13 Back into European Wildlife

*The Reintroduction of the Northern Bald Ibis (*Geronticus eremita*)*

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FAILURE AND SUCCESS

August 26, 2015, 09:40: in the morning after a cold night, the sun warms up and removes the last patches of fog. We are at the airfield of Mauterndorf in the Austrian Alps at 1,100 m above sea level; a team of 14 people and 31 juvenile northern bald ibis. Despite the wonderful surroundings, our mood is rather depressed. Our aim is to lead the group of ibis across the Alps to northern Italy.

Two hours ago, two microlight aircrafts started at the airfield, each with a human foster parent in the back seat. At the beginning, the birds followed them willingly, as we expected them to do. But after ten minutes, the birds headed back to the airfield. In the following two hours, the flight teams tried to lure the birds away with calling and endless circling. It felt as if the birds were fixed to the airfield with rubber bands. They followed for a few kilometers then turned back, again and again. Finally, after 67 flight kilometers in a radius of just 5 km around the airfield, the team gave up and landed with the birds. It was definitely not the first time that something like this had happened, but this time it was particularly frustrating, firstly, because four days ago the birds had followed perfectly for 120 km from the breeding site at the northern foothills of the Alps to Mauterndorf, and secondly, because this migration journey was an ambitious attempt to improve the human-led migration method by doubling the group size of the birds, and expectations were high. For now, there was only one course of action: relax, wait for the next morning, and

FIGURE 13.1 Human-led migration flight across the Alpine mountain range. The microlight is surrounded by a number of 30 juvenile birds that are imprinted on the two foster mothers in the back of each microlight.
Photo: C. Esterer

hope that the weather would be fine again and the motivation of the birds would be better – for whatever reason.

The next day began, and with it a new opportunity. After the start, the birds hesitated again and circled above the airfield. But after 15 minutes, the situation changed, most of the birds headed toward the microlights and followed. Within 25 minutes, we reached the highest point of the whole journey, the Katschbergpass, at 2,100 m above sea level. Usually, the birds lower their flight level after a pass and follow the topography of the landscape. But this time was different. We could keep the birds at a flight level of 1,400–1,600 m and follow a straight route across the Alps (Figure 13.1). After 2 hours and 25 minutes, we passed the border to Italy and reached the southern foothills of the Alps.

It was one of the most spectacular flights since the start of the project 13 years ago. Just two microlights and the birds in the endless sky, surrounded by mountains and glaciers and, later on, with a spectacular view of the Tagliamento River and the Adriatic Sea. The flight clearly demonstrated the power of social bonding. Up there in the sky, the birds could fly wherever they wanted. The only thing that hindered them from doing so was parental imprinting during the early stage of their life. An invisible, strong social bond between them and the foster parents in the microlights caused them to follow continuously for hours.

After 3 hours and 20 minutes and a 163-km flight distance, the formation landed. At the end of that day, the mood of the team was

FIGURE 13.2 Portrait of an adult northern bald ibis, with the characteristic long, curved bill and the naked face, surrounded by a "feather boa."
Photo: J. Fritz (For the color version, please refer to the plate section)

excellent: we were in Italy, at a wonderful airfield close to the Tagliamanto River, with a swimming pool, warm weather, and – most relevantly – an exciting and successful migration stage behind us. It is characteristic of our project and probably any such innovative project that success and failure follow in an irregular and mostly unexpected way. And even that exciting day was not perfect. Some of the birds had refused to follow the microlight and had returned to the airfield in Mauterndorf, where members of our team caught and kept them. On the following day, they got the opportunity to follow one of the microlights for the major part of that flight stage down to the airfield where they met up with the others.

HISTORY AND CURRENT STATUS

About 4,500 years ago, in Ancient Egypt, the northern bald ibis (Figure 13.2) was a sacred bird, probably due to his conspicuous sunbathing behavior that might have seemed like a blessing of sun god, Ra. It was used as a representation of the noun "akh" and related words. The notion of the "akh" has often been translated as "spirit" or "blessed dead" (Janak, 2011) in the Middle East. Therefore, Muslims worshiped them as leaders of the *hajj*, because the bird flew southward in fall in large numbers, just like pilgrims to Mecca. In European Christian culture, a mythological meaning similar to that of Ancient Egypt is evident by an altarpiece from the fifteenth century. It shows the Mount of Olives scene, with Jesus and the disciples in prayerful attitudes. A juvenile northern bald ibis at the edge of this picture represents the presence of death and the hereafter (Unsöld & Fritz, 2011). Despite this mythological context, northern bald ibises were also valued as edible birds. As such, they were hunted, and juveniles were taken from the nests shortly before fledging. It is assumed that this human threat was the main reason for the reduction of wild stock in Europe in the Middle Ages and finally the continental extinction at beginning of the seventeenth century (Gessner, 1557; Schenker, 1977, 2017).

Most knowledge about the historic occurrence and biology of the species in Europe comes from the Swiss naturalist, Conrad Gessner. In his famous book of birds (Gessner, 1557), he named the species as Waldrapp and Corvus sylvaticus and described its occurrence in parts of central and southern Europe and aspects of its behavior. He even dissected a juvenile and described the content of its stomach. Nevertheless, from the late-seventeenth century onward, after the species was eradicated in Europe, Gessner's Waldrapp was thought to be a mythical creature (Kumerloeve, 1978; Unsöld & Fritz, 2011).

In 1825, an ibis species was discovered on the coast of the Red Sea and was described as *Ibis comatus*. Four decades later, the ornithologists Rothschild, Hartert, and Kleinschmidt recognized that this bird was identical to the species described by Gessner. The systematic name of the species was changed to *Geronticus eremita* (L., 1758), and this name is still valid today.

After its extinction in Europe, the breeding sites of the species still covered parts of northern Africa and at the Arabic peninsula. But mainly during the twentieth century, the story of the northern bald ibis in these regions became a rather sad one, resulting in the fact that today the species is listed as critically endangered on the Red List of the International Union for Conservation of Nature (IUCN). This is the highest threat category. All wild colonies disappeared, with the exception of one population in Morocco on the Atlantic coast (Bowden et al., 2008; Fritz et al., 2017; Serra et al., 2015). This population consists of breeding colonies at two main sites on the Atlantic coastline, namely the Souss-Massa National Park (SMNP; south of Agadir) and Tamri (around 50 km north of Agadir) (Bowden et al., 2008; Sikli et al., 2016). During the 2017 reproductive season, Moroccan conservationists discovered two new breeding sites with at least three confirmed active nests incubated by adults at two distinct coastal cliffs on the Atlantic coastline north of Tamri. On the same day, they observed a group of 11–15 non-breeding birds together at the top of a cliff located a few kilometers further north. These findings suggest extension of the breeding range of this relict species along the Moroccan Atlantic coastline (Aourir et al., 2017).

