Universidade de Trás-os-Montes e Alto Douro

Rehabilitation of Swifts. *Apus apus* and *Apus pallidus* Morphometric Parameters Analysis

Dissertation of Integrated Masters in Veterinary Medicine

André Gonçalves Falcão e Cunha

Supervisor: Bruno Jorge Antunes Colaço

Co-supervisor: Ricardo Manuel Lemos Brandão

Vila Real, March 2019

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Declaro que esta dissertação de mestrado é resultado da minha pesquisa e trabalho pessoal e das indicações dos meus orientadores. O seu conteúdo é original e todas as fontes consultadas estão devidamente mencionadas no texto e na bibliografia final. Declaro ainda que este trabalho não foi apresentado em nenhuma outra instituição para obtenção de qualquer grau académico.

Vila Real, 2019

André Gonçalves Falcão e Cunha

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Resumo

A conservação da fauna selvagem ocorre a diversos níveis, um dos quais é o trabalho realizado nos centros de recuperação de fauna selvagem. Estes são responsáveis não só pela reabilitação de espécies animais selvagens autóctones, mas também pela sensibilização e educação da população para estas mesmas espécies. O andorinhão preto (*Apus apus*) e o andorinhão pálido (*Apus pallidus*) são duas espécies de aves que todos os anos são recebidas nos centros de reabilitação portugueses por diversos motivos.

O principal objetivo deste trabalho é o estudo das características morfológicas destas duas espécies no momento de devolução ao seu habitat natural, e a subsequente comparação com valores referenciados de forma a detetar diferenças que poderão ter impacto na sua sobrevivência após a sua libertação. Também se pretende analisar as taxas de sucesso e as causas de ingresso com a finalidade de identificar fatores de risco. Para tal foi elaborada uma base de dados com os dados de ingresso e libertação, e as biometrias de 312 andorinhões recebidos no CERVAS (Centro de Ecologia, Recuperação e Vigilância de Animais Selvagens) em Gouveia.

Neste estudo observámos que o ingresso destas aves é máximo em Julho, e que as entradas no centro devem-se principalmente a traumas e quedas do ninho. Os casos de trauma têm taxas de libertação (41.1%) menores devido às elevadas taxas de eutanásia (45.2%). As quedas de ninho têm uma elevada taxa de devolução à Natureza (73.3%). O peso de andorinhões no ingresso é maior em aves que são libertadas. Observámos também que as aves juvenis requerem um tempo de reabilitação (13.2 dias em andorinhões pretos e 14.2 dias em andorinhões pálidos) mais longo que adultos (1.4 dias em andorinhões pretos e 3.9 dias em andorinhões pálidos). O ganho de peso nestes animais está correlacionado com o período de reabilitação (r=0.492). Observámos ainda que o comprimento da asa de um andorinhão juvenil (160.74 milímetros em andorinhões pretos e 168.43 milímetros em andorinhões pálidos) é menor que o de um andorinhão adulto (160.84 milímetros em andorinhões pretos e 170.64 milímetros em andorinhões pálidos), nas duas espécies.

Podemos concluir que o estudo das características morfológicas permite delimitar valores padrão para andorinhões recuperados, o que poderá ser desenvolvido de forma a melhorar o processo de recuperação de forma a atingir valores biométricos previamente definidos, garantindo um desenvolvimento mais perto do natural, e aumentar a taxa de sobrevivência de animais libertados. A análise da causa de ingresso poderá permitir que o centro de reabilitação dirija melhor os seus esforços e recursos para otimizar o seu funcionamento e taxa de sucesso.

Palavras-chave: Vida selvagem; *Apus apus*; Andorinhão preto; *Apus pallidus*; Andorinhão pálido; Reabilitação

Abstract

The conservation of the wildlife occurs at various levels, one of which is the work which takes place in wildlife rehabilitation centres. These are responsible not only for the rehabilitation of autochthonous wild animals, but also the sensibilization and education of the population for these same species. The common swift (*Apus apus*) and the pallid swift (*Apus pallidus*) are two bird species that every year are received in the Portuguese rehabilitation centres for several reasons.

The main objective of this work is the study of the morphologic characteristics of these two species at the moment of reintroduction in their natural habitat, and the subsequent comparison to referenced values in order to detect differences which might impact their survival post release. We also intend to analyse the rates and the causes of ingress with the purpose of identifying risk factors. For this purpose, a data base was developed with the admission and release data, and the biometrics of 312 swifts received in CERVAS (Centro de Ecologia, Recuperação e Vigilância de Animais Selvagens) in Gouveia.

In this study we observed that the ingress of these birds is maximum in July and the admissions in the centre are mainly from traumas and nest falls. The cases of trauma have lower release rates (41.1%) due to the high euthanasia rates (45.2%). The falls from the nest have high reintroduction rates (73.3%). The weight of ingress of swifts is larger in birds that are released. We also observed that juvenile birds require a longer rehabilitation period (13.2 days for common swifts and 14.2 days for pallid swifts) than adults (1.4 days for common swifts and 3.9 days for pallid swifts). The weight gain of these animals is correlated to the rehabilitation period (r=0.492). We observed as well that the wing length of a juvenile swift (160.74 millimetres in common swifts and 160.8 millimetres in pallid swifts) is smaller than the one of an adult swift (168.43 millimetres in common swifts e 170.64 millimetres in pallid swifts), for both species.

We can conclude that the study of the morphological characteristics allows the delineation of pattern values for rehabilitated swifts, which can be developed in order to improve the rehabilitation process by reaching biometric values previously defined, ensuring a development closer to natural and increasing the survival rate of released animals. The analysis of the admission cause may allow the centre to better use their efforts and resources to optimize its operations and success rate.

Keywords: Wildlife; *Apus apus*; Common swift; *Apus pallidus*; Pallid swift; Rehabilitation

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Index

Index of figures

Index of graphs

Index of tables

I Literary Revision

1 Introduction

The IUCN (International Union for Conservation of Nature) Red list for threatened species, as of their last assessment, in 2016, lists the species *Apus apus* and *Apus pallidus* as those of least concern. As species which migrate to Africa for the winter and return to Europe and Asia for the warmer months (Hedenstrom et al. 2016; BirdLife International 2016a; BirdLife International 2016b), these two are a common occurrence in rehabilitation centres.

The increasing anthropogenic pressure in the environment is reflected on the health and conservation status of several wildlife species (Schenk & Souza 2014). This fact can be observed by the analysis of morbidity/mortality of animals admitted in rehabilitation centres, from direct or indirect Human influence, representing the most prevalent cause of admission (Molina-López et al. 2017; Schenk & Souza 2014).

Wildlife rehabilitation was defined by the International Wildlife Rehabilitation Council, in 2012, as “the treatment and temporary care of injured, diseased, and displaced indigenous animals, and the subsequent release of healthy animals to appropriate habitats in the wild”. As such, the process of rehabilitation of wildlife constitutes every action taken from the moment of capture of the animal up to the point where there is scientific evidence of its survival in the environment. Their reintroduction in the wild is as much part of the process as the medical treatment (Miller 2012; Grogan & Kelly 2013).

One important point of control is the existence of a network of rehabilitation centres and a functional communication and transport method between them. In Portugal, there are twelve wildlife rehabilitation centres spread throughout the continental territory, which depend on the help of the general population and the SEPNA (Serviço de Proteção da Natureza e do Ambiente), a division of the GNR (Guarda Nacional Republicana), to report, collect and deliver the debilitated or injured animals of the native wild fauna, to the respective rehabilitation centre (GNR n.d.).

These institutions are not only important in the practical aspect of treating the animals but they also provide a possibility in surveying the presence of threats to the wildlife or public health (Molina-López et al. 2017) and actions which involve the community, during which the education of the general public takes a particularly important place (Schenk & Souza 2014; Thompson 2015).

A lot of knowledge surrounding the biology and welfare of wild animals is not yet known, and the swifts are not an exception, in particular relating to the best rehabilitation process. By studying the morphological characteristics of these birds at the moment of reintroduction in their natural environment and comparing with the referenced values for wild birds of the same species, it’s possible to determine if the recovery process allows a natural development of the animal, and subsequently if it is lacking, and increase the knowledge surrounding the biology of these birds.

In this document, the literary revision will approach three different main topics. Firstly, the swift’s biology, which incorporates the taxonomy, morphology and development; secondly, the natural behaviour of these birds in the wild, including variations due to the weather; and finally, the rehabilitation process of swifts in places habilitated for this purpose.

2 Swift Biology

2.1 Taxonomy

Swifts are birds whose taxonomy and phylogeny are an area of disagreement, due to the lack of distinctive morphological characters (Thomassen et al. 2003). According to the Collins Bird Guide from 2017, in Portugal, six different species of swifts have been identified, with varying levels of frequency. There is the common swift (*A. apus*), the pallid swift (*A. pallidus*), the white-rumped swift (*A. caffer*), the little swift (*A. affinis*), the plain swift (*A. unicolor*) and the alpine swift (*A. melba*). At the moment, all of these belong to the Apodidae family, which is part of the Apodiformes order (Camfield 2004; Gill & Donsker 2018).

The two most common are the common swift and pallid swift, which are migratory birds and can be found in Portugal for reproductive purposes, during the warmer months of the year. In the case of the plain swift, it reproduces in the Canary and Madeira isles, and hasn’t been identified in continental ground (Svensson et al. 2017).

K: Animalia

P: Chordata

C: Aves

O: Apodiformes

F: *Apodidae*

G: *Apus*

Sp: *Apus affinis*

Apus apus

Apus caffer

Apus melba

Apus pallidus

Apus unicolor

Figure 1. Taxonomy diagram for the swift species

The distribution of these swifts is summarized in figure 2, based on all the atlas and national lists of the covered area from the last decade.

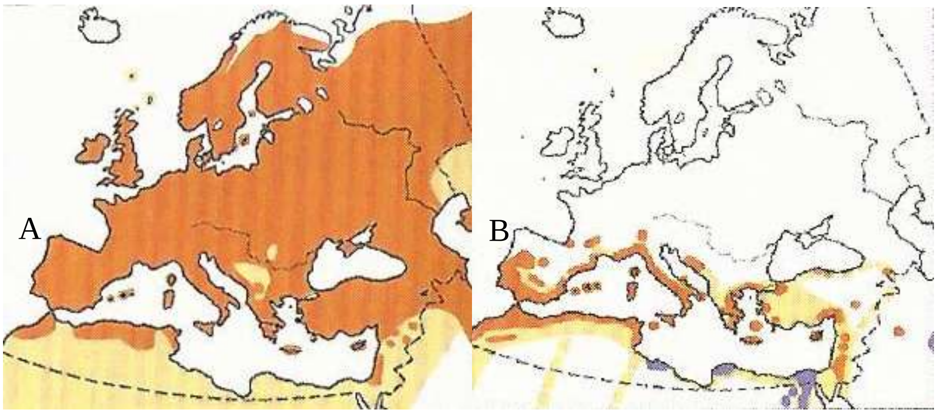


Figure 2. Palearctic distribution of common swifts (A) and of pallid swifts (B). Orange coloured territory corresponds to the range occupied during the reproductive season, beige coloured territory corresponds to the range where these species can be seen during migration and purple coloured territory corresponds to the range where the specie can be seen year-round, including while breeding. Adapted from Svensson et al. 2017.

The pallid swift can be found on the occidental and meridional Palearctic, on the Mediterranean region, Northern Africa until Turkey and Middle East, as for the common swift, it can be found all over the Palearctic, from western Europe and Northeast of Africa, through minor Asia, up to Mongolia (ICNB 2008).

In Portugal, the common swift, breeds regularly throughout the continental national territory (BirdLife International 2016a), while the pallid swift reproduces mostly in the central and southern regions (BirdLife International 2016b).

They are both migratory birds who winter in Africa. West and central Africa for the pallid swift, being considered a medium distance migrant (BirdLife International 2016b), and from the south Democratic Republic of Congo and Tanzania to Zimbabwe and Mozambique, in the case of the common swift, as a long distance migrating birds (BirdLife International 2016a)

2.2 Morphologic Differences between Swifts

2.2.1 Common Swift and Pallid Swift

These two species, as well as other swift species, lack specific morphological characteristics, hence the difficulty in distinguishing them (Thomassen et al. 2003). Still, some differences can be found (Figure 3).

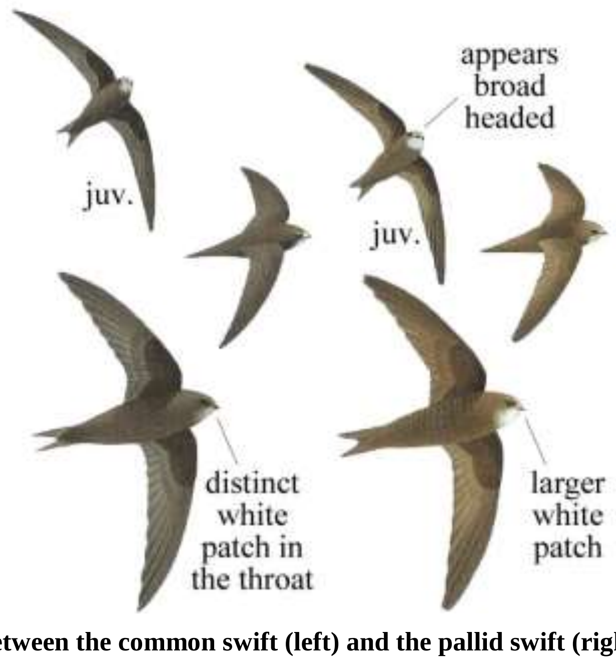


Figure 3. Differences between the common swift (left) and the pallid swift (right), regarding plumage and head size. Adapted from Svensson et al. 2017

While they have similar wingspan and length, the wings of the pallid swift are slightly broader, with a broader and flatter head, and a more rounded body (Cramp 1985). In 2015, Boano et al. were able to detect a difference in the distance between the outer rectrices of the tail, where pallid swifts have a smaller measure than the common swifts. In their study, the values ranged from 3 to 5,5 millimetre, only occasionally exceeding this value (Boano et al. 2015). This difference is also described in the Handbook of the Birds of Europe, the Middle East and North Africa, where they noted a difference of up to 20% in the angle of the furcation of the tail, larger in the pallid swift (Cramp 1985).

