UNIVERSITÀ DEGLI STUDI DI PADOVA
Dipartimento Biomedicina Comparata e Alimentazione
Department of Comparative Biomedicine and Food Science

Corso di laurea / First Cycle Degree (B.Sc.)
in Animal Care

Captive Management of Rescued European Insectivorous Bats

Relatore / Supervisor
Prof.ssa Magdalena Schrank

Laureanda / Submitted by
Sofia Rizzini
Matricola n. / Student n.
2067312

ANNO ACCADEMICO/ACADEMIC YEAR 2024/2025

Table of Contents

Abstract

European insectivorous bats face numerous anthropogenic and environmental threats, including trauma, predation, disease, climate-induced stress and habitat loss. Consequently, rescue and rehabilitation of debilitated individuals play an important role in their conservation. The aim of this thesis is to provide a comprehensive review of the biology, ecology and challenges facing European bat populations, with a particular focus on best practices for their rehabilitation in rescue centers.

The rehabilitation process begins with a clinical assessment of the bat's conditions, addressing key aspects such as hydration, nutritional status and ectoparasite removal. Captive housing must replicate natural conditions, ensuring proper temperature, humidity, light cycles and provide opportunities for social interactions through group housing. Water must be always available, whereas nutrition protocols vary according to the bat's developmental stage and health conditions. Adult casualties are gradually trained to self-feed on soft food and mealworms, while orphaned juveniles are fed milk replacers and weaned at the appropriate time.

Continual assessment is essential throughout rehabilitation to monitor progress and adjust care. Pre-release conditioning is critical: hand-reared juveniles must acquire essential survival skills such as flight and echolocation abilities, while adults require flight training to rebuild muscle strength. When environmental conditions are suitable, bats deemed fit for release are returned to the wild through soft or hard release methods, with the aim of supporting successful reintegration in the native population and preserving genetic diversity.

Additionally, this thesis addresses zoonotic risks and safety measures for rehabilitators, therapeutic and anesthetic protocols, as well as ethical considerations for euthanasia. Drawing from current scientific literature and rehabilitation guidelines, this review provides practical strategies for the effective care and release of rescued bats, contributing to broader conservation efforts among Europe.

Introduction

The order Chiroptera accounts for one fifth of the extant Mammalian species, counting more than 1400 species divided into 236 genera and 21 families (AMS, 2024). They are found in every continent except for Antarctica and occupy a wide range of environmental and dietary niches (Kunz & Fenton, 2005). Bats have an ancient lineage and, although relatively few fossil records exist (Eiting and Gunnell, 2009), the oldest date back to 52 million years ago in the late early Eocene epoch, with *Onychonycteris finneyi* being considered the oldest and most primitive known bat (Simmons et al., 2008).

Chiropterans have common mammal characteristics such as fur, external ears and mammalian dentition; they are homeotherms and give birth to young which they nurse with milk (Dietz & Kiefer, 2016). However, they show distinctive features that make them peculiar among mammals. The primary characteristics that distinguish them are their ability of active powered flight and the use of echolocation (Anderson & Ruxton, 2020). Echolocation enables them to find and capture prey in the dark by using sounds, making them well-adapted to a nocturnal life (Altringham, 2011). Many bat species are facultative heterotherms and hibernate during winter, which makes them vulnerable to the effects of climate change and rising temperatures (Salinas-Ramos et al., 2023). The lack of an efficient evaporative cooling mechanism to regulate high body temperatures and their relatively large body surface make them highly susceptible to dehydration (Welman et al., 2017), which leads to frequently observed heat stress in rescued animals, especially during the summer reproductive season. Bats often fall from the roosting site and this also exposes them to other threats such as predation and vandalism (Salinas-Ramos et al., 2023).

On account of their odd appearance and the fact that they host a wide range of zoonotic diseases, bats are often feared (Buckles, 2015). However, given their crucial ecological role in maintaining the stability of ecosystems and their significant economic value in controlling agricultural pest insects (Boyles et al., 2011), conservation efforts must be put in place to protect them. Bats conservation efforts are in place both on international and local levels. The Bonn Convention (UNEP, 1979), the European Union's Habitats Directive (European Union, 1992), and the Agreement for the Protection of Bats in Europe (UNEP/EUROBATS, 1994) provide legal protection for bat species that are found in the European area. These agreements offer a foundation for international cooperation in bat conservation and protection, particularly for migratory populations. Locally, rescue centers play a crucial role in rehabilitating and releasing individual bats, both orphan juveniles and adults, back into the wild. This review aims to explore the management practices used in wildlife rescue centers for rehabilitating bats, covering care from newborns to adults, as well as the rearing techniques required for their successful release back into the wild.

1. European Bats Biology and Ecology

1.1. Phylogeny and Distribution

The initial separation of Chiroptera into *Microbats* and *Megabats* was based on species size and presence or absence of laryngeal echolocation and dates back to Simpson's classification of mammals (Simpson, 1945). Jones and Teeling (2006) proposed a new classification of the group in Yangochiroptera and Yinpterochiroptera based on molecular studies. The first includes the former Microbats, also known as Vespertilioniformes, while the latter includes the former Megabats (fruit bats, or Pteropodiformes) and five Microbat families belonging to the Rinolophoidea superfamily (Figure 1).