At the beginning of our century, hope was aroused for the northern bald ibis in their former eastern range because of the unexpected discovery of a relict population of seven birds breeding in the Syrian desert (Serra et al., 2004). Significant international efforts were made to conserve this small population, including the protection of the breeding site (Serra et al., 2009), as well as satellite tagging to explore the migration route and to discover the wintering site in Ethiopia (Lindsell et al., 2009; Serra et al., 2013). However, despite international conservation efforts, the population declined. In 2010, an international team of conservationists decided on an invasive management action as a last resort to counter extinction. In early July 2010, three juveniles from the breeding colony in Birecik, Turkey, were released at the breeding site in Syria, in the presence of the last three remaining wild adults. Shortly after release, the juveniles followed one of the adults on migration from Syria southward across the Arabic peninsula. However, in the south of Saudi Arabia, they lost contact to the leading adult. While the adult continued to the wintering site in Ethiopia, the three juveniles died in the region (Fritz & Riedler, 2010).

Indeed, the experience of this supplementation attempt would have formed the basis for further conservation action. However, the difficult political situation as well as the extensive and uncontrolled hunting occurring over the whole region prevented a continuation of meaningful conservation activities. In 2014, the last wild bird disappeared, and since then the former wild eastern northern bald ibis population has been regarded as extinct (Serra, 2015, 2017).

FIGURE 13.3 Juvenile northern bald ibises on a migration flight, forming the characteristic energy-saving flight formation.
Photo: M. Unsoeld

LIFESTYLE

The ultimately failed conservation actions in the Middle East shed light on a characteristic of the northern bald ibis that is both essential and challenging for their conservation. The species was migratory all over its historic range (Figure 13.3). Known wintering sites were along the African east coast, mainly in Eritrea and Ethiopia, and along the African west coast down to Mauritania and Senegal (Bowden et al., 2008; Hancock, Kushlan, & Kahl, 1992; Lindsell et al., 2009).

Data on the regulation and patterns of migration are mainly available from satellite tracking of the former Syrian relict population (Lindsell et al., 2009; Serra et al., 2015) and from the European migratory release population, which comprises descendants from former colonies originating in the Moroccan Atlas (Fritz et al., 2017). The birds have a genetic disposition to migrate, which includes pre-migratory fattening (Bairlein et al., 2015), along with increases in body weight and corticosterone levels (Fritz, 2016). There are indications from different release projects that juvenile northern bald ibises, during their first fall migration, follow an internal vector that heads them south/southwest (Fritz et al., 2017; Serra et al., 2015; Yeniyurt et al., 2016). However, as is known from studies of the white stork (*Ciconia ciconia*) and other species, juveniles depend on social information from experienced individuals of the same species – so-called conspecifics – to reach common wintering sites for the first time (Chernetsov, Berthold, & Querner, 2004; Flack et al., 2016).

Experiences with the European migratory release population (Fritz et al., 2016) suggest that such a separation as was seen in the three supplemented juveniles that lost contact to the leading wild adult in the south of Saudi Arabia probably happens regularly in this species during fall migration. Juveniles are less powerful and enduring migrants than (sub)adult conspecifics. Thus, at a certain physiological status, they leave one group of adults to stay at a stopover site. After refattening, they would then join with another group of conspecifics passing by to continue the journey to the common wintering site. Similar patterns are also known for other species, especially white storks (*Ciconia ciconia*) (Chernetsov et al., 2004; Shephard, Rycken, Almalik, Struyf, & Erp van der Kooij, 2015). At low population sizes, juveniles falling behind might not get another chance to follow experienced conspecifics. This may have also been the reason why mainly (sub)adults were seen at the Ethiopian wintering site, while juveniles that hatched in the wild in Syria disappeared during the fall migration (Serra et al., 2015). The European reintroduction project aims to overcome this diminishing effect of low-size migratory populations by capture and active reunion of separated juveniles with experienced conspecifics along the flyway (Fritz et al., 2016).

Previous release projects did not account for the migratory lifestyle of the species, probably due to a lack of knowledge about their biology. For example, from 1983 to 1986, groups of juvenile, subadult, and adult northern bald ibises were released in Israel, but all birds disappeared (Mendelssohn, 2007). In Birecik, Turkey, a formerly large migratory colony declined rapidly from the middle of the twentieth century. From 1977 onwards, wild birds were caught and enclosed to build up a breeding colony, and from 1981, offspring of this colony were released – 67 birds in total. However, the majority of them did not follow the remaining wild birds to the south. In 1989, the wild Birecik population went extinct (Akçakaya, 1990; Kumerloeve, 1978).

It is known for numerous populations of migratory species that they have shortened their migration routes or turned into residents in response to certain environmental conditions – in recent times, mainly due to climate change (Flack et al., 2016; Visser et al., 2009). The last remaining wild population of northern bald ibis at the Moroccan coast is now resident. It is likely that those birds changed from a former migratory lifestyle to a resident one due to changing ecological conditions favoring a year-round stay (Bowden et al., 2003; Fritz et al., 2017). Nonetheless, a substantial number of juveniles depart every year from their breeding area (Bowden et al., 2008; Oubrou, 2017). Sight reports indicate that at least some of them fly for larger distances as far as Western Sahara and Mauritania. This corresponds with data of juveniles from resident colonies leaving the breeding area during the fall migration period at various other sites, like Grünau in Austria (Kotrschal, 2001), Birecik in Turkey (Yeniyurt, 2016), and Andalusia in Spain (Muñoz & Ramírez, 2017; Oubrou, 2017).

NORTHERN BALD IBIS RESEARCH AND REINTRODUCTION PROJECTS IN EUROPE

The captive northern bald ibis zoo population prospers (Boehm & Pegoraro, 2011). A recent genetic study indicates good genetic variability with no signs of inbreeding (Wirtz et al., 2016, 2018). This insurance population forms an essential basis for research and reintroduction projects.

In the 1990s, Ellen Thaler from Alpenzoo Innsbruck and her team tested a new release method. They were aware of the strong social bonding between parents and their offspring in this species, and they recognized its importance for social learning and the formation of behavioral traditions (Fritz et al., 2000). To account for that, human foster parents raised chicks. After fledging, these human-imprinted birds were kept free-flying. Human imprinting simulated a family structure, which enabled the young birds to become familiar with their habitat and learn how to forage while they were protected by the human foster parents (Pegoraro & Thaler, 1994).

