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EAZA Best Practice Guideline

for the

Socorro dove (*Zenaida graysoni*)

1st Ed., December 2024

EAZA ex situ programme (EEP)
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Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the “Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria”. These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Summary

The Socorro dove is currently one out of only five species of bird registered by the International Union for the Conservation of Nature (IUCN) global Redlist in the category Extinct in the Wild (EW). The species origin is the Mexican island of Socorro in the Eastern Pacific Ocean where it became extinct due to human activities in the early 1970s.

Fortunately, scientific expeditions brought a number of Socorro doves to the American mainland in the 1920s, and the species was subsequently held and bred in the aviaries of private pigeon and dove breeders. When, in the 1980s, it became clear that the species could not be found on Socorro Island anymore, scientists and conservationists started a dual course conservation project, subsequently called the Socorro Dove Project, with both *in situ* and *ex situ* activities.

Zoos in Germany started what has become an official EEP with EAZA in 1995 to save the species from final extinction. In close cooperation with conservationists in Mexico and the US, the conservation breeding programme set out to maintain and increase a sustainable population in human care with the aim to provide birds to be returned to their home island.

Socorro dove husbandry techniques had been used for decades by private breeders, but were not available as published information and needed to be adapted to the zoo setting. The species is not over-complicated in its husbandry requirements, although a number of specific aspects need to be considered for a successful maintenance. Feeding is similar to many related species and can be achieved with a variety of seeds, some greens and fruits (berries) and, especially during reproduction, animal protein (insects etc.). Of special importance is the necessity to provide dense cover in the aviaries to mitigate or avoid intraspecific aggression which has been repeatedly observed and may lead to injury or (even) death of the subordinate (usually female or offspring) individual. Ideally, Socorro doves are being held in pairs (of same or similar age), but groups of young birds or of a single-sex have also been held successfully, at least temporarily. The species prefers to breed in trees, preferably with a high degree of cover for security, but, in a few cases, nests have also been found on the ground. Although, in human care, hatches have been reported throughout the year, reproduction is more prevalent in the warmer months, which may reflect, at least in part, management practice and not necessarily biological needs. Good pairs may produce several clutches of, usually, one to three eggs and can, in exceptional cases, rear up to ten offspring per year. On the other hand, nests or even dependent offspring are being abandoned by the breeding pair at various stages of the breeding cycle to start over with nest building and/or laying, so that reproduction fails.

Although the number of participating institutions has steadily increased to more than three dozen over the years, the main challenge for successful development, i.e. the growth to a sustainable population size, of the EEP population has been, and still is, the lack of available aviaries. Therefore, institutions prepared to take the role of a Species Champion, by providing several aviaries for breeding pairs, are high on the agenda for this EEP.

Acknowledgements

These Best Practice Guidelines are based on the preliminary “Husbandry Guidelines for the Socorro dove”, by the author, as well as the “Socorro dove Husbandry Manual”, by Peter Shannon, former Curator of Birds, at the Albuquerque Biological Park, in 2017. A number of colleagues (Sara Jalali, Sabrina Linn, Jennifer Gübert, all Frankfurt Zoo) have helped at various stages of the draft and with the production of the final document. Special thanks go to Simon Rohner (Frankfurt Zoo), who transferred earlier versions into the EAZA BPG format and gave valuable input. Finally, I should like to express my warmest gratitude to the EAZA Pigeon & Dove TAG (Duncan Bolton, Nigel Simpson, Gary Ward) for support and friendship over the years, and the Socorro dove EEP participants and Species Committee members for their commitment to save the species from final extinction.

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Contents

Biology and Field Data

Biology

1.1. Taxonomy

This document follows the taxonomic classification of del Hoyo (2014):

Order	Columbiformes
Family	Columbidae
Subfamily	Columbinae
Tribe	Zenaidini
Genus	*Zenaida*
Species	*Zenaida graysoni*
Common Name(s)	Socorro dove, Grayson's dove

Taxonomic notes: *Zenaida graysoni* Lawrence, 1871

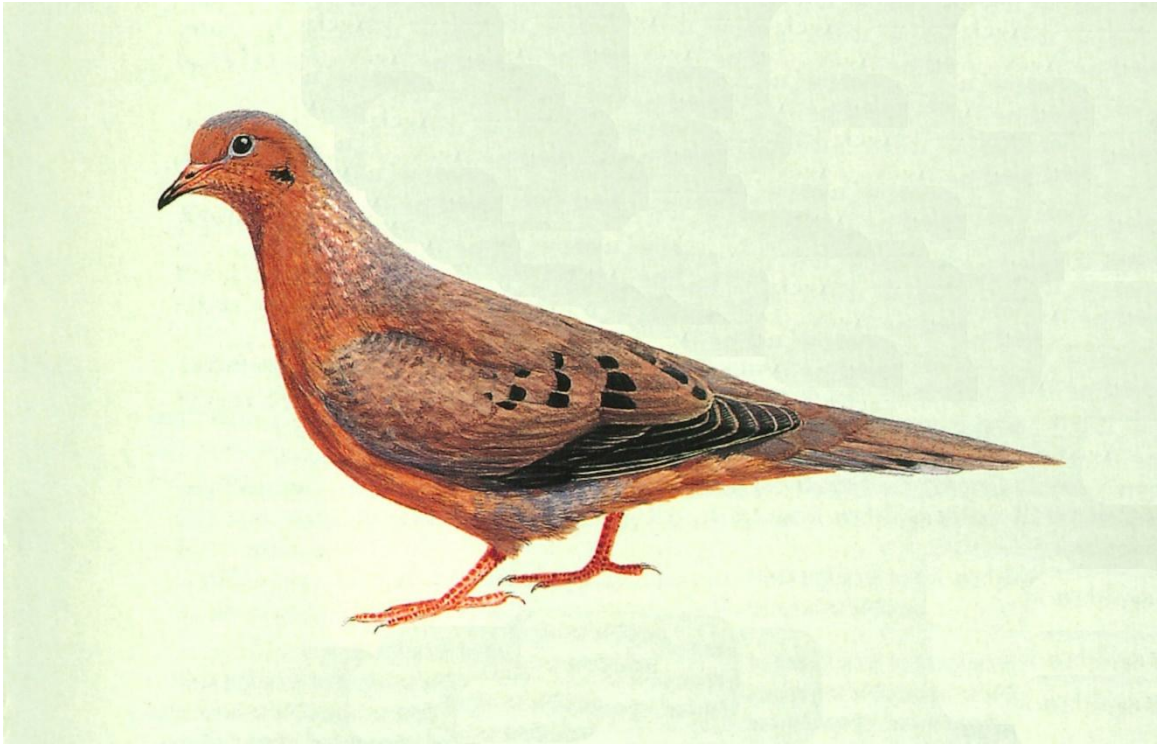

Fig. 1) Socorro dove (adapted from Handbook of the Birds of the World, Vol. 4, Plate 10, M. Elliott)

The Socorro dove was first described in 1871 by Lawrence, who gave it the scientific name "*Zenaidura graysoni*", in honour of American naturalist Andrew Jackson Grayson, who was the first to describe the species after his visit to Socorro Island in 1867. In the following years, there were different classifications of the Socorro dove. While part of the genus *Zenaidura*, both the Eared dove (*Zenaida auriculata*) and the Mourning dove (*Zenaida macroura*), were regarded as their closest relatives (del Hoyo, 2014). For many years, the species was even regarded as a subspecies (*Zenaida macroura graysoni*) of the Mourning dove, but intensive studies by Luis Baptista (Baptista et al., 1983) on

morphology, behaviour, vocalizations, and immunology justified classification as a full species. The species is monotypic.

1.2. Morphology

All morphometric measurements were derived from birds in human care.

Mean body size: 26.5 – 34.0 cm (del Hoyo, 2014)

Mean body weight: 165 – 215 g (del Hoyo, 2014).

Records from ZIMS (Species 360) indicate that body weights measured in zoos range between 150 and 200 g (n = 324), see Fig. 2.

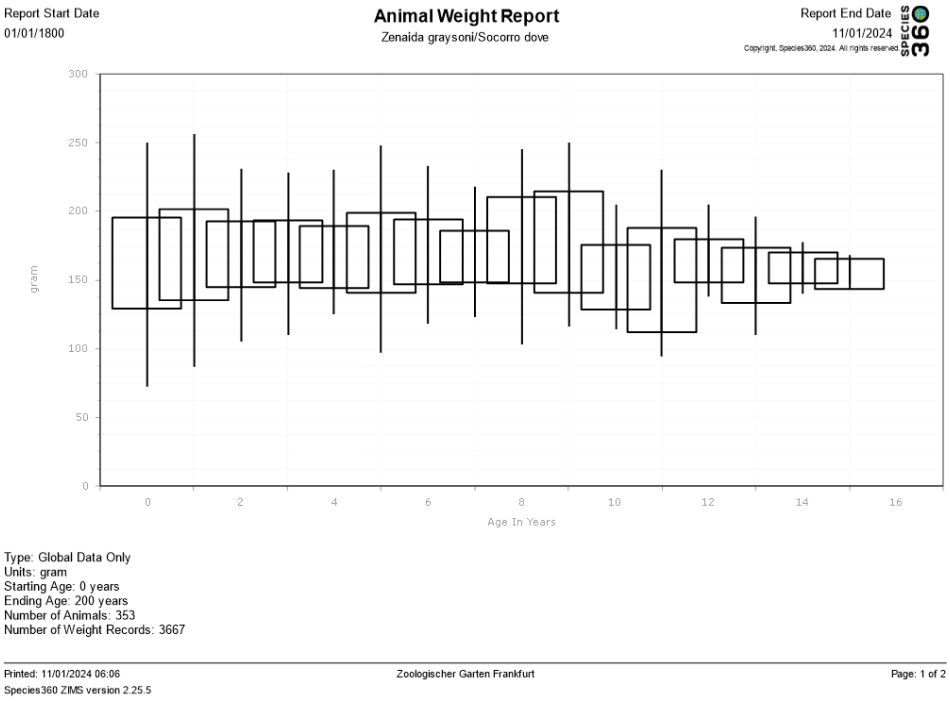

Fig. 2: Animal weight report from ZIMS for the Socorro dove (Species 360, accessed online 11 Jan 2024).

Additional morphological parameters (from Baptista et al., 1983) are listed in Table 1.

Table 1: Morphological characters of *Zenaida graysoni* (SD = Standard Deviation). Sexes are pooled (Baptista et al., 1983)

Character	Mean [mm]	SD	n
Wing length	153	5.7	22
Length of rectrix 1	129	9.7	21
Length of rectrix 2	124	10.1	21
Length of rectrix 7	83	6.7	19
Difference between 1st and 2nd longest rectrices	6	3.5	21
Width of rectrix seven at widest point	17	1.4	21
Length of longest undertail covert	64	7.9	22
Distance from tip of longest undertail covert to tip of longest rectrix	65	6.4	21
Chord of exposed culmen	16.3	0.8	22
Bill length from edge of nostril to tip of culmen	11.9	0.52	22
Culmen width from base of exposed culmen	4.9	0.49	22
Tarsus length	28.2	0.9	22

Colouration

To the inexperienced observer, male and female Socorro doves (see Fig. 3) seem to look similar (del Hoyo, 2014). The head and underparts are of deep cinnamon, while the upperparts are darker brown. The scapulars, tertials and inner wing-coverts are boldly spotted black and they have a black streak on lower ear-coverts. Socorro doves have pinkish legs and a dark grey bill with a reddish-pink base. The males have pink neck-side patches as well as a blue-grey nape, which are both smaller in females. In addition, the female colouration is slightly duller in general (del Hoyo, 2014).

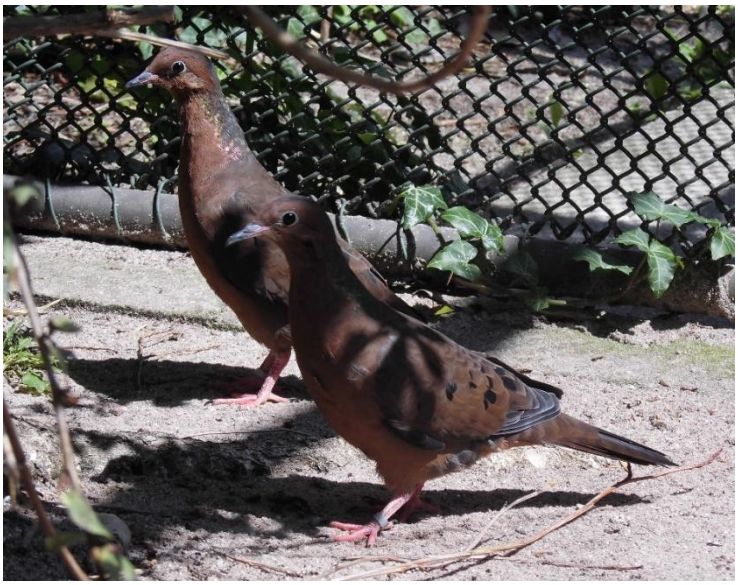

Fig. 3: Male (left) and female (right) Socorro dove (*Zenaida graysoni*) at Frankfurt Zoo.

Description

According to its size, the Socorro dove counts as a medium-sized dove (del Hoyo, 2014). The Socorro dove looks similar to its closest relative, the Mourning dove (*Z. macroura*). However, the Socorro dove is larger and slightly darker and has a longer bill. Moreover, relatively long legs compared to the Mourning dove indicate its adaptation to ground living which has, most likely, developed during the species' evolution on Socorro Island and is assumed to be due to the lack of ground predators there. In addition, there is a clear distinction between the Socorro dove and its closest relative in the shape of the tail feathers; also, the undertail coverts of the Socorro dove are brown while the Mourning dove has fawnish-white undertail coverts (Baptista et al, 1983; Fig 4). Besides these morphological differences, both species can be distinguished by their visual displays and vocalizations (del Hoyo, 2014; Baptista et al., 1983).

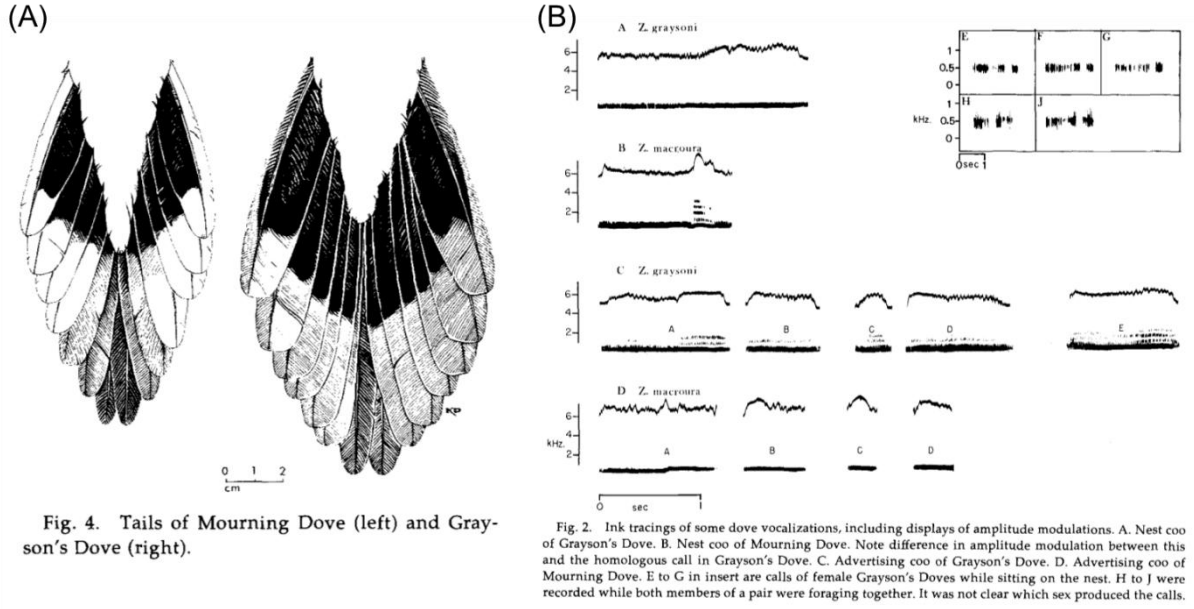

Fig. 4. Tails of Mourning Dove (left) and Grayson's Dove (right).

Fig. 2. Ink tracings of some dove vocalizations, including displays of amplitude modulations. A. Nest coo of Grayson's Dove. B. Nest coo of Mourning Dove. Note difference in amplitude modulation between this and the homologous call in Grayson's Dove. C. Advertising coo of Grayson's Dove. D. Advertising coo of Mourning Dove. E to G in insert are calls of female Grayson's Doves while sitting on the nest. H to J were recorded while both members of a pair were foraging together. It was not clear which sex produced the calls.

Fig. 4: Differences in morphology (shape of the tail feathers (A)) and vocalizations (B) between Mourning dove (*Z. macroura*) and Socorro dove (*Z. graysoni*) (Baptista et al., 1983)

1.3. Physiology

Information on heart rate, respiratory rate and body temperature are so far not available for the species.

1.4. Longevity

No information is available for birds on Socorro Island. EEP studbook data (n=1116; 31 Dec 2023) revealed generation time to be 2.50 years for birds in human care and maximum lifespan as 15.9 years for males and 12.0 years for females, respectively.

