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Conditions for Reintroduction of Captive-Bred Endangered Birds: A Review

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ABSTRACT

Reintroduction programs have been promoted across the world to recover and rehabilitate endangered birds through ex situ captive breeding and releasing to the nature. The ultimate aims of these reintroduction programs are recovery of sustainable populations in natural habitats. To ensure the success of the reintroduction programs, it is necessary to examine the followings in order to increase the success rate of releasing along with the development of captive breeding techniques: 1) Adequate habitat provision, 2) adaptability of captive-bred individuals, 3) survivability of released individuals, and 4) social interest and will. Before releasing captive-bred individuals, it should be reviewed whether there are habitats in which the limiting factor is removed, and assessed their long-term safety. The quantity and quality of the released individuals must be considered to increase the chances for mate selection, maintain genetic diversity, and acquire the ability to adapt to the wild. The release method must be decided in consideration of characteristics of the target habitats and individuals, and rational means such as careful observation, evaluation, and feedback must be provided throughout the release process. For the long-term success of recovery projects, social awareness, sustainable support, and related experts are needed. Satisfying these criteria can help to increase the success rates of reintroduction programs. For the bird reintroduction program in the future, the feasibility of the methods and procedures must be closely reviewed before starting.

Keywords: Captive breeding, Endangered birds, Reintroduction

Introduction

To date, reintroduction programs for endangered birds have been promoted using different methods globally. The importance of and need for the reintroduction of endangered wildlife was officially recognized in the "Convention on Biological Diversity" at the Rio Environment Conference in June 1992. This convention comprises a preamble and 42 articles with 2 annexes. The core content of the convention stresses that each party much strive for the "*in situ* and *ex situ* conservation" of animals and plants. Article 9 (c) specifies that parties have "adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions (UN, 1992)."

The reintroduction of wildlife, such as endangered birds, as promoted in this convention, is often performed

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using methods whereby the population size is increased through *ex situ* captive breeding. There have been many developments in captive breeding techniques for wild birds, raising the possibility of increasing the populations of endangered birds for almost all taxonomic families (Destro *et al*., 2018; Ewen *et al*., 2008).

Following captive breeding, the next step in wildlife reintroduction programs for animals and birds involves their successful release, in which captive-bred individuals return to their natural habitat and live independently. Many endangered bird reintroduction programs have aimed to restore sustainable populations in their natural habitats through release. In such programs, *ex situ* captive breeding is an intermediate step for release. The captive breeding stage ensures the safety of the birds before releasing, and ultimately prepares them for adapt to nature habitat. Accordingly, a series of processes, from rearing and captive breeding to release into the wild, are actively promoted for the conservation of endangered species. To ensure the success of these processes, however, it is necessary to examine which methods are useful for release and determine how they may affect the successful reintroduction of species. In addition, reviewing the reliability of various methods leading to the release of different species could help in this regard.

The success of captive breeding can be considered separate from the success of release. It is important to screen and review certain criteria to evaluate which conditions must be satisfied to increase the success rate of release, and *vice versa*. The lack of such procedures may lead to major setbacks in the restoration of endangered species into the wild, regardless of the expectations in the planning stage. Captive breeding programs have not always been successful for all bird species, and not all captive-bred species have been successfully released into the wild (Bubac *et al*., 2019; Fischer & Lindenmayer, 2000).

Although several successful cases of captive breeding and release have been reported for endangered birds, the necessary experience and technology to ensure the successful release of endangered species into the wild is still lacking. To solve this issue, it may be possible to predict the success of current or future programs by examining the following four categories, according to the release procedure being used (Fig. 1).

(1) Is there an appropriate habitat for the captive-bred birds, such that they can return to a natural or semi-natural state?

(2) Are the captive-bred individuals able to sufficiently adapt to the given environment and their natural lifestyle?

(3) Is there an effective method to increase the chances of survival of the released birds, until a sustainable population becomes established?

(4) Is there adequate social interest and will for the given task, which will require high levels of effort before a sustainable population can be established?

Here, therefore, we compare and review the four categories by evaluating global reports of reintroduction cases, with the aim of determining best practices regarding the release of endangered bird species during reintroduction efforts.

