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SURVIVAL OF CAPTIVE-REARED PUERTO RICAN PARROTS RELEASED IN THE CARIBBEAN NATIONAL FOREST

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Abstract. We report first-year survival for 34 captive-reared Puerto Rican Parrots (*Amazona vittata*) released in the Caribbean National Forest, Puerto Rico between 2000 and 2002. The purpose of the releases were to increase population size and the potential number of breeding individuals of the sole extant wild population, and to refine release protocols for eventual reintroduction of a second wild population elsewhere on the island. After extensive prerelease training, we released 10 parrots in 2000, 16 parrots in 2001, and eight parrots in 2002 ranging in age from 1–4 years old. All birds were equipped with radio-transmitters to monitor survival. The overall first-year survival estimate for the 34 parrots was 41% (CI = 22%–61%). Only one parrot died within the first week postrelease, with most (94%) surviving for at least eight weeks after release. Most (54%) documented mortalities were due to raptor predation, which claimed 21% of all released parrots. A captive-reared bird (male, age one), released in 2001, paired with a wild female and fledged two young in 2004. We also calculated survival based on 0% and 50% of observed predation losses and found hypothetical survival rates of 72% and 54%, respectively. Rigorous prerelease training and acclimation was believed to have improved initial postrelease parrot survival, and releasing mixed age-class groups suggests the potential for shortening the time to recruitment.

Key words: Amazona vittata, *captive-reared, mortality, predation, Puerto Rican Parrot, reintroduction, survival.*

Supervivencia de Individuos de *Amazona vittata* Criados en Cautiverio y Liberados en el Bosque Nacional del Caribe

Resumen. Determinamos la supervivencia de 34 individuos de cotorras *Amazona vittata* criados en cautiverio y liberados en el Bosque Nacional del Caribe, Puerto Rico entre el 2000 y el 2002. El propósito de las liberaciones era aumentar el tamaño de la población y el número potencial de individuos reproductores en la única población silvestre remanente, y refinar los protocolos de liberación para eventualmente establecer una segunda población silvestre en la isla. Después de un adiestramiento extensivo, liberamos 10 cotorras en el 2000, 16 cotorras en el 2001, y ocho cotorras en el 2002 fluctuando en edades entre uno y cuatro años. Cada individuo se liberó con un radio transmisor para determinar su supervivencia. La tasa general de supervivencia para 34 cotorras después de un año fue de 41% (IC = 22–61%). Sólo una cotorra murió durante la primera semana post-liberación, con la mayoría (94%) sobreviviendo por lo menos ocho semanas después de liberadas. La mayoría (54%) de la mortandad se debió a la depredación por aves rapaces, la que reclamó 21% de todas las cotorras liberadas. Una cotorra criada en cautiverio (macho, un año de edad), y liberada en el 2001, se apareó con una hembra silvestre y produjeron dos volantones en el 2004. Reduciendo la mortandad por aves rapaces informada en este estudio en un 100%, o en un 50%, resultó en tasas hipotéticas de supervivencia del 72% y 54%, respectivamente. Creemos que el adiestramiento y la aclimatación rigurosa pre-liberación mejoraron la supervivencia inicial post-liberación, y que la liberación de grupos de cotorras de edades mixtas sugiere el potencial de acortar el tiempo de reclutamiento.

INTRODUCTION

Releasing captive-reared individuals to supplement existing populations, or to reintroduce new populations has become a key component of many endangered species recovery efforts (Biggins et al. 1998, Maloney and Murray 2000, Wanless et al. 2002, Brightsmith et al. 2005). Although attempted with a wide variety of taxa, most releases have been conducted with birds and mammals (Griffith et al. 1989, Wolf et al. 1996). In contrast to mammalian releases, where

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most (73%) release stocks have been from wild populations, avian releases are most often (84%) derived from captive populations (Fischer and Lindenmayer 2000). Although a major goal of captive-release programs has been to supplement an extant wild population through an increase in the number of individuals (Griffith et al. 1989), the ultimate objective should be demographic augmentation through an increase in the number of breeding pairs (Beck et al. 1994). Not surprisingly, numerous measures are taken to maximize postrelease survival and thus, increase the likelihood of a species' recovery (Collazo et al. 2000, Wanless et al. 2002). Among them, prerelease training and acclimation can influence postrelease survival by improving physical condition and ameliorating or reversing potentially maladaptive behavioral traits acquired during captive-rearing (van Heezik et al. 1999, Collazo et al. 2003).

