FEASIBILITY ASSESSMENT FOR REINTRODUCING THE SLENDER-BILLED WHITE-BREASTED NUTHATCH TO SOUTH PUGET SOUND, WASHINGTON

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INTRODUCTION

Conservation efforts aimed at restoring biodiversity increasingly are turning to reintroduction as a tool to reestablish extirpated species to their former range (Griffith et al. 1989). Reintroductions may be required in cases where habitat loss and degradation has created fragmented habitats that prohibit dispersal pathways needed for recolonization. In some situations, reintroductions may be favored to accelerate the recolonization process, even when the extirpated species of interest has strong dispersal capabilities or habitat bridges exist between occupied and unoccupied habitat. Reintroductions are usually performed either through the release of captive-bred individuals or through the translocation of wild individuals from one part of their range to another (Griffith et al. 1989). In response to the increasing frequency with which reintroductions are being attempted, the IUCN (1995) developed guidelines for reintroduction efforts to insure that reintroductions are justifiable, that they are likely to succeed, and that the conservation world can gain knowledge from each reintroduction attempt, whether it is successful or not.

The Slender-billed White-breasted Nuthatch (*Sitta carolinensis aculeata*; hereafter SBWBNU) is an oak-habitat near-obligate bird that has been extirpated from its former range in the South Puget Sound, Washington. The nearest known population is in Clark County, WA, approximately 95 miles away in the northern Willamette Valley ecoregion (Chappell 2005). Small, disjunct patches of oak woodland occur from Clark County to the South Puget Sound, but recolonization of oak habitat in the South Puget Sound is unlikely due to the sedentary nature of the SBWBNU. Furthermore, the remnant SBWBNU population in the northern Willamette Valley is apparently declining, reducing the likelihood that individuals will naturally recolonize currently vacant habitat. Given current conditions, reintroduction appears to be the only means to restore populations of SBWBNU to their historic range within the oak woodlands of the South Puget Sound.

PURPOSE

In considering the reintroduction of a species to its former range, the first step is a feasibility study (IUCN 1995). Feasibility studies are critical to determine: (1) if existing habitats are suitable and of sufficient quantity to support a self-sustaining population; (2) whether the processes that led to extirpation are minimized or absent; and (3) if source populations are available. Feasibility studies are also vital in determining whether current social and economic conditions will allow a reintroduction effort, once initiated, to be maintained (IUCN 1995).

Here, we provide a scientific assessment of the feasibility of reintroducing the SBWBNU to oak woodlands in the South Puget Sound. Specific objectives of this assessment are to: (1) describe the conservation status and life history of the SBWBNU; (2) evaluate the possible causes of extirpation and determine whether they pose a threat to reintroduced populations; (3) identify and assess potential reintroduction sites with respect to habitat suitability, long-term conservation commitment, and ability to support a self-sustaining population; (4) identify and determine the availability of source populations; and (5) provide a recommendation on the potential to restore SBWBNU to South Puget Sound.

STATUS

Conservation status

The SBWBNU has been recognized as a species of conservation importance by most natural resources agencies and non-governmental conservation organizations within its range. At the highest level of recognition, it is a Washington Department of Fish and Wildlife (WDFW) *Candidate* species for listing as Threatened or Endangered in Washington (WDFW 2005a). Both states have listed it as a *Species of Greatest Conservation Need* in their recently completed Comprehensive Wildlife Conservation Strategies (WDFW 2005b, ODFW 2005). Federally, it is a U.S. Fish and Wildlife Service *Species of Concern* in Oregon and Washington (USFWS 2002). Among non-governmental conservation organizations, it is an Oregon-Washington Partners in Flight (PIF) *Focal Species* (Altman 2000), and a *Target Species* within The Nature Conservancy's (TNC) Ecoregional Assessment (Floberg et al. 2004.).

Systematics

The taxonomy of the White-breasted Nuthatch in North America is unclear (Pravosudov and Grubb 1993). As many as 11 subspecies of White-breasted Nuthatch have been described (Phillips 1986), although earlier evaluations by Ridgeway (1904) and Aldrich (1944) recognized 6 and 8 subspecies, respectively. Delineation of subspecies status has been based on aspects of morphology (body and bill size), plumage coloration, and ecology; in no instance has a range-wide taxonomic evaluation been conducted using modern molecular genetic techniques (Pravosudov and Grubb 1993, but see Leonard 2005).

In recent evaluations, only two subspecies, the SBWBNU and the Inyo White-breasted Nuthatch (*S. c. tenuissima*), occur west of the Rocky Mountains (AOU 1957). Both forms are found in Washington (Chappell 2005) and Oregon (Hagar 2003). The SBWBNU resides within a narrow band of lowland and foothill oak habitats, west of the Cascade and Sierra Nevada mountain ranges (Aldrich 1944, Philips 1986). The SBWBNU appears to be geographically isolated from *tenuissima,* which is found east of the Cascade and Sierra Nevada crest, to the western slope of the Rocky Mountains in Alberta, Montana, Wyoming, and Nevada (Aldrich

1944, Jewett et al. 1953, Phillips 1986). The SBWBNU is consistently smaller than the Inyo subspecies with shorter wings and bill and is paler dorsally and more brownish ventrally (Table 1; Aldrich 1944).

Historic and current distribution

The SBWBNU historically occurred in association with low elevation, mature deciduous forests (predominantly oak) from southwestern British Columbia into northern Baja, California west of the Cascade and Sierra Nevada Mountains (Pravosudov and Grubb 1993). References to its historic occurrence in southwestern British Columbia are limited to a few scant breeding season records (Munro and Cowan 1947), although there are no specimens to confirm this (Godfrey 1986). There are no historic or current records of the species occurrence on the San Juan Islands, Washington (Lewis and Sharpe 1987). There are a few non-breeding season records of the species in northwestern Washington north of Seattle (C. Chappell, pers. comm.), but it was likely never common north of Tacoma due to limited habitat availability (Rathburn 1902). Thus, its historic northernmost occurrence as a regular breeding species was the Tacoma/Olympia area in the southern part of the Puget Sound, Washington (i.e., South Puget Sound).

SBWBNU has been recently extirpated from the South Puget Sound and now reaches the northern extent of its range in the northern part of the Willamette Valley ecoregion at Ridgefield National Wildlife Refuge in Clark County, Washington near the Columbia River. Historically, the South Puget Sound and Willamette Valley populations may have been bridged by small breeding populations in oak habitats around Kalama, Woodland, and Centralia, Washington. However, there are no known records in this corridor (C. Chappell, pers. comm.). Range contractions such as observed in western Washington have not been noted elsewhere in the geographic distribution of the SBWBNU.

SBWBNU populations have always been patchily distributed, reflecting the patchy distribution of its preferred oak habitat. In the northern half of its range, geographic isolation and the discontinuity of populations are mostly a result of areas of unsuitable montane coniferous forest habitat. For example, populations in the three major western interior valleys of Oregon (i.e., Willamette, Umpqua, and Rogue) are separated by areas of coniferous forest ranging from 50-100 miles. Although the Willamette Valley and the South Puget Sound are not separated by montane coniferous forest, there are relatively large areas of lowland coniferous forests along with other nonsuitable habitats such as bottomland riparian forests and historic prairie (current agricultural land) that separate the patches of oak habitat.

Changes in Population Status

Populations of the SBWBNU have declined steadily in the South Puget Sound over the last century. The SBWBNU was considered common in oak-prairie habitat of the South Puget Sound at the time the first European settlers arrived (Cooper 1860). In the early 1900s, a significant decline of populations was reported in the Tacoma area (Bowles 1929), and by the mid 1900s, declines were noted across western Washington (Kitchin 1949). In the late 1960s, the SBWBNU was still found regularly at Fort Lewis Military Reservation in both oak and ponderosa pine habitats (Ken Brunner, pers. comm.). However, by the late 1970s, there were only nine known breeding sites, all with small populations, in the South Puget Sound (Chappell and Williamson 1984, Smith et al. 1997; Table 2). These populations vanished over the next 25 years until the last known breeding occurred in nest boxes at Flett Dairy in 1995 (Chappell 2005).

Population Trends

Breeding Bird Survey (BBS) population trends provide the best indication of the status of SBWBNU during the breeding season (Table 3). BBS data (1966-2004) indicate that the SBWBNU is doing relatively well throughout coastal California with significant increases over the long-term. Confidence in this pattern is high (i.e., large sample size, high abundance, trend consistency, see Sauer et al. 2003) both statewide and by ecoregions (Table 3). The recent (1980-2004) population trend is also positive, albeit with a slower rate of increase and less confidence. Population trends of SBWBNU in Oregon are less clear. In the Willamette Valley, both long-term and recent population trends are negative, although not significant (presumably due to the small sample size). In contrast, significant increases have been recorded in the Southern Pacific Rainforest Physiographic Region (SPR), which would seem to indicate that the species is doing well in the Rogue and Umpqua Valleys despite declines in the Willamette Valley.

The National Audubon Society's Christmas Bird Count (CBC) provides our best information on populations of SBWBNU during the nonbreeding season. The CBC results reveal a similar pattern to the BBS: in California and southwest Oregon populations are relatively stable, whereas in the Willamette Valley all counts reported declining populations (Figure 1). Especially steep declines are evident for the Sauvie Island, Portland, and Eugene counts, while declines in Corvallis and Salem appear to have leveled off over the last 10 years (Figure 1).

LIFE HISTORY

Habitat

The White-breasted Nuthatch inhabits both deciduous and coniferous forests across its range (Aldrich 1944, Root 1988, Howell and Webb 1995, Engstrom 1996), appearing to favor edge habitats over woodland interiors (Pravosudov and Grubb 1993). SBWBNU is a near-obligate species of mature oak habitats They also are known to occur occasionally as a breeding species in ponderosa pine patches where associated with oaks on Fort Lewis Military Installation, Washington (Ken Brunner, pers. comm.), and in cottonwood gallery forest along the Columbia River. In the Willamette Valley, Hagar and Stern (2001) found that the frequency of SBWBNU detection decreased as oak subcanopy cover and Douglas-fir canopy cover increased, and increased with the average diameter of oaks. Anderson (1970b, 1980) found that SBWBNU abundance was positively correlated with the average length of secondary oak branches and distance between trees. These data are in agreement with Viste-Sparkman (2005), who found nuthatches were more abundant in forests that occurred in a non-forested matrix (e.g., prairie) and had low canopy cover (Table 4). Similarly, in an oak woodland in California, white-breasted nuthatches were generally associated with low tree density (<100 trees/ha) and large tree diameter (>50 cm dbh)(Wilson et al. 1991).

The preference of SBWBNU for mature, open oak woodland may be partially explained by the presence of cavities, which are more numerous in oaks than in other deciduous species (e.g., big-leaf maple [*Acer macrophyllum*]) or in Douglas-fir (Gumtow-Farrior 1991). As a secondary cavity-nester, the SBWBNU relies on existing natural cavities or previously excavated cavities as nesting and roosting sites. The number of cavities in oak trees is positively related to tree diameter, and oaks in open-growth savannah conditions contain more cavities than oaks in densely spaced forests (Gumtow-Farrior 1991). The number of suitable cavities for SBWBNU has almost certainly declined over the past century due to the selective logging of large oak trees and the reduced frequency of fires, which has facilitated the invasion of oak savannah by Douglas-fir.

