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Comparing post-release survival and habitat use by captive-bred Cabot's Tragopan (*Tragopan caboti*) in an experimental test of soft-release reintroduction strategies

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Abstract

Background: Restoring a viable population by reintroduction is the ultimate goal of a large number of ex situ conservation projects for endangered animals. However, many reintroductions fail to establish a population in the wild, partly because released animals cannot acclimate to the native environment of the release site, resulting in very low survival rates. Acclimation training is a technique to resolve this problem, although it does not have positive results in all species. We tested whether acclimation training and soft-release could improve the reintroduction success for captive-bred Cabot's Tragopan (*Tragopan caboti*), an endangered pheasant in southern China.

Methods: Reintroduction of captive-bred Cabot's Tragopan was carried out in the Taoyuandong National Nature Reserve, China from 2010 to 2011. We built a soft-release enclosure for acclimation training in the typical montane habitat of this pheasant. Nine birds were acclimated to the environment of this release site in this cage for more than 50 days before release ("trained birds"), while 11 birds remained only in the cage for 3 days prior to release ("untrained birds"). Released birds were tagged with a collar radio-transmitter.

Results: Post-release monitoring revealed that the survival rate of trained birds was higher than that of untrained birds after 50 days (trained: 85.7%; untrained: 20.0%). Cox regression analysis showed that there was a significant difference in the mortality rates between the trained and untrained birds. In addition, a survey of the habitat of the experimental and the control groups showed significant differences in habitat selection between the groups.

Conclusion: Our study suggests that pre-release acclimatization training is an important factor that can lead to improved survival and habitat selection of captive-bred reintroduced tragopans.

Keywords: Diet, Habitat selection, Post-release survival, Reintroduction, Survival rate

Background

One of the most pressing challenges for animal reintroduction programs is to determine how best to help captive-bred individuals make the transition from captivity into the release site (Mitchell et al. 2011). Enhancing their ability to settle and persist in a release site increases the chances of their survival and ultimately the success of the reintroduction (Hardman and Moro 2006). Two types of release strategies are regularly used for animal reintroductions: soft and hard releases (Clarke et al. 2002). A soft release strategy involves a series of techniques, which promote the adaptation of captive-bred animals to the wild. These techniques include a period of confinement of captive-bred individuals at the proposed release site (Mitchell et al. 2011), usually within a predator-proof "soft-release enclosure", supplemented with food and water (Hardman and Moro 2006). The animals are confined over a predetermined period of time until they become acclimated to the environment of the release

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site (Scott and Carpenter 1987). A hard release strategy involves the immediate release of the animal into the release site without any period of adjustment to their new environment (Campbell and Croft 2001).

Soft-release strategies are widely advocated and the preferred release strategy for Galliformes reintroductions that use captive-bred stock (WPA and IUCN/SSC RSG 2009). This is in part due to the range of differences captive birds need to overcome between the release site habitat and conditions in captivity (Lockwood et al. 2005), as well as to the many stresses they face in their new environment, e.g., learning how to feed or avoid predators, find suitable roost sites, or identify appropriate habitat (Sarrazin et al. 1994). Questions remain whether the existing evidence is sufficient to warrant the general conclusion that soft-release strategies outperform hard releases (e.g. Wanless et al. 2002; Teixeira et al. 2007). All the same, there is little doubt that soft-release strategies have worked well for many animal reintroductions (e.g. Gatti 1981; Bright and Morris 1994) but not so for others (e.g. Castro et al. 1994; Lovegrove 1996; Ellis et al. 2000).

Improvements in soft-release strategies is still somewhat hampered by a lack of experimental approaches to animal reintroductions (Soderquist 1994; Sutherland et al. 2010; Jones and Merton 2012), particularly for methods with threatened bird species that use captive-bred individuals, for which there are very few assessments of release strategies (Franzreb 2004). This is somewhat understandable given the costs involved in many animal reintroductions and the threatened status of the target species. Historically, avian reintroductions have favored the use of captive-bred over wild-caught birds (Fischer and Lindenmayer 2000) with some soft-release strategies resulting in greater reintroduction success rates than hard releases (e.g. Meyers and Miller 1992; Tordoff and Redig 2001; Poulin et al. 2006).