In 1997–1999, a pilot release project was conducted in the Dominican Republic using captive-reared Hispaniolan Parrots (*Amazona ventralis*) to develop rigorous ''soft-release'' protocols for future releases of Puerto Rican Parrots (*A. vittata*; Collazo et al. 2000, 2003). These protocols consisted of extensive prerelease training and acclimation, and postrelease supplementation. Designated as an endangered species in 1967 after decades of precipitous population decline (Snyder et al. 1987), the endemic Puerto Rican Parrot is categorized as Critically Endangered by the IUCN Red List (Hilton-Taylor 2000) and is currently among the ten most endangered birds in the world (Wiley et al. 2004). An integral component of the recovery plan for this species includes releasing captive-reared birds to supplement the sole extant wild population in the Caribbean National Forest, estimated at 30–35 individuals, as well as reintroducing a second population in the Karst region of the island where the parrot was once abundant (USFWS 1999, Wiley et al. 2004). Although heavily deforested during the early twentieth century, the Karst region has since become largely reforested and is currently the largest contiguously forested region in Puerto Rico (Rivera and Aide 1998). The existence of two captive populations, totaling about 160 individuals, has made such recovery actions possible (USFWS 1999).

In the Caribbean National Forest, Red-tailed Hawks (*Buteo jamaicensis*) are a major threat to wild Puerto Rican Parrots (Snyder et al. 1987, Lindsey et al. 1994). For this reason, we subjected captive-reared birds to predator-aversion training (McLean et al. 1999, Griffin et al. 2000). Although we could not directly test the hypothesis that the training increased survival, other studies have shown that such training can positively influence postrelease survival (Ellis et al. 1977, van Heezik et al. 1999). Rather, we tested whether trained birds reacted positively to the training prior to release (i.e., exhibited an aversion reaction).

Here we report on first-year survival of 34 captive-reared Puerto Rican Parrots released in the Caribbean National Forest from 2000 to 2002. We also investigated the cause and level of early, postrelease mortality (i.e., within seven days postrelease). As a basic metric of success, we considered first-year survival rates within the normal range reported for wild Puerto Rican Parrot fledglings (i.e., 35%–65%; Snyder et al. 1987, Lindsey et al. 1994) to be indicative of a successful release. We also explored potential gains in survival if losses to raptor predation were lower than in the Caribbean National Forest under two hypothetical scenarios. Finally, we discuss the value of mitigating for sources of postrelease mortality, and of releasing mixed-age cohorts of parrots as a means to potentially shorten recruitment time.

METHODS

STUDY AREA

This study was conducted in the Caribbean National Forest (18°18′N, 65°47′W) located in northeastern Puerto Rico (Fig. 1). This mountainous forest reserve encompasses 19 650 ha of subtropical rainforest ranging in elevation from 200 m to 1074 m. Annual precipitation ranges from 200 cm in the foothills to over 500 cm at the highest peaks, with annual temperatures ranging from 11°C to 32°C, averaging 21°C (Snyder et al. 1987).

Several studies (Wiley et al. 1992, Sanz and Grajal 1998, Collazo et al. 2000) suggest that the best release sites for *Amazona* parrots are within historically occupied habitat. Therefore, we released parrots within, what has been for the past decade, an area of year-round heavy activity by wild Puerto Rican Parrots. The release area was dominated by the palo colorado (*Cyrilla racemiflora*) and tabonuco (*Dacryodes excelsa*) forest types, both of which are important

FIGURE 1. Map of the Caribbean depicting Puerto Rico and location of the Caribbean National Forest and the Rio Abajo Commonwealth Forest (within the Karst forest region) in Puerto Rico (adapted from U. S. Fish and Wildlife Service 1999).

nesting and foraging habitats for Puerto Rican Parrots (Snyder et al. 1987). As such, the release area met all criteria suggested by IUCN Reintroduction Guidelines for suitable release sites (IUCN 1995).

PRERELEASE ACCLIMATION

All release candidates were selected from the captive populations located at the Luquillo Aviary in the Caribbean National Forest, and the José Vivaldi Aviary, located in the Rio Abajo Commonwealth Forest in north-central Puerto Rico (Fig. 1). Parrots were held for approximately four months prior to their release in two large ($9.2 \times 8.0 \times 5.5$ m) outdoor flight cages located at the Luquillo Aviary.