Although they both have dark plumage, the common swift has uniform dark feathers except for a white spot over the throat. The pallid swift has a lighter shade of brown over the whole body, except for the dorsum and external primary wing feathers. Due to this difference, it is also possible to detect a dark mask around the eyes. In this bird, the white patch is also present over the throat and also forehead (Svensson et al. 2017).

There are slight differences between the adult and juvenile of the *Apus apus* species. Generally, the juvenile has a darker plumage except for the flight and tail feather, which have a paler brown and margined almost white. The body feathers are also different with pale tips and cleaner white covert. The same pale margins of feathers can be found in juveniles of the species *Apus pallidus* although more distinctly than those of the common swift's juveniles, which allows their identification (Cramp 1985).

2.3 Anatomic particularities

These birds have some characteristics which differentiate them from the rest of the animals which are worth going over.

Weight varies greatly on an individual scale, depending on the feeding conditions, with an average 5 gram variation between better and worse conditions. This value also depends on whether the animal has bred or not, which suggests that this factor causes a strain on the parents. However, from the collective information shown by David and Elizabeth Lack, a common adult swift weights 42,7 grams (Lack & Lack 1951).

The fact that they have a large wing span when compared to their body size, with wings composed of 10 long primary feathers and 8 to 11 secondary (Cramp 1985), allows for long flights, not only in distance but also in time (Guedes & Costa 1994). Their flight ability is also supported by the proximity of the "elbow" articulation to the body which gives the wing great flexibility and manoeuvre ability (Burnie 2002).

Their legs are short with four sharp front facing claws (Cramp 1985; Guedes & Costa 1994; Holmgren 2004) (Figure 4), which help with securing themselves against vertical and rocky surfaces. However, this is also a disadvantage when trying to lift from the ground after settling (Guedes & Costa 1994).

Figure 4. Photo of a young common swift's (*Apus apus*) foot grasping a wooden stick. Taken from Holmgren 2004.

Swifts' beaks have evolved in a way which allows them to feed while flying. They have a small beak with a wide base, permitting the complete opening of the mouth for capture of insects (Guedes & Costa 1994). Another particularity of these animals, at a digestive level is their lack of crop or cecum, and an enlarged salivary gland, particularly during the reproductive season since saliva is a component necessary for nest building (Cramp 1985).

With these characteristics, its normal that these birds have behavioural patterns specific to the species.

2.4 Growth and Development

During the lifetime of these animals, three stages can be differentiated. The nestlings, which corresponds to the period spent in the nest, juveniles, after the fledging and before reaching breeding maturity, and adults, when they complete their development.

For the most part, the first breeding takes place at around 2 years of age, although not usually successful (Cramp 1985). The common swifts' clutch has an average of two eggs per female in the specie *A. apus*, however, it can vary from one to four eggs, usually dependant on the weather conditions (Lack & Lack 1951; Catry et al. 2010). This is not the case for *A. pallidus*, in which the average is three per female (Cucco et al. 1992).

The weather is an important aspect to the time of the laying of the eggs and the clutch size of swifts, but while in the common swift the environmental conditions will affect mainly the last parameter, with up to three eggs per laying with better climate (Lack & Lack 1951; Cucco et al. 1992; Catry et al. 2010), in the pallid swift the weather will affect the time of laying, delaying it until June, with no changes over the size of the clutch. This is not a troubling issue, because the migration for these animals starts not in June, but in late summer and autumn (Cucco et al. 1992).

A particularity on the breeding biology of the pallid swift is the ability to produce two clutches per breeding season (Boano & Cucco 1989; Cucco et al. 1992; Cucco & Malacarne 1996b; Boano et al. 2015), which does not happen with the common swift. For this bird, the second one only happens in a replacement situation after early egg loss (Cramp 1985; Lack & Lack 1951).

The incubation period is also different between species, with the only similarity being that both sexes cover the eggs. This period, lasts on average eighteen or nineteen days in the common swift (Lack & Lack 1951; Cramp 1985) and twenty-one for eggs of pallid swifts (Catry et al. 2010; Cramp 1985). Besides the period of incubation, there is also a difference on the starting point. While the common swift usually starts the process when the last egg is laid, the pallid swift begins with the first one. Longer periods of incubation have been observed, but these happen in larger clutches, and the difference only happens with larger broods. This finding can be explained by the fact that the eggs receive less heat until the third has been laid, due to the extra heat from the night period. In these cases, the parents won't cover the eggs during the day until the rest of the clutch has been laid (Lack & Lack 1951).

After hatching, the average nestling period is of 42,5 days, with the shortest being 37,5, in good weather, and the longest 56,5 days, in bad. This suggests that bad weather can prolong the nestling period considerably (Lack & Lack 1951; Cramp 1985). In the case of the pallid swift, the nestlings are capable of flying at 46 days (Cramp 1985).

Even though the nestling period allows the study of the rate of development, the growth of the wing is a better indicator. In the best conditions, the wing will grow until 100 millimetres, which happens around the 22nd day. Afterwards, it grows 4 millimetres every day, and at the end, the growth rate will diminish and settle at an average 167 millimetres. It is important to take into account the weather, which can play a big part on the development, since bad climate will affect the food supply. In the cases where the weather is unfavourable during the late stages of development, the growth rate will be reduced, and the wing will reach an average of 160 millimetres, and in extreme cases, there might be permanent stunting (Lack & Lack 1951).

With unfavourable weather during the early stages, the starting growth period will be longer. Even so, there is still the possibility of correct growth, if the weather improves, in which case the wing can achieve the same size as in optimal conditions (Lack & Lack 1951).

At this moment the animal is capable of flight, still, there is evidence that the development continues until becoming an adult. When comparing the wings of juveniles and adults, the first's wing is several millimetres shorter than that of an adult. It's a possibility that this difference may be corrected during the first moulting (Lack & Lack 1951; Cramp 1985).

On the matter of weight, the birds of these species reach their peak weight at the end of the fourth week, after which they lose around 20%, with a final average of 41,4 grams (Lack & Lack 1951; Fusté et al. 2013; Martins & Wright 1993). As it happens with the growth of the wing, bad weather has a direct influence on the development of the swift, with different consequences according to the ages of the individual. When such conditions are present in the early stages, the animal may die, or the nestling period may be prolonged (Lack & Lack 1951). When in the middle and late stages, the animal might have a lower weight at fledging (Cucco & Malacarne 1996a; Holmgren 2004), which results in a reduced survival rate after leaving the nest (Lack & Lack 1951; Boano & Cucco 1989; Martins & Wright 1993; Cucco & Malacarne 1996b).

Although these changes in the growth may be seen as detrimental, in periods of food shortage they may function as an adaptative condition which help the animal withstand starvation, by diverting the energy resources from growth functions and conserving them for vital ones (Martins & Wright 1993). In addition, when undernourished, the animal loses thermoregulatory functions and becomes poikilothermic (Koskimies 1948; Lack & Lack 1951).

By studying both the dimension of the wing and the animal's body weight, one can safely determine whether the bird is developing well or not (Lack & Lack 1951).

It's important to consider the survival rate. Even if these birds lay several eggs, not all successfully hatch and some do not survive the growth period. From predation to accidental falling from the nest, there are several causes of death of young birds, although the major cause is starvation (Martins & Wright 1993). For this reason, the weather also plays a major role in the nestling survival rate (Lack & Lack 1951; Thomson et al. 1996).

There is significant variation of the survival rate of nestlings depending on the brood size, although the same cannot be said for the success rate of hatching. David and Elizabeth Lack reported an 86% survival rate, for broods with one chick, which decreases with the number of chicks, arriving at 31% for 3 chick broods (Lack & Lack 1951). This may be a result of selection of the best method to ensure reproductive success, since the parental effort increases with a larger clutch, which results in a higher risk of death to the parents (Martins & Wright 1993).

3 Behaviour in the wild

These two species are examples of animals which form colonies during their reproductive season, and although they usually do not form mixed colonies, in some instances the common swift has been seen together with the pallid swift (Cramp 1985; Cucco et al. 1993; Catry et al. 2010).

There can be found some differences when comparing the preferential habitat of these two species. While the common swift inhabits a wide range, and nests mainly in buildings, with the occasional rock crevice or tree hallows (Cramp 1985; Burnie 2002; BirdLife International 2016b), the pallid swift is more commonly found in coastal areas, around cliffs and gorges, although it can also be found in urban or desert areas, nesting in a variety of places, to the extent of occupying nests of House Martins (*Delichon urbica*) (BirdLife International 2016b). When inside their nests, swifts are particularly tame due to lack of threats, like predators. Nonetheless, when this does happen, the animal either flies away or attacks with their claws (Lack & Lack 1951).

3.1 Migratory Movements

As migratory birds, both these species can be found in Portugal during the warmer months. The common swift starts their reproductive period in March (ICNB 2008; Catry et al. 2010), remaining until late July and August when the young leave the nest to begin their migration and the adults follow after a few days. However, in some instances, some individuals can be seen until September, or later, due to being parents with late laying of eggs or passing through during their migration (Lack & Lack 1951; Cramp 1985). This does not happen for the pallid swift, whose reproductive period takes place usually in late May and June, time when it lays its eggs. In some cases, this period may be prolonged, when the females lay a second clutch, a common finding for the specie (Cucco et al. 1992).

After starting their migration, these animals are known for being able of staying airborne during their entire non-breeding period, including migratory flights (Hedenstrom et al. 2016; Akesson et al. 2012; Burnie 2002) during which, their anatomical characteristics are an advantage to this way of life (Burnie 2002)

3.2 Feeding habits

These birds are insectivorous and feed mainly on insects caught in the wings during flight (Burnie 2002; Lockley 1969; Cramp 1985), however their habits vary according to the weather, since the availability of food depends on whether the climate is favourable or not (Lack & Lack 1951). While, the common swift feeds mainly on flying insects and small and medium size spiders, avoiding any that have stingers, the pallid swift feeds on medium size flying insects (Cramp 1985). Although it’s difficult to say if one feeds on larger prey than the other, in 1993, Cucco et al. found that, in general, the pallid swift takes smaller prey than the common swift (Cucco et al. 1993).

By studying the frequency of visits to the nest, Lack and Lack estimated that the common swift feeds on an average of two hours per brood. However this number can vary greatly, from 4 to 33 visits in a 10 hour period (Lack & Lack 1951), which suggests the nestling’s ability to survive for longer periods of time without food. In the case of the pallid swift, the frequency rounds an average of 0,21 per hour (approximately once every 5 hours), without depending on the abundance of food, but on the brood size in order to ensure correct growth of the progeny (Cucco & Malacarne 1996b).

3.3 Flight pattern

There are many characteristics that separate the swifts’ flight pattern from other birds’, in particular the nocturnal flights, which will be approached later on.

Swifts display a typical alternation between wing beating and longer or shorter gliding intervals, during which they often 'tilt' and make short turns (Bäckman & Alerstam 2002). Another curious finding is the fact that their wing beats occur usually with a backward curve, sometimes seemingly at a uneven rhythm (Cramp 1985).

Together with their anatomical peculiarities and their ability to change the frequency of flapping of the wings in order to change directions (Burnie 2002), they are very aerodynamically efficient.

The typical flight pattern of these animals is usually marked by an ascent to high altitudes at dusk, where they fly through the night (Bäckman & Alerstam 2002), however this is also known to take place at dawn, possibly for navigation purposes. Afterwards they take long periods of gliding, marked by little flight activity (Hedenstrom et al. 2016).

Besides the typical flight pattern at high altitudes, facing the wind, they also perform circling flights usually at low wind speeds. Through these, they are able to avoid major displacement from their roosting spot (Bäckman & Alerstam 2002).

3.4 Nocturnal flights

One specific behaviour of these animals is the common occurrence of nocturnal flights, during which they have an "habit of roosting on the wing" (Bäckman & Alerstam 2001; Cramp 1985). Since they are more susceptible to the effect of the wind during this behaviour, they acquired different adaptative characteristics as to facilitate such an action, like echolocation (Thomassen et al. 2003) and changing their flight according to the characteristics of the wind (Bäckman & Alerstam 2001; Bäckman & Alerstam 2002).

Swifts' night flight patterns are usually characterized by their high altitude, and their orientation facing the wind direction, where depending on the wind velocity there is a direct proportionality to angular concentration (Bäckman & Alerstam 2002). Through these changes to their flight, they are able to avoid extensive dislocation and energy consumption (Bäckman & Alerstam 2001).