Field data

1.5. Conservation status, Zoogeography and Ecology

Distribution

The Socorro dove was endemic to Socorro Island. Discovered in the 16th century by Spanish explorers, Socorro is the largest of the four islands that make up the Revillagigedo archipelago, belonging to Mexico. It is located in the eastern Pacific Ocean about 700 kilometres (430 miles) due west of the Mexican city of Manzanillo and 480 km (290 miles) south-west of the tip of Baja California (Fig. 5). The island covers about 132 square kilometres (51 square miles) and measures approximately 16.5 km x 11.5 km (about 10.3 miles x 7.1 miles).

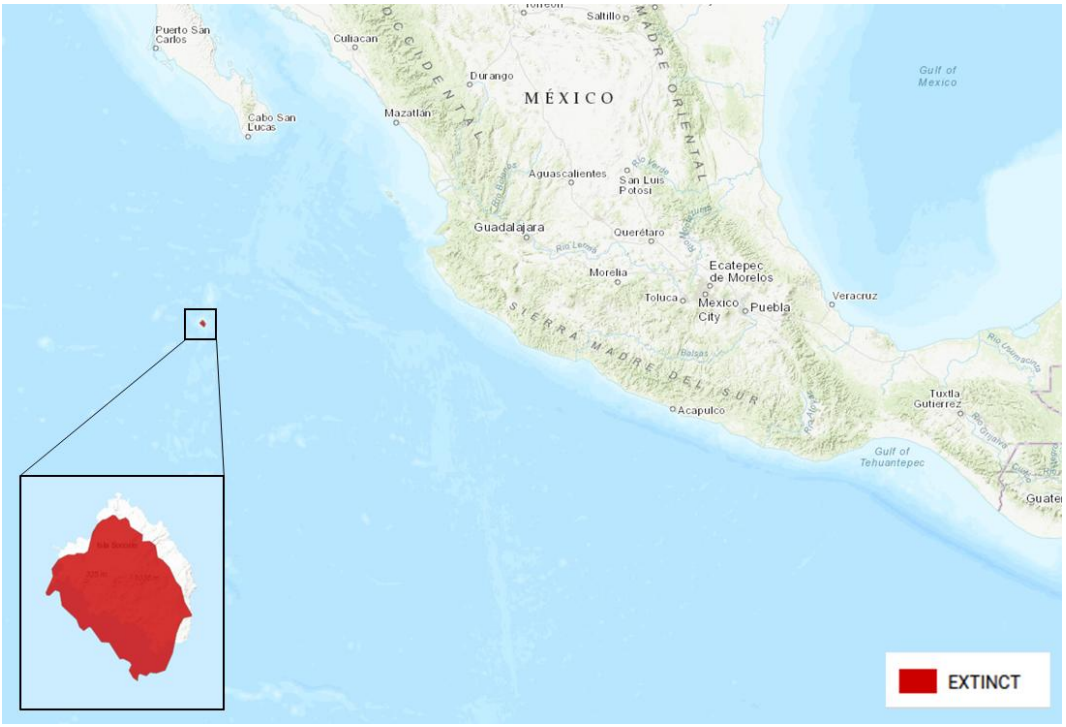

Fig. 5: Former distribution of the Socorro dove on Socorro Island, where it is now extinct (adapted from BirdLife International, 2024)

Habitat

The Socorro dove is a principally terrestrial dove. Dry and rocky bush land as well as forests (above 500 masl) are mentioned as main habitat with an upper elevation limit of 950 metres (BirdLife International, 2024). Flores-Palacios and colleagues (2009) define eight habitat types on Socorro Island, which may all have been originally inhabited to various degrees by the Socorro dove. These habitat types include *Conocarpus* shrub, grassland, prairie, *Croton masonii* shrub, *Pteridium* – *Dodonaea* shrub, tropical dry forest, tropical rain forest and lower montane cloud forest (Flores-Palacios et al., 2009); as regards climate, see Appendix I.

Due to the introduction of invasive species, there have been severe impacts on the island's ecology and, as a consequence, habitat alterations had occurred, which finally also led to the disappearance of the Socorro dove (see below). Habitat restoration on Socorro Island was initiated to remove extant sheep, control and eradicate feral cats, and start with ongoing removal of alien vegetation next to replanting of native species. A recent review and update of the native and introduced species of plant has been provided by Dominguez Meneses and colleagues (2023).

Population

No quantitative data exist for the size of the wild population of Socorro doves before colonization by humans. Early reports from the field show a somewhat contradictory picture. Anthony (1898) visiting the island in May 1897, stated that the species "did not seem to be at all common, but was perhaps more abundant in the higher parts of the island". Similarly, Brattstrom & Howell (1956) reported them to be "common around the lava rocks at low elevations on Socorro in March, but in November it was rare in such places and common above 1500 feet. At the higher elevations, the doves were usually found under fig trees (Ficus)". These observations seem to make sense, as May is late in the dry season and lower elevation areas usually are very barren at this time of year, whereas higher parts of the island are more humid benefitting from NE trade winds and are green all year round. McLellan (1926) in his report on the 1925 expedition also describes the species as "very numerous …, being particularly abundant on the higher wooded levels, and ranging almost to the top of the island; the central peak, Mount Evermann, reaches about 1,130 m".

To date (29 Oct 2024), the managed population in human care comprises of 195 (114.74.7) Socorro doves, distributed over 47 institutions in Europe and Asia (n=36), the US (n=10) and Mexico (n=1). The European population stands at 122 with a skewed sex ratio (69.48.5) of 1.44:1.

Conservation status

The Socorro dove is listed as Extinct in the Wild (EW) by the IUCN Redlist (Fig. 6); the last animal in its natural habitat was seen in 1972 (Murguía, 1982). Subsequent expeditions to the island in 1978 and 1981 failed to locate any Socorro doves (Jehl and Parkes, 1983). Fortunately, scientists of the California Academy of Sciences had taken at least 13 Socorro doves (McLellan, 1926) to California in 1925, although Gifford (1927) maintained to have received a total of 17 live Socorro doves from that expedition. Of these, four birds were sent to England (Bright, 1926) in the same year. In the following decades, the species has been kept and bred in the aviaries of private breeders. Consequently, it is fair to say that aviculture has prevented the extinction of the species (BirdLife International, 2024). Since the early 1990s, there has been an informal breeding programme, which became an official EEP in 1995. The reintroduction of the species to its home island is the main purpose of the EEP and has been planned accordingly right from the beginning.

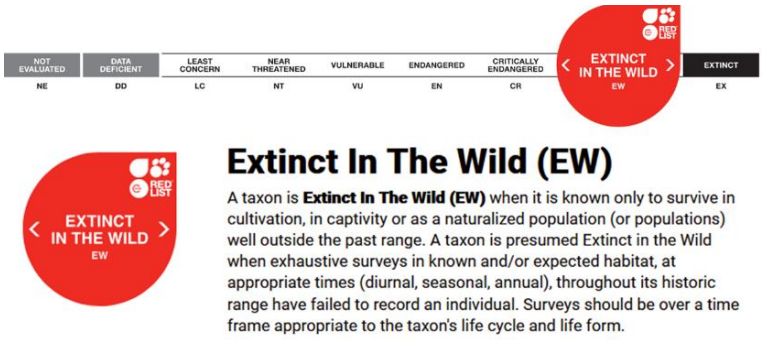

Fig. 6) Definition of the status Extinct in the Wild (EW) by the IUCN Red list (https://www.iucnredlist.org/species/22690740/178409463)

The reasons for the Socorro dove's extirpation on the island are complex, but there are several factors common to other island species declines around the world. High levels of understory grazing by

introduced (in the 1860s) sheep resulting in a massive degradation of the dove's habitat on the southern part of the island, combined with the introduction of feral cats by navy staff inhabiting a military base established in 1957 on the island have been regarded as the main factors for the decline of the wild Socorro dove population. The effect of cat predation was aggravated by the fact that the Socorro dove, like many other endemic land and seabirds, was not previously accustomed to ground predators. In his field notes of the 1867 expedition, Grayson (1871) remarked: „They are remarkably tame, perhaps more so than any bird of this order. One was captured by hand as it came into our camp and perched upon the rude table on which I was at work". Information from former navy personnel later suggested human hunting to be considered as an additional factor. More recently, introduced (invasive) plants have and still do compete aggressively with the native vegetation and may have a negative effect on the islands' flora and fauna (Domínguez-Meneses et al., 2023).

Genetic purity

As mentioned above, imports of Socorro doves to the US by the California Academy of Sciences (CAS) were documented for May 1925 (Gifford, 1927) and their presence was noted that same year in a private English collection (Bright, 1926). According to Nicolai (1991), an unknown number of birds of unknown source had found their way to Europe by the 1940s and were present in England, The Netherlands, Belgium, Denmark and Germany. However, there is no further documentation of any of these transfers; if they have taken place at all. It is unlikely, however, that these birds would have another source than the original imports. The subsequent history of the species in human care is poorly documented until the late 1980s. However, what is known is that female Socorro doves became less available due to small numbers of birds, differential life spans and, hence, skewed sex ratios favouring males. Ultimately, this led in a number of cases amongst private breeders to hybridization of *Z. graysoni* and *Z. macroura*. An early genetic study (Martínez, unpubl.) revealed that this holds true particularly for birds kept in the US. As a consequence, the latter turned out to be genetically suspect.

In 1991, an informal breeding programme was initiated in Germany by Cologne and Frankfurt zoos together with a handful of private breeders. In 1995, the European Association of Zoos and Aquaria (EAZA) approved an European Endangered Species Programme (EEP) for the species and, since then, this EEP has been run by Frankfurt Zoo. In 2008, a transfer of 12 Socorro doves from the EEP to the US was arranged to establish a managed satellite population outside of Europe. Reasons were, first and foremost, the outbreak of avian influenza in Europe. The move also helped to clear up aviary space in European collections, and starting a breeding population in North America gave a signal to Mexican authorities that the Socorro dove community was strongly committed to downlist the Socorro dove from the IUCN Redlist category Extinct-in-the-Wild (EW) by returning the species to a natural, wild state.

1.6. Diet and feeding behaviour

Field data about what Socorro doves used to feed on before becoming extinct in the wild, is anecdotal only and can only be inferred from habitat types in which individual birds were documented by early field researchers (e.g. Grayson, 1871; Anthony, 1898; McLellan, 1926; Brattstrom & Howell, 1956).

In human care, the Socorro dove, much like many closely related species, feeds on seeds, berries, greens and insects, worms, and other invertebrates.

1.7. Reproduction

There is hardly any information on reproduction from the wild. Anecdotal evidence from early expeditions to Socorro Island (e.g. McLellan, 1926; Brattstrom & Howell, 1956) suggests that breeding most likely occurred in the forested areas above 500 m (above sea level) and in the more humid north of Socorro Island. This is supported by a tendency to breed in locations providing shelter (cf. chapter 2.4.2).

Likewise, little is known about reproductive seasonality of the species in the wild, including what their natural inclinations would be as far as the timing of breeding is concerned. Edward Gifford, who had received 17 Socorro doves from the CAS expedition on 20th May 1925, speculated that "the 1925 breeding season on Socorro was over" (Gifford, 1927). However, in that same paper, he states that "On June 14, 1925, I saw the first courtship …", indicating that there may not have been a strict breeding season on the island at all. Data from the breeding programme show that the species may be capable of breeding year-round (see Chapter 2.4.2.). This also seems to hold for the (admittedly little) data from the Mexican sub-population. Aviary housed birds around the world are not subjected to as many vagaries of weather as their wild counterparts might be, so it is not known how exterior forces (temperature, hurricanes, food supply, etc.) would affect their nesting cycles. It is suspected that in the wild, the birds would have followed cycles based on the rainy season.

1.8. Behaviour

Andrew Jackson Grayson, who visited Socorro Island in 1867 and provided the first written account, started his field notes with the following words: "Of all the birds I met with on the Island, these seemed to be the most lonely; not a flock or even a pair were ever seen together" (Grayson, 1871), and, thus, named the species "Solitary dove".

From behavioural observations in human care, it is fair to assume that foraging took place during the day, while roosting will have occurred in trees during the night. The Socorro dove is adapted to ground-living and, therefore, spends much time on the ground during phases of activity. On Socorro Island, Socorro red-tailed hawks (*Buteo jamaicensis socorroensis*) may have predated on fledged doves, which has been assumed to have led to aggressive chasing of fledglings by their parent birds in order to drive the youngsters into cover and hide them from the hawks (Nicolai, 1991). The lack of a ground predator has left this (and other) endemic species of bird carefree and made them extremely vulnerable to introduced feral cats after the establishment of the human settlement on the island in 1957 (see above).

Section 2.: Management in Zoos and Aquariums

2.1. Enclosure

Socorro doves can be housed in a wide range of facilities (see Fig. 8-16). If birds are held in outdoor aviaries, a heated indoor shelter is advisable. Shelters can be constructed of either solid stonework or wood; the roof will need to be partially clear to allow natural light to enter. In general, the species has a very calm disposition. If necessary, they can be managed temporarily in smaller units for medical and veterinary treatment on a short-term basis, with a single bird in the space. This is especially important in cases where birds need extended medical care or are held in a quarantine situation. Socorro doves are fast and agile fliers, so it can be easier to capture a bird in a smaller space than in an aviary setting. Such spaces should always be available to house birds individually should there be a need to separate pairs quickly due to aggression or deal with injuries. Appropriate permanent housing would be similar to the facilities built on Socorro Island by the Socorro Dove Project for eventual use in the release programme as seen in Fig. 7.

Fig. 7: Breeding aviaries with solid indoor compartments (for protection during the hurricane season) on Socorro Island built by the Socorro Dove Project in 2004

Birds on display will be managed with different considerations. Size, materials, and shape of the spaces will result in deviation from the typical “box” described above. For the sake of appearance, exhibits may be constructed that add additional complexity to the husbandry of the birds. The public’s view of the exhibit may dictate the size and location of keeper access and how perching and plantings are arranged. Because the birds are fast flyers, the inclusion of a “safety cage” or a double door system in the aviaries is critical to prevent birds from escaping while the enclosure is being serviced.

Fig. 8: Large outdoor aviary at Paignton Zoo (Paignton)

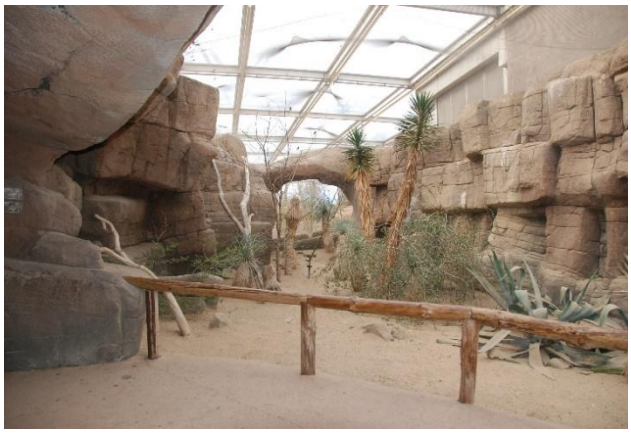

Fig. 9: Large indoor aviary at Burger's Zoo, Arnhem/NL

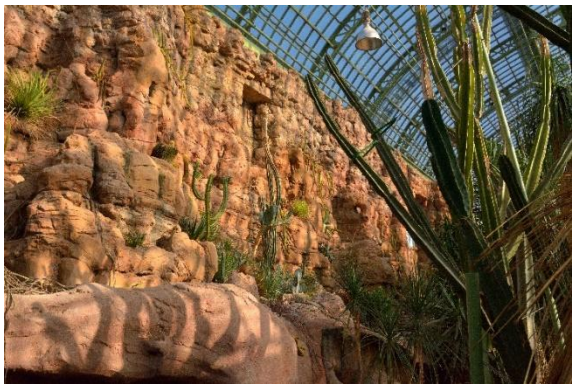

Fig. 10: Large indoor desert house at Vienna Zoo

Fig. 11: Large indoor tropical house at Warsaw Zoo

Fig. 12: Indoor breeding and display aviary at Frankfurt Zoo

Fig. 13: Outdoor breeding and display aviary at Landau Zoo

Socorro doves are usually fairly relaxed and stay primarily on the ground, so it might happen they simply walk out of the enclosure. Should a bird actually escape, it may remain in the area of the enclosures and the other birds. In this case, it might be possible to attract it back to the aviary by placing food inside the doorway. Chasing an escaped dove in an effort to catch it will most likely scare the bird away and it will be lost. Aviaries built in a series can facilitate introductions of birds to each other. Maintaining birds side-by-side for a period of time helps in judging their compatibility. Such an arrangement is also useful during mate-choice selection trials in which the bird targeted for pairing is housed with potential mates on either side before physical contact is allowed. Figure 17 shows one possible arrangement. In this design, the “pophole” gives birds access to the interior shelter or allows them to be separated by closing the “pophole” door. This layout is similar to the aviaries constructed on Socorro Island (Fig. 7).

The breeding aviaries behind the scenes at Albuquerque Biological Park (Figs. 14 & 15) and Marlow Bird Park (Fig. 16) followed similar designs. They are tall enough to walk through with some headroom (2.5 m seems ideal) but not so tall that they impede capture of birds when necessary.