The experiences of the trial release by Thaler and her team formed the basis for an experimental release project that started in the late 1990s at the Konrad-Lorenz Research Station in Upper Austria. The aim of this project was the establishment of the first free-flying, resident northern bald ibis colony. After some initial drawbacks, the colony prospered. The current population consists of more than 50 individuals. They are free-flying and self-sustaining during spring and summer, but due to the location of the colony at the northern foothills of the Alps, they require food supply during fall and winter (Kotrschal, 2004).

In 2004, a second free-flying, resident northern bald ibis zoo colony was founded at the Rosegg Animal Park in Carinthia, Austria, based on the experiences from the projects at Alpenzoo and at the Konrad-Lorenz research station. The whole Rosegg colony, which currently consists of more than 60 birds, descended from 21 founder individuals and a few supplemented birds.

Furthermore, in 2004, the Proyecto Eremita project started in Andalusia, Spain, with substantial commitment of the Zoo Jerez, aiming to establish a self-sustaining resident colony. As in the Austrian projects, chicks are raised by human foster parents for building up a release population. Later on, they also supplemented parent-raised juvenile birds taken from European zoo colonies. Over the years, a total of 274 birds were released to build up a resident colony that currently consists of about 100 individuals. The Andalusian birds are self-sustaining year round and breed regularly in natural cliffs (López & Quevedo, 2016). The colony is resident and remains in the area, which offers suitable feedings sites year round. However, as is known from other resident colonies, a proportion of juveniles tend to leave the area during the fall migration period. This is particularly true of juveniles from zoo-breeding colonies, which were supplemented to the release colony at an age of four to six months. At the end of September 2016, ornithologists observed a group of 11 birds crossing the Strait of Gibraltar toward Morocco and again in November 2016 with a group of six birds (Muñoz & Ramírez, 2017; Seminario, 2017). Interestingly, during the breeding season in 2017, Moroccan ornithologists observed a group of 11–15 non-breeding birds on the Moroccan coast (Aourir et al., 2017). This could be a coincidence, but it seems probable that the Spanish juveniles wintered in this region close to the breeding site of the Moroccan colony. In the future, GPS tracking will help to clarify these spatiotemporal patterns.

PROJECT LIFE+ NORTHERN BALD IBIS

In 1997, when researchers at the Konrad-Lorenz research station in Upper Austria started establishing of a sedentary colony of northern bald ibises, they expected the released birds would simply stay there for the whole year if they were provided with food and had continued contact with their human foster parents. However, in fall, all birds left the region, flying hundreds of kilometers. The same happened in fall of the next year. Thus, it became clear that these juveniles migrated, but into different, arbitrary directions, and – in most cases – meeting death. Johannes Fritz and some colleagues wondered if it would be possible to teach these birds an appropriate migrating route by the use of microlight airplanes. They were inspired by the movie *Fly Away Home*, which was quite popular at that time. In the narrative, which is based on the true story of Bill Lishman, a young girl raised a group of Canada geese (*Branta canadensis*), trained them to follow a microlight, and finally led them across the United States to an appropriate wintering site.

In 2001, the Waldrappteam started an experimental project with the aim to train human-raised, juvenile northern bald ibises to follow a microlight. In a 12-year feasibility study, with lots of trial-and-error learning, methods and techniques were tested and improved. Until 2013, a total of seven so-called human-led migration journeys were performed, in which 95 birds in total were guided from two sites within the historic breeding range north of the Alps across the mountains to the WWF-protected area of Oasi Laguna di Orbetello in southern Tuscany. This region is a wintering site for various bird species, and during the feasibility study, it also proved to be a suitable site for the northern bald ibis. This was an important insight, because there is

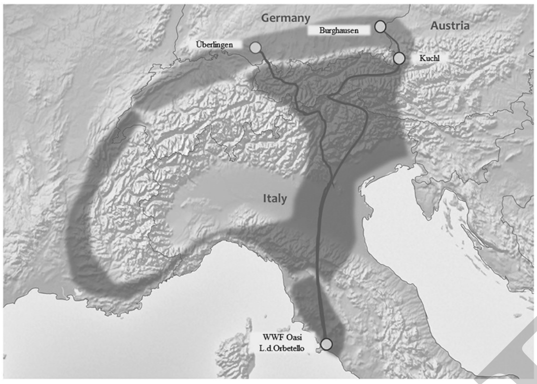

FIGURE 13.4 Range of the European migratory release population; breeding areas with three breeding sites north of the Alps, wintering area with the wintering site in the southern Tuscany, the gray shading in-between indicates the main, straight migration corridor as well as the secondary migration corridor around the Alpine arch; the two lines indicate the routes of the human-led migration flights.

no evidence for the specific wintering site of the former migrating European population of the northern bald ibis (Fritz & Unsöld, 2015).

In 2014, based on the experiences of the long-lasting feasibility study, the project turned into a European LIFE+ reintroduction project, co-financed by the European Union. Eight partners from Austria, Germany, and Italy aim for a sustainable reintroduction of a migratory northern bald ibis population in Europe. The implementation is based on the IUCN Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC, 2013). A steering committee, advised by international experts, supervises and monitors the implementation.

The major aim of the six-year project (2014–2019) is the establishment of three migratory breeding colonies, two of them in Germany (Burghausen, Bavaria, and Ueberlingen at Lake Constance, Baden-Wuerttemberg) and one in Austria (Kuchl, country of Salzburg). By the end of 2019, the population size should be at least 120 birds in total. All three breeding sites are linked with a common wintering site in southern Tuscany via a main migration corridor leading across the Alps (Figure 13.4).

FIGURE 13.5 The human foster mothers Anne-Gabriela Schmalstieg and Corinna Esterer (from left) surrounded by the human-imprinted juvenile birds; socially involved hand-rearing requires intense social interactions.
Photo: J. Fritz

HAND-REARING AND HUMAN-LED MIGRATION

The key method for the release of northern bald ibises into the wild and the establishment of a new migration tradition is imprinting of chicks to human foster parents and the human-led migration. We take the chicks from zoos with a maximal age of ten days to ensure optimal parental imprinting on the foster parents. The chicks are reared in natural nest groups with two to five individuals and an age difference of at least one day, so that species-specific nest ranking and sexual imprinting on their conspecifics are possible.