Here we report on an experimental reintroduction of Cabot's Tragopan (*Tragopan caboti*) using captive bred birds. Cabot's Tragopan is an endemic Galliforme species of southern China, restricted to dense montane forests at elevations between 700 and 1300 m. The species is considered Vulnerable due to the ongoing loss and degradation of its montane forest habitat (BirdLife International 2012). In total, its wild population in southern China may number fewer than 5000 individuals and its distribution has become highly fragmented (Zheng and Wang 1998). Studies on the captive breeding of Cabot's Tragopan started almost 30 years ago, examining artificial insemination techniques (Zhang et al. 2002, 2003; Zhang 2006) and techniques for hatching and breeding (Wen and Zheng 1998). The first captive-bred population was established at Beijing Normal University about 20 years ago, followed by several more at institutions such as the Wuyanling National Reserve and Hunan Wildlife Rescue and Breeding Centre. Reintroductions into areas where the species has become locally extinct but where threats to the species have diminished are now a critical component of a much wider national conservation strategy to improve its conservation status (Ding and Zheng 1996).

The aim of our experimental reintroduction was to use faecal analysis and post-release monitoring (radio-telemetry) data to compare the survival of captive-bred individuals reintroduced at the same release site, using different periods of confinement within the soft-release enclosure. First, we wanted to determine whether longer periods of acclimation training within a soft-release enclosure improved the post-release survival of reintroduced birds. Second, we compared patterns of habitat use between individuals reintroduced under the two different soft-release strategies in order to determine whether habitat preferences broadly matched those of known wild populations.

Methods

Study area

Reintroductions of Cabot's Tragopan were carried out at the Taoyuandong Natural National Reserve, in the Luoxiao mountains, Hunan Province, southern China (Fig. 1). This 237.86 km^2 reserve (elevation 550–1884 m) is located within the central Luoxiao mountains, with a mean annual precipitation of 2292 mm and daily temperatures ranging from 2.9 to 20.7 °C (Tan and Wu 2009). Relative humidity is >78% and the region experiences frost-free periods of over 200 days each year (Hou 1993). The dominant habitat type below 1600 m is an evergreen mixed deciduous-conifer forest, while areas at higher elevations (>1600 m) are dominated by scrubs (Tan and Wu 2009). The reserve currently hosts a forestry police station responsible for protecting and policing the reserve and its wildlife. Prior to 1982 the lower elevation areas (<1000 m) of the reserve belonged predominantly to a lumber farm for fir tree production and bamboo to support the local economy. Significant losses and degradation of native habitat and uncontrolled hunting of wild animals in the area are widely believed to have caused the decline of Cabot's Tragopan population and that of other species. A provincial reserve was established in 1982 when lumber harvesting ceased, allowing some of the forest vegetation to regenerate naturally, but hunting continued until 2002 when the reserve became a national nature reserve with a management bureau. A forestry police station was created with the purpose of protecting the biodiversity of the region. Cabot's Tragopan was observed in the region until 1990 (Hou 1993) and has not been recorded since.

