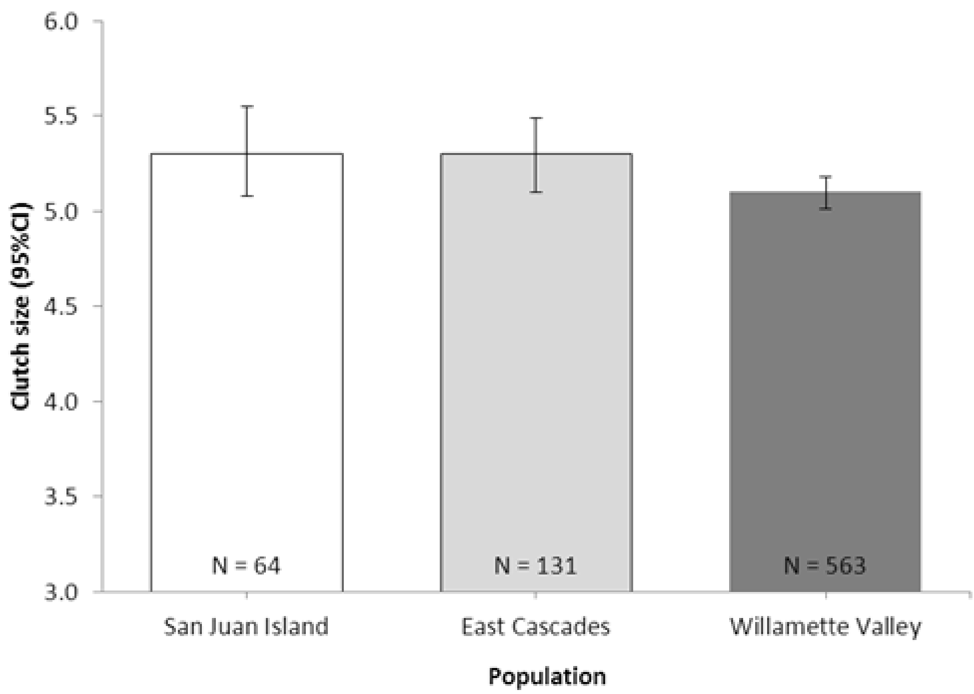


Figure 2-2. Mean clutch size and 95% CI for the reintroduced Western bluebird on San Juan Island and populations of Western bluebirds along the east slope of the Cascade Mts, Washington (Kozma and Kroll 2010) and in the Willamette Valley (Keyser et al. 2006)

Nest initiation. Over the five years of the study, mean nest initiation date for first attempts was 11 May $\pm$ 3 days (N = 34; Table 2-1). However, model results indicated that mean nest initiation date was significantly earlier, by almost three weeks, for returning pairs (mean = 2 May $\pm$ 3 days) than for translocated pairs (mean = 22 May $\pm$ 3 days; t-value = 6.03, df = 31, P < 0.001; Figure 2-4) and that nest initiation date varied as a function of year (t-value = 2.45, df =