Foster parents are key people for the release (Figure 13.5). At the beginning of April, they take over the responsibility for the chicks. They live in a surreal parallel world in the middle of Europe for the next six months. They stay with their birds all day, from the early morning to the evening, with some breaks. Other people are not allowed to approach the birds, and in presence of the birds, the foster parents communicate only with one another or with the birds.

Two main hand-rearing methods are used in bird translocation projects. One approach, *minimal-interaction rearing*, aims to limit human interaction as much as possible. This is mainly achieved by various types of full-body coverage or replacing humans with feeding-dummies. This keeps the caregivers exchangeable and is mainly motivated by the intention of avoiding chicks' imprinting on humans (Hartup et al., 2005). This method works in various cases, but it could be termed a "semi-Kaspar Hauser" approach, in reference to a German youth who claimed to have grown up in the total isolation of a darkened cell. The chicks grow up either in social isolation or with same-age conspecifics, but without parents or an adequate alternative. The cognitive and behavioral consequences of the social deprivation during ontogeny in birds is largely unknown, but a wealth of comparative psychological literature exists reporting adverse effects in humans and other mammals. Nonetheless, this technique is used successfully for reintroductions of largely solitary-living species, like Californian condors (*Gymnogyps californianus*; Chapter 15, this volume), or for individuals that remain in captivity.

For social-living species, minimal-interaction rearing seems to be more problematic. In northern bald ibises, an experiment with different hand-rearing techniques indicated that social isolation during hand-rearing causes differences in distress calls and begging behavior, as well as an impaired social, physiological, and morphological development after fledging (Tintner & Kotrschal, 2002). In whooping cranes (*Grus americana*), the seemingly lower reproduction success of human-raised and released individuals compared to parent-raised conspecifics may be caused by the rearing method, using full-body coverage and a feeding dummy (Hartup et al., 2005; OperationMigration, 2016).

In our project, *socially involved hand-rearing* is practiced, where the human foster parents are not only allowed but encouraged to interact with their chicks physically and acoustically, aiming to form a close social bond. The method is based on the concept of imprinting as defined by Konrad Lorenz (Bolhuis, 1991; Lorenz, 1937). Filial imprinting means to irreversibly learn during a sensible ontogenetic period to recognize particular individuals – the parents or, in our case, the foster parents. Consequently, the imprinted individuals act and react differently to parents than to other humans. In our case, the human-imprinted birds have a very tight and trustful relationship to their foster parents, while they are suspicious of and distant with other people. This effect is usually persistent. A human-raised bird recognizes and approaches its foster parent even after months of absence, while the escape distance to other people is similar to that of parent-raised birds (Fritz et al., 2017; Unsöld & Fritz, 2016).

Socially involved hand-rearing is a methodical prerequisite for human-led migration. Only a well-imprinted bird with a strong, trustful social relationship with the foster parents is willing to reliably follow them during the flights. Immediately after fledging, the flight training starts. At a first stage, the birds must habituate to the microlight, the sound of the engine, and the huge parachute. Thereafter, the major challenge for the birds is to associate the microlight with the foster parent, who sits on the back seat. To facilitate this learning process, the foster parents are asked and exclusively allowed to wear yellow shirts around the birds. About one month after fledging, the first flights take place, from the campsite to meadows nearby. During the training, the flight distance is gradually increased to 70 km and even more.

About mid-August, the training is finalized and the human-led migration begins (Figure 13.6). At this time, the birds begin showing migratory restlessness (Zugunruhe). The body mass reaches a maximum and the level of corticosterone, as a major hormone for the regulation of bird migration, is increased (Bairlein et al., 2015; Fritz et al., 2016). At that time, the wild birds in the already established release population depart from their breeding areas of Burghausen and Kuchl.

From 2004 to 2017, 11 human-led migrations were carried out. During the initial migration journeys, the mean daily flight distances were about 60 km. At the beginning of the project, flights took place only in the morning to avoid thermals. Meanwhile, we substantially improved the method. The daily flights lead over distances of up to 360 km and last for up to eight hours. A differentiated understanding of the northern bald ibis behavior and improved flight techniques of the pilots allow the birds to be led during thermal periods of the day as well, during which the birds change from formation flight to soaring and gliding (Portugal et al., 2014; Sperger et al., 2017; Voelkl & Fritz, 2017). In addition, the number of birds raised and released per season

(a)

(b)

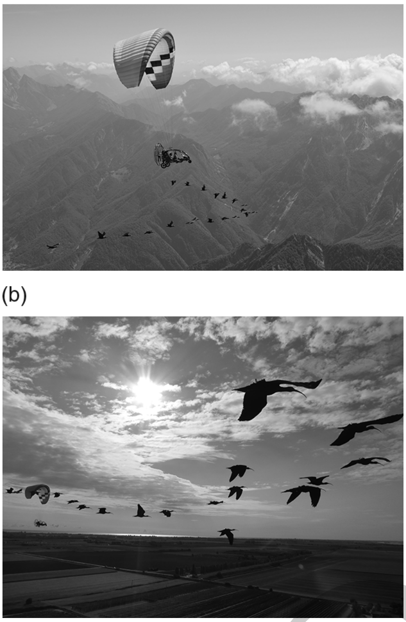

FIGURE 13.6 Human-led migration flight: (a) across the Karavanke mountain range on the border between Austria and Italy at a flight level of about 2,500 m above sea level – the birds show the characteristic V-shaped flight formation (photo: P. Przewang); (b) along the Italian Po Valley close to the Adriatic Sea – the picture was taken from one of the two identical microlight planes that lead the birds to the south.
Photo: A. G. Schmalstieg

has increased substantially. In the beginning, the groups consisted of about seven birds. Now, two professional foster parents raise groups of 30–32 birds per season.

Upon arrival at the wintering site, the birds remain in an aviary for some week. The foster parents gradually reduce their presence and finally leave, and local staff takes over the care and monitoring of the birds. After this habitation period, the aviary is opened, and the new generation of birds are released to integrate into the flock of conspecifics at the wintering site and become independent. Each bird only needs to follow the microlight to southern Tuscany once during the fall of their first year of life. This is sufficient for the birds in order to find their way back to the breeding sites in Austria and Germany.

STATUS AND PERSPECTIVE OF THE RELEASE PROJECT

As of November 2017, the wild population of migratory northern bald ibises in Central Europe comprises 101 individuals. About two-thirds of the population consist of individuals taken from zoos and released after the human-led migration (release birds; F0 generation). A third are individuals raised in the wild by their parents and guided to the wintering site by conspecifics (wild birds; F1+ generation). All birds have a common wintering area in southern Tuscany and belong to the three breeding areas Burghausen, Kuchl, and Überlingen. Since 2011, an increasing number of adult birds of the release population migrate annually to the breeding areas and raise chicks there. In fall, they return to the wintering site in the Tuscany with the juveniles following.

