AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 13, No 3, pp 300-306, 2021
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2021.03.050

Implications of captive breeding for the reintroduction of the Saker falcon (*Falco cherrug*) in Bulgaria

R. Petrov[1,2]*, Y. Andonova[1], Y. Gancheva[3], I. Klisurov[1]

[1]Green Balkans - Stara Zagora NGO, Stara planina str. 9, 6000 Stara Zagora, Bulgaria
[2]Department of General Livestock Breeding, Faculty of Veterinary Medicine, Trakia University, Student's campus, 6000 Stara Zagora, Bulgaria
[3]School of Sciences, Faculty of Science and Engineering, University of Wolverhampton, Wulfruna St, WV1 1LY Wolverhampton, United Kingdom

(Manuscript received 20 June 2021; accepted for publication 5 August 2021)

Abstract. *The Saker falcon (Falco cherrug) is a globally endangered species recovered in 2018 in Bulgaria. The only known active pair currently breeding in the wild in the country is made up of captive-bred and released birds, part of the first reintroduction programme for the species in Bulgaria and globally. As part of the project, sourced Saker falcons of known European origin are bred ex situ, the juveniles are parent-reared and released in the wild by means of the hacking method. The aim of this study was to evaluate the success and effectiveness of the captive breeding and rearing methods. The objective of the study was to investigate, compare and assess the results from fertilization, hatching, survival and hacking of captive bred Saker falcons registered over a 10-year period (2011-2021) at the Wildlife Rehabilitation and Breeding Centre (WRBC) Green Balkans, with a more detailed comparison of the breeding activities carried out in 2020 and 2021 (as the reintroduction programme was restarted in 2020). The results show more than threefold increase in output of laid eggs with the employment of the double clutching method in 2020 and 2021, and an overall 65% release rate of the hatched in the WRBC Saker falcons, for the investigated period.*

Keywords: conservation, endangered species, *ex situ*, raptors, restoration

Introduction

A massive decline of *F. cherrug* had been observed in Bulgaria over several decades. Similar to the rest of Europe, these declines were attributed to degradation of essential prey habitat. Other threats, which were believed to have contributed to the rapid decline of Saker breeding pairs were nest robbing (juveniles and eggs), human disturbance, infrastructure development and direct persecution (Iankov et al., 2013). Offtake for falconry in the late 1980s shrank the remaining Saker population to approximately 15 breeding pairs by the early 1990s (Iankov and Ruskov, 2007). The last breeding pair in Bulgaria was observed in 1997 (Ragyov et al., 2012). A national Saker survey, conducted in 2002-2004, as part of a conservation project by the Birds of Prey Protection Society (BPPS), found no breeding pairs (Ragyov et al., 2014). As a consequence, the Saker falcon was listed in the Biodiversity Act (2002) as a threatened species with priority for conservation (Annex 2), being protected throughout the country (Annex 3) and listed as critically endangered (CR) in the Red Data Book of the Republic of Bulgaria (2011). The necessary conservation actions which have been proposed, included nest guarding (in cases when active nests were found in the wild), intensive research aiming to investigate ecological aspects of Saker falcon behaviour, European souslik (*Spermophilus citellus*) conservation plans, prohibition of falconry and consistent reintroduction efforts (Domuschiev et al., 2011; Iankov and Gradinarov, 2012). Degradation and loss of steppes and dry grasslands through agricultural intensification and expansion (Lazarova and Balieva, 2020), as well as declines in livestock pastoralism appeared to be the main threats, which caused a decline in key prey species (BirdLife International, 2017), and consequently, a negative impact on the Saker falcon's western population numbers.

As a consequence of the national Saker survey conducted in 2004 in Bulgaria, when no breeding pairs were found, a feasibility study was carried out in 2008 (Ragyov et al., 2009), and soon after 2010 a Saker falcon reintroduction programme was initiated (Green Balkans, 2021). The Wildlife Rehabilitation and Breeding Centre (WRBC) of Green Balkans has actively participated in the development of a strategy for the Saker falcon reintroduction programme in Bulgaria, along with the Central Laboratory of General Ecology within the Bulgarian Academy of Sciences, and NGOs "Birds of Prey Protection Society", and "Fund for Wild Flora and Fauna". Specialised Saker falcon breeding facilities were designed and established in 2011 at the WRBC in Stara Zagora, Bulgaria. The aim of this study was to evaluate the success and effectiveness of the *ex*

*e-mail: rpetrov@greenbalkans.org

situ breeding and rearing methods used in the reintroduction of the Saker falcon near Stara Zagora. The objective of the study was to investigate, compare and assess the results from fertilization, hatching, survival and hacking of captive bred Saker falcons registered over a ten-year period (2011-2021) at WRBC, with a more detailed comparison of the breeding activities carried out in 2020 and 2021 (as the reintroduction programme was restarted in 2020).