Bäckman and Alerstam suggested that these animals will adapt their flight altitude, speed and orientation to better suit their goals. In a study performed in 2001, they discovered that swifts orientate themselves against the wind, especially when there are high wind speeds, and there is a higher risk of being carried backwards, when it exceeds their flight velocity (Bäckman & Alerstam 2001)

However, the same was not detected for their altitude and speed of flight, finding only a correlation between the altitude and temperature, where these animals tried to stay at an environmental temperature between 5,5 and 14,4º Celsius. In the cases where it was hotter, they would rise to higher altitudes (Bäckman & Alerstam 2001).

From this knowledge, they concluded that under the hypothesis of energy expenditure conservation, by orientating themselves they could minimize their displacement, while controlling the altitude or airspeed would result in a higher cost than compensatory homing flights, in response to strong winds, and, this way, they would be able to reduce energy consumption (Bäckman & Alerstam 2001).

In 2002, Bäckman and Alerstam continued their studies, and detected regular variations of orientation in accordance to wind direction, suggesting that these animals do not correct the orientation continuously, but do it in regular intervals.

3.5 Weather factors

Throughout this work, there have been examples of the impact of the weather on the biology of these two species, mainly the development and reproductive capacities of these species, but also the food supply (Cucco & Malacarne 1996b). Henceforth, it is to be expected that their behaviour will adapt to ensure their survival.

One of the first actions detected with bad weather and a drop in the temperature, is the clustering together of the birds on walls to conserve body temperature (Lack & Lack 1951; Holmgren 2004). However, this is not guaranteed to be enough and in some cases, there is evidence that the animals do not survive (Lack & Lack 1951).

Secondly, it is common for the progenitors to leave the nest and move for several kilometres, leaving the progeny alone. In cases where the younglings are left alone for a long time, they will enter a torpor state until it is warm enough. When this happens, the parents will return with food (Burnie 2002). If these conditions extend over a long period, their adaptative particularities will not be enough to assure their survival and, in extreme cases, may result in the dead of both the parents and nestlings (Lack & Lack, 1951).

Another curious finding is the arrival from the spring migration with the outermost primary feathers unmolted, when this process is known to finish during winter (Boano et al. 2015). Hedenstrom et al. found a statistically significant relation with periodical nocturnal flight inactivity, where birds which showed this pattern retained the feathers. As the molting of feathers is a costly process, in terms of energy consumption, there might be a physiological explanation for the flight inactivity in the winter (Hedenstrom et al. 2016).

Finally, as an alternative to roosting during nocturnal flights, these birds might chose to roost in tree foliage when there is little food available or the temperature is lower, and the animal is nearing exhaustion (Holmgren 2004).

4 Rehabilitation centres

The existence of rehabilitation centres is fundamental in the conservation of species natural to the environment, by monitoring the health of ecosystems, detecting threats to wild animal populations and improving of the wild animal welfare (Vogelnest & Woods 2008; Molina-López et al. 2017). However, the purpose for their existence is based on the release of healthy animals to their natural environment post recovery (Molina-López et al. 2017), ensuring that they are capable of natural behaviours and future breeding (Mullineaux 2014).

With the increasing anthropogenic pressure on their environments, there is a continuous influx of animals into veterinary clinics and rehabilitation centres. Although not the only cause of ingress, anthropogenic interference, direct or indirect, represents the most frequent cause of admission (Molina-López et al. 2017; Schenk & Souza 2014).

4.1 Arrival Process

From the moment the animal is first found, and the centre is informed, there is a necessity to collect correct information about the animal and the conditions it was found in. This way the veterinarian in charge of the rehabilitation will the able to better direct the medical approach. The first issue the collection team faces is the correct identification of the age and species of the animal in question, as different species have different necessities (Brandão 2008).

During this process, the animal should be kept somewhere calm and with little noise, with controlled heat and ventilation. A possibility is a cardboard box with holes and absorbent paper at the bottom, to protect the animal and avoid more damage (Vogelnest & Woods 2008; Galvez 2012).

After all the information has been exchanged and the official documentation has been signed (Figure 5), the animal should be the object of a complete physical exam to identify every problem present (RSPCA 2010; Galvez 2012), as one alteration in the body does not exclude others, and there is the possibility of some being complications. For example, debilitated animals are more prone to infectious or traumatic situations, and vice versa (Brandão 2008).

Admission Form

Individual Data

Specie: Common name____________ Scientific name______________________

Collection information

Date __/__/____ Time __:__

Place:

- Area: ______________________
- Parish: ______________________
- County: ______________________
- District: ______________________

Description of situation: ______________________

Suspected cause: ______________________

Collection: Private □ Institution □

- Name: ______________________
- Entity: ______________________
- Adress: ______________________
- Postal code: ______________________
- County: ____________ District: ______________
- Contact: ______________________

Maintenance conditions:

- Place: ______________________
- Food: ______________________
- Medication: ______________________

Transport and delivery to rehabilitation centre: Private □ Institution □

- Name: ______________________
- Entity: ______________________
- Adress: ______________________
- Postal code: ______________________
- County: ____________ District: ______________
- Contact: ______________________

Observations: ______________________

Admission signature: ______________________ Date: ____________

Figure 5. Example of admission form

Finally, after achieving a correct diagnosis, the animal should be adequately treated and handled (Brandão 2008; Mullineaux 2014). As such, it's necessary to assure the stabilization of the patient, be it recovering body temperature or rehydrating the animal (Fusté et al. 2013; Recasens et al. 2015) through oral or subcutaneous administration of fluids (Fusté et al. 2013; GREFA n.d.). Sometimes, the swift only requires a place to rest and recover, before releasing (Galvez 2012)

In some centres, a antiparasitic treatments are also performed routinely due to the commonality of cestode parasitism (Fusté et al. 2013), but for weak and sick cases, the treatment is advised (Galvez 2012).

At this point in the process it's important to determine whether the animal will be able to recover or not, and ensure that their welfare will not be compromised (Molony et al. 2007; Mullineaux 2014). In some cases euthanasia is the best option, when due to the injuries sustained and poor prognosis, the animal is unsuitable for release (Molony et al. 2007; Vogelnest & Woods 2008).

4.2 Causes

There are several causes responsible for the admission of wild animals in a rehabilitation program, and it's important to determine which one is being presented, since the treatment and recovery process varies according to the injuries sustained (Mullineaux 2014).

One of the most seen causes in this line of work are traumas (Mullineaux 2014; Molony et al. 2007; Molina-López et al. 2017), which are usually located in the wings as fractures or luxation. The degree of severity and complications of these issues depends on different factors as the time from injury to active treatment, or location of the problem, and occasionally, these lesions are accompanied by other irreversible ones (ocular or nervous lesions, internal haemorrhaging). These are a common finding as a result of gunshot wounds or traps which are, in most cases, of difficult recovery (Brandão 2008).

Malnourished and/or cachexic animals are another common case in these centres. This is usually a more severe situation with young animals, especially with those with less than 1 year of age, where there is a bigger mortality due to their lack of adaptation ability to the non-natural components of the environment and of survival skills. These are of difficult rehabilitation, particularly when they also suffer from severe dehydration. Besides their debilitated state, the lack of nutrients can lead to changes in their physiology, for example, bone growth alterations. For this reason, it's important to discourage the rehabilitation by privates, as they do not know of the animal's specific needs (Brandão 2008).

Related to this topic, is the finding of younglings resulting from removal or falling from the nest (Molina-López et al. 2017), which represents a big portion of total admissions in rehabilitation centres (Mullineaux 2014; Molony et al. 2007). In these cases, they should be returned to their nest as soon as possible, if there are no other evident problems. However, it is more frequent to keep them in the centre as there is little possibility to guarantee their safety (Brandão 2009).

Captivity and Capture are a particularly difficult topic as they are illegal and are to be reported to the authorities in case it is identified and can be punishable with a fee up to 3750€ in case of singular people or 44.890€ for collectives (Ministério do Ambiente e do Ordenamento do Território 2005). In some places it is the main cause for entry due to the high number of passeriform birds, although it also happens with other species (Brandão 2009; Molina-López et al. 2017). This category represents those animals which have been kept for a varying amount of time and/or collected by the authorities due to poaching or illegal training (Molina-López et al. 2017).

Electrocution is not as big a problem as it previously was, still, there are cases of birds who flew or stopped on an unprotected electricity poll. In these cases, most of the animals won't survive. The lesions and results will vary depending on the voltage but also on the size of the animal, as a bigger one will have a higher probability of survival due to their greater resistance to the degree of tissue destruction (Brandão 2009).

As with other areas of Veterinary Medicine, some animals will also go to these centres due to infectious agents, most commonly as a consequence from stress or a debilitating process. These are an especially important group as they are a potential source of infection not just for other animals, after reintroduction and while in captivity, but also to human health. For this reason, rehabilitation centres have a privileged position since it is easier for them to collect samples and develop data bases for epidemiological studies and monitorization of an infectious agent pool in a certain region (Brandão 2009).

One other important cause, even if not as common, is intoxication. When this happens, the animals that come in with signs of poisoning rarely survive, since, in most cases, the toxic has a fast-acting effect and the animal dies, sometimes in less than 30 minutes. Even with this problem, the biggest issue resides with their ability to accumulate and persist throughout the trophic chain, meaning that the ones who suffered from their effects can also pose a threat to other animals. At the moment, there are laws in place which prevent the use of the stronger toxics, as strychnine, and there is also Antidote Program which fights their usage (Brandão 2009).

Finally, there is the problem of oil spills or conspurcation. While it is mainly an issue for aquatic animals and it doesn't happen frequently on a large scale, it has a large effect causing the death of several animals and entry of a large number of animals into rehabilitation centres, sometimes exceeding their capacity. With these, it is important to guarantee the stability and survival of the animal before proceeding to clean (Brandão 2009).

Even if all these lead to a period of rehabilitation at these centres, when it comes to swifts, some are more common than others. For example, in adult swifts, it's more common to find cases of predation or exhaustion and debility, from bad weather and lack of food; and in nestlings or fledglings from hunger or failed attempts at flying (Galvez 2012; Martins & Wright 1993).

4.3 Facilities

During recovery, the nestlings should be kept in small groups, in plastic or cardboard boxes (Galvez 2012; Recasens et al. 2015).

In the case of young birds, the boxes can be kept uncovered until the end of development is nearing, by which time it is necessary to cover them (Recasens et al. 2015), in any case, one part of the box should be kept in the dark and concealed from the surrounding environment (Galvez 2012). The GREFA association describes a minimal size of 30 per 20 centimetres and 25 centimetres high (GREFA n.d.), however there should be enough space for the animals to move and stretch their wings to their full wingspan (Galvez 2012).

The bottom should be covered with paper to simulate the nest (Recasens et al. 2015) and aid in keeping the space clean and free of excrements (GREFA n.d.; Galvez 2012) (Figure 6).

Figure 6. Example of nest box used in CERVAS. Photo ceded by CERVAS

They should be kept somewhere where there is little variation to the temperature and humidity, at around 30º Celsius (Recasens et al. 2015). When the environment is at a lower temperature, a heating mat can be placed under the box, filling only half of the space, so that the bird can freely regulate their body temperature (GREFA n.d.; Galvez 2012).

Throughout the rehabilitation process, the animals should be monitored and fed appropriately, checking for dropping and healthy inter-animal relations (Galvez 2012).

4.4 Husbandry

The management of the animals during the rehabilitation process is vital to assure the survival of any animal after their release, and should be as similar as possible to the conditions found in the wild (Fusté et al. 2013). When it comes to feather's dystrophies and pathologies, the most common cases are those of birds bred in captivity (Pesaro 2014), hence the importance for ensuring the welfare ensuring their rehabilitation period.

4.4.1 Diet

Due to the common occurrence of these birds in rehabilitation centres, as insectivorous species (Thomassen et al. 2003; Fusté et al. 2013) it is necessary to assure that their nutritional needs are fulfilled, in order to prevent the undernourishment of the animal, and the subsequent release of impaired individuals (MacLeod & Perlman 2001; RSPCA 2010; Thompson 2015). In 2014, Stefano Pesaro presented a study of the occurrence of dystrophic feathers in young swifts after being given improper feeding, and found that an improper diet may be the most probable cause for these pathologies (Pesaro 2014).

In Europe, a big portion of these cases are from orphans, and since in these cases the feeding is done by the parents, they require hand-rearing for survival. The correct process will ensure that these birds will have an optimal plumage development and weight at release (Fusté et al. 2013).

In any case the duplication of the diet in the wild is hard to accomplish, due to the costs and the availability of insects. At the moment there have been made efforts to find an alternative to these constraints. Fusté, Obon and Olid tested the growth rates of hand-reared common swifts when fed with different diets and compared them to reference values of wild adult birds, found in literature (Fusté et al. 2013).

They used four different diets, one of rat meat, one of high protein-low carbohydrate cat food, one of crickets and moth larvae and another of mealworm. The results showed a greater similarity between wild birds and those reared with insect diets, even in cases where the clinical conditions at admission were worse. This did not happen for those fed the other diets, where in cases of extreme clinical condition, some animals did not complete the process of hand-rearing (Recasens et al. 2015). When evaluating the body growth, a difference was also detected, where those fed the non-insect diets had a stunted appearance (Fusté et al. 2013).

As such, they concluded that the usage of insect-based diets has better results and in cases where others are used, the change should be performed. The author also reported some concern in using mealworms as food for common swifts due to their nutritional composition, although it is a good alternative for crickets, with good results and lower economical costs (Fusté et al. 2013).

