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Free Flight Training as a Tool for Psittacine Reintroductions

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Simple Summary: Macaw and parrot populations are declining because of a combination of habitat loss and capture for the illegal trade. As a result, IUCN Red List data suggest many are candidates for captive-based conservation efforts. Unfortunately, when captive-raised parrots are released, many fly off and get lost in the landscape or get killed by predators, making it difficult to establish new populations. Previous research suggests that pet parrots trained using free flight methods can form good flocks in flight, avoid predators, and navigate well, all skills that should help them survive in the wild. Here, we conduct a small-scale, proof-of-concept study using free flight methods and three already trained adults in the release of six captive-bred Blue-and-yellow Macaws in southeastern Brazil. All six released birds stayed together and remained near the release site, avoided predators, learned to feed themselves, and survived without supplemental feeding for over one year. One bird was captured and briefly held by local people but was recovered and rereleased and is doing well. This work suggests that free flight training can help captive-raised parrots survive release into the wild and make it easier to establish new populations of parrots and macaws in areas where they have gone extinct.

Abstract: As habitat loss and other threats accelerate, ecological restoration and reintroduction science are becoming progressively more important. The psittacines are among the most endangered bird groups and are prime candidates for restoration through reintroduction. Unfortunately, post-release survival of captive-raised animals is often quite low because, in part, of high predation rates, low site fidelity, poor flight ability, and low flock cohesion. Current best practices in parrot release hold the birds in captivity for a year or more and include distinct methods to address each of these challenges. Here, we conduct a small-scale, proof-of-concept study using free flight methods and human-socialized trained adult birds to hand raise and release a group of six fledgling Blue-and-yellow Macaws in their historical range in southeastern Brazil. All six released birds showed strong flock cohesion and fidelity to the release site, avoided predation, and survived without supplemental feeding for over one year. One bird was captured by local people but was recovered and rereleased and it has reintegrated into the group and is still alive and doing well. The human-socialized trained adult birds modeled both desirable behaviors (flocking, foraging, reacting to predators) and undesirable behaviors and they were returned to captivity before the conclusion of this study. Our study suggests that free flight training has great potential to help captive-raised young attain a broad array of vital skills needed for survival post-release.

Keywords: flock cohesion; site fidelity; predator avoidance; survival skills; psittaciformes; animal training; mentor birds; reintroduction

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1. Introduction

The earth is currently undergoing a mass extinction event, which necessitates the use of increasingly intensive interventions to conserve biodiversity. In response to these needs, the fields of ecological restoration and reintroduction science are becoming progressively more important to help restore ecosystems and wildlife populations [1,2]. Psittaciformes (parrots, macaws, and their allies) is one of the most endangered avian bird orders, and the IUCN Red List suggests that ~50 species could benefit from ex situ conservation [3,4]. Ongoing reintroduction projects have re-established the previously extinct-in-the-wild Spix's Macaw and saved the Puerto Rican Parrot from extinction in the wild [2,5]. Despite these and other outstanding successes, reintroduction science is still beset with a variety of difficulties.

Survival rates of released animals are often notoriously low, and, unfortunately, first-year survival rates for released psittacines are often ≤50% ([6–10], but see these noteworthy exceptions [2,11–13]). The relatively low survival rates of psittacines are driven by a variety of factors, chief among them being predation and rapid dispersal from release sites [8,14,15]. High predation rates are often driven by poor predator recognition, group cohesion, and flocking skills [6,15]. Dispersal away from the release site usually leads to increased predation rates and reduced social interactions, making it more difficult for the new population to overcome the post-release Allee effects associated with low densities and small population sizes [2]. These problems are often more pronounced during the first releases into habitat without conspecifics, but they may have less impact once a core flock of released individuals is established at the site [13].

To overcome these challenges, psittacine release projects often use a piecemeal approach, with different methods used to address each key challenge. To reduce predation, prerelease predator recognition training has used attacks by live raptors, moving stuffed foxes, cutouts of jaguars, and other similar methods [15–18]. To increase site fidelity and group cohesion, release candidates are often held on site for extended periods before release, supplemental food is provided post-release, and captive conspecifics are held at the release site [2,5,13]. To increase flight ability, large prerelease aviaries are often used [5], with some projects providing specific flight training in these prerelease aviaries [18]. To improve foraging post-release, wild foods are commonly provided prerelease [8]. Another method to help prepare captive-raised birds for release and to increase the number of birds released is the integration of more experienced, wild-caught individuals into release groups [5,6,19]. Despite these diverse methods, problems of predation, site fidelity, and cohesion remain in many release projects.

Free flight training is a technique developed by parrot owners to train hand-raised parrots to fly outdoors [20,21]. In this method, birds are first encouraged to fly from point to point in a controlled environment (like inside an aviary) and then encouraged to fly increasingly longer distances outside under increasingly difficult conditions [22]. After training, the trainer recalls the birds to captivity. However, over time, the birds are gradually allowed to spend longer and longer times unsupervised outdoors until they can remain out in the wild on their own. When such training is begun around fledging age, birds naturally develop a broad array of vital survival skills. Woodman et al. [22] reported that of 37 parrot chicks that were free-flight-trained, 100% showed good flocking, group cohesion, predator recognition, and foraging on natural foods, and 0% were taken by predators during multiple years of exposure in an environment with a high diversity and abundance of avian predators. These birds also learned to navigate effectively in the landscape, with none of them lost to unexpected dispersal. In that work, Woodman et al. [22] hypothesized that adult birds trained using free-flight techniques could be used as a resource to help release candidates navigate in the landscape and learn skills like predator recognition, flocking, and foraging.

For free flight training, young birds are hand-raised and encouraged to fly during training by rewarding them with a hand-feeding formula [22]. In this way, the chicks interact with the environment and learn new survival skills, but the dependence on hand-feeding keeps them close to their human caretakers. In conservation release projects, approaching humans post-release is often undesirable and problematic [14,23,24]. However, trainers have noted that around weaning age (when hand-feeding ends and the birds transition to eating solid foods on their own), the bond between the chicks and trainers naturally weakens (CB pers. obs.). This weakening bond is not unexpected because parrots naturally disperse away from their parents after allofeeding ends and before their parents go to nest the next season [25–27]. These trainers' observations also match Brightsmith et al.'s [13] suggestion that when hand feeding and providing affection are terminated around weaning age, macaws do not approach humans post-release.

Free flight-based prerelease training speaks to current major issues in the release preparation of captive animals. Free flight training capitalizes on the innate behavioral plasticity and learning ability of young captive-bred birds. This training creates adaptive behavior rather than the expected maladaptive behaviors caused by captivity [28]. The expected deficits of typical captive-bred behavioral phenotypes [29] are avoided through the creation of wild-type behaviors.

In this study, we use commercially bred, hand-raised Blue-and-yellow Macaws (*Ara ararauna*) to test the general idea that free flight training can be used to raise and release psittacines successfully with all the necessary skills to survive in the wild. Here, we use a limited number of release birds to conduct a preliminary, proof-of-concept study to test the following specific hypotheses: (1) macaw chicks that are hand-raised and released using free flight training techniques: (a) have high survival post-release, (b) have high flock cohesion, (c) have high site fidelity, (d) navigate effectively in the landscape, (e) effectively avoid predators, and (f) survive on natural foods; (2) macaw chicks raised using free-flight techniques will sever bonds with human caretakers as they wean from hand-feeding; and (3) adult conspecifics raised using free flight training can be used as resource to help release cohorts learn vital survival skills.

