AVIAN RESTORATION IN EVERGLADES NATIONAL PARK

AN EVALUATION OF THE BROWN-HEADED NUTHATCH AND EASTERN BLUEBIRD REINTRODUCTION PROGRAM DURING THE 2-YEAR POST-TRANSLOCATION PERIOD (2002-2003).

Final Report

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EXECUTIVE SUMMARY

Reintroductions to reestablish extirpated populations are an increasingly important conservation tool. However, post-release studies and performance evaluations of reintroduced populations remain scarce and standardized criteria for determining success are lacking. In 1997, a reintroduction program to restore viable populations of Brown-headed Nuthatches and Eastern Bluebirds to Everglades National Park (ENP) was initiated as one test of the progress made towards restoration of the rare pine rockland ecosystem in ENP. During the period 1997-2001, 53 Brown-headed Nuthatches and 47 Eastern Bluebirds were translocated to ENP. Here, we present an evaluation of the reintroduction program during the 2-year post-translocation period (2002- 2003), and provide recommendations for future monitoring and management guidelines.

We evaluated the nuthatch and bluebird reintroduction program using two criteria: 1) the reintroduced population increased in size between successive years, and 2) reproduction and survival estimates were similar between the reintroduced and high-quality reference populations. We studied both species in Long Pine Key, ENP (reintroduced populations) and in two plots, each containing 10-12 territories, in Big Cypress National Preserve (reference populations). Territories were located annually by walking systematic transects and using playback vocalizations in suitable habitat. Nests were monitored every 3-5 days and fate determined. A nest was considered successful if it fledged at least one nestling; the number of juveniles was determined from two counts conducted < 3 weeks after the fledging date. Adults and offspring were color-banded when possible in both study areas. Size of the reintroduced populations was estimated at the end of each breeding season by counting the number of adults and juveniles on breeding and nonbreeding territories and non-territorial floaters. We compared the following demographic measures: clutch size (only bluebirds), nesting success, territory success, productivity (no. juveniles/territory), and apparent adult survival between the reintroduced and reference populations.

At the end of the 2003 breeding season, the reintroduced Brown-headed Nuthatch population consisted of 46 adults and 47 juveniles and was substantially higher than at the end of the translocation period in 2001. The nuthatch reintroduction program met the population size success criterion during both years of the post-translocation period, and also met the demographic success criteria, as demographic values (territory success, clutch size, nest success, productivity, adult survival) in the reintroduced population were similar to those in the high-quality reference population. At the end of the 2003 breeding season, the reintroduced Eastern Bluebird population consisted of 39 adults and 18 juveniles, and overall population size was substantially smaller in 2003 than 2001. The bluebird reintroduction program met the annual population size criterion of success in the first year after translocations were discontinued, but did not meet it the second year. Considering the extremely low number of juveniles produced in 2003 (18), population size in 2004 is likely to decline further. Like the nuthatches, the bluebird program met the demographic success criteria. However, bluebird reproduction in 2003 was substantially lower than in previous years and was lower than in the reference population. It is unclear if results from 2003 are a result of natural variation or part of a larger trend.

According to our evaluation criteria, the reintroduction program in ENP has been successful. Except for bluebirds in 2003, population sizes of both species increased annually, and reproduction and survival in the reintroduced population was similar to the high-quality reference population. The success of the reintroduction program suggests that management activities have made progress

in restoring the pine rockland ecosystem in ENP.

For the reintroduced nuthatch and bluebird populations to become self-sustaining, we believe the ENP fire program must continue restoration (2-3 yr interval) fires to reduce hardwood understory. Even though much of Long Pine Key has experienced a significant reduction in hardwood understory, the majority of Long Pine Key appears to remain unsuitable for either species. We believe that at least one more cycle of fires is needed to improve habitat suitability, particularly in the northern and western blocks of Long Pine Key. In addition, removing hardwood build-up along pine/glade ecotones, which is particularly important habitat for bluebirds, has not been addressed and needs to be a priority of future fire management activities.

We strongly believe that additional monitoring of the reintroduced populations is warranted, as both populations remain small and vulnerable to stochastic processes and management activities. Poor reproduction by bluebirds in 2003 and continued bluebird mortality attributed to automobiles are also reasons for concern. The most important reason to continue monitoring is to determine why the reintroduction is a success or failure. Demographic monitoring will answer this question by measuring annual variation in reproduction and survival and identifying the ecological correlates (fire, hydrology) to these parameters. This, in turn, will provide the data necessary to develop population viability models that evaluate long-term persistence and the effects of random catastrophic events on extinction probabilities.

Continued monitoring will also provide information to develop specific management guidelines for the reintroduced populations, and demographic measures can be used to evaluate ongoing and proposed fire and hydrological restoration activities. To date, restoration efforts in uplands have generally been overlooked within the south Florida landscape, in part, because connections between uplands and hydrology are not as clearly apparent as in other southern Florida ecosystems. Undoubtedly, hydrology plays a role, but the extent and mechanisms of that role and the ecological services that pinelands provide within the landscape remain unclear. There is a critical need for research that explores the ecological relationships between uplands and hydrology, and how fire, the primary disturbance factor in this system, interacts between the two. Cavity-nesters, such as bluebird and nuthatches, would appear to be ideal study species for this research, as the disappearance of over 40% of the cavity-nesting community from the pine rocklands suggests this guild may be the most sensitive upland fauna to ecosystem change. Indeed, cavity-nesters have been identified as critical components in the uplands conceptual model, and identified as strong candidates for use as performance measures to evaluate hydrological restoration activities in the pine rockland ecosystem (Uplands Performance Measure Workshop – Draft Summary 2002).

Finally, continued monitoring of these reintroduced populations will help guide decisions about future reintroduction for other extirpated species in ENP such as Red-cockaded Woodpeckers, and will contribute to global avian conservation as information on landbird reintroductions are lacking.

INTRODUCTION

Reintroductions of native species to reestablish extirpated populations in previously occupied habitats or augment threatened populations are an increasingly important conservation tool (Griffith et al. 1989, IUCN 1995). However, post-release studies and performance evaluations of reintroduced populations remain scarce and standardized criteria for determining success are lacking (Scott and Carpenter 1987, Griffith et al. 1989, Cade and Temple 1995 Sarrazin and Barbault 1996, but see Ostermann et al. 2001). This is particularly true for avian translocations of passerine or near passerine species, which have been reintroduced less frequently than other taxa.

Detailed studies of post-release activities are critical to: 1) assess the reintroduction methods, 2) assess the status and viability of the reintroduced population, and 3) provide assessment criteria for future reintroductions of the same or similar species in other areas (Sarrazin and Barbault 1996, Sarrazin and Legendre 2000). Monitoring and performance evaluations can be particularly useful in situations where a species reintroduction is only one component of a habitat or ecosystem restoration program (Armstrong and Ewen 2002). Under these circumstances, the reintroduction of a species can be considered one test of the progress made in ecosystem restoration, and research that assesses population viability and identifies limiting factors can be used to guide and evaluate management activities, and may provide direction for decisions about future reintroductions (Armstrong and Ewen 2002).

In southern Florida, the pine rockland ecosystem is "critically imperiled" (Noss et al. 1995, USFWS 1999) and poses a significant restoration challenge. Pine rocklands occur in the Big Cypress Swamp, mostly in Big Cypress National Preserve (BCNP), and along the Atlantic coastal ridge, which terminates in Everglades National Park (ENP). The most dramatic losses have occurred on the Atlantic coastal ridge, which has been reduced in area by more than 90% (Fig. 1; Doren et al. 1993). The largest remaining tract is the 8,100 ha upland area in Long Pine Key, ENP.

In the pine rockland ecosystem of southeastern Florida, seven species of breeding bird have been extirpated: Summer Tanager (*Piranga rubra*), Wild Turkey (*Meleagris gallopavo*), Brown-headed Nuthatch (*Sitta pusilla*), Eastern Bluebird (*Sialia sialis*), Red-cockaded

Woodpecker (*Picoides borealis*), Southeastern American Kestrel (*Falco sparverius paulus*), and Hairy Woodpecker (*Picoides villosus*) (Snyder et al. 1990, Slater 2003). Although specific causes have not been identified, these losses are likely due to habitat loss and fragmentation from residential and agricultural development, habitat degradation resulting from altered fire and hydrological regimes, and effects associated with small populations (Robertson and Kushlan 1974, Snyder et al. 1990).

In 1997, a reintroduction program to develop and implement translocation techniques aimed at restoring viable populations of Brown-headed Nuthatches and Eastern Bluebirds to ENP was initiated as one test of the progress made in restoring the rare pineland ecosystem (e.g., restoration of natural fire regimes, protection and recovery of the area from logging) represented by Long Pine Key, ENP. Natural recolonization by either species was considered unlikely due to the distance between remaining isolated habitat islands and was not expected to improve through hydrological restoration (i.e., CERP), even though habitat characteristics of Long Pine Key appeared suitable to support viable populations of each species. The forest had matured to approximately 60 years of age, abundant snags were present due to Hurricane Andrew in 1992, and, based on density estimates from nearby populations, Long Pine Key should be able to support > 200 territories of each species (Slater 1997). In addition, the ENP fire program had recently initiated a fire management plan to reduce hardwood understory buildup, which had developed over a decade of fire suppression, through high frequency (2-3 year interval) restoration fires, and was developing a long-term maintenance fire regime based on natural fire patterns in south Florida rocklands.

During 1997-2001, 53 Brown-headed Nuthatches and 47 Eastern Bluebirds were translocated to ENP from source populations in BCNP and nearby areas. In 2001, 13 nuthatch and 16 bluebird breeding territories were established in ENP and translocations were discontinued. Even though these populations were small, it was believed they were sustainable and would continue to increase in size with appropriate fire management and typical environmental conditions (Slater 2001).

