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Parrot Free-Flight as a Conservation Tool

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Abstract: The release of captive-raised parrots to create or supplement wild populations has been critiqued due to variable survival rates and unreliable flocking behavior. Private bird owners free-fly their parrots in outdoor environments and utilize techniques that could address the needs of conservation breed and release projects. We present methods and results of a free-flight training technique used for 3 parrot flocks: A large-bodied (8 macaws of 3 species and 2 hybrids), small-bodied (25 individuals of 4 species), and a Sun Parakeet flock (4 individuals of 1 species). Obtained as chicks, the birds were hand-reared in an enriched environment. As juveniles, the birds were systematically exposed to increasingly complex wildland environments, mirroring the learning process of wild birds developing skills. The criteria we evaluated for each flock were predation rates, antipredator behavior, landscape navigation, and foraging. No parrots were lost to predation or disorientation during over 500 months of free-flight time, and all birds demonstrated effective flocking, desirable landscape navigation, and wild food usage. The authors conclude that this free-flight method may be directly applicable for conservation releases, similar to the use of falconry methods for raptor conservation.

Keywords: psittaciformes; macaw; conure; parakeet; reintroduction techniques; hand-rearing; pioneer flock; training; survival; flocking; predator evasion

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1. Introduction

Reintroduction is often a necessary conservation strategy in the face of rapid environmental change and anthropogenic impacts [1]. However, the successful release of captive-raised parrots has been limited due to a variety of problems, including predation, loss of fear of humans, inadequate foraging skills, poor landscape navigation skills, and inappropriate socialization [2–4]. In terms of best practices, released parrots often do better when added to established flocks [1,3,4]. However, there are not always appropriate flocks available, and creating a wild parrot flock de novo from captive-reared birds is a challenge [3,5,6].

For parrots, prerelease training can be a key factor in project success. Prerelease training is broadly defined and can encompass a wide variety of behavior-developing or -modifying techniques. Techniques include the birds observing predation events, keepers providing experience with wild foods to encourage food plant recognition, or operant conditioning training to recall to a protective aviary [4,7,8]. Researchers have been successful in encouraging birds to recognize wild foods, remain near the release site, interact in group settings, increase stamina, and recognize predators [2,4,9–14]. However, many of these methods could be improved, and methods for creating other key survival skills, including effective flocking, landscape navigation, and coordinated response to predators, remain undocumented.

During raptor conservation activities, many key elements of breed and release projects are developed using or modifying established practices of falconry [15], including captive breeding, rearing, physical conditioning, and release methods. Falconry methods applied

to conservation have traditionally outperformed newly developed techniques [16,17], allowing these practices to speed species recovery using predeveloped, field-proven methods. For raptors, release success can be impressive: The long-term survival of captive-reared kestrels can match that of wild-bred individuals using falconry techniques and falconer staff participation [18].

Similar to falconry, there is a system for flying parrots outdoors called free-flight [19]. However, unlike falconry, parrot owners and breeders have historically had less participation in conservation actions [9]. Current parrot free-flight includes the sport flying of pet parrots, outdoor educational bird shows, and parrot keeping, where parrots fly in and out of building windows, similar to an indoor-outdoor pet door. Free-flight tends to utilize internet groups, classes, and in-person seminars to disseminate this practice [19,20]. This paper focuses on a popular method developed by the author Chris Biro (C.B.), heretofore referred to as the free-flight method. Since 1999, C.B. has trained over 400 students in using this method.

This system starts with the trainer creating a strong human-animal bond and site fidelity through the attendance, nurturance, and comforting of chicks during early development. Certain behaviors, including recalling to a trainer, flying point to point between trainers, getting off objects on command, and becoming wary when humans warn of danger are developed using an operant conditioning approach [21]. Once these basic behaviors are established, the trainer takes the birds outside and allows them to interact with the environment, then recalls them back into the safety of captivity. The trainer systematically exposes the birds to more and more complex and dangerous environments. Shortly after fledging and without the need for an operant conditioning protocol, the birds develop skills in flocking, aerial maneuvers, alertness, predator evasion, landscape navigation, wild food consumption, and utilization of information from heterospecifics. These behaviors appear to be generated through animal-environment interaction.

By comparison, most parrots in breed and release projects are provided normal captive care in cages and aviaries in breeding facilities and release sites [6,13,14,22–24]. Unfortunately, these conditions do not allow the animals to develop many of the "instinctive" behaviors that are needed for survival in the wild [3]. In wild individuals, these survival skills normally emerge as a product of the animals' interactions with the environment during their development [25], and in young parrots, these interactions often occur under the guidance and protection of their parents or other conspecifics [26]. In this way, the animals' survival behaviors are calibrated to the environment in which they are raised. Even in domestic animals, such as dogs and mice, that are carefully bred for consistent temperament and behavior, variations in postnatal experiences can have significant lifelong effects [27].

Studies of predator recognition and avoidance in birds have shown how inappropriate escape behaviors can form. Development in a captive environment may create less functional responses than wild development [28]. This is likely because each bird undergoes a threat learning process and has an individualized set of responses to the world formed during early development [29]. Without the necessary experiences during growth and development, the brain circuits that underlie normal behaviors may not form [30]. As a result, captive-raised birds are often considered poor candidates for release into the wild [3,7].

The free-flight method outlined here attempts to overcome this issue by providing the needed experiences during postnatal and juvenile development. Using the broad definition of prerelease training, free-flight "training" can be thought of as developing key survival techniques in release candidates through a combination of limited formal operant conditioning training in early development followed by intentional and sequential exposure to carefully selected and increasingly complex environments. Simply, free-flight is allowing birds' developmental processes to spontaneously fulfill their function by providing the opportunity at the correct age.

The objective of this paper is to introduce a community-based method that that has the potential for use in conservation science. To communicate this method, we document the mortalities and behavioral outcomes of 37 parrots of 7 species and 2 hybrids trained by C.B. using this method in 3 different flocks over a total period of 17 years.

2. Materials and Methods

C.B. began experimenting with free-flight techniques in 1993 and began using the specific method reported here in 1997. The activities reported on in this paper were conducted between 1997 and 2016. Author Constance Woodman, C.W., and C.B. began their collaboration in 1999. Starting in 2008, C.B. and C.W. worked together to document the method in writing [31] and compiled training and behavioral records of all the birds flown by C.B. In 2010, C.B. began formally teaching his expanded version of these methods to pet owners.

In 2016, we conducted a more formal research project to document the methods used and the results during the first year of creating a new free-flying flock. This process was reviewed by the Texas A&M University Institutional Animal Care and Use Committee (IACUC), College Station, TX, USA, and determined to be exempt from Animal Use Protocol on 3 February 2016, as the study utilized recording the outcomes when using pre-existing methods of private individuals (C.B.) from outside the university.

The training process used in this study begins with unweaned, pre-fledge birds and trains them in a series of more and more complicated physical and ecological systems. The guiding principle of this process is that, when placed in the appropriate environments, the birds' behaviors are shaped by interaction with the environment and other animals [31]. The method relies on the birds' natural responses to wild environments during juvenile development as opposed to behaviors shaped one at a time through interactions with a human trainer. Through this process, normal parrot survival skills develop by mimicking what happens in the natural rearing process of parrots raised in the wild by their parents.

The birds learn in 6 distinct environment levels (heretofore referred to as training levels, Figure 1). As the birds' abilities improve, they progress from simple environments (level 0: Indoors in a room) to highly complex environments (level 5: Forests and landscapes with major elevation changes inhabited by dangerous avian and mammalian predators with potentially dangerous weather conditions).

As a note, some verbiage in this paper disagrees with the language used by the free-flight community. We have attempted to codify and explicitly define some activities that are part of the culture of free-flight. For example, a trainer will verbally warn their birds of impending threats intuitively and not define communication as a part of training. Here, we refer to the "human alarm call" that alerts birds to threats, even though that specific term is not a part of the practice of free-flight.