Approximately one month prior to each release, parrots were moved from the flight cages to two adjacent acclimation cages at the release site. Each parrot was fitted with a ''dummy'' transmitter collar to acclimate them to a radiotransmitter (Collazo et al. 2003). During acclimation, the parrots were also subjected to flight conditioning to maintain physical stamina (Collazo et al. 2003).

Predator-aversion training, although implemented in 2000, was intensified in 2001 by exposing parrots to a series of events (four phases) that, in the wild, would actually culminate in predation. Wild parrots presumably learn appropriate predator recognition and responses from wild parents, a benefit unavailable to naïve captive-reared birds (McLean et al. 1999, Griffin et al. 2000). Thus, we used these events to simulate predator encounters in the hopes of increasing survival of captive-reared birds. Phase One consisted of exposing the parrots to a hawk ''whistle-call'' combined with a flyover of a hawk silhouette (via a cable and pulley system suspended over the cage). This training phase was designed to establish the parrots' baseline response to the stimulus. One hour later, the same exercise was repeated (Phase Two) combined with a simulated attack on the release cage by a trained live Red-tailed Hawk. The next hour (Phase Three), the live hawk was again released after passage of the silhouette and allowed to actually attack a tethered Hispaniolan Parrot in the presence of the caged Puerto Rican Parrots. The Hispaniolan Parrot, the most closely related congener to the Puerto Rican Parrot (Snyder et al. 1987), was used as a functional surrogate of the Puerto Rican Parrots. Although the hawk was controlled on a leash, the Hispaniolan Parrot was also equipped with a protective covering that prevented injury to the parrot from the hawk's talons. One hour after Phase Three, the initial training phase (i.e., whistle call and silhouette) was repeated (Phase Four) to document the parrots' post-treatment responses to the initial stimulus. Parrot responses were videotaped and categorized as either ''vigilant'' (hiding, ''freezing'' in place, or visually scanning the canopy) or ''nonvigilant'' (constant movement or vocalizations; Lima and Dill 1990). We used a McNemar test (Sokal and Rohlf 1981) to evaluate pre- and post-treatment differences in numbers of parrots exhibiting vigilant versus nonvigilant behaviors. We assumed that vigilant behavior by parrots conferred some advantage in the presence of avian predators, based on responses to predators by similar species (Ellis et al. 1977, Westcott and Cockburn 1988).

Parrots showed a strong positive response ($G = 25.7$, $P < 0.001$) to the predator-aversion training. Overall, 84% of birds ($n = 25$) exhibited increased vigilance behavior following exposure to the exercise. None of the birds exhib-

TABLE 1. Survival data for 34 captive-reared Puerto Rican Parrots released in the Caribbean National Forest, Puerto Rico, 2000–2002.

Year released	Number released		Age[1]				Alive		Dead		Fate unknown		Raptor predation	
	F	M	1	2	3	4	F	M	F	M	F	M	F	M
2000	5	5	5	0	3	2	1	4	4	1	0	0	2	1
2001	6	10	9	5	2	0	0	3	1	4	5	3	1	1
2002	1	7	5	3	0	0	1	1	0	3	0	3	0	2
Totals	12	22	19	8	5	2	2	8	5	8	5	6	3	4

[1] Age in years at time of release.

ited a decrease in vigilance following the training.

Approximately one week prior to release, dummy collars were removed and a functioning radio-transmitter was attached to each parrot. We used Holohil (Carp, Ontario, Canada) Type SI-2C transmitters modified from a design by Meyers (1996). All transmitters operated in the frequency range of 164–166 mHz.

RELEASE AND MONITORING

Captive-reared Puerto Rican Parrots were released over 3 years (2000–2002, Table 1). We released 10 parrots on 27 June 2000. Sixteen more were released on 18 May 2001. A third group of nine was released on 14 May 2002; however, one lost its transmitter immediately upon release, and was not included in survival analyses. Released parrots ranged in age from one to four years old (Table 1). We released multiple age classes in an effort to potentially shorten the time to recruitment, thereby amplifying the demographic impact of released birds (Sarrazin and Legendre 2000).

Parrots were released at dawn. Supplemental feeders were provided and relocated every three to four days to encourage birds to search for food in different locations. Supplemental feeding continued for 10–14 days, albeit decreasingly, until birds ceased visitation.