2. Materials and Methods

2.1. Study Site

This study was conducted at a private ranch of 50 ha (21°24.356′ S, 47°25.857′ W) in the state of Sao Paulo near the city of Santa Rosa de Viterbo. The site is located in the Atlantic semi-deciduous forest vegetation type in the Brazilian Atlantic Forest [30] in the subtropical moist forest Holdridge Life Zone [31]. The area has a highly fragmented mixture of native forest patches, agricultural fields (mostly sugar cane and corn), citrus orchards, and cattle pasture. The ranch raises cattle and has two full-time employees (relatives of HM) and three farm dogs. Other local people also visited the ranch irregularly throughout this study, mostly on weekends.

2.2. Research Team and Project Structure

The field team consisted of only 2 people. HM was the project lead and was on site regularly from 23 April 21 to early February 2022, during which he conducted training, feeding, and monitoring. CB is an experienced parrot trainer and instructor who was at the site from 22 April to 21 June and conducted flight training and feeding of all release candidates. HM took CB's online parrot training course in 2017 (see https://www.libertywings.com/ for more information on the course, accessed on 6 August 2024) and since that time has been free-flying the three pet Blue-and-yellow Macaws that were used as the temporary kernel flock (see the Section 2.4 Temporary Kernel Flock below). This manuscript focuses on only a portion of the full scope of reintroduction using free-flight methods, specifically the use of the kernel flock and the training and release of the first two cohorts of juveniles to establish a core flock on site (Figure 1).

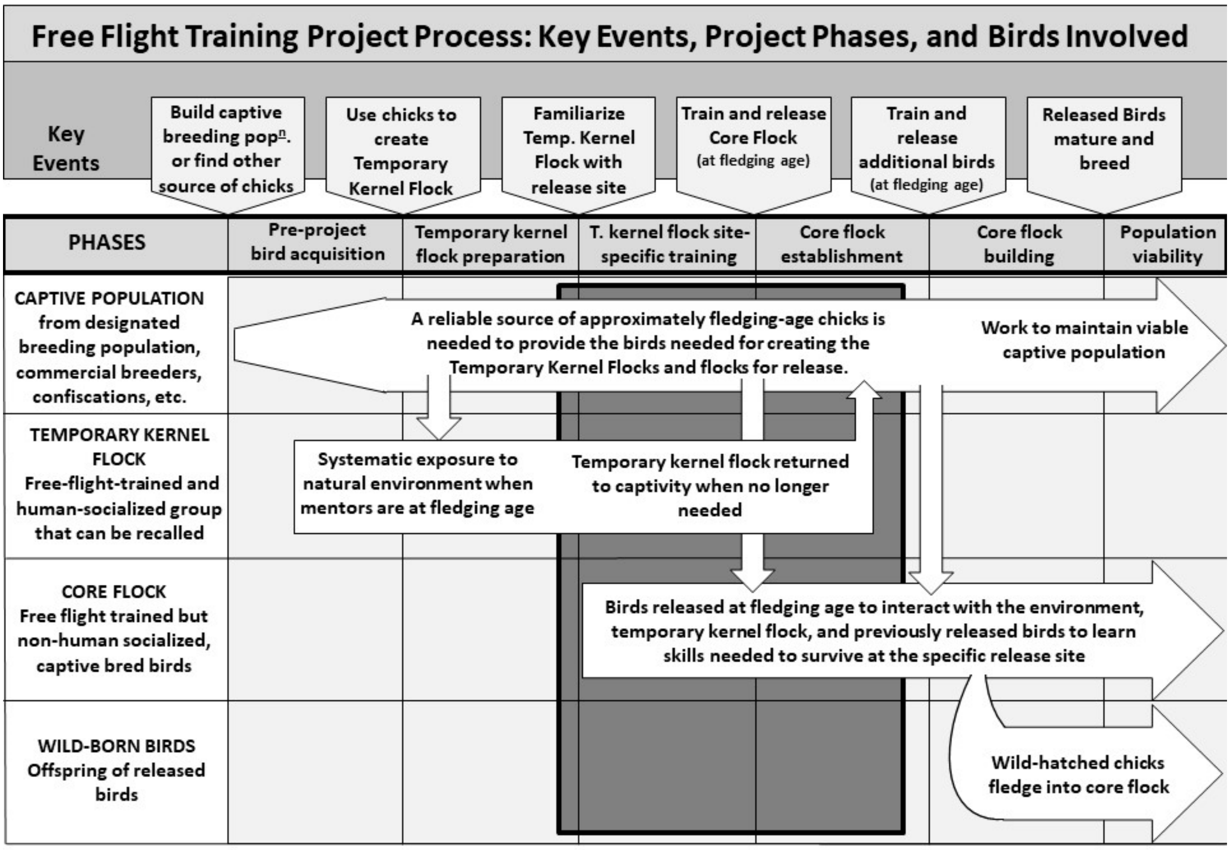

Figure 1. Free flight training project process chart. This chart shows the different stages of a release project using free flight training and a human-socialized temporary kernel flock. This manuscript focused on the phases within the dark gray box including the final preparation of the kernel flock, the liberation of the release candidates, and the return of the temporary kernel flock to captivity. However, the full process includes a variety of additional steps including creating or finding a reliable source of fledging age chicks, initial free flight training of the temporary kernel flock, releasing additional birds to the established core release flock, and reproducing the release flock.

2.3. Birds and Basic Care

The birds for release were six Blue-and-yellow Macaws that were bred in licensed commercial breeding facilities in Brazil. We trained and released the birds as two distinct cohorts of three birds each (Cohort 1: #01, #02, and #03 obtained on 11 February, 11 February, and 13 March 2022 and Cohort 2: #04, #05, and #06 obtained on 10 May 2022) The birds were obtained when they were between 42 and 95 days of age (Table 1), and the species normally fledges around 90 days of age [26]. Chicks were fed commercial hand-feeding formula 2–3 times per day as needed until release. The birds were handled briefly and only for hand-feeding to avoid over-socializing them with humans, and they were kept with their release cohort members to allow them to socialize with other macaws. One bird (#03) was much more human-oriented than its peers upon arrival. We marked each bird by attaching a numbered round metal tag (made by Anilhas Capri) around the neck of each bird using multi-strand steel wire and crimps. The birds were considered "release candidates" as per the literature [2,5,32] until they were definitively released (i.e., not being returned to the aviary and night) and no longer hand-fed.

Table 1. Key milestones for the six Blue-and-yellow Macaws released in southeastern Brazil. Hatch date is given, and all subsequent rows show bird ages in days. "Acquired" is the age at which the bird was brought to the research site. First indoor flights were conducted inside a 7 m aviary. First and 15 m outdoor flights were conducted between fixed perches. Left outside 4+ h and overnight show the first time the birds were left out on purpose (superscripts show birds that stayed out unexpectedly before this was planned). Last supplemental feeding indicates the age at which the birds were no longer given access to feeders containing pellets.

Bird	01	02	03	04	05	06	Mean	SD
Hatch	31-Dec-21	31-Dec-21	4-Jan-22	4-Feb-22	20-Feb-22	20-Feb-22		
Acquired	42	42	68	95	79	79	68	21.5
First indoor flight	99	99	95	109	94	95	99	5.6
First outdoor flight	134	134	130	118	105	107	121	13.3
15 m flight outdoors	140	140	136	123	107	109	126	15.2
Multi bird flight training	141	141	137	122	106	108	126	16.2
Left outside 4+ h	145 [a]	145 [a]	140 [a]	122 [a]	106	109 [a]	128	17.9
Left out overnight	166 [b]	165 [b]	162	131 [b]	115	115	142	24.8
Last time in aviary	205 [c]	205 [c]	201 [c]	170	154	154	182	25.0
Last hand feeding	210	210	206	175	159	159	187	25.0
Last supplemental feeding	348	348	344	313	297	297	325	25.0

[a] On one or more occasions during flight training, these birds missed landings and spent a few extra unplanned minutes to hours out of the cage before the age listed here. [b] On one or two occasions, these birds did not return after training and spent an unplanned night outside the aviary before the age listed before returning to the trainers the next day. [c] These three birds were returned to the aviary briefly after #03 was captured by local people and subsequently recovered by the research team. See text for more details.