They also suggested that the increase of feeding frequency of 5 times a day, could improve the final weight (Fusté et al. 2013). Ideally, the animals should be fed every 3 hours, or at a higher frequency, for birds in poor conditions or with no feather coverage (Recasens et al. 2015; GREFA n.d.).

It is important to rehydrate the animals before starting the feeding process and with forced feeding. The insects should be placed in the posterior portion of the throat, with the help of tweezers (Recasens et al. 2015; Galvez 2012). By giving wet insects, it will be easier for the animal to swallow and allows the hydration of the individual (GREFA n.d.; Galvez 2012).

During this process, the handler must take care not to damage or soil the wings, which can be done by wrapping the bird loosely with a soft material (Matthes n.d.; Galvez 2012), and protect the beak, which due to its fragility can break, by opening the mouth from the side or by pulling the skin on the underside (Galvez 2012).

4.1.2 Welfare

The animal's welfare should be protected to the best capacity of the centre and the people working there. As such the ability to exercise during the rehabilitation period should be guaranteed.

The space inside the cages are an important part of this, as it allows them to open and close their wing to their full size at will, and avoid damage (Agriculture Victoria 2000; Galvez 2012). Also, on the matter of infrastructures, the material of the artificial nest can soften the floor and allow the swift to exercise their legs, the paper placed there will facilitate the management of the cage and prevent the feathers from getting dirty (Galvez 2012).

While in the nest, these animals usually perform "push-ups" by extending their wings and lifting their body, in order to exercise and take notice of their body's dimensions for flight (Wright et al. 2006; Galvez 2012)

Another aspect which helps the development of natural behaviour and exercising is the presence of vertical towels to which the swifts can cling to (Galvez 2012) (Figure 7).

It's also possible to give them space to move and fly, placing them on the floor of a wide room. In these cases, the animal should be protected by hanging curtains or towels and softening hard surfaces (Galvez 2012).

As with all wildlife species, the contact of these animals with humans should be limited, since animals suffering from socialization problems or imprinting should not be released (Blair 2001; Mullineaux 2014; Thompson 2015; Molina-López et al. 2017). Even so, these birds have been shown to be quite accepting of our presence nearby, and the practitioner's correct handling can be helpful in reducing stress by stroking the throat or ruffling the back of the head (Galvez 2012)

Figure 7. Usage of a vertical towel to allow natural swift behaviour. Photo ceded by CERVAS

5 Reintroduction criteria

The rehabilitation and subsequent release of wild animals into their natural habitat is dependent on a series of factors. While some encompass the different animals, some are more specific and attend to the biology and needs of the specie in question.

By studying these factors, it should be possible to better direct the centre's resources and improve the chances for a successful recovery, without compromising the animal's welfare (Molony et al. 2007).

5.1 Morphometric parameters

The two main morphometric parameters to analyse, as to determine if the animal is ready for release, are the wing length and the body weight.

Young birds were considered ready for release when all the primary feather are no longer sheathed and have a 160 millimetre wing length, with an extra 35 beyond the tail feathers (Fusté et al. 2013; Matthes n.d.). Even so, it is necessary to take into account other factors like the fact that a bird without one wing feather can be able to fly allowing it to reach the nest and breed (Galvez 2012).

The weight should also be taken in consideration, as a measure of their development(Lack & Lack 1951; MacLeod & Perlman 2001; Galvez 2012), with a recommended value of 40 grams (GREFA n.d.; Matthes n.d.; Galvez 2012). However, when it comes to nestlings, there is evidence that a lower body weight will have little effect on their survival after fledging, due to the common decrease of mass before this process takes place. This finding can be explained by the loss of fat reserves, stored for starvation periods (Martins & Wright 1993), to ensure continual growth, even without food provisions, which is an important step to allow the bird to take flight with an aerodynamically efficient body shape (Wright et al. 2006).

Wright, J et al. (2006) suggested that each swift (*Apus apus*) can facultatively adjust their development, in terms of mass loss and wing length, in order to achieve an optimal wing load, according to their "facultative adjustment theory". Their study concluded that these animals' wing load was very similar, even with different body mass or wing lengths, supporting the hypothesis presented.

5.2 Clinical Examination

In order to determine if the individual is ready for release, it's necessary to perform a physical exam. During this procedure the veterinarian can also take the time to collect the biometric data.

According to the diagnosis, the exam should be directed to more specific aspects, for example, if the animal entered the centre because it was an orphan, it is important to verify that it has reached the age and weight necessary to be able to fly without any issues (Recasens et al. 2015).

It's also important to determine if the animal is harbouring any infectious agent with detrimental effects over the animal itself or others post release, although the testing before release may not be very reliable when the knowledge of the disease is limited (Vogelnest & Woods 2008).

5.3 Extrinsic Factors

Besides the previously discussed factors, related to the biology of the animal, it is necessary to consider some aspects related to the environment (RSPCA 2010; Thompson 2015). As such, these birds are to be released in open areas with some height off the ground and an abundance of other wild animals, of the same species (Fusté et al. 2013). To assure this, the individuals must be released during the migratory period where they can be found in the territory in question. The existence of a soft ground will help in case the animal won't be able to fly well, permitting a soft landing (GREFA n.d.; Galvez 2012).

Most authors agree that the swifts should be released without being thrown and should fly of their own free will. As such, the person in charge of this process should hold the in their open hand and wait (Galvez 2012; Recasens et al. 2015; Matthes n.d.; GREFA n.d.). As a healthy bird is capable of lift off, if this does not happen, it may be indicative of an existing problem (Galvez 2012) (Figure 8).

Figure 8. Swift release. Photo ceded by CERVAS

II Aims

This work is mainly intended to study the biometric parameters of two species of swifts which exist in Portugal (*Apus apus* and *Apus pallidus*) and compare the morphometric parameters of rehabilitated individuals to those of wild birds of the same species.

As more specific aims:

1. Compare biometric measurements between the two species;
2. Compare biometric measurements between the two age groups (juveniles and adults) of successfully released swifts;
3. Compare biometric measurements obtained from the rehabilitation centre in Gouveia (CERVAS) to referenced values in the bibliography;
4. Study the admission and survival rates to detect risk factors;
5. Analyse the rehabilitation success to detect risk factors.

III Materials and Methods

1 Collection Site

1.1 Enclosure

The swifts rehabilitated at CERVAS are kept in carboard boxes of various sizes, with their sides perforated, as to allow circulation of air. The number of animals kept inside depends on the size of the box.

Inside, the birds have plastic round boxes filled with newspaper to simulate the nest. The newspaper is used in these cases as it gives a solid surface for the swifts to rest on while softening the ground. Another advantage of this material is the easy access and it's easy to replace, keeping the space clean.

These boxes are kept in a separate room, closed where there is little personnel circulation and the temperature is kept at a stable level. This way, the contact with humans is limited to when it is strictly necessary.

1.2 Husbandry

At this centre, contact with the animal species is kept at a strictly necessary level, usually when it's time to feed them.

At the centre, the first feeding moment takes place after the arrival of the personnel, between 9:00 and 10:00 am. The first step is to grab the bird being fed, being mindful of the wings and feathers to avoid extra damage and roll it in a towel to keep it immobile.

The diet used consists of 10 to 15 mealworms, specifically larvae of the specie *Tenebrio molitor*, placed in tap water, this way the birds also have the intake of water. The mouth is open by pulling on the skin under the beak or by pushing the finger through the side and is kept open until the worms are placed in the throat of the animal. This step is aided by the usage of clean tweezers.

Ideally, the feeding of these animals takes place every 3 hours, including during the night.

2 Sample

For this study, three hundred and twelve swifts, of the species *A. apus* and *A. pallidus*, were examined and statistically analysed, however not every animal had the complete information which is being studied (Table 1). The data has been collected from 2006 until the end of 2017, to varying degrees of completion, from the Portuguese rehabilitation centre, CERVAS. All of the information was compiled in a data base, which was later studied.

Table 1. All the animals present in this study. Data regarding their specie, admission status, age at ingress and the number of individuals

Specie	*Ingress State*	*Age at ingress*	*N*
Apus apus	Alive	Nestling	61
		Juvenile	12
		Adult	30
		Total	103
	Dead	Nestling	7
		Juvenile	3
		Adult	11
		Total	21
	Total	Nestling	68
		Juvenile	15
		Adult	41
		Total	124
Apus pallidus	Alive	Nestling	106
		Juvenile	22
		Adult	30
		Total	158
	Dead	Nestling	15
		Juvenile	6
		Adult	9
		Total	30
	Total	Nestling	121
		Juvenile	28
		Adult	39
		Total	188
Total	Alive	Nestling	167
		Juvenile	34
		Adult	60
		Total	261
	Dead	Nestling	22
		Juvenile	9
		Adult	20
		Total	51
	Total	Nestling	189
		Juvenile	43
		Adult	80
		Total	312

From the totality of live animals, one hundred sixty-nine (64,8%) were successfully released, 47 were euthanised, 29 died in two days and 16 died after that. In 51 of the cases, the animals were found dead. When brought to the centre alive, for recovery, several causes can be responsible for their state. The reasons were as follows: cases of trampling (N=6), accidental captivity (N=3), illegal captivity (N=1), collision (N=19), undernourishment or debility (N=17), conspurcation (N=2), predation (N=8), falling from the nest (N=193) and trauma (N=61). In two cases, the cause was not accurately determined.

Besides this information, for each bird, the following data was collected: date of arrival and of release, gender (male, female or unknown), age at ingress and at release (nestling, juvenile or adult), the area of origin (Figure 9), cause for collection, the end result (released, dead, died in two days, died after 2 days or euthanised) and different biometric values (weight at ingress and at release, length of the wing, the eighth primary feather, the beak and the head, and the length, depth and width of the tarsus). The parish, county and district were recorded for each bird's origin.

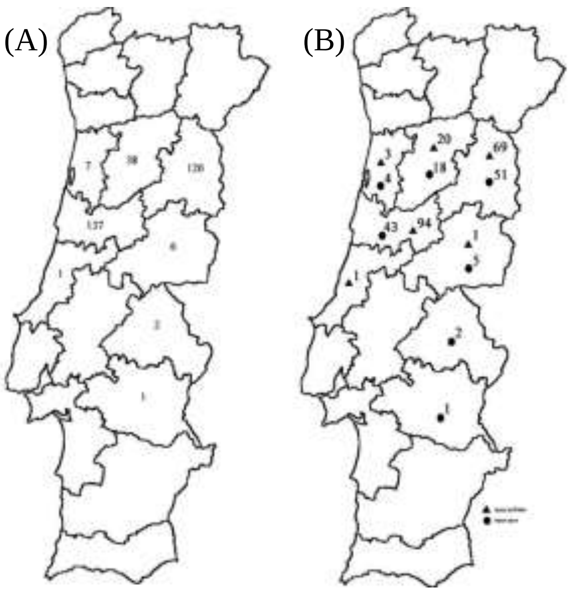


Figure 9. Map showing the distribution of swifts brought to CERVAS. (A) shows the totality of birds, without discrimination by species and (B) the number of admissions of birds according to species, where the circle corresponds to *Apus apus* birds and the triangle to *Apus pallidus* birds.

As these animals do not have sexual dimorphism, most animal were classified as undetermined except for six cases, two males and four females. As such, this parameter will not be evaluated in this study.

3 Methods of data collection

At the arrival at the centre, the personnel collect all the information regarding the finding and collection of the bird which is used for filling in an internal file (Annex A). When the animal is brought in by the authorities (SEPNA), they have an official form which requires a signature by the person in charge of the centre. In this form, the information regarding the animal, species, moment and place of collection, position and state of the animal, and the person who reported the case is described.

3.1 Morphometric parameters

The different biometric parameters were measured using a more adequate tool, depending on the characteristic. The wing and eighth primary feather were measured with a ruler, to the nearest millimetres, the beak, head and the tarsus with an analytical pachometer, also to the millimetres, and the weight with a digital scale (OHAUS adventurer), to the nearest 0,01 grams. The ruler and the pachometer had an error of 0,5 millimetre, and the scale a 0,005-gram error. All the measurements were performed by the veterinary doctor in charge of the centre (Dr. Ricardo Brandão).

The wing is measured from the carpal joint to the tip of the longest primary feather (Figure 10A), while the eighth primary is measured from the point of its insertion to its tip (Figure 10B).

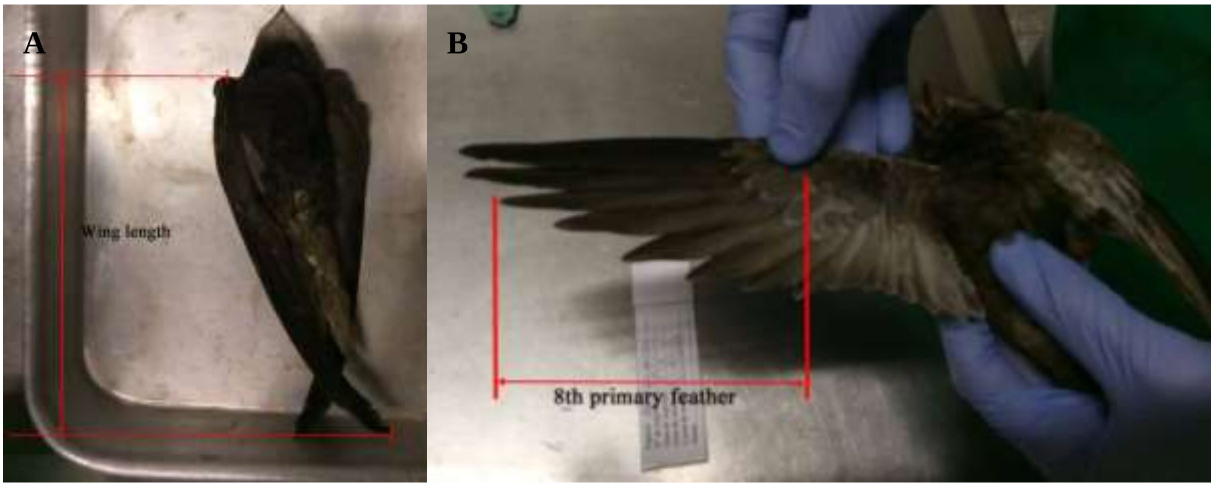


Figure 10. Measurement of the wing length (A) and the eighth primary feather (B) of a swift

The head is measured from the back of the cranium to the tip of the beak, and the bill from the insertion point in the skull to its tip.