The length should enable sustained flight, not just hops from perch to perch. Therefore, 3.0 m x 3.0 m x 2.5 m (L x W x H) is advised for this purpose (see 2.1.5) in behind the scenes breeding aviaries.

The facilities in Albuquerque Biological Park (Fig. 14, 15) were a series of adjacent aviaries with interior doors allowing for different configuration of the space. With all the doors open, one large space could be created. If all the doors were closed, four individual aviaries were available. This was beneficial for both introductions and when it was necessary to flock young birds and provide a larger space for managing them.

Fig. 14: Outdoor breeding aviaries at Albuquerque Biological Park (ABQ)

Fig. 15: Interior view of Albuquerque breeding aviaries (ABQ)

An attached shelter with access ports provides more options for housing birds. The birds will quickly learn to pass through these small ports to access perching, heat, food and water dishes, and nest sites. One advantage of such a design is that with windows or artificial lighting, these shelters can become additional holding space, if necessary, by closing the portals.

Fig. 16: Complex of breeding aviaries (behind the scenes) at Marlow Bird Park

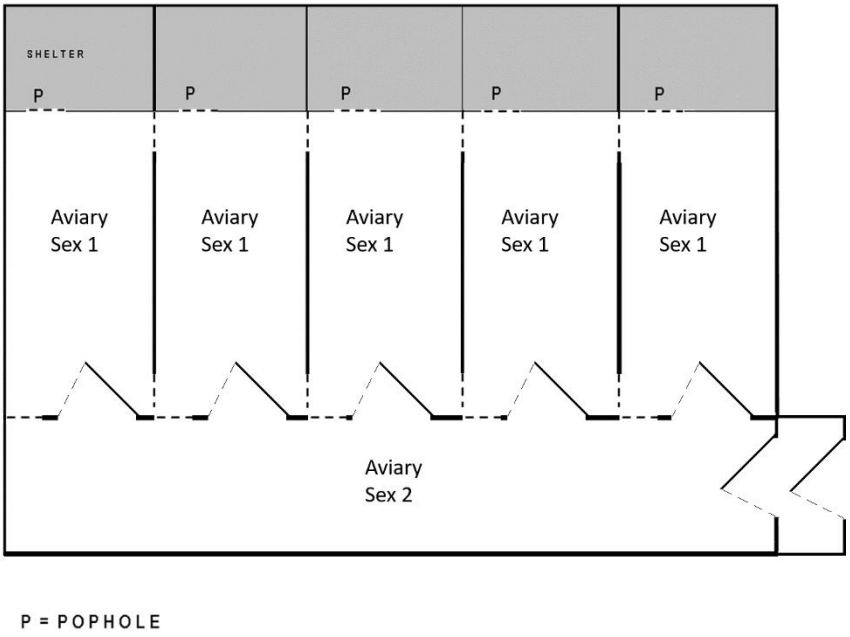

Fig. 17: Aviary design for pair formation of Socorro doves (adapted from Stewart (1999) for Pink pigeons)

In the most flexible aviary systems, the bird selected for pairing is housed in a space perpendicular to the birds of the opposite sex, thus allowing it to approach the birds in all the other enclosures and potentially demonstrate an interest in one particular bird. Fig. 17 shows a situation in which the aviaries are interconnected allowing birds to pass from one space to another if needed. This is useful for introducing birds and for separating them easily during introductions without having to handle them.

2.1.1. Boundary

Outdoor aviaries made of wire mesh, preferably in dark colours (sometimes with dark green external coating or painted with a dark colour) for better viewing, have proven highly successful and are therefore recommended. In indoor aviary situations, solid structures can be made of brick, stone, blocks and moulded cement for natural rockwork. The roof should be constructed of reinforced glass or double-pane plexiglass. Any large windows in aviaries should be shaded in when new birds are introduced to the aviary.

Mesh size: Aviary mesh size will be dictated by the local conditions. Elimination of mice will require smaller meshes (12 mm). If snap traps are used for mouse control outside the aviary, careful placement anywhere near the aviaries is required because the doves will stick their bills through small holes in mesh and potentially injure themselves (P. Shannon, pers. comm.). The presence of digging pests and predators might require that mesh be buried in the ground to prevent entry from below. Space design should take into consideration the possible need for cockroach and spider control.

Predator control: The possibility of predation should also be taken into consideration for aviary construction. Possible predators of doves include mammals, birds and reptiles, but even mice predating eggs were recorded. In this respect, placing perching away from the top and side meshes will help to reduce the loss of birds from predators reaching into the enclosure, especially at night. Smaller mesh will help to reduce this potential hazard. In extreme predator situations, a secondary layer of mesh spaced several inches away from the primary caging may be required. Some types of predators will work as a team to scare the birds and then attack them as they cling to the wire mesh. Low wattage nightlights can help birds see movement in the enclosure and safely manoeuvre inside the space if they are roosted.

Barriers between adjacent dove enclosures: Consideration may need to be given to covering the lower portion of the enclosure with fabric or other visual barrier to reduce aggressive pacing of individual doves along the fence line. Paired birds seem to eventually accept the territorial boundaries established by the enclosure mesh. Unpaired males may be disruptive to adjoining pairs, thus requiring visual barriers. Unpaired males can also be disruptive to existing pairs by calling to the female. This visual and auditory contact in the aviaries can result in the breakdown of established pair bonds and formation of new ones, even without direct physical contact. In such cases, separation which avoids visual and auditory contact will help to ease the problem.

2.1.2. Substrate

The birds will spend considerable time on the ground foraging and during courtship, so the substrate should be easy to maintain. Leaf litter and soil represent ideal substrates. Forest bark and leaf litter will also be used as nesting material and provide good enrichment for foraging birds. Sand is appropriate but can be dusty. Coarse sand or small pebbles are also functional, but can also be hard to clean. Sawdust or pine shavings are the least easy to keep clean.

Attention should be paid to the doves' feeding habitat when choosing any substrate. If the birds are fed in dishes on the ground, the lips of the dishes should be high enough to prevent too much scattering of food out of the dish. The birds will tend to scratch through the food and scatter it everywhere as part of their feeding routine. The taller the sides of the dish, the less scattering of the diet will occur. One option is to put the food dish in a larger plate or tray with sides to help keep the food contained. They will also learn to eat from elevated dishes. If the perching near the dish is

adequate, they may eat directly out of the dish without scattering food. To prevent inaccessibility of food in cases of (usually male) aggression, additional food sources should be available.

A patch of fine sand on the ground will be attractive for dust bathing and should be part of the daily cleaning routine.

2.1.3. Furnishing and Maintenance

Vegetation / cover: Aviaries should be densely planted; where possible using evergreen shrubs and trees to provide both perching and cover. Most plant types are acceptable for Socorro doves, with evergreen plants providing extra shelter for birds during the winter months in northern areas.

Facilities should otherwise provide vegetation in the form of artificial plants or other visual barriers. The visual barriers can be as simple as cardboard hung throughout the enclosure to break up visual sight lines (see Fig. 18). This is especially important if multiple birds are held together (which can often be the case with juvenile flocks or newly introduced pairs). As juveniles mature, it is important that less dominant birds in the social hierarchy have places to be out of sight of dominant birds. During breeding season, the pair needs to have a sufficiently complex environment that the male can locate a suitable nest site and the female has safe places to remove herself from view.

Fig. 18: Simple device for hiding for subordinate Socorro doves at Marlow Birdpark

Vegetation or other “cover” also needs to be provided on the ground. When chicks fledge, they may spend several days on the ground before being comfortable perching. Depending on their age, they may not yet be capable of controlled flight immediately after fledging. They will come out of hiding to meet one or both parents for feeding until they begin to forage on their own. Hiding from the female or the male (depending on who the primary caretaker is) is important for the new fledgling(s). This cover is especially important if the female goes to nest again before the offspring is independent. As long as the female is on the nest with new eggs, the male may continue to tend the fledged chicks. But, when the female is off the nest, the chick(s) need a place to hide where she will not bother them. In a situation where the male is “driving” a female to a nest site, even a large amount of “cover” may not be sufficient to protect her. He will always know where she is and if she is not amenable to his advances, a male can bully a female to the point of exhausting or even killing her. However, with a highly compatible pair, the male will allow the female to visit the food dish without harassment. Even the best exhibit in terms of space, perching, and vegetation may not be adequate if the pairing is not

a good match. This is why it is so important to observe the birds and understand what their behaviours mean.

Perching: Birds should have a variety of perching options. Perches of various diameters provide exercise for the feet and reduce or prevent development of toe pad calluses. Even though dowels are easily installed, especially in small spaces, natural branches make for better perching because of their natural size variation and texture. Creating a perching structure with dowels and then attaching a variety of branches to that structure is a simple solution to the problem. Hemp rope strung across open spaces is also a good, flexible material to use, especially for longer spans. PVC pipe should be avoided as a perching material because it can be difficult for birds to grip and provides no texture. If PVC is an unavoidable material, it should be tightly wrapped with small diameter rope to create a rough surface. Elastic bandage material such as that used for veterinary purposes can be a quick alternative to give smooth surfaces a bit of texture. It is especially useful for perching in a small holding space. Depending on the space, the birds will typically choose the highest point available to them for perching. The same holds true for nest site selection. If hanging perches are considered, the supporting wires must be wrapped in rope or other material to reduce the possibility of injury should a fast flying bird strike it. Large logs or branches placed on the aviary floor are regularly used for perching.

Given the opportunity, the birds will sunbathe on the ground or on elevated perches.

Light

Light can come from various sources. Natural is typically best. The birds will sunbathe if given the opportunity. With artificial lighting, full spectrum fluorescent fixtures are preferred. It is unclear how manipulation of day length might affect the birds or timing of breeding. Birds in Europe have had chicks hatching throughout the year, although they seem to have a slightly truncated breeding season. At Albuquerque Biological Park, New Mexico/US, all birds have access to natural light cycles. At their latitude, the birds breed throughout the year, but the typical breeding season seems to begin in late November and continue into September.

In indoor areas, provision of UV light may be of help, but has not (yet) been investigated specifically for this species. However, Basel reported to have significant improvement of egg shell stability with supplemental UV light installed (pers. comm.). Generally, the subject of supplementing UV A and/or UV B lighting in birds is still developing. Information to this end, including technical aspects such as lamps available, is, however, available on the internet (e.g. https://exoticdirect.co.uk/news/benefits-uv-lighting-birds-part-two/; https://www.birdline.co.uk/unlocking-the-secrets-of-uv-lighting-for-birds/). Companies may not be active in every country; it is recommended, therefore, to investigate this from a local perspective.

Temperature

Environmental factors will vary according to the location of where the doves are kept. For an exemplary overview of climate conditions in four different locations where Socorro doves are/were kept, including Socorro Island, see Appendix I.

Even though this is a tropical species, the birds are relatively winter hardy. In northern Europe, birds have been maintained with outdoor access year round provided they have shelter from wind and rain and have a heat source as appropriate. This is not recommended in colder regions as it is suspected to have negative effects on their health and reproductive performance. In warmer climates or in summer months, shaded areas should be provided, preferably by natural vegetation. The doves will also benefit from either a sprinkler system or hosepipe watering during warm and dry periods.

In Europe, birds are held in both indoor only spaces, and with indoor/outdoor access. In Albuquerque, birds in some enclosures were given indoor/outdoor access throughout the year. Initially after the first birds had arrived in Albuquerque, they would be driven into the night quarters on very cold nights. It was subsequently found that, when giving them free access, some individuals would choose to remain outside on cold nights even when they were familiar with moving through access portals to the heated inside space. On occasion, when overnight temperatures were anticipated to be lower than minus 9° C, all birds were routinely locked indoors. But, other than those occasional extreme temperatures, birds with indoor/outdoor access were not restricted. In Albuquerque, no apparent ill effects from cold temperatures were seen. Nevertheless, in colder climates, birds should have access to indoor areas that provide a minimum temperature of 15° C.

2.1.5. Dimensions

The aviary size for a single pair of Socorro doves should have a minimum length of no less than 3.0 m, a width of 3.0 m and a height of 2.5 m (see above). In this size aviary, only single pairs should be housed. Although there is no fixed dimension that can be recommended as "best" (e.g., individual behavioural traits and/or local circumstances may play a role), birds will benefit from aviaries larger than this and can, then, be housed with other species.

Outdoor aviaries should provide a shelter of no less than 1.5 m x 1.5 m x 2.5 m (LxWxH), although this is to be regarded as absolute minimum, whereas best practice would be 3.0 m x 3.0 m x 2.5 m.

As mentioned above, single doves may be kept in smaller units for a (very) limited amount of time when in need of medical care.

It may be noted here that aviary size is only one of many features important for the safety and well-being of the animals.

2.2. Feeding

2.2.1. Basic Diet

There is no "standard" Socorro dove diet since the availability of ingredients varies by location. Having been found in human care for nearly a century, it can be suspected that the Socorro dove's food habits have been moulded around what aviculture has provided. The species was found to be far more omnivorous compared to Mourning doves. In human care, it can be assumed that their diet comprises of appr. 70% seed or seed equivalents and 30% "other" (fruit, vegetation, insects). In the following, examples of Socorro dove zoo diets are given for long-standing breeding programme participants.

Frankfurt Zoo diet: The diet comprises of a dove seed mixture plus smaller seeds for exotic birds (millet), a house-made soft food with some greens and small stones (grit). Live food may be offered occasionally, such as mealworms and small crickets.

Albuquerque Biological Park diet: The basis of the Albuquerque Biological Park diet has been seeds (red and white millet), milo, wheat, safflower, chopped fruits and greens, and insects during the rearing of young (mealworms, waxworms, small crickets). Old food should be picked up routinely to prevent the development of mould and the attraction of roaches and mice. Maintenance of natural vegetation in the Albuquerque dove enclosures has not been a priority due to the number of birds involved and the variety of housing options. The birds do not seem to be attracted to live plants for consumption.

Chester Zoo diet: Chester Zoo offered 30 g zoo-made pheasant mix, 5 g softbill mix, 2 g insect mix, 2-3 mealworms, "pinch" Avimix (multivitamin/mineral mix; https://www.vetark.co.uk/products/bird-wildlife/avimix) per bird and feed.

2.2.2 Special Dietary Requirements

During breeding, the amount of animal protein food (insects, etc.) might be increased. Quantitative data, however, does not exist. Following a case of bone fracture in one female, Albuquerque Biological Park routinely supplemented with dicalcium phosphate powder (CA- 25%, P- 18%) "with about 1/8 tablespoon mixed in each food bowl".

2.2.3. Method of Feeding

The doves can be fed on the ground or on raised feeders. On the ground, the birds will tend to dig through the food bowl and scatter the contents. Placing the food bowl in a larger pan does help to keep the food better contained and reduce the amount of effort that goes into cleaning. The birds will tend to pick through the food provided and select the things they like. Weight gain has been monitored at some places (e.g. Albuquerque), with diet formulation and volume changes made as appropriate.

Birds can learn to perch on feeding platforms. However, such platforms need to be of sufficient size to allow both perching birds and a large enough food bowl. If perching right next to the feeding bowl is possible, the birds may feed directly out of it without scattering food. Food platforms should be flat with a small lip to prevent food dishes from falling off, and have enough room to accommodate both the dish and the perching birds. The platform can be elevated on a pole approximately 50 to 60 cm off the ground; this will prevent pests getting to the food and make cleaning feeding areas easier. Food platforms should be placed in a dry area, indoors. Basel Zoo reported good experiences with using catch up cages for routine feeding in smaller aviaries to reduce stress in case of necessary capture.

The best time for feeding is in the morning. At Frankfurt Zoo, food is prepared in the morning and early afternoon and given twice, before 10.00 am and after 03.00 pm.

Live food such as crickets and mealworms can be scattered around the aviary floor at different times of the day, giving birds a stimulating and enriching food source.

Water: Water should be provided by giving a water bowl of sufficient dimensions to allow the birds access, and should be cleaned and disinfected on a regular basis. Where possible, water can be provided in the form of a shallow pond or pool, with the edges sloping to allow the birds easy access to the water to drink. Where it is possible, the doves will use water splashing from a waterfall or shallow bowl for bathing. Similarly, a mister system hung overhead can encourage water bathing.

2.3. Social Structure

A key factor to successful management of the Socorro dove is an understanding of how they behave throughout their lives, whether in groups, as pairs, as singletons, or in mixed species aviaries. Different strategies are necessary depending on age, social status, and reproductive history of each individual. Notably, Socorro doves can show high aggression, not only between, but also within pairs and also towards fledglings. Groups have been maintained with varying success in large, densely structured

aviaries (e.g. at Cologne and London). Like other doves, the birds are at least seasonally monogamous and should ideally be kept in breeding pairs.

2.3.1. Basic Social Structure

There is no information on the basic social structure from field observations, but it can be assumed that the species preferentially lived and reproduced in pairs on Socorro Island. Young, non-breeding birds may have gathered at suitable feeding sites, but evidence from the field is lacking.