2.4. Temporary Kernel Flock

We used three previously trained adult Blue-and-yellow Macaws to create a pioneer or temporary kernel flock (sensu Woodman et al. [22]). These birds were trained to participate in the sport of parrot free flight as fledglings by HM using the method developed by CB ([22] and LibertyWings.com). They were over three years old and had been free-flying as a unified flock at a peri-urban home 12.7 km from the release site in Santa Rosa de Viterbo since January 2019. These birds had well-developed survival behaviors (predator avoidance, landscape navigation, wild foraging, and flock cohesion) but were bonded to HM. He intentionally maintained them trained and semi-dependent on human care so that he could recall them using verbal cues and food, move them from place to place, and return them to captivity as needed.

This temporary kernel flock of three previously trained adult birds was allowed to fly free around outside at the release site for about 2.5 weeks to allow them to become familiar with the surrounding landscape. This was performed before the release candidates began to fly outside. The threefold objective of using these human-socialized birds as a temporary kernel flock included the following: (1) to allow the newly released birds to join a flock of conspecifics that already has knowledge of the landscape and key survival skills, (2) to provide released birds with models from which to learn key survival skills, and (3) to allow them to be recalled, moved, and rereleased as needed during this study. This temporary kernel flock likely imparted benefits to the released birds through increased total group size (and associated vigilance benefits [33]), improved landscape navigation, effective behavioral models, and possible other socially induced epigenetic effects [34]. Given the fact that these birds served as more than models for social learning and could be recalled as needed, we use the terms "temporary" and "kernel flock" and avoid the term "mentors" or similar words as are often applied to more experienced individuals included in reintroduction projects [5,35].

2.5. Post-Release Monitoring

The birds were monitored ad hoc by the researchers when they were on site from late April 2021 to early February 2022. During training, the birds were observed twice per day (usually during feedings), and observations were summarized in daily journal entries and in table form biweekly to document each individual's progression in different behavioral competencies (Table S1). However, it was difficult for HM to record the natural behaviors of the released birds because, when he was visible, the birds would typically stop what they were doing and approach or watch him, likely watching to determine if he would provide food. After February 2022, HM maintained contact with local people who lived on the ranches and received regular reports on the birds including information on presence, absence, numbers of birds, and consumed food. To ensure the reliability of these data, he visited every 3 months or so to check the reports of the locals and confirm the survival and location of the birds (last visit completed in early April 2024). At no point during this project did he have reason to suspect that the data from the ranch residents was unreliable. Monitoring by ranch personnel and others is easier because the nearest conspecifics reported are small numbers of stragglers ~50 km to the south. As a result, all groups of six Blue-and-yellow Macaws seen in the region represented our birds.

2.6. Basic Flight Training

The free flight training approach used here is based on the principles and techniques of Guided Behavioral Development (or human-guided learning, sensu Woodman et al. [22]) used to train pet parrots to fly in a wide range of complex environments across the USA. In this study, we trained the six release candidates with less extra handling and more contact with the other release candidates and kernel birds than would be performed with pet birds. We tried to minimize undesirable human socialization and encourage them to be feral and independent from the weaning stage onward. In this way, our release candidates were raised for permanent release to create a core for an eventual reestablished wild population.

The training aviary was 7 m long, 1.8 m wide, and 3 m high. The front 3 m was covered with metal roofing. The aviary had an internal door so it could be divided into two sections (1.8 m and 5.2 m long), and the entire back was a two-part door that could be opened to allow the birds to fly in and out of the aviary (Figure S1 and Video S1).

The release candidates were transferred to the training aviary at 92 $\pm$ 8.6 days of age (n = 6). To encourage birds to fly from point to point, we placed two perches about ~1.3 m apart inside the aviary. When the birds flew from one perch to the other, they were rewarded with a squirt of hand-feeding formula from a squeeze bottle (Figure S2). This was repeated at feeding time, twice a day, starting at 98 $\pm$ 5.6 days of age (n = 6). The birds were encouraged to fly between perches 10 to 20 times per session until they had consumed their full meal ration of about 150 mL or lost interest. The distance between perches was gradually increased between training sessions until they could fly the length of the aviary. At about 121 $\pm$ 13.3 days of age (n = 6), we started training outside the aviary, as the birds could comfortably fly the length of the aviary and began to anticipate flying to the next perch to obtain the formula. For outdoor training, one of the perches was placed outside the aviary, the back door was opened, and the birds were picked up, placed on a perch 2 to 3 m from the back of the aviary, and then encouraged to fly to a perch inside the aviary (see Video S2). As the birds improved, the perches were moved further apart until they were about 15 m apart (126 $\pm$ 15.2 days, n = 6).

2.7. Flock Flight and Increased Freedom

Once individual birds were able to fly 15 m perch to perch outside the aviary effectively (128 $\pm$ 19.4 days old, n = 6), multiple birds were trained simultaneously in order to encourage the birds to form flocks in flight. During this early flock training, the first cohort (#01 to #03) flew with the temporary kernel flock birds, and the second cohort (#04 to #06) flew with different subsets of the first cohort and kernel flock birds. No specific training actions were performed to encourage the birds to fly in flocks. However, having them out together during training allowed them to make their first flights in groups.

To encourage the birds to move about as a flock and help them transition to life in the wild, we left them outside for longer periods of time as they aged. About 10 days after their first outdoor flight (first release cohort) or 1 to 4 days after their first outdoor flight (second release cohort), we allowed the birds to start remaining outside for 4 + hours at a time after their 15 to 20 min of structured flight training, but, when possible, they were still returned to the aviary before nightfall. All birds were left out overnight on purpose for the first time around 14 or 15 June (age 142 ± 25 days, n = 6), and after 24 July (age 187 ± 25 days, n = 6), both release cohorts always remained out overnight and were not locked in the aviary again (with one exception, see Section 3.3 Landscape Use and Navigation below).

2.8. Use of the Temporary Kernel Flock in Training

To allow the young release candidates to begin to become familiar with and observe the behavior of the older birds, the temporary kernel flock birds were often held in the smaller partition of the aviary or in a small cage inside the aviary. The proximity facilitated bonding and social learning, but keeping them separate reduced the chances of hostile interactions between the two groups.

About nine days after the first release cohort began training outside the aviary, the three temporary kernel flock birds were let out to fly with them during the training sessions (chick age 133 ± 2.3 days, n = 3). This gave the young release candidates a chance to fly with the more experienced birds from an early age. At this point, the kernel flock had been flying at the release site for just under a month, so it knew the immediate vicinity quite well and was able to navigate effectively without problems. When the birds in the first release cohort (#01 to #03) were 153 ± 3.5 days old, all were flying regularly with the kernel birds. The second release cohort (#04 to #06) was let out with the first release cohort and the temporary kernel flock at a younger age and were regularly flying with them by about 113 ± 8.7 days of age (n = 3). The adult kernel birds flew free with the two cohorts of released birds on and off from early June until 4 September 2022 when the kernel birds were returned to their home in Santa Rosa (see Section 3.3 Landscape Navigation and Spatial Use below). These kernel birds were also used to model feeding on solid foods as part of the process of weaning the babies off the hand-feeding formula (see Section 2.9 Feeding below).

2.9. Feeding

The birds were offered solid foods to chew on at age 65 ± 5 days (n = 3, release cohort one) or upon arrival (age 84 ± 9 days, release cohort two) while still being hand-fed. These first foods included wild fruits (*Syagrus romanzoffiana*, *Psidium myrtoides*, and *Psidium guayava*), wild tree flowers (*Handroanthus* sp. and *Bauhinia* sp.), fresh produce (apples, oranges, chili peppers), and humid parrot pellets (High Energy NuTropica). Wild foods were given irregularly before the birds were released; the quantity and type of these wild foods we provided depended on researcher time and food availability in the study area.