Material and methods

Breeding programme

In the Wildlife Rehabilitation and Breeding Centre (WRBC) Green Balkans there were 12 aviaries adapted for the captive breeding and management of Saker falcons. They were situated in a large building, with a single corridor that provides access to all aviaries (Figure 1). Ten of the aviaries measured 4 m in length, 3 m in width and 3 m in height. Two of the cages were bigger in size, measuring 4 m in length, 5 m in width and 3 m in height, and are dedicated to Sakers which can no longer breed, and to injured individuals. The Saker falcon breeding aviaries had special adaptations specific to the species. The cages were constructed from solid wood panels, which restricted visual contact with humans. Each cage had mesh roofing, which allowed natural light and fresh air flow. In every aviary there was also a mesh window 40 cm in height and 70 cm in length, in front of which the Saker falcons perched to observe their surroundings, and also noticed in advance as people were approaching, which minimised stress. There were two nesting platforms in each aviary, measuring 1 m in width, 0.5 m in length and 0.15 m in depth. The nesting material used in each platform was manmade and was composed of small stones and rocks. A small circular opening was present on each aviary wall, bordering the corridor. A curved tube, attached to the opening on the inside of the aviary, allowed feeding of falcons without any visual contact with humans in order to reduce stress. The feeding opening was situated above a feeding table. In each aviary, there was a shallow dish for water, measuring at least 60 cm in diameter. A large rock (45 cm in width, 35 cm in length, 35 cm in height) was placed near each dish, for the purpose of encouraging the natural behaviour of Sakers drinking water while standing on rocks and boulders. The rock also facilitated natural nail filing.

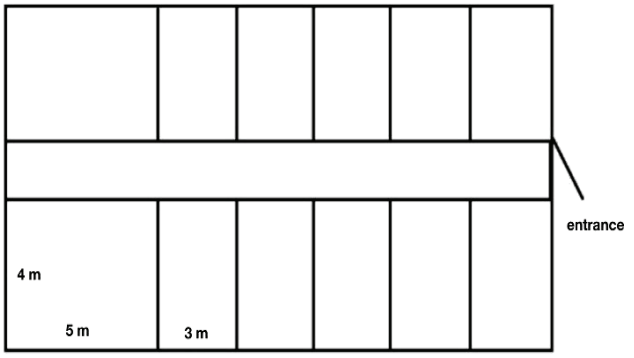

Figure 1. A diagram illustrating a view from above of the Saker falcon breeding aviaries (diagram not to scale)

At the beginning of the Saker falcon breeding season (late December - early January), multiple techniques, designed to encourage breeding behaviour, were adopted in an *ex situ* conservation management programme. The initial step during the courtship period was to increase the frequencies at which food was offered for the stock of breeding pairs. The amount of food was kept the same (150-200 g per bird, per day), however, the meals were increased from two per day to three per day. The falcons had a weekly menu - on Monday they would be offered day-old chickens, on Tuesday - rats, on Wednesday - quail, on Thursday - rabbit meat, on Friday - day-old chickens again, on Saturday - horse meat or beef depending on availability, and on Sundays they were not being fed. All food items were stored in a walk-in freezer for a minimum of 72 hours in advance, in order to destroy harmful microorganisms that may be present. After thawing in a fridge for 24 hours, the daily portions of each pair were prepared. The guts of all food items were removed, except from day-old chickens. The tails of rats were cut off and the yolk sacks of day-old chickens were removed. During the breeding season, vitamins and mineral dry supplements (Versele-Laga "Ferti-Vit", Versele-Laga "Opti-Breed" and Versele-Laga "Calci-lux") were added to the meat. These supplements were designed to promote sexual drive and productivity, as well as to support good eggshell formation. The prepared portions of food were given to the birds at morning, noon, and evening. Each morning, leftover food from the previous day was collected and removed. The Saker falcons were subjected to a constant background noise of between 50-60 decibels, provided by a radio, with the aim of minimising the stress caused by staff entering and exiting the breeding facilities during feedings.