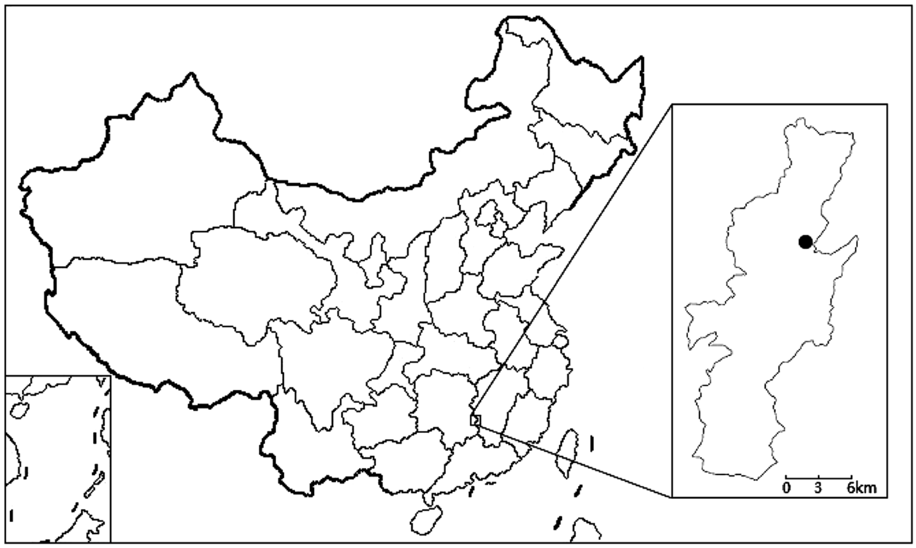

Fig. 1 Location of the Taoyuandong National Nature Reserve in the Luoxiao mountains, Hunan Province, southern China

Previous studies have revealed the patterns of habitat associations exhibited by wild Cabot's Tragopan populations throughout its restricted range in China. During winter months, the species shows a preference for evergreen mixed deciduous-conifer forests, dominated by *Lithocarpus* sp., *Cyclobalanopsis* sp., *Schima superba* and *Daphniphylum macropodium* species, as well as areas with dense understorey vegetation, bare ground cover, close to freshwater sources (Young et al. 1991). Elsewhere in its native range, the species is known to prefer tall, dense mixed forests close to the edges of forest-scrub ecotones at higher elevations for breeding (Ding and Zheng 1997; Deng et al. 2005) and tend to occupy larger, less isolated mixed forest stands rather than smaller fragments, particularly those with a high proportion of *D. macropodium* trees. Based on earlier recommendations by Tan and Wu (2009), its elevation range and quality of habitats, cessation of logging and hunting, its protected area status and the presence of protected area staff policing the reserve, the Taoyuandong National Nature Reserve was identified by the project stakeholders as the most suitable release site for the experimental reintroduction.

Source of birds for reintroduction

Previous phylogeographic studies show that Cabot's Tragopan has two management units (MUs) separated by the Ganjiang River (Dong et al. 2010). The IUCN/SSC (2013) pointed out that a mixture and hybridization of these two historically isolated populations may result in lower fitness of offspring and/or loss of species integrity. So we sourced captive-bred individual birds from the MU found west of the Ganjiang River from the Hunan Wildlife Rescue and Breeding Center (HWRBC), which has been breeding Cabot's Tragopan since 1997 and developed as the largest pure line western Cabot's Tragopan population in the world. Currently the captive-breeding population suitable for reintroduction has reached a total 70 birds in recent years, with a sex ratio of 1:1, established from offspring of individuals of the western MU. Twenty-one individuals of Cabot's Tragopan (10 males and 11 females) were selected for this research, all aged between 4 and 7 years (the reproductive age of both male and females in captivity is 2–13 years; Zhang and Zheng 2007). With permission of the State Forestry Administration and quarantine by the veterinarian of the HWRBC, these healthy birds were placed in special animal transportation cases and transported to the release site within 12 h of being placed in the cases.

Soft-release enclosure and acclimation training

We built a soft-release enclosure in the mixed broadleaf-conifer forest at an elevation of 1370 m for acclimation training. We used wire netting to construct the enclosure over an area that contained native trees and vegetation that forms an integral part of the diet of wild Cabot's Tragopan and then covered the enclosure with nylon netting (Fig. 2a–d). A small brook also flowed through the enclosure, which provided water for the release cohorts within the enclosure. Nylon and wire netting were then sewn together with nylon thread. The complete enclosure had an area of 1300 m^2, 6 m in height.

We separated the individual birds for reintroduction into two experimental groups: one group selected for a

Fig. 2 The soft-release enclosures used for the reintroduction of Cabot's Tragopan at the Taoyuandong National Nature Reserve, Hunan Province, southern China (**a**, **b** inside of enclosure; **c**, **d** outside of enclosure). All pictures photoed by Boye Liu