A proportion of 67 percent of the human- and parent-reared juveniles survive their first year of life (calculated for the generations 2008–2016). About 32 percent of the birds reach sexual maturity with an age of three years. These are comparatively good values. In the Spanish northern bald ibis reintroduction project, the survival rate of the released birds after the first year is around 45 percent. For wild populations of the white stork, the survival rate for the first year is published at around 35 percent (Flack et al., 2016). Despite a comparatively good survival rate, we lose up to 30 birds each year. The reduction of the rate of loss is a priority objective to ensure a steady growth of the population. The primary mortality causes are electrocution on unprotected, medium-voltage electricity pylons (~25 percent), followed by illegal hunting in Italy (~14 percent). For about 42 percent of lost birds, the cause of death is unknown; the birds simply disappear, especially during migration flights (Fritz et al., 2017). We assume that electrocution and bird hunting are the predominant causes of losses in these cases as well.

The share of losses due to bird hunting was substantially higher in the period of the feasibility study (2002–2013) – up to more than 70 percent (Fritz & Unsöld, 2015). Extensive measures since the beginning of the LIFE+ project are gradually taking effect. Thanks to a wide range of information campaigns and extensive media coverage, the reintroduction of the northern bald ibis has become one of the most well-known and popular biodiversity conservation projects in

Italy, and it is by now also well known among bird hunters. A very significant success was the prosecution of a hunter who shot two northern bald ibises in the region of Livorno, Tuscany. In 2016, he was convicted for a penalty and the loss of his hunting license. He appealed, but in 2017, the Supreme Court confirmed the verdict. This has created a very important precedent in the fight against this form of environmental crime, indicating that poaching of endangered species is not a trivial offense.

Measures against electrocution were not planned per se in the current LIFE+ project; however, budget redeployments allowed us to finance a pilot project in cooperation with the Salzburg electricity grid operator, Salzburg Netz GmbH, to secure a substantial part of the dangerous electricity pylons at the breeding site in Salzburg. The protection measures mainly consist of the installation of bird protection coverages on the pylons, which prevent birds sitting on a pylon from contacting the power line.

The currently ongoing LIFE+ project runs until the end of 2019. Projections suggest that we will reach the major objective of establishing a European migratory northern bald ibis population with at least 120 individuals. However, this is really a milestone rather than a final objective. A population of this size is far from being self-sustaining. In cooperation with the Leibnitz Institute in Berlin, we are currently defining the so-called minimum viable population size (MVP); according to current estimates, it will be between 300 and 400 individuals. Exceeding the MVP is not possible within a period of six years, neither for the northern bald ibis nor for other species.

Waldrappteam are preparing for a follow-up project from 2020 to 2027, with the primary objective of reaching or exceeding the MVP. This is quite an ambitious goal. It shall be achieved through a comprehensive package of measures, including the continuous growth of existing breeding colonies and the foundation of further breeding colonies in Switzerland and south of the Alps in Carinthia, Austria.

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FLAGSHIP CAMPAIGNS

As an addition to the reintroduction, we aim to continue and extend our campaigns against the two major mortality causes – illegal bird hunting and electrocution on medium-voltage electricity pylons. It can be assumed that illegal bird hunting and electrocution also significantly affect the populations of numerous other bird species. Illegal bird hunting is primarily a threat to migratory bird species, while electrocution affects large birds in particular, whether migratory or sedentary. Thus, our campaigns concern priority actions that are in line with European biodiversity objectives, in particular the Birds Directives (Directive 2009/147/ EC) and the relevant national framework laws. The northern bald ibis is used in this context as a suitable flagship species in order to reach overall aims (Walpole & Leader-Williams, 2002).

The entire release population is equipped with GPS transmitters. This whole-population monitoring allows us to calculate the losses in relation to the total population size. Such "hard facts" are an essential basis for communicating the relevance of measures against illegal hunting to all stakeholders. The performance of commercial GPS transmitters has been steadily improving, allowing for ever-denser monitoring with numerous positions per day. In addition, so-called "geofencing" allows for automatic alerting and changes to a higher frequency of GPS position transmission when a bird flies into an area with particularly intense (illegal) hunting.

For the follow-up project, we also plan to develop and install a so-called "instant alert system." For this purpose, a specific type of GPS device has to be developed, with an additional function called a "dead body indicator." This uses a specific sensor technology to detect when a bird is shot, and at this occasion it transmits the actual position in real time. Specific information processing should ensure that within a maximum of 90 minutes, a member of a volunteer network along the migration route can reach the location concerned, securing evidence and initiating police investigations. Ultimately, the instant alert system should contribute to a significantly higher success rate in identifying offenders.

A particular value of the northern bald ibis as a flagship species is the possibility of implementing real monetary damage in case of an accident due to the reintroduction project. Explicit damage claims prevent the prosecutor from closing a reported case quickly, instead instructing appropriate criminal investigations. The monetary damage also offers the opportunity for civil lawsuits. This is accompanied by a high potential for deterrence, since the estimated monetary damage per bird amounts to up to €75,000.

BASIC SCIENCE ON BIRD FLIGHT AND BIRD MIGRATION

For over a century, ringing birds with small, metal bands has been the predominant method for studying bird migration. Kicked off by the Danish school teacher Hans Christian Mortensen in 1899, the banding scheme became possibly the largest coordinated research endeavor ever conducted. Over the course of more than 100 years, thousands of bird ringers – some being professional researchers, but most being amateur volunteers – have fitted about 200 million birds with rings with individual identification numbers (Birkhead et al., 2014). Recaptures of ringed birds and ring recoveries from bird carcasses allow certain inferences to be made about dispersal and migration patterns, but despite this massive effort, information gained from the ringing scheme is rather coarse-grained. Most birds ringed are never found again, and only a small proportion of ringed birds are resighted more than once. Ringing therefore tells us where birds migrate or disperse, but we do not learn much about how they travel or what they do on their way.