In general, SBWBNU avoid closed coniferous forest habitats, but data are lacking on the amount of coniferous forest that they will tolerate. In the Willamette Valley, survey points where nuthatches were detected had less conifer within 1 km (2 percent) than where they were not detected (10 percent; Table 4, Viste-Sparkman 2005). However, study blocks were located specifically in oak habitats, and thus did not represent a range of cover from coniferous to oak habitat. The maximum amount of conifer within 1 km of survey sites where nuthatches were detected was 20 percent. At nest sites, the mean percent of coniferous forest within 1 km was approximately 7 percent, with a high of nearly 60 percent (Viste-Sparkman 2005, Table 4).

The only data on vegetation features that SBWBNU select at nest sites is from the Willamette Valley. There, nuthatches nested almost exclusively in oak trees and mean DBH and the number of cavities was higher in nest trees than in random trees (Viste-Sparkman 2005, Table 5). Mean nest height ($\pm$S.E.) in oak trees was 6.10 ($\pm$3.17; n = 51) m. Nest sites were also strongly associated with nonforested cover, primarily agricultural areas, supporting their apparent preference of edge habitats (Table 5)

Density and territory size

Breeding densities of SBWNU are generally low due in part to their relatively large territory size and the patchy distribution of their preferred oak habitat. In five Oregon white oak stands in the Willamette, densities fluctuated between 1 and 4 birds/10 ha throughout the year (Anderson 1970a). A more recent study in oak habitats of the Willamette Valley found that

SBWBNU density varied with respect to size and composition of oak woodland patches (Viste-Sparkman 2005). In the interior of large woodlands (> 130 m from edge), SBWBNU density was 0.32 pairs/10 ha (CV = 48.0%) compared to 1.18 pairs/10 ha (30.6%) in large woodland edges (< 65 m from edge). Density was highest in small woodlands (< 65 m from 2 edges; 2.7 pairs/10 ha, 23.1%; Viste-Sparkman 2005), perhaps due to the high edge to area ratio.

There is little information on the size of White-breasted Nuthatches territories, but territory size is probably variable, reflecting habitat conditions. In the Great Plains, white-breasted territories ranged from 10-15 ha in wooded areas and approximately 20 ha in semi-wooded habitats (Butts 1931). Based on Viste-Sparkman's abundance data, mean territory size of SBWBNUs in oak woodlands was 7.1 ha (Viste-Sparkman 2005), but was smaller (3.8 ha) in small oak woodland patches. In oak-dominated habitats of California, SBWBNU territory size derived from spot-mapping as part of the Breeding Bird Census program was 12 ha, but decreased to 8 ha when oak was co-dominant with pine.

Site fidelity

There are no data on site fidelity by SBWBNU, but White-breasted Nuthatches across their range typically remain in the same territory year-round (Bent 1948, Pravosudov and Grubb 1993). Banding recovery data indicate an extremely high degree of site fidelity for this resident species. Of the 80,709 White-breasted Nuthatches banded throughout the species' range since 1914, 3,139 were recovered (a bird banded in one location and encountered in another) between 1920 and 1999; of these only 55 (<2%)were found >20 km from their point of initial capture (Leonard 2005, United States Geological Survey [USGS], Patuxent Wildlife Research Center, Bird Banding Laboratory). Across its range, there are 1,336 banding records of SBWBNU, and only 2 of 29 recoveries (7%) were found greater than 20 km from their banding location (USGS, Patuxent Wildlife Research Center, Bird Banding Lab).

Food habits and foraging

There are few studies of the White-breasted Nuthatch's food habits. However, based on the species wide distribution through most of North America, their diet likely varies regionally to some degree. From spring to fall, White-breasted Nuthatches are primarily insectivorous, gleaning a wide variety of egg, larvae, and adult invertebrates (Jewett 1944, Pravosudov and Grubb 1993). Seeds (e.g., acorns) and other plant matter may also comprise a significant portion of the diet, particularly in the winter and spring (Martin 1951, Pravosudov and Grubb 1993). However, the diet of SBWBNU appears to include less plant matter than the diet of White-breasted Nuthatches elsewhere in North America.

The only study of SBWBNU food and foraging habits was conducted in the Willamette Valley (Anderson 1976). SBWBNU in western Oregon oak woodlands consumed spiders (Order Aranea), beetles and weevils (Coleoptera), true bugs (Hemiptera), earwigs (Dermaptera), and butterflies and moths (Lepidoptera; presumably mostly larvae) (Anderson 1976). Seeds (sedge and grass) were rarely consumed by SBWBNU in western Oregon oak forests and only were only a substantial part of their diet in the winter. In contrast to food habitat studies in other parts of their range, acorns were not found in the nuthatch's diet. Given the moderate climate of the Pacific lowlands, nuthatches in Washington and Oregon may not be as dependent on winter seeds as in other parts of their range, as invertebrates appear to be available throughout the winter (Anderson 1976).

The White-breasted Nuthatch forages primarily on trees, and gleans the majority of its food items from the trunk, limbs and inner parts of branches. Due to its low center of gravity and short legs, the nuthatch is able to exploit all parts of a branch, including the underside, occupying a unique foraging niche within the bird community. In Illinois, where oaks were the preferred foraging species, White-breasted Nuthatches favored large branches (>7.5 cm) over smaller ones (Wilson et al. 1991). Similarly, SBWBNU in the Willamette Valley foraged more frequently on primary branches and trunks than smaller secondary branches (Anderson 1970). Larger branches may be preferred due to their increased surface area, which in turn supports greater prey biomass. In addition, these larger and older branches may have more extensive moss cover, which also may contribute to prey abundance (K. Viste-Sparkman, pers. comm.).

Breeding biology and demography

Clutch size. Although the White-breasted Nuthatch has a large geographic range and is common in many parts of the country, published information on their demography is scarce. The limited data that is available on clutch size, nesting success, and productivity suggests nuthatches have relatively high reproductive potential, an important factor related to successful translocations of wildlife (Griffith et al. 1989). Female white-breasted nuthatches produce large clutches (4-10 eggs) but are almost always single brooded, even after nest failure. Across its range, mean clutch size (± SE) is 7.3 + 1.2 egg (Table 6, Bent 1948) but likely varies with latitude (Pravosudov and Grubb 1993). In the subspecies *S. c. cookii* (eastern U.S), mean clutch size was 7.3 ± 1.1 eggs (*n* = 50; Pravosudov and Grubb 1993), while in northern Florida and Georgia (*S. c. carolinensis*) mean clutch size was 5.1 + 1.1 eggs (*n* = 32; Leonard 2005).

Nesting success and productivity. Measures of nesting success and productivity follow clutch size patterns. During a two-year study, in the Willamette Valley, Oregon, Mayfield nest success (Mayfield 1961) was 75% (*n* = 64; CI, 64% to 88%) (Viste-Sparkman 2005, Table 6). Mayfield nest success from only those nests in oak trees was 71% (*n* = 50; CI, 58% to 86%); nest success in nestboxes was 100% (*n* = 10; Viste-Sparkman 2005). In Arizona, nests success was lower, as was the sample size (52%; *n* = 9; Li and Martin 1991). Apparent nest success (# successful/# attempted) for the Eurasian Nutatch (*Sitta europea*), of which it shares a closer resemblance in life history and ecology than other North American nuthatches (Pravosudov and Grubb 1993), were similar to that estimated by Viste-Sparkman (2005): 72% (81 of 113) of Eurasian Nuthatch nests were successful in Sweden (Nilson 1984) and 76% (28 of 37) were successful in Siberia (Pravosudov and Grubb 1993; Table 6). White-breasted Nuthatch nesting success in mixed pine-oak habitats in northern Florida and southern Georgia are low (39%) compared to other regions of the United States, but in agreement with overall patterns of low reproduction for all cavity-nesters in the southeast United States (Leonard 2005). In the Willamette Valley, Oregon, the mean number of fledgling produced per successful nest was 4.90 ± 0.23 (SE; range 1-7; *n* = 39 ; Viste-Sparkman 2005). Mean number of fledglings in Siberia was similar (5.11 ± 0.28; Pravosudov and Grubb 1993).

Survivorship. Only one study of survivorship in White-breasted Nuthatches has been published. Karr et al. (1990) estimated a mean annual survivorship rate of 35 ± 1% (*n* = 32) for nuthatches in Maryland (1980-1987). In Siberia, mean annual adult survivorship was 64% (Pravosudov and Grubb 1993), while in Europe annual winter survival varied between 43 and 74% (Enokson 1988).

CAUSES OF EXTIRPATION

Understanding the factors that led to the extirpation of the SBWBNU from the South Puget Sound is an essential step in evaluating the feasibility of reestablishing the species through reintroduction. Only in those situations where the factors that likely contributed to the extirpation have been abated or removed should reintroductions be attempted (IUCN 1995).

Although rarely are specific causes of extirpations easily determined, we use information regarding the chronology of landscape change and historical accounts of SBWBNU in the South Puget Sound along with information on the species ecology and population biology to identify the primary factors that likely played a significant role in the loss of this species from the South Puget Sound.

Habitat Loss and Degradation

The most obvious factor likely related to the disappearance of the SBWBNU from the South Puget Sound is the loss and degradation of oak habitats. Prior to Euro-American settlement (~1850s), over 40% of the South Puget Sound contained a mix of oak savanna and open woodlands, wetland oak, and riparian oak habitats (Hanna and Dunn 1996). Oak habitats were interspersed along with grasslands, conifer savanna, and forested and non-forested wetlands, forming a mosaic of open habitats throughout the region (Chappel and Crawford 1996). These open habitats were maintained by frequent fires, typically applied by Native Americans (Van Perdue 1996), and oak habitats were mostly found along ecotones with grassland or conifer and wetland forest.

Beginning in the 1850's, when the U.S. Government began giving land to settlers, the extent and structure of oak habitats in the South Puget Sound landscape began to change drastically. As the region's population increased, oak habitats were eliminated by residential and commercial development and agriculture. This pattern continued unabated until recently, when the advent of concerted conservation efforts towards oak and prairie habitats began to slow the decline. Today, less than half of the original extent of oak habitats in the South Puget Sound is still present (Hanna and Dunn 1996). Remaining oak habitats are primarily riparian or wetland oak; the majority of open oak savanna and open woodland habitats, the favored habitat of SBWBNU, have been lost (Hanna and Dunn 1996).