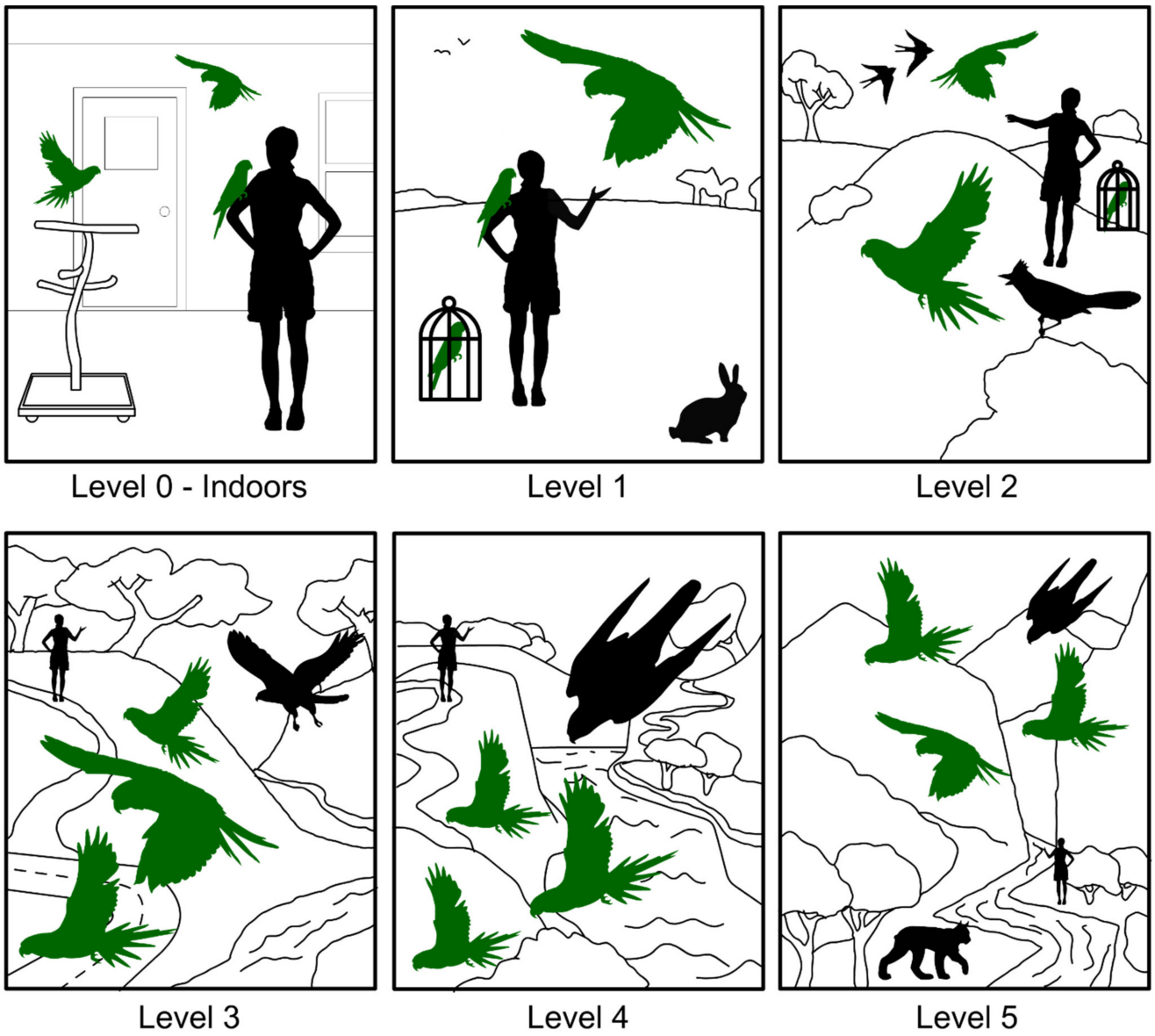

Figure 1. Schematic diagram showing the physical and ecological complexity of sites used for training parrots in this study. Loss of line of sight and landscape feature complexity increases with level. Key level elements include the presence of wild animals: Harmless at level 1, harassing to level 2, casual predator investigations in level 3, occasional determined predator at level 4, and immediate predation threat at level 5. Each image in the sequence shows how landscape features influence the ease of retrieving birds by vehicle or by foot, from contained birds indoors at level zero; to retrieval not being possible at level 5. Note the caged member of the social group (the "anchor bird") in levels 1 and 2 whose contact calls help keep other birds near the training site.

2.1. Flock Descriptions

For this study, we report on the raising and training of 37 individual birds. These birds were flown in 3 flocks, a large-bodied mixed-species macaw flock, a small-bodied mixed-species parrot flock, and a Sun Parakeet flock. All birds were reared and trained similarly except as noted below.

The small-bodied flock included a total of 25 different birds: Sun Parakeets (*Aratinga solstitialis*) $n = 16$, Mitred Parakeets (*Psittacara mitratus*) $n = 5$, Senegal Parrots (*Poicephalus senegalus*) $n = 3$, and a Burrowing Parakeet, (*Cyanoliseus patagonus*) $n = 1$. This group was active for 16 years (1997–2013). Not all birds were intended to be made fully independent, as C.B. focused on a subgroup of show flyers and others were less intensively trained.

The large-bodied flock included a total of 8 different birds: Hybrid "Calico" macaws (*Ara chloroptera* x *Ara militaris*) $n = 3$, Blue-Throated Macaws (*Ara glaucogularis*) $n = 2$, a Scarlet Macaw (*Ara macao*) $n = 1$, a Blue-and-Yellow Macaw (*Ara ararauna*) $n = 1$, and a hybrid "Shamrock" Macaw (*Ara macao* x *Ara militaris*) $n = 1$. This group was active for 13 years (2000–2013). This flock was trained to be maximally independent.

The Sun Parakeet flock included a total of 4 birds, all Sun Parakeets $n = 4$. This group was active for 1 year (2015–2016). This flock was used only for documentation of the early rearing process, and transition from indoor to outdoor flying and training was only conducted at levels 1–3.

When outdoor nesting attempts occurred in mature birds, the birds were not allowed to progress to wild reproduction to avoid creating naturalized populations.

2.2. Locations

The large and small-bodied flocks primarily flew in a rural area outside of Moab, UT, USA. The average temperature during the study period was 14.2 °C, with an extreme maximum of 43.9 °C and an extreme minimum of −21.1 °C. Average annual rainfall was 233 mm [32].

The birds were also transported by C.B. and flown in multiple locations in the Western United States, including locations in Washington State, California, and Oregon. The Sun Parakeet flock was fledged in College Station and primarily flown outdoors in Dripping Springs, TX, USA. The average temperature during the study period was 20.1 °C, with an extreme maximum of 39.4 °C and an extreme minimum of −15.6 °C. Average annual rainfall was 1189 mm [32].

Each group of birds added to the flocks had a different set of location experiences. The sites utilized for level 1, for example, comprised about 20 sites utilized across all 3 flocks. Some birds were trained in only 1 level and 1 area, others were trained in multiple level1 locations. For the 2 longer-term flocks, the small and large-bodied flocks, new level 2, 3, and 4 locations were frequently identified and utilized. Site identification included casual recognition of a site while traveling, where birds might only be flown once with permission of a property owner.

The 3 free-flight flocks varied in their range size based on training. The Sun Parakeet flock was not trained to travel between locations, while the 2 longer-term flocks were. The large-bodied flock was encouraged to follow a vehicle over multi-kilometer trips, further than what was done for the small-bodied flock.

2.3. Data Types and Collection

Data on the large-bodied and small-bodied flocks were drawn from C.B.'s archives and C.W.'s photography and notes. The archives consisted of dated emails, SMS text messages, content and meta-data of digital photographs, and content and meta-data from videos. The data included each birds' name, species, age at first outdoor training, date of each bird's entry into their flock, duration of participation, the reason the bird left the flock, a maximum level reached, and total time spent flying outdoors. To record the Sun Parakeet flock rearing process, a video camera with a time-lapse recording function was mounted above the playpen to record the chicks and monitor how they utilized the space. Records for the Sun Parakeet flock consisted of content and meta-data from normal and time-lapse video, content and meta-data data from photographs, and contemporaneous notes taken by C.W.

Total time flying in a natural environment was estimated based on 12 h of daily flying when not working at seasonal educational shows. Hours flying were calculated per bird, meaning if a group of 10 birds flew for 4 h, there would be 40 h of flying time recorded. To understand how outdoor flight mortality outcomes compare to conservation outcomes of similar outdoor duration, a "flight months" metric was created. The hours of outdoor flying are converted to "flight months", consisting of 30 counts of 12 h outdoors. Mortality

outcomes were analyzed using the Mayfield method [33], calculating the risk of death for 1 year. All data are presented as mean ± standard deviation unless otherwise noted.

2.4. Level 0

2.4.1. Goals

The skills the birds gained at level 0 were skills for socialization, weaning, and fledging. Meeting all the criteria in Table 1 were needed for the bird to move to a level 1 environment.

Table 1. Level p environmental characteristics and mastery criteria for parrot free-flight training. The birds in this study completed level p criteria between the time of fledge and weaning, ~70 d for Sun Parakeets, ~100 d for macaws.

Environmental Features	Mastery Criteria
• Handfeeding location. • Enclosed spaces such as a living room or outdoor aviary • No wild species.	• Trainer linked with the consistent meeting of care needs through associative learning. • Accepts food and water from the trainer. • Accepts interaction from trainer including snuggles and toy play readily. • Steps up on the trainer. • Approaches trainer on foot or wing when separated. • Returns to the trainer with recall cue. • Leaves perch with "get off" cue. • Lands on difficult to reach perches. • Flies throughout the entire space. • Orients to other birds in flight ("tagging," "chasing"). • Aerial maneuvers (i.e., "jinking" sudden turn in the air).

2.4.2. Acquisition

To document the general early rearing process for all flocks, 4 captive-bred, hand-reared, incubator-hatched Sun Parakeets from different clutches were purchased from a commercial bird breeding facility and assembled into an aggregated group of young. The hatch dates of the birds were unknown, but the developmental stages were roughly estimated as 33 days old (n = 1) and 40 days old (n = 3). When acquired, the chicks were able to walk between locations, thermoregulate, and possessed adequate stamina and coordination to climb up and over Carefresh-brand bedding (http://www.carefresh.com/ accessed on 22 February 2021) substrate and return to the nest box after play periods. At the time of acquisition, the chicks were not yet human-socialized. Gaping, swaying, and cowering in the presence of human beings were observed.