longer experimental acclimation training period. The first group consisted of ten "trained" or "acclimated" birds (five males and five females). The birds of the second group were "untrained" and remained in the enclosure for a much shorter period; this group consisted of eleven birds (five males and six females). One male bird belonging to the longer acclimated trained group died before release. The remaining individuals were kept in the soft-release enclosure for more than 50 days (five birds were kept for 53 days and four for 56 days). Following the dietary recommendations for captive tragopans published by the HWRBC, we provided 100 g corn per tragopan every day at the beginning of acclimation training. We placed corn in different areas of the enclosure and gradually reduced the feeding frequency to 100 g per tragopan every 3 days from day 11 to day 20 and every 6 days from day 21 to day 30. After 30 days, we provided only 100 g per tragopan every 10 days. Five birds, kept in the enclosure for 53 days, were released on 3 October 2011. Another four birds, kept in the enclosure for 56 days, were released on 23rd October 2011. The shorter acclimation untrained group spent only 3 days within the soft-release enclosure prior to release as two release cohorts. Four pheasants (two males and two females) of the untrained group were released on 9 September 2010 and another three males and four females were released on 23 October 2011.

To examine the effect of reduced supplemental feeding within the enclosure and track acclimation through changes in their diet, we collected fecal samples from individual tragopans and samples of every plant species in the soft-release cage 15 days before releasing the birds. Slides of fecal powder and epidermis of plant samples were made following the method devised by Johnson et al. (1983). Fragments of plant epidermis in fecal slides were distinguished and counted following the method described by Li et al. (1997).

Post-release monitoring

Released birds were tagged with a collar radio-transmitter (RI-2D, Holohil Systems Ltd., Canada). The average body mass of a male Cabot's Tragopan is about 1.3 kg and for females approximately 0.9 kg. The radio transmitter weighted 15 g, below the recommended threshold of 3% of their mass (Kenward 2001). We used a TRX-2000 receiver (Wildlife Co, USA), a 3-element Yagi antenna, a compass and a GPS (60CSx, Garmin, USA) to monitor radio-transmitter signals. Locations of reintroduced tragopan were recorded by ground triangulation. We obtained two bearings (intervals were no longer than 15 min, with an enclosed angle of approximately 90° and distance from the signal >200 m) in order to calculate their location. Each bird was located every 2 days during the 12-h period from 06:00–18:00 (Kauhala and Tiilikainen 2002; Bernardo et al. 2011a). If a bird seemed to remain stationary for 6 days, we conducted field checks to determine whether the bird was dead or alive.

Habitat surveys

To compare the habitat preferences of the trained and untrained groups, we measured several structural habitat characteristics within known locations of individual reintroduced tragopans which were found dead or alive and had remained at these localities for more than 6 days. We collected the following habitat data from five 100 m^2 vegetation survey plots: thickness and cover of leaf litter, density, height and cover of herbs, shrubs, trees and moso bamboo (*Phyllostachys edulis*), tree diameters at breast height (DBH) and average distances to trees. The first (central) plot was located at the exact position of the bird (alive or dead) with the remaining four plots positioned 20 m away from the central plot following the four cardinal compass directions. We calculated the mean of the five circular plots as data for the home range. Gradient, distance to road and distance to water were measured from the position of the bird. Four habitat data points of the trained and nine habitat data points of the untrained groups were used in habitat selection analyses.

Data analysis

We used the non-parametric Mann–Whitney U test to compare differences in the structural habitat characteristics of the sites selected by both the trained and untrained reintroduced groups. Results were considered significant if $p < 0.05$ (two-tailed test). We used Cox regression analyses, from the package Survival (Therneau and Lumley 2009) in R software (R Core Development Team 2014) to compare the mortality between sex (male vs. female), release year (2010 vs. 2011) and group (trained vs. untrained).

Results

Pre-release soft-enclosure changes in the tragopan diet

Fecal analysis revealed noticeable changes in the diet of individual tragopans during their time in the soft-release enclosure. Following acclimation, faecal analysis revealed that the percentage of epidermis from corn and plants in the faeces collected from individuals within the enclosure was similar to the composition of the diet of corn and wild plants. The amount of epidermis from wild plants in the faeces of tragopans was 89.1%, suggesting that the captive-bred tragopans changed their diet to feed on wild plants growing within the soft-release enclosure.