The leg was measured for three dimensions: length, width and depth. The first is measured from the intertarsal joint to the distal extremity of the tarsometatarsus bone, the second is the medial-lateral measure of the bone and the third the cranial-plantar measure (Figure 11). When determining the length of the tarsometatarsus bone, it’s helpful to bend the leg to open the intertarsal articulation.

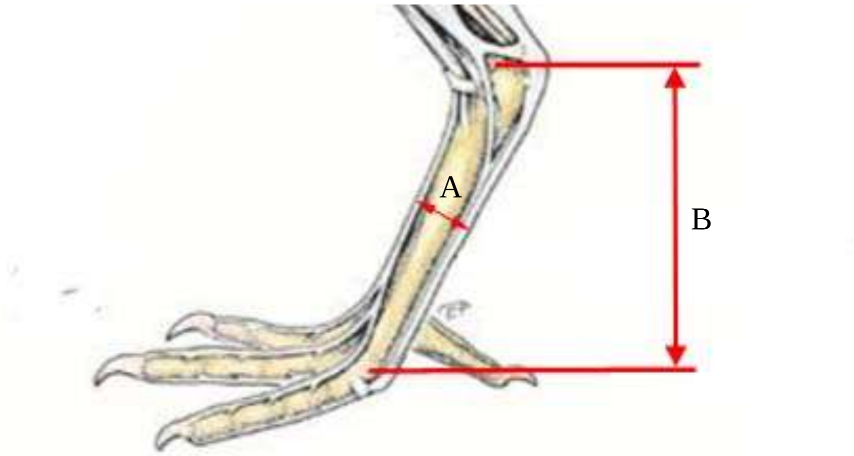


Figure 11. Depth (A) and length (B) of the tarsus of birds (tarsometatarsus bone)

Finally, the weighting of the bird only requires placing the animal on the scale. As these are calm species, with difficulty at flying from the ground, they do not require a lot of management for this process.

4 Statistics

Statistical analysis was carried out using the SPSS 25.0 statistical software (IBM SPSS Statistics 25). At the start, the Levene test was used to determine the equality for each biometric parameter, including weight, and afterwards the t test for independent samples was applied to detect if any of them had any differences between the two sample groups being studied. This test was also used in order to detect differences in rehabilitation time between juveniles and adults, and common swifts and pallid swifts. P values less than 0.05 were considered to be statistically significant. In these tests, only released animals were considered.

The Pearson product-moment correlation was used to detect the existence of some degree of correlation (linear dependence) between two continuous variables, and the Bonferroni correction was applied when comparing the entry weight of swifts according to the result of the rehabilitation process, and the rehabilitation period of the different admission causes. Only animals admitted alive were considered for the study of these relations.

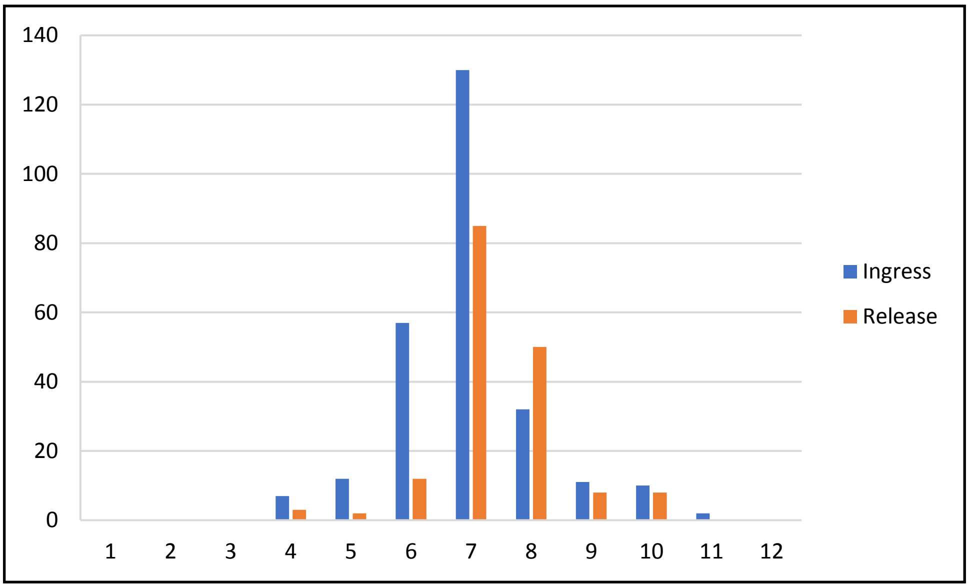
The cause of ingress and the final state of the animal were cross tabulated which allowed the detection of differences between the second according to the first, and vice-versa.

IV Results and Discussion

This work has the purpose of analysing and studying the anatomical characteristics of rehabilitated swifts. The results will be discussed as they are being presented.

1 Admission rates

When studying the ingress of live swifts per month, we noticed a peak in the warmer months (June, July and August), in which both species will be reproducing in the continental territory (Cucco et al. 1992; ICNB 2008; Catry et al. 2010), and the highest number of individuals should be present (nestlings, juveniles and adults), due to the completion of their spring migration. Their numbers will start to dwindle by the coming of the autumn, when they begin their winter migration to Africa (Graph 1).



Graph 1. Frequency of swifts' admissions and releases from CERVAS by month

It is also possible to compare the release numbers, through which we find 2 individuals who enter the centre in November. However, the latest release reported takes place in October since both cases of November did not survive. Even if this was not the case, the release this late in the year would be a big risk for their survival, as there are very few reported cases of swifts in Portugal during this season and the worse weather may compromise their survival. As such, it might be best to keep the swifts in the centre until the return of these species to the area covered by the rehabilitation centre, which would be difficult considering the extra management required.

We also studied the cause of admission, with the most common being falling from the nest (N=193), followed by trauma of undetermined aetiology (N=61) (Table 2). When comparing the results from the centre in Gouveia, Portugal (CERVAS), with the ones from (Torreferrusa) (Molina-López et al. 2017), the admissions follow the same pattern, except when it comes to illegal captivity, where this centre had only 4 cases.

Table 2. Number of admissions of swifts according to cause of ingress

Causes of admission	***Frequency (N)***	***Percentage (%)***
Run-over	6	1.9
Accidental captivity	3	1.0
Illegal Captivity	1	0.3
Collision	19	6.1
Debility/Undernourished	17	5.4
Unknown	2	0.6
Conspurcation/Oil	2	0.6
Predation	8	2.6
Nest Fall	193	61.9
Trauma	61	19.6
Total	312	100.0

When looking into the ages of the birds at admission (Table 3), the most common occurrences are nestlings (N=189), which explains the fact that most cases which were presented in CERVAS resulted from falling from the nest.

Table 3. Number of admissions of swifts discriminated by age

Age at admission	***Frequency (N)***	***Percentage (%)***
Adult	80	25.6
Juvenile	43	13.8
Nestling	189	60.6
Total	312	100.0

2 Body Weight

When in the wild, both species are expected to have significant variance of their weight, depending on the season and weather conditions (Lack & Lack 1951; Boano et al. 2015). However, since the swifts rehabilitated were fed by the centre's personnel at predetermined hours and kept from their natural environment, it's expected that they should not have the same weight gain pattern as in the wild.

The body weight of the adults of both species was compared and no difference was found between the two groups ($p>0.05$) (Table 4).

Table 4. Adult swift's body weight measurements before release from CERVAS

Feature	***A. apus (AA)***		***A. pallidus (PA)***		***Difference AA-PA***	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Release Weight (g)	39.66 ± 4.05 (34.00 – 44.00)	7	35.99 ± 4.08 (31.31 – 44.00)	16	-0.706	0.489

When making the same comparison with the values for the juveniles, there is a significant difference, where juvenile common swifts are heavier than pallid swifts ($p<0.05$) (Table 5).

Table 5. Juvenile swift's body weight measurements before release from CERVAS. * Statistical significance between the two means (p<0.05)

Feature	***A. apus (AJ)***		***A. pallidus (PJ)***		***Difference AJ-PJ***	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Release Weight (g)	37.12 ± 3.94 (30.00 – 47.30)	40	35.35 ± 4.59 (28.00 – 47.00)	88	2.102	**0.038***

The weights of common swifts increased with age, however the difference was not statistically different between juveniles and adults (p>.05) (Table 6). The same happened when comparing the mean body weight of pallid swifts (p>0.05) (Table 7).

Table 6. ***Apus apus*** **body weight measurements before release from CERVAS**

Feature	***Juvenile (AJ)***		***Adult (AA)***		***Difference AA-AP***	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Release Weight (g)	37.12 ± 3.94 (30.00 – 47.30)	40	39.66 ± 4.05 (34.00 – 44.00)	7	1.567	0.124

Table 7. ***Apus pallidus*** **body weight measurements before release from CERVAS**

Feature	***Juvenile (PJ)***		***Adult (PA)***		***Difference PA-PP***	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Release Weight (g)	35.35 ± 4.59 (28.00 – 47.00)	88	35.99 ± 4.08 (31.31 – 44.00)	16	0.516	0.607

When comparing the referenced values (Table 8) for common swifts with those obtained from CERVAS, it's noticeable that the first are all above the second, for both adults and juvenile birds. Even so, the average from the rehabilitation centre is inside the referenced value range in both cases. Since the majority of referenced values were obtained from animals captured in the wild, we can infer that even if the weight at release is lower than what is recommended by the bibliography (40 grams) (Galvez 2012; GREFA n.d.; Matthes n.d.), the swift has the necessary weight for survival.

As for the pallid swift, there is fewer information and it's only possible to compare the adult individuals of this specie. Since there is a study developed in Portugal, the reference value obtained from this source has more relevance than the others, as the environmental conditions are similar to ours. As such, even though the average weight of released pallid swifts is quite lower than those of wild birds from Italy and Gibraltar, this difference is halved when compared to those captured in Portugal (Cramp 1985; Costa & Elias 1998; Boano et al. 2015).

The difference between the two age groups of common swifts was previously described by Lack and Lack, in 1951 (Table 8), although the interval between the two was rather small. In addition to this comparison, Cramp, S. (1985) has collected the values for adults of both species and registered a difference between the average weight where adult common swifts are heavier that pallid swifts. Although there isn't a statistical significance in our results, the same finding is present in our study, with a four-gram difference between the means of the body weight of the two species.

The lack of information on juvenile pallid swifts is a limitation, therefore it could be relevant to compare the weight values between the two species. However, since our results gave a statistically significant difference between the two species (Table 5), this comparison may not be accurate.

Table 8. Swift's body weight in different locations. ND = not determined

Reference	***Location***	***N***	***Mean weight (g) (range)***
Common swift fledglings			
Lack & Lack 1951	UK	73	41.4 (34.0 – 52.0)
Pellinger 2006	Hungary	16	53.6 (not given)
Fusté et al. 2013	Spain	28	40.3 (33.0 – 46.5)
Common swift adults			
Lack & Lack 1951	UK	102	42.7 (35.9 – 52.2)
Gladwin & Nau 1964	UK	237	42.8 (not given)
Cramp 1985	Gibraltar	24	44.9 (not given)
Pellinger 2006	Hungary	15	48.4 (not given)
Pallid Swift fledglings	**ND**	**ND**	**ND**
Pallid Swift adults			
Boano et al. 2015	Italy	134	40.2 (not given)
Costa & Elias 1998	Portugal	382	38.7 (not given)
Cramp 1985	Gibraltar	100	41.3 (not given)

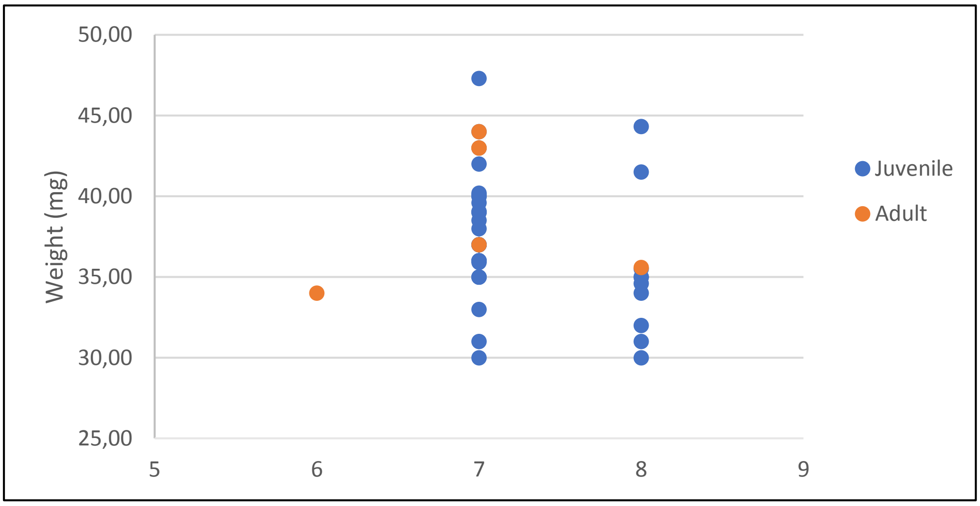
The referenced values from Fusté et al. (2013) correspond to swifts which were hand reared in a rehabilitation centre, and the value from Pellinger, A. (2006) on common swift fledglings is measured at the end of the weight gain period, which explains the difference to the other values of the same group, after this period, the weights measured had a mean of 46.13 ± 4.33 (N=14).