However, continued monitoring of the reintroduced populations was recommended for a minimum of two additional years for several reasons (Slater 2001). First, since the resiliency of the small populations to catastrophic, environmental, or demographic stochastic events is unknown, monitoring provides a means to assess the cause of a rapid decline in population size and prepare an appropriate response. Secondly, demographic monitoring would provide a tool to evaluate the success of the reintroduction program, and if monitoring was extended beyond the two years, data would contribute to an analysis of the long-term viability of these populations. Finally, data collected during the post-translocation period could be used to develop a database for which future avian reintroductions in southern Florida or other parts of the world could be evaluated.

In this report, we present the results from monitoring during the 2-year post-translocation period and evaluate the success of the Brown-headed Nuthatch and Eastern Bluebird reintroduction program. Specific objectives are: 1) to monitor population size and demographics of the reintroduced populations, 2) to compare demographic rates between reintroduced populations and populations in a high-quality reference site, and 3) to provide recommendations for future monitoring and management guidelines.

METHODS

Study area.—We studied Brown-headed Nuthatches and Eastern Bluebirds from late-February through July 2002-2003 in the Long Pine Key region (reintroduced populations) of ENP and in Raccoon Point (reference populations) in BCNP (Fig. 2). Long Pine Key is an 8,100 ha upland area that contains approximately 4,600 ha of pine forest (Snyder et al. 1990, Doren et al. 1993). Within the relatively continuous pine forest, embedded habitats include *Muhlenbergia* prairie, hardwood hammocks, and cypress forest (Olmstead et al. 1983). The pine forest is mostly even-aged, a result of extensive logging in the 1940's, and snags are abundant due to Hurricane Andrew in 1992 (Doren et al. 1993). During the past seven years, the ENP fire management program has implemented an aggressive prescribed fire regime to reduce hardwood and saw palmetto (*Serenoa repens*) understory that had developed from historic winter-season burning and recent (< 10 years) fire suppression. This shift in management was aimed at restoring the herbaceous and graminoid dominated understory, which is characteristic of this ecosystem (Snyder et al. 1990). The Raccoon Point site was the primary donor site for the reintroductions, and served as a high quality reference site for demographic comparisons with the reintroduced populations. Raccoon Point is an area of unlogged, old-growth pine forest within a cypress (*Taxodium* sp.) mosaic (Fig. 2), and a natural fire regime has been maintained with prescribed fire. In general, the herbaceous and grass components are well developed, while the shrub layer contains a sparse to moderate amount of saw palmetto and hardwoods. Nuthatches and bluebirds were monitored on two plots, each containing 10-12 territories (Slater 2001).

*Demographics and population size.—*We began searching for Brown-headed Nuthatch nests in late-February, when they typically begin excavating cavities, while searches for bluebird nests started in late-March. In both study areas, breeding territories were located annually by walking systematic transects and using playback vocalizations in territories of prior years and in unoccupied areas where habitat appeared suitable. Individual birds were followed until excavation and nest-building behaviors were noted. Upon incubation (clutch complete) a nest site was classified as a nesting attempt. Thereafter, nest status was monitored every 3-5 days until nestlings fledged or the nest failed. Clutch size was determined at accessible bluebird nests using a Tree Top Peeper^{TM} System (Sandpiper Technologies, Inc., Manteca, CA); the system did not work for nuthatch nests, because their cavity entrances were too small for the camera probe. A nest was considered successful if it fledged at least one nestling. The number of juveniles was determined from at least two counts conducted < 3 weeks from the fledging date. The first count was usually within 7 days of fledging and the second count was made to determine if any young were missed during the first observation. Whether a nest failed or was successful, we revisited the territory for follow-up observations to determine if renesting occurred.

Adults and offspring were color-banded when possible in both study areas. Most breeding adults were captured at, or near, the nest site. Juveniles were banded as nestlings at accessible nests, or with mistnets and playbacks when they became independent, usually about a month after fledging. Marked birds were resighted during nest searches or from behavioral observations at the nest. If an adult was detected during the period from approximately 15 February - 15 July it was considered alive in that year.

Brown-headed Nuthatch and Eastern Bluebird population size in Long Pine Key was estimated at the end of each breeding season by counting the number of adults and juveniles on breeding and nonbreeding territories and non-territorial floaters. Adults that disappeared from their breeding territory were assumed to have died, because there were few instances where adults that left a breeding position were relocated on other territories. We assumed a juvenile was alive at the end of the breeding season unless it disappeared before it was capable of independence. Our principal assumption for estimating population size is that all individuals were located. Besides our systematic transects, we conducted 100 point-count surveys throughout Long Pine Key in an effort to locate additional territories (Slater 2002).

*Evaluation of the reintroduced populations.—*Undoubtedly, the primary goal of a reintroduction project is to establish a self-sustaining population (Scott and Carpenter 1987, Griffith et al. 1989). However, the term self-sustaining is ambiguous without a defined temporal framework and without taking into account various dynamic scenarios, including unexpected catastrophic events (Sarrazin and Barbault 1996). Data needed to determine sustainability under these scenarios include long-term demographic data. At this time, we believe data are too sparse for such a robust population viability analyses.

We evaluated the nuthatch and bluebird reintroduction program during the post-translocation stage (2002-2003) using two criteria. The first criterion was that the size of the reintroduced populations increased between successive years. This criterion, which has been used throughout the reintroduction program, is important because population size is strongly related to the probability of persistence by species populations (Jones and Diamond 1976, Soule´ et al. 1988, Rosenzweig 1995 Foufopoulos and Ives 1999).

Our second criterion of success was that reproduction and survival estimates were similar between the reintroduced and high-quality reference populations (i.e., Raccoon Point). Comparing results of restoration efforts to reference conditions is the ideal approach to measuring restoration success (National Research Council 1992). Raccoon Point was selected as the reference site because it was believed to represent an "ideal" or "target" population: the site is one of the few virgin stands of pine forests in southern Florida, it has been burned on a natural time interval and frequency, and Brown-headed Nuthatches and Eastern Bluebirds are abundant.

We compared the following reproduction measures: clutch size (only bluebirds), nesting success, territory success, and productivity (no. juveniles/territory) between the reintroduced and reference populations during the post translocation period (2002-2003). Although mean incubation date is not a direct reproductive measure, we compared this measure because it may provide insight into whether environmental factors that cue breeding are similar between the two sites, and because there is some indication from previous studies that individuals that breed earlier are more successful. Mean incubation date, clutch size, and overall productivity were compared using a two-way analysis of variance (ANOVA). Territory success was compared between sites using a chi-square test. Daily nest survival rates were calculated using the Mayfield method (Mayfield 1961, 1975) and compared between populations using program CONTRAST (Hines and Sauer 1989).

We used program MARK (version 3.1; White 2002) to compare apparent survival and recapture probability for the reintroduced and reference populations. In this study, apparent survival rate (phi) 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 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. Our survey data consists of live recaptures for the period 1998-2003. No previous attempt has been made to analyze these data using empirical modeling techniques, so we felt analyses that covered the translocation and post-translocation period were warranted. Sample sizes and the number of years are insufficient to estimate these parameters for only the post-translocation period using empirical modeling programs like MARK.

Our primary objective was to determine if adult survival rates differed between the reintroduced and reference populations. Too few juveniles were captured to include an age dependent factor. Only translocated adults that exhibited territorial behavior were included in the analyses; translocated birds that disappeared after release were not included.

Global (i.e., fully parameterized) models were developed for Brown-headed Nuthatches and Eastern Bluebirds that included time (t) and group (g; reintroduced vs. reference population) as factors. A goodness-of-fit test was conducted on the global model using program RELEASE within MARK to test the two primary assumptions of the model: 1) marked animals at time (*i*) have the same probability of being recaptured (p_i), and 2) marked animals in the population at time (*i*) have the same probability of surviving to time *i* +1. In addition, RELEASE provides an estimate of the variance inflation factor or overdispersion (c-hat) to adjust for lack of fit. We attempted to improve model fit by using nested models with reduced numbers of parameters. All models were constructed using the sin link. Model fit was assessed using Akaike Information Criteria (AIC) values that were corrected for c-hat (QAIC). AIC is a quantitative method that treats model selection in an optimization framework as opposed to a hypothesis-testing framework (Burnham and Anderson 1998). Model fit can be improved and bias reduced by adding parameters; however, adding parameters increases model complexity and variance (i.e. reduced precision). AIC methods measures how well a model fits, but incorporates a penalty for the addition of parameters, thus AIC provides a satisfactory trade-off between bias and variance (Burnham and Anderson 1998). The best fit model has a QAIC value of zero; however other models with QAIC values ≤ 2 from the best fit model are equally parsimonious. We obtained estimates of phi and p from the best fit model, and calculated annual estimates of phi and p and unconditional variance by using Akaike weights and model averaging so as to include model uncertainty (Burnham and Anderson 1998)

RESULTS

Brown-headed Nuthatches

*Population size.—*At the end of the 2003 breeding season, the reintroduced Brown-headed Nuthatch population consisted of 46 adults and 47 juveniles and was substantially higher than at the end of the translocation period in 2001. We observed a decrease in population size from 2001 to 2002, but an increase from 2002 to 2003 (Fig. 3). However, we believe the decrease from 2001 to 2002 was due to a population underestimate, as opposed to a decrease in population size. If the 2002 population estimate was correct, 46 of the 51 (90%) individuals counted in 2002 would have had to survive to obtain the 2003 estimate of adults. We believe this rate of survivorship is unreasonably high, and think it is more probable that several territories were not found in 2002. We rule out immigration as a factor in the population increase since the closest population is > 30km away and nuthatches are considered to have relatively small dispersal movements (Norris 1958). Based on an annual survivorship of 69% (see survival), 66 individuals (adults and juveniles) would have been needed in 2002 to obtain the 46 adults estimated in 2003. Sixty-six individuals is higher than our 2002 field-based estimate and higher than the population estimate in 2001. Thus, we believe we met our population size criteria in each year of the study.