2.4.3. An Enriched Rearing Environment

For all 3 flocks, the rearing setup was intended to maximize opportunities for interaction with the environment. The environment, built as a playpen, was roughly 1 m × 1 m with 0.5 m-high cardboard walls (Figure 2). A small box with a paper towel flap provided a cavity for the birds. The box and playpen were routinely refilled with clean bedding. Various objects, climbing opportunities, and foods were placed on the bedding, including toys and soft comfort "cuddle" items. A lamp on a timer provided 12 h per day of direct lighting. The chicks were old enough to thermoregulate so they could be safely reared without a temperature-controlled brooder. This general setup focused on free-choice activity, where chicks could remain inside a dark box or leave the box and engage with multiple activities in the environment. Additional rearing and housing details are similar to those described by Speer [34]. Additional parrot developmental complexity, a topic much too complex for this methodology, has been described by Bond and Daimon [35].

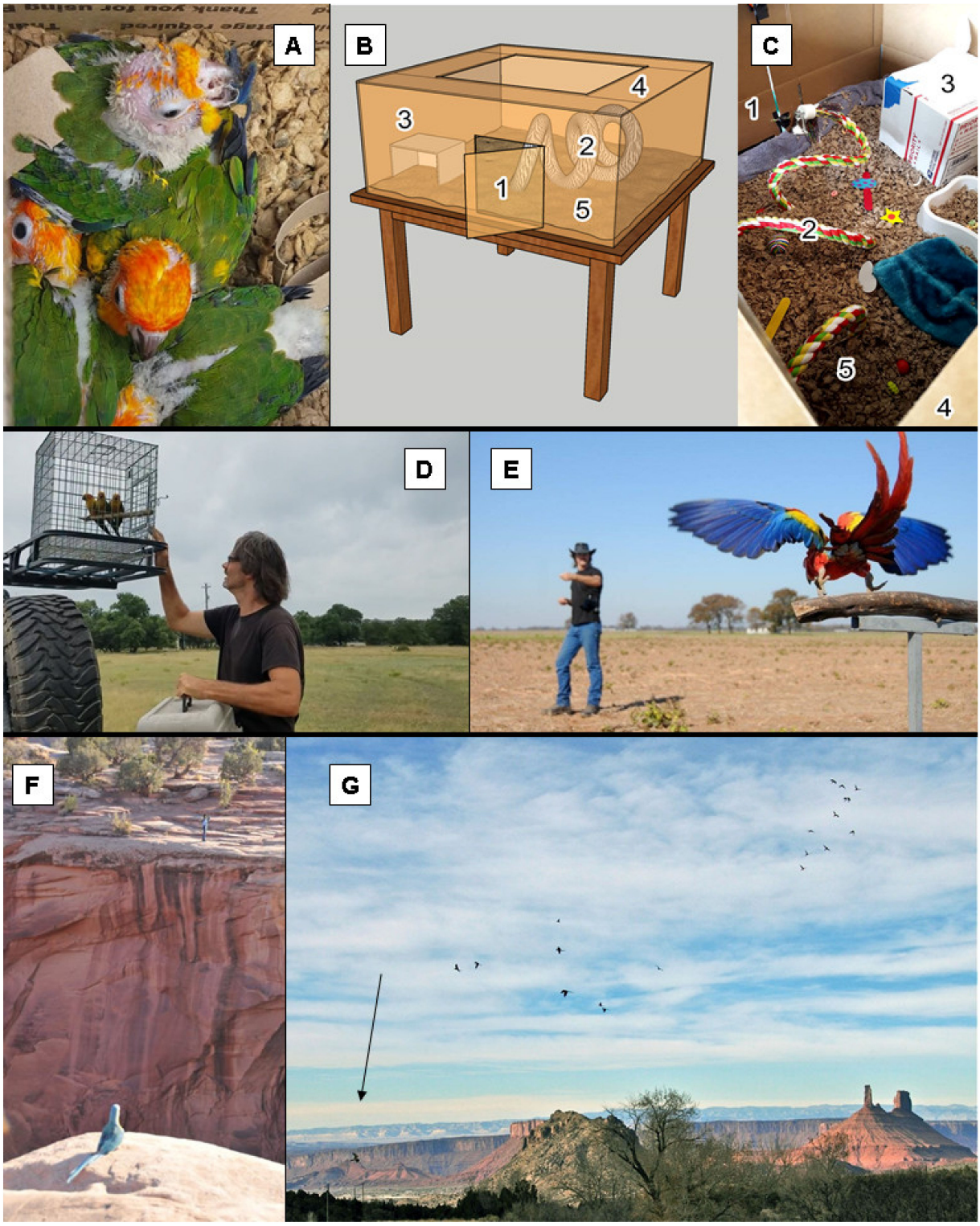

Figure 2. Stages during free-flight training: (**A**) Sun parakeets flock at the time of acquisition, 33–40 days old. Chicks showed a lack of human socialization through gaping and swaying as well as cowering; (**B**,**C**) Playpen rearing area. 1. Feeding access door. 2. Wire cored rope climbing coil. 3. Box with paper towel entry flap. 4. Overhang to prevent climbing out. 5. Carefresh-brand bedding on the floor and in brooder box; (**D**) Author Chris Biro at a level 1 area appropriate for small birds, an open area of about 3 hectares. Note the transport carrier and anchor birds' cage; (**E**) Author Chris Biro at a level 1 area appropriate large-bodied birds, utilizing a much larger open area of about 16 hectares. Note the portable perch for back and forth flying; (**F**) Complex landscape navigation training (levels 3–5). Trainers on either side of a canyon and cliff complex recall the birds at the safest crossing points to train landscape navigation; (**G**) The large and small-bodied flock escape from a hawk (arrow) at the home base.

2.4.4. Feeding and Training

All chicks in all 3 flocks were hand-fed using plastic syringes and commercial Kaytee-brand hand-feeding formula (https://www.kaytee.com accessed on 22 February 2021). The objective of syringe feeding was to enable normal use of the beak and tongue as opposed to feeding by gavage needle where the mouth is bypassed. Solid food, including apple slices, breakfast cereals, and Zupreem parrot pellets (https://zupreem.com accessed on 22 February 2021), were provided daily to enable a smooth transition to weaning and maximize options for chick activities.

Feedings broadly followed the manufacturer's recommendations and varied based on individuals' ingested amount per feeding, digestion speed, and age. Body condition scoring, a common veterinary technique, was utilized to monitor health [36].

The introduction of the recall cue was paired with feeding times. During feeding times, the chicks ran to the syringe and followed the human hand to different areas of the playpen while the recall cue was presented. The cue was a verbal "here birds" or the bird's specific name to train for individual recall versus full group. Over time, the birds came to the cue whether or not the syringe was present.

The Sun Parakeets weaned at approximately 60 days of age. To check that the wean was complete, the birds were weighed at the time of cessation of hand feeding and 1 week later. Weight losses of <5% indicated birds were maintaining body condition and the wean was successful.

2.4.5. Handling

To ensure that the chicks became comfortable interacting with the researchers, chicks were handled several times a day. Handling consisted of petting, holding, carrying, and interacting. Chicks approached human hands spontaneously 3 days after acquisition for the Sun Parakeets flock. The chicks were taken on 30-min trips to indoor or outdoor spaces away from the playpen roughly every 2 days.

2.4.6. Fledging

Once chicks had well-developed wing feathers, at approximately 50 days of age for the Sun Parakeets, they began spontaneously climbing to higher perches and intensely flapping their wings. By the time the chicks fledged, they were already responsive to the recall cue, having run to the hand while being called during feedings. As the birds became proficient at hopping to the trainer, hops were regularly practiced until they became short flights. The goal was to produce maximum flight skills available within this contained environment and to establish a behavior routine of flying to the human on cue, building the recall behavior prior to fledge.

The playpen environment was modified for the fledge by adding a second rope perch, with a loop extending above the playpen. A perch "tree" was set up near the playpen for flight practice. By day 60 of age, the Sun Parakeets spontaneously flew to the researcher and areas around the rearing area. The Sun Parakeets flew frequently throughout the day. As weaning occurs after fledging, parakeets who flew to the researcher for food were fed first, creating a competitive situation that rewarded fast response to the recall cue.

To develop a "get off" behavior, birds were spoken to sharply immediately upon landing in an unsafe location. The harsh volume and tone of voice resulted in them flying off. The birds appeared to become more sensitive to the sharp "get off" cue and readily responded more immediately as time went on. When birds could fly as a group, engage in aerial acrobatics, be individually or jointly recalled, and responded to a "get off" cue, they were ready to transition to a level 1 environment. The birds were called over for food, touch, or play, then shooed back to the perch or placed on the perch. Then, they were recalled again and given more attention or hand-feeding as a reward. The flying away and back to the trainer repeatedly led to a habit of back-and-forth flying to nearby approved objects, called "point-to-point" or "A-to-B" flight. Nonapproved landing sites were identified through the get off cue.