At age 126 ± 24 days (n = 6), the birds were given access to feeders with dry pellets, and we began to wean the release candidates from the hand-feeding formula. We slowly phased out hand feedings (first skipping the morning hand-feeding at age 148.5 ± 25.0 days [n = 6 birds]). As part of this process, we left the six young in the aviary all day with one or more of the temporary kernel birds for about 6 days so that they could serve as models for eating the pellets. Beginning at age 153 ± 25 days (n = 6 birds), we started irregularly skipping both hand feedings on select days. Once the birds did not show signs of excessive hunger (insistent begging) we skipped two, then three days in a row. By 29 July, all hand-feeding was stopped (age 186.5 ± 25.0 days, n = 6 birds). Because hand-feeding ceased on 29 July and the birds were no longer returned to the aviary after 24 July; therefore, 29 July is considered the final release date for the released birds in this study.

At about 235 ± 25 days of age and 114 ± 12 days (*n* = 6) after their first outdoor flights, we began to transition the birds to fully wild foods by keeping pellet feeders inside the aviary and only opening the aviary for <1 h per day in the afternoon. By restricting food in the morning, we stimulated the birds' natural interest in finding local foods, but the supplemental feeding in the afternoon prevented the lack of food from becoming a crisis. We further restricted pellets skipping first one, then two, then three days in a row, and then providing pellets only when the birds begged HM or showed other hunger-related behaviors (*n* = 10 days from mid-November to mid-December). Pellets were provided for the last time on 14 Dec when the birds were 324 ± 25 days of age and 203 ± 12 days after their first outdoor flights (*n* = 6).

We documented the wild plant species the birds fed on through opportunistic observation of the birds, by looking for chewed food plants near the aviary and talking to ranch hands and other local people who had seen them feed.

We helped the birds learn to feed on the macaw palm (*Acrocomia aculeata*), which is common at the site and known as a valuable food source for macaws [36]. At 140 ± 25 days old (*n* = 6), we gave them cut-up pieces of palm fruits irregularly for about 1 week. Then, at 255 ± 25 days old (*n* = 6), we removed fruits from the tree, peeled away the hard exocarp, and placed the fruits on the ground next to other fruits that had naturally fallen from the tree (as an aside, it is not recommended to encourage macaws to forage on the ground, and this would not likely be performed in the future). Over the next 10 days, we led the flock four times to different palms with ripe fruits so they could feed on the fruits on the ground. On three occasions (November 26, 27 and December 8), HM picked up bird #03, climbed up a ladder, and placed it on a raceme of palm fruits still attached to the trees to encourage the flock to feed directly on the hanging fruits.

Water was provided in dishes at all times when the birds were held in the aviary. Post-release, water was provided in dishes in or near the aviary, and no specific training was provided to help the birds transition to natural water sources. However, after the birds started drinking reliably from local water supplies (age~8 to 9 months) we reduced access to water over a one-week period and then eliminated all supplemental water.

Regarding breaking bonds with human caretakers, in macaws and other large psittacines, parents and chicks apparently sever their close connections at some point post-weaning and before renesting the following season, likely when the chicks are between about 7 and 11 months of age (Vigo-Trauco and DJB, unpublished data and [26,37,38]). In order to ensure that the release candidates would sever their bonds with their human caretakers during the post-release period, we took a few important steps. Hand-feeding was performed by only two researchers (HM and CB) to help ensure that the birds would not consider all people potential food sources. We ended all hand-feeding when the birds were just over 6 months old (about three months after normal fledging age) to ensure that the birds would not continue to obtain positive reinforcement from approaching humans after they no longer needed hand-feeding. We did not perform specific activities to haze or scare off the young macaws. After hand-feeding ended, bird #03 continued to land on HM. Most of the time, there were few interactions between HM and #03, but on some occasions, HM moved #03 to other areas (to the aviary, to macaw palms, etc.), always trying to get #03 to stay away from contact with other people and to interact more with food sources or with the other birds.

3. Results

Of the six birds trained with free-flight techniques, 100% showed strong flock cohesion, 100% showed fidelity to the release site, 100% avoided predation, and 100% survived without supplemental food and water for over one year. None of the birds got lost in the landscape in the first 2+ months post-release. However, at 220 days of age and 86 days after its first outdoor flight, one bird was captured by local people. Fortunately, the bird was recovered by the research team and rereleased. After rerelease, this bird remained with the other five and, as of two years post-release, all six birds were alive and living free without any supplemental feeding. No reproductive behavior was recorded in this group because all individuals had yet to reach reproductive age at the time this article was written. This gives a 3-month and 1-year success rate of 83% (one of six captured) and a first-year survival of 100% (six of six alive and doing well).

3.1. Flight and Flock Formation

The release candidates took their first flights in the aviary at about 102 $\pm$ 6 days of age and could fly the full 4 m distance within the aviary within 6 days after their first flights (average 3.5 $\pm$ 0.8 days, Table 1). At age 121 $\pm$ 13.3 days (n = 6), the birds took their first flights from perches inside the aviary to perches 2 to 3 m outside the aviary, and by about 5 days later, they were capable of flying between perches set 15 m apart. During these early solo flights outside the aviary, five of the six birds did not just fly directly between the two perches but circled around before landing on the second perch (the birds made their first exploratory flights 5.2 $\pm$ 2.7 days after their first outdoor flight, range 1 to 7 days, n = five birds). On eight occasions during training, the birds missed landing on the second perch and landed on the aviary or on trees within about 15 m of the aviary (Video S3). On these occasions, they spent anywhere from a few minutes up to a few hours in the trees before coming down and rejoining training or entering the aviary. These incidents always happened within the first 10 days of flying outside (4.25 $\pm$ 3.4 days, n = 8, range 1 to 9 days since the first outdoor flight). During the first week of training outside the aviary, the birds would occasionally perform longer exploratory flights of 200 to 300 m, and three of the six birds perched in the trees and did not come down or re-enter the aviary before dark and spent an unplanned night out in the trees (2.7 $\pm$ 2.9 days after first outdoor flight, range 1 to 6 days n = three times), but all returned to the group and the aviary the next day.

By 4.5 $\pm$ 2.9 days after their first outdoor flight, the six juvenile birds were allowed to fly with the adult kernel birds. When let out together during training, the young macaws began to fly together both with other released birds and the adult kernel flock birds. This early flocking was especially obvious when multiple birds were out, and one would give a startle or alarm call causing all to fly During the unsupervised time outside the aviary in the first weeks after release, they spent most of their time in the stand of trees within 30 m of the aviary, but they occasionally flew off to stands of trees 200 to 400 m away. In all these locations, they were within contact call range and always returned to the aviary area without incident. By 26 $\pm$ 0 days after the first flight outside the aviary (n = three birds), the first cohort of release birds regularly flew together in a coherent flock. The second cohort of released birds that started flying at a younger age and was allowed to interact with cohort one during early flight training, showed similar flocking abilities in only 8.7 $\pm$ 1.5 days (n = 3) days after its first flights outside the aviary.

Even after the birds were proficient at flocking, the birds did not usually move around as a single unified flock. When in flight, the released birds most commonly flocked with the other members of their release cohort. Less commonly, the six released birds flew together, and the group of six was occasionally joined by one of the kernel flock birds (Caio). Only occasionally (and usually in response to a strong alarm call), the six released birds and three temporary kernel flock birds flew together in a single group of nine. However, this group of nine did not stay together for long: once it was clear that there was no imminent danger, they would break up into the temporary kernel and permanent core flocks again, staying in the general vicinity or perching in the same or adjacent trees. After the birds were ~8 months old, they sometimes flew in pairs (#01 and #02, #04 and #06, and #03 and #05). The birds were seen flying as singles only on a few occasions, and it was usually #03 and occasionally #05.