Discussion on Procedure and Cases of Release

Is there an appropriate habitat that meet the goals of the endangered birds being released?

Releasing endangered birds into inappropriate habitats increases the likelihood of failure. In many cases involving

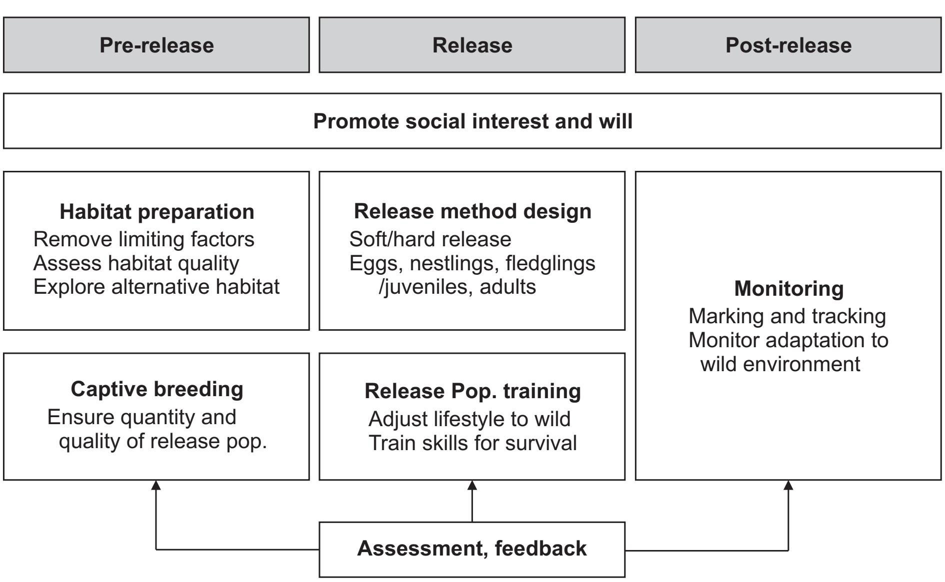

Fig. 1. Considerations according to the reintroduction procedure.

the captive breeding and release of endangered birds, the target habitat for release was close to the habitat where the species in question were last seen. In such cases, the factor that originally led to said species becoming endangered must first be corrected. The failure to correct such factors could lead to the released individuals becoming extinct, rather than in them regaining the opportunity for natural reproduction. The fundamental cause of endangerment must therefore be either corrected or greatly improved before returning the species in question back into the target habitat.

One example of such a case is the reintroduction of the Peregrine falcon (*Falco peregrinus*), which has been promoted since the late 1970s in the United States of America (U.S.). The Peregrine falcon Reintroduction Program was implemented on the basis that the problem of contamination by artificial chemical compounds, which had originally led to the extinction of these falcons from the eastern part of the U.S., had largely been corrected following the establishment of long-term restrictions on the use of such chemicals (Bollengier *et al*., 1979). The use of organo-pesticides such as dichlorodiphenyltrichloroethane (DDT), which are artificial compounds within the chlorinated hydrocarbon series, led to their biomagnification in the food chain. The reintroduction program was carried out after sufficiently correcting for this issue (Barclay & Cade, 1983). In other reintroduction programs worldwide, the root cause of extinction has often been corrected prior to release of the endangered individuals, highlighting the importance of fixing this problem to ensure the adequacy of the habitat for the species being released.

Efforts and studies have also aimed remove the limiting factors that have decreased the population of the California condor (*Gymnogyps californianus*), prior to the release of captive-bred individuals (Ricklefs, 1978; Wilbur *et al*., 1980). Thus, it is not sufficient to simply hope that the species being released will be restored to a sustainable population, without first understanding the limiting factors and fixing the original cause of endangerment. Such a lack of understanding and preparation will only lead to poor survival of the released individuals, thus leading to the failure to satisfy initial expectations.