In addition to the loss of habitat, the degradation of oak habitats in the South Puget Sound has likely contributed to the extirpation of the SBWBNU. Habitat degradation has occurred primarily through Douglas-fir invasion, which has been mediated by reduced fire frequency and structural changes in the understory vegetation due to colonization of invasive species (Chappel and Crawford 1996). Fire suppression of oak habitats began in the 1850's when settlers began occupying Native American lands, and the frequent fires that Native Americans purposefully set became rare. This change in the fire regime has altered the composition and structure of oak habitats by promoting a shift from oak-dominated forests to those co-dominated or dominated by Douglas-fir. This shift is especially detrimental to SBWBNUs, which generally avoid forests with significant amounts of Douglas fir (Viste-Sparkman 2005). The lack of fire has also reduced the suitability of many remaining oak woodlands by favoring a shift towards stands characterized by a high density of young trees with few branches. Furthermore, remaining oak woodlands are also threatened by a lack of recruitment of young oaks due to dense monocultures of invasive understory plants such as Scotch broom (*Cytisus scoparius*).

Cavity Availability

The disappearance of large oak trees likely played a particularly significant role in the extirpation of SBWBNU from the South Puget Sound. Large oak trees provide significantly more cavities than smaller oak trees (Gumtow-Farrier 1991), and thus are a critical resource for an obligate cavity-nesting species. The availability of numerous cavities across the landscape would have reduced nest-site conflicts with other cavity-nesters and provided SBWNU with the opportunity to select cavities of high-quality. The importance of large oak trees has been recognized since at least the early 1900s, when Bowles (1929) suggested that SBWBNU declines he observed in Pierce County were related to the death of the largest oaks in the area (although he didn’t expand on the cause of death of the trees). Given anecdotal reports such as Bowles (1929), and given a century of continuously expanding human population centers, the availability of large oak trees has likely been a limiting factor to SBWBNU populations for at least the past century in the South Puget Sound. Concomitant declines of at least two other cavity-nesting species that utilize oak habitats, the Western Bluebird (*Sialia mexicana*) and Lewis' Woodpecker (*Melanerpes lewsii*), also suggests that there were a limited supply of cavities and potential cavity sites.

Competition for nest sites with European Starlings (*Sturnus vulgaris*), a cavity-nester introduced to North America in 1890, has also been suggested as a factor in the extirpation of the SBWBNU in the South Puget Sound (Chappel 2005). Starlings are aggressive competitors for nest holes, often usurping them from other cavity-nesters in situations where nest sites are limited (Weitzel 1988). In the Willamette Valley, starlings were observed occupying several SBWBNU cavities several weeks after adults were observed nest-building (Viste-Sparkman 2005). However, even though starlings can affect the breeding success of local populations of cavity nesters (Ingold 1994, 1996), there is little evidence that starlings have contributed to the decline of any native cavity-nesting birds (Koenig 1997).

We believe there are at least two factors that indicate starlings likely played only a secondary and minor role in the decline of SBWBNU. First, the arrival of the starling to South Puget Sound in the mid 1900’s (Wahl et al. 2005) occurred after SBWBNU declines were noted. Thus, starlings would have only played a role in the decline of SBWBNU as their populations became small and vulnerable to demographic effects. Secondly, although starlings are abundant in the agricultural landscape of the Willamette Valley and in western Washington, they appear to be less common in forested settings, especially those around the South Puget Sound. We observed few starlings on field trips to potential reintroduction sites in the South Puget Sound.

Food Availability

A reduction in the availability of acorns, a possible overwintering food source, due to the decline of oak woodlands also has been suggested as a potential factor contributing to the decline and extirpation of SBWBNU (Chappel 2005). In some parts of the White-breasted Nuthatch's range, acorns appear to be an important winter food source (Ehrlich et al. 1988, Pravosudov and Grubb 1993). However, as described earlier, acorns are not known from the diet of SBWBNU, nor have individuals been observed foraging on acorns in western Washington or Oregon (Anderson 1972, Viste-Sparkman BA, *pers. comm*.). Based on this evidence, we believe it is unlikely that the lack of acorns as an overwintering food resource was a factor in their decline.

Similarly, the loss of large oak trees may have impacted the SBWBNU through changes in their primary food source, invertebrates. By virtue of their greater surface area, larger oak trees support more invertebrate biomass than smaller trees (Jackson 1979). However, this explanation as a factor in the decline and extirpation of SBWBNU seems unlikely for two reasons. First, two other oak–associated bird species, Western Bluebird (near-extirpated) and Lewis's Woodpecker (extirpated), both of which have completely different prey bases and foraging modes, have also undergone steep declines. The common theme for all three of the species would have been the same as described above: steep reductions in the area of oak woodland and savannah; degradation of remaining patches, including conditions that resulted in a decrease in cavity availability; and effects associated with small populations (see below).

Secondly, other oak-associated species with similar foraging niches as SBWBNU, such as Black-capped Chickadee and House Wren, did not decline to any significant degree during the same time period.

Effects Associated With Small Populations

As habitat loss and degradation decreased SBWBNU population size and isolated populations, SBWBNUs became vulnerable to the suite of negative effects associated with small populations (i.e., genetic drift, demographic and environmental stochasticity). Small and isolated populations often exhibit reduced genetic variability (e.g., Westemeier et al. 1998). Reduced genetic variability can lead to increased homozygosity, which eventually results in fitness declines due to inbreeding depression, and can limit the ability of populations to adapt to environmental change (Mills and Tallmon 1999, Keller and Waller 2002). Population growth rate of small populations is especially sensitive to demographic stochasticity, and small populations are vulnerable to catastrophic incidents such as severe storms. Eventually, populations can become so small and isolated that individuals have difficulty locating conspecifics (allee effect), with obvious consequences for reproduction. Given the history of habitat loss and habitat fragmentation, and the sedentary nature of SBWBNU, all of these factors have likely played some role in the extirpation of SBWBNU from the South Puget Sound region.

Conclusions

We believe the primary cause of the decline and extirpation of the SBWBNU in South Puget Sound is almost certainly the loss and degradation of oak habitat. As oak woodlands and savannahs became smaller and more isolated, so too did the SBWBNU populations that depended on them for habitat. In addition, many of the remaining oak woodlands have suffered from the invasion of conifers, the spread of non-native understory species, and a lack of oak recruitment. These changes, in combination with the continued loss of large oak trees to age and logging, have resulted in diminished habitat quality for SBWBNU, including a reduction in the availability of cavities for nesting. Finally, as populations became smaller and more isolated, the deterministic effects of habitat loss and degradation combined with the stochastic processes of small populations to eliminate the SBWBNU from the South Puget Sound

ADDRESSING THE CAUSES OF EXTIRPATION

Oak Habitat Loss and Degradation

In recent years, there has been a considerable emphasis on oak habitat conservation in the Puget Lowlands, most notably in the South Puget Sound. Much of this has been coordinated under the auspicies of the South Puget Sound Prairie Landscape Working Group. Among state agencies, oak woodlands have been accorded special status as a ‘priority habitat’ by the Washington Department of Fish and Wildlife, and oak-dominated community types have been designated as ‘Priority 1’ for conservation by the Washington Natural Heritage Program (GBA Forestry 2002). Although development continues to result in some habitat loss, prairie-oak habitats are increasingly receiving protection for conservation purposes. Several relatively secure areas exist in which to consider long-term conservation of this ecosystem, including the reintroduction of SBWBNU. In addition, many state land management agencies and nonprofit conservation organizations are actively engaged in projects to restore oak habitats, with additional areas targeted for restoration efforts for the foreseeable future (Table 7). As degraded areas are restored and previously disturbed oak woodlands mature, habitat conditions for SBWBNU should continue to improve. In particular, we expect cavity availability to increase. In those situations where cavity availability is currently not high enough to support SBWBNU, nestboxes, which this species readily uses, can be used as short-term habitat augmentation until forests mature.

Effects associated with small populations

Successful reintroduction requires establishing populations large enough to counteract the stochastic processes that can plague small populations. We evaluate this issue below in Habitat Assessment. Genetic viability of a founder population should be addressed as part of the reintroduction process by translocating birds from multiple, large populations. Post-release monitoring should be used to determine whether reintroduced populations are exhibiting effects associated with small populations (IUCN 1995, Slater 2004).

Conclusions

SBWBNU were most likely extirpated from the South Puget Sound Region due to habitat loss and habitat degradation. Although much of the lost habitat is irreplaceable, land protection and conservation easements have slowed the decline. Several large tracts of oak woodland are now protected from future development. In addition, ongoing restoration efforts in existing oak woodlands have improved habitat quality for SBWBNU. The trend towards protecting and restoring remnant oak woodlands is projected to continue into the future, which will yield further increases in the amount and quality of habitat available for a reintroduced population of SBWBNU. Consequently, we agree that considering reintroductions of SBWNU, as addressed in this assessment, is both appropriate and timely.

HABITAT ASSESSMENT OF POTENTIAL RESTORATION SITES

Determining if sufficient habitat exists to support a self-sustaining population is an essential element of a feasibility assessment for a species reintroduction (IUCN 1995). We performed a habitat assessment for the SBWBNU in the South Puget Sound region using a multistep approach. At the first step, we identified potential reintroduction sites within the historic range of SBWBNU in the South Puget Sound by using information obtained through expert opinion and field visits, assessments of land ownership (e.g., ease of access, management); assessments of the amount, quality, and availability of oak habitats; and the degree of conservation activity (completed, ongoing, and proposed). In the second step, we estimated the amount of potential oak habitat available to nuthatches in each candidate site selected in Step 1 by analyzing vegetation data with Geographic Information System (GIS) software. This information, in turn, allowed us to predict the number of individuals (or breeding territories) that candidate sites could support. Finally, we constructed a set of population models, using data from field studies in Oregon, published literature, and our best knowledge, to evaluate the likelihood a reintroduced population could be established and remain viable.

Site identification

Expert opinion on potential reintroduction sites was garnered from personnel associated with a broad spectrum of governmental agencies and conservation organizations during two initial meetings and subsequent conversations and site visits. Participating organizations included: WDFW, Washington Department of Natural Resources, Washington Natural Heritage Program, United States Department of Defense (USDOD), U.S. Fish and Wildlife Service, The Nature Conservancy (TNC), and Oregon State University.

Initially, we recognized five potential reintroduction areas that had substantial oak habitat and historical nuthatch records: Fort Lewis Military Reservation (managed by USDOD), Scatter Creek Wildlife Area (WDFW) and Scatter Creek drainage, Glacial Heritage Preserve (Thurston County and TNC) and Black Creek drainage, the Lakewood area in southern Tacoma, and the Chehalis/Centralia region. All but two of the areas consist of one or more protected sites and their adjacent lands. It was necessary to identify sites in this way because oak habitats are patchy across the landscape and most conservation lands, alone, are likely inadequate to support a nuthatch population. Using sites visits, expert opinion, and data associated with the sites, we further evaluated each site based on (1) the amount and quality of habitat in each area; (2) the degree to which lands were protected from future development; (3) the ease with which sites could be accessed; and (4) the past, current, and projected future amount of oak restoration and management ongoing within each area. Karen Viste-Sparkman, who completed her master's thesis on the reproduction ecology and habitat use of SBWBNU in oak habitats in the Willamette Valley, participated in site visits. Karen provided expert opinion on whether the habitat features believed to be associated with nuthatches were present. The agency and organization biologists provided in-depth information on current oak management activities.