2.4.7. Human Alarm Call

When chicks were observed engaging in a problematic activity, such as climbing an object that would fall over, the trainer would warn the chick in a louder, stern tone. As chicks frequently had such problems, the chicks learned to associate the tone with coming danger, a precursor to the training creating increased outdoor wariness in later levels.

2.4.8. Move to Outdoor Caging

After confirming that weaning was complete, the Sun Parakeet flock was moved full-time to a tall outdoor aviary that was approximately 5 m by 3.5 m by 2.7 m tall in Dripping Springs, TX, USA. The aviary allowed for nearly constant, unmonitored flying, and physiological adaptation to the mild early summer outdoor environment. The large-bodied and small-bodied flocks were split across similar aviary buildings when not out flying. These outdoor aviaries were at the home base site. Back-and-forth flying was developed from the food- and comfort-seeking flights to the trainer. Large, portable perches were introduced into the outdoor aviary and utilized for back-and-forth flying practice.

2.5. Level 1

2.5.1. Landscape Setting

The landscape features of these sites were all similar and can be summarized as large, flat areas with few trees or shrubs similar to prairies or agricultural fields. There were limited opportunities for biotic interactions and only mild weather (Table 2, Figure 1). The transport vehicle was parked adjacent to the flying area to train the birds to return to this easily discernable landmark.

Table 2. Level 1 environmental characteristics and mastery criteria for parrot free-flight training. Training occurred as close to fledging as possible, and older individuals were observed to be more likely to panic fly or not bond with the group. Birds in this study gained mastery within about 3 weeks of flying. All criteria were mastered before birds were moved to the next-level environment.

Environmental Features	Mastery Criteria
• Open field. • Light wind. • No precipitation. • Distant wildlife. • Simple retrieval by foot or vehicle.	• All previous criteria. • Repeated practice flying at low and high altitudes. • Fly with and against the wind. • Demonstrate endurance through multi-minute continuous flapping flight. • Introduced to flocking outdoors with others. • Fly low the majority of the time (high flight is associated with nervous behavior, indicating the bird is unready for more complexity). • Tendency to stay near rally point vehicle between flights. • Develop complex movements initiated during aerial play. • Utter alarm and contact calls. • Respond appropriately to flockmate's contact and alarm calls through increased wariness, reply calling, and approaching calling flockmate.

2.5.2. Goals

The skills the birds gained at level 1 were foundational skills for flying in an outdoor space and returning to the trainer. Meeting all the criteria in Table 2 was needed for the bird to move to a level 2 environment.

2.5.3. Point-to-Point Flying

Before the training sessions, portable perching stored in the rally vehicle was set up adjacent to the rally vehicle. The bird(s) were taken from the carrier by hand and placed onto a portable perch. The trainer walked a few meters away and began the "point-to-point" back-and-forth perch flight routine developed during level 0. This back-and-forth routine

was utilized to acclimate the birds to the new conditions in level 1 through a familiar routine. During the first outdoor flights, 1 bird at a time practiced point to point.

2.5.4. Rally Vehicle and Anchor Bird

During initial training, not all birds were taken out to fly at once. Birds not being trained were placed in a cage on the top of the rally vehicle, as shown in Figure 2. These caged bird(s) were able to contact call with the bird(s) being trained, forming an "anchor." During training sessions, the birds rarely flew outside of the contact call range of these anchor birds to which they were socially bonded, which helped them remain near the rally vehicle.

2.5.5. Recall Cue

The recall cue developed at level 0 was put into practice at level 1. Recall practice began with the back-and-forth flying routine and continued each time the bird flew off the perch and explored the area. When multiple trainers were available, birds could be recalled between trainers to practice distance flying and build stamina. The constant presence of the vehicle and anchor bird(s) during recall, as shown in Figure 2 helped reinforce the vehicle as the return point.

2.5.6. "Get Off" Cue

The "get off" cue, developed at level 0, was utilized at the level 1 outdoor location. Birds were cued to "get off" when they entered dangerous situations such as approaching powerlines or landing on a vehicle that was not the rally vehicle.

2.5.7. Human Alarm Call

Using warning tones while speaking in a louder voice, the trainers could verbally increase the birds' awareness. For example, if another vehicle approached but the birds were oblivious, the trainer would speak in a louder, warning tone, and the birds would increase their attention to the environment and notice the oncoming car. Through practice, the birds learned that the warning tone signaled a need for increased vigilance.

2.5.8. Flying in a Group

Chicks initially flew 1 at a time. Other socially bonded birds were held back in a cage on the rally vehicle. As the birds explored, they were praised for exploratory flights and increasingly complex aerial maneuvers. Once each bird was competent in outdoor point-to-point flying, the birds would be placed as a group on the portable perches and to fly point to point as a group until they became confident enough to explore the area and expand beyond point-to-point flights. Confidence was judged by a lack of fear-associated behaviors. Fear-associated behaviors included high flight, increased respiration, raised hackle feathers for moderate fear, completely smooth feathering for strong fear, dilated pupils, panting, tight gripping of the perch or arm, alarm vocalizations, and distress vocalizations [37].

2.5.9. Feeding on Plants

Feeding on plants was limited in level 1 except when birds were flown near lone trees or shrubs present in the landscape. Utilization of sparse trees of shrubs for practicing recall coming down from trees and flying up into them was conducted occasionally. Upon contacting a tree or shrub, the parrot inevitably began chewing on buds, seeds, shoots, and leaves. The "get off" cue was utilized to discourage chewing on plants that the trainer felt were inappropriate or might have been toxic.

2.5.10. Situations Special to Level 1

If the trainer felt that 1 or more birds were fearful, the birds were placed back in their carriers to allow them to acclimate to the site and watch their socially bonded fellows fly. When startled, some birds occasionally flew up very high (>40 m). When this happened,

the anchor bird usually initiated back-andforth contact calls. The high-flying bird would circle the anchor bird and the trainer, eventually tiring and circling and gliding back to the anchor bird and trainer at the rally vehicle. The recall cue was utilized during the high flying to encourage the bird to return.

Circling flights, increased speed, and increased distance away from the trainer occurred. Eventually, all birds engaged in sudden movements using their tail to maneuver, called "jinking," recreating the aerial play patterns seen at level 0. This initial pattern of behavior was similar for all flocks.

Uncontrolled flights associated with strong fear states were called panic flights. In a panic flight, there was no response to the recall cue. Panic flights were rare. A prolonged panic flight was observed on a single occasion in 2014 when C.B was building a new macaw flock. The event is worst-case and is noteworthy enough to include even though the bird was not from the 3 studied flocks. A straight-line panic flight away from the rally vehicle was observed by C.W. when C.B. was flying a macaw. After 13 min of flight, the bird tired, lost altitude, and landed. The bird was not observed to engage in another panic flight over subsequent weeks. As the bird was being flown in an appropriately wide, agricultural field complex, the bird never left the line of sight or entered a forested area. Nervous flying at unusually high altitudes was only observed at level 1.

2.6. Level 2

2.6.1. Landscape Setting

Level 2 landscapes consisted of various shrubby fields, gentle hills, and sparsely treed areas (Table 3). Flying through trees introduced the birds to territorial songbirds, while flying in the vicinity of bodies of water provided harassing, curious gulls. Level 2 landscapes did not contain known dangerous predators except as aerial silhouettes on the horizon. Retrieval of birds was possible by off-road vehicle.

Table 3. Level 2 environmental characteristics and mastery criteria for parrot free-flight training. The average time to master level 2 was 3 weeks. Mastery time could be extended depending on the exact location and wildlife presence. The frequency of wildlife interactions was a limiting factor.

Environmental Features	Mastery Criteria
• Hills, shrubs, and small or isolated trees. • Breezy or gusting wind. • Mist or drizzle. • Non-dangerous wild species that follow or harass. • Retrieval by foot or vehicle relatively easy	• All previous criteria. • Recalls to the trainer from shrubs and trees. • Chooses perches for easy takeoff. • Startle response to strange species. • Joins flock in flight. • Coordinated group escape from curious or harassing wildlife initiated by any flock member. • Recalls after a momentary loss of sight of the trainer. • Returns to and follows rally vehicle over short distances.

2.6.2. Goals

The primary goals of level 2 were to encourage brief, independent navigation when the line of sight is broken, build stronger flocking skills, introduce interaction with shrubs and trees, and interact with wildlife to begin the development of antipredation behaviors (Table 3).

2.6.3. Rally Vehicle and Anchor Bird

During level 2, 1 bird was typically an anchor bird while the others were flying. During level 2, birds required less individual monitoring of behavior as panic flights and confusion were less frequent than during initial level 1 experiences.

The rally vehicle was parked close to the trainer, continuing to build an association of returning to the vehicle after periods of activity. The vehicle was often driven a short

distance during training, changing the location of both the trainer and the vehicle. These alterations in location made it possible to train the flock to follow the vehicle and orient to a changing rally point.

2.6.4. Point-to-Point Flying

Similar to level 1, back-and-forth flying was utilized to adapt the birds to the new environment until they became comfortable with exploring. Birds were let out individually for training or as a group.