2.3.2. Changing Group Structure

There are several scenarios for birds to be introduced to each other. If the establishment of compatible pairs is desired, self-selection of partners from multiple options will result in the most compatible and successful pairings. This is obviously facility-dependent. The more flexible the facility, the more likely desired outcomes can be achieved. As always with animal introductions, the birds should be watched carefully for a certain period of time after the introduction. Intraspecific aggression, sometimes without recognisable warnings, has been reported for the species, even within successfully breeding pairs. As stated above, a dense aviary structure is the most important measure to avoid harmful situations.

Flocking juveniles: Young birds of either sex can be held in mixed-sex flocks up to about six months of age. Recently weaned chicks are generally easy to integrate into an existing juvenile flock by first housing them in adjacent aviaries and, usually after a few days, mixing them with an established group. Contact with young conspecifics promotes rapid socialization and independence. Once the oldest males in a mixed-sex flock mature, they may begin harassing other birds, regardless of sex, and will need to be removed from the group. Females can usually be kept in the juvenile flocks for longer, but they may also start harassing younger birds as they get older. It is important to constantly monitor the individuals in the flock in order to detect chasing, intimidation, and displacement behaviours. In choosing future partners, putting young birds together prior to maturity can be one method of mate selection. As long as they are of similar age, a male and a female housed together will often form a pair bond and proceed to nest without the typical displaying and courtship seen with older birds that are brought together as adults.

Flocking older same-sex birds: Male-only groups raised and maturing together can potentially be held in a group for up to two years. However, great care needs to be taken to observe the flock dynamics on an ongoing basis. The largest all-male group that Albuquerque was able to maintain for an extended period of time was four birds that were raised together (aviary size and internal structure unknown). To maintain a male flock, the dominant male(s) may need to be removed as soon as dominance and aggression is apparent. The birds in such groups will typically separate themselves spatially, even though at times they may come to the ground to feed communally. These young males will establish their own “safe” places within the enclosure to which they will retreat after feeding. Aggression in such groups may be sporadic, but it never ceases entirely. For these arrangements to succeed, all-male flocks must not have visual or auditory contact with females.

Female groups typically do not demonstrate the same social tensions as seen in male flocks. They are easier to establish and maintain for longer periods of time, although they, too, need to be constantly

monitored for compatibility. Unlike male flocks, it is easier to hold females of varying ages together in the same enclosure. However, introducing very young birds into an existing female group may take more effort to be successful. As with juvenile flocks, side-by-side introductions may be necessary before putting birds together in the same space. Adding more than one bird to a female group at the same time can help with the development of a cohesive social group. As with all-male flocks, except when foraging, birds in female flocks will space themselves as far from each other as possible. Placement of perching at different elevations helps to disperse tensions.

With both sexes, any time an individual is added or removed from a flock, this will change the flock hierarchy and may result in unanticipated social changes requiring intervention. Altering the group structure in an aviary will always require careful monitoring. Since a shortage of holding spaces has long been an issue with Socorro doves, the ability to successfully house multi-bird groups is an important management tool for larger collections. It is recommended that there always be empty holding spaces available for use when social dynamics change and birds need to be separated, especially as the breeding season begins and progresses. The ability to mix single doves with other bird species is invaluable in these situations. It is currently unclear whether flocking of older, reproductively senescent birds of either sex is feasible. Most facilities have not had the numbers of birds or adequate space to test this strategy. The National Zoo in Washington, D.C., did attempt to flock their five older birds in a large aviary in an effort to stimulate nesting. At the time, two of the males were about seven years of age, one was about four, and the two females were about seven years of age. Although some nesting did occur, no fertile eggs were produced.

Flocking mixed-sex adults: Socorro doves, in general, seem to behave like many species of dove when held in groups. They will come together to explore newly presented food dishes and then separate for perching or resting. They may engage in random periods of mingling, especially during enclosure maintenance or other disturbance. Groups of non-breeding individuals are most likely to interact without aggression in contrast to what would be expected with sexually active birds. Ultimately, reproductive imperatives will dominate their behaviour. Although there are exceptions, most Socorro dove management revolves around breeding and results in one pair of birds per enclosure.

Group management leading to pair formation can be approached in several different ways. The choice of techniques depends on the available space, the configuration of that space, the number of birds involved, climate constraints, and expertise of the personnel caring for the birds. In all potential reproductive scenarios, there is a behavioural repertoire that the birds typically follow which leads to success. Mate selection is probably the most important factor. Compatible and productive pairings tend to develop most readily when birds can choose their own partners. This can most easily occur in a flock situation in which a dominant male can select a partner and actively drive out all the other doves. However, when genetic considerations are important and the choice of mates is artificially limited, variations on this strategy may have to be employed.

One approach is to mix two males and one female together until a pairing is apparent (or vice versa – one male and two females). As with larger groups, monitoring these trios closely for indications of aggression is vital. Once the pairing is apparent, the third bird must be removed. As with other arrangements, aggressive behaviour will not stop once it has begun. Housing individual birds in adjoining aviaries (as seen in Fig. 17) is a safe way to familiarize birds with each other before putting them together. By observing their behaviour, compatible birds may signal their preferences. Early in the Albuquerque Biological Park programme, a male and two female Socorro doves were held in sequence and it became apparent that the two “females” had chosen each other. Albuquerque Biological Park staff took a chance based on the birds behaviour and put them together. They went on to nest and produced offspring. This “female” was obviously mis-sexed. Had observations not taken precedence over what the records indicated, it may have taken much longer to discover the error.

If the side-by-side introduction is not possible for two unfamiliar birds, it is best to house the female in the space for a few days to allow her to become familiar with the location of perches, food and water, and potential hiding spots prior to the introduction of the male. However, this is the least desirable method of introducing birds. Extreme vigilance and observation is required, more so than with other introduction techniques. It will typically be apparent immediately whether or not the birds will be compatible in the short term. A alternate version of the side-by-side strategy, i.e. directly joining male and female in the same aviary, requires the monitoring of all birds within visual and auditory range of each other. Just because birds are not in adjacent spaces or cannot see each other, does not mean they are not aware of their presence. Males call to attract mates and females may respond to them. Even if other birds are closer, that auditory or distant visual attraction may be enough to solidify a (potentially unintended) pair bond. The cues to watch for include vocalizing, pacing the enclosure edges and behaviours apparently directed at a distant bird.

Some facilities, such as the Paignton Zoo (UK), have been successful (at least temporarily) in keeping multiple pairs of Socorro doves together. Their large, heavily planted outdoor aviary (see Fig. 19) has allowed for breeding to occur among groups of birds. It has been suggested that having many birds in a large space may reduce the aggression towards any one individual. If so, birds, nevertheless, occasionally need to be removed from the aviary due to aggression. Also, female aggression towards other birds was occasionally reported. The success of such an arrangement depends on proper facilities and staff expertise (Gregson, pers. comm.).

Fig. 19) Socorro dove outdoor breeding aviary at Paignton Zoo (UK) (Paignton)

When twelve Socorro doves first arrived in Albuquerque Biological Park in November 2008, they were initially randomly divided into two groups of six. They were housed indoors in two rooms 1.8 m x 2.5 m x 3.0 m (W x H x L), three males and three females in each room. In the first room, the dominant male in the group very quickly established his dominance and within the first week, four birds had to be removed. One of those four birds had been mis-sexed and was eventually found to be a male (see the results mentioned above). The presence of four males in this relatively small space may have contributed to the rapid development of aggression in the room. The dominant male and his chosen partner produced eggs less than five weeks later. In the second room, one male had to be removed

soon after the birds' arrival. The five remaining birds (2.3) were housed together for about four months. After that, tensions developed among the birds and the extra male was removed from the enclosure. By observing the chasing behaviour of the remaining male, the pair was ultimately identified and the two extra females were removed.

In group settings in smaller spaces, the dominant male will usually target one bird for harassment. Once it begins, the harassment will be relentless and will not cease. There may be short breaks in the chasing, but ultimately the dominant male will not stop harassing the subordinate bird and either of the two (depending on management aims) must be removed. If the subordinate bird is removed, the dominant male's attentions will turn to the next most subordinate individual. It must never be assumed that the birds will eventually "work it out". They will not, and the result will be injury to the subordinate bird or even death. During the breeding season, male Socorro doves are typically very territorial. In the presence of other birds (male or female), the dominant male will aggressively chase the subordinate bird until it is removed. This chasing will occur both on the ground and on the perches and in the vegetation. As the subordinate bird tires, physical contact can occur. Even in situations where the males are housed side-by-side, aggressive behaviour can be demonstrated by one or both birds "patrolling" the enclosure partition. This behaviour may or may not decline once it is apparent that neither bird can cross that barrier. A single male can even be disruptive to a pair in an adjoining aviary and may need to be relocated to avoid disruption of that pair bond.

2.3.3. Sharing Enclosure with other Species

Socorro doves mix reasonably well with other species (but see 2.4.1.). Zagreb Zoo reported a successful combination with turacos (*Tauraco erythrolophus*), and Frankfurt Zoo tested mixing the doves with tinamous (*Eudromias elegans*), grosbeaks (*Passerina brissonii*), and tanagers (*Ramphocelus bresilius*). However, Heidelberg reported mixing with tanagers was not possible, as the female tanager attacked the Socorro doves during the breeding season (even in two different aviaries with different individuals). On the other hand, Basel had combinations with a wide variety of passerines without any issues.

Problematic mixes can be with other species of dove and species that look and behave similarly to doves (tinamou, quail, etc.). Because of possible aggression from Socorro doves towards other birds, larger species of the order of Galliformes may be considered. When combined with similar looking species, single (male or female) doves mix better than pairs of Socorro doves. The fact that they are easy to work around, curious and generally not flighty make them suitable for mixed-species enclosures. However, they are not showy or dramatic. In planted aviaries, they can be difficult to locate, especially when they are resting as they blend in easily into vegetation.

2.4. Breeding

Little has been published on the behaviour of Socorro doves. Baptista and colleagues (1983) described breeding postures and vocalizations during mating. The urge to reproduce drives much of their activity. Success or failure depends on both partners following their hard-wired behaviour patterns at the right time and in the correct order.

A successful pair can clutch and rear several times a year.

2.4.1. Mating

The process of courting, choosing a mate, nest site selection, and production of offspring all seem to be important factors in maintaining the strength of a pair bond. The pattern followed is highly structured and even if the steps are abbreviated, the entire repertoire of behaviours appears to be necessary. This course of events serves to synchronise the partners, and is critical for successful reproduction. If one of the birds is out of step with the other, the breeding effort may fail, even after eggs have been laid. Repeated failure may necessitate a change of partners.

Following pair establishment, it is not recommended to have other doves (of any species) in the enclosure because the latter may be harassed by the male Socorro dove. Species such as quail, tinamou, or other ground dwellers with similar physical attributes will be targeted for harassment and will likely need to be removed. Young Socorro dove males can be particularly pugnacious toward similar species early in their breeding lives. Compatible pairs will typically forage together. When perching, they will frequently sit near each other, sometimes within reach of the partner. In such situations, mutual preening can be observed. In some pairs, pre-copulatory mutual feeding may occur as part of the pair bonding process.

Once birds are successfully paired, there are still some behaviours that need to be monitored. There can be a fine distinction between aggressive chasing and sexual “driving”. Aggressive chasing by the male may occur in the initial pairing phase (e.g. at Zagreb Zoo), but can also be due to incompatibility or reluctance of the female to accept his advances and/or the nest site the male suggested. If not interpreted correctly, this behaviour by the male can result in injury or death of the female. “Driving,” on the other hand, is employed by the male to direct the female to a nest site he has chosen. If a good pair bond has developed, this is more of a ceremonial activity and serves to strengthen the pair bond. It also helps to synchronize the breeding cycle for both birds. After a pairing has occurred and nesting is approaching, the male may dictate how far from the nest site the female can wander. As long as she remains within a defined perimeter, he will not chase her. There will be periods when she leaves the nest area for feeding, bathing, etc. but at some point he may return to driving her until she returns to the vicinity of the nest site. Because the breeding behaviours occur in rapid succession, there is usually little concern of adverse encounters between compatible partners.

Males may, however, hurt their partner if incompatibilities develop. Typically, the male will insist on the female remaining on or near the nest and if she does not comply, he may “drive” her to the point of exhaustion or injury. Importantly, once the aggressive behaviour begins, these incompatibilities are unlikely to improve and the birds should be separated. It is possible that after a period of separation, the birds can be reintroduced to one another, especially if they have been held in adjoining aviaries. Following all the same parameters for evaluating pair formation with unfamiliar birds, observation of compatibility during the new introduction remains critical. Outside the typical breeding season, male aggression is much reduced, although it may still occur, especially with younger males.

Although it is unusual, previously compatible and successfully breeding pairs may not remain productive or compatible over the course of an entire season. Sometimes chicks can be fledged from several sequential clutches and then the pair begins to fail. Any number of problems can arise. The female may produce a new clutch of eggs in the same nest before the first eggs hatch. She might abandon eggs in one nest to lay a new clutch in a different location. If the male moves with her to the new location, the first clutch will fail. He is unlikely to remain attached to the first nest, but if he does, both clutches will fail. Nest relief by one of the partners may begin to decrease resulting in abandonment of the nest. Chicks may hatch but at some point be abandoned in order for the pair to begin the nesting cycle again. The first egg in a two-egg clutch may fail to hatch at the expected 16 days and the nest might be abandoned. Also, disturbance at the nest could prompt nest abandonment.

Pairs that remain compatible over several seasons are likely to stay that way. However, fertility usually declines after their first breeding season together. They will continue to do all the other appropriate behaviours (nest building, incubating, etc.) but the evidence of courting will decline, as will fertility. Birds like this can often be useful as foster incubators and surrogate parents. Compatible birds that have not demonstrated breeding behaviour within the first season together are unlikely to reproduce. In these situations, consideration should be given to re-pairing them in the following year. It can be productive to stimulate a compatible pair through the introduction of a novel male or female in an adjoining enclosure. A new male in the vicinity might stimulate the paired male to begin territorial defence behaviours. As with mate choice trials, a novel bird in an adjoining enclosure may encourage either member of the pair to switch partners. Auditory or visual contact with other doves can also disrupt existing pairs.

In the Pink pigeon (*Nesoenas mayeri*), it appears that an important management strategy is to separate the pairs outside the breeding season and bring them together for breeding, even to the point of doing it several times within the season to stimulate breeding (Stewart, 1999). With Socorro doves, once birds are successfully paired and compatible, they typically remain that way for the entire season. Even after the breeding season, established pairs can remain together and actively nest the following year (or years). However, with most long-term pairs, fertility drops off after the first successful season.

At the Smithsonian National Zoological Park in Washington D.C./US, after early breeding successes, their birds ceased to breed and did not fledge any further chicks. The staff experimented with separating birds for several months at a time in order to stimulate breeding. They also attempted flocking their five birds in a single large aviary. Although some nest building occurred in this large communal space, none of these breeding attempts were successful (Hallager and Brader, pers. comm.). In such a situation, re-pairing seems the best way forward.

2.4.2. Egg Laying and Incubation

Nesting: The timing of pairing and breeding appears to be variable depending on the geographic location. As mentioned above, there is little knowledge as to what natural breeding times and natural cycling for the Socorro dove look like. However, it is assumed that wild birds followed cycles dominated by the rainy season (cf. App. I).

Birds in Europe will breed throughout the year, with a clear peak of breeding activity in the summer months: predominately in April through September with peaks in June and July (Fig. 20). This pattern may, at least in part, be a reflection of management decisions taken with regard to local climate conditions.

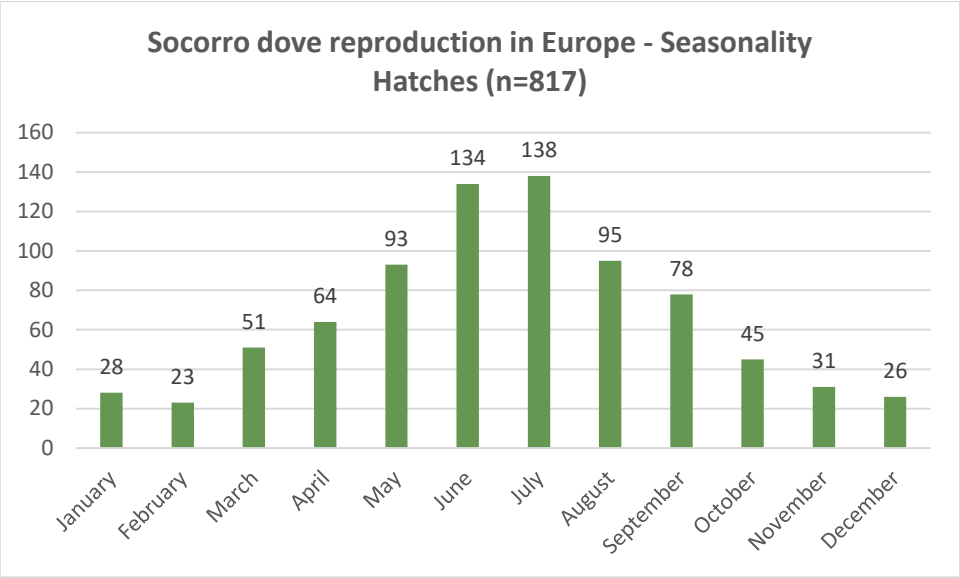

Fig. 20) Seasonal distribution of breeding activity in European collections

In Albuquerque Biological Park, the birds are provided access to nest sites throughout the year and encouraged to breed whenever they choose. As a result, the breeding season tends to begin in late November and can run until the following September. The birds are generally moulting between September and November. So every effort is made to be sure that introductions are conducted early in the breeding cycle to increase the possibility of repeated nestings. Although chicks hatched in every month of the year, the peak months for reproduction have been March through September. The lowest number of hatches occurred in October.