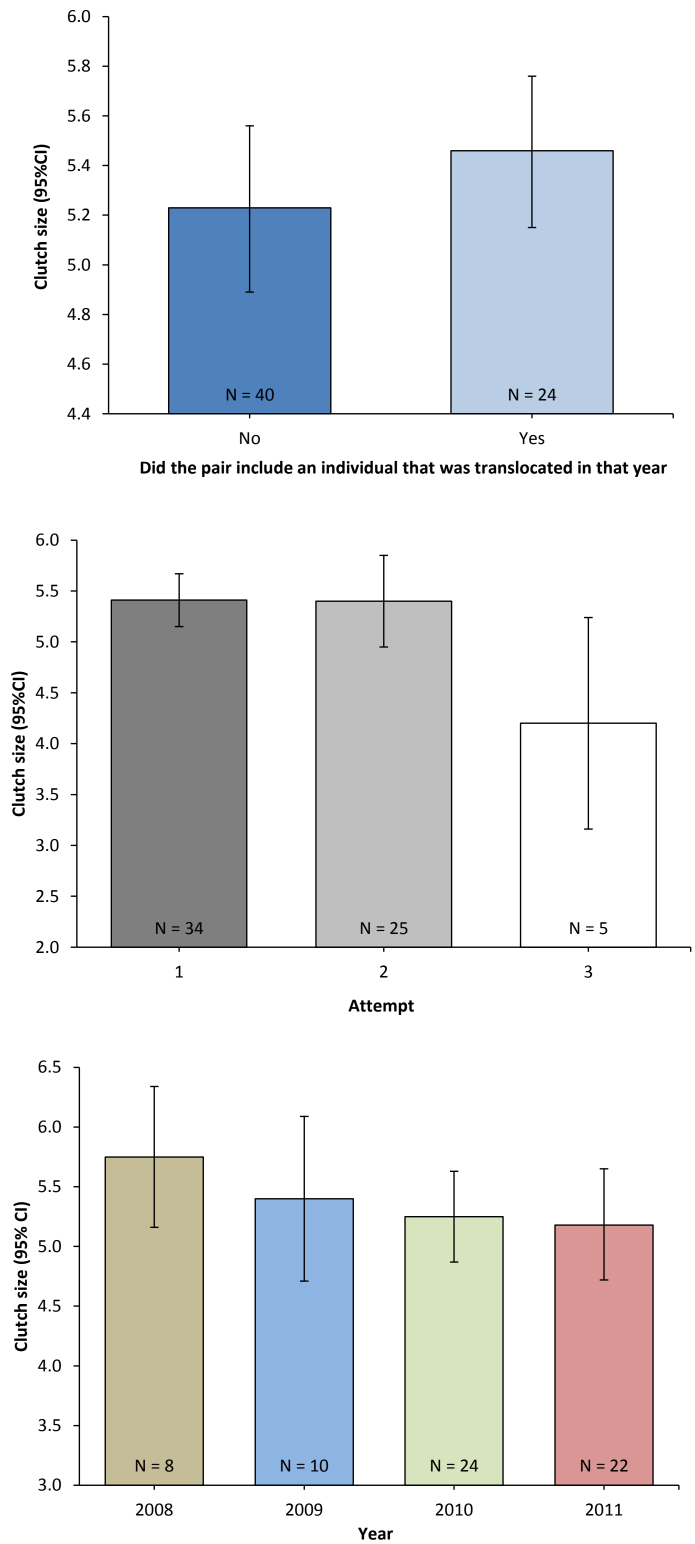


Figure 2-3. Mean clutch size and 95% CIs of translocated pairs versus returning pairs (top), by attempt (middle), and by year (bottom) for Western bluebirds in the reintroduced population on San Juan Island, Washington, 2008-2011.

31, *P* < 0.02; Figure 2-4). Returning pairs showed the most annual variation with mean nest initiation date ranging from 2 May in 2009 to 20 April in 2010 to 7 May in 2011.

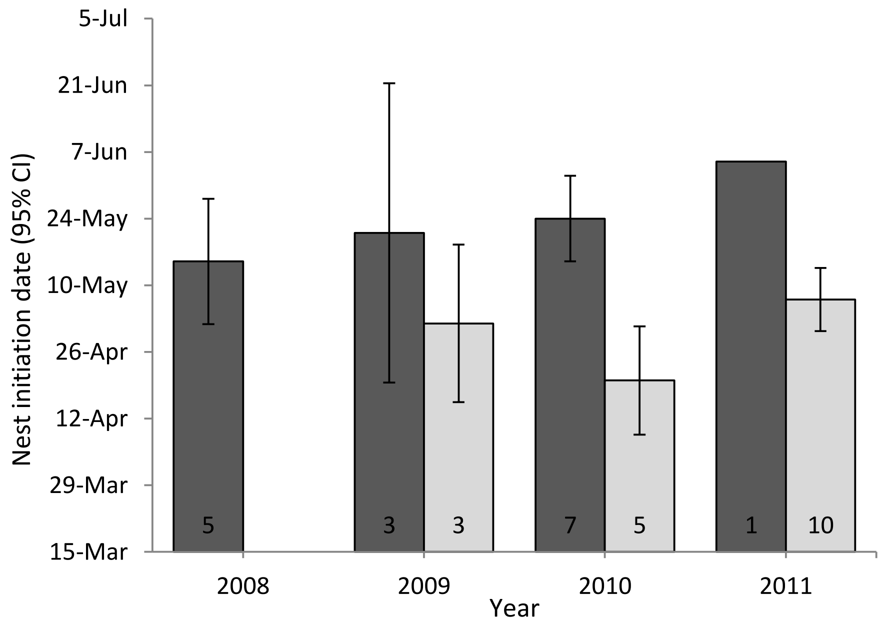


Figure 2-4. Mean initiation date (95% CI) of first attempts by translocated pairs (dark bars) and returning pairs (light bars) of Western bluebird on San Juan Island, Washington, 2008-2011.