2.6.5. Recall Cue

The recall was practiced throughout the 1- to 6-h sessions, with significant focus on coming down from trees and shrubs. The birds followed the trainer around single trees of isolated forest fragments and learned to follow and recall even when visibility was blocked by trees and hills.

2.6.6. "Get Off" Cue

Birds were cued to "get off" when they entered potentially dangerous situations or attempted to consume unsafe items. Observed uses included interrupting perching on a stump near to the ground, landing on dangerous cacti, and landing on powerlines.

The "get off" cue was utilized to direct the birds to safely utilize perching in trees and shrubs. Members from all 3 flocks were not permitted to rest in dense tree cover or other locations where the birds could not see approaching predators. Inexperienced birds would initially perch close to the trunk of a tree and would be discouraged from doing so using the "get off" cue. Using the "get off" cue led to permanent behavior of perching on outer branches where emergency takeoffs were unobstructed by dense branches.

2.6.7. Human Alarm Call

The human alarm vocalizations initially developed in level 1 were utilized in subsequent levels. By increasing alertness in the flock, the trainer selectively sensitized the birds to dangerous situations. The level of volume and harshness of tone were commiserated with the danger. Birds were alerted to be wary at the approach of harassing wildlife. Bird wariness was increased selectively, such as for a dangerous hawk's silhouette flying far away. However, bird wariness was intentionally not increased for a harmless vulture silhouette at the same distance, building recognition of predators before close encounters.

2.6.8. Flying in a Group

Birds from the same cohort were permitted to fly together when each individual showed competence in recalling from trees or shrubs and when there was a break in the line of sight to the trainer. Birds were flown as individuals or in subgroups of the full flock to focus on skill development in specific members.

Birds from all flocks tended to group in response to the approach of harassing wild animals. When available, more experienced birds were added to level 2 birds in training once the newly flying birds showed competency in recalling from trees and broken line of sight. When flying with more experienced birds from outside the study, the Sun Parakeets flock learned to respond to the alarm calls and escape flights of the macaws and cockatoos. Sometimes, the Sun Parakeet flock would follow and perch next to the larger birds C.B. brought out to go flying, apparently gaining information about how to use the landscape from the more experienced flyers.

2.6.9. Feeding on Plants

Birds would almost always chew spontaneously on the nearest plant parts whenever they landed in foliage. The "get off" cue was utilized to discourage landing on spiny plants or chewing on undesirable plants.

2.6.10. Situations Special to Level 2

Northern mockingbirds, (*Mimus polyglottos)*, blue jays, (*Cyanocitta cristata)*, grackles (*Quiscalus* spp.), and various gulls (genus *Larus*) were observed to chase and threaten the parrots. Interactions with aggressive, non-dangerous birds like these allowed the free-flight flocks to practice grouping and responding to threats. The flocks spontaneously grouped up and fled or stood their ground in response to harassment. For example, the Sun Parakeet flock would occasionally group and chatter or chase harassing wildlife, beginning the development of mobbing behavior.

Through repetition, the flocks learned what stimuli indicated real danger. Initial inappropriate hypersensitivity to certain kinds of harmless events, such as a vulture high and far away on the horizon, became appropriate after multiple repetitions. Eventually, the birds learned to accept a distant vulture while still reacting to approaching raptors.

2.7. Level 3 through 5

2.7.1. Landscape Progression and Training Activities

Level 0 developed a bond between the trainer and birds and established many basic flight skills within a contained space, while levels 1 and 2 focused on expanding early skills to unconfined but open spaces. Basic outdoor flight skills, including beginner-level navigation, flocking strengthened recall, and avoidance of harassing wildlife, were achieved in levels 1 and 2. Increased 3-dimensional flying and brief loss of sight to the handler were achieved in level 2. The next levels were incremental increases toward fully independent function in the landscape. The environmental complexity increased from level 3 through 5 (Table 4), matching the trainer's evaluation of behavior mastery. Level 4 conditions were frequently similar to level 5, and only differed based on landscape access for the trainer. The trainer's ability to access a disoriented, injured, or struggling bird was an important factor in choosing a level 4 versus 5 locations. At level 5, there was no ability for recovery or rescue, emphasizing the need for fully independently functioning birds.

During level 3 through 5 training, the tools developed in earlier levels were utilized to encourage more complex behavior. The human alarm call was used to sensitize birds to new dangers in their environment without deleterious trial and error. The rally vehicle was parked out in the open as much as was possible to keep the return point visible to the birds in the increasingly hilly and forested terrain. Anchor birds were mainly utilized during the initial visits to new sites. An anchor bird was carried on the trainer's hand to encourage other birds to follow while on a hike, teaching routes and moving birds to desired training locations. Hand-carried anchor birds were also used to encourage reluctant birds to fly down from a tree or cliff or enter an area with novel features. Birds were recalled while the rally vehicle was in motion. The vehicle drove along access roads between sites, guiding the small and large-bodied flocks to fly between sites.

Back-and-forth flying practice was utilized to encourage the birds to safely interact with complex landscape features (Figure 2). A second trainer was often present to recall the birds to a location where the birds were unlikely to fly alone. Examples included canyon and cliff navigation, selection of safest crossing points over water or forested terrain, and selection of cliff diving sites to develop skill in diving escape behaviors.

Table 4. Level 3 through 5 environmental characteristics and mastery criteria for parrot free-flight training. The time for new flocks to reach levels 4 and 5 was normally within 1 year and before 2 years of age. Not all birds reached level 5, as intentionally flying the birds without the ability to retrieve or under immediate predator threat was not necessary for developing skills.

Level 3 Environmental Features	Mastery Criteria
• Substantial elevation variation. • Open forest. • Small ponds/small streams. • Windy, light precipitation. • Investigative pursuit by aerial predators. • Retrieval by foot and off-road vehicle.	• All previous criteria. • Exploration and learning of landscape, circling and exploration patterns. • Consistent routes between features, and preferred, safe, perching areas. • Habituation to weather and precipitation, respond by appropriate sheltering instead of anxiety behaviors. • Ability to fly during wind gusts. • Some mobbing or intimidating behaviors toward harassing wildlife. • Complex aerial escape maneuvers. • Recall after 2–3 min of loss of sight of the trainer.
Level 4 environmental features	**Mastery criteria**
• Water basins or major streams. • Windy, heavy precipitation. • Chance of pursuit by a determined aerial predator. • Retrieval is possible only by foot or specialty vehicle due to limited vehicle access.	• All previous criteria. • Fly up and down cliffs. • Complex diving and escape maneuvers. • Habituation to heavy precipitation. • Strong flight negotiating wind gusts. • Strong flock mobbing, escape, and predator confusion behaviors. • Recall readily after 5–10 min out of sight of the trainer. • Intelligent disobedience, refuse cues if there are hazards present.
Level 5 environmental features	**Mastery criteria**
• Extreme elevation changes and landforms. • Low visibility due to precipitation. • Large bodies of water or swift-moving water. • Immediate threat from determined predators. • Retrieval not possible due to landscape or lack of specialty vehicles.	• All previous criteria. • Function completely independently between sporadic recall cues. • Safely negotiate immediate and serious predator threats.

2.7.2. Goals

Level 3 through 5 training developed familiarity and appropriate responses to a variety of landforms, predators, local food plants, and weather conditions. Most bird activities consisted of the birds experiencing and reacting to biotic and abiotic environmental factors in the human selected environment, with guidance to move the birds through the landscape where certain experiences in the environment was provided by the trainers. As the birds functioned more independently, they were expected to engage in "intelligent disobedience," a concept most often encountered in service dog training [38]. The animal should be aware enough of the environment to refuse a trainer's cues that increase risk until the risk passes.

3. Results

A total of 37 parrots across 3 free-flight flocks logged a total of 501.2 flight months during this study. Total combined mortality during outdoor flying was six birds or 16%. The causes of outdoor flying mortality were human environmental hazards (pesticides

n = 2, powerline n = 1, wind turbine n = 1) and weather associated with flying birds in cold climates (n = 2). A total of 20 birds were retired either before or at the end of the study.

The large-bodied flock was flown over 13 years. The members of the large-bodied flock logged 147.3 flight months total (18 ± 3.2 months per individual, n = 8 individuals). The longest membership was 25.5 flight months over 9 years for a scarlet macaw, who was retired, the shortest membership was 15.3 flight months over 7 years for a blue-throated macaw, who was also retired (Table 5).

Table 5. Outcomes for three free-flight parrot flocks from 1997–2016 flown in the continental United States. Of 37 birds, 6 died due to abiotic hazards in the environment and 11 died due to husbandry-related issues. LB is large-bodied flock, SB is small-bodied flock, S is Sun Parakeet flock. Flight months are defined as 30 twelve-hour days flying in wildland spaces. Age level 1 is the age, in months, when a bird began flying outside. The level attained is the highest level on the free-flight Biro system of 0–5 environmental complexity.