Any time new pairings are being established, their aviary should have been prepared for nesting prior to the birds being introduced to the space. If the birds are in breeding condition, their behaviours can progress from courtship to nest site selection, nest building, egg production, and incubation in a very short period of time. In cases where birds have had visual or auditory access prior to physical introduction, they may move directly into nest selection and construction once they are in the same enclosure.

Socorro doves prefer to nest in a cave-like sheltered situation. Artificial nests will be accepted, but natural structures, e.g. in strong branching trees, are ideal. Nest sites are generally chosen off the ground but they do not need to be in the highest locations of the enclosure. The physical attributes of the enclosure and placement of artificial structures should dictate where nesting might occur. The choice of sites is variable for each pair but the male almost always chooses the location. Even if the female picks another spot, he will typically force her to the site he prefers. The male may become aggressive if the female does not cooperate. This lack of synchronisation in nest location selection may result in nesting failure and the necessity to separate previously compatible pairs.

Fig. 21: Socorro dove artificial nests with parent and chicks (day 9; right; left unknown) at London Zoo (ZSL)

Socorro doves will readily accept platforms, woven or wire baskets, open boxes, etc. for nesting activities (e.g. Fig. 21). All the nesting in Albuquerque Biological Park (Fig. 22) has taken place in structures provided by the keepers. None of the birds have ever constructed a nest from scratch although they will collect nesting materials as part of the courtship process. In anticipation of egg laying, the birds will gather small twigs, long grasses, and even leaf litter to line the centre of the nest cup. A variety of materials should be scattered on the ground for use by the birds. As long as the nest foundation is sturdy, the birds may choose to add a minimal amount of material to the nest. It is usually best to provide artificial sites that are easily accessed in order to facilitate quick and efficient monitoring of eggs and chicks. They should be designed so that the birds can land nearby and walk along a perch to access the nest cup. For most birds, their preference when incubating is to be sitting below the edge of the nest out of view. The use of artificial plants around the edge of the nest can provide additional security and will allow birds to stealthily approach and exit the nest.

Fig. 22: Pair of Socorro doves nesting in the Albuquerque Biological Park aviaries (ABQ)

Socorro doves will also readily accept nest sites inside night shelters where the light can be reduced, thereby providing additional security for the nest. There should always be a minimum of two potential nest sites provided so that the birds have a choice of locations. Socorro doves will readily accept appropriately designed nest structures so their placement can be dictated by the needs of the keepers for access to the sites. As previously mentioned, whenever the female tries to select a nest site, the male may or may not allow this to happen. He almost always makes the final choice. With actively nesting birds, one nest may be abandoned and the nesting effort moved to another location even

when eggs or chicks are present. Courtship and the establishment of bonds will constrict the female into a smaller radius of movement away from the nest site. As long as she remains within the prescribed boundaries, the male should not be aggressive toward her. There will be periods when she can leave the nest site for feeding, bathing, etc. but at some point the male is likely to return to driving behaviour until she returns to the area of the nest. Once eggs are laid, this type of driving behaviour ends.

Egg laying and incubation: As with courtship and pair bonding, nesting is a highly structured process. Deviation from the typical pattern of behaviours can result in abandonment of eggs or chicks. The onset of egg laying is fairly easy to predict. The female will begin continually sitting on the nest a day or two before the first egg is laid. According to data from the Socorro dove EEP studbook, mean clutch size is 1.43 (n=710; Fig. 23).

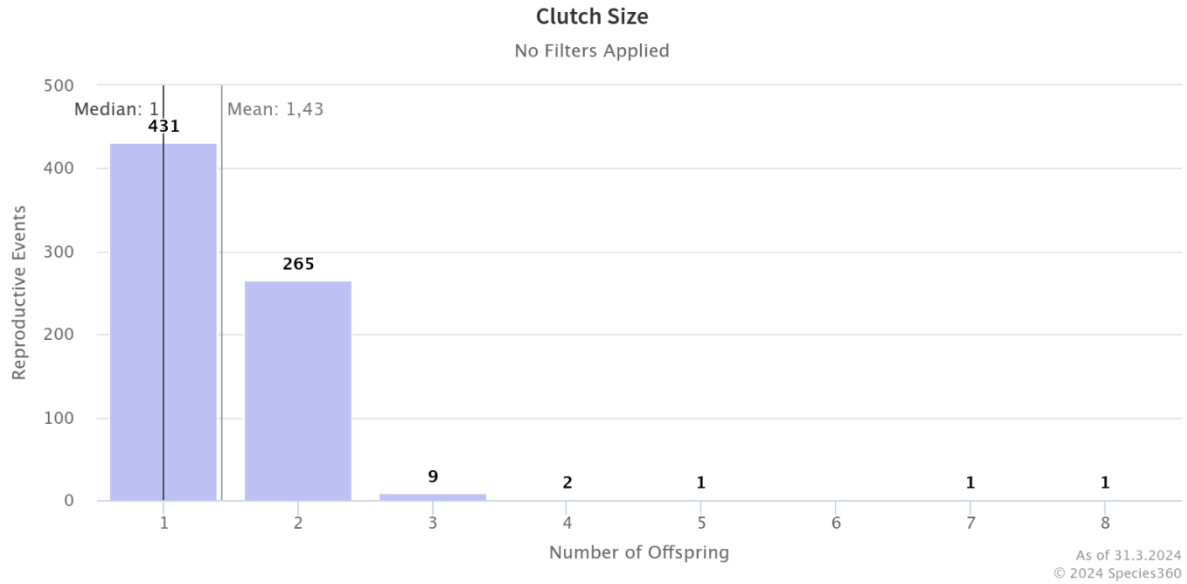

Fig. 23: Clutch size in Socorro doves of the EEP population (1995-2023)

However, it is not clear whether clutch size was always recorded correctly, as many nests were not checked on a daily basis and (especially very young) hatchlings may disappear unnoticed. As in many other species of dove, the usual clutch size is two. Occasionally a third or fourth egg is laid. These third and fourth eggs may not be laid in the regular interval of two days. They may come three or four days after the first two eggs. Sometimes only a single egg is laid in a clutch. Once the eggs are laid, as with other pigeons and doves, the pair takes turns incubating. The female typically incubates at night and the male during the day. The timing of this changeover can be fairly predictable for each pair. The male may come and go during daylight hours but the nest is rarely left unattended for more than 30 minutes at a time.

Incubation begins with the laying of the first egg. The second egg is usually laid two days after the first, frequently in the morning. When incubating birds leave the nest, the eggs are not covered. Except in the colder months, eggs can be left unattended for up to half an hour with no ill effect. If eggs are found to be cold, they are likely to have been abandoned, especially if they are cold early in the morning. During the day, it should always be confirmed that enough time has passed before intervening. Or, if in doubt, eggs should be replaced with dummies in the nest until it is certain that the adults are not returning. At Albuquerque Biological Park, when three or four eggs were produced, the adults have never been allowed to care for more than two eggs or chicks at a time. These larger clutches can be managed by moving an older chick out of the nest for hand- or foster-rearing and replacing it with a newly hatched chick from the incubator. The adults never seemed to notice the size disparities with these younger chicks. Infertile pairs readily accept chicks from the incubator if they had been incubating for the appropriate amount of time. Most birds will accept dummy eggs in place of real ones.

2.4.3. Contraception

Techniques possible to limit the number of offspring include separation of sexes and the manipulation of eggs, either by egg replacement with artificial eggs or piercing. There is hardly any experience with long-term housing of single sex (esp. male) groups. But, given the potentially highly aggressive nature of Socorro dove males, this can, currently, not be recommended. If at all, then keeping groups of young birds (i.e. younger than nine months of age) being under very close surveillance by keepers may be successful for a while.

2.4.4. Birth – Hatching

Studbook data shows that, in the European population, 60.7 % of chicks (n=431) hatched as singletons and 37.7 % (n=265) in twos. Incubation is generally not variable, with a 16-day incubation period being typical. Chicks that hatch at 14 or 15 days are likely to be compromised. Eggs that have not hatched by day 17 are unlikely to hatch on their own and will require assistance. If an egg has not hatched by day 16, the pair might abandon the nest, even if the egg is fertile. A second egg is likely to be lost at this point since it will be two days behind the development of the first egg. However, there are some individual birds that will incubate longer than expected. The incubation period for a second egg may sometimes be shortened by as much as 36 hours so that a chick hatching in the early morning may be joined by a clutch mate later that same afternoon. Indoor housing may make it sensible to think about UVB and/or Vitamin D supplementation.

Actively nesting birds should be difficult to scare from the nest. The sitting bird will vigorously defend the nest by vocalizing and slapping a hand that invades the nest cup to check on eggs or chicks. Eggs

can be easily (although inadvertently) damaged by the intruding hand or by the bird itself. The chicks are quite vigorous and supple but care needs to be taken to prevent the attending adult from stepping on the chick. On rare occasions, small chicks have been found out of the nest, possibly due to entanglement with the parent's legs or plumage during nest change-overs. There is no indication that adults have actively ejected chicks from the nest.

With sequential cycles, some pairs will use the same nest site repeatedly. Others may choose a different nest for each clutch. This frequently occurs when a current nest cycle is not completed and there are still eggs or chicks in the nest. Providing at least two nest sites gives the doves the option of starting a new nesting cycle while abandoning a current nest. It may be that having a single nest site might alleviate the issue of nest abandonment, but this has not been tested. More than likely, more eggs would just be laid in the currently occupied nest if there were no other options. Some zoos in Europe (e.g. Frankfurt) have reported eggs apparently from more than one clutch deposited in the same nest. Should there be a second nesting attempt begun in a different location while there are still eggs or chicks in the nest, the first nest will inevitably fail because the pair will not attend to two nests at the same time. The hard-wired process of nest exchange by the adults will usually shift to the new location.

Fertility can be variable. A newly established pair might be infertile for one or two clutches before producing offspring. The first year of a pairing seems to be the most productive. Over a period of several seasons, pairs kept together tend to show reduced fecundity. However, if they remain compatible and continue to nest, they can be excellent foster-parents. The incidence of re-nesting after chicks fledge or eggs do not hatch can be variable. Some pairs will recycle while there are eggs still in the nest. Other pairs may abandon chicks in order to begin another nesting cycle. Some pairs begin nesting immediately after chicks fledge while they are still dependent. Others may not nest again for weeks following a fledging, or indeed, not again for the rest of that season. Females can produce a relatively large number of eggs whether in the presence of a male or not. This may be a contributing factor in the abandonment of a nest to begin a new clutch. The female may be physiologically producing more eggs than a nesting cycle can support. In the absence of a male, production of eggs appears to be random.

2.4.5. Development and Care of Young

Parent-rearing: As stated before, it is rare that a chick is ever ejected from the nest. If a very young chick has fallen from the nest, it should be warmed and given subcutaneous fluids to revive it. Assuming the parents are still in attendance, if the chick appears strong, it can usually be returned to the nest. If the chick remains sluggish or unresponsive after warming, it is unlikely to survive and there is no point in trying to return it to the parents. The chick must be able to raise its head and elicit a feeding response from the adults. Any nesting pair that has a chick of similar age or slightly older can be called into service to foster a robust, rejected chick. Sometimes a nest will be abandoned just before anticipated hatching of the first egg. This scenario is most likely when the female is re-cycling and needs to select a nest location for the next clutch. Absent of this re-cycling stimulation, it is unclear what prompts a pair to desert a nest just prior to hatch. It is unknown if the male is playing some role in nest abandonment.

Day 16 in the incubation timeline is critical. If the first egg has not hatched by that day, the pair may abandon the nest. This can be true even if both eggs are fertile. It may be that their internal clock tells them there should be a chick and if that is not the case, they may abandon the nesting attempt. This is not the case for all individuals, but is true for most. If the nest is left unattended for more than 30 minutes, steps may need to be taken to replace the egg(s) with dummies and move the eggs to the

incubator or surrogates. Once the nest has been left unattended for an hour, they will not be returning to it.

With two-egg clutches, as soon as the first chick hatches, the parents will feed it from their crop. The crop milk they produce is thin, but very quickly solids from the adult's crop can be passed on to the chick(s). A healthy chick will always have food in the crop. When an egg hatches in the nest, the parents will remove the egg shell and deposit it away from the nest. This is an important cue for both parents that an egg has hatched. It also confirms to the keeper that a hatching has occurred without disturbing the nest. If it is possible to monitor the fullness of the chick's crop in the nest, health status can be routinely evaluated. Chicks which are not being adequately fed will quickly grow weaker and become less able to solicit food from the adults. The action of feeding requires that the chick be able to place its bill into the parent's mouth. The parents cannot feed the chick if it does not respond to them. To this end, cameras can be used to monitor nests. A chick which does not have a full crop at all times is being neglected and is unlikely to survive. If everything else is proceeding normally, supplemental feeding of the chick using a feeding tube may be possible.

Development of the young: It should be stressed that some pairs will tolerate human disturbance at the nest, while others will not. Very occasionally, even experienced parents may accidentally crush a chick in the nest shortly after hatching. There is no way to predict this and it is not common. In contrast to the egg incubating period when the parents may leave the eggs for short periods of time, chicks will rarely be left unattended during their first week of life. Heidelberg Zoo reported a very interesting behaviour (in two different pairs): During handling of chicks for banding, adults of both sexes showed a distraction behaviour feigning broken legs, and flapping both wings while lying on the ground (similar to some wader species). At the point of fledging (Fig. 24), the chicks may be left alone for extended periods with the parents coming back to feed them on the nest. The chicks will ultimately leave the nest on their own, but will continue to pursue the parents to be fed. Late in the season, the chicks may continue to depend on the parents for a longer period. In contrast, early in the season when the adults are anxious to recycle, the chicks may either be abandoned in the nest or shortly after fledging while the female produces a new clutch. At this point, the chicks may continue to depend on the male for feeding while the female incubates. While off the nest, some females may chase the fledged chicks, but without negative effect. Chicks will fledge between 14 and 20 days of age. They will typically be independent of the adults at about six weeks. This timeline can be shortened considerably if the pair has begun to nest again. Therefore, and due to several possible matings per year, up to 12 young can be produced by a single pair in one year.

Fig. 24: Socorro dove fledglings at London Zoo (ZSL)

If either of the parents becomes obviously aggressive toward the chicks in anticipation of another nesting cycle, the chicks will need to be removed from the enclosure. The age at which the need for separation of offspring from parents seems variable and down to individuals or, even, individual situations. At Frankfurt Zoo, chicks have been separated (from either parents or sire) at a minimum age of 25 days (due to aggression by the sire) and a maximum age of 90 days (for a total of 17 clutches after 1 Jan 2000). If the chicks are not completely self-feeding, it can be helpful to house them with other juveniles of a similar age to stimulate self-feeding behaviour. Basel placed two not completely self-feeding chicks in an aviary adjacent to a single adult; this seemed to help stimulate feeding even though they were not in the same aviary. Older chicks still in the nest may even feed each other. The male may continue to feed the chicks when he is not tending to the new nest. After fledging, the chicks may not be flighted (depending on how long they remained in the nest) and may spend their first few days on the ground, hiding under the low vegetation that was prepared prior to the first nesting attempt. Younger birds will only emerge to be fed by one or both of the adults. Within a week, they should be exploring the enclosure and beginning to perch. Once they are able to fly adequately, they are unlikely to spend time hiding.

According to the data from the EEP studbook, the youngest age at first clutch for both females and males is close to 6 months; while the oldest male to have bred was 12.4 (n=181), the oldest female was 10.7 (n=180) years of age (ZIMS for Studbooks, 31 Dec 2023). Nevertheless, median and average age of reproduction is about 2.2 years, and birds rarely reproduced at the age of 6 years or older (Fig. 25).

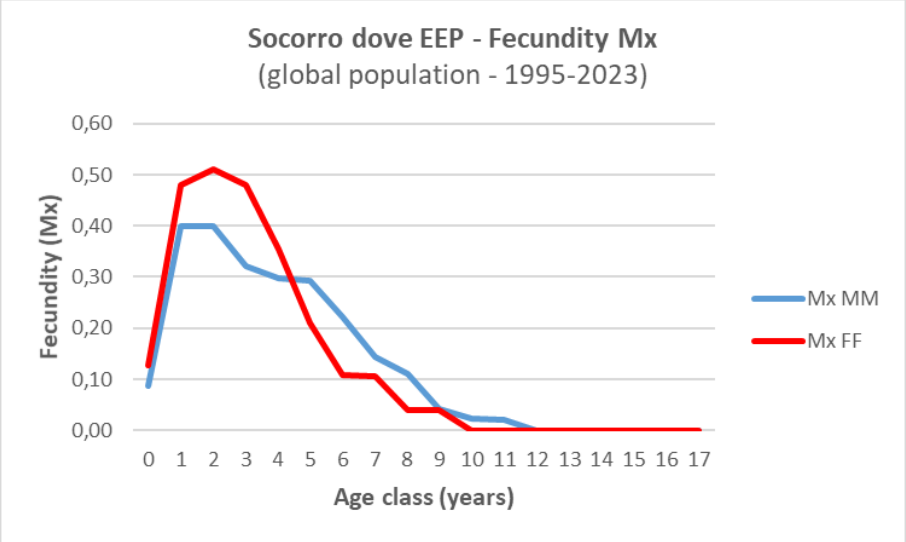

Fig. 25: Age-related fecundity (Mx) of Socorro doves in the EEP (global) population (n=915)

2.4.6. Hand-Rearing

Artificial incubation: When it has been necessary to collect abandoned Socorro dove eggs for artificial incubation, standard incubation techniques have been successfully employed. A typical avian incubation temperature of 37.5 °C and a relative humidity ranging between 40 and 60 percent is adequate. The eggs should be turned 180 degrees a minimum of five times a day, but more frequent turning is probably better. Mechanical incubators can be more reliable, but hand turning will suffice.