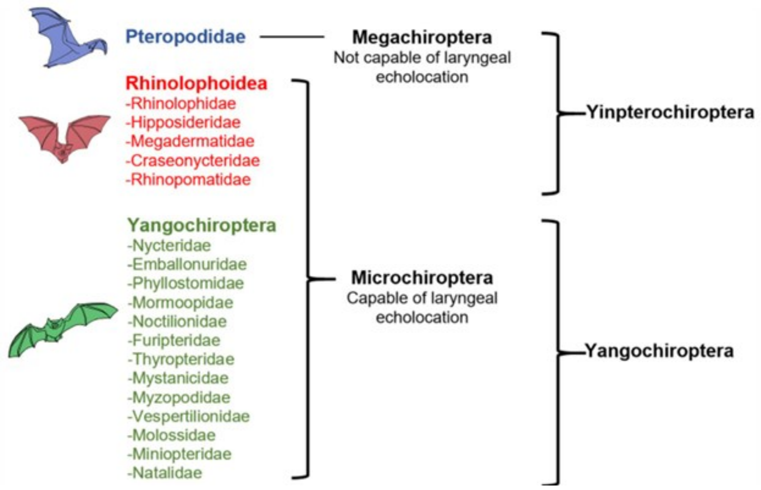

Figure 1 Phylogenetic groupings of chiropterans (Anderson & Ruxton, 2020)

Europe is home to 55 bat species from the suborders Yangochiroptera and Yinpterochiroptera (UNEP/EUROBATS, 1994). The Yangochiroptera include mainly the Vespertilionidae family, with species from several genera such as Myotis, Hypsugo and Pipistrellus, as well as some species from the Emballonuridae (*Taphozous nudiventris*) and Molossidae (*Tadarida teniotis*) families. The Yinpterochiropterans found in Europe consist of horseshoe bats (Rhinolophidae family) and one species of fruit bat, *Rousettus aegyptiacus* (Pteropodidae family).

Taxonomic and systematic data are in constant evolution, mainly because some species are cryptic (e.g., *P. pipistrellus* and *P. pygmaeus*; Figure 2) (Jablonka et al., 2009), but nowadays molecular analysis has made it possible to tackle the problem of group identification for many cryptic species (Dietz & von Helversen, 2006). Hybridization can occur occasionally, further complicating the identification and classification of species and leading to continuous changes in our knowledge of bat species distributions (Dietz & Kiefer, 2016).

Figure 2 Characters of the species *P. pipistrellus* (164-167) and *P. pygmaeus* (168-171; Dietz & von Helversen, 2006).

1.2. Anatomy

Being a heterogeneous group, bats display a wide range variation in facial structures (e.g., ears, eyes, snout shapes and nasal appendages). While the ears evolved as echolocation receivers, the mouth and nose function as sound transmitters. Strong muscles on their upper body support the head during flight and allow a powerful bite. Bat dentition reflects the type of diet: carnivorous and insectivorous species have sharp, predator-like teeth, whereas frugivore and nectarivore bats possess flat cusps and narrower faces. Teeth variations enable the differentiation of related species (Dietz & Kiefer, 2016).

During echolocation bats emit high-frequency sounds that bounce off surrounding objects and produce echoes that allow them to create a three-dimensional map of their surroundings. This process allows bats to orientate even in complete darkness, explaining their adaptation to a nocturnal lifestyle (Voigt et al., 2017). Production of sounds seems to be possible thanks to the specialized stylohyal-tympanic articulation (Veselka et al., 2010). Morphological changes in bat larynges allow distinct species to rely on different echolocation strategies, differentiating for example between nasal and oral emitters (Brualla et al., 2024). Variations in the external and inner ear structure allow bats to perceive and process sounds for echolocation. There is a connection between increased relative cochlear size and echolocation ability (Simmons et al., 2008), but large pinnae are not an essential feature (Anderson & Ruxton, 2020). However, the pinna-tragus arrangement allows modification of sounds entering the external ear canal, enhancing the ability to accurately perceive their source direction (Lawrence & Simmons, 1982). About the inner ear, differences in the cochlear spiral ganglion neuroanatomy (neurons which connect the hair cells in the cochlea to the brain) exist, with Yangochiroptera species showing a major apomorphy from Yinpterochiroptera (Sulser et al., 2022). Cave-dwelling Pteropodids differ from larynx-echolocating bats as they use tongue-clicking and rely mainly on vision.

Being frugivores and nectivores, they do not need echolocation to detect small targets like insects (Jones & Teeling, 2006).

The wings are formed by a series of skin membranes called "patagium", extending from the fifth digit of the forelimb to the ankle and, in most species, also from the ankle to the tail (Anderson & Ruxton, 2020). A schematic representation of the bat wing is presented in Figure 3.