Although several individuals of a species can be secured through successful captive breeding practices, poor habitats will limit the restoration of such species upon release even in historic range. Wilson and Willis (1975) described these endangered species as 'orphan species'. Therefore, the successful release of endangered species to the wild is dependent on finding an adequate habitat and performing experimental releases. Even in areas where the species in question has not previously been inhabited, the chances of survival, including adaptability after release, may be guaranteed to be higher than in their last-seen habitat, provided other suitable survival conditions are in place.

Successful cases of release have also been achieved for local endemic species that reside on remote islands; most of the endangered bird species listed today fall into this classification.

The Mauritius kestrel (*Falco functatus*), Mauritius parakeet (*Psittacula echo*), Pink pigeon (*Nesoenas mayeri*), and Mauritius fody (*Foudia rubra*) are all endemic to the island of Mauritius in the Indian Ocean. These species were captive-bred and released to the nearby Reunion Island, following which they have successfully adapted and been restored in this new habitat (Temple, 1981). This is a case where Reunion Island was selected as the remained area with the best survival conditions for the orphan species, and the release was decided after fully considering whether or not they may affect the native species originally living on the island. In New Zealand, the exchange release of endemic species between islands has been adopted as an important strategy for the reintroduction of endangered species (Flack, 1978). Similarly, several species of Amazonian parrots (*Amazona* spp.) have undergone the same process in the Caribbean Sea (Collazo, 2003; Sanz & Grajal, 1998).

The target habitat must be also assessed regarding the long-term safety of the captive-bred species in question after their release. Predicting the future is a challenging process; however, the underprepared release of captive-bred species into new habitats with an uncertain future is likely to end in failure. To prevent such cases, it is necessary to consider their artificial release into habitats that have been already designed or designated for the conservation of wildlife species (e.g., national parks, ecosystem conservation areas, wildlife reserves, or wetland reserves). In these cases, the released birds can be guaranteed a relatively safe habitat in the long term. For example, Whooping crane (*Grus americanus*) individuals were intensively released into the Grays Lake National Wildlife Refuge in Idaho, U.S. (Ellis *et al*., 1992).

Are the captive-bred individuals in a suitable condition for natural release?

In addition to the selection of an appropriate habitat, the unique characteristics of the individuals being released is another factor that can affect the success of reintroduction efforts. Two factors must be considered in this regard: the quantity and quality of the individuals being released to the nature.

The fundamental question in this regard is whether there is a sufficient number of captive-bred individuals to ensure their effective restoration. This is an important consideration for "establishing a sustainable population," which is the goal of release. If the wild population is small, and the goal of release is to increase the number of target population, then the number of released individuals must be equal to or greater than the population decline of the species in question. If the annual decline in the number of individuals in a wild population can be compensated by the release of captive-bred individuals, then the endangered species in question may sustain.

However, if the goal of the project is to somewhat recover or restore a highly endangered species other factors must be considered. Biologists in the fields of genetics and evolution have studied with interest and concern that increasing a population from a small number to a much larger number causes a variety of problems. Such problems can be split into two categories.

The first category concerns scenarios where it is desirable to restore a population from an extremely small number to a stable number in a short period to ensure the future of the species in question. Notably, in these scenarios it is desirable to allow free selection between several individuals of both sexes. If a small number of birds is released into a large habitat, then they will be more likely to face difficulties in breeding. Therefore, releasing as many individuals as possible at once could help to overcome this limitation.

Second, concerning long-term survival, it is desirable to ensure that many individuals exchange various genetic traits with each other. The theoretical model of population genetics suggests that at least 50 genetically different individuals are required to form a basic population when restoring a species to achieve rapid recovery (Frankel & Soulé, 1981; Franklin, 1980). A small initial population may be disadvantageous for continuous adaptation and survival in an irregular natural environment, due to the limited exchange of genes over generations.

Various species restoration programs in the U.S. have been conducted in stages, to allow the natural release of as many individuals as possible. For example Peregrine Falcone natural release projects has been conducted when the annual captive-bred population exceeded 100 individuals (Barclay & Cade, 1983). In the case of Whooping Cranes captive breeding had been continued until the growth rate reaches a certain number, with the breeding project expanding in scale every year (Kepler, 1978).