Although the average weight of the species is noteworthy, it's also important to analyse the values per month, as there is evidence of significant variation between the months (Lack & Lack 1951; Gladwin & Nau 1964; Costa & Elias 1998; Fusté et al. 2013).

Through the study of the graph we note constant variation of the weights of the four groups throughout the year. The common swift, which is released between June and August has a peak during July, for both the adult and juvenile birds (Table 9 and Graph 2).

Table 9. Mean body weight (g) of *Apus apus* birds before release from CERVAS. Data is discriminated by month

Month	***Adult***			***Juveniles***		
	Mean ± SD	N	Range	Mean ± SD	N	Range
June	34.80 ± 1.21	2	34.00 – 35.60	35.00	1	-
July	42.75 ± 1.26	4	41.00 – 44.00	37.82 ± 3.66	29	30.00 – 47.30
August	37.00	1	-	35.29 ± 4.47	10	30.00 – 44.32

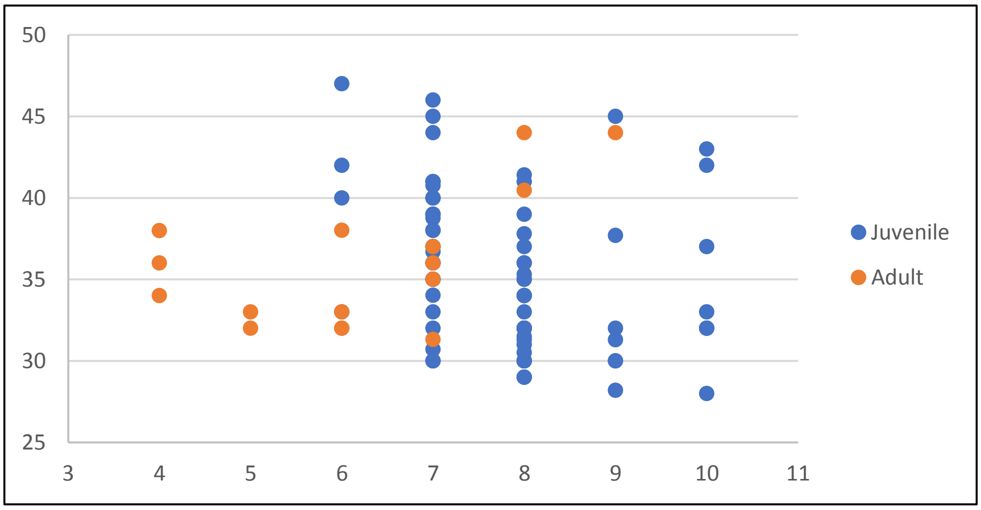


Graph 2. Body weight (g) distribution of *Apus apus* birds before release from CERVAS. Data is discriminated by month of release

The pallid swift follows a different pattern than the common swift. The adults have higher weights in August and September, while with the juveniles, this happens in June. During the other months the weights are more constant, with slight variations (Table 10 and Graph 3).

Table 10. Mean body weight (g) of *Apus pallidus* birds before release from CERVAS. Data is discriminated by month

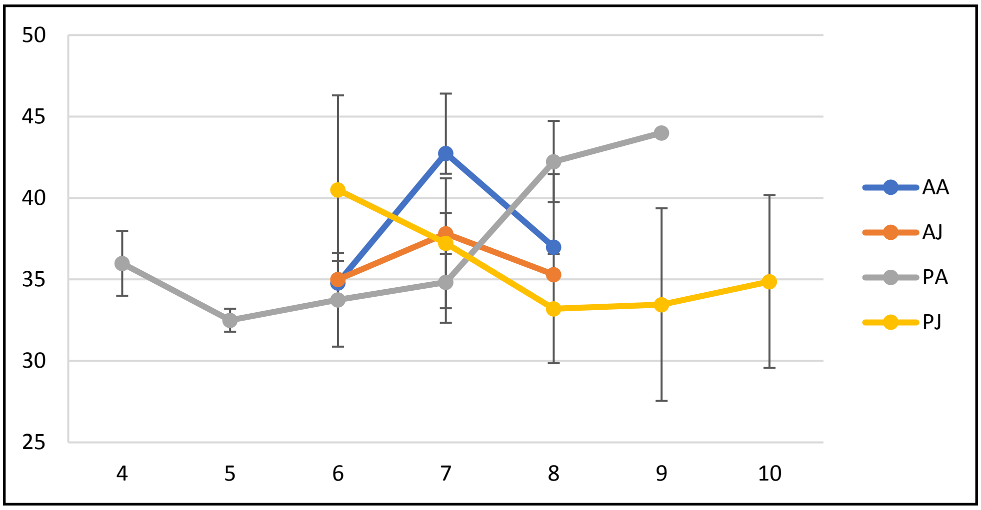
Month	Adult			Juveniles		
	Mean ± SD	N	Range	Mean ± SD	N	Range
April	35.99 ± 1.99	3	34.00 – 37.98	-	-	-
May	32.50 ± 0.71	2	32.00 – 33.00	-	-	-
June	33.75 ± 2.48	4	32.00 – 38.00	40.50 ± 5.80	4	33.00 – 47.00
July	34.83 ± 2.48	4	31.31 – 37.00	37.22 ± 3.99	36	30.00 – 46.00
August	42.24 ± 2.50	3	40.47 – 44.00	33.21 ± 3.34	33	29.00 – 41.40
September	44.00	1	-	33.46 ± 5.91	7	28.20 – 45.00
October	-	-	-	34.88 ± 5.30	8	28.00 – 43.00



Graph 3. Body weight (g) distribution of *Apus pallidus* birds before release from CERVAS. Data is discriminated by month of release

When studying the collective variations of these four groups, adult and juvenile of the two species, in three of them there is a decrease in the average weight at release in august, while the *Apus pallidus* adults' release weight increases in this month and the one after (Graph 4).

Costa, L. T. and Elias, G. L. (1998) found significant difference between the months of April and June, and May and July, with birds heavier in the first, when studying adult pallid swifts. Boano et al. (2015) found similar results, with higher weights in June and September, and lower from April to May, and again in August, in individuals equal to those of the previous referenced study. The seasonal variation detected in these animals may be due to their reproductive behaviour, where the lowest weights correspond to the increased effort to collect food to feed their chicks, or it might be a result of weather and insect abundance (Boano et al. 2015).



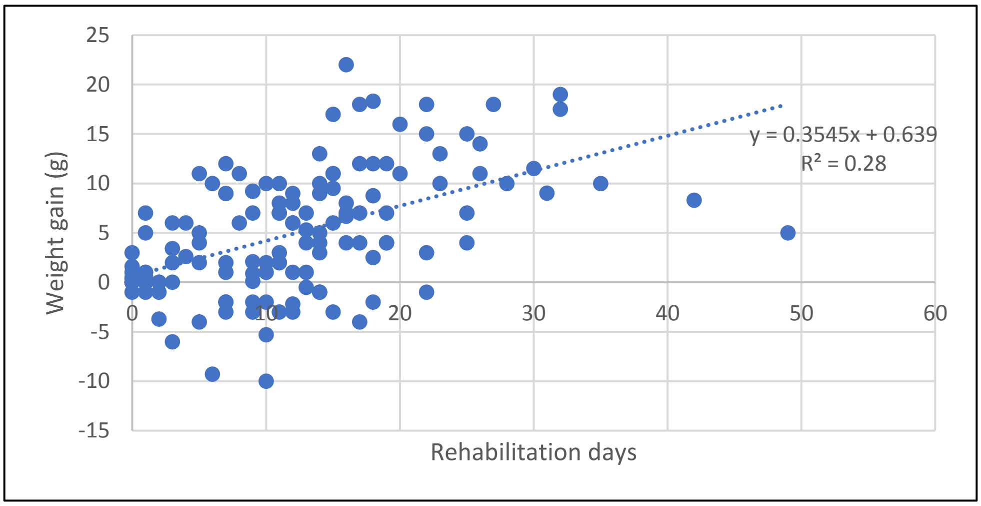
Graph 4. Mean body weight (g) of swifts before release from CERVAS. Data is discriminated by month. AA – Adult *Apus apus* birds; AJ – Juvenile *Apus apus* birds; PA – Adult *Apus pallidus* birds; PJ – Juvenile *Apus pallidus* birds

As it was said before, it would be expected that these birds should have less variation when it comes to the weight, due to the conditions they are kept in, and the lack of the reproductive stress associated with the presence of clutches. However, this is not what the evidence shows. As these are wild animals, it's possible that the stress caused by their manipulation will result in decreased weights, although the results gathered by Fusté et al (2013) show that the weights, on average, can be higher. Another possibility is the period of captivity which may have a negative effect on their weight gain.

We observed through the Pearson correlation that there is a direct relation between the weight gain and the rehabilitation period (r=0.492) (Table 11), where the increase in days kept in rehabilitation has a proportional increase in weight gain (b=0.3545) (Graph 5). Therefore, it's possible that by keeping the birds for more days in the centre may result in a higher weight at release.

Table 11. Correlation between the period of rehabilitation and weight gain. * statistically significant when compared the two means (p<0.05)

		Rehabilitation days	*Weight gain (g)*
Rehabilitation days	**Pearson correlation**	1	0.492*
	Sig. (2 tailed)		0.000
	N	198	168
Weight gain	**Pearson correlation**	0.492*	1
	Sig. (2 tailed)	0.000	
	N	168	168



Graph 5. Regression line of weight gain on the period of rehabilitation in the centre

We also placed some hypothesis for the reason why these animals had lower weight measures in the months before the reproductive season ends. As seen in the bibliography, there are cases of these birds surviving with less body mass, and since the winter migration has started by then, it's necessary to determine whether it's more beneficial for the swift to remain in the centre for the winter, until the return of the specie, or to release it as it is. In the cases from the centre, the veterinary team must have concluded that the birds would be able to survive in the wild and decided to release it.

3 Morphometric Parameters

Through the biometric values collected, it was possible to compare the two species (Table 12 and 13) and detect any differences between juveniles and adult individual of each specie (Table 14 and 15).

In the adults of both species, there weren't any significant differences in any of the biometric parameters (Table 12), which was not the case for the juveniles, in which the mean width of the tarsus of the common swift was larger than the one of the pallid swift (Table 13). However, since the difference between the two is less than a millimetre, and the ranges overlap, this characteristic should not be used to differentiate the juveniles of the two species.

Table 12. Adult swift's biometric measurements before release from CERVAS. * statistically significant when compared the two means (p<0,05)

Feature	***A. apus (AA)***		***A. pallidus (PA)***		***Difference AA-PA***	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Wing length (mm)	168.43 ± 5.50 (160.00 – 178.00)	7	170.64 ± 7.29 (152.00 – 180.00)	14	-0.706	0.489
8th Primary (mm)	142.50 ±10.61 (135.00 – 150.00)	2	118.00 ± 8.49 (112.00 – 124.00)	2	-	-
Bill (mm)	6.37 ± 0.49 (6.00 – 7.00)	6	6.68 ± 0.62 (5.50 – 7.50)	14	-1.066	0.300
Head (mm)	31.62 ± 1.14 (30.50 – 34.00)	7	31.24 ± 2.15 (26.00 – 35.00)	14	0.441	0.664
Tarsus length (mm)	10.84 ± 0.88 (10.00 – 12.00)	7	10.70 ± 1.69 (7.50 – 13.00)	14	0.203	0.841
Tarsus depth (mm)	2.03 ± 0.09 (2.00 – 2.24)	7	2.26 ± 0.38 (2.00 – 3.00)	14	-2.080	0.054
Tarsus width (mm)	2.27 ± 0.37 (2.00 – 2.91)	7	2.17 ± 0.23 (2.00 – 2.50)	14	0.646	0.536

When comparing the same parameters for the juveniles and adults of the specie *A. apus*, there were significant differences between the wing length, the size of the 8th primary feather and the size of the head. For all three, the measure of the adult was larger than those of the juveniles (Table 14). There is a decrease in the size of the tarsus depth, however since the ranges for adults and juveniles are very similar, the difference can be explained by the sample size, since there are only 7 measurements for adult common swifts.