Data for the fresh weights for eggs collected from the nest is available from Albuquerque Biological Park and have ranged from 6.8 - 9.1 g, averaging about 7.73 g. The measurements of these eggs have ranged from 27.91 x 21.62 mm to 31.27 x 22.16 mm. This is not a comprehensive list of weights and measurements of all the eggs that have been incubated, but represents a large sample size from many years of data collection (Shannon, pers. comm.).

Eggs left in the nest for incubation and hatching are typically not handled for data collection. The hatching cycle for Socorro doves is typical of most birds. Generally, if the chick reaches the external pipping stage, it will hatch. Artificially incubated eggs do seem to have a disproportionate number of malpositioned embryos. However, since most chicks are hatched under the parents and have a short pip-to-hatch interval, it is not known how prevalent malpositions might be among parent-incubated eggs. Artificially incubated embryos that are positioned incorrectly (upside down, sideways, longitudinally, etc.), will typically hatch if they make an external pip anywhere on the shell.

Should the hatching process extend past 16 days, assistance may be required to free the chick. Incubating birds will typically accept dummy eggs in place of their own. This facilitates manipulation of eggs by moving them between nests or to and from the incubator. Incubating doves will accept newly hatched chicks from the incubator as long as the 14-16 day timeline for length of incubation is followed.

Hand-rearing: Hand-rearing is the least practical way to raise Socorro doves. Because behavioural consequences of hand-rearing are not yet fully understood, this management strategy should be approached with caution. The time and effort directed towards hand-rearing could ultimately prove to have been poorly spent. It should be considered as an option when rapid population growth is required, the facilities and expertise exist to make it feasible, or a genetically / demographically important chick is at risk.

There are three scenarios in which hand-rearing might need to be considered: The first is when a fertile egg is hatching in the incubator and there are no foster birds available to receive it. The second is when the nest is abandoned while a chick is in the nest; this may happen due to either the loss of a parent, or the pair has begun a new nesting cycle in a new location prior to the chick fledging. The third is rejection of a chick in the nest due to illness, injury, or some type of disturbance at the nest that prompts the parents to leave.

Albuquerque Biological Park has found raising chicks that hatch in the incubator to be extremely challenging to rear successfully: “Of the one dozen or so chicks that the Albuquerque Zoo has attempted to raise from the point of hatch, only three survived. The first female had significant deformities of the toes (a housing issue). The second one was a male and was imprinted on humans to the point that he was unlikely to ever pair properly and breed. The third chick, however, was a female that did pair up and breed successfully. Most of the other chicks died in their first week. Staff attempted seeding the crops with fluid from adults but this did not seem to have any positive effect. Considering the time and effort that went into these hand-rearing attempts and the outcome, this

should not be considered a viable approach to Socorro dove breeding without greater expertise" (Shannon, pers. comm.).

However, a recent attempt at hand-rearing Socorro doves has been successful, and, as reported, with an achievable amount of input. A summary of events contributed by Gavin Harrison, Assistant Curator of Birds at the Waddesdon Manor Aviary (UK), is given unabridged in Appendix II:

If chicks are abandoned in the nest and have had some parental care, they are relatively easy to hand-rear to fledging. The process can be time-consuming. Very young chicks (one to five days old) can require feeding every two hours so as not to overfeed them. But, unless there are medical considerations, they do not require feedings through the night. As they get older, the feedings become less frequent as judged by the volume of food they are fed and the time it takes for the crop to clear. Depending on the age when the chicks were pulled, the chicks should be independent and self-feeding within two weeks. It is generally best to have at least two chicks raised together both for the benefits of socialisation and to promote faster weaning. Chicks reared in a cohort tend to develop faster. There are numerous baby bird formulas on the market, which suffice for raising Socorro doves. Some holders will hand-feed dove chicks from an open syringe whereas others use a metal feeding tube to supply formula directly into the chick's crop. A small amount of liquid "formula" can be easily inserted into the crop by an experienced keeper. Care must be taken not to overfill the crop. A parent-reared chick's crop will feel "mushy" and look like a balloon. Tube feeding should not duplicate this crop appearance, merely maintain a supportive volume of food. Once a chick becomes compromised, it is very difficult to save it. Either way, dove chicks past a few days of age tend to be hardy and are adaptable to a wide range of techniques.

Foster-rearing: It is beneficial to have options for foster-care of abandoned eggs or chicks. Ideally, larger collections of Socorro doves will have compatible non-reproductive pairs that have been proven to be capable of raising chicks. Edinburgh Zoo has reported successfully fostering an abandoned chick to an active nest that already held one chick (C. Oulton, pers. comm.). Since timing is critical for Socorro doves to be willing to accept chicks, ring-necked doves (*Streptopelia capicola*) or other domesticated species can be used as backups should a Socorro dove need to be fostered. These domesticated birds are more likely to be willing to raise a dove on short notice than will a pair of Socorro doves. In Albuquerque Biological Park, a nesting pair of two female ring-necked doves has been used for fostering newly hatched Socorro dove chicks when necessary. For social development, it may be advisable to have conspecific(s) in an adjacent aviary. However, this strategy does require facilities and staffing resources that may not always be available. Fortunately, over the years a limited number of Socorro doves have needed to be foster-reared. These chicks can be birds that hatched in the incubator and for which there are no adult pairs suitable to foster them to when needed. Of a total of 68 foster-reared Socorro doves (i.e. 5.9%) in the EEP studbook (n=1145), 29 (43 %) did not reach 30 days, and another four died before the age of nine months.

2.4.7. Population Management

In human care, Socorro doves can and have bred year-round. In Europe, there is, however, a clear peak during the summer months with fewest hatch events from October to December (Fig. 26). However, the data is most likely biased, to an unknown amount, by management decisions to separate pairs as a response to, or even to prevent from the outset, aggressive (and potentially fatal) interactions.

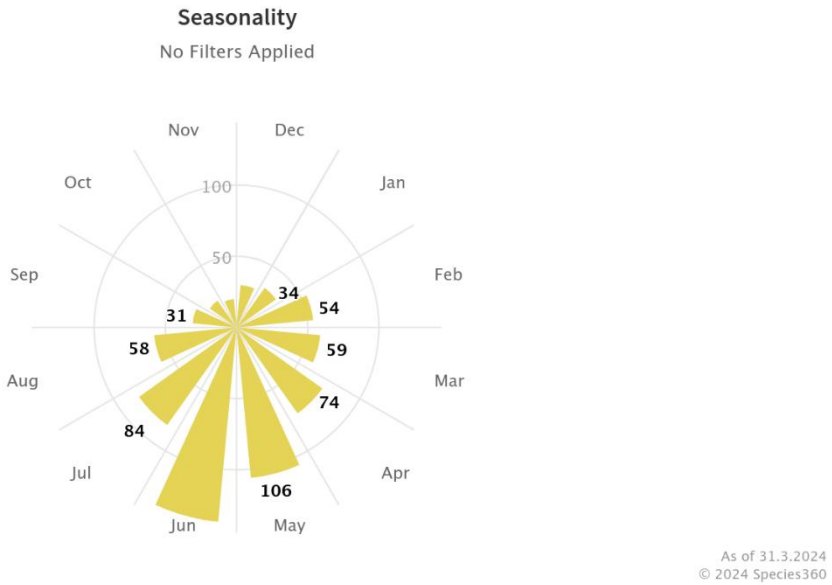

Fig. 26: Seasonality of reproduction in the European population of Socorro doves

A similar picture appeared at Albuquerque Biological Park (Fig. 27), where the breeding season begins in December and may extend into August-September, sometimes October, depending on the circumstances of pairing, nesting success, and pair compatibility.

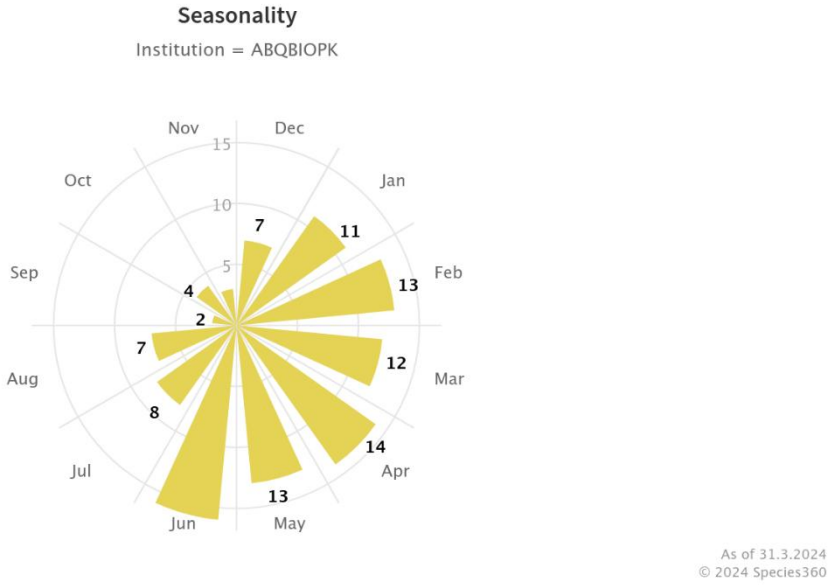

Fig. 27: Seasonality of reproduction in Albuquerque population of Socorro doves

As a result, there can be offspring as early as December that could potentially be mature by the end of June. Flocking youngsters throughout the course of the breeding season becomes a viable and often necessary management strategy. However, care must be taken when flocking early-season juveniles with later chicks that may not be ready to deal with potentially sexually motivated aggression by the older birds.

Interestingly, the (still somewhat limited) data from the Mexican subpopulation (Fig. 28) seem to show a peak in Dec/Jan with hatches, albeit fewer, also occurring from March to September.

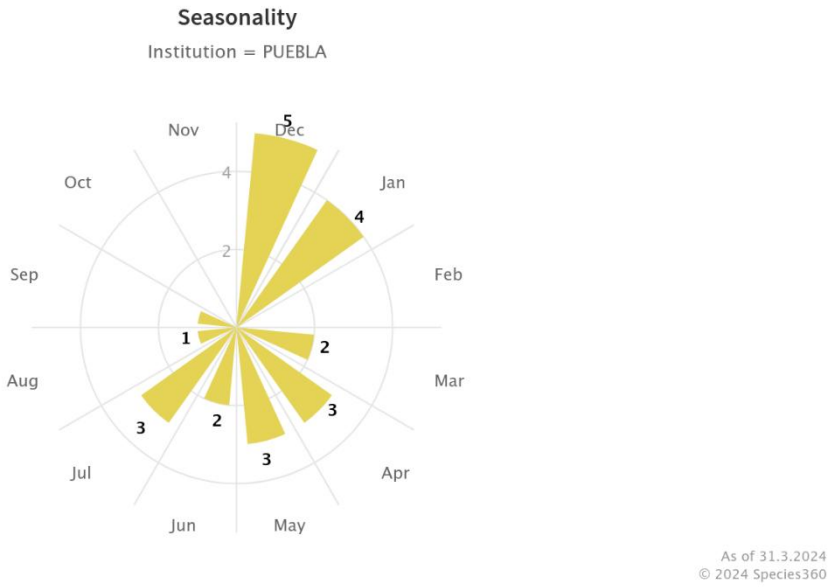

Fig. 28: Seasonality of reproduction in Mexican (Africam Safari) population of Socorro doves

It is advisable to confirm the sexes of young birds as soon as possible so that they can be managed appropriately. Techniques are available for non-invasive sexing of birds from eggshells (single chick clutches) or from a drop of blood after a chick has fledged. Young mixed-sexed juvenile flocks can typically be viable until the older males in the flock mature. Once a male juvenile begins to present territorial or display behaviour toward other birds in the flock, he must be removed in order to maintain stability of the group. This is especially important if the other juveniles (of either sex) in the group are not yet displaying mature behaviour.

A group of juvenile males raised together can potentially be maintained successfully for up to two years. However, there needs to be sufficient vertical space and cover to allow the birds to separate themselves spatially. It may appear that birds in such flocks are compatible, but closer observation is likely to show that, aside from the times they come together to feed communally, the birds will have established small territories to which they retreat where other birds will not typically bother them. Introducing a new bird into these stable groups is typically not possible because it will disrupt the social order.

Typically, mature males can only be housed alone or with a single female partner except in very large spaces. Mature females can more easily be held in female-only flocks. However, there can be dominant females in same sex flocks that may become aggressive toward other birds. As always, regular observation is necessary to determine the compatibility of groups. Whenever individuals can see or hear other birds, there will be communication between them. This can be problematic, if birds are “paired”, but begin responding to visual or auditory stimuli of a bird in another location (especially in adjacent enclosures). There have not been any injuries noted from these changes in attraction. However, when pair bonds begin to break down, it has been important to be proactive in removing the offending bird or re-pairing birds as appropriate. Once the pair bond begins to dissolve in the presence of other birds, it is not likely to be restored.

2.5. Behavioural Enrichment

At this point in time, there is little information on specific measures to promote behavioural enrichment. Aviary structure and social structure seem to be the key factors in keeping this species successfully. As mentioned before, dense cover, ideally provided by natural vegetation, helps in mitigating the potentially adverse effects of intraspecific aggression. To promote breeding, keeping the species in pairs of similar age is the way forward. It has been speculated that keeping two or more pairs in close proximity (adjacent aviaries) may have a positive effect on reproductive success, although no quantitative data has been made available so far.

2.6. Handling

2.6.1 Individual Identification and Sexing

If the chicks are going to be close-banded, this has to occur while they are still in the nest. They grow quickly and if one waits until after fledging, the band may not slide over the toes. The band size that has been used repeatedly is 9.0 – 9.5 mm and it is put on the chick at ten days of age. A number of EEP holders have successfully used rings of 6.5 mm issued by the EEP during the early years of the programme.

It should be noted that chicks of this age might be prone to jumping from the nest after being handled. To reduce this risk, it is advisable to keep a hand over the chick when it is returned to the nest until it appears to be calm. One of the parents should return quickly. Plastic roller pigeon (or other suitably sized) bands are used for visual ID later as needed. If “spiral” type bands are used, they must be monitored to ensure that the end does not work its way into the scales of the leg and cause injury.

2.6.2. General Handling

When Grayson described the species as “the friendly dove”, this was indicative of their calm nature and approachability. Even in large spaces, the birds have a tendency to be underfoot and curious about activities in the space. Especially when fresh food is presented, they are not shy about approaching the dish even when the keeper is busy with other tasks. Care needs to be taken to not accidentally step on a bird or have it follow you out of an open door. Some birds can be habituated to being touched, however Socorro doves should only be handled when necessary and should not be over-handled. They have the potential to lose large numbers of feathers if they are handled incorrectly. Whenever birds are handled, they should be weighed to add to the database of normal weights.

2.6.3. Catching and Restraining

A deft touch is required to catch a Socorro dove quickly and safely. They should be restrained using one hand around the body of the bird, holding both wings firmly into the body. The head of the bird can be held between the index and forefinger of the same hand. If the handler’s hands are too small and find holding with one hand difficult, two hands can be used. Hold both hands around the bird’s body, the left hand on the left hand side of the body and the right hand on the right hand side of the body holding both wings firmly into the body. Birds that are spooked or chased with a net can become quite evasive. Typically, in larger spaces, at least two people are required in order to facilitate moving a bird back and forth until it is netted. Even in small spaces, they are swift and agile fliers. Care must

be taken to prevent injuries that can happen when aggressive use of the net results in accidentally striking a bird with the ring or handle of the net. Birds should not be chased to the point of exhaustion. If a bird is not captured within the first few minutes of the effort, a rest period should be initiated to give the bird a chance to recover from the exertion.

To avoid capture by predators, their feathers are loosely attached and pull away easily when tugged. During aggressive chases by the keeper, the birds are prone to losing feathers if handled or chased roughly. Tail feathers are the most vulnerable. This is especially true during a chick's first moult and the adult's fall moult when many feathers are growing simultaneously. The aim, once the bird is in hand, must always be to control the body and wings in as short a time as possible. The feathers lost during a capture event do begin to re-grow quickly. During periods of moult, care must be taken to avoid damaging actively growing "blood feathers". These feather shafts are engorged with blood and may bleed profusely until cauterized or pulled.