In addition to the number of individuals released, the qualities of the released individuals are another factor that can affect the successful restoration of species. Thus, it is necessary to prepare procedures to evaluate the qualities of such individuals, such as their genetics, behavior, physiology, and health. From a genetic viewpoint, individuals that have not been bred captively through several generations are ideal for natural release. Captive breeding over multiple generations can limit genetic selection through free gene exchange. Another issue is that during captive breeding, individuals can become over-adapted to artificial survival conditions, rather than to their natural habitat. This may lead to inadequate adaptive selection, which is undesirable for individuals that will eventually be released into a natural habitat.

Additionally, genetic bottleneck effects can occur in the process of captive breeding over multiple generations, which is another serious genetic downside. Genetic bottleneck effects have commonly been observed during the process of producing numerous individuals from a small population (Denniston, 1978; Franlkel & Soulé, 1981). In the process of the captive breeding and natural release, birds can face two genetic bottleneck effects. The first effect is observed when the species is captured from the wild for captive breeding, which the second effect occurring when the captive-produced individuals are selected for release.

To overcome the first effect, it is necessary to prepare a founder population for captive breeding that has as many distantly related individuals as possible. The second effect can be overcome by selecting as many different genetic groups as possible among the bred individuals when releasing them to the wild. For example, the release population should be composed of individuals with different body types and different levels of resistance to natural disasters. If possible, the wider the difference, the better. These approaches have proved to be effective in various captive breeding and release programs. In particular, these approaches have helped to ensure the successful reintroduction of Peregrine Falcone in the U.S. (Barclay & Cade, 1983).

The qualities and characteristics of the birds being released can also be determined through the breeding process. Behavioral and health-related problems can arise during breeding, and the quality of individuals that are selected for release are often determined by these characteristics from the breeding process. In the past, several release programs have failed due to inappropriate sexual imprinting, extreme tameness toward human beings, inadequate adaptation in captive breeding conditions, and poor health (Cade & Fyfe, 1978; Curio, 1996). These problems have decisive effects on the success of release programs following captive breeding; however, the severities of these problems may also differ depending on the species in question; the life history, general characteristics, and innate or acquired behavioral development processes of said species must first be understood.

Under certain captive breeding conditions, birds may develop problems related to "imprinting." Birds that are raised by humans can often suffer from the problem of being overly sexual or socially intimacy with their adoptive parents. Selecting individuals that exhibit such imprinting behaviors can lead to poor prognosis regarding their reintroduction into the wild.

Captive breeding requires significant levels of care and effort. However, it is also necessary to provide technological learning processes that allow individuals to properly recognize the opposite sex of the same species to ensure that they undertake normal sexual behavior when released into the wild. One credible strategy in this regard involves allowing a mother bird of the same species to rear young birds after hatching. If the young birds are instead being raised by humans, the use of a puppet that imitates the head and beak, pattern, and color of the mother bird constitutes another effective strategy. In fact, young individuals of Peregrine falcon that were naturally released first spent significant amounts of time with parents of the same species during certain phases of growing, or spent time with a large number of young birds of the same species (Sherrod, 1983). In the captive breeding of Andean condors (*Vultur gryphus*) for natural release, puppets that resembled mother birds were used, with direct eye contact between young condors and humans being kept to a minimum; this strategy proved effective for their successful natural release (Wallace & Temple, 1987).

However, despite these efforts to prevent imprinting, birds will inevitably come into frequent contact with humans during captive breeding. Frequent contact can not only make birds tame to humans but can also prevent them from being vigilant against human behavior and presence when released. Therefore, developing familiar relationships between humans and individuals for release is undesirable.

For example, hawks that were raised and released after frequent contact with humans were easily killed by humans (Snyder & Snyder, 1974). Based on this experience, a learning stage on the topic of negative conditioning for humans was implemented for the release projects of Peregrine falcon (Sherrod & Cade, 1978). Birds released without such pre-conditioning have frequently been killed in human-related accidents and have become easy targets of hunters. Domesticated Hispaniolan parrots (*Amazona ventralis*) were released into their past habitat in the Dominican Republic, but they have since been hunted and consumed for food by Haitian farmers (Snyder *et al*., 1987). Additionally, similar experiences have been documented regarding the release of domesticated Hawaiian nene goose (*Branta sandvicensis*), until they eventually adapted to living in the wild (Berger, 1978). In contrast, Ellis *et al*. (1978) provided learning to Masked bobwhites (*Colinus virginianus ridgwaty*) to ensure that they could cope with other predators before their release into the wild; this led to a significantly improved survival rate.