3.2. Role of Temporary Kernel Flock Birds

Starting about three weeks before the first outdoor flights of the release birds, the temporary kernel flock birds were allowed to spend 8 to 12 h per day free around the release site. During this period, they often disappeared for periods of 4 h or more. We do not know where these birds went during their explorations other than a single report from neighbors, who observed two birds at a farm in Bocaina around mid-May, 3 km to the northwest of the release site.

During the times when the temporary kernel birds were held in cages with or adjacent to the release candidates, the interactions between the kernel birds and the release candidates were minimal: no mutual preening or aggression was noted, and the young did not beg from the older bird.

About nine days after the first release cohort began training outside the aviary, the three temporary kernel flock birds were let out to fly during the training sessions (starting at chick age 133 ± 2.3 days, n = three birds). On 6 June, #04 and #05 were completing training flights outside the aviary when one of the birds from release cohort one gave an alarm call. At this point, birds #01, #02, #03, #04, and #05 and two of the kernel birds all took flight at once. As many of the release candidates were still new to flying, the birds formed a somewhat loose and "messy" flock then quickly broke up into their cohort-based groups and returned to the areas where they were perched originally.

During the time when the temporary kernel birds were kept at liberty with the release birds, these types of startle flights were repeated regularly. However, other than this, there was not much direct interaction between kernel and release birds: no aggression, no physical contact, and no apparent counter-calling were recorded. However, when inactive, the release birds and kernel birds usually remained in the same clumps of trees, normally within about 20 m of visual and auditory contact. At night, the release birds would normally roost in the trees above the aviary, while the kernel birds would roost about 275 m away in the trees above the farmhouse.

There were some unexpected negative issues regarding the temporary kernel flock. Because the kernel birds were purposefully maintained as human-dependent, they sometimes sought out contact with humans. On 30 June, one of the kernel birds (Caio) flew to the kitchen at the farmhouse, where it was fed by one of the residents while all the released birds watched. Since we did not want the release birds to learn this behavior, we met with the farm staff after this event and reiterated the importance of not feeding any of the macaws. As far as we can tell, this problem did not recur, and we have no evidence that the released macaws ever approached people on the farm.

As mentioned above, the temporary kernel birds were raised at a home only 12.7 km southwest of the release site in Santa Rosa de Viterbo (hereafter referred to as Santa Rosa). At that home, they were allowed to fly freely for the previous three years. On 2 June, after about 35 days of flying at the release site, all three kernel birds flew back to Santa Rosa. HM brought the birds back to the release site by car, but they flew back four times over the next week. On 11 June, the birds woke in the morning at Santa Rosa and then flew on their own to the release site. After this, the birds flew frequently back and forth between the release site and Santa Rosa.

On 7 August, one of the temporary kernel birds (Odun) flew with all six of the released birds to Santa Rosa (~16:15), where these seven birds met up with the other two kernel birds that were already there. When this happened, HM was at Santa Rosa, and upon seeing the arrival of the six released birds, he immediately got in his car and drove back to the release site. When he drove away, all nine macaws left. When HM arrived at the release site (~17:30), all nine macaws were there. All nine spent the night at the release site. After this, the kernel birds chose to spend more time in Santa Rosa, but on 13 August, Oden and birds #01 and #02 flew to Santa Rosa and spent the night there. The next morning at dawn, all three birds flew back to the release site. After this, the kernel birds spent progressively less time at the release site until 4 September, after which they were kept in their home aviary in Santa Rosa for the duration of this study.

3.3. Landscape Navigation and Spatial Use

During the first two to three months after the release candidates began flying outside, they rarely departed the area within a 250 m radius of the release area. During the day, they spent most of their time in the tall trees over the aviary or near the farmhouse and slept either in the clump of trees immediately adjacent to the release aviary or in the clump of trees above the farmhouse. Before 7 August, there was no indication that the birds wandered away from the site. Each time HM was present at the site, the birds were within a ~250 m radius of the aviary.

As mentioned above, on 7 August (about 60 to 85 days after the first outdoor flight of the two cohorts), all the released birds flew with the temporary kernel bird Odun to the Santa Rosa site. On that same day, all flew back to the release site (total flight distance > 25 km). On 9 August, #03 was seen by local people at a site 11 km south of the release site and then disappeared. It seems that people from another town captured #03 around 11 August and held it for 5 days, after which it was turned over to a wildlife rescue practice and then returned to the researchers. The method of capture is unknown.

All other released birds remained at the release site from 8 August to 12 August. On 13 August, the five remaining released birds apparently left the release site around 9 AM. As mentioned above, #01 and #02 spent the night in trees at Santa Rosa, while birds #04, #05, and #06 were unaccounted for. All five release birds returned to the release site in the morning on 14 August.

After being recovered from the people who captured it, #03 was held alone in the aviary at the release site for 13 days. During this time its release cohort members (#01 and #02) usually remained within about 30 m of the aviary and, if they wandered too far away, they returned when #03 vocalized. On 30 Aug, #01 and #02 were recaptured and placed in the aviary with #03, and all three birds were rereleased together four days later. Post-release, #01, #02, and #03 remained in the vicinity of the aviary and were always present when HM visited the site.

However, the members of the second release cohort (#04 to #06) flew as a flock and regularly left the release site in the late morning (about 09:30–10:00 a.m.) and returned in the afternoon (04:30–05:00 p.m.). Upon return, they usually flew into the aviary to obtain food and water before roosting in the trees by the house. During this time, all six birds roosted in the same tree but clearly in two groups of three. At some point, probably between July and September, a group of birds was seen briefly by local people at the farm in Bocaina. It is uncertain if this was just the core flock of released macaws or a mix of the released birds and the kernel flock birds.

Through late September, the birds of release cohort two slowly reduced their time away from the release site, suggesting that they were moved through the landscape less. From late October to late December, it seemed that the birds rarely left the immediate area around the release aviary. Throughout this time, we slowly reduced access to the pelleted diet (see the Section 3.4 Food and Water below) to encourage movement. However, the birds continued to spend most of their time in the immediate area of the release aviary. Starting around 25 December (about 7 months after the first outdoor flights) and 10 days after all access to pellets was eliminated, the birds transitioned to the farm in Bocaina. From 28 December 2022 to about March 2023, they roosted in tall Eucalyptus trees at the Bocaina site. In March 2023, the birds changed their roost site back to the release site. Since this time, the birds have roosted consistently near the release site but have rarely been seen feeding at the release site. Instead, they apparently depart in the early morning and return just before going to roost (as of April 2024). According to the local residents, the birds usually move in two groups of three (probably the release cohorts).

3.4. Food and Water

All six released birds learned to find sufficient natural food and water and survived for over 18 months without supplemental food or water. Based on the observations of HM and the local residents, we suspect that the birds ate at least 15 different food items the first year post-release (Appendix A). Here, we report on a few milestones in this process.

While still in the holding cage, the birds of release cohort one were first seen chewing on solid foods from their food bowls around 75 days of age. All six birds began regularly eating pellets from the feeders around 5 months of age (155 ± 25 days, $n = 6$), but this was only after we began to skip the morning rations of the hand-feeding formula regularly. The released birds were seen chewing on fruits or other potential food items within 2 to 24 days after their first outdoor flights (11 ± 8 days post-first flight, $n = 6$). By 14 September (~8 months of age) our observations suggested that five of the birds were able to forage effectively on natural foods. However, when access to pellets was restricted in the mornings of 17 and 20 September, all the released birds started begging for food from HM. After this, pellet consumption increased and wild food consumption decreased. In addition, the birds seemed to move less within the release area and spend more time in the immediate vicinity of the aviary and feeding stations. In addition, the birds were rarely away from the release area. Pellet consumption remained high until the birds were forcibly weaned off pellets by completely phasing them out during November and December when the birds were about 10 months old (see the Section 2 Methods for more details on this).