In larger spaces, the doves will utilize as much height as they are provided. Consideration needs to be given to circumstances in which birds will need to be caught. Depending on the space, perching should be arranged so individuals can not perch out of reach in case they need to be captured. In small aviaries, Socorro doves should be caught using dark cloth bag nets preventing them getting tangled. In larger aviaries or tropical houses, the use of trapping areas should be used. Birds can be enticed into these areas with food, then caught using the bag net. Basel uses either capture/ feeding cages in aviaries, or mobile catch up cages in free-flight halls with great success (Fig. 29).

Fig. 29: Capture/feeding cages for birds used at Basel Zoo. (Basel)

2.6.4. Transportation

In the past, many zoos have built their transport boxes themselves and, thus, various types of crates were in use. In recent years, animal transportation has been conducted increasingly by specialist animal transport companies who usually have their own stock of crates for the different species with their different requirements. At any rate, regulations put down in IATA container requirement 15 (International Air Transport Association (IATA), Live Animal Regulations LAR, 2024) should be followed. For short land transports of a few hours (max) or in-house moving of doves, cardboard boxes of adequate size can be recommended.

2.6.5. Safety

Socorro doves are not aggressive and will cause no harm to keepers looking after them. Awareness of birds escaping needs to be considered as these birds tend to fly straight and low or walk on the ground and can be overlooked.

2.7 Veterinary: Considerations for Health and Welfare

So far, the Relevant Death Information (RDI) on SPECIES360' ZIMS Husbandry revealed only 14 % "Useful RDI records" for the species (Fig. 30), despite repeated efforts by the EEP to collect post-mortem reports from participating EEP institutions.

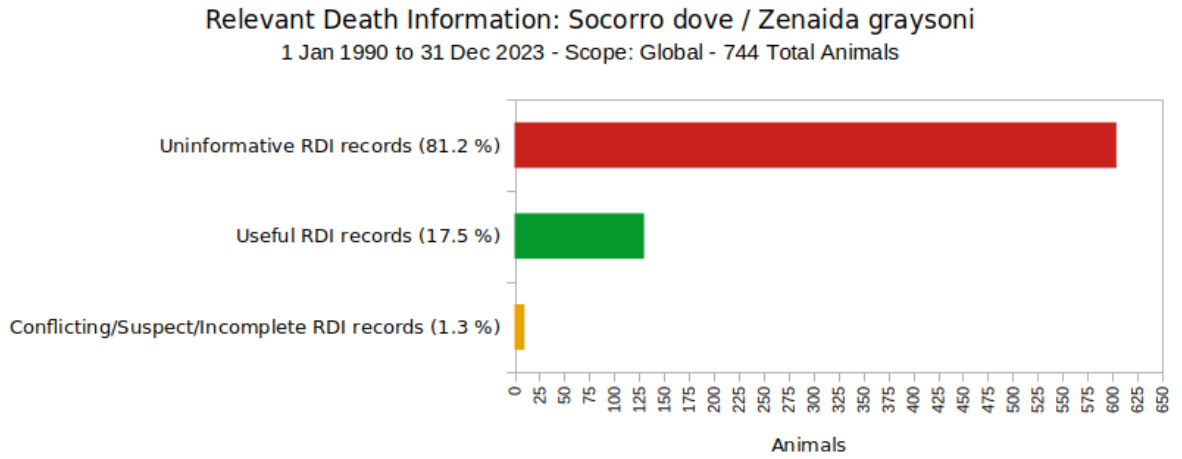

Fig. 30: Relevant Death Information 1990 – 2023 (ZIMS Husbandry; SPECIES360)

In collaboration with the EEP and the vet advisor, the Wildlife Health Department of the Zoological Society of London established a mortality survey programme in 2024. This important analysis is dedicated to establishing means of prevention of unnecessary deaths, especially with the aim to stabilize population size and to address the skewed sex ratio (in favour of males). These factors are believed to be of exceptional importance, given the species' status in the wild (IUCN EW) and the EEP population's main conservation role ARK/Insurance (Stadler et al, 2023), in combination with the in situ efforts of the Socorro Dove Project to return the species to its home, Socorro Island.

Health: Typical quarantine procedures apply to the movement of birds between facilities. Each institution develops its own protocols. These might include physical exams, disease screening, isolation, testing for specific pathogens, or other precautions to prevent introduction of novel organisms to an institution's collection.

Drawing blood for routine medical testing is feasible. Leg sticks can be difficult, but jugular draws are possible for skilled practitioners.

Tears of the skin anywhere on the body are relatively easy to stitch and usually heal quickly.

Albuquerque Biological Park reported a bird that entangled a leg in the fibres of an overhead shade cloth overnight. By the time it was discovered in the morning, the leg had been so badly damaged that it had to be removed at the hip. The bird recovered and subsequently learned to successfully manoeuvre on the single leg. Similar cases were reported from the EEP population. Such injuries usually lead to exclusion of these individuals from the breeding stock as they are no longer able to copulate successfully. Depending on the birds' genetic status and if there are no welfare concerns, it may be advisable to continue trying to breed from them.

Non-infectious diseases: Weight issues have been reported to plague Socorro doves but are relatively easy to manage. The birds will over-eat high calorie items if given free choice. Regular recording of weights whenever a bird is in hand should provide an individual database to help identify a healthy weight range for each bird. Since the birds are generally housed singly or as pairs, it is relatively easy to customize diets as needed for weight management. Underweight birds may need to be offered higher calorie diets if their weights remain persistently low. Social stressors should be considered as a possible factor leading to low weights.

Albuquerque reported the loss of one female due to inadequate calcium levels and thin bone density. The problem was discovered when she was found on the ground, unable to walk. During supportive care, she laid a poorly calcified egg. Following recovery, she was given supplemental calcium and returned to her enclosure. Shortly thereafter, she was found on the ground with fractures of both legs and wings. Despite treatment, she did not survive. Subsequently, the rest of the doves were routinely supplemented with calcium and phosphate (cf. chapter Diet/ Special dietary requirements). It is unclear as to whether this female's reproductive status played a role in calcium depletion for the production of this (her only) egg. Basel also reported to have lost two young (aged 21 and 32 days, respectively) offspring with broken legs. Because the doves can lay a considerable number of eggs in the course of a year, whether nesting or not, calcium depletion should be considered an important factor in maintaining good health.

Machine incubated eggs have routinely resulted in malpositioned chicks, but this generally has not prevented them from hatching. Because most parent incubated eggs were not handled prior to hatching, it is unknown whether these malpositions were present in naturally incubated eggs.

Infectious diseases: Good hygiene management and precautions such as to ensure that food and water bowls are cleaned regularly will help prevent the spread of infectious disease. Removing faeces that collect on or under favoured perches should also be part of routine husbandry. Preventing the intrusion of small birds (finches, warblers, etc.) helps to reduce potential disease transmission from wild birds.

Viral diseases: Avian pox (AvP) is frequently seen in wild bird populations of many bird species. It has also occurred in Socorro doves in human care, notably in at least one institution in the US. As with most doves, typical symptoms are the development of sores and pustules on the legs and face. With supportive care, the disease appears to be self-limiting. Whenever infections occur, concern should be focused on the possible transmission of the disease to other individuals. It is spread via contact transmission. An infected bird can deposit the virus on perches, substrates, edges of food bowls, preening by other birds, or from faeces. It can also be spread by mosquitoes. So far, birds that have recovered from AvP have been (and should be in the future) removed from the managed Socorro dove

population since it is unknown at this point how their exposure might affect future transfer of birds including potential returns to Mexico or release efforts.

To date, West Nile Virus (WNV) does not seem to have been reported in Socorro doves. However, WNV remains a concern, especially with regard to future potential releases of birds on Socorro Island. As part of a reintroduction plan, screening procedures will be developed for WNV and any other potential infectious diseases.

Avian influenza (AIV) has become a regularly re-occurring concern in recent years for bird collections in both Europe and the US, but also on a global level. Outbreaks have periodically forced the closure of bird exhibits in zoos in order to protect collections from inadvertent exposure via public contact. Recent outbreaks of varying intensity (predominantly H5N1 and H7N3) have been reported from basically all parts of the world (see e.g. https://www.woah.org/en/disease/avian-influenza/). It is currently restricting bird movements in various regions and almost certainly will have effects on future movements of zoo birds between facilities. The virus has been present also in Mexico for decades, and it prohibited the transfer of Socorro doves from the EEP to Mexico, and, more recently, affected the one from Albuquerque to Africam Safari in 2016. A survey of AIV in pigeons and doves in 2014 indicated a low susceptibility to the virus (Abolnik, 2014); it is unknown, however, whether Socorro doves are susceptible to AIV and how its presence might affect future re-introduction efforts on Socorro Island.

Parasites: As with other dove species, routine screening for endoparasites should be conducted. When housed outdoors, the birds may have exposure to wild bird droppings, a potential source of parasite stages. Faecal flotation exams are the most common screening technique used. Ectoparasites seem to be uncommon. However, ABQ documented occasional cases of sticktight fleas (*Echidnophaga gallinacea*), which were easily controlled by a dusting with commercial poultry powder.

In 2011, Chester Zoo reported a series of renal trematode infestations ("eucotylid trematodiases") in a number of (endangered) bird species including Columbiformes. A subsequent study discussed the epidemiology, pathology and consequences for the management of these endangered species and highlighted preliminary work on developing an effective ante mortem diagnostic PCR test kit (Unwin et al., 2012).

In order to assess potential health risks prior to any planned Socorro dove re-introduction, pathogen screenings of the avifauna of Socorro Island were carried out in 2004 and 2009. Various lineages of *Haemoproteus*, a blood parasite, were identified via PCR and microscopy in the Socorro ground dove (*Columbina passerina socorroensis*), the mourning dove, and the Northern mockingbird (*Mimus polyglottos*). Another blood parasite, *Leucocytozoon* spp., was isolated from mourning and ground doves. In addition, Plasmodium (*Haemamoeba*) sp. was detected in a single mourning dove. Pigeon louse flies (*Pseudolychia canariensis*) were present on several mourning doves. Louse flies serve as vector organisms for haemosporidian parasites such as *Haemoproteus* spp. In both mourning and ground doves, nematodes (*Ascaridia* spp.) were present in the faeces. Whether Socorro doves in the wild originally have been infested with these parasites with health-related consequences remains unknown. Once they will be re-introduced on Socorro Island, however, they will certainly establish new host-parasite interactions (Carlson et al., 2013; Yanga et al., 2011). The authors of these studies, therefore, suggest additional investigations on potential infestation and effects of the identified parasites in captive Socorro doves prior to any release.

Bacteria and fungi: Chick mortality in the nest can be high, as, e.g., in the early stages of the Albuquerque Socorro dove programme. Overall 30-day mortality in the European population stands (PMx; April 2024) at 36 %. Chicks were frequently being lost in the first few days after hatch from a variety of common organisms (*Aspergillus sp*., *Candida sp*., etc.). A programme of prophylactic treatment of the adults' drinking water with antibiotics after hatching largely eliminated the problem.

Miscellaneous: When feathers have been lost due to routine moult or traumatic injury, they tend to be replaced quickly. A condition in which feathers on the head and neck are lost due to excessive scratching has been documented in several birds in a number of institutions. This feather condition may follow a traumatic injury but has also been reported to occur spontaneously. Topical treatment of the exposed skin does not seem to facilitate healing. The condition does not appear elsewhere on the body. Both the causation of the behaviour (which may include husbandry, genetics or other) and the overall effect on the population is, so far, not yet clear and is, therefore, on the list of activities of the EEP vet advisor.

Mortality: The Socorro dove appears to be a hardy aviary species. Aside from chick mortality (according to PMx, 30-day mortality of the global EEP population between 1995 and 2023 (n=746) is 0.22, with males (n=384) at 0.21 and females (n=362) slightly higher at 0.23), old age and traumatic injury seem to have been the major factors in the deaths of Socorro doves. First-year mortality of the same data set was 0.33 (n=672) and similar between the sexes with 0.32 (n=343) in males and 0.34 (n=329) in females. Whereas there were few sex differences in the young birds, average mortality of reproducing birds (0.20; n=272) differed strongly between the sexes with 0.16 (n=141) in males and 0.24 (n=131), i.e. 50 % higher, in females.

Beyond the first year, and during the reproductive phase, attrition rates show no particular increase or decrease with any of the annual age classes. Qualitatively, reasons for adult mortality have included age, predation, male-on-female aggression, capture injuries, and a variety of unique events. However, as mentioned above, a thorough analysis of Socorro dove mortality and its causes is underway and is expected to provide useful insights into the demographic population dynamics.

2.8. Specific Problems

The managed population of Socorro doves has long been skewed toward males. An analysis of the European population sex ratio at birth (this includes only those birds that survived to an age at which sex determination was possible) between 1995 and 2023 has been in favour of males in 26 of 29 years (Fig. 31).

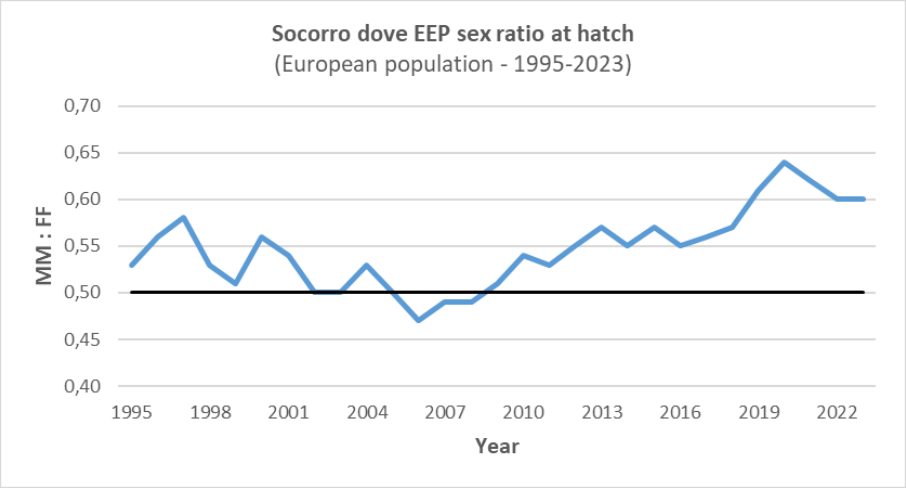

Fig. 31: Proportion of male to female hatches in the European population of Socorro doves (1995 – 2023)

The same holds for the global population (Fig. 32)

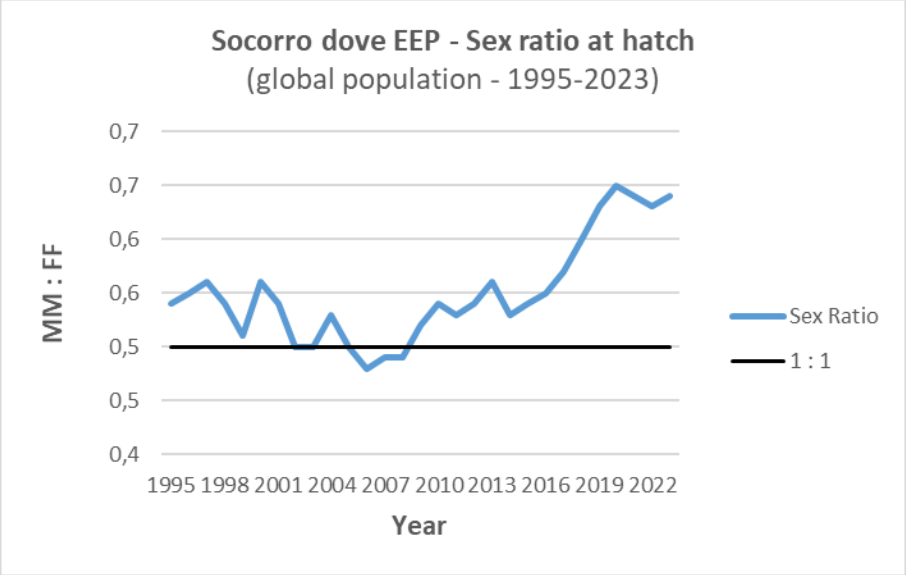

Fig. 32: Proportion of male to female hatches in global population of Socorro doves (1995 - 2023)

In addition, female deaths have been higher in all but the first year age classes (Fig. 33), …

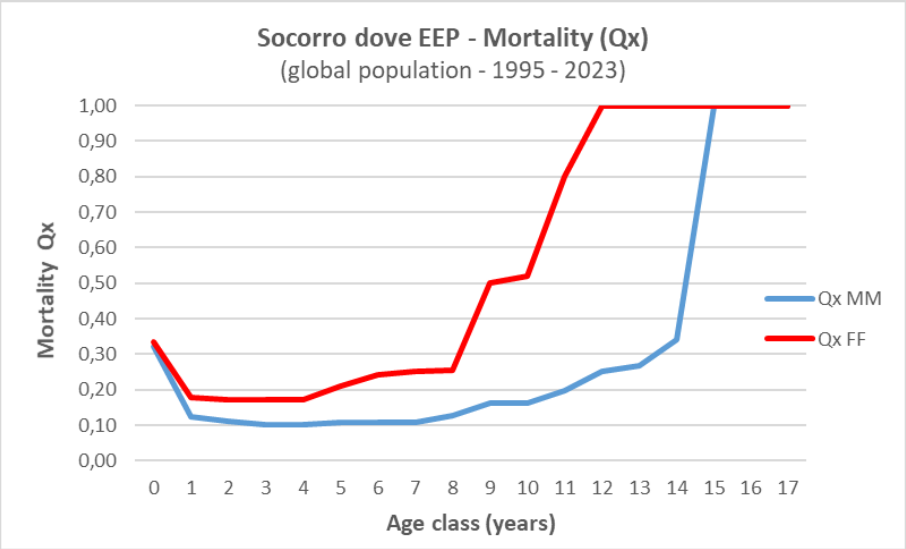

Fig. 33: Sex-related mortality (Qx) in Socorro dove (global population 1995 - 2023)

… and, consequently, survival in males is higher and males have longer lifespans than females (Fig. 34).