At least three video cameras were installed in each aviary, prior to placing the Saker falcon pairs in them, in order for courtship attempts and egg laying to be captured. One camera was focused on each nest at all times. An additional camera was set up to overview the entire aviary. The breeding pairs were monitored daily through the 24/7 video surveillance, and footage of observed courtship behaviour such as food passing and vocalisation was saved within the WRBC database for monitoring purposes. The date and time of copulations and egg laying were recorded on an Excel spreadsheet.

Rearing techniques

After natural parental incubation for five to ten days, the eggs were taken away and placed in an incubator (Masalles - type falcon C30-S), set to maintain a temperature between 37.3°C and 37.7°C, and a relative humidity of 30%. The eggs were automatically turned every hour in the incubator. A high intensity egg candler ("OvaView"), and a digital heart pulse monitor ("Egg Buddy Mk2") was used every other day to assess the development of the capillary system in the egg yolk sac membranes, as well as the development of the embryo. At a later stage, when signs such as slight movements of the eggs and vocalisations from within the eggs were first recorded, the eggs were placed in a small bowl inside the incubator, in order to prevent them from rotating. As soon as an egg began to crack, the humidity was gradually raised to 70% - an essential technique used by falconers to prevent the egg

membrane around the cracks from drying out. A dry membrane is often difficult for hatchlings to break through. For identification purposes, newly hatched chicks were marked with a permanent marker, on either wing, head, or back, and hand-reared for ten days. The young falcons were fed with finely chopped rats and mice. The meals were prepared utilising the same methods as the ones used for the breeding birds, with the exception that for hatchlings only fresh ingredients were provided from the vivarium facility at the WRBC. The only supplement added to the meat fed to the chicks was an enzyme (Versele-Laga "Probi-Zyme"), in order to support healthy digestion. Finely chopped bone cartilage was occasionally offered to the young chicks, for the purpose of promoting bone development. The meat was cut into small pieces (<0.2 g) and was fed to the chicks using stainless steel flat tweezers. The chicks were fed every two to three hours, without efforts to prevent visual contact with humans, which was being done with the breeding pairs. In addition, the incubator temperature was reduced by 0.2-0.5°C after each feeding. In order to minimise the chance of imprinting of humans, the young chicks were returned to the aviaries 10 days after hatching, either in the nests of their biological parents, or of foster parents.

Young falcons were prepared for hacking approximately 30 to 35 days after hatching. Firstly, they were caught in the aviaries using nets, and placed in specialized bird carriers for transportation to the veterinary facilities. Morphological measurements, such as, weight and tarsometatarsus girth, and length of beak and wings were recorded. The sex of each falcon was determined at that point (tarsus girth <3 mm, and weight <850 g for males; tarsus girth >3 mm, and weight >900 g for females). After disinfecting the area with alcohol, a microchip was injected between the breast in the pectoralis major musculature. Microchipping was performed on every released bird for identification purposes, allowing the falcons to be found again in the wild in Bulgaria and abroad. The presence of microchips allows the birds to be imported back to the country in case this is needed. Metal and coloured identification rings were placed on the left and right leg, respectively, to indicate year and place of hatching. The colour of the coloured rings changed annually in order to facilitate the identification of observed birds in the wild. The methodology was set by Green Balkans NGO and coordinated with the Bulgarian Ornithological Center of the Bulgarian Academy of Sciences. The microchip numbers and identification ring codes of each bird were recorded. Ectoparasites were eliminated using "Pik" powder. The falcons were dewormed internally using "Panacur 10".

Three different breeding techniques were adopted between 2011 and 2020. Natural egg incubation with no human intervention was allowed during all breeding seasons, apart from breeding seasons 2016, 2020 and 2021. Sequential egg removal was trialed during breeding season 2016. It involved the removal of eggs soon after they were laid. The first three eggs produced by each pair were taken one by one in order for the female to continue laying eggs and complete the clutch. During breeding seasons 2020 and 2021, the method of double-clutching was employed. In order to maximise egg production, the laying of a second clutch was encouraged by taking away the eggs laid in the first one. Ten days after the laying of the last egg, the whole clutch was removed from the nest at once.

The breeding programme included the release of the captive bred Saker falcons in the agricultural lowlands near Stara Zagora, via adaptation aviaries (hacks) installed on suitable for the species trees. The birds were kept closed in them for ten days in order to get accustomed to the surroundings without risking predation. Food was left for them twice a day, and after being released they were monitored daily by a field team for up to four months.