Productivity. From 2008 to 2011, we banded 32, 44, 84, and 77 nestlings, respectively. Nesting success, on average, was 69% (Table 2-1), but was substantially lower in 2011 (56%) than in the three previous years (range = 70-80%). Of the 22 nests that failed, 13 (60%) were attributed to predation, 5 (23%) were due to abandonment, 1 was due to a nest box falling, and the remaining were due to unknown causes. We believe house sparrows (*Passer domesticus*) were a significant predator based on evidence of broken eggs and subsequent nesting attempts by the sparrows in boxes. At 6 of the nest failures, we found remains of dead breeding females in or near the nestbox. At least one female was killed by a house cat; the specific cause of death for the other five is unknown, but predators observed regularly include House Sparrows, forest raptors (e.g., sharp-shinned hawk; *Accipiter striatus*), and raccoons (*Procyon lotor*).

The mean number of young fledged from successful nests in the reintroduced population on San Juan Island was 5.3 $\pm$ 0.2 (*N* = 46; 95% CI: 4.7, 5.4) and did not differ significantly from that found by Kozma and Kroll (2010) in the population of bluebirds in the east slope of the

Cascade Mountains (mean = 4.5 ± 0.2; N = 80; 95% CI: 4.1, 4.9). The mean number of young fledged from all nests, including unsuccessful nests, in the reintroduced population was 3.4 ± 0.3 (N = 68; 95% CI: 2.8, 4.0) and did not differ significantly from a growing bluebird population in the Willamette Valley (Keyser et al. 2004; mean = 3.3 ± 0.1; N = 563; 95% CI: 3.1, 3.5). Perhaps the best measure of productivity is the number of young per breeding female because annual fecundity is directly related to population growth. On San Juan Island, the mean number of young produced per breeding female was 5.8 ± 0.6 (N = 41; 95% CI: 4.6, 7.0), which although was higher by 1.0 young per breeding female, did not differ significantly from female productivity in the Willamette Valley (Keyser et al. 2004; mean = 4.8 ± 0.2; N = 153; 95% CI: 4.4, 5.3).

On San Juan Island, generalized linear modeling indicated that mean number of young fledged per breeding female did not differ between translocated pairs and returning pairs (t-value = -1.3, df = 37, P = 0.20), years (t-value = -0.19, df = 37, P = 0.85), and age of breeding female (SY vs. ASY; t-value = 0.23, df = 37, P = 0.47).

Survival

During the period from 2007 to 2011, we banded 387 bluebirds, 139 (103 adults, 36 nestlings) that were translocated to San Juan Island and 246 (9 adults, 237 nestlings) on San Juan Island. After censoring individuals, we included the capture histories of 277 individuals in the survival analysis (Table 2-2).

Table 2-2. Summary of capture history by age, sex, and year for Western bluebird individual included in the survival analysis.

	2007	2008	2009	2010	2011	Total
Adult						
female	1	5	4	9	6	25
males	1	4	5	5	4	19
Nestlings						
female		13	18	41	37	109
male		13	24	43	44	124
Total	2	35	51	98	91	277

Estimates of c were 1.13 (model deviance/mean deviance of simulations) and 0.99 (observed c/mean of c derived from simulations). As values did not substantially depart from 1.0 there is no indication of overdispersion, and therefore we did not adjust parameter estimates. The best model, as evaluated by AIC, from the candidate (nested) models indicated apparent survival varied between juvenile males and females and adults and that recapture probability was constant between juveniles and adults (Table 2-3). From this model, apparent survival equaled 0.45 (95% CI: 0.33, 0.58) for adults, 0.09 (0.05, 0.19) for juvenile females, and 0.24 (0.16, 0.34) for juvenile males (Figure 2-5); recapture probability equaled 1.00. Although two other models were close to gaining equal support with a ΔAIC of 2.09, parameter estimates were nearly identical in all cases. Therefore, we concluded that the best model was appropriate and did not consider averaging models to obtain parameter estimates.

Table 2-3. Candidate models explaining variation in apparent juvenile and adult survival (Φ) of Western bluebirds and recapture probability (p) for breeding Western bluebirds on San Juan Island, Washington, USA, from 2007 to 2011.