Species	Flock	Age Level 1	Start Level 1	End Training	Membership Months	Flight Months	Level Attained	Fate
Blue & Yellow Macaw	LB	3	Apr-00	Apr-07	84	21	4	Wind turbine mortality
Scarlet Macaw	LB	3	Oct-04	Mar-13	102	25.5	5	Retired
macaw hybrid	LB	3	Jul-06	Mar-13	78	19.5	5	Retired
macaw hybrid	LB	3	Jul-06	Jan-12	66	16.5	5	Aviary fight mortality
Blue-Throated Macaw	LB	3	Jul-06	Mar-13	66	16.5	5	Retired
Blue-Throated Macaw	LB	3	Dec-06	Mar-13	61	15.25	5	Retired
macaw hybrid	LB	12	Oct-07	Mar-13	66	16.5	5	Retired
macaw hybrid	LB	3	Oct-07	Mar-13	66	16.5	5	Retired
Mean ± SD		4.1 ± 3.0				18.4 ± 3.2	4.9	
Patagonian Parrot	SB	3	Jun-97	Mar-13	154	38.5	5	Retired
Mitred Parakeet	SB	3	Jun-97	Aug-06	99	24.75	4	Electrical line mortality
Mitred Parakeet	SB	3	Jun-97	Aug-04	75	18.75	5	Pesticide mortality
Mitred Parakeet	SB	3	Jun-98	Jul-07	87	21.75	4	Aviary fight mortality
Mitred Parakeet	SB	3	Jun-98	Aug-04	63	15.75	4	Pesticide mortality
Sun Parakeet	SB	3	Apr-99	Mar-07	94	23.5	4	Aviary fight mortality
Sun Parakeets	SB	3	Nov-04	Mar-13	101	25.25	5	Retired
Sun Parakeets	SB	3	Nov-04	Nov-06	24	6	4	Husbandry issue
Sun Parakeets	SB	3	Nov-04	Nov-06	24	6	4	Husbandry issue
Sun Parakeets	SB	3	Nov-04	Nov-06	24	6	4	Husbandry issue
Mitred Parakeet	SB	4	Feb-08	Mar-13	61	15.25	5	Retired
Sun Parakeet	SB	3	Mar-08	Mar-13	60	15	4	Retired
Sun Parakeet	SB	3	Mar-08	Mar-13	60	15	4	Retired
Sun Parakeet	SB	3	Mar-08	Mar-13	60	15	4	Retired
Sun Parakeet	SB	3	Mar-08	Mar-13	60	15	4	Retired
Sun Parakeet	SB	3	Mar-08	Aug-10	30	7.5	4	Natural death
Sun Parakeet	SB	3	Mar-08	Feb-13	60	15	4	Weather mortality
Sun Parakeet	SB	3	Mar-08	Feb-13	60	15	4	Weather mortality
Sun Parakeet	SB	3	Mar-08	Mar-13	60	15	4	Husbandry issue
Sun Parakeet	SB	3	Nov-08	Nov-08	0.1	0	0	Husbandry issue
Senegal Parrot	SB	3	Mar-08	Mar-11	36	9	3	Husbandry issue
Sun Parakeet	SB	3	Mar-10	Mar-13	36	9	4	Retired
Sun Parakeet	SB	3	Mar-10	Mar-13	36	9	4	Retired
Senegal Parrot	SB	5	Mar-10	Mar-13	34	8.5	5	Retired
Senegal Parrot	SB	5	Mar-10	Mar-10	0.1	0	0	Husbandry issue
		3.8 ± 0.57				15.2 ± 7.6	4.2	
Sun Parakeet	S	3	Jul-15	Jul-16	12	1.1	3	Retired
Sun Parakeet	S	3	Jul-15	Jul-16	12	1.1	3	Retired
Sun Parakeet	S	3	Jul-15	Jul-16	12	1.1	3	Retired
Sun Parakeet	S	3	Jul-15	Jul-16	12	1.1	3	Retired
		3.0 ± 0				1.1 ± 0	3.0	

The small-bodied flock was flown over 16 years. The members of the small-bodied flock logged 349.5 flight months total (15.2 ± 7.6 months per individual, n = 25 individuals). The longest membership in the small-bodied flock was 38.5 flight months over a 16-year span for a burrowing parrot, who was retired, and the shortest membership was 0 flight

months for a Senegal parrot and Sun Parakeet that were not yet bonded to a human trainer, escaped before starting outdoor training, and were subsequently unrecovered (Table 5). These two birds' zero values of outdoor training duration were omitted to calculate means and standard deviations.

The Sun Parakeet flock was flown for 1 year, and the total flight months were 4.4 (1.1 ± 0 flight months per individual, $n = 4$ individuals). All birds from the Sun Parakeet flock were retired after 1 year, with no early exits from the flock.

3.1. Predation and Husbandry-Related Mortality

No birds were killed by predators even though they flew in predator-rich environments. Predators seen at the Moab, Utah location included *Accipiter* hawks, *Buteo* hawks, peregrine falcons (*Falco peregrinus*), golden eagles (*Aquila chrysaetos*), coyotes (*Canis latrans*), fox species (genus *Vulpes*), and bobcats (*Lynx rufus*). The two long-term flocks, small-bodied and large-bodied, were primarily flown in a hawk migration area. The largest observed migration was a kettle of 197 hawks. The predators seen at the Dripping Springs, TX, USA location included *Buteo* hawks, *Accipiter* hawks, feral domesticated cats, fox species, and coyotes. Mortality was primarily due to husbandry issues (Table 5). Of the 37 birds studied, 11 died during captive management. These deaths occurred unrelated to outdoor training and included dying naturally during sleep or accidental escape of a young bird before any training began. The death during husbandry and training combined translates into a mortality rate of about 45%.

To understand this mortality in terms of risk over time in outdoor environments, the Mayfield method [33] was utilized. The calculation did not include the two fledged chicks that escaped before the start of outdoor training. During birds' first year of flight months, there was 100% annualized daily survival probability during outdoor training. During the first year, six birds were considered husbandry-related moralities, creating a 59% annualized daily survival probability related to handling and care. After the first year, annualized survival probability during training decreased to 77%. Annualized post-first year captivity and husbandry survival probability were 60%.

Flocking and Responses to Predator Threats

During level 0 training, hand-fed chicks flew as a group to be fed when formula was presented, practicing the fundamentals of group flight. The birds also tended to follow one another around the human home while expanding their activity area from the playpen. Social play during flight consisted of chasing, following, and pouncing, such as landing by grabbing the tail of a flockmate. During level 1, the groups became more cohesive, with birds increasingly seeking to remain with the group. During level 2, defensive flocking was developed through repeated interactions with harassing wild birds. Sometimes, flocking coordination was developed from a single, prolonged set of interactions with a particularly tenacious wild bird, such as a black vulture (*Coragyps atratus*), that followed the Sun Parakeet flock for an hour. In other cases, interactions with multiple wild birds formed the basis of a predator response. After each iteration or harassment, flocking behavior became more cohesive, forming coordinated vigilance, escape, and mobbing behaviors as seen in wild birds. A gull or a jay that might initially scatter the birds during early interactions would face a coordinated, alarm calling group during subsequent interactions.

Once birds gained level 2 mastery, flocking behavior was highly developed and consistent in all three flocks, with birds seldom leaving the line of sight of the group. Coordinated alarm calling and escape developed at that time. Level 3 training developed birds' discrimination between non-dangerous wildlife and animals that posed a predation threat. Early mobbing behaviors of agitated chatter and approach of predators by the flock, observed in earlier levels, grew to be aggressive in rare circumstances, unrelenting mobbing in level 4 conditions.

Interactions with predators were primarily with avian predators. It is estimated that over 100 aerial predation attempts were observed across the 3 flocks, primarily hunting

attempts by bird-hunting *Buteo* and *Accipiter* hawks. When a predator was observed, one bird would typically alarm call and launch into flight, and its fellows would immediately launch as well. All three flocks responded to predator observation with a pattern of identification, alarm calling, launching, forming tight flying groups, predator avoidance, effective perching for escape, and exhibiting wariness. All three flocks utilized loud, continuous vocalizations in the presence of predators. If the birds were already airborne when a predator was observed, an initial bird would alarm call and the birds would form into a tighter group while already in the air.

The large and small-bodied flocks were observed, in some cases, mobbing predators and strange animals that approached the flock. Mobbing was a spectrum of behavior, ranging from tentatively approaching the target while the group alarm-called to the extreme of chasing and biting. Typically, the flocks alarm-called and stood their ground, facing the target as a group. C.W. observed one instance in the large-bodied flock and one instance in the small-bodied flock where flock members aggressively chased a target. In one instance of extended mobbing, the large-bodied flock drove a golden eagle that approached the flock out of a valley and up over the cliff rim about 2km away for approximately 10 min before breaking off pursuit. The small-bodied flock showed high aggression when they chased a pet parrot of a species that was not a part of their flock that had been accidentally let loose and flew into their midst. The flock surrounded the bird in the air, physically pushed the offending bird to the ground, and forced it to land, where a trainer broke up the skirmish.