Reproduction.-In the reintroduction site, 15 territories occupied by $\geq$ 2 individuals and 4 territories that contained a single bird were located in 2002. In 2003, 20 territories occupied by $\geq$ 2 individuals and 1 territory that contained a single bird were located. In the reference site plots of Raccoon Point, 17 and 20 territories were located in 2002 and 2003, respectively; all territories were occupied by $\geq$ 2 individuals. Brown-headed Nuthatches on 33 of 35 (94%) territories that contained $\geq$ 2 individuals attempted breeding in the reintroduced population, while nuthatches attempted breeding at 29 of 37 (78%) territories in the reference site plots.

In general, reproductive measures were similar between the reintroduced and the reference population; however, overall productivity was substantially higher in the reintroduced population (Table 1). Mean incubation date (first attempts) did not differ between the reintroduced and reference population, but differed between years (F = 13.46, df = 1, P = 0.001). In the reintroduced population, 76% (25 of 33) of breeding territories nested successfully, while 66% (19 of 29) of territories were successful in the reference population (X^2_1 = 2.09; P = 0.15). Daily nest survival rates were similar between years for both populations, thus years were pooled for the comparison between sites. For the period 2002-2003, daily nest survival rates did not differ between the reintroduced (0.9897; nest success = 72%) and reference population (0.9839; nest success = 60%; X^2_1 = 1.01, P = 0.32)(Fig. 4). Productivity was significantly higher in the reintroduced population (2.06 $\pm$ 0.23) than the donor population (1.20 $\pm$ 0.27; F = 5.97; P = 0.02) and differed between years (F = 10.98; P < 0.01)(Fig. 4).

Survival.-From the period 1998 – 2003, 65 adults and 71 adults from the reintroduced and reference populations, respectively, were included in the survival analysis (Table 2). We selected a global model that included site and time (annual variation) in phi and time in p (i.e.,

phi_{g*t}, p_t). We did not include the site effect (g) in the recapture rate parameter because there is no reason to believe that the probability of resighting an individual differed between populations. Brown-headed Nuthatches maintain year-round territories, they are sedentary, and adults have rarely been observed leaving a territory to breed in another territory (Norris 1958, Slater 2003). A goodness of fit test using program RELEASE (within program MARK) indicated that the model phi_{g*t}, p_t fit sufficiently well (chi-square = 9.36, df = 8, $p = 0.31$) to be used as a global model. There was slight overdispersion in the data set (c-hat = 1.17) and all models were subsequently adjusted by this value. The best model from the candidate (nested) models indicated apparent survival varied by site and recapture probability was constant (Table 3). No other models were $\leq$ 2QAIC values to the selected model suggesting that this was the most appropriate model. Under the selected model apparent survival was substantially higher in the reintroduced population (0.69) than the reference population (0.49), but 95% confidence intervals overlapped slightly (Fig. 5). Recapture probability equaled 1.00 for both populations indicating that individuals were always resighted, and did not appear to engage in temporary emigration. Annual estimates of apparent survival using weighted averages reinforce the strength of the best-fit model, as annual survivorship varied by site, but not by year (Fig. 6).

Eastern Bluebirds

Population size.-At the end of the 2003 breeding season, the reintroduced Eastern Bluebird population consisted of 39 adults and 18 juveniles. Although more adults were present in the 2003 population than at the end of the translocation period, overall population size was substantially smaller in 2003 than 2001 because few juveniles were produced in 2003. Population size increased from 2001 to 2002, but decreased from 2002 to 2003 (Fig. 7). Thus, for the first year post-translocation (2001-2002) we met our population size criteria of success, but we failed to meet it in the second year (2002-2003).

Reproduction.- In the reintroduction site, 23 territories were found in 2002, and 18 territories were found in 2003. In both years, several bluebirds were heard or seen in other areas, but no territories were verified. In the reference site, 17 and 24 territories were located in 2002 and 2003, respectively. Eastern Bluebirds pairs at 38 of 41 (93%) territories attempted breeding in the reintroduced population and 37 of 41 (90%) bluebird pairs attempted breeding in the reference population.

Reproductive measures were similar between the reintroduced and the reference population (Table 4). Bluebirds in the reintroduction population nested earlier than the reference population in 2002 but later in 2003, resulting in a significant difference in the interaction term year*site ($F = 5.59$, df = 1, $P = 0.02$). Overall, mean incubation date (first attempts) in the reference population was marginally earlier than in the reintroduced population ($F = 3.13$, df = 1, $P = 0.08$)(Table 4). Mean clutch size (first attempts) did not differ between the reintroduced (3.61 $\pm$ 0.14) and reference population (3.80 $\pm$ 0.19; $F = 0.69$, df = 1, $P = 0.41$). In the reintroduced population, 57% (21 of 37) of breeding territories were successful, while 46% (17 of 37) of territories in the reference population were successful ($X^2_1 = 0.87$; $P = 0.35$). Nesting outcome at one breeding territory in each site was unknown. Daily nest survival rates were similar between years for both population, thus years were pooled for the comparison between sites. For the period 2002-2003, daily nest survival rate was similar between the reintroduced (0.9720; nest success = 40%) and reference population (0.9640; nest success = 31%; $X^2_1 = 0.82$, $P = 0.37$) (Fig. 8). Overall productivity was slightly higher in the reintroduced population (1.51 $\pm$ 0.25) than the donor population (1.10 $\pm$ 0.23) but did not differ significantly ($F = 0.73$; df = 1; $P = 0.40$)(Fig. 8).

Survival.- From the period 1998 – 2003, 69 adults and 54 adults from the reintroduced and reference populations, respectively, were included in the survival analysis (Table 5). For bluebirds, we selected a global model that included site and annual variation in phi and p (i.e., phi_{g*t}, p_{g*t}). Unlike the nuthatch analysis, we included the site effect (g) in the recapture rate parameter because bluebird adults did not maintain year-round territories and were observed switching territories among years. Thus, bluebirds in the reference site might be more likely to move off a plot and not be resighted even though they were still alive. In the reintroduction site, when a bluebird switched territories it was usually resighted since we searched all suitable habitat. A goodness of fit test using RELEASE indicated that the model phi_{g*t}, p_{g*t} fit sufficiently well (chi-square = 13.09, df = 9, $p = 0.15$) to be used as a global model. There was slight overdispersion in the data set (c-hat = 1.45) and all models were subsequently adjusted by this value. The best model from the candidate (nested) models indicated apparent survival did not vary by site, but recapture probability did (Table 6, Fig. 9). The second best model, which suggested apparent survival did vary between sites was close to gaining equal support with a QAIC of 2.09. No other models were ≤ 2 QAIC values to the selected model suggesting that this was the most appropriate model. Under the selected model, apparent survival equaled (0.60) for both populations, but recapture probability was 1.00 in the reintroduced population and 0.74 in the reference population (Fig. 9). The annual estimates of phi and p estimated by model averaging using Akaike weights, supported the strength of the best-fit model, indicating little variation in apparent survivorship between the reintroduced and reference population (Fig. 10)

DISCUSSION

Brown-headed Nuthatches

The Brown-headed Nuthatch reintroduction program met the population size success criterion during both years of the post-translocation period. With this accomplishment, the nuthatch reintroduction program has met the population size success criterion in every year since translocations were initiated (Slater 2001). Given that 47 juveniles fledged in 2003, population size should increase in 2004.

Population size is an important criterion to monitor in a reintroduction program since it has been shown to be a major factor in determining persistence in populations for a variety of animal species and taxa (Jones and Diamond 1976, Soule´et al. 1988, Rosenzweig 1995 Foufopoulos and Ives 1999). The larger the population, the more resilient it is to random environmental events, such as winter storms, drought, or hurricanes, that may directly reduce population size or have a negative influence on survival or reproduction. Although no "magic number" of individuals has been defined as a successful or "viable" reintroduced population, Beck et al. (1994) suggested a population of 500 individuals defined success. However, without taking into account variation in life histories and habitat quantity and quality this number appears rather arbitrary (Sarrazin and Barbault 1996). Ultimately, population viability, and thus success, needs to be measured in terms of extinction probability rates, which incorporate population size, growth rate, and variation due to unexpected catastrophic events (Sarrazin and Barbault 1996). The next critical step in evaluating the Brown-headed Nuthatch program is to conduct such a population viability analysis.

Nuthatches colonized new areas in the western part of Long Pine Key (Blocks A, B, and C), where prescribed burns have been frequently conducted over the last 5 years to reduce hardwood understory and create a graminoid- and herbaceous-dominated understory that is believed to be representative of the historic condition of pine rocklands (Snyder et al 1990). Nuthatches are more abundant in pine stands that have experienced fire and lack a dense understory (Slater 1997, Provencher et al. 2001, Provencher et al. 2002), and the restoration and maintenance of a natural fire regime in Long Pine Key is critical to continued nuthatch population expansion into unoccupied areas.

The reintroduced Brown-headed Nuthatch program also met all of the demographic success criteria, as demographic values (territory success, clutch size, nest success, productivity, adult survival) in the reintroduced population were similar to those in the high-quality reference population. In fact, productivity and survival were substantially higher in the reintroduced population. Higher productivity by nuthatches in the reintroduced population compared to the reference population was also found during the translocation period (Slater 2001). These results indicate that in those areas where nuthatches occur in Long Pine Key, habitat appears capable of supporting nuthatch demographic characteristics that are representative of other viable populations.