Telemetry of the released parrots began immediately following each release. Most radio-tracking was done from canopy-level observation platforms (20–35 m above ground), or from strategic points along roads and trails. Attempts were made to locate birds three to four times per week for the duration of the life of the transmitter (10–14 months) or parrot. If telemetry indicated that a parrot had not moved in two to three days, a concerted effort was made to locate the individual and visually determine whether it was still alive.

SURVIVAL ANALYSES

We used the Kaplan-Meier procedure to estimate weekly and annual survival (Pollock et al. 1989, Collazo et al. 2003). We report first-year survival rates for each release group (years 2000, 2001 and 2002), as well as weekly survival and first-year survival rates for all birds combined. Data were pooled such that sampling intervals (i.e., weeks postrelease) for each group matched. We were justified in pooling data because each release occurred at the same site and during the same time period (May–June) each year, and all prerelease treatments were similar. The only difference among years in prerelease treatments was that protocols for the predator aversion training were better defined (i.e., systematically quantifying responses by parrots) for birds in 2001 and 2002 than for birds in 2000. We used 53 weeks from the date of each release as the cutoff point for estimating first-year survival. We assumed that there were no age-specific differences in survival among birds. Because parrots are gregarious, we violated the assumption of independent survival probability among individuals within each release group. Therefore, our estimates could have yielded narrower precision levels, although it is not known by how much (Collazo et al. 2003).

To determine how different levels of raptor predation may influence survival, we estimated first-year survival rates for released parrots using two hypothetical levels of raptor predation: namely, no losses and 50% of the losses reported in this study. The former level is justified because it mirrors the low level of raptor predation (4%) following experimental releases of Hispaniolan Parrots in the Dominican Republic (Co-

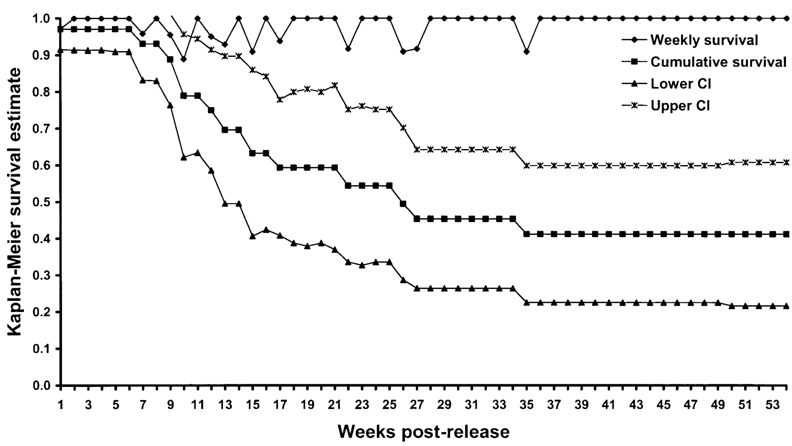

FIGURE 2. Combined weekly and cumulative survival rates for all 34 captive-reared Puerto Rican Parrots released from 2000–2002, Caribbean National Forest, Puerto Rico. Estimates were based on the Kaplan-Meier estimator. Data were pooled so that weeks postrelease matched for each group. Lower and upper CI's are the 95% lower and upper confidence intervals.

llazo et al. 2000, 2003). The 50% level was arbitrarily selected to illustrate potential gains if raptor predation was half of that recorded in this study. Using the estimate of survival for all birds combined across years, hypothetical estimates were obtained by removing all or systematically half of known predation losses over time. Kaplan-Meier survival estimates are reported with their 95% lower and upper confidence intervals, and data are reported as mean ± SE. Statistical significance was accepted at $P \leq 0.05$.

RESULTS

The first-year survival estimate for birds released in 2000 was 50% (CI = 19%–81%), for birds released in 2001 survival was 45% (CI = 7%–83%), and for 2002 survival was 48% (CI = 0%–95%). For all years combined, the survival estimate for all released parrots was 41% (CI = 22%–61%; Fig. 2). Of the 34 parrots released, 13 (38%) were confirmed as dead, 10 (30%) were known to be alive 53 weeks after release, and the fate of 11 (32%) was unknown (radio signal lost; Table 1). Only one parrot died within the first week following release. Most (94%) released parrots survived at least eight weeks after being released. Most (54%) deaths occurred 9–17 weeks postrelease (i.e., August–October), with only one death recorded after 27 weeks postrelease (Fig. 2).