Our analysis indicated that only Fort Lewis Military Reservation and the Scatter Creek drainage provided protected oak habitats in sufficient quantity and quality to establish SBWBNU's and allow for population growth. Both of these sites are targeted for future conservation and management actions designed to improve the quality of oak habitat, and both allow relatively easy access to monitor reintroduced populations.

The following are summary assessments for all five sites in the order in which they were ranked.

<u>1) Fort Lewis Military Reservation.</u>

The Fort Lewis military base is a 39,000 ha U.S. Army installation centered in the core of the South Puget Sound Prairie region between Tacoma and Olympia. Fort Lewis has recognized the importance of maintaining natural ecosystems on its lands (Dunn and Ewing 1997) for both its primary mission to provide military training grounds for U.S. troops and for conservation and sustainability of biodiversity and functioning natural ecosystems.

Land ownership. This is the only proposed reintroduction area owned and managed by a single agency, USDOD, an ideal attribute for initiating a reintroduction program. TNC and Washington State agencies are also significant management partners of oak prairie habitats at Fort Lewis. Access to the majority of the military reservation is allowed either by virtue of being open to the public (about 50% of the lands are open for a variety of recreational activities) or through access granted for research purposes.

Habitat quality. The quality of oak habitat is variable across the reservation from apparently suitable habitat with relatively large oak trees to forest patches with younger oaks, which would require providing supplemental nest sites. In many areas, oak habitats are heavily invaded by Douglas-fir. However, restoration of oak habitats is a priority of the wildlife management division (J. Lynch, pers. comm.) and given the degree of current and projected management the amount and quality of oak habitats will increase (see below). Moreover, Fort Lewis contains the largest area of naturally occurring ponderosa pine (*Pinus ponderosa*; ~ 775 ha) west of the Cascades (Foster 1996). SBWBNU were a common resident in these habitats as recently as the late 1960's (Ken Brunner, pers. comm.), providing a secondary habitat for nuthatches in an already habitat-rich site.

Degree of conservation activity. Restoration and management activities in the prairie, oak, and pine habitats of Fort Lewis have been significant (Table 7), continue to be a primary objective of both wildlife and forestry divisions at Fort Lewis, and serve as a model for other sites throughout the South Puget Sound region. Restoration of oak and pine habitats occurs both directly and indirectly. Direct restoration actions include logging, exotic plant removal, or prescribed fire to create habitat conditions for a suite of oak- and pine-obligate species (e.g., Western Gray Squirrel (*Sciurus griseus griseus*). One example is the removal of Douglas-fir from 186 ha of oak habitats on south Weir Prairie, which will be completed over the next two years. Recently, the SBWBNU was listed as a target species in the Fort Lewis management plan enabling biologists to direct management actions for this species (J. Lynch pers. comm. [or cite management plan]). Management also occurs indirectly through Fort Lewis's forestry division, which always consider opportunities for oak and pine release as part of each timber management plan (J. Lynch, pers. comm.).

<u>2) Scatter Creek Drainage.</u>

Scatter Creek drainage is located approximately 35 km southwest of Fort Lewis Military Reservation. Scatter Creek is a tributary of the Chehalis River.

Land ownership. This potential reintroduction area along Scatter Creek and its associated uplands includes a variety of oak habitats under public and private ownership. The largest areas protected from future development are the South and North Scatter Creek Wildlife Management units. TNC has also invested heavily in this area, working with private landowners to develop conservation easements in oak/prairie habitats.

Habitat quality. There are substantial areas of oak habitats found along the riparian areas of Scatter Creek, with lesser amounts in the praire/oak upland areas. Based on our field visits, much of the riparian and upland oak habitat at the South Scatter Creek Wildlife Management area appeared suitable for nuthatches, as did several large patches of riparian oak on private lands nearby. However, many areas are heavily invaded by Douglas-fir.

Degree of conservation activity. There is significant restoration and management of oak habitats ongoing in this area, which is the primary reason that it can be considered a reintroduction site. At the Scatter Creek Wildlife Management Units, Douglas-fir has been, and is proposed to be, removed or topped from oak habitats to release oaks and provide snags for foraging and nesting by cavity-nesting birds. Consideration is being made to purchase land between the north and south units to create a larger and connected conservation area. Management in this area will also be directed towards the Western Gray Squirrel, a state threatened species (M. Linders, pers. comm.), which in many cases will benefit SBWBNU. TNC is also working with landowners in this area to promote the management and conservation of oak habitats. The primary example is a recently acquired conservation easement on the Cavness property, which contains approximately 50 ha of riparian oak habitat. Although Douglas-fir has invaded the majority of this site, logging plans are being developed to remove this species (E. Delvin, pers. comm.).

3) Glacial Heritage and Black Creek Drainage.

Like the Scatter Creek drainage much of the oak habitat in this area is riparian, but there is substantially less of it compared to Scatter Creek. Black Creek lies just north of Scatter Creek (Glacial Heritage is less than 3.5 km from the WDFW Scatter Creek Wildlife Area), and thus could serve as a satellite area for a reintroduction to Scatter Creek. Black Creek also drains into the Chehalis River.

Land ownership. This area contains a 445 ha county park, Glacial Heritage, that is managed by TNC as the centerpiece for their prairie/oak habitat conservation actions in Thurston County. Remaining lands are mostly private. TNC is also working with private landowners in this area to protect and restore oak/prairie habitats, mostly through conservation easements and education.

Habitat quality. Glacial Heritage contains approximately 70 ha of riparian oak along Black Creek (E. Delvin, pers. comm.), some of which appears suitable for SBWBNU's, whereas other portions remain heavily degraded by conifer invasion. Areas invaded by conifers will be targeted for restoration over the next several years, providing suitable habitat for SBWBNUs in the future. Across much of the upland areas on private lands, scattered oak patches, many of which contain large trees represent suitable habitat for nuthatches. There are also stands of oak just east of Oakville that may be suitable for nuthatches (C. Chappell, pers. comm.); however, we were unable to visit these sites.

Degree of conservation activity. There has been, and will continue to be, significant conservation efforts aimed at restoring oak habitats at Glacial Heritage (E. Delvin, pers. comm.). In addition, TNC is working with private landowners to protect and manage oak habitats. We do not know of other conservation activities that are ongoing in this area.

4) Chehalis/Centralia region

The Chehalis/Centralia area sits at the southernmost fringe of oak habitats of South Puget Sound area, and appears to be outside the core of its historical abundance. This area contains the fewest historical records of nuthatches, and thus it is an unlikely choice to initiate a reintroduction. Because of its improbable status as a reintroduction site, we did not conduct a field visit to this area.

Land ownership. Land ownership is primarily private.

Habitat quality. We did not visit oak habitats in this area. However, oak stands, some of which are reported to be fairly large, can be found near Cowlitz Prairie, and SBWBNU have been sighted in this area (C. Chappel, pers. comm.).

Degree of conservation activity. No known conservation activities area ongoing in this area.

5) Lakewood, Tacoma.

Although this is the last known site where nuthatches bred in the South Puget Sound region, there appears to be less opportunity for this location to serve as a reintroduction area due to significant urbanization, lack of protected status for oak habitats, and few opportunities to restore habitat.

Land ownership. Ownership is almost completely private with dense residential housing and business developments. Several small parks, including the 36 ha South Puget Wildlife Management Area managed by WDFW, are located in this area.

Habitat quality. We visited the Flett Creek site where nuthatches last nested in the South Puget Sound. The site was characterized by open oak stands with trees large enough to support nuthatches. However, the site was small and embedded in urban habitats. Scattered large oaks were found in many subdivisions and private residences. Although the presence of urban areas is not detrimental to nuthatches, the limited habitat and lack of protection for the majority of oaks within this area, preclude this site as a primary reintroduction area

Degree of conservation activity. Oak planting restoration activities are ongoing at South Puget Sound Wildlife area (Table 7).

Habitat Analysis

The second objective of our habitat assessment was to estimate the amount of habitat potentially suitable to SBWBNUs at the two sites identified as possible reintroduction sites in the prior step, Fort Lewis Military Reservation and the Scatter Creek drainage (Figure 2). Because we lack adequate information on habitat quality across sites, we do not attempt to determine the specific amount of habitat currently suitable for nuthatches. Instead, we estimate the amount of potentially suitable habitat based on aspects of the size and configuration of habitat patches in relation to nuthatch use. Potential habitat is thus defined as the amount of habitat currently suitable for nuthatches plus the amount of habitat that could serve as suitable habitat either through forest maturation and/or habitat restoration. We use this information to predict the number of nuthatches that each area could support based on estimates of SBWBNU territory size, and we use this estimate as a measure of carrying capacity in our preliminary population models. Finally, although we are unable to determine the exact amount of area presently suitable for nuthatches in each site, we derive coarse estimates of currently suitable habitat based on our field visits, data from vegetation layers and other data sources, and knowledge of the species' ecology. We discuss how we expect the amount of suitable habitat to increase based on the amount of management and restoration directed at those habitats that SBWNBU utilize.

Methodology

All spatial analyses were performed with tools in ArcMap (ArcView 8.3, ESRI, Redlands, CA). To determine the amount of oak habitat available for nuthatches, we used the vegetation map of oak and prairie habitats in the Puget Lowland and Willamette Ecoregions of Washington State created by the Natural Heritage Program of the Washington State Department of Natural Resources (Chappell et al. 2003). This dataset provides the most recent and most complete oak habitat coverage for the South Puget Sound, outlining the extent of four oak cover types: oak-dominant forest or woodland canopy, oak-conifer forest or woodland canopy, scattered oak canopy, and urban oak canopy (Chappell et al. 2003). Oak-dominant forest includes habitats with > 25% crown cover of oaks and <25% crown cover of conifers in the main and upper canopy layers; broadleaf trees (e.g. ash, maple, madrone) other than oak may be co-dominant with oak. Oak-conifer forest is comprised of a mixed main and upper canopy layer of oak and conifer, with each contributing > 25% crown cover. Scattered oak canopy is described as 5-25% total tree cover, of which over 50% is oak, and urban oak is urban habitats with a minimum of 10% crown cover of oak. For the Fort Lewis Military Installation, we used data from Foster (1996), to provide estimates of the extent of ponderosa pine.

We obtained a boundary layer for the Fort Lewis Military Reservation from USDOD and created a boundary layer for the Scatter Creek area, which included the riparian corridor from near the junction of Scatter Creek and the Chehalis River, east to Rock Prairie just south of Tenino (Figure 2). These boundaries served as the extent of our study areas. For the first step, we determined the total amount of oak and pine habitat within each study area (i.e., the amount of available habitat; Table 8). Fort Lewis contains 1641 ha and 775 ha of oak and pine habitat, respectively, while the Scatter Creek area contained 538 ha of oak habitat (Table 8). For both sites, the majority of oak habitat was oak-conifer forest and oak-dominant forest, with neither site having significant amounts of scattered or urban oak canopy.