Table 13. Juvenile swift's biometric measurements before release from CERVAS. * statistically significant when compared the two means (p<0.05)

Feature	*A. apus (AJ)*		*A. pallidus (PJ)*		*Difference AJ-PJ*	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Wing length (mm)	160.74 ± 5.67 (150.00 – 170.00)	35	160.84 ± 6.19 (137.00 – 175.00)	83	-0.083	0.934
8th Primary (mm)	129.86 ± 5.64 (120.00 – 135.00)	7	128.75 ± 7.46 (118.00 – 135.00)	4	0.280	0.786
Bill (mm)	6.19 ± 0.84 (5.00 – 9.00)	34	6.35 ± 0.82 (5.00 – 10.00)	81	-0.932	0.353
Head (mm)	30.13 ± 1.55 (26.00 – 32.00)	34	30.52 ± 1.29 (24.50 – 33.00)	82	0.146	0.165
Tarsus length (mm)	10.98 ± 1.21 (8.00 – 13.00)	34	10.81 ± 1.05 (8.50 – 14.00)	81	0.775	0.440
Tarsus depth (mm)	2.12 ± 0.21 (2.00 – 2.59)	34	2.05 ± 0.20 (1.50 – 2.50)	81	1.831	0.070
Tarsus width (mm)	2.38 ± 0.33 (1.98 – 3.00)	34	2.14 ± 0.28 (1.50 – 3.00)	81	3.845	0.000*

Table 14. Common Swift's biometric measurements before release from CERVAS. * statistically significant when compared the two means (p<0.05)

Feature	*Juvenile (AJ)*		*Adult (AA)*		*Difference AJ-AA*	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Wing length (mm)	160.74 ± 5.67 (150.00 – 170.00)	35	168.43 ± 5.50 (160.00 – 178.00)	7	3.286	**0.002***
8th Primary (mm)	129.86 ± 5.64 (120.00 – 135.00)	7	142.50 ±10.61 (135.00 – 150.00)	2	2.395	**0.048***
Bill (mm)	6.19 ± 0.84 (5.00 – 9.00)	34	6.37 ± 0.49 (6.00 – 7.00)	6	0.521	0.606
Head (mm)	30.13 ± 1.55 (26.00 – 32.00)	34	31.62 ± 1.14 (30.50 – 34.00)	7	2.407	**0.021***
Tarsus length (mm)	10.98 ± 1.21 (8.00 – 13.00)	34	10.84 ± 0.88 (10.00 – 12.00)	7	-0.292	0.772
Tarsus depth (mm)	2.12 ± 0.21 (2.00 – 2.59)	34	2.03 ± 0.09 (2.00 – 2.24)	7	-1.814	0.084
Tarsus width (mm)	2.38 ± 0.33 (1.98 – 3.00)	34	2.27 ± 0.37 (2.00 – 2.91)	7	-0.746	0.460

The results found for the pallid swift differ from those of the common swift. The only parameter with significant difference is the wing length, which grows around on average 10 millimetres from a juvenile to an adult (Table 15). One curious finding with these values is the difference in the size of the 8th primary feather, where the mean from the adult is smaller. As there are only two samples, it is hard to take any conclusions and a more extensive study is required.

Table 15. Pallid Swift's biometric measurements before release from CERVAS. * Statistically significant when compared the two means (p<0.05)

Feature	*Juvenile (PJ)*		*Adult (PA)*		*Difference PJ-PA*	
	Mean ± SD (Range)	N	Mean ± SD (Range)	N	T test	P
Wing length (mm)	160.84 ± 6.19 (137.00 – 175.00)	83	170.64 ± 7.29 (152.00 – 180.00)	14	5.343	**0.000***
8th Primary (mm)	128.75 ± 7.46 (118.00 – 135.00)	4	118.00 ± 8.49 (112.00 – 124.00)	2	-1.607	0.183
Bill (mm)	6.35 ± 0.82 (5.00 – 10.00)	81	6.68 ± 0.62 (5.50 – 7.50)	14	1.438	0.154
Head (mm)	30.52 ± 1.29 (24.50 – 33.00)	82	31.24 ± 2.15 (26.00 – 35.00)	14	1.732	0.087
Tarsus length (mm)	10.81 ± 1.05 (8.50 – 14.00)	81	10.70 ± 1.69 (7.50 – 13.00)	14	-0.229	0.822
Tarsus depth (mm)	2.05 ± 0.20 (1.50 – 2.50)	81	2.26 ± 0.38 (2.00 – 3.00)	14	2.005	0.064
Tarsus width (mm)	2.14 ± 0.28 (1.50 – 3.00)	81	2.17 ± 0.23 (2.00 – 2.50)	14	0.383	0.703

The significant difference found in the size of the wing supports the theory that the wing keeps on growing after the swift leaves the nest, posterior to the first moult (Lack & Lack 1951). The same reason can be used to explain the same finding with the size of the 8th primary feather. In relation to the difference in the head, we observed a difference in means close to 1.5 millimetres, which can be attributed to animal growth.

The findings for the pallid swift show a statistically significant difference (p<0.05) for the size of the wing. This follows the same train of thought as for the common swift, where the wing achieves its full size after the first moult.

When comparing these values with those from the bibliography, there are some differences found as well, both for the common and the pallid swift.

For the common swift, Cramp, S. collected different biometric values for this bird, differentiating between gender and age. In this study, the average wing size for birds from the Netherlands, Britain and West Germany measured as follows: 173 millimetres (adults), 166 millimetres (male juveniles) and 168 millimetres (female juveniles) (Cramp 1985).

One other study was performed, prior to the previous one, between the years of 1946 and 1950, where Lack, D. and Lack, E. measured the growth of the wing. At the time of fledging, or when the bird first flew, the wing had an average of 165 millimetres, and 173 millimetres for adults. This study was performed on common swifts living in Oxford, and the results take into account cases of birds growing in bad weather, which may result in retarded or better growth of the wing (Lack & Lack 1951).

By comparing the values described with the ones obtained from the rehabilitation centre, where the common swift has an average of 161 and 168 millimetres, for juveniles and adults respectively, in both cases the wing was shorter than in those of the bibliography, by at least 5 millimetres to the lowest average. This difference might be due to the recovery process, from the frequency of feeding to the lack of supplementation, or other factors not yet discovered, which have a hand in the adequate development of this specie.

In the case of the pallid swifts, in 2015, Boano et al. found a significative difference between the two genders of pallid swift, where the wing of males was rounded to 177 millimetres and 174 millimetres for females, in adult pallid swifts captured in southwestern Italy (Boano et al. 2015). Before this study others were performed. In Portugal, in 1998, the average wing size measured 175 millimetres (Costa & Elias 1998) and, in 1985, Cramp, S. also collected their morphometric characteristics from individuals in the Canary Islands, Madeira, Northern Algeria, Tunisia, Spain, Southern France and Italy. In this book, the adult pallid swift has a wing with 171 millimetres, and the juvenile has a smaller wing by 2 millimetres (Cramp 1985).

As with the common swift, there is also some difference between the size of the wing recorded in CERVAS and the ones from the bibliography for pallid swifts, although on a smaller scale (3 millimetres to the lowest average), or, as described by Cramp, S., the means are the same. This indicates that whichever factor is responsible for the decreased growth in birds of the specie *A. apus,* does not have the same influence over pallid swifts. Considering the feeding habits of these birds, it’s possible that the mealworms are better able to fulfil their nutritional requirements.

This difference also goes against the theory of the existence of a west-to-east gradient in wing size, with higher values found more to the west (Boano et al. 2015; Costa & Elias 1998), which is not observed in this study.

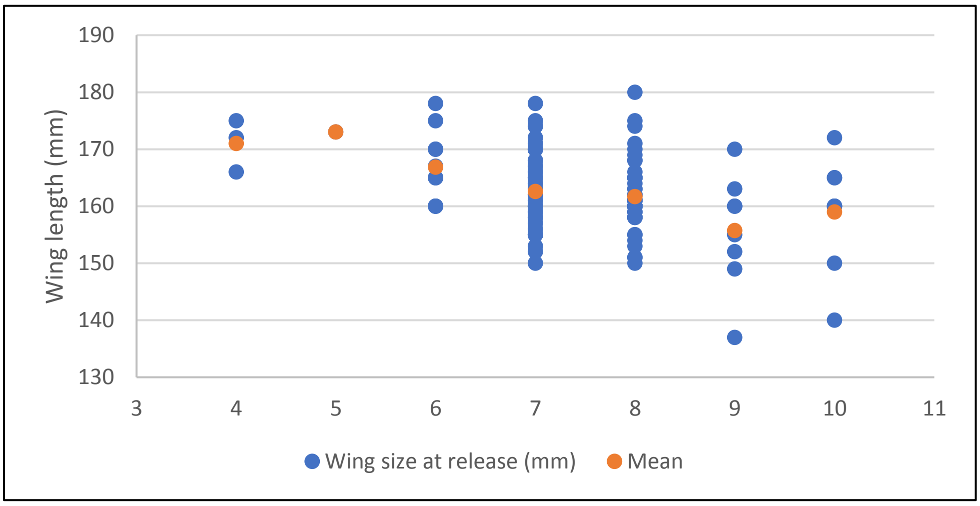
The 8th primary feather is another characteristic which was monitored by Boano et al. in 2015, with an average of 140 millimetres. This value is quite larger than the one from our results, however since there is a small sample further studying should be performed.

The length of the bill is another characteristic measured which has been referenced in the literature. Cramp, S. (1985) registered the size of the beak at an average of 6.6 millimetres for common swifts, and 6.6 and 6.7 for male and female pallid swifts respectively (Cramp 1985). One other source lists this characteristic as having on average 6.25 millimetres (Boano et al. 2015). These references are on par with the values collected from CERVAS, where the mean for this parameter is 6.8 millimetres.

As with the previous biometric comparison, the length of the tarsus is also described in the same sources, and the average value from the rehabilitation centre where the samples were collected matches the lengths found in the bibliography, with a difference of less than 1 millimetre between the corresponding means. In 1985, Cramp, S. noted that the adult male common swift had an average length of 10.9 millimetres and the female 11.3 millimetres, while the adult male pallid swift's tarsus had 11.1 and the female 11.4 millimetres, on average (Cramp 1985). Boano et al. (2015) also measured this anatomic characteristic, registering a mean of 10.5 millimetres (Boano et al. 2015).

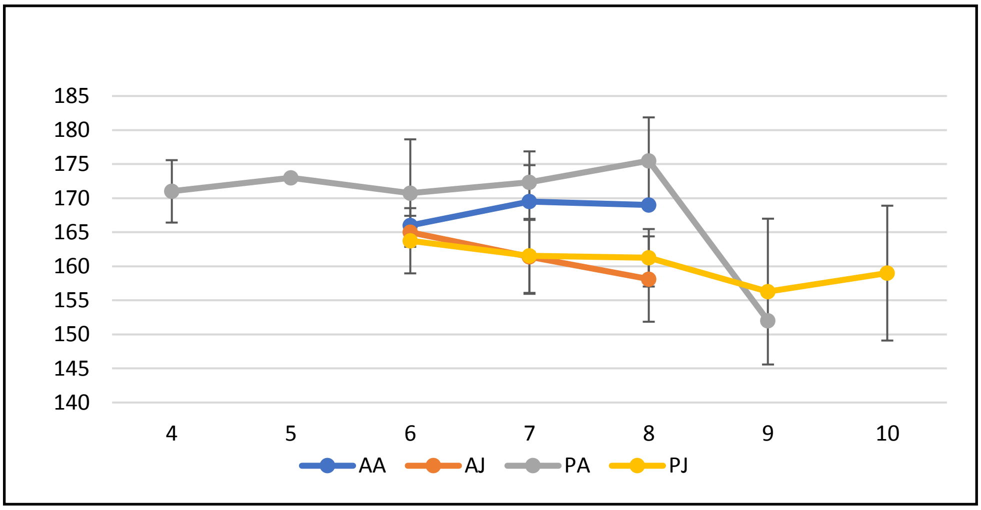
It's necessary to refer that while Cramp, S. registered values for males and females of the two species, none of them were found to be significant.

When analysing these parameters, it's possible to have some idea on the correct development of the animals. In this case, we note that the wings, in most cases, grew to the standard size necessary for release (N=104), and when this did not happen the bird was judged capable of flight by the team of the rehabilitation centre and it would be able to survive back in the environment (N=39).



Graph 6. Distribution and mean wing length (mm) of swifts prior to release from CERVAS. Data is discriminated by month

When we study the dispersion of the animal's wing size at release (Graph 6), we note that the cases where the wing was smaller happen in the last months prior to the migration of the species to Africa. As such, to prevent a longer stay in the rehabilitation centre, through the winter, the birds are released near the limit of the recommended value. This conclusion is supported by the following graph where this parameter is discriminated according to age and specie (Graph 7).



Graph 7. Mean wing length (mm) of swifts before release from CERVAS. Data is discriminated by month. AA – Adult *Apus apus* birds; AJ – Juvenile *Apus apus* birds; PA – Adult *Apus pallidus* birds; PJ – Juvenile *Apus pallidus* birds

As with the weight, the wing size is in general below the recommended value for release, however, by taking into consideration the "facultative adjustment hypothesis", suggested by (Wright et al. 2006), this observation may be explained as a consequence of the birds' need to achieve an optimal wing load, necessary for flight.

Since it’s not yet possible to follow the state of the animal post release, from lack of funds and the labour necessary to accompany all of these cases, unless the serial number from the ring placed is cross referenced when, and if, the individual is detected somewhere else, it’s difficult to determine the real success of the rehabilitation process and, as such, it’s possible that these differences may be detrimental to their re-adaptation to the wild and result in behaviours more or less defective.

4 Survival rates

It is noteworthy that the trauma cases are the ones with the lowest rehabilitation success, with a 21.4% of release rate, and are also the ones with the highest rate of euthanasia (61.9%). Although conspurcation resulted in half of the sample being euthanised, this value has little statistical significance since there are only two reported cases in the rehabilitation centre CERVAS (Table 16).