Results

Fertilisation, hatching and hacking success (2011-2021)

Totally, 310 eggs were laid by Saker falcons at the WRBC between 2011 and 2021. On average, 51% of the eggs laid each season were infertile (Figure 2). For just one season, in 2016, the technique of sequential egg removal was implemented. There was no difference in the number of laid eggs in 2016 and previous years, however the percentage of unfertilised eggs increased from 13% in 2015, to 64% in 2016. Nevertheless, 44% of the laid eggs successfully hatched during the studied period on average (Figure 3). The highest number of eggs was laid in 2021 and due to this the highest number of unfertilised eggs was recorded, however, it amounted only to 45% of the laid eggs, which is lower than the average for the studied period. The lowest number of unfertilised eggs was recorded in the 2015 breeding season (only 13% were infertile), which was also the year with the highest hatching success (88% of all laid eggs). In breeding seasons 2020 and 2021 only 24% of all laid eggs were hatched each year. The highest rate of mortality was recorded in 2014, when 25% of the hatched chicks died before release. There were no recorded deaths of young Saker falcons in 2012, 2013 and 2015. Mortality rate in hatched chicks during breeding season 2021 was relatively low - only 15% of the hatched falcons died (Figure 4). Nevertheless, during breeding season 2021, 44% of pre-hatched chicks died in the shell. Between 2012 and 2021, 65% of the hatched Saker falcons were hacked by the WRBC (Figure 5). Up to 2015, the hacking method was piloted, and in 2012 only imported birds were released. Between 2015 and 2021, an average of 82% of the hatched birds were released via the hacking method.

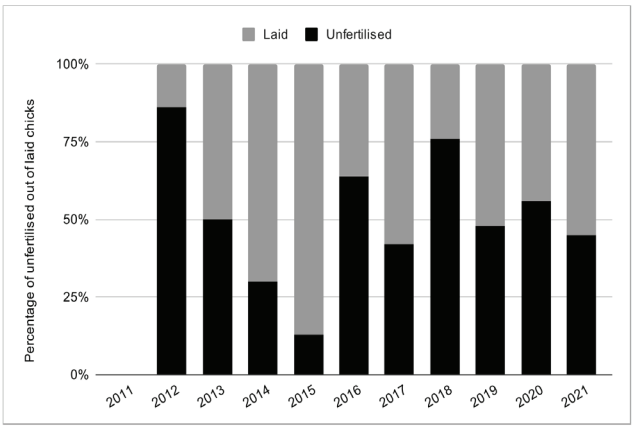

Figure 2. Number of unfertilised Saker chicks out of laid eggs for the period 2011-2021 at the WRBC

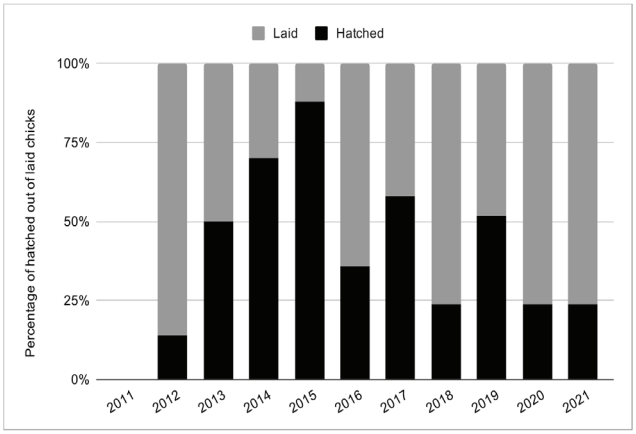

Figure 3. Number of hatched Saker chicks out of laid eggs for the period 2011-2021 at the WRBC

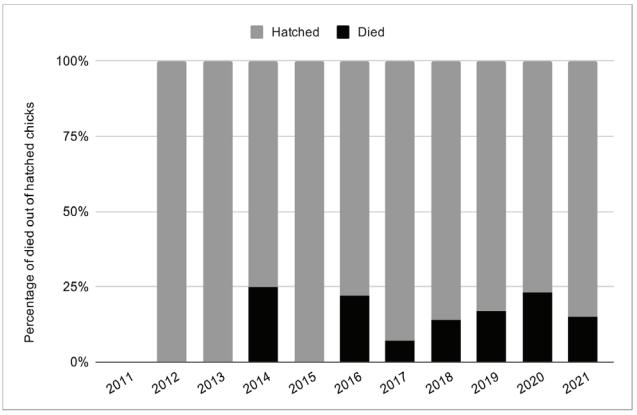

Figure 4. Percentage of dead Saker chicks out of the hatched for the period 2011-2021 at the WRBC