Model	Delta AICc[b]	Model Likelihood	No. of parameters	Deviance
$\Phi_{\text{a2-juvenile(sex/.)/adult(./.)}}$, $p.$	0.	1.00	4	26.2
$\Phi_{\text{a2-juvenile(sex/.)/adult(sex/.)}}$, $p.$	2.1	0.35	5	26.2
$\Phi_{\text{a2-juvenile(sex/.)/adult(./.)}}$, $p_{\text{a2-juvenile(.)/adult(.)}}$	2.1	0.35	5	26.2
$\varphi_{\text{a2-juvenile(./.)/adult(./.)}}$, $p.$	3.4	0.18	3	31.7
$\varphi_{\text{a2-juvenile(sex/.)/adult(sex/.)}}$, $p_{\text{a2-juvenile(.)/adult(.)}}$	4.2	0.12	6	26.2
$\varphi_{\text{a2-juvenile(./.)/adult(sex/.)}}$, $p.$	5.5	0.07	4	31.6
$\varphi_{\text{a2-juvenile(./.)/adult(./.)}}$, $p_{\text{a2-juvenile(.)/adult(.)}}$	5.5	0.07	4	31.7
$\varphi_{\text{a2-juvenile(./.)/adult(sex/.)}}$, $p_{\text{a2-juvenile(.)/adult(.)}}$	7.6	0.02	5	31.6
$\varphi_{\text{a2-juvenile(sex/.)/adult(sex/time)}}$, $p_{\text{a2-juvenile(.)/adult(.)}}$	9.5	0.01	11	20.6
$\varphi_{\text{a2-juvenile(sex/.)/adult(sex/time)}}$, $p_{\text{a2-juvenile(.)/adult(.)}}$[a]	11.8	0.003	12	20.6

[a] The global model included variation in age: juvenile survival by sex, but not time, adult survival by sex and time; and variation in recapture probability by age with time held constant.
[b] The lowest AIC_c score was 224.41.
[c] calculated c values for the global model were 1.13 and 0.99, therefore estimates were not adjusted.

Survival estimates from Program Mark were nearly identical to estimates of return rates (Table 2-4), which is not surprising given recapture probability in the best model was 1.00. We compared survival estimates from the reintroduced population with estimates from the Willamette Valley (Keyser et al. 2004) using 95% CIs. Keyser et al (2004) did not report 95%

Table 2-4. Return rates and survival estimates of banded Western bluebirds on San Juan Island, Washington 2007-2011.

	No. banded	No. returned	Return rate	
2007-2008				
Adults	2	0	0%	
2008-2009				
Total adults	12	4	33%	
Adult males	6	1	17%	
Adult females	6	3	50%	
Total juveniles	30	4	13%	
Juvenile males	14	3	21%	
Juvenile females	13	1	8%	
2009-2010				
Total adults	17	10	59%	
Adult males	9	6	67%	
Adult females	8	4	50%	
Total juveniles	48	8	17%	
Juvenile males	23	8	35%	
Juvenile females	17	0	0%	
2010-2011				
Total adults	32	13	41%	
Adult males	19	8	42%	
Adult females	13	5	38%	
Total juveniles	84	14	17%	
Juvenile males	43	8	19%	
Juvenile females	41	6	15%	
TOTAL (2007-2011)				**Estimates from Program Mark**
Total adults	63	27	43%	
Adult males	34	15	44%	0.45
Adult females	27	12	44%	0.45
Total juveniles	162	26	16%	
Juvenile males	80	19	24%	0.24
Juvenile females	71	7	10%	0.09

CIs, and thus we transformed parameter estimates of φ and SE to the logit scale to calculate 95% CI and then back transformed estimates to the probability scale, ensuring that estimates are bound by 0.0 and 1.0. Keyser et al (2004) found support for differential survival by sex in adults, which was not detected in the reintroduced populations. Adult male survival on San Juan Island (0.45; 95% CI: 0.33, 0.58) was marginally significantly lower than in the Willamette Valley (0.63; 95% CI: 0.58, 0.70), but adult female survival did not (Figure 2-5). In another contrast, Keyser et al (2004) did not find variation in survival by sex in juveniles (0.26; 95% CI: 0.22, 0.30. Although this estimate is similar to male juvenile survival, female juvenile survival on San Juan Island (0.09; 95% CI: 0.05. 0.19) was significantly lower than in the Willamette Valley (Figure 2-5)