The miniaturization of electronic devices and advances in satellite technology have opened up completely new opportunities for studying migrating birds. In 1984, a bald eagle became the first bird to be successfully fitted with a satellite transmitter for tracking its position over a period of eight months. With a mass of 170 g, this first generation of transmitters could only be fitted to the largest birds and, using the Advanced Research and Global Observation Satellite (AGROS) animal tracking application system, the spatial resolution was still limited to approximately 1 km. Satellite transmitters were soon replaced by much lighter global navigation satellite system (GNSS) receivers mainly using the GPS satellite system. GPS receivers have a much higher spatial accuracy (±2.5 m) and, because of their low weight, they can be fitted to most birds. Using post-processing to correct for systematic error, locations can be pinpointed to within 2.5 cm. Modern GPS receivers are often complemented by a tiny inertial measurement unit (IMU). An IMU consists of a set of accelerometers, gyroscopes, and sometimes also magnetometers for detecting the acceleration, rotation, and spatial orientation of the bird.

Over the past years, Waldrappteam has used a variety of different GPS units with different specifications. Trackers are GPS units that receive GPS signals, calculate the position of the bird, and transmit this information via the Global System for Mobile Communications (GSM) network. Sending data requires power, and as power is limited by battery size and battery size is limited by weight constraints, this means that the number of positional fixes that can be transmitted via GSM is rather limited. Fitting small solar panels to the GPS unit allows operating times of several months, though transmission is still limited to a few positional fixes per day. Since 2014, Waldrappteam has been fitting birds with GPS trackers before permanently releasing them in their wintering area. The monitoring of the released birds is an important pillar of the conservation effort, but it also delivers valuable scientific data for understanding large-scale movement patterns of migrating birds. Perhaps most surprising for us were the big individual differences that we found between birds. While one bird was observed crossing the Austrian Alps close to their highest peak (the Grossglockner, at 3798 m), others made at the same time an over 1000-km detour, circumscribing the Alps by flying from southern Germany all the way to Cannes before turning eastward and following the Ligurian coast down to their wintering area.

During the human-led migration, the human foster parents still have close contact with the animals, allowing them to fit birds with GPS devices directly before the start of each migratory leg and retrieving the devices afterwards. In 2011, 2014, and 2017, birds were fitted with a different type of GPS device during the southbound migration: data loggers that store positional data internally. The data can only be read out after retrieving the devices – something that can be done during the human-led migration, but otherwise is rarely possible. As loggers do not send data and as batteries can be recharged after every migratory leg, this allows recording and storing of positional data at much higher rates – up to 50,000 positional fixes for a flight of four hours, thus revealing fine details of the birds' flight behavior. The fine-scale positional data have allowed us to study aspects of formation flight during migration.

Like geese, cranes, and other larger bird species, northern bald ibises form echelons and V-shaped formations. The question of why birds do this is still not completely resolved. The generally accepted explanation is that flying in such a formations helps the birds save energy by utilizing the updraft produced by the preceding bird. Yet, while this explanation sounds very plausible, there are to date no empirical data actually proving that assertion or showing how much energy birds can save this way. Measuring energy consumption during free flight is technically very difficult, but the data collected during the human-led migration helped us get closer to an answer. The acceleration data from the IMUs could be used to identify the wingbeats of the animals and to show that birds synchronize their wingbeats in the way expected for maximizing energy savings (Portugal et al., 2014).

Furthermore, we could see how the birds coordinate in order to maintain these formations. In a formation, each bird can profit from the updraft produced by the preceding bird – except the first bird, which has to work harder. How do the birds solve this cooperation problem? Positional data recorded at one-second intervals allowed us to observe that birds regularly swap positions, so that each bird contributes to the extra effort of leading (Voelkl et al., 2015; Voelkl & Fritz, 2017). Unlike cyclists riding in pace lines, the ibises do not rotate position in the way that the leader falls back after a while and rejoins the formation at the rear position, but birds frequently swap position with their next neighbor: number one is swapping position with number two, number four with number five, etc. This system of immediate turn-taking is called direct reciprocation and seems to be a very good strategy to prevent single individuals from "cheating" by contributing less to the leading effort than others.

Finally, the fine-grained GPS data also allowed us to look into another aspect of flight strategies during migration: the alternation between phases of straight flight powered by active wing flapping and phases of passive soaring–gliding flight, where birds glide on the outstretched wing, using thermal updrafts or deflected winds to gain height (Sperger et al., 2017).

At the end of each migratory leg of the human-led migration, the birds are housed in a spacious (9×12 m) mobile aviary until the migration commences. This is done in order to protect the birds from predators, but also to ensure that the birds do not fly off on their own before reaching the targeted wintering area. At the same time, this temporary confinement allows researchers to make close-up behavioral observations and to take physiological measurements. Behavioral screens of aggressive encounters and socio-positive interactions allow the determination of the rank order and the social network of the animals and to study whether social relationships change over the course of the migration. Bodyweight is measured daily and foster parents keep a detailed record of individual food intake; blood samples are taken at the start and at the end of the migration as part of routine veterinary monitoring. During the human-led migration in 2008, birds received additional injections of doubly labeled water and additional blood samples were taken before and after each flight in order to study metabolic changes during migration flights (Bairlein et al., 2015).

Again, such a study design was only possible because researchers and birds made the journey together and because the foster parents could easily handle the birds due to the strong social bond between foster parent and bird.

CONCLUSION

"Reason for hope" is the motto of our project. From a current perspective, this motto is well founded. There are concrete prospects that the survival of the northern bald ibis can be sustainably secured in the wild. Given the United Nations estimate that 100–200 plant and animal species disappear daily, our endeavor may seem like the proverbial drop in the ocean. But, in fact, it is much more than that. In a survey recently conducted at Zoo Vienna, the northern bald ibis was the second most popular species after the giant panda, for which the zoo is known. The fate of this charismatic bird is able to touch people, engage their interest, and inspire the protection of species. This is, in addition to all immanent objectives and outputs, a value in itself. In addition, the enthusiasm and idealism common to so many people in our team can generally provide a positive perspective for our future. And this seems to us to be of high societal value today – a shared value and responsibility of zoos, conservationists, and their supporters.

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REFERENCES

Akçakaya, H. R. (1990). Bald ibis *Geronticus eremita* population in Turkey: An evaluation of the captive breeding project for reintroduction. *Biological Conservation*, *51*(3), 225–237.

Aourir, M., Bousadik, H., El Bekkay, M., Oubrou, W., Znari, M., & Qninba, A. (2017). New breeding sites of the critically endangered northern bald ibis *Geronticus eremita* on the Moroccan Atlantic coast. *International Journal of Avian & Wildlife Biology*, *2*(3), 1–4.