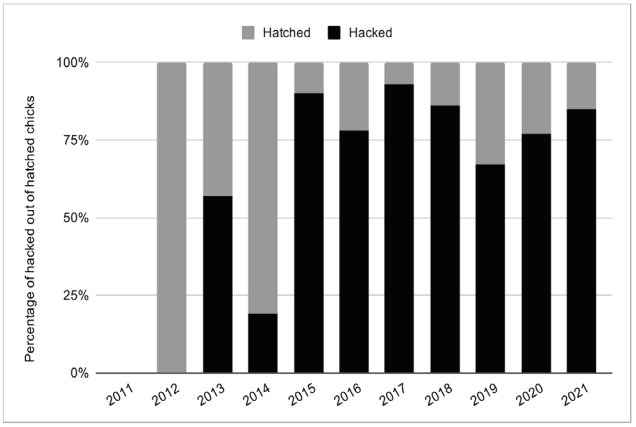

Figure 5. Percentage of hacked out of hatched Saker chicks (without the imported birds) for the period 2011-2021 at the WRBC

Fertilisation, hatching and hacking success (2020-2021)

During breeding seasons 2020 and 2021, successful copulation and egg laying was recorded in 95% of the breeding pairs. During these two seasons, in which the method of double clutching was employed, the number of laid eggs was more than three times higher than in seasons 2011-2019 (an average of 70 and 19 eggs, respectively, for the two periods). The number of pairs was kept between 8-12, with the exception of 2011, when there were only two breeding pairs formed. In 2020 four pairs produced a second clutch, and in 2021 the double-clutching method was employed on eight Saker falcon pairs. The average number of eggs laid in the first and second clutch was 5 and 4, respectively. A higher number of fertile eggs was recorded in the first clutch of the four pairs (57%) than in the second (43%) (Figure 6). However, the average number of both hatched and reared chicks for the two seasons was higher in the second clutch, estimated to 52% and 56%, respectively, of all laid eggs. In the 2020 breeding season, 8 pre-hatched chicks died in the egg. From these, 6 were laid in the 2nd clutch. Three young falcons died after hatching, two in the 1st clutch, and one in the 2nd. During breeding season 2021, all breeding pairs successfully copulated and laid 84 eggs in total. Nevertheless, chicks were hatched from clutches produced from only 8 out of the 12 breeding pairs. Artificial incubation was used for 57% of those eggs, whereas the rest of the eggs were incubated naturally by the parents.

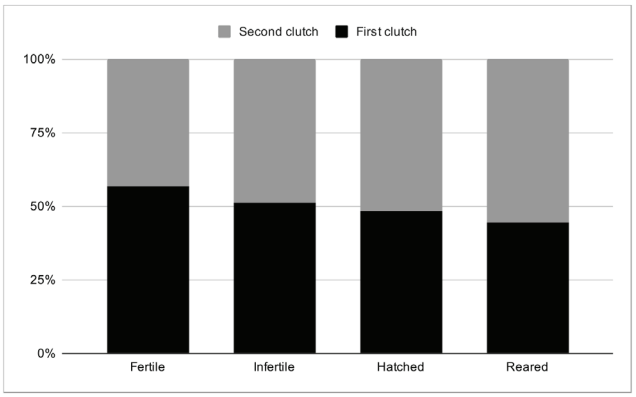

Figure 6. Percentage of fertile and infertile eggs, and of successfully hatched and reared chicks in the first and second clutches of breeding pairs at the WRBC in 2020 and 2021

Discussion

Although reintroduction of captive-bred individuals is undoubtedly an important component of wildlife conservation, it is a controversial management action due to issues arising with genetic factors such as adaptation, inbreeding and loss of diversity. At the Wildlife Rehabilitation and Breeding Centre (WRBC) Green Balkans, a founder stock of Saker falcons was formed using adult birds obtained from breeding centres in Germany, Czech Republic and Slovakia, along with juvenile birds bred from these founders (Dixon et al., 2020). During 2017, 2018 and 2019 the composition of breeding stock was changed by replacing old birds with younger individuals imported from Austria, Germany, Hungary, Poland and Slovakia. The number of breeding pairs at the WRBC appeared to be low when compared to falcon reintroduction efforts that took place in other geographical areas, e.g. Texas (USA) and Poland (Brown and Collopy, 2008; Sielicki and Sielicki, 2009). Nevertheless, attempts to maintain the genetic diversity within the small

captive population were made by modifying the composition of the founder stock and by acquiring birds from other European countries. Translocations were the preferred conservation tool when reintroduction attempts were made in small geographical areas (Teixeira et al., 2006). The translocation of wild-caught Saker falcons from the Pannonian Basin was initially considered as a cheaper, more practical option. However, because the Pannonian Saker population has been the focus of intensive conservation activity, concerns about the potential impact on the donor population meant that there was no consensus among conservationists (Dixon et al., 2020). The translocation of birds from Saker falcon populations outside the European Union was deemed unfeasible due to logistic, political and administrative reasons (Ragyov et al., 2010).