Of the 13 known mortalities, seven (54%) were conclusively caused by raptor predation. This assertion was based on physical evidence of talon punctures in skeletal remains, or dismembered parrot remains and transmitters found lodged in epiphytes several meters above ground. The cause of the remaining deaths could not be ascertained, although disease or additional raptor predations cannot be discounted. Raptors were responsible for the loss of at least 21% of all released Puerto Rican Parrots. In the absence of raptor predation, the hypothetical first-year survival of all captive-reared birds would have been 72% (CI = 53%–91%), and with half of the observed raptor predation first-year survival would have been 54% (CI = 34%–74%).

During the 2004 breeding season, three previously released captive-reared parrots attempted to nest. One breeding pair consisted of a captive-reared male and female, both released in 2002 at the age of two years and one year old, respectively. Unfortunately, this nesting attempt was unsuccessful. The other nesting attempt comprised a wild female and a captive-reared male released in 2001 at the age of one year old. This pair successfully fledged two chicks from a tree cavity traditionally used by wild parrots.

DISCUSSION

Captive-reared Puerto Rican Parrots were successfully released in the Caribbean National Forest. For all years combined, first-year survival was 41%, similar to that of wild Puerto Rican Parrot fledglings (Snyder et al. 1987, Lindsey et al. 1994; U.S. Fish and Wildlife Service, unpubl. data). However, precision of first-year survival estimates for individual release groups was markedly poor. Difficulties in tracking birds often resulted in several missing radio signals during any given weekly sampling interval. Loss of radio signals effectively reduced the number of animals ''at risk'', and thus, lowered the precision of estimates (Pollock et al. 1989, Zehfuss et al. 1999). We were encouraged, however, by the similarities in point estimates and annual survival trajectories. They suggest that the potential influence of postrelease environmental conditions was not markedly different among years, and that the overall survival estimate (41%) provides a reasonable, comprehensive indicator of survival.

The majority of mortalities recorded in this study coincided with parrots' dispersal from the release area. Most birds of each release group remained together and relatively near (<500 m) the release site for six to eight weeks postrelease (U.S. Fish and Wildlife Service, unpubl. data). These results are in contrast to Collazo et al. (2003) who reported that higher survival of released Hispaniolan Parrots was related to increased dispersal. The loss of at least 21% of 34 released parrots to raptors is also in sharp contrast to Collazo et al. (2003), who reported losses to raptors of only 4% during experimental releases of Hispaniolan Parrots. These differences are probably artifacts of the differences between release environments. In Parque Nacional del Este, Dominican Republic, released Hispaniolan Parrots dispersed into an area of low raptor density and joined a large resident population (Collazo et al. 2000). In contrast, Puerto Rican Parrots dispersed mainly into areas void of resident Puerto Rican Parrots and into areas with a relatively high density of raptors (Snyder et al. 1987, Rivera-Milan 1995). Raptors preyed upon Puerto Rican Parrots that were either solitary or accompanied by only one other released bird (THW, pers. obs.). Apparently, once released parrots lost the benefits accrued from flocking (Westcott and Cockburn 1988, South and Pruett-Jones 2000), they became more vulnerable to predation. Snyder et al. (1994) reported a similar pattern of raptor predation for Thick-billed Parrots (*Rhynchopsitta pachyrhyncha*) released in Arizona.

It is possible that the radio-transmitters predisposed some parrots to predation, however we do not believe this is the case. The neck-mounted SI-2C transmitter configuration (Meyers 1996) is relatively small, visually unobtrusive and weighs less than 4% of the average body weight (280 g) of an adult Puerto Rican Parrot. Moreover, once fitted to a parrot, the parrot's neck feathers tend to cover and partially obscure the device from view. Further, all parrots were acclimated to the device for one month prior to release (see Collazo et al. 2003). Although there are no comparable data on predation of nonradio-tagged Puerto Rican Parrots, Snyder et al. (1994) reported no differences in predation between Thick-billed Parrots released with and without radio transmitters.