Birds that are captive-bred for a long time before release usually only acquire a limited set of skills necessary to live in a cage, instead of learning the essential behaviors and functions required for survival in the wild. This leads to them experiencing difficulties when adapting to their natural habitat following release. Notably, it is difficult for captive birds to learn how to find, catch, and handle food in a natural environment. In captive breeding conditions, food is provided in an unnatural manner, leading to birds becoming accustomed to this convenient method of obtaining food. Therefore, the survival of these birds after release depends on how quickly they can adapt to dealing with a variety of new and varied food in nature can determine their continued survival. For example, captive-bred Hispaniolan parrots that grew familiar with being artificially fed in caged conditions experienced difficulties in consuming food in the wild upon release, and so died of starvation (Collazo *et al*., 2003; Snyder *et al*., 1987).

A captive breeding environment can also promote and impose unnatural habits on birds by providing living conditions that differ greatly from their natural environment. These differences include responses to vocalizations of the same species, the nature of sleeping areas, and the processes of searching for water and food (Fyfe, 1978). Although there may be many differences depending on the species in question, it is common that various learning conditions must be provided before captive-bred individuals are released into the wild. These learning processes can significantly improve the survival rates of released individuals.

Health during captive breeding is another factor that greatly influences the survival of individuals after release. Captively raised and bred individuals must be free from diseases and parasites prior to release and should be physically fit. Poor health (regarding feather and muscle condition, and the accumulation of subcutaneous fat) before release is not ideal; it can lead to individuals struggling to change their lifestyle after release, therefore, the released individuals may show a poor survival rate. Individuals with diseases and parasites will also have low survival rates. Moreover, these individuals should not be allowed to join with existing wild populations, as this could lead to diseases and parasitic infections, which may be fatal, entering these wild populations (Kemp *et al*., 2020; Woodford & Rossiter, 1994). In the International Crane Foundation program, for example, cranes with herpes virus are considered to be unsuitable for release (Olsen *et al*., 2016).

Are release procedures adequate and effective?

Birds that are released into the wild must adapt to sudden changes in their lifestyle, compared to their captive breeding environment; this may be stressful for released individuals. Even if individuals with good health are selected and are released into a natural habitat with ideal conditions, the process of release is a further factor that needs to be considered regarding the successful reintroduction of endangered species. Several procedures are required for release.

The birds in question should be provided with the opportunity to undergo a gradual and smooth change in lifestyle, rather than experiencing rapid changes. It is also important to ensure that the number of released individuals is not too small that they become "lonely." In particular, artificial multi-step procedures are required to adjust the lifestyle of birds and ensure a smooth transition in their living environment. Birds must be constantly monitored during this transition, and the process must help the released birds to acquire those functions that are essential functions for survival in the wild.

In many cases, the age of the released individual can determine how well it will adapt to this transition in its living environment. Fledglings, though naturally prone to high mortality, can quickly acquire necessary life skills and are excellent at adapting to new environments. Thus, they constitute ideal individuals with optimal physical conditions and psychological states for release into the nature (Le Gouar *et al*., 2008; Sarrazin & Legendre, 2000; Schaub *et al*., 2004; Temple, 1978).

Adult birds who are acclimatized to their captive breeding environment, however, can be relatively naive when coping with new and sudden changes in their environment. Thus, they are unsuitable for release. Adult birds also require a relatively long process of habit transition prior to release. This is consistent with observed differences in learning ability with respect to age. Young birds can learn new skills relatively quickly, based on imprinting. In contrast, adult birds need to undergo gradual habit transitions through associate learning, which must be conducted over a longer period (Canessa *et al*., 2014; Carrie *et al*., 1999; Clark *et al*., 2002; Earnhardt *et al*., 2014).