The highest release rates from CERVAS are cases of, accidental (100%) and illegal (100%) captivity and admission due to predation of these birds (75%), however, due to the small sample size, these results may not reflect the reality. The next cause with the highest release rate is the falling from the nest, with a 73.2% release rate from 172 cases (Table 16).

Table 16. Outcome rates (frequency, percentage and cumulative percentage) discriminated by cause of admission. N=261

Cause	*Final state*	*N*	*Percentage*
Trampling/ Run-over	Released	3	50.0
	Euthanasia	2	33.3
	Died in 2 days	1	16.7
	Total	6	100.0
Accidental Captivity	Released	3	100.0
Illegal Captivity	Released	1	100.0
Collision	Released	12	70.6
	Euthanasia	5	29.4
	Total	17	100.0

Debility/ Undernourishment	Released	7	77.8
	Died in 2 days	2	22.2
	Total	9	100.0
Unknown	Released	1	100.0
Conspurcation/ Oil	Released	1	50.0
	Euthanasia	1	50.0
	Total	2	100.0
Predation	Released	6	75.0
	Died in 2 days	2	25.0
	Total	8	100.0
Falling from Nest	Released	126	73.2
	Euthanasia	13	7.6
	Died in 2 days	21	12.2
	Died after 2 days	12	7.0
	Total	172	100.0
Trauma	Released	9	21.4
	Euthanasia	26	61.9
	Died in 2 days	3	7.1
	Died after 2 days	4	9.5
	Total	42	100.0

These findings can be explained by the severity of the injuries, where the trauma cases won't be able to recover to a point in which they will be able to survive back in the natural environment, resulting in higher morbidity and mortality (Molony et al. 2007; Grogan & Kelly 2013; Molina-López et al. 2017). This also explains the fact that cases of trampling by cars has a lower release rate (50%), when compared to the other causes of ingress.

This is not the case for falls from the nest or captivity, where, as long as the birds do not sustain heavy injuring, they only require food and shelter where they can develop their body and behaviours as naturally as possible.

We also investigated the relation between the result of the rehabilitation process and the cause of ingress. In this test we grouped cases of death before and after admission.

From Table 17 we note that both the released cases and the euthanasia ones have significant differences according to the cause of ingress, where the release rate of trauma cases is significantly lower than those of nest falls, and the euthanasia rates is significantly higher, which reflects a lower possibility of rehabilitation for traumas.

Table 17. Analysis relating the final state (release, died and euthanasia) and the cause of admission. [a] is statistically different from [b] ($p<0,05$). N=261

		Captivity	*Debility/ Undernourished*	*Unknown*	*Conspurcation/ Oil*	*Nest Fall*	*Trauma*
Release	N	4[a, b]	7[a, b]	1[a, b]	1[a, b]	126[b]	30[a]
	%	100.0%	77.8%	100.0%	50.0%	73.3%	41.1%
Euthanasia	N	0[a, b]	0[a, b]	0[a, b]	1[a, b]	13[b]	33[a]
	%	0.0%	0.0%	0.0%	50.0%	7.6%	45.2%
Died	N	0[a]	2[a]	0[a]	0[a]	33[a]	10[a]
	%	0.0%	22.2%	0.0%	0.0%	19.2%	13.7%
Total	N	4	9	1	2	172	73
	%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

By reversing the variables, we get some more results, in Table 18 the outcome rates have significant differences for admissions caused by trauma and nest falls, between euthanasia and the other two. This information can be translated by the fact that in cases of trauma there is a significantly higher probability of euthanasia as the animal won't be able to survive even if the ailment is healed, and cases of falling from the nest have a lower rate of euthanasia, since these cases usually don't involve compromising injuries to their survival after rehabilitation. There were no differences found between the animals which died, and the ones released, for both causes.

Table 18. Analysis relating the final state (release, died and euthanasia) and the cause of admission. [a] and [b] are significantly different (p<0.05). N=261

		Release	*Euthanasia*	*Died*
Captivity	N	4[a]	0[a]	0[a]
	%	100.0	0.0	0.0
Debility/Undernourishment	N	7[a]	0[a]	2[a]
	%	77.8	0.0	22.2
Unknown	N	1[a]	0[a]	0[a]
	%	100.0	0.0	0.0
Conspurcation/Oil	N	1[a]	1[a]	0[a]
	%	50.0	50.0	0.0
Nest Fall	N	126[a]	13[b]	33[a]
	%	73.3	7.6	19.2
Trauma	N	30[a]	33[b]	10[a]
	%	41.1	45.2	13.7
Total	N	169	47	45
	%	54.2	15.1	17.2

The relation between the admission weight and the outcome of the rehabilitation process was also studied and there were significant differences between them (Table 19). As the weight between adult and juvenile swifts wasn't found to be different, no discrimination was made for this test.

Table 19. Analysis relating the final state (release, died and euthanasia) and the weight at the moment of admission (g). [a] is statistically different from [b] (p<0.05)

	Mean (g)	*N*	*Standard Deviation*
Released	31.1622[a]	148	7.63188
Euthanasia	30.9268[a]	41	6.41635
Died	26.1905[b]	42	7.42191
Total	30.2165	231	7.60468

Swifts which were later released were admitted at the centre heavier than the ones that were dead or died at the centre. This can be explained by the fact that these birds have more severe conditions and, in general, a poorer prognosis, which is reflected by their lower weight; also, many disorders have loss of weight as a clinical sign.

As with released birds, the cases of euthanasia have higher weight at admission than those that died. Usually, in these centres, the euthanasia is performed by the veterinarian due to physical limitations which impair its flying ability (shoulder or elbow luxation and irreversible ocular damage, for example) (Haupt n.d.) in which cases it's an acute process and the body mass hasn't been affected directly.

The entry weight of birds which were later released and those that were euthanised don't have a significant difference.

5 Recovery period

The causes of admission which resulted in longer periods of rehabilitation, on average, at CERVAS were falls from the nest (14.6 days). It's important to take notice that the cases of conspurcation and of unknown origin only have been described once for each, in this centre (Table 20). For this reason, these ones have little value when studying the effect of the cause of admission over the period of rehabilitation.

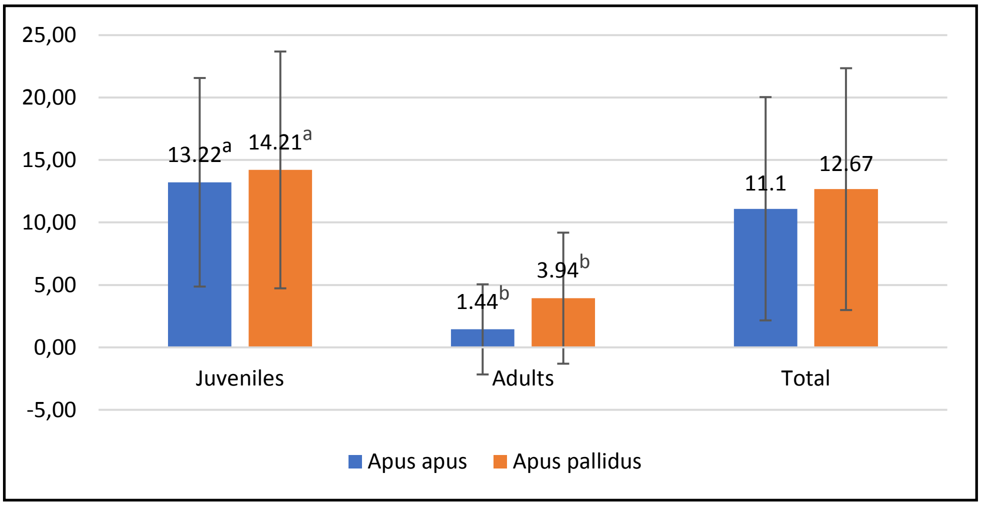
Table 20. Mean of days spent in the rehabilitation centre until release according to the cause of admission. [a] is statistically different from [b] ($p<0.05$). N=168

	Mean (days)	***N***	***Standard deviation***
Captivity	5.75[a, b]	4	7.303
Debility/Undernourishment	2.00[a]	7	4.435
Unknown		1	-
Conspurcation/Oil		1	-
Nest Fall	14.60[b]	125	8.940
Trauma	6.33[a]	30	7.303

When related to the period of rehabilitation there are significant differences between cases of nest falls and, debility and/or undernourishment and trauma, with the first cases having a longer recovery time. This observation might be due to the large number of young birds that fall from their nest and are brought to the centre. There, these birds will need to complete their development before the reintroduction in their natural habitat, a process that takes time.

The trauma cases are those where extreme cases will not be considered for recovery or die soon after their admission. In fact, trauma cases have the lowest rate of release (41.1%) of this rehabilitation centre, with a significantly lower value than the one for nest falls (Table 5). As for the debility or undernourishment cases, further analysis is required, as no significant difference was found between the release rates, meaning that these might be cases where the animals only required somewhere to regain their strength.

In CERVAS, there is no difference between the means of the rehabilitation period between the two species. However, the is a noticeable difference between adults and juveniles released from CERVAS, where adult swifts, of the two species (*Apus apus* and *Apus pallidus*) have a rehabilitation period significantly lower than the one of juveniles of the same species (Graph 8).



Graph 8. Average number of days spent in the rehabilitation centre until release for common swift (*Apus apus*) and pallid swift (*Apus pallidus*), adults and juveniles. $\mathbf{N_{\textit{A. apus}\ juveniles}=41}$; $\mathbf{N_{\textit{A. pallidus}\ juveniles}=91}$; $\mathbf{N_{\textit{A. apus}\ adults}=9}$; $\mathbf{N_{\textit{A. pallidus}\ adults}=16}$; $\mathbf{N_{\textit{A. apus}\ Total}=50}$; $\mathbf{N_{\textit{A. pallidus}\ Total}=107}$

When we look at this new information with the previously discussed, the longer rehabilitation period of swifts released as juveniles is due, in part, to the high number of nestling admissions at the centre, which will require the time to fully develop.

V Conclusions

1. The number of live swifts admitted in CERVAS is highest in July;
2. The number of swifts reintroduced from CERVAS peaks in July;
3. The most common causes of admission in CERVAS are falls from the nest and trauma;
4. Nestlings make the largest portion of ingresses to CERVAS of common and pallid swifts;
5. Juvenile common swifts are heavier than juvenile pallid swifts;
6. There are no differences between the weights of juvenile and adult swifts, of both species, before reintroduction in the wild;
7. The common swifts released in July are heavier;
8. The weight gain is correlated with the length of the rehabilitation period;
9. The length of the wing, the eighth primary feather and the head of the adults of common swifts are significantly longer than the juveniles of the same specie;
10. The length of the wing of the adults of pallid swifts are significantly longer than the juveniles of the same specie;
11. The length size of swifts released in September and October are smaller;
12. Trauma cases have the lowest reintroduction rates, resulting in euthanasia, in most cases;
13. Accidental and illegal captivity cases have high reintroduction rates and but low occurrence rate, in these species;
14. Swifts that fall from the nest have a higher probability of release than euthanasia;
15. Birds that were released are significantly heavier at admission than those that died;
16. Cases of illegal captivity, falling from the nest and conspurcation or oil are the ones which require a longer rehabilitation period;
17. Juvenile swifts require longer rehabilitation periods when compared to adults.

The study of the morphological characteristics allows the delineation of pattern values which can be used to improve the rehabilitation process by reaching biometric values previously defined, ensuring a development closer to natural and increasing the survival rate of released animals. Also, the analysis of the admission causes may allow the centre to optimize the use of their efforts and resources to improve their efficacy.

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Annex A - Admission form used in CERVAS. Form ceded by CERVAS

ICNF
Instituto da Conservação da Natureza e das Florestas

aldeia

CERVAS
Centro de Ecologia, Recuperação e Vigilância de Animais Selvagens
FICHA DE INGRESSO

Dados do indivíduo

Espécie: Nome comum ____________ Nome científico ____________

Dados da recolha

Data: ___ / ___ / 201___ Hora: ____ : ____

Local: Coordenadas UTM ____________ Lugar ____________
Propriedade/Zona de Caça ____________
Freguesia ____________
Concelho ____________ Distrito ____________

Descrição da situação ____________

Suspeita de causa ____________

Recolha:
Particular ☐ ICNF ☐ GNR/SEPNA ☐ Polícia Florestal ☐ Bombeiros ☐ ONG ☐ Outros ☐
Nome: ____________
Organização/Entidade: ____________
Morada: ____________
Código Postal: ______ - _____ Localidade ____________
Concelho: ____________ Distrito ____________
Telefone: ____________ Telemóvel ____________ E-mail: ____________

Condições de manutenção:
Local: ____________
Alimentação: Não ☐ Sim ☐ Tipo: ____________
Medicação: Não ☐ Sim ☐ Tipo: ____________

Transporte e entrega no CERVAS:

Particular ☐ ICNB ☐ GNR/SEPNA ☐ Polícia Florestal ☐ Bombeiros ☐ ONG ☐ Outros ☐
Nome: ____________
Organização/Entidade: ____________
Morada: ____________
Código Postal: ______ - _____ Localidade ____________
Concelho: ____________ Distrito ____________
Telefone: ____________ Telemóvel ____________ E-mail: ____________

Notas/Observações: ____________

Responsável pela recepção: ____________