Research has found that many factors could have an impact on the reproductive success of captive adult Saker falcons, such as stress, age, diet, aviary design and unsuitable pairing of males and females. The formation and maintenance of a pair-bond was reported to be essential for optimising reproductive success in monogamous species (Nedelcu and Hirschenhauser, 2013), such as falcons. At the beginning of the reintroduction programme (2012) we recorded the highest rate of unfertilised eggs, 86%, which was expected due to the yet inexperienced pairs and/or pair incompatibility. During 2013, 2014 and 2015 productivity increased, possibly with the increasing experience of the pairs. Similar findings were well documented in captive populations of peregrine falcons (Clum, 1995). The same trend may be expected when females experience a change of mate, which may explain the sudden decrease in fertilised eggs after breeding season 2017, when new birds were imported to the centre, augmenting the composition of the founder stock. The WRBC breeding team implemented a number of techniques which mitigated the negative impacts on breeding behaviour caused by the establishment of new pairs. Adult birds at the centre were paired after careful examination of individual behavioural traits.

The high number of unfertilised eggs during 2016 indicated that the method of sequential egg removal, stimulating the female to lay more eggs in an attempt to complete a clutch (Jones, 2004), was unsuccessful. A factor that could have had an impact on the outcome of this trial was the unsuitable design of the breeding facilities at the WRBC. The nest boxes were attached to the interior wall of each aviary, with no possible access from the maintenance corridor. Saker falcons have highly developed parental care and appear to be very aggressive in nature (Rahman et al., 2015). These behavioural traits led to physical struggles between team members and the female often up to 20 min long. Sequential egg removal has been previously documented as an effective method in breeding of other species of birds (Jones, 2004), and it could be a potentially useful technique in falcon breeding, if stress-inducing factors are eliminated.

Many species of birds, which only produce one clutch of eggs per season, were reported to be able to lay a second clutch, if the first nesting attempt fails (Leus, 2011). This ability to recycle was exploited within many captive breeding programs. During breeding seasons 2020 and 2021, the first clutches produced by eight of the breeding pairs at the WRBC were removed 10 days after the last egg was laid, because harvested eggs have better hatchability if they have received 7-10 days natural incubation (Jones, 2004; Nager et al., 2000). In breeding seasons 2020 and 2021, although the number of laid eggs was relatively high, only 24% of them successfully hatched. These results indicated issues that may have been encountered during the two years. In 2020 the high number of unfertilised eggs was undoubtedly caused by low copulation rates between breeding individuals, which was also confirmed by video surveillance. This was as expected because many of the females had experienced multiple changes of mates within a three-year period (2017-2020). A higher mortality rate in pre-hatched chicks was observed in the second clutch. Human intervention and artificial incubation were excluded as possible causes because egg incubation under controlled temperature, humidity and rotation cycles maximised hatching success (Burnham, 1983). The cause of late embryonic mortalities of Saker falcons at the WRBC during breeding season 2020 was unclear. However, the most likely causes appeared to be nutritional problems in adults, which could not only affect fertility and hatchability of eggs, but also cause egg-borne infections (e.g., Salmonella spp., mycoplasmas, adenoviruses, etc.) (Rideout, 2021). Attempts to resolve this issue had been made by the WRBC breeding team, including careful veterinary examination of the dead embryos and collection of blood samples. The collected blood was sent for analysis to an external laboratory. To date (2021), the outcomes of these investigations remain unclear. The identification and correction of nutritional problems was an essential task, thus veterinary involvement in the programme was necessary. Embryo pathology was an important tool used in disease diagnosis and can be employed to optimise incubation and hand-rearing parameters. Furthermore, it can be used as an early indicator of disease outbreaks (Rideout, 2021). Mortality in hatched chicks in breeding season 2020 was caused by ectoparasites (ticks). Captive birds were known to be more prone to parasites as compared to wild birds who were able to leave unfavourable environments (Ombugadu et al., 2019). Although only three chicks died from ectoparasites, such occurrences should cause a major concern. Ticks feeding on a small bird could cause anaemia, reduced growth and weight loss (Ombugadu et al., 2019), therefore necessary measures, such as systematic sanitation of bird cages, facilities and equipment were taken, and in the breeding season of 2021 this problem was eliminated.