Practical methods for returning captive-bred birds into the wild have been developed in a variety of ways. However, one common aspect is "gentle release." In fact, programs featuring "abrupt releases" have led to failures more (Bright & Morris, 1994; Mitchell *et al*., 2011; Resende *et al*., 2021).

A gentle release can be ensured through several methods; young birds can either be raised by a mother from the wild or fostered by a mother bird in the wild. Release processes that mimic the natural release process of the mother bird leaving the young bird from the nest represent another effective method. "Hacking", which has been used in release of young falcons, is one such process (Dixon *et al*., 2019; Dzialak *et al*., 2006; Sherrod *et al*., 1982). When releasing adult birds, gradual modifying their captive environment to close to the natural state can help them to adapt. This involves gradual changes in the habits of the birds, in new breeding environments that imitate their natural habitat, rather than enforcing abrupt changes in their habits.

The foster parenting of eggs or offspring from captive breeding programs by mother birds in the wild leads to the highest success rate of release into the wild. This involves the switching of fertile eggs or nestlings, which has been applied to the Puerto Rican parrot (*Amazona vittata*) and Western populations of Peregrine falcon (Burnham *et al*., 1978; Herzog, 1995). The high success rates obtained when using this approach can be attributed to the natural experiences and learning processes that the offspring gain by living with a wild mother, and to the opportunities they are afforded to adapt to a wild environment.

However, there are several limiting factors in this process. Foster parenting allows a relatively large number of eggs or offspring from captive breeding to be raised by a small number of mother birds in the wild, instead of their own natural reproduction. Thus, this method is difficult for endangered bird recovery. In fact, there are significantly lower numbers of mature mothers of Puerto Rican parrot and Peregrine falcon in the wild than the number of eggs and offspring that have been raised in captive breeding programs. Another limitation is that young birds can learn inappropriate habits from their mothers, especially if the species in question originally became endangered due to the newly acquired habits of the remaining wild population (Temple, 1978).

The advantage of foster parenting, however, is that the offspring can easily learn essential species-specific habits, which are difficult to teach under captive breeding conditions. It has been demonstrated that Aleutian Canada geese (*Branta canadensis leucopareia*) offspring can easily learn their seasonal migration route from their mothers (Springer *et al*., 1978).

If there are sufficient basic data from research, the raising of captive-produced offspring by adoptive parents from other closely related species is a possible option. This method is referred to as cross fostering. In general, the offspring do not initially present any problems as they grow up when using this method. However, as they grow older, the unique characteristics of the adoptive parents (i.e., diet, social behavior, seasonal migration, habitat, and nest selection) may be imprinted, inevitably leading to serious errors (Cade & Temple, 1995).

The U.S. program to cross-foster the endangered Whooping crane using Sandhill crane (*Grus canadensis*) mother birds was controversial (Drewien & Bizeau, 1978). It resulted in hybrids between the two species being born in the wild, leading to major modifications being made to the program (G. Archibald, personal communication, 1994). The plan in the U.S. to cross-foster Peregrine falcons with Prairie falcons (*Falco mexicanus*), and Masked bobwhite with Texas bobwhite (*C. v. texanus*) mothers (Ellis *et al*., 1978; Hernández *et al*., 2006) is another controversial issue.

Various hacking methods that imitate the processes of falconery are widely used when preparing birds for release (Fyfe, 1978; Sherrod & Cade, 1978; Temple, 1978). These processes involve supplying food to the fledglings from a distance until they acquire necessary skills for survival. This is an effective method for ensuring a smooth transition from the captive breeding environment to natural environment. Hacking has many advantages, for example it allows for to release into the nature in more places and in larger numbers of fledglings. Furthermore, large numbers of the same species can be reintroduced into the natural habitat at once. Therefore, various methods that have been modified according to the unique characteristics of different species have been developed and used for release (Temple, 1978).

Hacking has a further advantage in that young offspring can be taught to learn various skills that are necessary for survival in the wild. It is possible to make the most of existing knowledge of the life history, and learning programs that imitate the life history of said species in nature can be applied. This allows the offspring to learn the conditions required for survival, such as diet, habitat, nest selection, and sexual selection, prior to release.