Post-release survival

On 9 September 2010, we released four pheasants (two males and two females) from the untrained group. After 11 days, two males and one female died, while the fourth bird was lost for unknown reasons. Examination of the recovered remains of the untrained birds revealed that two birds were victims of predation and one died for unknown reasons. On 3 October 2011, five of the captive-bred tragopans, which had spent 53 days becoming acclimated in the soft-release enclosure, were released. On 23 October 2011, we released another 11 birds, seven from the untrained group and four of which had spent a total of 56 days becoming acclimated in the soft-release enclosure. Until the cessation of post-release monitoring on 23 December 2011, six of the trained individual birds were still alive (two males and two females which had been released on 3 October and one male and one female which had been released on 23 October) with one other bird confirmed dead. The radio signal from the two remaining birds was lost. Of the untrained birds, two were still alive, while five were confirmed dead. Examination of the recovered remains of dead untrained birds revealed that four of these birds were victims of predation and one died for unknown reasons. The cause of mortality for the trained birds remained unknown for we were unable to locate or recover any remains, other than the radio-tag of one bird from a stream.

Survival rate of trained individuals after 50-days post release was 85.7% (Fig. 3) significantly different from the 20% survival of the untrained birds (Cox regression $\beta = -2.389$, SE $= 1.119$, $z = -2.136$, $p = 0.033$), while there were no significant differences between the sexes (Cox regression $\beta = 0.446$, SE $= 0.732$, $z = 0.610$, $p = 0.542$) and release years (Cox regression $\beta = -0.351$, SE $= 0.782$, $z = -0.449$, $p = 0.654$). On 10 July 2012, we conducted additional post-release monitoring to re-find the birds released in the previous year. Three radio signals were recorded, all belonging to the trained acclimated group. Of these, two birds (one male and one female) were still alive, having survived for a total of 281 days post-release, while the remaining bird was confirmed dead.

Post-release habitat selection by captive-bred tragopans

We found significant differences in the post-release patterns of habitat selection between the trained and untrained groups of captive-bred tragopans (Table 1). Trained males and females showed a distinctive preference for broadleaf forest habitats with larger trees, less bamboo and herb vegetation cover and at greater

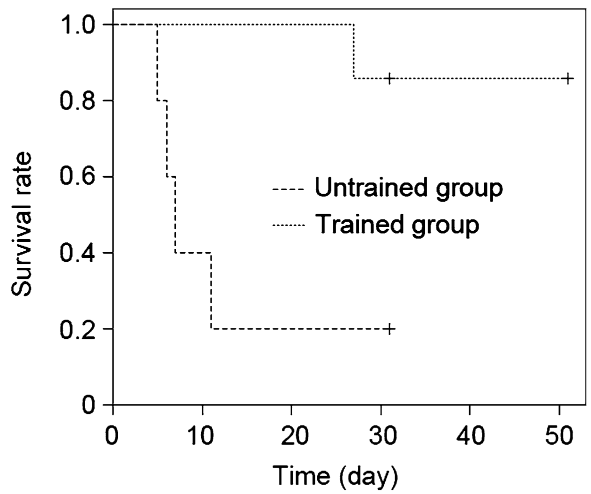

Fig. 3 Survival rate of acclimatized and non-acclimatized captive-bred Cabot's Tragopans reintroduced into the Taoyuandong National Nature Reserve, Hunan Province. The *plus symbols* denote censored observations

distances from roads or water (Table 1). The untrained birds preferred bamboo-dominated forests, with large bamboo plants and a considerable cover of herbs (Table 1).

Discussion

Effect of acclimation on post-release survival

In this study, we have demonstrated experimentally the beneficial effects of soft-release enclosure acclimation training on the post-release survival of reintroduced captive-bred Cabot's Tragopans. For the first 50-days post-release, the difference in survival rate between the untrained and trained acclimated birds was >60%. Direct comparisons of survival rates with previous avian reintroductions are somewhat problematic, given that they differ in release protocols and length of acclimation. Nevertheless, the probability of survival (85.7%) of Cabot's Tragopan is somewhat higher than for earlier avian reintroductions of other species using soft-release strategies. The survival of captive-bred Attwater's Prairie Chicken (*Tympanuchus cupido*) during the first 2 weeks after their release following an acclimation periods of 14 days was 47.4%, but only 19.4% after a 3 day release; their survival was not significantly different beyond 14 days of post-release (Lockwood et al. 2005). Bernardo et al. (2011a) reported a post-release survival rate of 75% for reintroduced captive-bred Red-billed Curassows (*Crax blumenbachii*), that was significantly affected by the length of time individual birds spent in the soft-release enclosure. Studies of soft-release strategies for some mammal reintroductions have also reported that captive-bred individual animals held for longer periods of acclimation have a much higher survival rate than individuals held for shorter times or those released using a hard-release strategy (e.g. Hardman and Moro, 2006; Ryckman et al. 2010; Rouco et al. 2010). Collectively, these data provide further support for adopting soft-release strategies for future reintroductions of Cabot's Tragopan and possibly for other threatened Galliforme species.