3.2. Behavioral Outcomes

Behavioral outcomes are summarized in Figure 3. The two long-term flocks were outdoors regularly for long durations. The large- and small-bodied flocks were most regularly free-flown in the area around the home base, ranging up to 2 km normally. The two flocks occasionally flew further away when at the home base, but excursions were difficult to verify due to the lack of telemetry. The conditions at the Utah home base ranged from level 2–4 based on predator presence and weather. The normal flying day was approximately 12 h a day of flight time, varying depending on seasonal day length. Outdoor flight time for the small- and large-bodied flocks involved periods of no supervision, estimated to be up to 2 h, while trainers were in a nearby building. There were almost always more experienced birds present at the home base when new juvenile birds were let out to free-fly. Occasionally, birds would not recall at the end of the day and would outdoors overnight, but the frequency of these overnights was not recorded.

The Sun Parakeet flock home base in Dripping Springs, TX, USA was adjacent to a heavily forested area ranging from level 3 to 4, requiring the development of level 3 skills before flying at the home base. Their free-flight sessions were up to 6 h a day. Experienced free-flight trained birds from outside the Sun Parakeet flock were less often present at the home base when the Sun Parakeet flock was free-flown due to the difficulty of casual tracking of birds in among the dense trees.

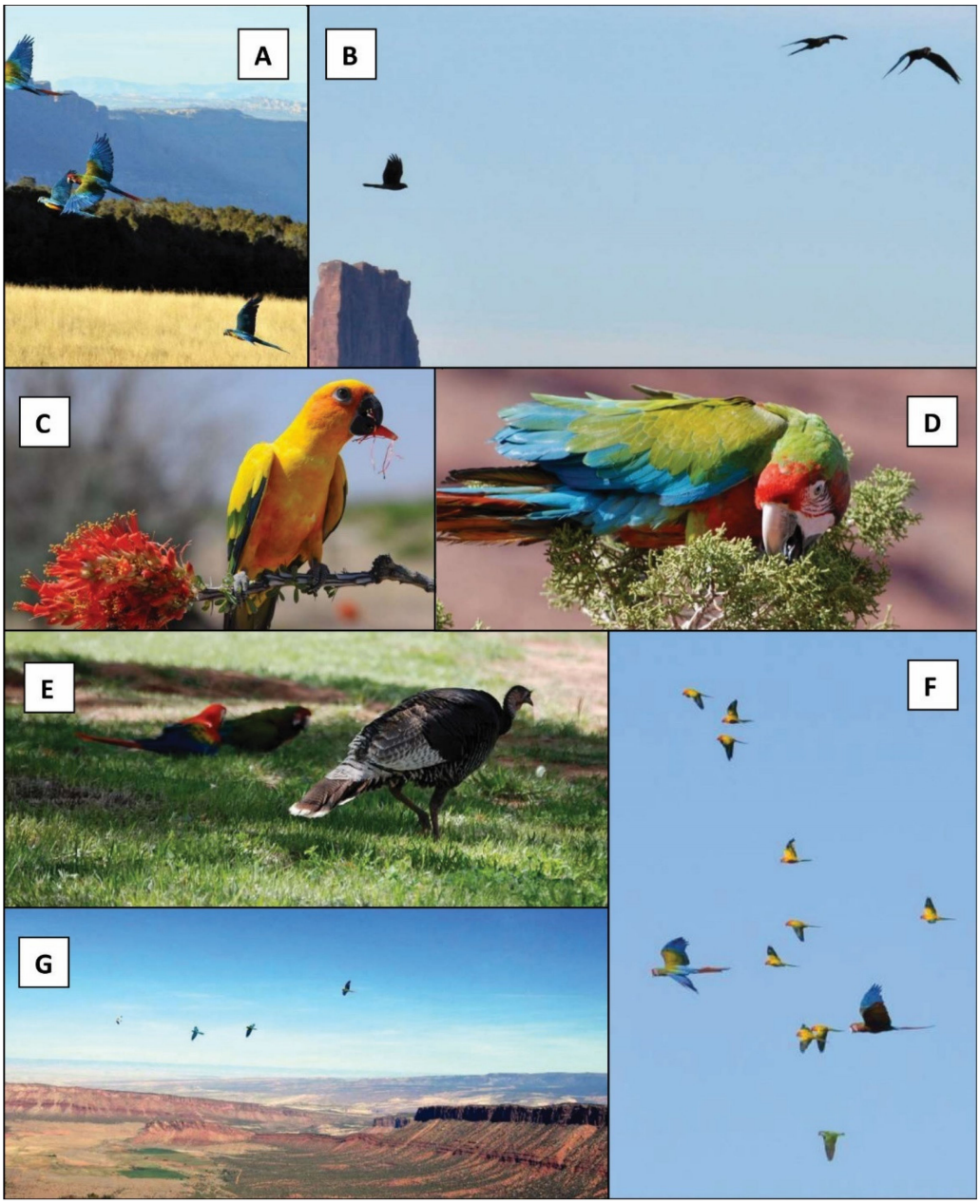

Figure 3. Survival behaviors in free-flight trained parrots. (**A**) Large-bodied flock coordinated during an escape launch. (**B**) Blue-throat macaw and hybrid macaw evade a hawk. (**C**) Sun parakeet foraging on ocotillo (*Fouquieria splendens*) flowers. (**D**) Hybrid macaw foraging on juniper (Genus *Juniperus*) berries. (**E**) Scarlet and hybrid macaws forage alongside a wild turkey, *Meleagris gallopavo*. (**F**) Multispecies flocking in response to a predator. (**G**) Large-bodied flock engaging in long-distance navigation.

3.2.1. Landscape Navigation

No birds permanently left the home base site during training. Failed site fidelity was seen only in two fledged birds that escaped from the small-bodied flock prior to the start of formal outdoor training, a Sun Parakeet and a Senegal parrot, that had 0 h of outdoor training (Table 5).

Physical fitness was developed early in training, starting at level 1. The birds in all three flocks made extended flights as a form of social or individual play. Play flying was indicated by nonaggressive aerial dogfighting and jinking. Aerial circling in response to

novel situations or wildlife presence was common, with investigative flights greater than 10 min of length regularly observed.

The free-flight training occurred in multiple spatially disparate landscapes. Through experience, the birds learned to navigate in novel landscapes. Once familiar with areas, the birds spontaneously went to nearby locations which were visible from the air, apparently recognizing landmarks and flying between them. The large- and small-bodied flock sometimes returned home or flew to the next location in known training routes spontaneously. The large-bodied flock executed the longest spontaneous navigation recorded: The group flew 11 km to return to the home base after training. The birds were also trained on routes through repetition. Travel involved repeating the route of the rally vehicle or the foot route of the trainer. Experienced birds would fly ahead of the trainer through a complex canyon or drainage system, having learned how the group would travel through the area based on earlier experiences. The large-bodied flock followed the rally vehicle for the longest duration, more than 3 km.

Practice within the landscape focused on navigating cliffs, canyons, hills, trees, and other landscape features at each level, emphasizing staying up high and enabling maximum line of sight for the three flocks. Birds flew over and not through heavily treed areas when navigating between locations, stayed above narrow canyons, and perched at the highest point of landforms whenever possible. The only flock that did not go between identified training locations spontaneously was the Sun Parakeet flock, as they were in a semirural residential area where it was not possible to fly between areas without disturbing property owners. Skill gains were an obvious progression. For example, macaws would dive off a 4m bluff with a hiking trail at a level 3 location while a trainer above and below used point-to-point flying to encourage diving. For level 4, those same macaws dove and rode the air currents down a landscape-sized, steep cirque, where the trainer had less access and ability to interact. At level 5, macaws fully and independently navigated major canyons and were not accessible to the trainer.

3.2.2. Foraging on Wild Foods

All three flocks were observed feeding on local plants (Figure 3). In all three flocks, all the birds routinely consumed the berries of junipers (Genus *Juniperus*), and specific individuals occasionally ate maple (*Acer* ssp.) seeds. The birds of all flocks daily chewed on leaf buds, seeds, any present fruits, and catkins of local plants.

The three parrot flocks were joined daily by other wild birds that foraged nearby on the ground, in adjacent trees, or in the same tree as the parrots. The parrots and wild birds appeared to form temporary foraging assemblages, where the parrots could receive information and copy behaviors of the wild birds. At least one time, the large-bodied flock was observed dropping to the ground to search for food in the grass with a single wild turkey (*Meleagris gallopavo*) despite the flock's training to stay off the ground (Figure 3). The turkey and macaws foraged safely within this novel multispecies complex, and the macaws' non-wary behavior suggested that this event had previously occurred. When wild birds, which were most often doves and songbirds, alarm-called or flushed, the parrot flocks increased wariness or launched into flight, demonstrating learning of heterospecific signals and behavioral cues.

4. Discussion

These hand-raised parrots trained with free-flight methods successfully developed skills in flocking, predator evasion, navigation of complex landscapes, and wild food use. These successes align well with the key goals of parrot prerelease training [4,6] and show that our methodology can avoid skill deficiency and aberrant behavior associated with many hand-raised parrots [2,7,26]. Whereas the level of human effort for free-flight training is high, it is comparable to other intensive bird management schemes utilizing hand-rearing, wild nest management, cross-fostering, and intensive soft release [12,39–42]. As a result,

we feel that this free-flight method of human-guided learning has great potential for use in conservation releases.