Bairlein, F., Fritz, J., Scope, A., Schwendenwein, I., Stanclova, G., Van Dijk, G., … Dittami, J. (2015). Energy expenditure and metabolic changes of free-flying migrating northern bald ibis. *PLoS ONE*, *10*(9), e0134433.

Birkhead, T., Wimpenny, J., & Montgomerie, B. (2014). *Ten Thousand Birds: Ornithology since Darwin*. Princeton, NJ: Princeton University Press.

Boehm, C. & Pegoraro, K. (2011). *Der Waldrapp: Geronticus eremita – Ein Glatzkopf in Turbulenzen*. Magdeburg: VerlagsKG Wolf.

Bolhuis, J. J. (1991). Mechanisms of avian imprinting: A review. *Biological Reviews*, *66*, 303–345.

Bowden, C. G. R., Aghnaj, A., Smith, K. W., & Ribi, M. (2003). The status and recent breeding performance of the critically endangered northern bald ibis Geronticus eremita population on the Atlantic coast of Morocco. *Ibis*, *145*(3), 419–431.

Bowden, C. G. R., Smith, K. W., Bekkay, M. El, Oubrou, W., Aghnaj, A., & Jimenez-Armesto, M. (2008). Contribution of research to conservation action for the northern bald ibis *Geronticus eremita* in Morocco. *Bird Conservation International*, *18*, 74–90.

Chernetsov, N., Berthold, P., & Querner, U. (2004). Migratory orientation of first-year white storks (*Ciconia ciconia*): Inherited information and social interactions. *Journal of Experimental Biology*, *207*(6), 937–943.

Flack, A., Fiedler, W., Blas, J., Pokrovsky, I., Kaatz, M., Mitropolsky, M., … Wikelski, M. (2016). Costs of migratory decisions: A comparison across eight white stork populations. *Science Advances*, *2*(1), e1500931.

Fritz, J., Bisenberger, A., & Kotrschal, K. (2000). Stimulus enhancement in greylag geese: Socially mediated learning of an operant task. *Animal Behaviour*, *59*(6), 1119–1125.

Fritz, J., Feurle, A., & Kotrschal, K. (2016). Physiological regulation of bird migration: A study with northern bald ibises undergoing human-led autumnal migration. *Journal of Ornithology*, *147*(5), 168.

Fritz, J., Hoffmann, W., & Unsöld, M. (2016). Back into European ecosystems: The LIFE+ northern bald ibis reintroduction project in Central Europe. In C. Böhm & C. Bowden (Eds.), *Report of 4th IAGNBI Meeting Seekirchen* (pp. 47–56). Innsbruck: Alpenzoo.

Fritz, J., Kramer, R., Hoffmann, W., Trobe, D., & Unsöld, M. (2017). Back into the wild: establishing a migratory northern bald ibis *Geronticus eremita* population in Europe. *International Zoo Yearbook*, *51*(1), 107–123.

Fritz, J. & Riedler, B. (2010). Neue Hoffnung für das Überleben einer hoch bedrohtesten Zugvogelart im Mittleren Osten: Freisetzung von Jungvögeln bei den letzten migrierenden Waldrappen in Syrien. *Vogelwarte*, *48*, 417–418.

Fritz, J. & Unsöld, M. (2015). Internationaler Artenschutz im Kontext der IUCN Reintroduction Guidelines: Argumente zur Wiederansiedlung des Waldrapps Geronticus Eremita in Europa. *Vogelwarte*, *53*(2), 157–168.

Gessner, C. (1557). *Historiae Animalium Liber III, Qui Est de Avium Natura; Erste Deutsche Übersetzung*. Zurich: Christoffel Froschouer.

Hancock, J. A., Kushlan, J. A., & Kahl, M. P. (1992). *Storks, Ibises and Spoonbills of the World*. London & San Diego, CA: Academic Press.

Hartup, B. K., Olsen, G. H., & Czekala, N. M. (2005). Fecal corticoid monitoring in whooping cranes (*Grus americana*) undergoing reintroduction. *Zoo Biology*, *24*(1), 15–28.

IUCN/SSC (2013). Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Ecologial Applications. Retrieved from https://portals.iucn.org/library/efiles/documents/2013-009.pdf.

Janak, J. (2011). Spotting the akh. The presence of the northern bald ibis in Ancient Egypt and its early decline. *Journal of the American Research Centre in Egypt*, *46*, 17–32.

Kotrschal, K. (2001). The Grünau project is in its 5th year: How to establish a Waldrapp Geronticus eremita colony from scratch. In C. Böhm & C. Bowden (Eds.), *Proceedings of the International Advisory Group for the Northern Bald Ibis (IAGNBI): Newsletter 2001*. Innsbruck: Alpenzoo.

Kotrschal, K. (2004). The Grünau Project: Establishing a semi-wild colony of Waldrapp Ibis. *WAZA Magazine*, *5*, 12–15.

Kumerloeve, H. (1978). Waldrapp, *Gerontocus eremita* (LINNAEUS 1758) und Glattnackenrapp, *Geronticus calvus* (BODDAERT 1783): Zur Geschichte ihrer Erforschung und zur gegenwärtigen Bestandssituation. *Annalen des Naturhistorischen Museums in Wien*, *81*, 319–349.

Lindsell, J. A., Serra, G., Peške, L., Abdullah, M. S., Al Qaim, G., Kanani, A., & Wondafrash, M. (2009). Satellite tracking reveals the migration route and wintering area of the Middle East population of critically endangered northern bald ibis *Geronticus eremita*. *Oryx*, *43*(3), 329–335.

López, J. M. & Quevedo, M. A. (2016). Northern bald ibis reintroduction program in Andalusia. In C. Böhm & C. Bowden (Eds.), *Proceedings of 4th International Advisory Group for the Northern Bald Ibis (IAGNBI) Meeting Seekirchen, Austria* (pp. 57–67). Innsbruck: Alpenzoo.

Lorenz, K. Z. (1937). The companion in the bird's world. *The Auk*, *54*(3), 245–273.

Mendelssohn, H. (2007). Experimental releases of Waldrapp ibis *Geronticus eremita*: An unsuccessful trial. *International Zoo Yearbook*, *33*(1), 79–85.

Muñoz, A.-R. & Ramírez, J. (2017). Reintroduced northern bald ibises from Spain reach Morocco. *Oryx*, *51*(2), 204–205.

OperationMigration (2016). End of ultralight-guided migration. Retrieved from http://operationmigration.org/InTheField/2016/01/23/end-of-ultralight-guided-migration.