In the next step, we determined the amount of potentially suitable habitat for SBWBNUs. In the South Puget Sound, the majority of oak habitats across the landscape occur as discrete patches. In many cases, these patches may be too small or too isolated for nuthatches to utilize. We incorporated these patterns using the following approach to derive the amount of potentially suitable oak habitat for SBWBNU's. First, we selected all oak habitat patches ≥ 5 ha in size. We used a 5 ha habitat patch as a starting point because it is a compromise between the area needed for a territory (~10 ha) and the fact that in some locations multiple small patches of oaks were close enough and large enough for a nuthatch to use, but would not be selected under our 5 ha criteria. We were not concerned with removing isolated patches of oak because in both of our study areas few patches were isolated by greater than 2 km. Next, we selected all oak patches that were within 150 m of the ≥ 5 ha patches selected in the prior step because we assume that nuthatches, once present, will move among patches in proximity to each other, regardless of size. In the Willamette Valley oak habitats, SBWBNU territory size was 7.1 ha, although many nuthatch territories were found in patches smaller than 5 ha (Viste-Sparkman 2005). Consequently, we believe we are taking a conservative approach to estimating potential habitat. Based on her experience studying SBWBNUs in Oregon, Viste-Sparkman (pers. comm.) considered our approach reasonable.

Results and discussion

The analysis identified 1131 ha (69% of 1641 ha) of potentially suitable oak habitat in Fort Lewis, the majority of which is presently characterized as oak-conifer forest (783 ha), followed by oak-dominant forest (249 ha), and urban oak (80 ha; Table 8). The amount of ponderosa pine forest in Fort Lewis that we considered to be potential habitat for SBWBNU is the 500 ha tract of forest in the center of the northern part of Fort Lewis (the Eastgate/B-N forest; Foster 1996). We included this forest because it is the only tract targeted for restoration. Currently, this forest includes about 180 ha of forest with a dense overstory dominated by Douglas-fir (currently unsuitable) and 320 ha of open pine forest in various conditions. The restoration target for this tract is a mixture of pine savanna and open pine/Doug-fir forest (Foster 1996). We believe the majority of pine savanna and some of the pine/Douglas-fir forest would provide suitable habitat for nuthatches. In the Scatter Creek site, our analysis resulted in 478 ha (89% of 538 ha) of oak habitat being classified as potential nuthatch habitat (Table 8). In Scatter Creek, the amount of oak-conifer and oak-dominant forest was nearly identical, 237 and 209 ha, respectively.

Using these estimates as the amount of potentially suitable habitat for nuthatches, we determined the number of nuthatch territories that each site could support. Although nuthatch territory sizes in eastern locations of North America appear to be fairly large, ranging from 10-20 ha (Pravosudov and Grubb 1993), estimates from oak habitats in the Willamette Valley are smaller (7.1 ha; Viste-Sparkman 2005). Nevertheless, we used a conservative estimate of 10 ha/nuthatch territory to estimate the potential carrying capacity of each site. We consider the conservative approach appropriate, as these oak woodlands, which are near the northernmost extent of their range and on relatively unproductive soils, may provide lower quality habitat for SBWBNU than oak woodlands found further south. Overall, we estimate that Fort Lewis could support approximately 163 territories (326 individuals), while Scatter Creek could support 47 territories (94 individuals).

We believe the stepwise process that we have followed results in a conservative yet reasonable estimate of the number of nuthatches that each site could support. Based on our field visits and data from the oak vegetation layers, we believe substantial areas of habitat are presently suitable for nuthatches, particularly at Fort Lewis Military Reservation. Many of the oak habitats at Fort Lewis that we visited appeared suitable for nuthatches based on habitat characteristics associated with nuthatches in the Willamette Valley (Viste-Sparkman, pers. comm.). Most notable were the large patches of oak in the center of the installation near the Vietnam Village area. According to the vegetation coverage data, approximately 300 ha of oak habitat have <25% conifer in the main and upper canopy, of which the majority should be currently suitable for nuthatches. In addition, Fort Lewis has approximately 200 ha of open pine habitat that is likely suitable for nuthatches. In Scatter Creek > 230 ha of oak habitat has <25%

conifer in the main and upper canopy, of which the majority should be suitable for nuthatches (Table 8).

Conservation efforts toward nuthatch habitats

Estimating changes in the amount of suitable habitat change over time is as important as estimating the amount of currently suitable habitat. Suitable habitat may increase due to restoration efforts taking place in the region, particularly if they are directed towards protected lands. Alternatively, habitat may be lost to development or other land-use changes. When a comprehensive conservation effort is in place, such as in the oak/prairie habitats of South Puget Sound, it may be useful to initiate a reintroduction program earlier in the timeline, because of the time lag in establishing a population and allowing for its growth. For example, in the reintroduction of Brown-headed Nuthatches to pine forests in the southern Florida, it has taken eight years from the start of translocations for the population size to reach approximately 80 breeding adults (i.e., 30 territories; Slater 2005). In addition, the reintroduction process itself can benefit habitat conservation efforts due to the interest and enthusiasm generated by returning a species to the wild.

Given the number of conservation and restoration actions directed at oak habitats in the South Puget Sound region, we expect the amount of suitable habitat for nuthatches to increase substantially in the future (Table 7). This is especially true for the Fort Lewis area, which, due to its large size and single ownership, provides the ideal conditions for landscape restoration. For example, the 160 ha of oak habitat on the South Weir Prairie that is scheduled to be treated through fir removal over the next two years would likely provide an area suitable for 16 nuthatch territories. Substantial restoration efforts have also been conducted on other lands in the region, particularly by TNC, and that trend is expected to continue. Overall, in the last 5 years, 834 ha of oak woodland have been treated to restore conditions characteristic of oak-prairie habitats, and that number is expected to double over the next 5 years (Table 7). Although not a significant landholder in the South Puget Sound region, WDFW also is concentrating much of its management towards oak-prairie habitat, particularly as it relates to the recovery efforts for the Western Gray Squirrel. Although the Western Gray Squirrel is not an oak-obligate like the nuthatch, preferring oak-conifer transitional communities (Ryan and Carey 1995a, 1995b), some restoration actions for this species should benefit the nuthatch.

Preliminary population models

As a final step of the habitat assessment, we simulated a reintroduced SBWBNU population and evaluated its population dynamics using population-modeling software. Population models are important for understanding population persistence and the effects of management actions (Reed et al. 2002). As such, simulation models can also be useful to assess the likelihood of success for a species reintroduction. We performed this exercise based on a proposed SBWBNU reintroduction to Fort Lewis, as this site was identified as the best choice to initiate a reintroduction program.

To perform this analysis we used Program Vortex, Version 9.57 (Lacy et al. 2005, Miller and Lacy 2005), which is an individual-based simulation model for population dynamics. Vortex is capable of incorporating demographic, environmental, catastrophic, or genetic variation and allows the user to track population behavior over time, providing estimates of population size, population growth rates, and extinction probabilities. This simulation allows us to model a variety of biological and management scenarios and resulting nuthatch population behavior using information on age of reproduction, mean birth and age-specific death rates, and sex ratio. When possible we used data from the Willamette Valley, which is the closest and most similar population, in terms of habitat use, to the extirpated South Puget Sound population; when data were absent from the region, we used data from other locations reported in the literature. In some cases, reliable data were not available, such as for adult and juvenile mortality, and in those situations we used our best professional knowledge and data from the literature for similar species.

We constructed eight population models using data (and error estimates where necessary) on reproduction, survival, carrying capacity, and management scenarios (rate of translocation) (Table 9). For breeding parameters, we assumed that age of first reproduction occurred in the first year for females (Pravosudov and Grubb 1993). We input nesting success estimates of 70% and 75% based on estimates from the Willamette Valley for only those nests in oak trees and in all nests (including nestboxes), respectively (Viste-Sparkman 2005). Viste-Sparkman (unpub. data) found mean productivity (SE) was 4.90 ($\pm$ 0.23) for successful females and we used that value in our models.

Adult and juvenile mortality rates for White-breasted Nuthatches represent some of the weakest components of the population models. Karr et al. (1990) found White-breasted Nuthatch adult survival (SE) was 0.35 ($\pm$ 0.1), but this was based on only 39 captures of 32 individuals. Because of the low sample size and an intuitively low adult survival estimate, we decided not to use these data. Instead, we based our survival estimates on an ecologically similar species (based on mass and nesting habits), the Black-Capped Chickadee, for which adult mortality in the Pacific Northwest region has been estimated using transient models of survival from data collected by the Institute for Bird Populations (IBP) and their network of banding stations. Michel et al. (2005) found a mean adult mortality of 0.54 for chickadees in the northwest from the period 1992-2001. We also included two lower rates of mortality, 50 and 45 percent because we again felt that the IBP mortality estimate was high. In the northeast, Loery et al. (1997) found a mean adult mortality of 0.38 during a 35-year study of Black-capped Chickadees, which is much lower than the estimates we used in our models. In all of our population models, we assumed juvenile mortality was higher than adult mortality and used either 65 or 70 percent mortality. We created three combinations of adult and juvenile survival estimates representing a low, moderate, and high rate of survival and compared these between the two rates of nesting success. The longest lived individual reported for this species is over 9 years, and we used that number as the maximum age of reproduction (Klimkiewicz et al. 1983).

We lacked any information on the impacts of inbreeding on the survival of nuthatches, or the consequences of catastrophic events, thus we did not include genetic or catastrophic variation in the models. We do not expect genetic variation to be an important issue for a reintroduction of SBWBNU because founder birds would be translocated from large populations where heterozygosity is presumably high (see Source Populations). Catastrophes that might occur in the Pacific Northwest and that might have a population-level effect include extended freezes, possibly reducing food availability or hindering the species ability of thermoregulate, or a catastrophic fire. Although we have no information on which to model these scenarios, we acknowledge that they could influence the outcome of any population model.

Finally, for all the models we began the simulation with an initial population size of zero. We supplemented the population with six females and six males per year for four years. This level of supplementation is calculated from a proposed translocation rate of 20 adults per year with 60% (12 individuals) successfully establishing territories. In south Florida, 60% of released Brown-headed Nuthatches established territories Slater (2002). For two models, we supplemented the population for 5 years to evaluate the effect of a longer translocation period using the intermediate level of survival values and each nesting success estimate. We set the carrying capacity at 326 individuals (e.g., 163 territories), our estimate of the number of nuthatches that Fort Lewis could support. For each scenario we ran 1000 simulations for a period of 100 years.

We found a wide variety of model outcomes (Table 10, Figure 3, 4.). Except for Model 1, which included the combination of low nesting success (70%) and high mortality rates (54%, 70%, all of our models had increasing population trends. The majority of model scenarios indicated the probability of extinction was low and resulted in large population sizes, suggesting that the Fort Lewis site is capable of supporting a SBWBNU population. Our results indicated that the most sensitive vital rate was mortality. When mortality values were set at the lowest levels (54% adult mortality, 70% juvenile mortality) the probability of extinction was 99 and 87 percent with breeding success set at 70 and 75%, respectively (Models 1 and 4). However, a 5% reduction in mortality for each age group reduced the probability of extinction to 8 and 1% (Model 2 and 5) with mean population sizes of >250 individuals. Mortality rates are one of the weakest components of our constructed models due to the lack of empirical data for nuthatches. However, we believe our mortality estimates are fairly conservative. The only other known mortality estimate for nuthatches in North America, based on color-banded individuals, comes from south Florida, where Brown-headed Nuthatches had apparent mortality of 30% in a reintroduced population and 50% in a high-quality reference population (Slater 2004). Both these estimates are lower than our highest mortality values in our simulated models.