3.5. Macaw Palm Fruits

In June, when the macaws were about 5 months of age, HM provided chopped macaw palm fruits. The birds were very interested in them and chewed on them, but they were not able to consume much. However, when the fruits were opened and left on the ground in October (when the birds averaged about 8.5 months old), at least four of the released birds began consuming them within 24 h. Within two weeks, some birds took the fruits off the ground and flew to nearby perches to eat them, and by 14.5 ± 10.5 days (range 4 to 32 days, n = six birds), the birds could effectively peel the hard exocarp off the fruits and consume the soft endocarp. We did not observe the birds feeding on or picking palm fruits that were still hanging on the tree. However, we had limited ability to observe the birds foraging and may have missed the development of this important behavior.

3.6. Water

The birds regularly drank from the water dishes in the aviary. In late September (128 ± 12 days post-first flight), we saw two released birds on the ground drinking water from a leaking hose about 300 m from the release aviary. Two weeks later, we confirmed that all birds perched on the ground and drank water from leaking hoses in this area. Once the water dishes were removed from the cage in late October, this behavior of drinking from the leaking hose was observed frequently until at least mid-December, most commonly right after the birds ate very dry pellets. However, after we stopped providing pellets and the birds moved to the new site in Bocaina in late December, the birds were not ever seen going to the ground or drinking water (as of April 2024).

3.7. Predators and Predation

None of the birds were killed by predators during this study, and we did not witness any attacks on the released birds by raptors or mammals. We did observe a variety of raptors on site including White-tailed Hawk [*Geranoaetus albicaudatus*], Orange-breasted Falcon [*Falco deiroleucus*], Crested Caracara [*Caracara plancus*], Yellow-headed Caracara [*Daptrius chimachima*], Bat Falcon [*Falco rufigularis*], American Kestrel [*Falco sparverius*], and Plumbeous Kite [*Ictinia plumbea*]. The White-tailed Hawk and Orange-breasted Falcon are capable of attacking a fledgling and even an adult macaw, suggesting that there is some risk from avian predators at this site. On two occasions, the macaws showed clear reactions to the presence of large raptors. When the birds were about 5 months old (only 26 ± 12 days post-first outdoor flight, $n = 6$), a White-tailed Hawk was seen circling above the release site, and all nine birds (six released and three kernel flock) took flight and were seen circling high and calling loudly. As they flew, the macaws separated into three groups of three birds each. After the hawk was out of sight, the birds quieted down and dropped to lower altitudes until they landed on trees near the aviary. Similarly, about 6 months later, one macaw gave an alarm call after a large unidentified hawk flew over. All six released birds took flight immediately as a single group. Some birds gained height faster, and the group split into two groups of three. As with the previous incident, after the hawk was out of sight, the birds returned to their preferred perch trees.

On eight other occasions, we recorded "startle flights", where the macaws took flight rapidly and circled before landing again. On six occasions, they flew in response to an alarm from one of the other macaws. On two occasions, they flew in response to an alarm from a Golden-capped Parakeet (*Aratinga auricapillus*). On at least one other occasion, there was a loud alarm call by a Golden capped Parakeet (with no apparent cause), but the macaws did not take flight.

At least two wild mammalian predators are known to be on site, tayra (*Eira barbara*) and ocelot (*Leopardus pardalis*), both of which are capable of depredating fledgling or adult macaws [5,39]. Given the nocturnal and retiring habits of these mammals, we are not surprised that we saw no direct interactions or predation attempts by these mammals. However, the farm at the release site had 3 dogs, and the farm in Bocaina had between 10 and 12 farm dogs. About four days after the first flight of the second release cohort, a farm dog approached the release aviary. In this case, one of the kernel birds gave an alarm call, and all nine birds took flight.

Going to the ground is dangerous for macaws as they are more susceptible to capture by not only raptors but also humans and predatory mammals. In the first three months post-release, the birds occasionally approached HM when near the aviary, perched low or on the ground, and solicited food or social interaction. However, after weaning, this behavior stopped for all birds but #03. Around the time of its capture by local people, #03 was noted landing very close to the ground, which may have predisposed it to being captured. From early October to late December 2022 (about 6 months after the first outdoor flight), all the birds went to the ground to drink water from a leaking hose and to pick up fallen palm fruits and immature mangoes. However, after the birds transitioned to the farm in Bocaina (about 7 months after the first outdoor flight), they were never recorded on or near the ground.

3.8. Interactions with Humans

During hand feeding, all birds went to HM and CB to receive food, but even during this period, the birds were never seen approaching people other than these two hand feeders. This is noteworthy because, as a working ranch, there were frequently other non-project personnel present on site. After the birds were weaned off hand-feeding (around six months of age), none of the birds were reported to approach people at either the release site or the Bocaina ranch (other than HM who provided food). After the end of hand-feeding, all six of the birds approached HM at least once. Four of them only approached HM during the process of weaning off pellets (~7 to 11.5 months of age). However, the other two birds (#03 and #05) regularly approached within 3 m of HM post-weaning. Bird #05 occasionally perched near HM but did not allow itself to be touched or picked up, and then it slowly lost interest in approaching HM. The last time it approached within 3 m was when it was 266 days old (13 November). Bird #03 frequently approached HM, often landed on him, allowed itself to be picked up, and remained near him even in the absence of being fed. However, neither the local people nor the researchers saw this bird approach other people. In addition, when other people were near HM, #03 would not approach. We do not know how the bird was captured by local people in August, but it may have approached someone or have been captured in some sort of snare. The willingness to approach HM continued until #03 was ~10 months old. At this point, the group of released macaws moved to the Bocaina farm. After the move to Bocaina, HM did not try to approach the group, and #03 was never seen approaching people again.

4. Discussion

The 100% success rates for release site fidelity and flock cohesion coupled with the 100% survival and 83% overall success rates (if the captured bird is not considered a success) compare very favorably with the rates found in other macaw and parrot releases [5,8,13].

These results suggest that free flight training has great potential to use captive-raised young to create release candidates with a broad array of vital survival skills.

Hand-raised animals are normally considered inferior release candidates when compared with parent-raised or wild-caught individuals [6,40] as these birds often show extreme levels of naivete when foraging and evading predators and are willing to approach humans. Most parrots likely learn vital survival skills in the first few months post-fledging. However, in most psittacine release projects, the birds are held in captivity for at least one year or more [2,5,6,11,12]. In this way, most release candidates learn what it takes to survive and thrive in a cage during this critical post-fledging learning period. Then, after one year or more, they are released into the wild where they need to learn a much more complex set of skills including flocking, predator avoidance, landscape navigation, and foraging on wild foods. However, with the free-flight technique used in this study, we were able to fly birds outside by age 3.5 to 4.5 months old and definitively release them by 5.5 to 7 months of age, allowing them to use their natural period of intense learning to acquire the skills needed not just to survive in the wild but to survive in the specific environment of the release site.

Some authors have asserted that parental guidance may be necessary for the development of key survival skills in many psittacines [6,27,41–43], and the poor performance of captive-raised Thick-billed Parrots upon release in the 1980s led some authors to question whether any captive-raised birds could be returned to the wild [43]. However, our results suggest that birds produced by commercial breeders can develop the vital skills needed for survival in the wild when free flight training is used to expose them to the correct environment during the correct developmental stage.