Density-dependent effects on reproduction and survival have been observed for many species (Sinclair 1989), and have been shown for birds in comparative (Arcese and Smith 1988) and experimental studies (Dhondt et al. 1992, Both 1998). It is unclear if increased reproduction and survival of the reintroduced nuthatch population may be due to density-dependent effects. Identifying the factors associated with nuthatch reproduction and survival should be priorities for future research, as results will provide additional tools to evaluate the reintroduction program and to evaluate restoration activities (fire, hydrology) in the pine rockland ecosystem. If density-dependent effects are in place, we expect that reproduction and survival values will decrease as the size of the reintroduced population increases.

Eastern Bluebirds

The Eastern Bluebird reintroduction program met the annual population size criterion of success for the first year after translocations were discontinued, but failed to meet it the second year. Population size decreased substantially in 2003, and although more adults were present in the population in 2003 than in 2001, overall numbers (including juveniles) were substantially lower. The population decline in 2003 was the first year that the bluebird population has not increased in size during the reintroduction program, as it increased markedly during the translocation stage (Slater 2001). The cause of the population decline is unclear, particularly since productivity was high in 2002 and we expected high recruitment into the breeding population. The population decline may have been associated with high winter mortality or with emigration by individuals who possibly left due to unfavorable conditions. Considering the extremely low number of juveniles produced in 2003 (18), population size in 2004 is likely to decline further.

Like the nuthatches, the bluebird program met all of the demographic success criteria. However, there is reason for concern as reproduction in 2003 was substantially lower than previous years and was lower than the estimates in the reference population. In prior years, demographic measures were higher in the reintroduced population than the reference population. However, both bluebird and nuthatch reproduction has exhibited significant annual variation. Thus, it is unclear if results from 2003 are a result of natural variation or part of a larger trend. In 2003, bluebirds in the reintroduced population nested extremely late, pairs on at least two territories did not breed, and several single females were observed moving among territories and exhibiting breeding behavior (cavity-guarding and nest-building) without males. All of these behaviors suggest that conditions were not favorable for breeding.

SYNTHESIS AND RECOMMENDATIONS

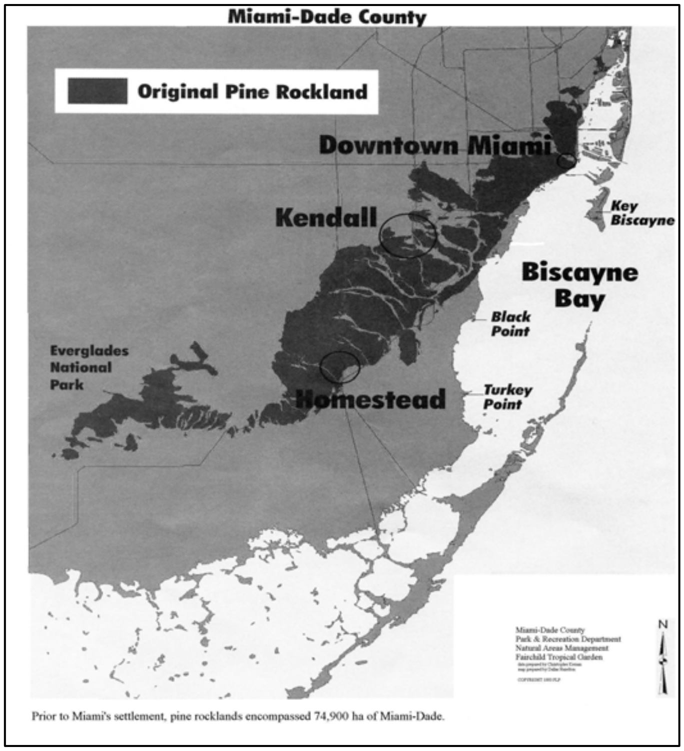
According to our population size and demographic criteria, the Brown-headed Nuthatch and Eastern Bluebird reintroduction program in ENP has been successful during the post-translocation period. Except for bluebirds in 2003, population sizes of both species increased annually, and reproduction and survival in the reintroduced population was similar to the high-quality reference population. However, the population decline and poor reproduction by bluebirds in 2003 is a significant cause for concern. To compound their vulnerable status, automobiles killed at least two adult bluebirds in ENP during autumn of 2003 (R. Snow, pers. comm.); although cars have previously killed juvenile bluebirds (Slater 2001), these are the first known cases of adult mortality. Bluebirds are vulnerable to automobile mortality because they often forage along mowed roadsides and pick up insects killed by vehicles. We estimate that the breeding population in 2004 will contain approximately 34 adults (~ 17 territories), based on the estimated population size of 57 individuals in 2003 and a survival rate of 0.60. Bluebirds have the reproductive potential to rebound from this decline, as they are multi-brooded. Their demographic response in 2004 will be a significant test of the reintroduction program.

The definitive test of success for the nuthatch and bluebird reintroduction program is the establishment of viable, self-sustaining populations. In order for this to occur, we believe the ENP fire program must continue restoration (2-3 yr interval) fires to reduce hardwood understory and develop a long-term maintenance fire regime that mimics natural fire patterns. The establishment of small populations and successful breeding by both species suggest that fire management activities have made progress in restoring the natural plant community structure and composition in the pine rocklands of Long Pine Key. Both species are fire-dependent and prefer open shrub and understory layers with minimal hardwood development. However, even though much of Long Pine Key has experienced a significant reduction in hardwood understory, the majority of Long Pine Key appears to remain unsuitable for either species. We believe that one more cycle of fires is needed to improve habitat suitability for the reintroduced species, particularly in the northern and western blocks of Long Pine Key. In addition, removing hardwood build up along pine/glade ecotones, which is particularly important habitat to bluebirds, has not been addressed and needs to be a priority of future fire management activities.

We strongly believe that additional monitoring of the reintroduced populations is warranted as both populations, particularly bluebirds, remain small and vulnerable to stochastic processes and management activities. Perhaps the most important reason to continue monitoring is to determine why the reintroduction is a success or failure. Demographic monitoring will answer this question by measuring annual variation in reproduction and survival, and identifying the ecological correlates (fire, hydrology) to these vital population rates. This, in turn, will provide the data necessary to develop population viability models that evaluate long-term persistence and the effects of random catastrophic events on extinction probabilities.

Continued monitoring will also provide information to develop specific management guidelines for the reintroduced populations, and demographic measures can be used to evaluate ongoing and proposed fire and hydrological restoration activities. To date, restoration efforts in uplands have generally been overlooked within the south Florida landscape, in part, because connections between uplands and hydrology are not as clearly apparent as in other southern Florida ecosystems. The upland ecosystem in southern Florida is a non-wetland habitat island within a large wetland matrix. Undoubtedly, hydrology plays a role, but the extent and mechanisms of that role and the ecological services that pinelands provide within the landscape remain unclear. There is a critical need for research that explores the ecological relationships between uplands and hydrology, and how fire, the primary disturbance factor in this system, interacts between the two. Cavity-nesters, such as bluebird and nuthatches, would appear to be ideal study species for this research, as the disappearance of over 40% of the cavity-nesting community from the pine rocklands during the mid-1900's suggests this guild may be the most sensitive fauna in the uplands to ecosystem change. Indeed, cavity-nesters have been identified as critical components in the uplands conceptual model and are strong candidates for use as performance measures to evaluate hydrological restoration activities (i.e., CERP) in the pine rockland ecosystem (Uplands Performance Measure Workshop – Draft Summary 2002).

Another reason to continue monitoring is to protect the financial investment that has been made to this program. Approximately $200,000 has been spent on reintroducing and monitoring each of these species. Monitoring would provide the opportunity to detect substantial population declines due to extreme circumstances, and provide time to develop appropriate responses. Because techniques for the translocation of these species have been developed, supplementing existing populations is a cheaper alternative to initiating a new reintroduction program. Finally, continued monitoring of this reintroduction project will help guide decisions about future reintroduction for other extirpated species such as Red-cockaded Woodpeckers and will contribute to global avian conservation as information on landbird reintroductions are lacking.



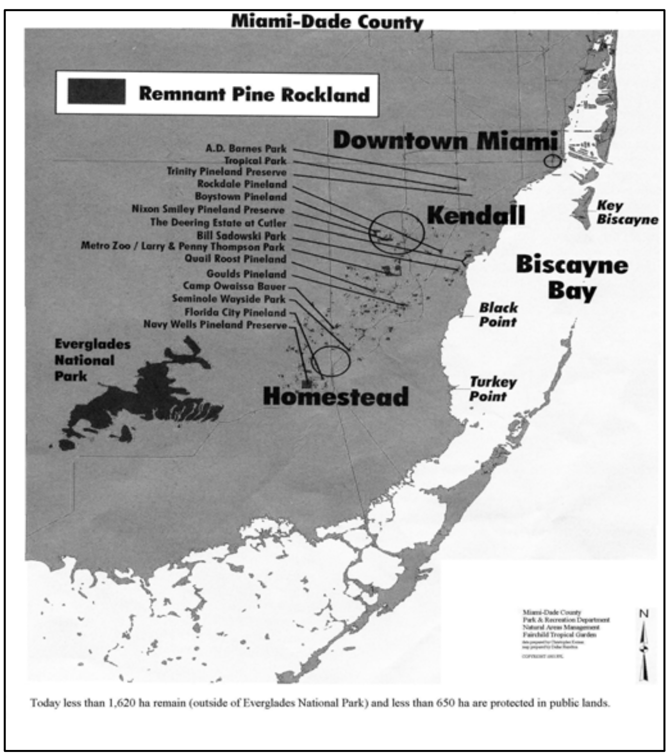


Figure 1. Distribution of Slash Pine forests of the Miami rock ridge in southeastern Florida prior to 1900 (top) and in 1993 (bottom).