In contrast, the effect of increasing breeding success was not as substantial as varying mortality, but mean population size over time was slightly higher for models with higher breeding estimates and fewer simulated populations went extinct. We believe that our breeding success estimates were our most reliable data input into the models as it came from a nearby population and data were collected recently.

Increasing the number of years that translocations were conducted did not appear to influence population persistence. From a management standpoint, the results are favorable because it means a shorter, less costly, reintroduction period could be proposed.

In general, the population modeling suggests that, at least for the Fort Lewis site, a self-sustaining SBWBNU population could be achieved via reintroduction. However, caution is warranted as the population models were constructed without empirical estimates of juvenile or adult survival, which are not available, and did not consider the potential impact of unpredictable, catastrophic events. At the same time, reproduction and survival rates can be higher in a reintroduced population due to the absence of density-dependent factors. Indeed, estimates of both fecundity and adult survival were significantly higher in a reintroduced population of Brown-headed Nuthatches in south Florida compared to a high-quality reference population (Slater 2001, 2004). Thus, our models likely represent a reasonable middle ground between overly optimistic and overly pessimistic projections of potential population growth.

LOCATION AND STATUS OF DONOR POPULATIONS

We considered several factors in our evaluation of potential donor populations: proximity, population size, and conservation status. Proximity of donor populations is important because nearby populations are expected to be genetically similar to the extirpated population. The size of the donor population provides a heuristic measure of genetic variation within the population, and is also important to ensure that birds can be removed from the population without threatening the existing population. Finally, the trajectory of the donor population size has been found to be important in reintroductions (Griffith et al. 1989). Reintroductions that translocated birds from stable or increasing populations were more successful that those using birds from declining populations (Griffith et al. 1989).

Based on these considerations, we have identified three areas that could serve as donor populations: (1) the mid-Willamette Valley near Corvallis and Dallas, OR, (2) the Umpqua Valley near Roseburg, OR, and (3) the Rogue Valley near Medford, OR. California populations were not considered in this assessment, as they are too far away to consider in the initial stages of a reintroduction.

The Willamette Valley population is best because of its proximity, which makes it likely to have a greater degree of similarity to the extirpated population. The Willamette Valley population is also most attractive from a logistical standpoint, as it is closer to the proposed reintroduction site. Finally, SBWBNU populations around Corvallis and Dallas appear to be relatively stable (Figure 1). The Umpqua Valley and the Rogue Valley would serve as important secondary sites, insuring that a large number of birds could be translocated within a year. Using these sites would also increase the genetic variability of the founder population.

CONCLUSIONS AND RECOMMENDATIONS

Reintroductions should only be considered if the processes that caused the initial extirpation are no longer operating (IUCN 1995). In the South Puget Sound, habitat loss and degradation of oak habitats was a primary driver of the extirpation of SBWBNUs. The fragmentation of suitable habitat may have also exposed SBWBNUs to the stochastic processes associated with small populations (inbreeding depression, demographic stochasticity, and Allee effect). Although habitat for SBWBNU can never be restored to its original extent, efforts to protect and restore oak and prairie habitats by numerous government agencies and conservation organizations have created a landscape suitable for the re-establishment of SBWBNU. However, because conservation in oak habitats is relatively recent, and thus the majority of oak habitats are second-growth forests that have a limited supply of natural nest cavities, successful establishment of a reintroduced population may require the short-term use of artificial nest boxes. As oak forests mature, the availability of natural cavities will increase.

We identified two potential reintroduction sites, Fort Lewis Military Reservation and the Scatter Creek drainage, that offer the necessary attributes for a successful reintroduction of SBWBNUs to the South Puget Sound region. Historical records indicate that SBWBNUs were common in both sites. Today, both sites provide habitat in sufficient quantity and quality to establish SBWBNU's and allow for population growth, have ongoing conservation efforts directed toward oak habitats, and afford access to monitor a reintroduced population. Fort Lewis is the best choice for a reintroduction because it has the greatest amount of potential habitat for SBWBU (Table 8), and thus the highest potential carrying capacity. Moreover, the area is managed by a single agency, improving the ability to conduct and track the progress of a reintroduction program. Because of its large size and single ownership, Fort Lewis has also served as the centerpiece for oak and prairie habitat restoration and management in the South Puget Sound region, and that is expected to continue into the future (Table 7). If a population of SBWNUs was reestablished to the Fort Lewis area, it would serve as the core population within the South Puget Sound region. The Scatter Creek drainage is nearly connected to the Fort Lewis area, and the reestablishment of nuthatches there could occur through additional translocations or natural colonization.

At least three source populations were identified in Oregon for a SBWBNU reintroduction. The most important is in the Willamette Valley because of its proximity to the South Puget Sound, which insures that individuals most genetically similar to the extirpated population would comprise a portion of the founder population. Although SBWNUs are declining overall in the Willamette Valley, numbers near Corvallis appear stable, and thus any removal of birds should be conducted from this location. Farther south, the Umpqua (Roseburg) and Rogue (Medford) Valleys also have stable to increasing SBWBNU populations and would serve as additional sources of nuthatches.

The reintroduction of SBWNUs to the South Puget Sound oak habitats would follow those techniques used by Slater (2001) in the successful establishment of Brown-headed Nuthatches in southern Florida. In that study, approximately 63% of released individuals established a territory. Slater (2001) found that both soft- and hard-release techniques appeared to work equally well, and the most important factor related to translocation success (i.e., probability of establishing a territory) was the population size of the reintroduced population. Thus, it is critical to translocate a significant number of individuals in the first year of translocations to insure that some are established.

Based on our assessment of existing conditions and the results of population modeling, we believe that a reintroduction program for SBWBNU in the South Puget Sound region is biologically feasible. The reintroduction would build upon existing conservation efforts directed at the restoration of oak woodlands, and would likely benefit existing efforts by generating increased public interest in the management of oak woodlands and prairies. Indeed, the successful reintroduction of SBWBNU to oak habitat would serve as a measure of the progress made in the restoration and management of oak woodlands. We recommend designing funding strategies to initiate a SBWBNU reintroduction program.

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Table 1. Morphological and plumage characteristics of *S. c. aculeata* and *S. c. tenuissima* (from Aldrich 1944).

Morphological Characteristics	**S.c. aculeata**	**S.c. tenuissima**
Wing length (mm)		
male	84.8 (83-87.5; *n* = 20)	90.5 (88-94; *n* = 22)
female	83.8 (80.5 – 86; *n* = 10)	89.0 (87-93; *n* = 14)
Exposed culmen (mm)		
male	17.8 (16-19)	20.9 (19-22.5)
female	17.1 (16-18)	19.8 (18.5 – 23.5)
Plumage Characteristics		
Under parts	More brownish	Purer white
Back	Paler	Darker
Thighs and under tail-coverts	Lighter chestnut	Darker chestnut

Table 2. Recent breeding sites of SBWBNU in the South Puget Sound (from C Chappel, pers. comm.).

Site	Year	Comments
Flett Dairy/Flett Creek	1995	Two pairs breeding in nest boxes
Seeley Lake area	1994	Status unclear; may be Flett birds
Western State Hospital	1991	
Fort Steilacoom Park	1991	
East side Lake Steilacoom	1991	
New Tacoma Cemetery	1989	Regular in winter; unknown status in summer
North American Lake Park	1980s	Year-round resident
Scatter Creek Wildlife Area	1980	
Ponce de Leon Creek, Lakewood	1970s	

Table 3. Slender-billed White-breasted Nuthatch population trend (percentage change per year) results based on BBS trend data for the period 1966-2004 (From Sauer et al. 2003).

Years	1966-2004			1966-1980			1980-2004		
Location[a]	Trend	*P*[c]	*n*	Trend	*P*	*n*	Trend	*P*	*n*
NPR BCR (l)[b]	-4.3	0.14	36	-0.5	0.88	17	-2.6	0.39	29
SPR PHY (l)	2.3	0.24	26	-3.3	0.57	13	5.1	0.02	20
WIL VAL (l)	-6.4	0.39	8	10.0	0.69	4	-6.8	0.37	6
COCA BCR (h)	3.0	0.00	66	3.8	0.40	42	1.6	0.39	58
LA RAN (l)	1.8	0.50	9	0.8	0.86	8	-1.2	0.76	7
CA FOO (h)	2.2	0.08	53	8.4	0.19	35	1.0	0.57	49
CA (h)	2.2	0.06	117	6.5	0.21	66	1.3	0.47	105

[a] NPR BCR = Northern Pacific Rainforest Bird Conservation Region
SPR = Southern Pacific Rainforests BBS Physiographic Area
WL = Willamette Lowlands BBS Physiographic Area
COCA BCR = Coastal California Bird Conservation Region
LA RAN = Los Angeles Ranges BBS Physiographic Area
CA FOO = California Foothills BBS Physiographic Area
CA = California

[b] Credibility measures based on statistical rigor: (h) = high confidence in the trend; (l) = low confidence in the trend

[c]

Highly significant increasing trend	*P* <0.01
Moderately significant increasing trend	*P* = 0.01-0.05
Significantly increasing trend	*P* = 0.05-0.10