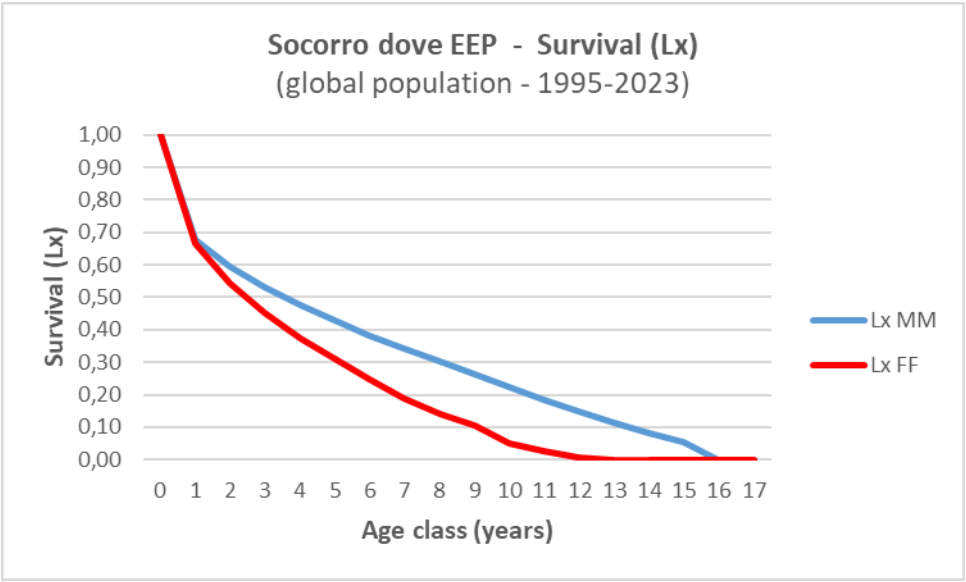

Fig. 34: Survival (Lx) of male and female Socorro doves (global population 1995 - 2023)

The skewed sex ratio presents challenges for efficient utilisation of available space. Recruitment of additional participants or increased holding capability of existing partners will be necessary in order for the population to expand. Planning for the retirement of birds needs to be part of the overall management programme for the species. Facilities that can use older birds for education or display will become increasingly important. With birds potentially living for 10 – 16 years, well beyond their average reproductive life spans, space will need to be devoted to older individuals as they reach

reproductive senescence. Efforts should be made to maximize their value as ambassadors for conservation, both on a global scale and specifically for Socorro Island. In view of these challenges, the EAZA Long-Term Management Plan for the species entails the option to send old age and/or male surplus birds to non-EAZA facilities to relieve important aviary spaces for reproductive individuals.

Eventual re-introduction efforts will change the dynamics of the programme from population maintenance to rapid expansion in order to support releases. This new phase will require different skills and infrastructure. Much of the planning for this effort lies in the future. The generations of keepers, curators and support staff who have worked on this effort are to be commended for their devotion to the management of this little-known species. Without that drive to forestall the disappearance of one of the rarest of the rare, the Socorro dove could have easily slipped into the history books as just another casualty in the race toward extinction.

2.9. Recommended Research

As laid down in the Long-Term Management Plan for the species (Stadler et al., 2023), the following research topics will be of prime interest in the coming years**:**

- The causes and treatment of neck-scratching behaviour;
- the causes of the sex ratio imbalance in favour of males and a comparison to the (potentially differential) mortality of males and females of various other pigeon and dove species;
- the effects of the relatively long history of the species in human care on the extant *ex situ* population;
- a comparison between the current pedigree based on assumptions of the relatedness of the founder individuals, originating from extensive enquiries with the Socorro dove breeders, vs a genetic assessment to validate those assumptions on a molecular level.

Ideas to investigate the age-related decrease of reproduction would be appreciated.

In addition, the following research projects, based at the Zoological Society of London (ZSL), have been initiated:

1. "**Retrospective Mortality Review of Socorro Doves (*Zenaida graysoni*) held in European and North American Zoological Institutions between 2003 and 2023**" by the Wildlife Health Department of ZSL in collaboration with the EEP vet advisor;

2. "**The Socorro Dove as a model for studying species changes occurring during captivity**", to be conducted in combination with a similar study on another Extinct-in-the-Wild (IUCN EW) species of bird, the Sihek (also known as the Guam Kingfisher). The interest here is in morphometric data of current (breeding programme) individuals (both living and deceased) in order to compare with data from wild specimens, which are, in principle, available in museums. This information is intended to help in determining morphological variation between "modern-day specimens and pre-extirpation museum specimens", but also indicate those morphological traits may have changed since the species entered captivity. In addition, there is interest in basic information on reproduction (egg data), which may indicate the recovery potential of the species.

3. "**Recovery planning of Extinct-in-the-Wild species, linking wildlife health with population viability, and understanding recovery potential of endangered species**." As a tool, a matrix population model will be used to get estimates of how sensitive the population growth rate is to different sex- and age-classes in the population. The interest is primarily on species with long breeding seasons and where good demographic data exists to try out the different models.

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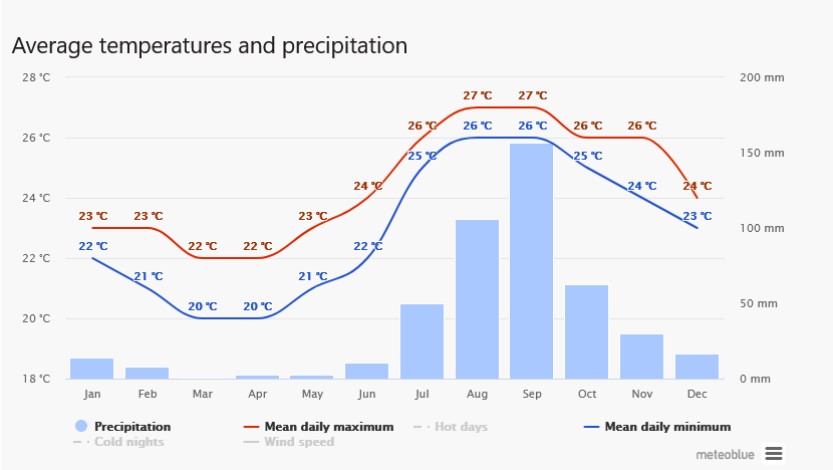
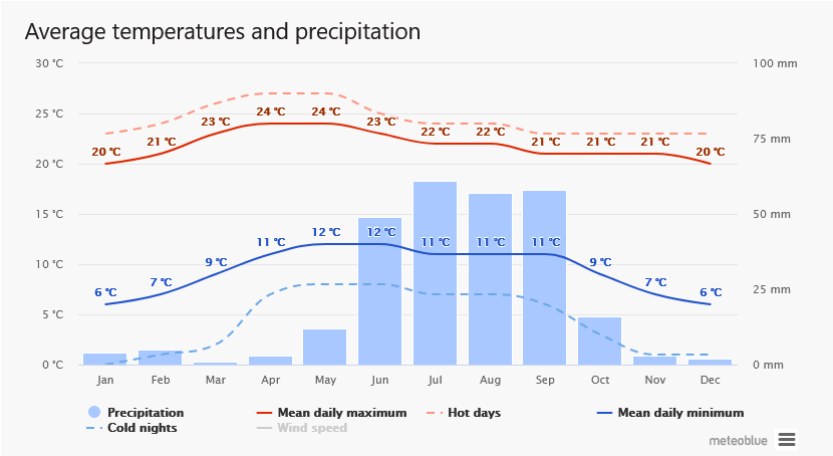
Appendix I



Climate data for Socorro Island (avg 1993-2023; from https://www.meteoblue.com)



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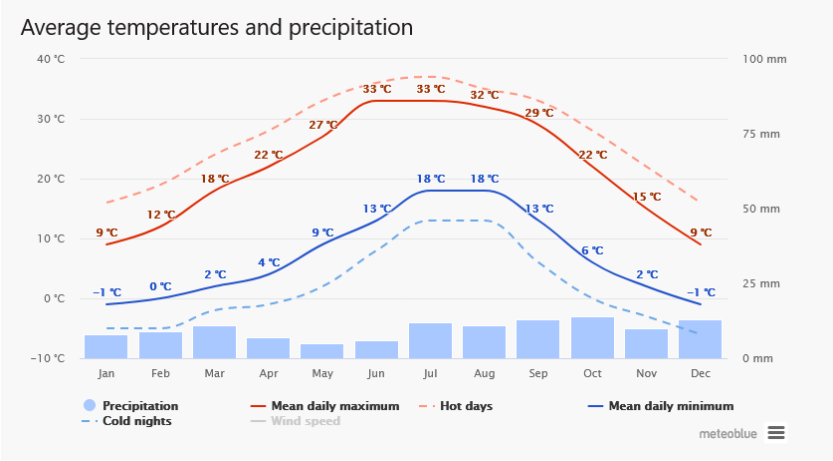

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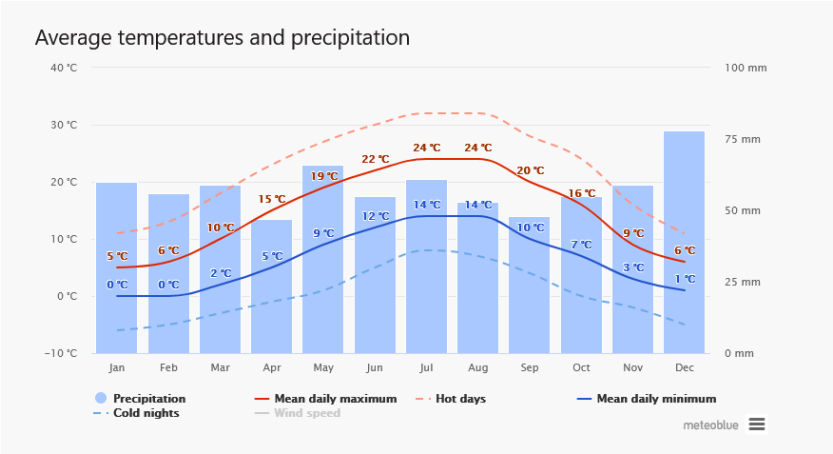

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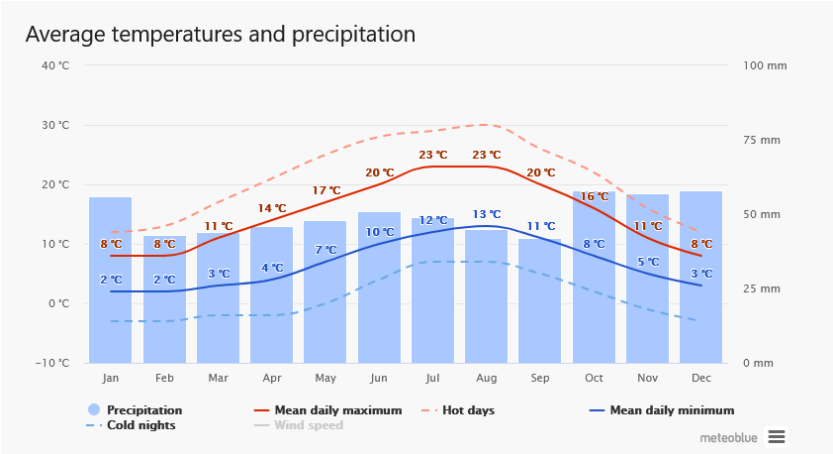

Climate data for London/UK (avg 1993-2023; from https://www.meteoblue.com)

Appendix II

Hand-rearing of Socorro dove, *Zenaida graysoni*, at Waddesdon Manor Aviary

(Gavin Harrison, 2024)

The Socorro dove pair at Waddesdon, which includes a genetically important aging male (8 years old) that had not previously produced any offspring, repeatedly failed to incubate eggs to full-term. In one of the attempts, the squabs hatched but died at less than 24 hours old. In other attempts, we tried to foster eggs under Green-winged dove, Luzon and Mindanao bleeding-heart dove, however, this was unsuccessful. The decision was, therefore, made to attempt hand-rearing in August 2024, when there were two fertile eggs in the incubator with no option to foster-rear at the time of hatch. As there were two viable eggs, it was considered optimal to attempt hand-rearing in the hope that there was lower risk of imprinting when rearing two squabs together.

We experienced no problems during the hand-rearing process of these two squabs, which is contrary to reported experiences of hand-rearing this species at Albuquerque Zoo. At Waddesdon, the process was relatively straightforward and not greatly time consuming, with the squabs surviving to fledging and beyond (writing in Nov 2024; squabs now 2.5 months old, self-feeding etc.), without apparent health issues. Factors believed to largely contribute to success were: 1. Experience of hand-rearers (predominantly with parrots and passerines, although limited experience with doves and pigeons), 2. Use of commercial pigeon/dove crop milk replacement powder, 3. Use of crop needle to administer feed directly to crop.

The two eggs were incubated at 37.5° C with around 40% humidity and automatically turned. At hatch, we reduced the temperature to 36.5° C and increased humidity to 70%+ with no auto-turning. Once hatched (31 August 2024), the squabs were kept in a brooder at 36° C and 60%+ humidity. The temperature was not reduced until day 6, when it was reduced to 34° C.

Following hatch, both squabs received a couple of drops of boiled water with Avipro (avian probiotic) from the end of a 1 ml syringe every hour until their first feed. One of the squabs passed its first faecal around four hours post-hatch. Both squabs received their first feed at 7:00 am on Day 1, which was around 15 (squab 1) and 10 (squab 2) hours post-hatch. Both squabs were given 0.3 ml of crop milk powder with boiled water mixed to a thin consistency and allowed to drink the formula from the end of a 1 ml syringe. It proved to be quite difficult to avoid formula dribbling down the squabs' neck and body, leading to soiling and potential chilling the squabs. It also took some time to get the formula into the crop at each feed.

On Day 1, the squabs were fed every 4 hours from 7 am to 9 pm. The last two feeds on Day 1 were undertaken using a steel crop needle, directly syringing 0.3 ml into the crop, which resulted in a much quicker and cleaner feeding process. The formula was always delivered at around 30-40° C, as cold formula may affect digestion. Similarly, refusal to feed (if allowing to drink directly) too hot a formula could burn the crop. Formula was made fresh with boiled

water and then fed when 40° C. Following the feed, it was stored in a fridge until the next feed time. Chilled formula was warmed by placing the syringe in a cup of boiled water for a couple of minutes. The formula was then tested on the back of the hand before feeding. Formula was not stored in the fridge for longer than 12 hours before feeding or discarding.

By Day 3, squabs received 2-3 ml of crop milk formula direct to crop with a crop needle every 3-4 hours from 7 am to 9 pm. By Day 5, the squabs received 5 ml of crop milk formula four times per day at 7 am, 12 pm, 5 pm and last feed at 9 pm. This volume increased to a maximum of 10 ml at each feed by Day 14. Around Day 5, 1/3 of the formula was Kaytee exact hand-rearing powder. By around Day 14, the mixture was completely Kaytee exact formula and by this point, pigeon seed mix was offered from a teaspoon with the sides bent up (similar to feeding parrot chicks).

By Day 14, the squabs were attempting to fledge from the nest container. On Day 16, they were moved from the brooder to a fledging cage and offered adult diet and water in shallow dishes. Feeds were slowly reduced until around Day 30 from four 10 ml feeds to three to two to one evening feed around 4 pm. This evening feed was then stopped after a further two days after the squabs were seen regularly self-feeding from food dishes and the cage floor.

We note that it is important to ensure that the crop fully drains at least once in 24 hours to ensure that the crop contents do not become sour. See Table HR1) for weights (Day 0 to 15) and Figure HR1) for images of the squabs (Day 2, 6, 11 and 16).

Day	BW (g) squab 1	BW (g) squab 2
0	6.3	6.5
1	6.5	6.5
2	8.5	8.7
3	11.6	12.6
4	20.7	22.2
5	24.1	24.9
6	36.3	34.8
7	43.3	42.9
8	52.6	52.0
9	60.2	58.3
10	67.1	65.1
11	74.4	71.7
12	80.8	79.2
13	86.8	83.4
14	98.0	96.5
15	106.0	101.0

Table HR1) Body weights (BW) for two Socorro dove squabs (Waddesdon Manor Aviary, August 2024)

Day 2

Day 6

Day 11

Day 16

Figure HR1) Development of Socorro dove squabs during hand-rearing at Waddesdon Manor in 2024. (Waddesdon Manor)