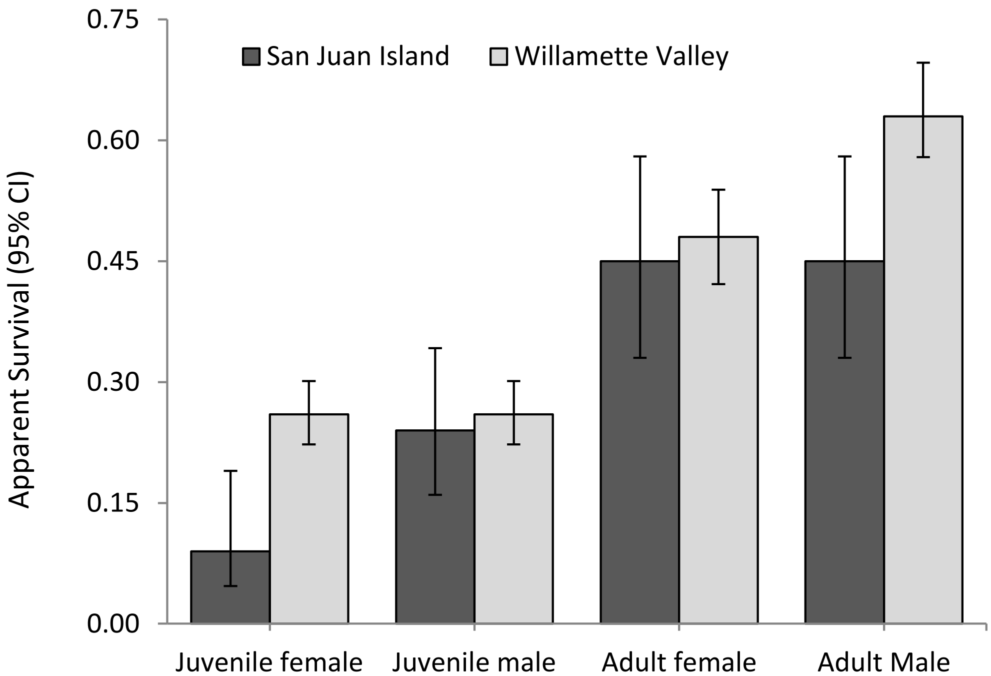


Figure 2-5. Apparent survival estimates (95% CI) for Western bluebirds on San Juan Island, Washington, 2007-2011 and Willamette Valley, Oregon, 1995-2002.

Discussion

Results from this study indicate significant progress towards the successful establishment of a reintroduced Western bluebird population on San Juan Island, Washington, a site where they have been extirpated since 1964. During the five-year period in which translocations were conducted (2007-2011), the reintroduced population of Western bluebirds on San Juan Island met our simple criteria of annual increases in population size and successful reproduction by translocated individuals and their offspring. The reintroduced population also achieved the majority of our robust criteria: reproduction and survival parameters were similar between the reintroduced population and high-quality reference populations elsewhere in the Pacific Northwest. The only robust criteria the population failed to meet was that survival by adult males and juveniles females was significantly lower than in a high-quality reference population. However, we suspect those results are due to differences in statistical methods and sparse data rather than a systemic problem in the population. With the cessation of translocations, further monitoring will be needed to determine whether the population continues to grow as expected, ultimately reaching the carrying capacity of San Juan Island.

Despite their simplicity, population growth and successful reproduction by translocated individuals and their offspring are key benchmarks of success early in this study because they indicate that migratory pathways, which had not been used in over 40 years, were reestablished and that habitat in the reintroduction site was suitable for successful reproduction. The observed growth in population size of the reintroduced bluebird population on San Juan Island was due to an increasing number of both translocated birds and non-translocated birds. Growth in this latter category is especially important, as it indicates the return migration of island-born individuals and the likely immigration of individuals from other populations. Of some concern is the fact that growth rate declined in each year of the 5-year period, especially in the last year. However, the winter and spring of 2011 were characterized by unseasonably cold and wet weather conditions, which may have influenced overwinter survival or caused individuals to delay or forgo migration to the breeding grounds.