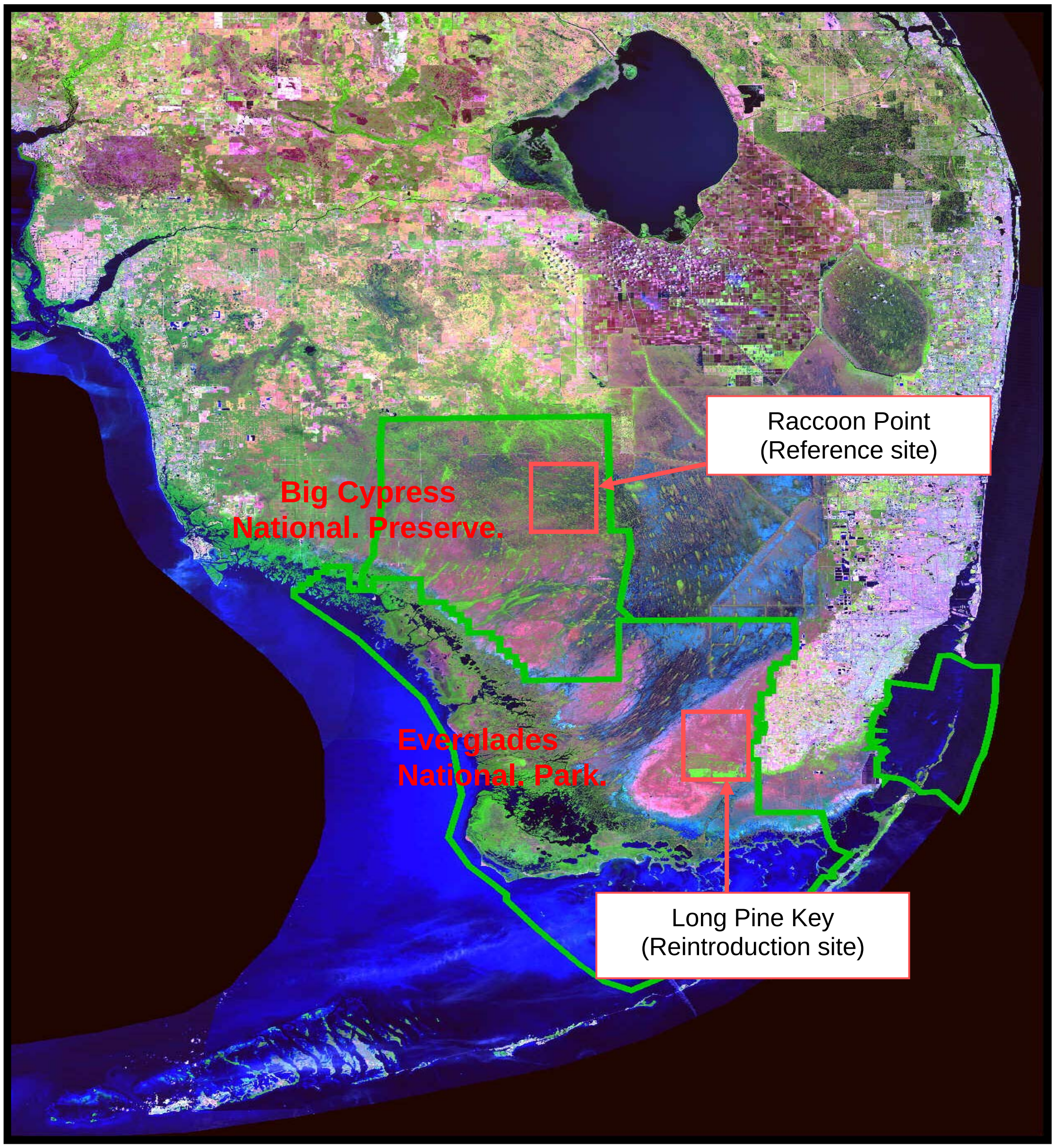


Figure 2. Map of southern Florida National Park Units containing the reintroduction site and the high-quality reference site of the Brown-headed Nuthatch and Eastern Bluebird reintroduction project.

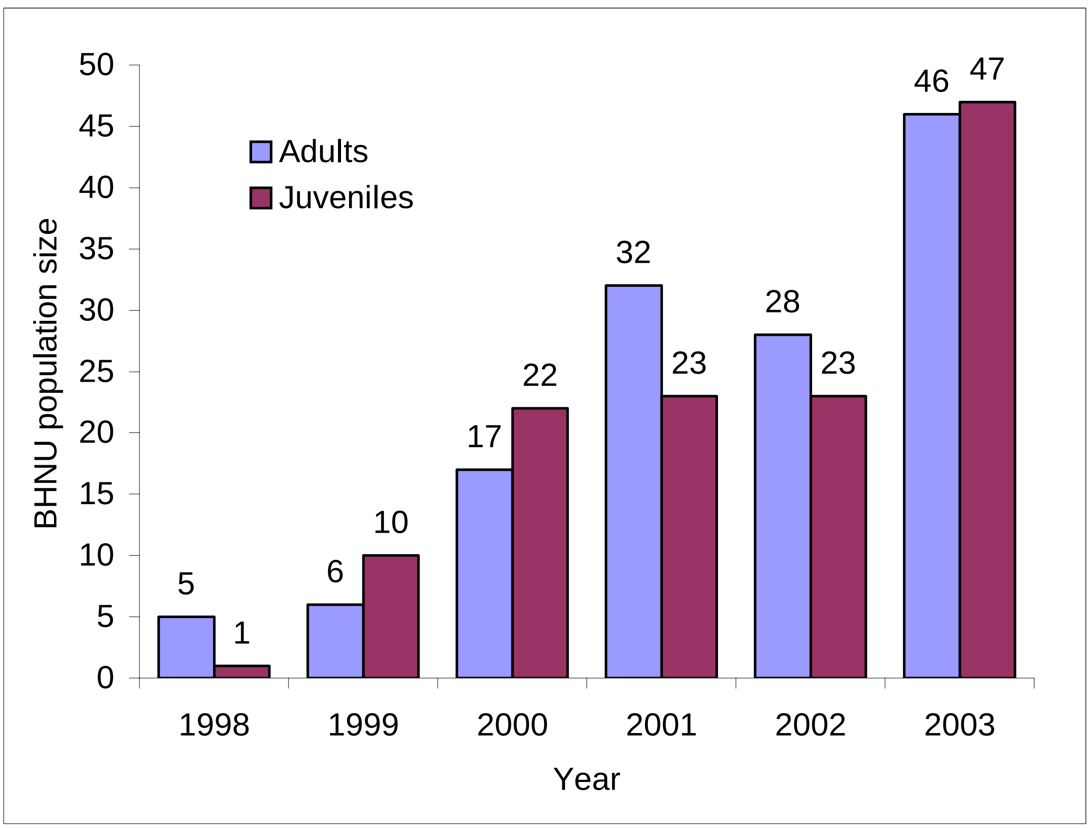
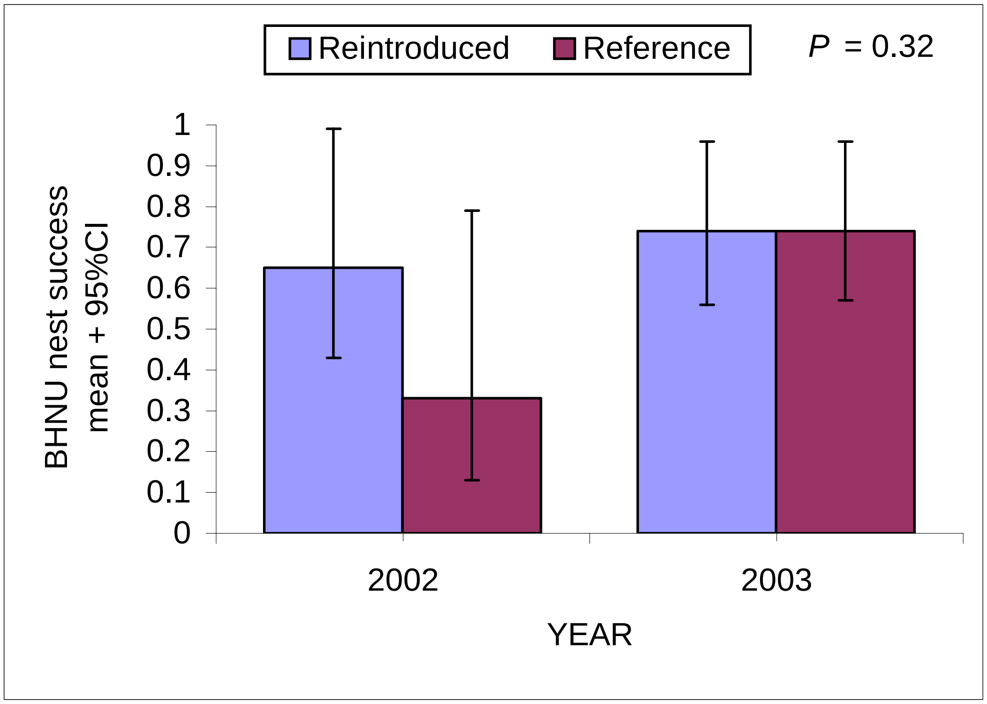


Figure 3. Brown-headed Nuthatch post-breeding season population size in the reintroduced population (LPK) during the period 1998-2003.

Table 1. Brown-headed Nuthatch reproductive measures (± S.E.) and comparisons between the reintroduction site (Long Pine Key, ENP) and the reference site (Raccoon Point, BCNP) between 2002-2003.