4.1. Survival Rates

Our 100% survival rate with management (and 83% success if the captured and rereleased bird is considered lost) supports our hypothesis that birds raised with free-flight techniques survive well post-release. In a review of 47 psittacine releases, White et al. [8] defined the first-year survival rates for a successful parrot release as ">50%", and only 64% of the releases in their study met this criterion. The recent releases of Spix's Macaws and Puerto Rican Parrots by state-of-the-art projects have had first-year survival rates of 40 to 70% [2,5]. First-year survival rates for large macaws are often higher than those of smaller species because of the lower predation risk faced by large birds and because success rates may vary among preserved areas and agricultural areas or other modified landscapes like those used in our study [13]. Across six releases of *Ara* spp. macaws, first-year survival ranged from 59% for Red-and-green Macaws in Argentina to 92% for Scarlet Macaws in Costa Rica, with a mean of 77 ± 16% survival for six projects [11,13,18]. Similarly, 14 wild-caught Blue-and-yellow Macaws released in Trinidad had a first-year survival of ~71% [44]. This suggests that our free-flight release techniques produce results for hand-raised large macaws that are at or above the upper range of those found in the literature. This finding is even more noteworthy as the release of larger groups often results in higher survival rates for parrots and a variety of other taxa [2,6,13,45–47], and this release of only six birds constitutes a relatively small release.

4.2. Flocking and Group Cohesion

Larger group sizes are known to provide a wide variety of advantages to many species, including reduced predation rates, increased opportunities for finding mates, improved foraging efficiency, etc. In parrots, most species spend nearly all their time in social groups ranging from pairs to flocks of 100s individuals [48–50], and flying in cohesive flocks is a key anti-predator response [2,6]. While parrots are naturally drawn to conspecifics, many captive-raised parrots fly off and spend much time alone when released into the wild [6,8,13,23]. Projects using captive-raised individuals have reported great variation in group cohesion and, in extreme cases, even brief lapses in flock cohesion resulted in losses to predators [6,12]. Group cohesion rates can range widely among release methods, even when used on the same species: Puerto Rican Parrot flock cohesion rates ranged from <20% for "precision releases" of pairs of birds up to 100% for advanced soft release methods [2]. In our study, all the released macaws spent nearly all their time in groups, most commonly splitting into two groups of three, i.e., the cohorts in which they were raised and released. Given the small number of birds in each release cohort, it seems noteworthy that we obtained a 100% flock cohesion rate. These findings clearly support our hypothesis that macaws raised with free flight training can flock effectively.

4.3. Site Fidelity and Landscape Navigation

Unexpected dispersal has been identified as a major problem that reduces the success of avian translocations [14]. In many projects, released parrots disperse out into the landscape shortly after release [9,12,15,24,51]. If not recaptured and returned, many of these birds never return to the release site and are predated or otherwise lost to the project. Ideally, released birds should remain near the release site where they can receive supplemental food, interact with conspecifics, and help the new population overcome the initial Allee effects post-release [2]. In an attempt to reduce fly-offs, researchers in Brazil allowed single male Golden Parakeets to fly loose in the release area in the days before release, but site fidelity remained low (~35% [10]). Similarly, recall training used for Orange-bellied Parrots in Australia did not prevent fly-offs, with site fidelity of only about 50% [52]. In contrast, in our project, the birds were allowed to repeatedly fly as a group in the release area for weeks during their flight training. Post-release, all our birds remained in the immediate vicinity of the release aviary for 2 to 3 months after their first flights and roosted together nearly every night within 3 km of the release site for about two years post-release. This supports our hypothesis that free-flight release methods can create birds with high site fidelity. However, studies with larger numbers of released birds are needed to further test this hypothesis.

Recent studies suggest that holding additional conspecific parrots in captivity in the release area works as a social attractant and increases site fidelity in released birds [2,5,11]. The high site fidelity rates in our current study were achieved with no additional birds being held in captivity on site. Fortunately, it would be simple to use free-flight techniques and hold additional birds on site to maximize site fidelity.

For released individuals who establish a stable home range post-release, many start using a relatively small area and then expand their home ranges over time [5,6]. In our case, movement throughout the landscape was minimal (~250 m radius) during the first ~5 months post-release while we were still providing supplemental feeding, with one major exception. As described above, about 2 to 3 months after the first flight and 2 weeks after final release, one kernel bird flew with the released birds ~13 km to Santa Rosa. This was followed by about one week of intense movements by the released birds, during which all the released birds left the area, spent a night away from the release site, and #03 was captured by local people. This scenario seems similar to what happened with Spix's Macaws in Brazil, where groups dispersed away from the release site but one of the birds did not return to the site with the group [5], underlying the potential risks of long-distance movements in recently released parrots. After the long-distance movements in our study, release cohort two apparently spent more time away from the release site. However, this exploratory phase was short-lived, and within about a month, all the birds apparently remained within just a few hundred meters of the release site.

Feeding stations are known to influence the spatial use of released birds [23,53], and our project was no exception. Once supplemental feeding ended, the birds finally began to spend more time away from the release area. They roosted for a few months at the nearby Bocaina farm and since that time, apparently used feeding sites away from both the release area and Bocaina. These types of food-driven shifts in range by released birds have been reported in a variety of release projects including Golden Parakeets and Blue-fronted Amazons in Brazil [7,10,23] and Thick-billed Parrots in Arizona [6]. To date, we have no evidence that the released birds returned to the area around Santa Rosa (the home area of the kernel birds). However, the observation that the kernel bird led the young released birds to this point of interest > 10 km from the release site seems very similar to the long-distance post-fledging movements undertaken by wild macaw adults with young [54]. As a result, we would not be surprised if the released birds remember this location and return to Santa Rosa at some point in the future.

Without the use of radio collars, it is impossible to know the details of the movements of the birds post-release. However, the fact that none got lost in the landscape (the capture of #03 notwithstanding) and that all the birds traveled at least 10 km from the site and returned and remained within 3 km of the release site for nearly 2 years, supports our hypothesis that free flight training can produce macaws that are able to navigate effectively in the landscape.

4.4. Predator Avoidance

High predation rates are a frequent problem for avian release projects [2,5,6,14], and mechanisms to reduce predation have been identified as an important factor in parrot release success [8,17]. In our project, we did not perform any specific predator aversion training. However, the 0% predation rate, high flock cohesion, and appropriate responses to large raptors and farm dogs support our hypothesis and Woodman et al.'s [22] suggestion that birds released using free-flight techniques should be well-equipped to avoid predators. The release candidates likely learned to react to potentially dangerous predators (larger raptors and dogs) from the kernel flock birds. However, our release site had few avian predators that posed a significant threat to the released macaws. As a result, future studies with smaller species in more predator-rich environments that compare free flight and traditional methods would be ideal to test the true potential of free flight methods for reducing predation.

4.5. Use of Natural Foods

Training release candidates on natural foods is common in many releases, and supplemental feeding is seen as an important part of post-release success in many projects [2,13,55]. In our case, natural foods were given irregularly, and rarely were they given on branches or in other items mimicking their natural presentations. Post-release, the birds were documented consuming 14 different wild species (Appendix A). We worked to encourage the birds to consume macaw palm fruits, but they remained mostly dependent on the pelleted diet for about 4.5 months until they were forcibly weaned from pellets. Projects that placed more emphasis on providing natural foods prerelease report much quicker transitions to natural foods [10]. Despite their delayed switch to natural foods, all six birds were still alive over 18 months after the end of all supplemental feeding, supporting our hypothesis that birds raised with free-flight techniques can survive without supplemental feeding.