Replicating a wild diet within the soft-release enclosure is essential for facilitating the acclimation of captive-bred

Table 1 General habitat characteristics from locations of radio-tracked reintroduced captive-bred Cabot's Tragopans at the Taoyuandong National Nature Reserve, Luoxiao mountains, Hunan Province, southern China

		DW (m)	DR (m)	CL	TL (cm)	DB (N/100 m^2)	CB
Trained group ($n = 4$)	Mean ± SD	117.5 ± 61.3	132.5 ± 51.2	0.74 ± 0.13	5.8 ± 2.4	1.1 ± 2.2	0.0025 ± 0.005
Untrained group ($n = 9$)	Mean ± SD	25.0 ± 48.5	35.6 ± 64.0	0.78 ± 0.11	5.2 ± 1.8	8.6 ± 7.1	0.14 ± 0.13
Trained versus untrained acclimatized	p value	0.007*	0.025*	0.736	0.820	0.069	0.045*

		DH (N/m^2)	HH (cm)	CH	DS (N/100 m^2)	HS (cm)	CS
Trained group ($n = 4$)	Mean ± SD	11.1 ± 4.8	18.2 ± 4.3	0.16 ± 0.11	26.8 ± 13.2	2.0 ± 0.4	0.28 ± 0.15
Untrained group ($n = 9$)	Mean ± SD	28.2 ± 18.0	30.4 ± 22.3	0.43 ± 0.21	24.4 ± 16.7	1.7 ± 0.8	0.21 ± 0.21
Trained versus untrained acclimatized	p value	0.081	0.710	0.050*	0.800	0.257	0.414

		GR	DT (N/100 m^2)	HT (m)	DBH (cm)	CT	FW (N/100 m^2)
Trained group ($n = 4$)	Mean ± SD	31.3 ± 11.1	7.1 ± 3.8	10.4 ± 3.2	31.1 ± 4.4	0.30 ± 0.06	4.5 ± 3.2
Untrained group ($n = 9$)	Mean ± SD	35.0 ± 20.3	8.2 ± 3.1	8.5 ± 2.4	25.1 ± 5.7	0.27 ± 0.13	3.1 ± 3.1
Trained versus untrained acclimatized	p value	0.585	0.604	0.414	0.045*	0.604	0.432

Habitat variables are defined as follows: DW = distance to the nearest water; DR = distance to the nearest road; CL = percentage cover of leaf litter; TL = thickness of leaf litter; DB = density of moso bamboo; CB = percentage cover of moso bamboo; DH = density of herb; HH = height of herbs; CH = percentage cover of herbs; DS = density of shrubs; HS = height of shrubs; CS = percentage cover of shrubs; GR = gradient; DT = density of trees; HT = height of trees; DBH = diameter at breast height; CT = percentage cover of trees; FW = density of fallen/dead wood

* Significant two-tailed test $p < 0.05$

individuals to the wild (Parker et al. 2012). We found that a longer period of acclimation within the soft-release enclosure that had been designed to contain native understory vegetation profoundly changed the diet of captive-bred tragopans. Faecal analyses revealed that our trained (acclimated) birds began to eat wild food plants within several days after entering the soft-release enclosure. In fact, in just 1 month, we found that individual birds were able to eat almost all known food plant species typical of the diet of Cabot's Tragopan in the wild (see Zheng et al. 1986; Cheng et al. 2008) that were found within the enclosure. Other reintroduction studies using captive-bred individuals have found that similar soft-release enclosures, that capture part of the native understory vegetation of the release site, can prove beneficial for post-release survival (e.g. Bernardo et al. 2011a, b) but these studies also utilized post-release supplemental food and water provision. Few experimental studies have used faecal analyses as a complimentary tool to gauge the progress of acclimation training for captive-bred birds in reintroductions. We suggest that monitoring soft-release acclimation training using faecal analyses can help reintroduction practitioners develop further refinements to the design of soft-release enclosures and will contribute to the successful welfare of captive-bred animals that require lengthy periods of soft-release acclimation training.