	Reintroduction site		Reference site		
	2002	2003	2002	2003	*P*
Territories	19	21	17	20	
Breeding territories	14	19	9	20	
Mean incubation date	28 March (± 5)	16 March (+ 2)	2 April (± 3)	14 March (+ 5)	0.84
Territories successful	9 (60%)	16 (84%)	4 (40%)	15 (75%)	0.15
Daily nest survival	0.9868 (± 0.0067)	0.9905 (± 0.0042)	0.9659 (± 0.0137)	0.9907 (± 0.0042)	0.32
Productivity (no. young/terr)	1.64 (± 0.36)	2.47 (+ 0.32)	0.44 (± 0.15)	1.95 (+ 0.32)	0.02



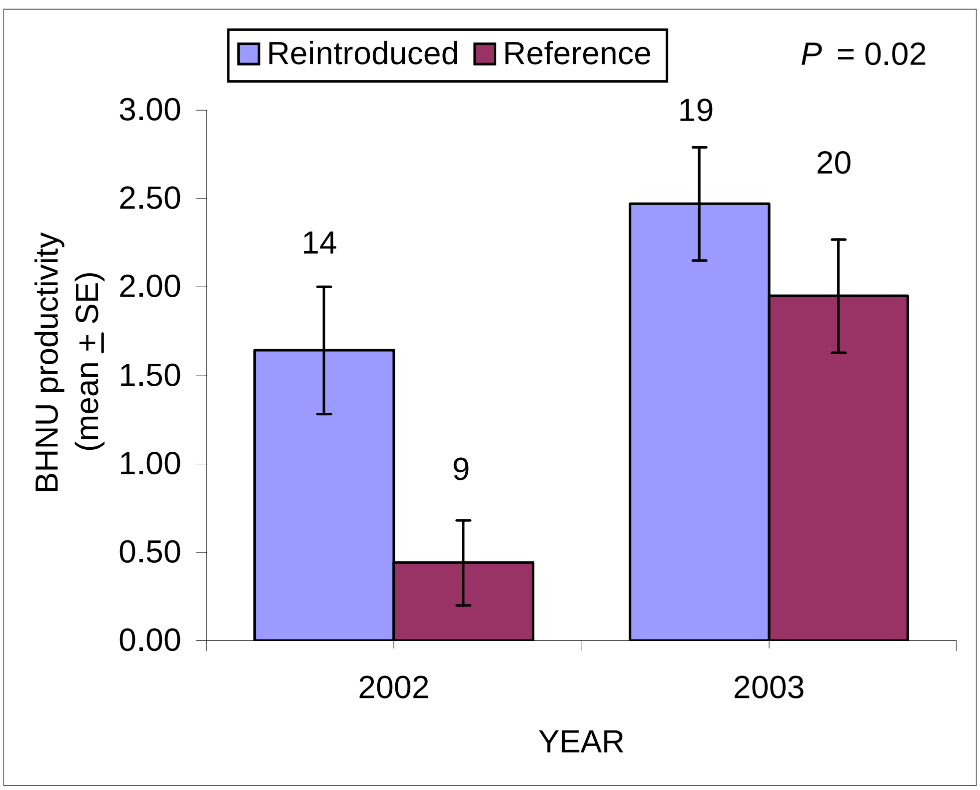


Figure 4. Brown-headed Nuthatch nest success (top) and productivity (bottom) at the reintroduction site and the reference site in 2002-2003.

Table 2. The number of newly marked adult Brown-headed Nuthatches entered into the reintroduced and reference populations each year from 1998-2003.

	1998	1999	2000	2001	2002	2003	Total
Long Pine Key	6	4	14	16	8	17	65
Raccoon Point	3	6	23	11	13	15	71

Table 3. Mark-recapture modeling for Brown-headed Nuthatches in the reintroduction site (Long Pine Key, ENP) and the reference site (Raccoon Point, BCNP) between 1998-2003. Corrected by c-hat = 1.1700000.

Model structure[a]	QAIC	Δ QAIC	QAIC Weights	Likelihood	Parameters	QDeviance
phi(g),p(.)	196.591	0.00	0.84678	1.0000	3	26.593
phi(.),p(.)	200.320	3.73	0.13120	0.1549	2	32.395
phi(g),p(t)	205.137	8.55	0.01180	0.0139	7	26.593
phi(t),p(.)	206.055	9.46	0.00746	0.0088	6	29.687
phi(.), p(t)	208.764	12.17	0.00193	0.0023	6	32.395
phi(g*t),p(.)	211.277	14.69	0.00055	0.0006	11	23.753
phi(t),p(t)	212.665	16.07	0.00027	0.0003	9	29.687
phi(g*t),p(t)	218.315	21.72	0.00002	0.0000	14	23.753

[a] g = group effect of site (reintroduction vs. reference), . = constant, t = time or annual variation.

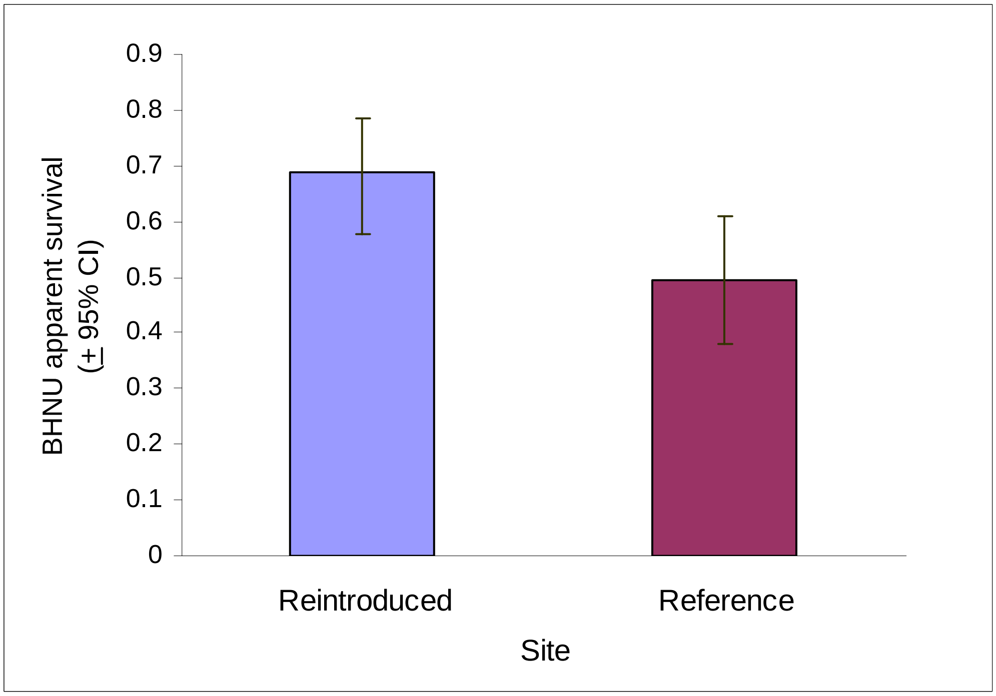


Figure 5. Brown-headed Nuthatch apparent survival as estimated by the best fit model [phi(g),p(.)] in Program MARK.

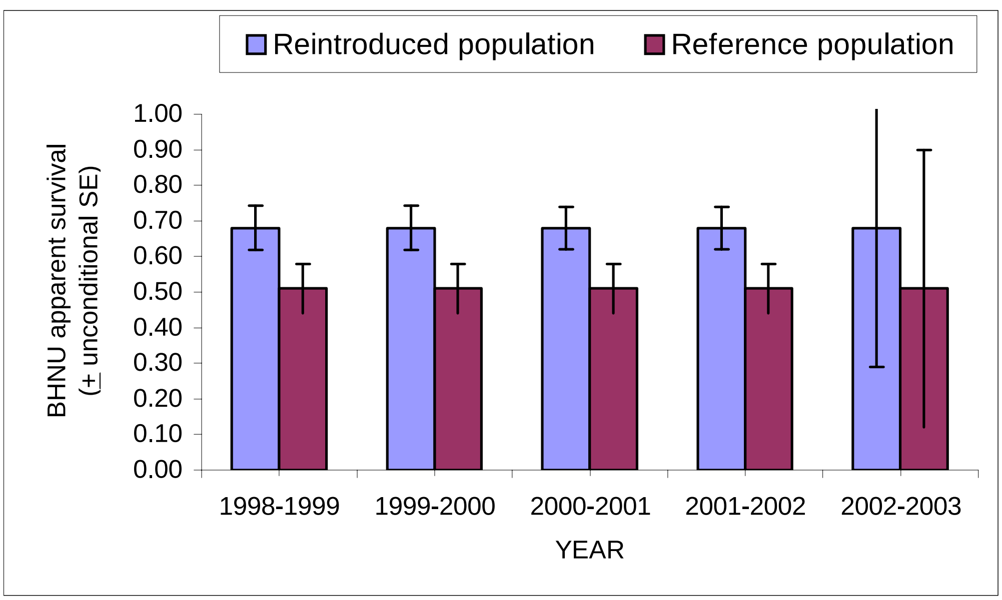


Figure 6. Brown-headed Nuthatch annual apparent survival estimated by modeling averaging for the global and nested models in Program MARK.