4.6. Severing Bonds with Humans

For birds raised in captivity, habituation (including lack of fear of humans and approaching humans for food post-release) is a recurring problem [5,9,12,41]. As a result, minimizing attraction to people can be very important for post-release success [23]. Previous studies on macaws suggest that eliminating direct feeding and affection after weaning age can help reduce these habituation problems [13]. Our current study supports this hypothesis: despite being hand-raised, none of the birds were ever seen approaching people other than the hand feeders, and five of six individuals slowly lost interest in the researchers once hand-feeding was stopped. The one bird that retained an interest in HM post-weaning, which was the only one captured by local people, was the most human-socialized upon arrival, reinforcing the need to eliminate extra handling and attempts to bond with release candidates beyond just hand-feeding. Most macaw and other parrot chicks normally separate from their parents after direct feeding stops and before the parents return to nest the next season [25–27,37,56]. In many parrot species, fledglings may be left in groups (or creches) by their parents, and juveniles congregate in groups of similarly aged birds [26,27,37]. In this way, social interaction and social learning often occur among groups of young birds. By ceasing direct feeding a few months after fledging age and using a group of similarly aged young birds, it seems that our free-flight techniques effectively exploited the chicks' natural tendencies to separate from parents and join peers of similar age. This may explain why our birds' attraction to people faded during the months post-release even though they were fully hand-raised. However, if this hypothesis is correct, it is vitally important that future projects ensure that neither researchers nor local people hand feed the released birds in this crucial time during the first months post post-weaning to ensure that the birds naturally lose interest in humans.

4.7. Use of Trained Conspecifics

Reintroducing social species with high learning capacity is historically difficult [19,57]. Projects using relatively small numbers of individuals with few survival skills and little to no knowledge of the resources and dangers in the surrounding landscape may have problems establishing new populations of smart and valuable parrot species [6,10]. Studies have suggested a variety of different methods to address these issues, including releasing animals in larger groups, releasing birds at sites with wild or captive populations, prerelease training for vital survival skills, and integrating wild-caught individuals with new release candidates to increase group size and serve as kernels [2,5,13,19].

Woodman et al. [22] hypothesized that free-flight-trained human-socialized birds could be used to create a temporary kernel flock that release candidates could join and then be recaptured after the released flock was established. In our study, we tested this hypothesis using three privately owned, free-flight-trained adult conspecifics that had flown for three years in the local environment and for over a month at the release site. These temporary kernel birds served to increase the total number of birds at the release site, had well-developed survival skills (flight, flocking, predator recognition and avoidance, and foraging), and a working knowledge of the surrounding landscape. While direct interactions between the kernel birds and released birds were rare, the released birds were nearly always within the visual or auditory range of these kernel birds when both were at liberty. On occasion, the released birds also engaged in short- and long-distance flights with kernel birds. The presence of the kernel birds allowed the released birds to learn through observation about important foraging and other survival skills and learn about the surrounding landscape.

Unfortunately, the use of these human-habituated birds as a temporary kernel flock had some problems. The fact that these birds were highly habituated to HM, were able to fly back to their suburban home in Santa Rosa, and occasionally approached other people for food meant that they occasionally modeled undesirable behaviors for the released birds. As discussed above, by leading the newly released birds on large-scale movements shortly after the final release, the kernel birds may have contributed to the loss and capture of #03. Moving forward, it would be good to test different options for kernel flocks like using kernel flocks trained explicitly for the project or other birds that have no undesirable knowledge of the local landscape. In addition, it would be good to release birds with the free-flight method without using a kernel flock. With this knowledge, researchers can better determine the potential costs and benefits of using human-socialized adult kernel flocks in future parrot releases.

4.8. Study Limitation

Because this study was designed as a small-scale, proof-of-concept study we only re-leased a small numbers of birds. As a result, we have few repetitions, and this prevented us from obtaining a robust measurement of survival success. This makes it difficult to for us to draw broader conclusions about parrot and macaw release in general. One important methodological note is that future studies should have a designated person as a data collector who does not ever feed the birds. This should help eliminate the problem we had where birds did not continue their natural behaviors when HM was present, as they seemed to be watching and waiting to be fed. The budgetary limits are also significant. This study was conducted by one paid person and one volunteer for less than $50,000 US dollars. Given the low budget and staffing levels, the study was by its nature quite descriptive. For these same reasons, we chose not to create an experiment in which we simultaneously released birds using standard release techniques. Now that we have established that the free-flight method works for releasing macaws into the wild, future research projects should consider releasing a control group using standard release techniques. Such a controlled study would allow for a more robust comparison between methods and better quantify the relative advantage of free-flight training.

5. Conclusions

Releases of captive-raised organisms including parrots continue to face a variety of challenges as high predation rates, low flock cohesion, and high rates of dispersal from release areas continue to impact many release projects [5,9,10]. To date, most projects that have taken on these issues have used a piecemeal approach, using different methods to address each problem such as the following: predator recognition, flight ability, site fidelity, etc. [2,10,16,17,23,58,59]. In addition, methods for creating other key survival skills in captive-raised parrots, including effective flocking, landscape navigation, and coordinated responses to predators, have yet to be developed. Given that the currently available prerelease training techniques each address only a limited subset of the known problems, project managers must cobble together a variety of disparate techniques to prepare release candidates. However, even after state-of-the-art training, many release candidates may still lack important survival skills.

The findings of this small-scale, proof-of-concept study support our hypotheses that commercially bred macaws that were hand-raised from the early nestling stage and released as fledglings using free-flight methods have excellent flocking skills, high site fidelity, good landscape navigation, effective predator avoidance, and very high survival rates. Parrot chicks' natural tendencies to separate from their parents and form social groups with peers of similar age during their first year post-fledging [26,27,37,56] may have been key in breaking bonds with the people who hand-fed them. These findings suggest that captive-raised birds, when allowed to interact with the environment from an early age using free flight training, can develop the full array of vital survival skills lacking from so many captive-raised animals, without the need for piecemeal training to fix problems one at a time. Now that we have shown that free flight training can be used to establish a core flock of released birds, additional studies that directly compare traditional release and free flight methods are needed to determine if free flight training is more effective for psittacine reintroductions.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/birds5030035/s1, Video S1: The aviary; Video S2: Initial flights to and from the mobile aviary; Video S3: Bird in training misses flying to the perch inside the aviary; Table S1: Example of a bi-weekly developmental progress assessment; Figure S1: Free flight training project process chart; and Figure S2. The portable aviary.

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Appendix A

Table A1. Food consumed by released Blue-and-yellow Macaws in southeastern Brazil. The common names used in Brazil are provided since many have no meaningful names in English. "First consumed" shows the calendar month in which the birds were first seen consuming the species (for comparison, all birds started flying outside in May and June). "Naturally occurring" shows whether the plants fed upon by the parrots were there naturally (Yes) or non-native or planted by people (No).

Brazilian Name	Family	Latin Name	Ripeness and Part	First Consumed	Naturally Occurring
Morototo	Araliaceae	*Didymopanax morototoni*	Ripe fruits	August	Yes
Morototo	Araliaceae	*Didymopanax morototoni*	Unripe fruits	October	Yes
Eucalyptus	Myrtaceae	*Eucalyptus* sp.	Ripe seeds	September	No
Manga	Anacardiaceae	*Mangifera indica*	Unripe fruits	October	No
Manga	Anacardiaceae	*Mangifera indica*	Ripe fruits	November	No
Mandacaru	Cactaceae	*Cereus jamacaru*	Flower buds	November	Yes
Jambo amarelo	Myrtaceae	*Syzygium jambos*	Ripe fruits	November	No
Ora-pro-nobi	Cactaceae	*Rhodocactus grandifolius*	Unripe fruits	November	Yes
Abacate	Lauraceae	*Persea americana*	Unripe fruits	December	No
Mandacaru	Cactaceae	*Cereus jamacaru*	Flower buds	January	Yes
Guapuruvu	Fabaceae	*Schizolobium parahyba*	Ripe fruits	January	Yes
Seriguela	Anacardiaceae	*Spondias purpurea*	Ripe and unripe fruits	January	Yes
Cajamanga	Anacardiaceae	*Spondias dulcis*	Ripe and unripe fruits	January	Yes
Caju	Anacardiaceae	*Anacardium occidentale*	Pseudofruits, fruits, and nuts	January	No
Jeriva	Arecaceae	*Syagrus romanzoffiana*	Fruits	January	Yes
Guava	Myrtaceae	*Psidium guajava*	Ripe fruits	January	No

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