As a result of the captive management actions undertaken by the WRBC team between 2011 and 2021, 115 Saker falcons have been hacked on Bulgarian territory. The number of wild-nesting pairs in Bulgaria was expected to increase with the progress of the reintroduction programme, restarted in season 2020, as more birds were being released (Lazarova et al., 2021). Future development of the programme is linked with the expectation that the founding wild population will recruit breeding

individuals from neighboring regions, and consequently facilitating gene flow amongst existing fragmented populations (Lazarova et al., 2021). A pair of Saker falcons, formed of reintroduced individuals in 2015, was discovered to breed near the hacking site between 2018-2021. Moreover, offspring produced by the pair successfully fledged. This indicated that restoring populations of locally extinct birds to areas of their former range through reintroduction of captive-bred individuals could be a potentially useful and effective conservation tool.

Conclusion

Restoring a population of locally extinct species through reintroductions requires persistent long-term efforts. Between 2011 and 2021, 310 eggs were laid by the Saker falcon breeding pairs at the Wildlife Rehabilitation and Breeding Centre (WRBC) Green Balkans. Fertilisation and hatching success varied over the years as different methodologies were employed. The percentage of unfertilized eggs increased from 13% in 2015 to 64% in 2016. This dramatic increase was a consequence of stress related to sequential egg removal. On the other hand, the employment of a double-clutching method during the two seasons since the programme was restarted (2020-2021) showed a threefold increase in output of laid eggs. Nevertheless, only 24% of them successfully hatched. Understanding the cause of undesired effects such as low copulation rates due to unsuitable pairing of birds, ectoparasite-caused mortality of hatched chicks and nutritional problems in adults, and implementing new techniques in order to eliminate or minimise them, will ensure the future improvement of the results. Involving other zoos and specialised bird of prey centres can expand the scope of the species reintroduction programme and lead to more bred and released in the wild birds. Despite encountered issues, the Saker falcon breeding programme has been successful. Two individuals released in 2015 as part of the reintroduction programme, have been discovered to successfully breed in the wild in 2018 and 2019. This established the possibility of hacked Sakers surviving in the wild until maturity and returning to the region of their release to breed. This was further confirmed by change of the female bird in 2020, which was released in 2016, along with two successful breeding seasons for the new pair. The expected result of the programme is to successfully establish a self-sustaining population of Saker falcons in Bulgaria.

Acknowledgements

The Saker falcon reintroduction programme has been funded over the years since its inception by the Mohammed bin Zayed Raptor Conservation Fund, United Arab Emirates; Armeec JSC; Environment Agency of Abu Dhabi (EAD); Mohammed bin Zayed Species Conservation Fund and the People's Trust for Endangered Species (PTES), United Kingdom.

References

Biodiversity Act, 2002. State Gazette (SG) 77/09.08.2002. Last amended SG 98/27.11.2018 (Bg).

BirdLife International, 2017. Falco cherrug (amended version of 2016 assessment). The IUCN Red List of Threatened Species, from https://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22696495A110525916.en. Retrieved 29th June 2021.

Brown JL and Collopy M, 2008. Nest-site characteristics affect daily nest-survival rates of northern aplomado falcons (*Falco Femoralis Septentrionalis*). The Auk, 125,105-112. DOI: 10.1525/auk.2008.125.1.105

Burnham W, 1983. Artificial incubation of falcon eggs. The Journal of Wildlife Management, 47(1), 158-168.

Clum N, 1995. Effects of ageing and mate retention on the reproductive success of captive female peregrine falcons. American Zoologist., 35 (4), 392-339.

Dixon A, Ragyov D, Acebes D, Rahman L and Klisurov I, 2020. Movement and survival of captive-bred Saker Falcons, *Falco cherrug*, released by wild hacking: implications for reintroduction management. Acta Ornithologica, 54, 157-170. https://doi.org/10.3161/00016454AO2019.54.2.003.

Domuschiev D, Michev T, Stoyanov G, Petroc Ts, Ruskov K and Vatev I, 2011. Saker falcon, from http://e-ecodb.bas.bg/rdb/bg/vol2/Facherru.html. Retrieved 29th June 2021.

Green Balkans, 2021. Breeding programme. from https://greenbalkans-wrbc.org/en/Short_history_of_the_program-p. 357. Retrieved 29th June 2021.