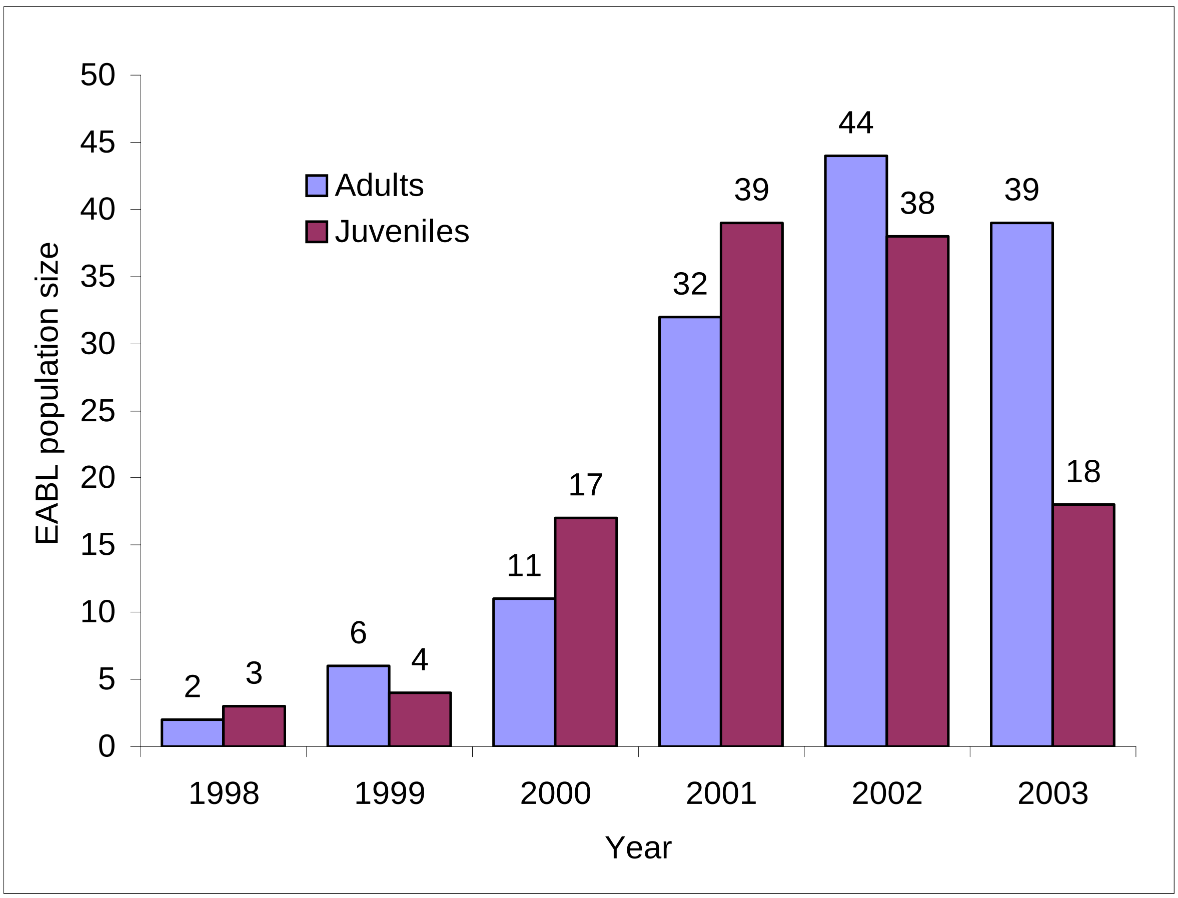
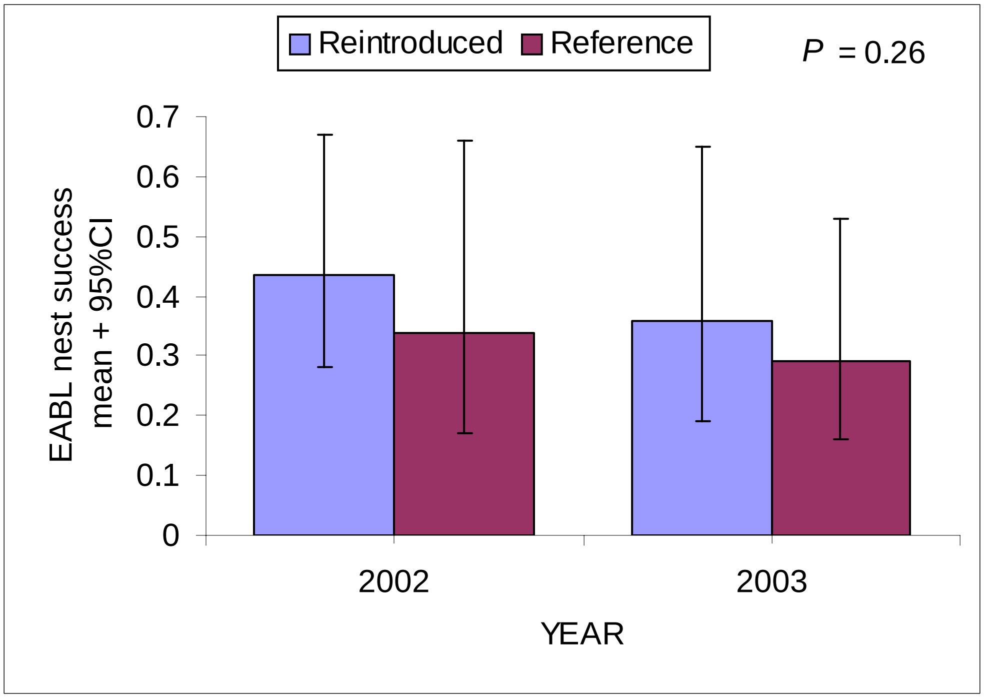


Figure 7. Eastern Bluebird population size in Long Pine Key, ENP between 1998-2003.

Table 4. Eastern Bluebird reproductive measures (± S.E.) and comparisons between the reintroduction site (Long Pine Key, ENP) and the reference site (Raccoon Point, BCNP) between 2002-2003.

	Reintroduced site		Reference site		*P*
	2002	2003	2002	2003	
Territories	23	18	17	24	
Breeding territories	22	16	17	20	
Mean incubation date	19 April (± 3)	1 May (± 3)	21 April (± 4)	15 April (± 4)	0.08
Mean clutch size	3.85 (± 0.19)	3.36 (± 0.20)	3.80 (± 0.37)	3.80 (± 0.20)	0.41
Territories successful	14 (64%)	7 (44%)	7 (41%)	10 (50%)	0.35
Daily nest survival	0.9743 (± 0.0068)	0.9685 (± 0.0094)	0.9667 (± 0.0103)	0.9621 (± 0.0093)	0.26
Productivity (no. young/terr.)	1.73 (± 0.33)	1.20 (± 0.39)	0.88 (± 0.30)	1.45 (± 0.35)	0.40



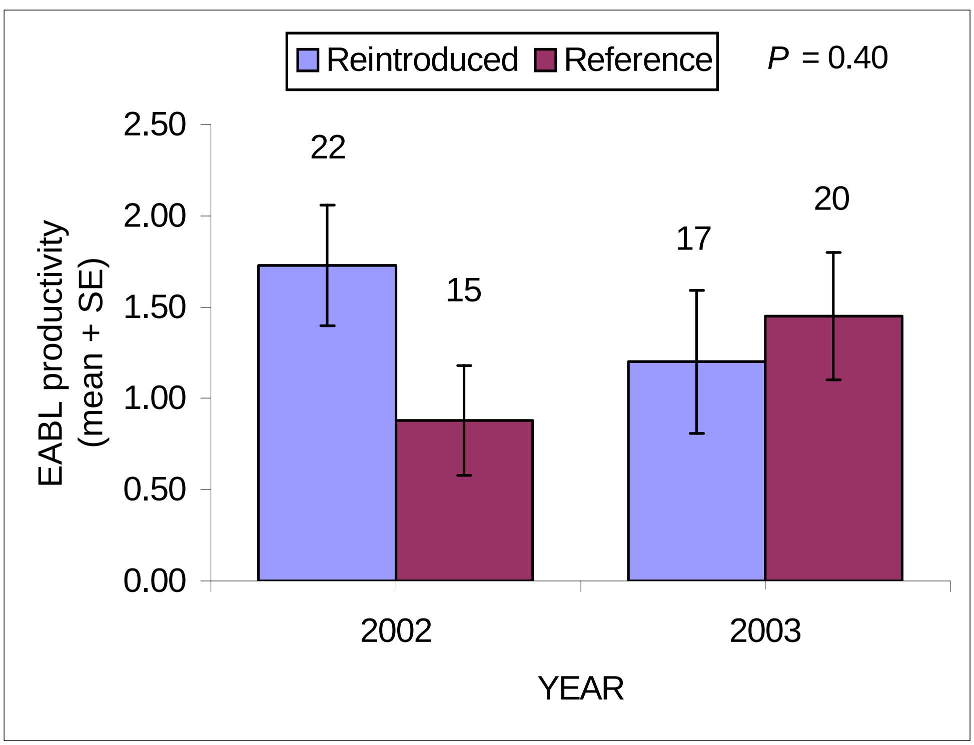


Figure 8. Eastern Bluebird nest success (top) and productivity (bottom) at the reintroduction site and the reference site in 2002-2003.

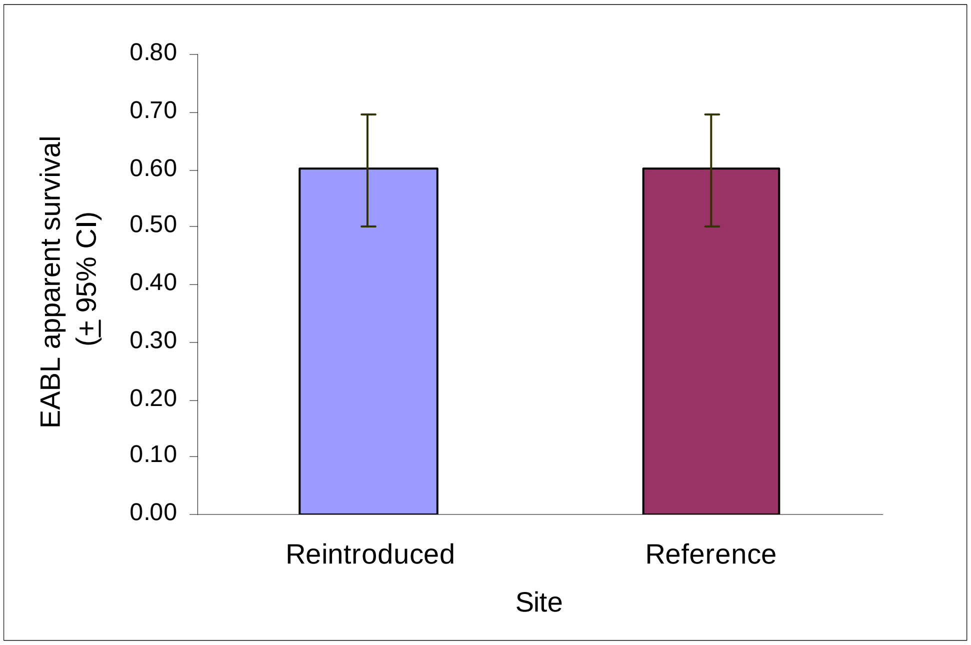
Table 5. The number of newly marked adult Eastern Bluebirds entered into the reintroduced and reference populations each year from 1998-2003.