4.1. Flocking, Predation, and Mortality

Captive-bred parrots commonly lack vital survival skills, such as being able to form a cohesive flock, and are often considered unsuitable for release due to lack of antipredator behaviors [2,7]. As a result, predation is a major cause of failure in parrot releases. A review of 100 releases for 10 species showed that high predator presence was the main predictor of release program failure, and that predator training was a predictor of post-release survival [4]. Fortunately, all birds in our study demonstrated appropriate antipredator behaviors, including identification of predators, flocking, increased vigilance, mobbing, and evasive landscape use. As a result, there were zero predation events in the studied flocks despite multiple observed interactions with predators. This contrasts with projects that have shown major losses of released birds and failure to establish a second generation due to predation [2,5]. Current antipredator training techniques teach release candidates to associate a predator with a fear state. For example, training used with Puerto Rican Amazons includes the following steps: (1) A silhouette of a hawk is passed over the cage while playing a hawk call, (2) a captive hawk attacks the aviary, and (3) a captive hawk attacks an armored Hispaniola parrot (*Amazona ventralis*) in full sight of the caged birds [12]. Whereas White et al. utilized a captive raptor, this free-flight training utilized naturally occurring encounters with non-dangerous harassing birds present in the environment to build early individual and group skills, then utilized increasingly dangerous predator interactions in the field to train aversion to specific species. Although both techniques increase wariness and vigilance, only free-flight training improves coordinated group responses to predators including flocking, evasive maneuvers, and mobbing. As a result, the use of free-flight training may help further reduce predation rates in hand-raised and released Psittacines.

4.2. Landscape Use

None of our birds permanently left the home base area or got lost in the landscape during this study. This stands in stark contrast to soft-release projects with a variety of macaws and parrot species where birds permanently left the release area, reducing the success of the projects [2,6,7,43,44]. The panic flights that have caused problems for these other reintroduction projects only occurred during our level 1 flying, which was always conducted in areas with few places to perch where it was relatively easy to recover the bird once it flew until exhaustion. Our success in preventing flyoffs was likely due to the gradual way that our training introduced birds to navigation in the landscape and our use of the anchor bird during the early stages of free-flying. Our use of anchor birds resembles the widely adopted practice of using caged conspecifics as an attractant to help keep released Psittacines near the release site [9,10,14,45].

During our study, we trained the two long-term flocks to navigate among major landmarks and find high-quality patches in a semi-arid and marginal landscape in Utah. The birds flown near springs and streams with fruiting trees and shrubs knew how to travel among high-quality patches. This skill is likely beneficial during conservation release projects, as multiple studies have shown that released Amazon parrots that ranged farther had higher survival rates presumably because they could exploit resources over a wider geographic area [10,11]. In addition, many native populations of large parrots move across hundreds of kilometers, ostensibly tracking food resources [26,45–47], and this may be key to long-term survival. To date, no parrot reintroduction projects have reported methods to train individuals to navigate to distant points in the landscape. Long-distance training may have benefits, where trainers fill a role typically provided by conspecifics. Random exploration by newly released blue-and-yellow macaws without an established flock were associated with higher mortality than newly released macaws following an established flock's pattern of landscape use [44]. Our results suggest that free-flight training may be

useful in simultaneously reducing unwanted abandonment of the release area and teaching birds how to navigate among food sources, habitat patches, and other distant resources in the landscape.

4.3. Foraging

Teaching birds to forage on their own was not a focus of our free-flight training. However, through their natural habit of chewing plants they encountered, the parrot flocks all learned to consume wild foods. One of the unique aspects of this free-flight method is that interactions with naturally occurring native wild birds occurred during flying and foraging. These interactions appear to have led to the unintended benefit of learning to forage with a mix of wild species. Members of all three free-flight flocks foraged alongside other native species. These types of mixed-species foraging groups likely have multiple benefits as multispecies bird flocks are more likely to successfully utilize novel food sources [48]. Multispecies flocking might help naïve released birds utilize food sources and is an area in need of further study. In addition, all three flocks increased wariness and scanning in response to alarm calls or flushing of other birds. Eavesdropping on the signals of other animals, even when not participating in a multispecies flock, can also confer survival benefits as information transfer among different taxa likely improves predator avoidance [49,50]. As a result, free-flight training that includes interaction with native species can produce birds that can both forage more effectively and benefit from interactions with native species.

4.4. Human-Guided Learning

Our ability to recall birds allowed us to move them in and out of captivity and move them among training sites with different sets of resources, risks, and physical features. However, the use of recall in conservation releases of parrots is not unique. Release methodologies used with echo parakeets (*Psittacula eques*) included a recall cue to bring birds to a home aviary, where supplemental food was provided [8]. These parakeets were then given increasing exposure to the environment around the release site, through longer and longer outdoor periods between recall, until they were free-living. In our free-flight training, using complete recall back to cages provided us with the ability to transport our birds to new locations and expose them to sequentially more complex and dangerous sites and ecosystems throughout the training process. In this way, we shaped the flocks' landscape use through human knowledge and intent. Effectively, the human trainer determined the landscape usage patterns the birds normally learn from their parents and other conspecifics.

The flexible, "plastic" development of young parrots is not spontaneous, as behaviors develop from extended environmental and social interaction [26,51,52]. This plastic developmental process allows parrots to adapt to widely varying circumstances.

Naturalized populations of parrots can adapt to environments strikingly dissimilar to their ancestral range, such as *Amazona* parrots in Germany [53] and other locations throughout the world [54]. In the wild, behavioral flexibility allows wild parrots to adapt to human-altered environments [52,55] and transmit behavior socially among individuals [26]. When carefully planned, hand-rearing has the potential to magnify the ability of a parrot to adapt to its environment. When animals are raised by human caregivers, their behavioral repertoire may increase through the introduction to novel food types, foraging behaviors, and habitats unused by their ancestors [56]. Using the free-flight technique presented here, trainers should be able to customize the birds' landscape knowledge to the exact locations and resources that the trainers want them to exploit, even if those resources are quite distant. This should allow researchers to customize birds for specific release areas by imparting knowledge of the landscape that is not a part of traditional soft-release techniques.

The long-term effects of hand-rearing parrots for release are not well understood. Captive breeding programs regularly utilize hand-rearing with successful reproduction by hand-reared birds [57], suggesting sexual imprinting is not a major problem in this

clade. Concerns about human-socialized animals being easily poached or engaging in human-wildlife conflict could be reduced if human-socialized birds were recalled after functioning as a core flock for the release of non-socialized birds. It is not yet known if the natural dispersal phase when subadult birds leave their family group would disrupt the parrot-human bond.

4.5. Potential Use of Free-Flight Training in Conservation

The 0 to 5 level system presented here is a useful way to compare animal survival skills to the complexity and dangers of potential release sites, even when the skill-building and learning processes are different among projects. For example, using the level system to analyze the classic thick-billed parrot releases in Arizona [2], the birds for release lacked coordinated flocking responses, which are required for mastery of a level 2 environment in the free-flight methodology we present here. By comparison, the environment and predator presence suggest that the Arizona release site was appropriate only for birds that had mastered skills equivalent to level 4 or 5 training. From such an analysis, the thick-billed parrots would not have been considered ready for release at this site, and plans for additional training or an alternative release site could have been considered.

In some instances, getting the first released parrots established at sites without conspecifics can be challenging, especially in areas with high predation rates [2,5,6,44]. We propose that, using the techniques we outline here, projects should be able to create pioneer flocks of birds that can (1) be recalled to captivity as needed, (2) have highly advanced flocking and predator avoidance skills, (3) safely forage on a wide diversity of natural foodstuffs, (4) utilize other native bird species as information sources and foraging partners, and (5) navigate safely and effectively among resource patches in the landscape surrounding the release area. Though, unlike a permanent pioneer flock, these birds would form a kernel for new additions but would not be intended to remain in the wild. Once the kernel flock is established, additional young birds could be raised with minimal human socialization and be released shortly after fledging into this pioneer flock using techniques similar to traditional soft-release methods. This mixture of human-socialized and non-human-socialized birds could then remain together in the wild for months without being recalled until the non-human-socialized birds have learned the core survival skills and landscape navigation. This overlap period could be similar to the amount of time wild parrot chicks stay with their parents post-fledging. Once this overlap period is complete, the human socialized birds could be recalled and removed from the environment, leaving only a core flock of non-human-socialized birds. After recall, this trained flock could then be used to establish new flocks in other areas or to help raise additional release candidates. In this way, parrot free-flight training could help jumpstart parrot reintroduction efforts similar to the ways that falconry has revolutionized raptor reintroduction science.

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Institutional Review Board Statement: The project was reviewed by the Texas A&M University Institutional Animal Care and Use Committee (IACUC) and determined to be exempt from Animal Use Protocol on 3 February 2016, as the study utilized recording pre-existing methods of private individuals from outside the university.

Informed Consent Statement: Not applicable.

Data Availability Statement: Video and photographs of early rearing and bird flight are available upon request. These videos and photos include private individuals, their property, and their homes, containing personal details. As such, the videos cannot be posted publicly.

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