Equally important was documenting nesting attempts by a pair of released parrots and the successful pairing of a third released individual with a wild bird to produce two young in 2004. All three of these release survivors either attempted or bred successfully by age four. This was encouraging, given that a fundamental goal of the release program was not only to numerically supplement the wild population, but also to increase the breeding population. The minimum time elapsed from release to nesting (two years) was less than the minimum reproductive age for the species (three to five years; Snyder et al. 1987), suggesting that releasing mixed-age cohorts of parrots (e.g., one to four years old) may potentially shorten time to recruitment, an important consideration when attempting to reintroduce new populations (Beck et al. 1994, Brightsmith et al. 2005). In Peru and Costa Rica, released captive-reared Scarlet Macaws (*Ara macao*) also formed breeding pairs with resident wild birds, and several reproduced within 2–4 years after release (Brightsmith et al. 2005).

These results have important implications for reintroduction plans of a second population of Puerto Rican Parrots in north-central Puerto Rico (USFWS 1999, Wiley et al. 2004). The anticipated reintroduction area (Karst region) has a significantly lower density of Red-tailed Hawks (0.23 $\pm$ 0.05 per km^2; n = 87 count stations) than in the Caribbean National Forest (1.56 $\pm$ 0.25 per km^2; n = 84 count stations; Z = 5.3, $P < 0.001$; Rivera-Milan 1995; Rivera-Milan, unpubl. data). We believe that such differences could result in lower predation pressure, and hopefully, increased postrelease survival as suggested by our hypothetical scenarios.

Differences between release environments also highlight the importance of minimizing manageable sources of mortality (e.g., early postrelease mortality) to mitigate others (e.g., raptor predation). For example, only one Puerto Rican Parrot died within the first week after release. In contrast, Snyder et al. (1994) reported that, in the absence of rigorous prerelease protocols, 30% of released Thick-billed Parrots died within one week of release. These early postrelease losses may amplify the cumulative impact of losses to other factors, such as predation (Snyder et al. 1994). We believe that extensive and intensive prerelease protocols helped to minimize early postrelease mortality of released Puerto Rican Parrots, similar to the work by Collazo et al. (2003) in which improvements in prerelease training increased postrelease survival.

For highly social or flocking species such as parrots, minimizing early postrelease mortality may also yield group survival benefits. For example, Ellis et al. (2000) reported that high survival of hand-reared Mississippi Sandhill Cranes (*Grus canadensis pulla*) was due, in part, to postrelease association with parent-reared (i.e., more savvy) members of their release groups. Similarly, Brightsmith et al. (2005) found that maximizing and maintaining postrelease social interactions of captive-reared Scarlet Macaws promoted higher long-term survival. Intuitively, the immediate postrelease period likely constitutes the steepest part of the transitional learning curve for adapting to the release environment. Accordingly, early postrelease losses may effectively reduce efficiency of social learning and attendant survival benefits (Curio 1988, Griffin et al. 2000).

We sought to improve the predator awareness of captive-reared parrots by a realistic, stimulus-based training exercise. While we cannot assert that such training prevented postrelease losses, results and recommendations from other studies suggest that it might (Sanz and Grajal 1998, McLean et al. 1999, van Heezik et al. 1999, Griffin et al. 2000). However, we demonstrated that parrots developed some level of aversion, which might be advantageous during the days following their release. Predator-aversion training could be particularly valuable for other avian species released in similar high predation environments. Releasing birds into environments where such limiting factors are minimal should only amplify survival gains accrued via appropriate prerelease training. We believe that the transient stress to individuals during aversion training is justified by the potential for gains in survival at the population level, and thus, reductions in extinction probabilities (Brook et al. 1997, Todd et al. 2002). We concur with McLean et al. (1999) in their assertion that knowingly releasing naïve captive-reared animals into a high predation environment without at least some form of aversion training borders on the unethical.

We reiterate the recommendation of Collazo et al. (2003) for employing standardized release protocols and quantifying vital parameters to gauge the success of release programs. Although not all captive releases will require, or benefit from, the same levels of prerelease training (Brightsmith et al. 2005), using standardized procedures facilitates valid comparisons and extrapolation of results to other populations and species. We conclude that protocols used in this work, coupled with releasing multiple age-classes of parrots, are effective recovery tools for the extant population of Puerto Rican Parrots in the Caribbean National Forest and may increase the likelihood of successfully reintroducing a second population of parrots elsewhere on the island. Release programs for other captive-reared birds should conduct thorough *a priori* evaluations of potential postrelease mortality factors and adapt prerelease training accordingly. With any endangered species release program, as cumulative data become available, analyses should also explicitly examine the effects of covariates on survival (e.g., sex, age, food dispersion, and abundance).

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