Oubrou, W. (2017). Northern Bald Ibis breeding expansion : two new sites found in Morocco. *MaghrebOrnitho* (December). Retrieved from www.magornitho.org/2017/12/northern-bald-ibis-breeding-expansion.

Pegoraro, K. & Thaler, E. (1994). Introduction of Waldrapp ibis on the basis of family bonding: A successful pilot study. *International Zoo Yearbook*, *33*, 74–79.

Portugal, S. J., Hubel, T. Y., Fritz, J., Heese, S., Trobe, D., Voelkl, B., . . . Usherwood, J. R. (2014). Upwash exploitation and downwash avoidance by flap phasing in ibis formation flight. *Nature*, *505*(7483), 399–402.

Schenker, A. (1977). Das ehemalige Verbreitungsgebiet des Waldrapps *Geronticus eremita* in Europa. *Der Ornithologische Beobachter*, *74*, 13–30.

Schenker, A. (2017). Replik zum Beitrag von Armin Landmann betreffend den Waldrapp *Geronticus eremita*. *Vogelwarte*, *55*(2), 129–138.

Seminario, Y. (2017). Migration of the reintroduced bald ibises from Spain to Morocco. *MaghrebOrnitho*, November. Retrieved from www.magornitho.org/2016/11/migration-reintroduced-bald-ibis.

Serra, G. (2015). The northern bald ibis is extinct in the Middle East – But we can't blame it on IS. *Ecologist* (May). Retrieved from https://theecologist.org/2015/may/29/northern-bald-ibis-extinct-middle-east-we-cant-blame-it.

Serra, G. (2017). *The last flight of the ancient guide of Hajj*. Self-published. Apia, Samoa. Retrieved from www.thelastflight.org.

Serra, G., Abdallah, M. S., Assaed, A., Abdallah, A., Al Qaim, G., Fayad, T., & Willliamson, D. (2004). Discovery of a relict breeding colony of northern bald ibis *Geronticus eremita* in Syria. *Oryx*, *38*(2), 1–7.

Serra, G., Bruschini, C., Peske, L., Kubsa, A., Wondafrash, M., & Lindsell, J. A. (2013). An assessment of ecological conditions and threats at the Ethiopian wintering site of the last known eastern colony of critically endangered northern bald ibis *Geronticus eremita*. *Bird Conservation International*, *23*(4), 399–413.

Serra, G., Lindsell, J. A., Peske, L., Fritz, J., Bowden, C. G. R., Bruschini, C., . . . Wondafrash, M. (2015). Accounting for the low survival of the critically endangered northern bald ibis *Geronticus eremita* on a major migratory flyway. *Oryx*, *49*(2), 312–320.

Serra, G., Peske, L., Abdallah, M. S., Al Qaim, G., & Kanani, A. (2009). Breeding ecology and behaviour of the last wild oriental northern bald ibises (*Geronticus eremita*) in Syria. *Journal of Ornithology*, *150*(4), 769–782.

Shephard, J. M., Rycken, S., Almalik, O., Struyf, K., & Erp van der Kooij, L. (2015). Migration strategies revealed by satellite tracking among descendants of a population of European white stork (*Ciconia ciconia*) reintroduced to Belgium. *Journal of Ornithology*, *156*(4), 943–953.

Sikli, L., Oubrou, O., & El Bekkay, M. (2016). Morocco wild population update. In In C. Böhm & C. Bowden (Eds.), *Proceedings of 4th International Advisory Group for the Northern Bald Ibis (IAGNBI) Meeting Seekirchen, Austria* (pp. 29–30). Innsbruck: Alpenzoo

Sperger, C., Heller, A., Voelkl, B., & Fritz, J. (2017). Flight strategies of migrating northern bald ibises – Analysis of GPS data during human-led migration flights. *AGIT ⊠ Journal Für Angewandte Geoinformatik*, *3*, 62–72.

Tintner, A. & Kotrschal, K. (2002). Early social influence on nestling development in Waldrapp ibis (*Geronticus eremita*). *Zoo Biology*, *21*(5), 467–480.

Unsöld, M. & Fritz, J. (2011). Der Waldrapp-ein Vogel zwischen Ausrottung und Wiederkehr. *Wildbiologie*, *2*, 1–16.

Unsöld, M. & Fritz, J. (2016). Artenschutzprojekt Waldrappteam: Potenzial und Risiken von Prägung als Methode für den Artenschutz. *Vogelwarte*, *54*, 365–366.

Visser, M. E., Perdeck, A. C., van Balen, J. H., & Both, C. (2009). Climate change leads to decreasing bird migration distances. *Global Change Biology*, *15*(8), 1859–1865.

Voelkl, B. & Fritz, J. (2017). Relation between travel strategy and social organization of migrating birds with special consideration of formation flight in the northern bald ibis. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *372*(1727), 20160235.

Voelkl, B., Portugal, S. J., Unsöld, M., Usherwood, J. R., Wilson, A. M., & Fritz, J. (2015). Matching times of leading and following suggest cooperation through direct reciprocity during V-formation flight in ibis. *Proceedings of the National Academy of Sciences*, *112*(7), 2115–2120.

Walpole, M. & Leader-Williams, N. (2002). Tourism and flagship species in conservation. *Biodiversity and Conservation*, *11*, 543–547.

Wirtz, S., Boehm, C., Fritz, J., Hankeln, T., & Hochkirch, A. (2016). Isolation of microsatellite loci by next-generation sequencing of the critically endangered northern bald ibis, *Geronticus eremita*. *Journal of Heredity Advance*, *107*(4), 363–366.

Wirtz, S., Boehm, C., Fritz, J., Kotrschal, K., Veith, M., & Hochkirch, A. (2018). Optimizing the genetic management of reintroduction projects: Genetic population structure of the captive northern bald ibis population. *Conservation Genetics*, *19*(4), 853–864.

Yeniyurt, C. (2016). Conservation of the northern baid Ibis, Birecik, Turkey 2013–2016. In C. Böhm & C. Bowden (Eds.), *Proceedings of 4th International Advisory Group for the Northern Bald Ibis (IAGNBI) Meeting Seekirchen, Austria* (pp. 34–39), Innsbruck: Alpenzoo.

Yeniyurt, C., Oppel, S., Isfendiyaroglu, S., Özkinaci, G., Erkol, I. L., & Bowden, C. G. R. (2016). Influence of feeding ecology on breeding success of a semi-wild population of the critically endangered northern bald ibis *Geronticus eremita* in southern Turkey. *Bird Conservation International*, *27*(4), 537–549.