The strongest evidence for reintroduction progress towards the successful establishment of the reintroduced population is clearly that clutch size and productivity measures on San Juan Island were similar to values found in two other Pacific Northwest bluebird populations (Keyser et al. 2004, Kozma and Kroll 2010). In fact, the number of young fledged per breeding female was 1.0 young higher in the reintroduced population than in the Willamette Valley, which although not statistically significant should be considered biologically significant. To some extent, we might expect that demographic rates in a small reintroduced population to be higher than populations at, or near, carrying capacity, as density-dependent factors should be absent. Higher productivity in the reintroduced population may also reflect supplemental food provided to breeding pairs during periods when adults are feeding nestlings and dependent offspring. Supplemental food has been shown to increase fecundity in Eastern bluebirds (need to find citation)

Estimates of survival in the reintroduced population, on the other hand, were mixed in meeting our criteria of reintroduction progress. Both juvenile female and adult male survival estimates were significantly lower in the reintroduced population than in the Willamette Valley, whereas estimates of adult female and juvenile male survival did not differ. We believe the substantially lower differences in juvenile female return rates on San Juan Island (0.09; return rate range: 0 -15%) compared to the Willamette Valley (0.26) are most likely a product of different modeling techniques used to calculate survival. We estimated apparent survival using live recapture data; with apparent survival, permanent emigration and death are confounded because an animal will appear to have died even though it is alive but has dispersed from the study area. Keyser et al (2004) estimated survival using live and dead captures, which allows for the estimation of the probability of site fidelity. This procedure reduces the problem of discerning death from emigration, and produces a more accurate estimate of actual survival. In the Willamette Valley, fidelity rates for juveniles averaged 58% across all study year. As such, we can rather safely assume that a modest, but unknown, portion of the mortality estimated in our study is actually due to emigration, and therefore the differences in survival estimates between the reintroduced and reference population may not be significantly different. As monitoring continues on San Juan Island, consideration of incorporating of dead recaptures into the monitoring effort should be considered.

We lack any specific information to explain the lower survival estimates of adult males. The range of adult male annual return rates (17-67%) on San Juan Island varied substantially yet encompassed the mean estimate found in the Willamette Valley. The fidelity rate of adults was approximately 100% in the Willamette Valley, and thus we have no reason to suspect that male adults on San Juan Island are permanently emigrating from the population. We suspect that our estimates, calculated with sparse data over a short-time period, may simply not reflect the full spectrum of survival by male adults. Overall, survival estimates should become more robust as the sample size increases and the data set covers a more substantial time period.

Post-release monitoring has also revealed two interrelated issues that deserve further monitoring because of their potential to influence population establishment and persistence of the reintroduced population of bluebirds. These issues include the presence of a male bias in the sex ratio of the population and substantial mortality of breeding females. Sex bias was most apparent in 2009 and 2010, but moderated in 2011, perhaps due to the reintroduction of single females into the population and higher recruitment of juvenile females in 2011. Male sex bias appears to be a product of two factors: generally low site fidelity by juvenile females and high mortality of adult females during the nesting period. We expect that in the long-term, low site fidelity by juvenile females should be offset by immigration of females from other populations, but with the absence of nearby populations to serve as a source, the likelihood of robust immigration is uncertain. Future monitoring will help evaluate immigration patterns and population structure. With regards to the issue of high female mortality at nest sites we believe that issue may be addressed through management. Mortality of nesting females is a product of predation, and thus placing nest boxes in safer locations may influence the rate of female mortality. For example, nest boxes should not be placed in locations that might be attractive to house sparrows, an aggressive nest competitor, such as near houses or other structures. Educating private landowners on proper nest box placement will be an important management activity, especially following the cessation of translocations.

We found no effect of translocations on clutch size or productivity, even though translocated pairs nested later than returning pairs. This is interesting because seasonal declines in reproductive success have been reported for other species, including cavity-nesters (Hochachka 1990, Lloyd and Slater 2007). From a methodological standpoint, this result suggests that reintroductions, even those later in the breeding season, may be as effective as those conducted early in the season. It is also possible that the availability of supplemental food may have moderated any consequences of breeding later in the season.

Clearly, further monitoring will be needed to validate success of the Western Bluebird reintroduction on San Juan Island now that translocations have been completed. To date, however, our monitoring indicates significant progress towards the goal of population establishment, in which the population continues to increase in size until the carrying capacity of the island is reached. Although we do not know the exact carrying capacity of the island, we suspect that the island should support > 25 territories. The distribution of the local population should also not be limited to San Juan Island, as available habitat is present on both adjacent islands and the mainland in the United States and Canada. In 2011, we had verified sightings of banded birds during the breeding season on Lopez Island and Vancouver Island, Canada. Future monitoring should continue to focus on measuring population size and demographic rates. Reliable estimates of population size will be dependent on continued community involvement because the majority of territories were discovered by private landowner. As such, outreach and education should still be considered important components of the monitoring effort.

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