However, after reviewing these methods and releasing the individuals, the released individuals must be continuously monitored. In general, it is important to continuously seek rational means, such as careful observation, evaluation, and modification of methods, throughout the process of release. To accommodate feedback, improve methods, and expand research opportunities, it is also important to simultaneously use marking and tracking methods, such as color bands or radio-telemetry, on released individuals (Black, 1991; Ewen & Armstrong, 2007; Sarrazin & Barbault, 1996).

Is there sufficient social interest and will to recover the endangered species?

Another factor that must be considered for the long-term success of endangered bird recovery projects is social awareness. Projects involving the reintroduction of endangered species back into the wild must be supported by social interest and will. Initially, society may show relatively high levels of interest in a particular project. However, over time, interest in the project can often decline significantly. Accompanied by declines in parties' willingness to cooperate, support, and invest, this can lower the chances of successful restoration (Kleiman *et al*., 1994; Primack, 2008).

Most programs focusing on the reintroduction of endangered birds ultimately aim to save endangered species. Therefore, long-term motivation is essential to achieve these goals. Reintroduction programs must primarily aim to maintain sustainable wild populations of endangered species. Simultaneously, these programs must effectively maintain and conserve the species-specific life history and ecological characteristics of the wild population. Only then will such programs be socially recognized and gain increased interest and support.

Peregrine falcon reintroduction projects in the U.S. have been continuously reviewed and modified through computer-aided modeling approaches to set long-term targets and reach their goals of creating sustainable wild populations. The project was planned for approximately ten years; it led to the successful reintroduction of the Peregrine falcon and to the establishment of populations in the eastern region of the U.S. The Peregrine falcon that was reintroduced is a resident or migratory bird, the wild population of which has increased over time. As a result, the species has been removed from the endangered species list, and is now being continuously monitored as a threatened species (U.S. Fish and Wildlife Service, 2003).

Conclusion

Herein, we have highlighted and discussed items that must be reviewed and satisfied as prerequisites for reintroduction of captive-bred endangered bird species. The series of processes required in this endeavor fundamentally require human skills and effort. However, few researchers have the talent necessary for captive breeding and release. In particular, the captive breeding of endangered birds, inducing them to adapt to their natural environment, and releasing them are all challenging process that require logical thinking, appropriate knowledge, experience, and innate talent. Therefore, strategies must be sought to support the training of experts.

Realistically, in Korea, it is doubtful that necessary habitats currently exist to support captive-bred and released species, so as to ensure their continuous and stable long-term survival. Thus, it may be necessary to determine whether the end goal of reintroduction needs to be reconsidered, regarding the availability of a natural or semi-natural state. Problems related to available habitats cannot be solved by a single expert, or by restoration teams. Rather, these problems require awareness of the whole society, adequate laws and institutions, the accumulation of academic studies and technology, and the establishment of various educational programs by private environmental movements and social groups. In addition, when Korea's environment and habitat conditions are not suitable, the will of international cooperation is necessary to properly fulfill the role of a gene bank by releasing the species to high-quality environments in neighboring countries for the future of endangered species.

To date, not every case of captive breeding has been successful. Similarly, not all bird species and individuals are fit for release into the wild. Thus, programs must involve an appropriate habit, population, and method, in addition to social interest and will. Satisfying these previously described qualities and criteria can help to increase the success rates of reintroduction programs. Moreover, the probability of failure must be reduced by using and supplementing effective and modified methods in the process of captive breeding and release.

In certain cases, it is necessary to determine whether the goal of a program should be a test release or should instead include a long-term captive breeding plan, with the aim of establishing a sustainable wild population. In addition, for all species that may require reintroduction in the future, the feasibility of the methods and procedures must be closely reviewed to increase the chances of recovering endangered species. As there are currently insufficient measures for the proper reintroduction of endangered species, active measures must be implemented to prevent the extinction of endangered wild species.

Conflict of Interest

The authors declare that they have no competing interests.

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