Environmental conditions play a major role in the survival of animals. All of our tragopan cohort releases in 2010 and 2011 were conducted on days of suitable (similar) weather conditions, i.e., no rain, windy conditions or snow. However, we did not measure specific environmental factors such as temperature, humidity, rainfall, or snow levels for the duration of our post-release monitoring period. Thus, our comparison of the survival of birds released over a 2-year period may not be without bias, especially since only untrained non-acclimated individuals were released in 2010. It is quite possible that the climate and other resources at the release site may have been more adverse throughout 2010 compared to 2011, when the first cohort of birds was released. This would have affected the survival of those birds, in which a high proportion of their cohort died. In the subsequent year, the remainder of the birds were released over a 1-month period which again may have impacted their survival. Gaps such as these in the experimental release of tragopans were simply due to the number and timing of suitable captive birds becoming available for our experimental reintroduction. Such experimental reintroductions of threatened species using captive-bred individuals is an expensive conservation research program and it was not possible to have a standardized number of birds from each group ready for release in each year. So, we encourage future experimental approaches of soft-release strategies to consider standardizing the number of individual birds from different trained and untrained groups released at similar time of year and also to record environmental variables related to the climate of the release site during post-release monitoring, in order to examine more precisely the factors affecting survival of reintroduced birds using different soft-release strategies.

Effect of acclimatization on post-release habitat selection

A lack of knowledge of species habitat requirements has been a major factor leading to the failure of reintroductions of both captive-bred and wild-caught individuals (Wolf et al. 1996; Stamps and Swaisgood 2007). Fortunately, in this instance, we had access to a series of studies on the habitat preferences of wild Cabot's Tragopan populations (e.g. Qian and Zheng 1993). Consequently, we were not constrained to use post hoc assessments of habitat quality and were able to compare patterns of habitat selection between the trained and untrained groups with what is known of other wild tragopan populations. Reintroduced captive-bred tragopans from the untrained cohort selected lower elevations for their habitat, dominated by bamboo, whereas the trained tragopans selected habitats more typical of wild populations. Improvements of habitat selection behavior of captive-bred animals by acclimation training have also been documented by other captive-release studies (e.g. Bright and Morris 1994; Islam et al. 2013; Blythe et al. 2015).

Earlier reintroduction programs have revealed species preferences for habitat containing features similar to their natal habitat (Pinter-Wollman et al. 2009; Bradley et al. 2012). This phenomenon, called natal habitat preference induction (NHPI), has been recorded for a range of animal taxa (Davis and Stamps 2004). Positive early experiences of captivity environment caused animals to choose habitats containing cues comparable to natal habitat (Stamps and Swaisgood 2007). In our research, the preference of the untrained pheasants for unsuitable bamboo habitat may reflect negative impressions of their natal captive environment, whereas trained birds, which established affinity for the environment of their release site, preferred the "typical" known habitat for wild populations of the species. Given that captive-bred animals have no experience of the habitat of their release site, it is essential for reintroduction practitioners to minimize any contrast in habitat quality between the soft-release enclosure environment and that of their immediate release site to improve the likelihood of post-release settlement of captive-reared birds (Biggins et al. 1999; Roe et al. 2010).

Our study shows that pre-release acclimation training is an important factor to improve survival and habitat selection of captive-bred reintroduced tragopans.

Although construction and management of the soft-release enclosure is expensive and labor intensive, the benefits of training captive-bred birds to the environment of their release site contribute to the overall success of the reintroduction and sufficient reasons to offset these costs.

Authors' contributions

YZ and GZ conceived and designed the research, BL and LL participated in the field work, BL, CX and HL carried out the analyses, BL drafted the earlier version of the manuscript and HL, YZ and GZ revised it. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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