Iankov P and Ruskov K, 2007. Study and conservation of the Saker Falcon (*Falco cherrug*) in Bulgaria. Bulgarian Society for the Protection of Birds, 1, 1-21.

Iankov P and Gradinarov D, 2012. Conservation strategy of the Saker Falcon (*Falco cherrug*) in Bulgaria. Aquila, 119, 31-45.

Iankov P, Stoyanov G and Ragyov D, 2013. National Action Plan for the Saker falcon (*Falco cherrug*) in Bulgaria. Technical Report, 1, 1-91 (Bg).

Jones CG, 2004. Conservation management of endangered birds. In: Bird Ecology and Conservation: A Handbook of Techniques (eds. W.J. Sutherland, I. Newton, and R. Green), New York: Oxford University Press, pp. 269-301. DOI:10.1093/acprof:oso/9780198520863.003.0012

Lazarova I and Balieva G, 2020. Pesticide agents as factors for wild animals poisoning. In: 12 Scientific Conference of the Bulgarian FP 2019 - Book "Climate changes a global threat for the food chain", Risk Assessment Centre on the Food Chain, Sofia, pp. 18-40 (Bg). https://doi.org/10.5281/zenodo.3647855.

Lazarova I, Petrov R, Andonova Y, Klisurov I and Dixon A, 2021. Re-introduction of the Saker Falcon (*Falco cherrug*) in Bulgaria - preliminary results from the ongoing establishment phase by 2020. Biodiversity Data Journal, 9, e63729.

Leus K, 2011. Captive breeding and conservation. Zoology in the Middle East, 54, 151-158.

Nager R, Monaghan P and Houston D, 2000. Within-clutch trade-offs between the number and quality of eggs:

experimental manipulations in gulls. Ecology, 81, 1339-1350.
Nedelcu I and Hirschenhauser K, 2013. Maintenance of the monogamous pair bond. In: The social life of geese (eds. I. Scheiber, B. Weib, J. Hemetsberger and K. Kotrschal), London, Cambridge University Press, pp. 65-87.
Ombudagu A, Echor B, Jibril A, Angbalaga A, Lapang P, Micah E, Njila M, Isah L, Nkup C, Dogo K and Anzaku A, 2019. Impacts of parasites in captive birds: A review. Journal of Neurology, Psychiatry and Brain Research, 1, 1-12.
Ragyov D, Kmetova E, Dixon A, Franz K, Koshev Y and Nedialkov N, 2009. Saker Falcon, *Falco cherrug*, reintroduction in Bulgaria: Feasibility study, SESN, Sofia, Bulgaria (Bg).
Ragyov D, Dixon A and Kowalczyk K, 2010. Re-introduction of the Saker falcon to Bulgaria, South-East Europe. In: Global re-introduction perspectives: additional case studies from around the globe (ed. P.S. Soorae). IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE.
Ragyov D, Koshev Y, Kmetova E, Gradev G, Stoyanov G, Stoev I and Marinov D, 2012. Preparatory activities for Saker Falcon (*Falco cherrug*) reintroduction in Bulgaria: habitat management and electrocution risk assessment. Aquila, 119, 91-103.
Ragyov D, Biserkov V, Gradev G, Ivanov I, Stoynov E, Stoyanov G, Domuschiev D and Dixon A, 2014. Past and Present Status of the Saker Falcon, *Falco cherrug* (Aves: Falconidae) in Bulgaria (Bg).
Rahman L, Batbayar N, Purev-Ochir G, Etheridge M and Dixon A, 2015. Influence of nesting location on movements and survival of juvenile Saker falcons *Falco cherrug* during the post-fledging dependence period. Ardeola, 62, 125-138.
Red Data Book of the Republic of Bulgaria, 2011. Vol. 2. Animals, from http://e-ecodb.bas.bg/rdb/en/vol2/. Retrieved 29th June 2021.
Rideout B, 2021. Pathology of the Avian Embryo: What Veterinarians Need to Know About Pathology as a Disease Surveillance Tool for Avian Captive Propagation.
Sielicki S and Sielicki J, 2009. Restoration of Peregrine Falcon in Poland 1989-2007. In: Peregrine Falcon populations - status and perspectives in the 21st century (eds. J. Sielicki and T. Mizera), Poznan University of Life Sciences Press, Poznan, Poland.
Teixeira C, Schetini De Azevedo C, Mendl M, Cipreste C and Young R, 2007. Revisiting translocation and reintroduction programmes: the importance of considering stress. Animal Behaviour, 73, 1-13.