	1998	1999	2000	2001	2002	2003	Total
Long Pine Key	2	5	10	29	15	8	69
Raccoon Point	2	3	15	13	10	11	54

Table 6. Mark-recapture modeling for Eastern Bluebirds in the reintroduction site (Long Pine Key, ENP) and the reference site (Raccoon Point, BCNP) between 1998-2003. Based on c-hat = 1.45.

Model structure[a]	QAIC	Δ QAIC	QAIC Weights	Likelihood	Parameters	QDeviance
phi(.)p(g)	169.9613	0	0.52010	1.0000	3	33.45969
phi(g)p(g)	172.0529	2.0916	0.18277	0.3514	4	33.44568
phi(t)p(g)	172.4339	2.4726	0.15107	0.2905	7	27.34146
phi(.)p(.)	173.8763	3.915	0.07344	0.1412	2	39.45304
phi(g)p(.)	175.4984	5.5371	0.03264	0.0628	3	38.99674
phi(t)p(.)	176.1102	6.1489	0.02404	0.0462	6	33.20815
phi(t)p(t)	177.7481	7.7868	0.01060	0.0204	8	30.43584
phi(g)p(t)	179.3181	9.3568	0.00483	0.0093	7	34.22566
phi(g)p(g*t)	184.9313	14.97	0.00029	0.0006	12	28.43377
phi(g*t)p(.)	186.296	16.3347	0.00015	0.0003	11	32.14201
phi(g*t)p(t)	188.1656	18.2043	0.00006	0.0001	13	29.29201
phi(g*t)p(g*t)	189.9338	19.9725	0.00002	0	16	23.72984

[a] g = group effect of site (reintroduction vs. reference), . = constant, t = time or annual variation.



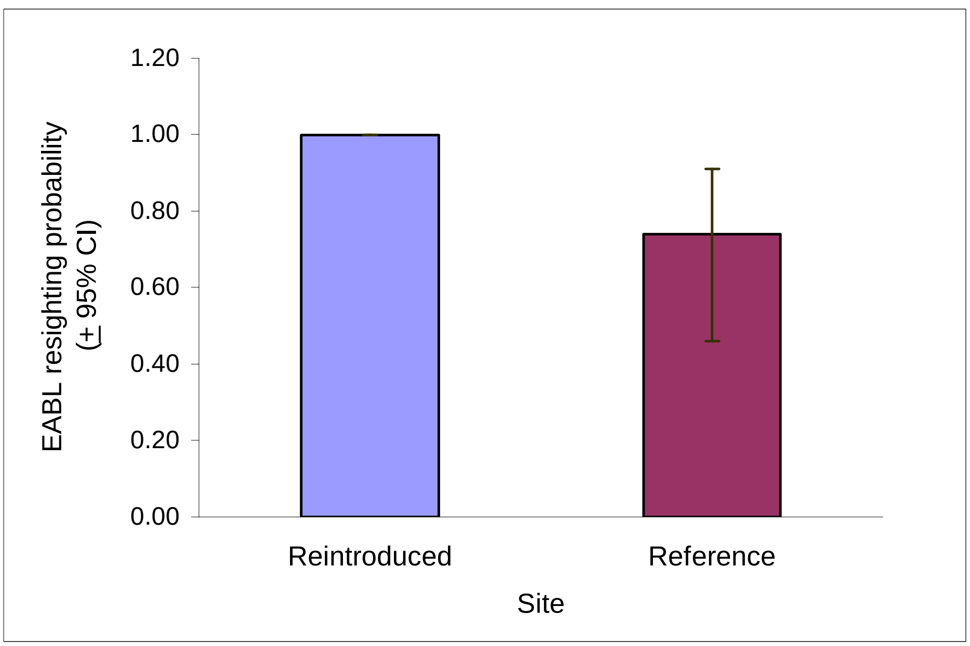


Figure 9. Eastern Bluebird apparent survival (top) and resighting probability (bottom) as estimated by the best fit model [phi(.),p(g)] in Program MARK.

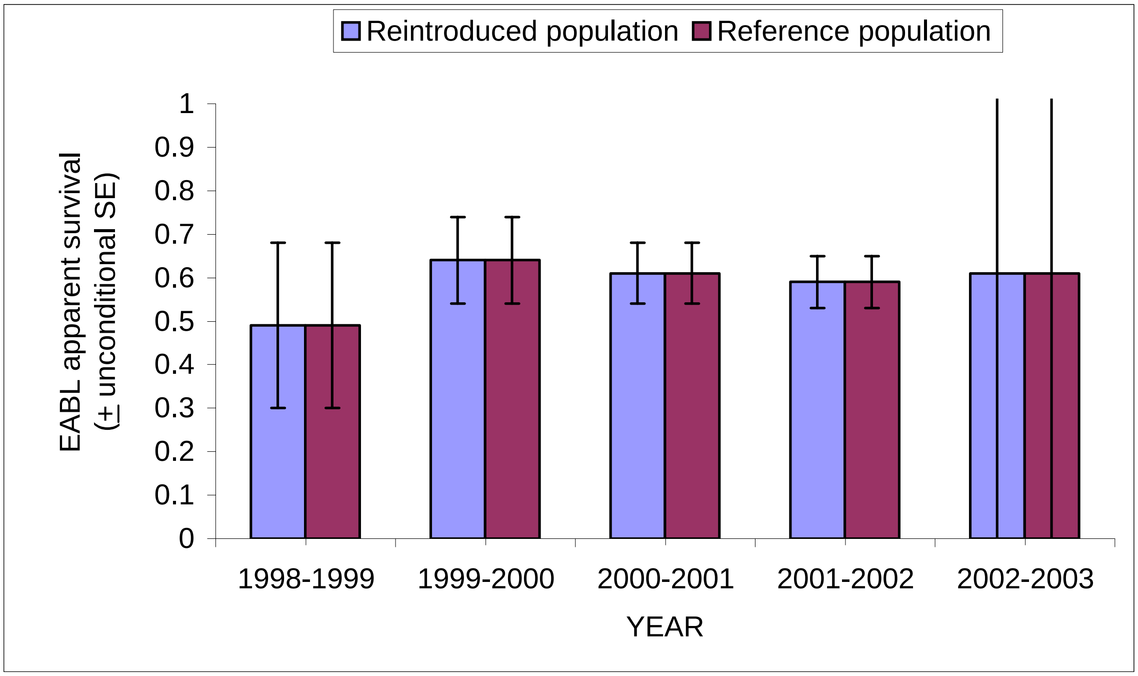
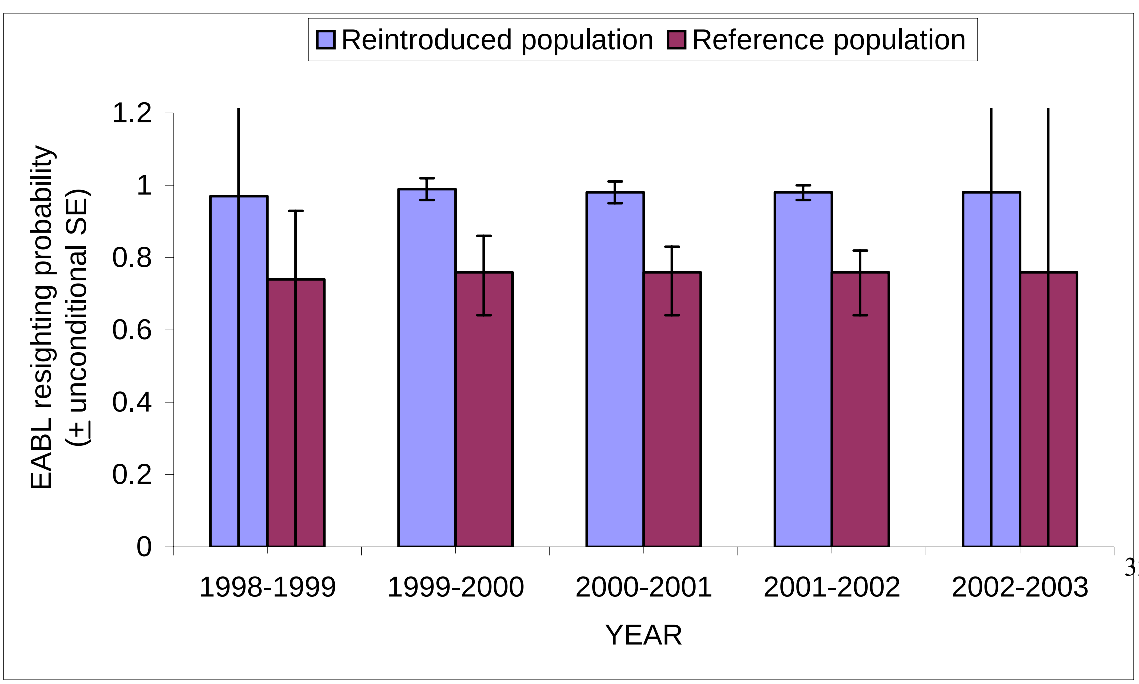


Figure 10. Eastern Bluebird annual apparent survival (top) and annual resighting probability (bottom) estimated by model averaging for the global and nested models in Program MARK.



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