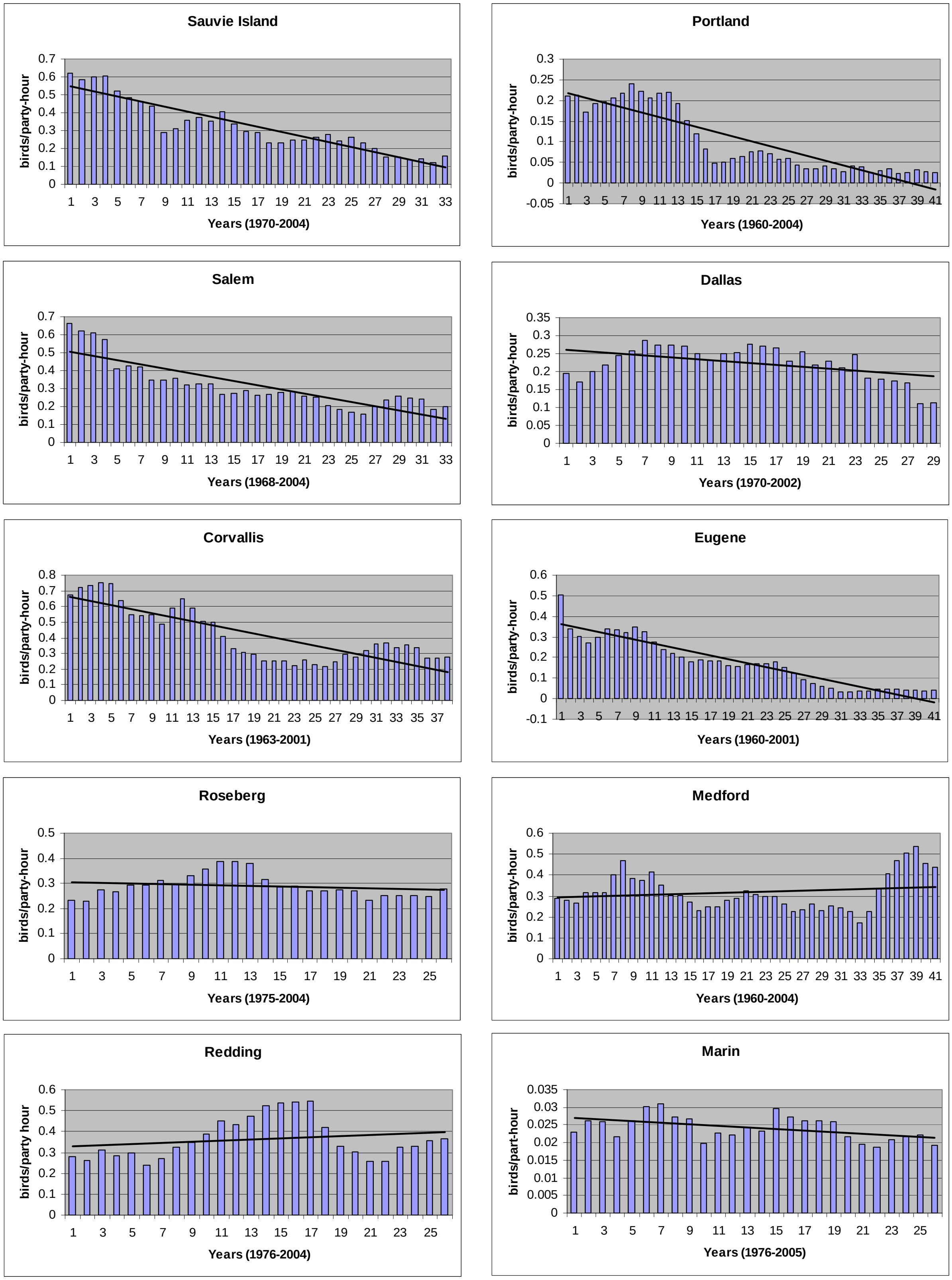

Figure 1. Slender-billed White-breasted Nuthatch population trends from Christmas Bird Count Data for Oregon and California sites. Data are 5-year moving averages (i.e, the number of birds per party-hour for each year is the mean of that year's results plus the two previous years and the two following years.

Table 4. Vegetation characteristics of SBWBNU nest sites and survey points where SBWBNU were detected and where they were not detected (Viste-Sparkman 2005).

	SBWBNU Nest sites (*n* = 66 nests)		SBWBNU Detected (*n* = 30 points)		SBWBNU not detected (*n* = 30 points)	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Canopy cover (%)	NA	NA	55.2 (3.71)	15.7 - 94.0	71.9 (3.20)	41.1 - 92.9
% Non-forest cover within 178 m	56.0 (3.42)	0.0 – 96.8	56.6 (5.44)	0.0 - 95.0	21.9 (4.35)	0.0 - 61.4
% Non-forest cover within 1 km	72.63 (2.4)	26 – 96.6	73.7 (3.76)	34.9 - 96.1	57.6 (3.19)	34.4 - 94.0
Total no. conifers per 0.16 ha	NA	NA	1.6 (0.94)	0.0 - 26.0	9.0 (2.28)	0.0 - 38.0
% Conifer cover within 178 m	2.40 (0.95)	0 – 50.1	0.50 (0.49)	0.0 - 14.6	3.2 (1.71)	0.0 - 38.1
% Conifer cover within 1 km	7.7 (1.50)	0.0 – 57.8	2.1 (0.78)	0.0 - 20.3	10.3 (2.37)	0.0 - 43.0

Table 5. Vegetation characteristics of SBWBNU nest sites in oak trees and random oak trees (Viste-Sparkman 2005).

	Nest trees (*n* = 55)		Random trees (*n* = 79)	
	Mean (SE)	Range	Mean (SE)	Range
Nest-tree dbh (cm)	70.3 (3.9)	10.0 – 136.9	47.7 (3.2)	10.0 – 122.0
No. cavities	8.3 (0.9)	1.0 -28.0	2.4 (0.4)	(0.0 – 13.0)

Table 6. Reproductive measures for White-breasted Nuthatches in North America and Eurasian Nuthatch.

Location	Habitat	Clutch Size	Nesting Success	Productivity (young/successful nest)	Author
Western Oregon	Oak woodlands		75%[a] *n* = 61	4.9 + 2.3 *n* = 39	Viste-Sparkman (2005)
Eastern U.S.		7.3 + 1.1 *n* = 50			
Arizona	Mixed conifer - deciduous		52% [a] *n* = 9		Li and Martin 1991
N. FL and S. GA	Mixed pine-oak	5.1 + 1.1 *n* = 32	39%[a] *n* = 69	3.7 + 2.3 *n* = 30	Leonard 2005
North America		7.3 + 1.2			Bent 1948
Eurasian Nuthatch (*Sitta europea*)					
Europe	Deciduous, Deciduous - pine	6.8	72 [b] *n* = 116		Nillson 1986 (or 1976if I can find it)
Siberia	Riparian	6.5 + 1.2 *n* = 37	76%[b] *n* = 37	5.1 + 1.5 *n* = 37	Pravosudov 1993

[a] Estimated with Mayfield method (Mayfield 1961)
[b] Apparent nest success (# successful/# attempted)

Table 7. Number of hectares of management or restoration directed towards oak habitat in the South Puget Sound region.

		Time frame			
Location (Lead Organization)	**Management action**	**Last 5 years 2000-2005**	**This year 2005**	**Next year 2006**	**Next 5 years 2006-2010**
Fort Lewis (USDOD)	Doug-fir removal or snag creation	202	51	61	253
	Scotch Broom and other invasive removal	405	192	182	759
	Oak planting	4	1	1	10
	Oak thinning in oak habitat	121	40	66	405
Glacial Heritage and other conservation easements (TNC)	Doug-fir removal or snag creation	12	20	20	40
	Oak planting	2	2	4	12
Scatter Creek WMA (WDFW)	Doug-fir removal or snag creation	8	2	2	8
	Oak thinning in oak habitat	2	0	2	4
South Puget Sound WMA (WDFW)	Doug-fir or exotic removal	4	2	2	10
	Oak planting	4	1	1	10
West Rocky Prairie WMA (WDFW)	Doug-fir or exotic removal	0	0	4	20
	Oak thinning in oak habitat	0	0	0	2
	Oak planting	0	0	4	20
Mima Mounds (WDNR)	Doug-fir removal or snag creation;	8	0	0	0
	Removal of exotic understory	20	0	0	0
NRCS (WHIP funds for private lands)	Oak planting	6	0	0	0
	Removal of exotic understory	34	0	0	0
TOTAL		**834**	**312**	**350**	**1555**

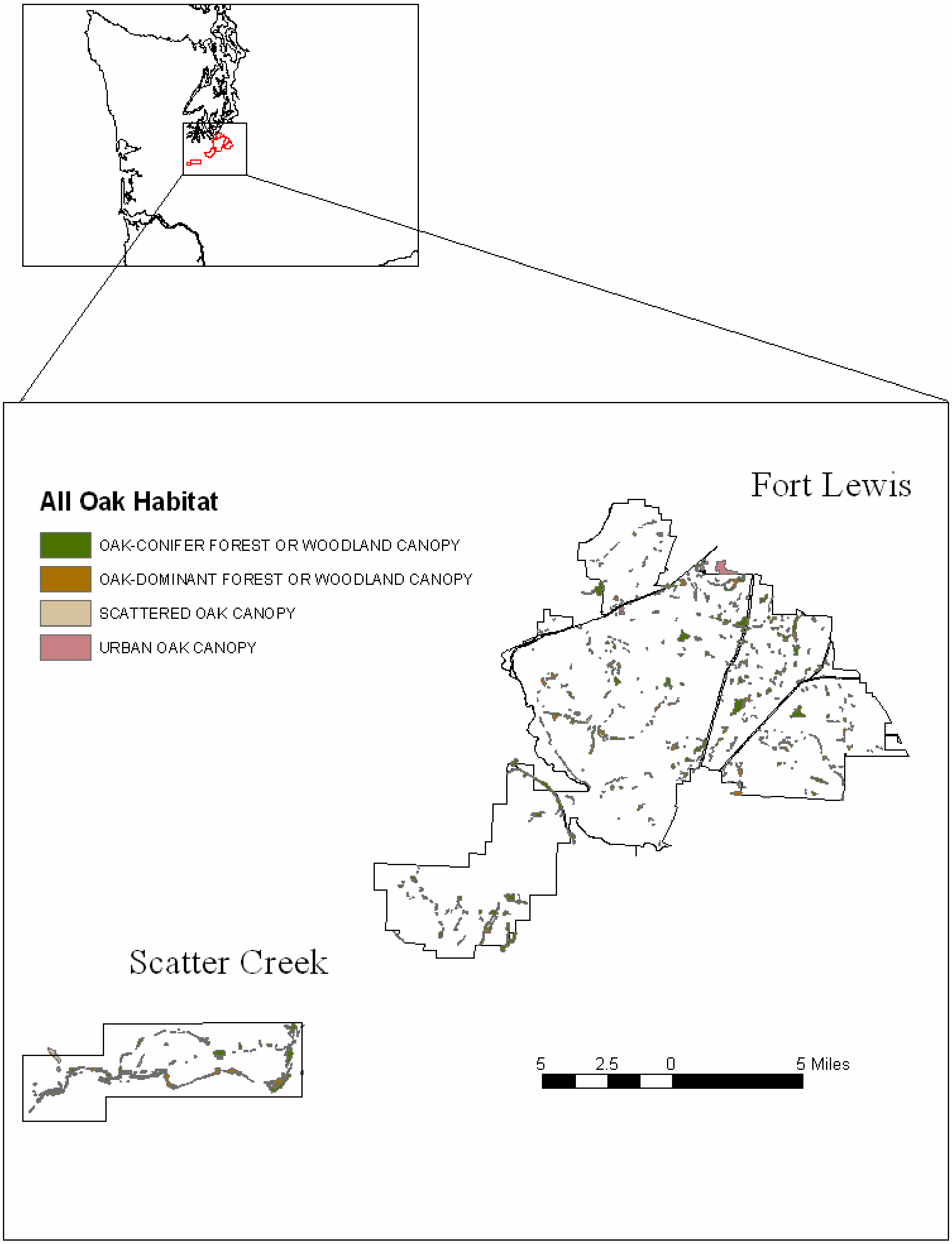

Figure 2. Oak habitats at the Fort Lewis and Scatter Creek sites in South Puget Sound (Data from Chappel et al. 2003).

Table 8. Total number of hectares of oak and pine habitat (ha) at two potential reintroduction sites for SBWBNU in South Puget Sound and the amount of habitat that is potentially suitable for SBWBNUs.

		Oak habitats[a]				Pine Habitat[b]	
SITE		OC[c]	OD	SO	UO	PP	Total
Fort Lewis	Total available habitat	1071	453	36	81	775	2416
	Potential SBWBNU habitat	783	249	19	80	500	1631
Scatter Creek Drainage	Total available habitat	268	234	32	4	0	538
	Potential SBWBNU habitat	237	209	32	0	0	478

[a] Data from Chappell et al. (2003)
[b] Data from Foster (1996)
[c] Habitat categories (See habitat assessment for description): OC = Oak-conifer dominant forest, OD = Oak-dominant forest, SO = Scattered Oak Canopy, UO = Urban Oak Canopy, PP = Ponderosa Pine forest.

Table 9. List of model inputs for eight population models run with Program Vortex.

	Model scenarios							
Model Inputs – common to all models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Age of first reproduction for males and females	1	1	1	1	1	1	1	1
Maximum age of reproduction	9	9	9	9	9	9	9	9
Maximum number of young	7	7	7	7	7	7	7	7
Sex ratio at birth	50%	50%	50%	50%	50%	50%	50%	50%
Initial population size	0	0	0	0	0	0	0	0
Carrying capacity	326	326	326	326	326	326	326	326
Adults supplemented per year	10	10	10	10	10	10	10	10
Model Inputs – varied among models								
Percentage successful females	70	70	70	75	75	75	70	75
Environmental variation in breeding	13.3%	13.3%	13.3%	13.3%	13.3%	13.3%	13.3%	13.3%
Mean no. of young produced	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90
Juvenile mortality	70%	65%	70%	70%	65%	70%	55%	60%
SD in mortality due to environmental variation	5%	5%	5%	5%	5%	5%	5%	5%
Adult mortality	54%	50%	45%	54%	50%	45%	50%	54%
SD in annual mortality due to environmental variation	3%	3%	3%	3%	3%	3%	3%	3%
Number of years supplemented	4	4	4	4	4	4	5	5

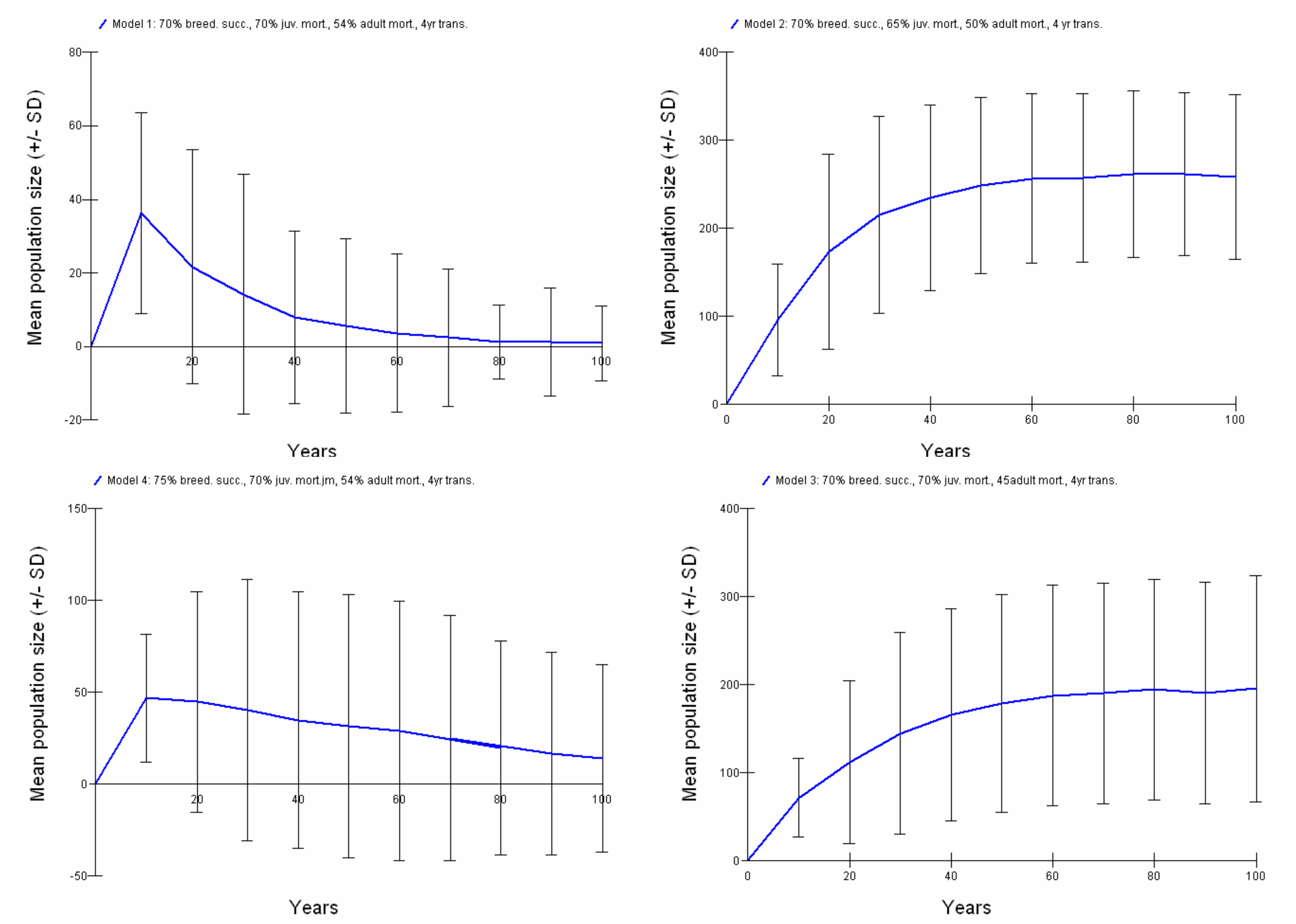

Figure 3. Model results showing the mean number of individuals for 1000 simulations (includes successful and extirpated populations) over 100 years.

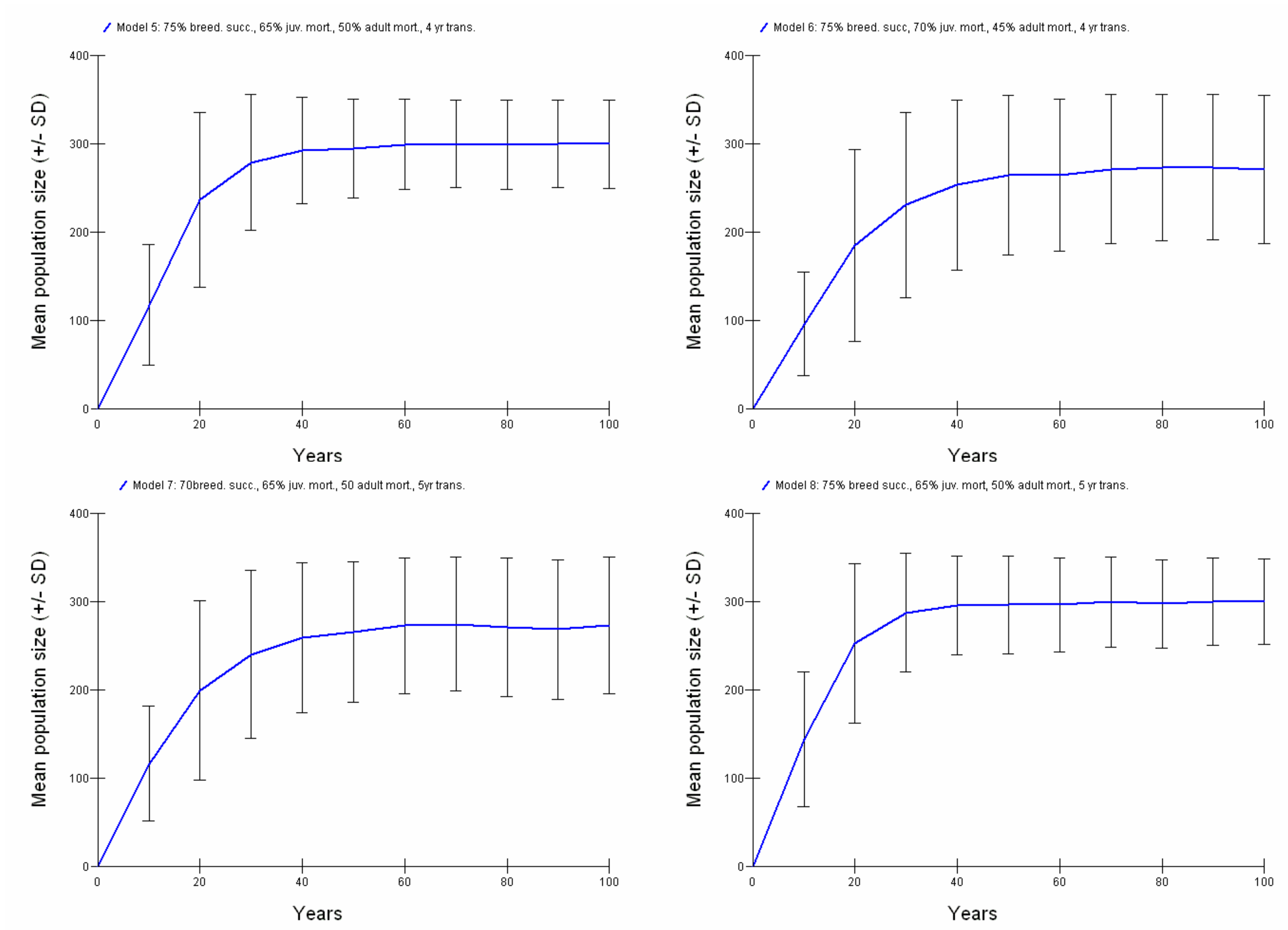

Figure 4. Model results showing the mean number of individuals for 1000 simulations (includes successful and extirpated populations) over 100 years.

Table 10. Model parameters and outcomes of SBWBNU population models (all runs based on 1000 simulations

Model	Breeding success	Adult Mort.	Juv. Mort.	Years translocated	Lambda	Deterministic r	Stochastic r	SD(r)	Prob. of extinction	Mean pop. size (all populations)	SD	Mean time to extinction (SD)
1	70	54	70	4	0.97	-0.029	-0.04	0.34	0.989	0.83	10.14	29.9 (16.4)
2	70	50	65	4	1.10	0.093	0.09	0.22	0.076	258.35	93.89	32.8 (15.7)
3	70	45	70	4	1.06	0.059	0.05	0.23	0.228	195.74	128.53	39.5 (21.8)
4	75	54	70	4	1.02	0.008	-0.01	0.30	0.871	14.06	50.94	36.3 (20.9)
5	75	50	65	4	1.14	0.131	0.13	0.21	0.011	299.9	50.2	24.1 (11.8)
6	75	45	70	4	1.10	0.093	0.09	0.21	0.053	271.45	83.69	34.3 (18.5)
7	70	50	65	5	1.10	0.093	0.09	0.22	0.032	273.44	77.23	33.7 (14.4)
8	75	50	65	5	1.14	0.131	0.13	0.21	0.011	300.42	48.47	24.9 (13.7)