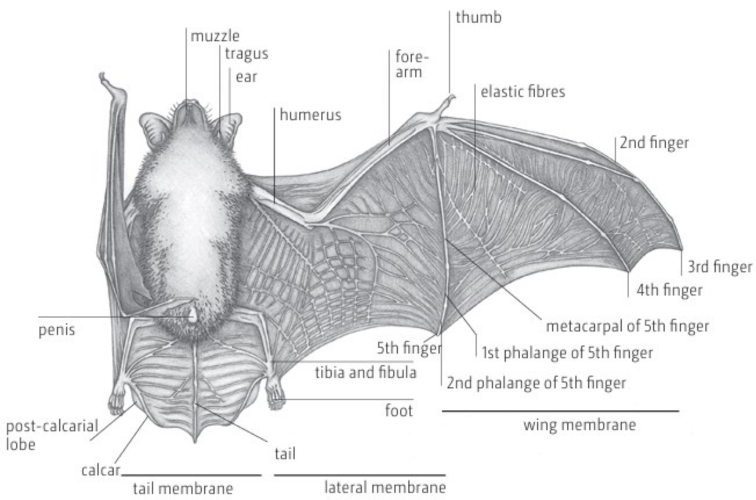

Figure 3 Schematic representation of bats' anatomy (Dietz & Kiefer, 2016)

Other adaptations to flight include a considerable number of joints on the forelimbs, which allow fine control of wing movement, and very thin cortical walls, that provide high bone density to maximize strength while also minimizing weight (Anderson & Ruxton, 2020). Powered flight is energetically costly, especially for bats due to their fast and complex flight trajectories (Voigt et al., 2017). Bats lack an efficient respiratory system like that of birds, which may explain their relatively limited body size, as flight becomes more challenging with increasing size (Anderson & Ruxton, 2020). New research suggests that bats meet their elevated metabolic requirements through oxidative phosphorylation and manage oxidative stress through enhanced DNA repair mechanisms (Shen et al., 2010).

1.3. Ecology

Insectivorous bats of Europe are highly social animals that live in groups throughout most of the year, forming different colonies, depending on the season, for specific purposes (Gruppo Italiano Ricerca Chirotteri, 2018). An overview of their biological cycle is visible in Table 1 and Figure 4.

Spring	Bats awake from hibernation and begin to move towards reproductive sites.
Summer	Reproductive season lasts from June to August, with a gestation period of 40-50 days. Adult females aggregate in roosts called *nurseries* and typically give birth to a single

	altricial pup. The newborn is nursed with milk and develops rapidly: its eyes open at 3-10 days, fur begins to grow within the first week, and teeth develop after about 10 days. While the mother hunts, the pup stays in the nursery until it learns to fly, at around 3-5 weeks of age. During this period, juvenile mortality is quite high due to several factors, such as predation or maternal weakness, caused primarily by food scarcity or adverse weather conditions.
Autumn	Both sexes meet in *swarming* roosts, where females select males and mate. Reproductive strategies are numerous and vary greatly between species. Sperm storage, delayed fertilization and embryonic diapause may be found.
Winter	Bats enter hibernation to minimize their metabolic expenditure. Their body temperature drops to match the surrounding environment, their heart and respiratory rates slow significantly and, to maintain a stable internal temperature, most bat species take shelter in dense groups in roosting sites called *hibernacula*, to minimize heat loss. This period typically lasts around 80 days, though it can vary. Bats may occasionally interrupt hibernation to move to a better roost or to hydrate. Bats can also enter a state known as torpor, which is less intense. They lower their body temperature to ~15°C to conserve energy. This allows them to decrease their metabolic rate and save energy during the day, when they are not active.

Table 1 Biological cycle of insectivorous European bats (Gruppo Italiano Ricerca Chirotteri, 2018).

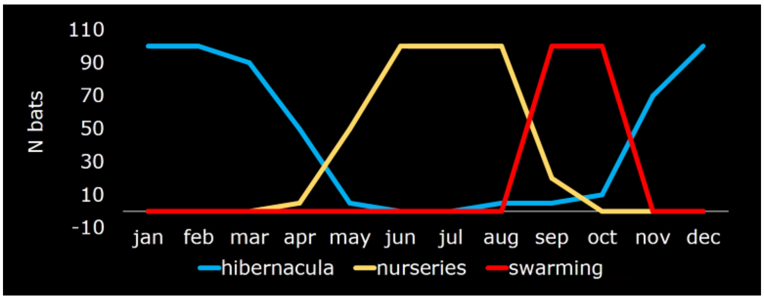

Figure 4 Monthly variation in bat presence across different roost sites (Ancillotto, 2025)

Bats may travel large distances to reach suitable hibernation sites. Sedentary bat species cover distances ranging from a few tens to 100 kilometers, while long-distance migrants travel regularly 3000-4000 kilometers between their summer breeding areas to winter habitats (e.g., genus *Nyctalus* and *Pipistrellus nathusii*) (Hutterer et al., 2005). Recently, researchers were able to monitor the migration patterns of 125 female common noctules (*Nyctalus noctula*) across central Europe (Hurme et al., 2025). A map of their migratory routes is provided in Figure 5.

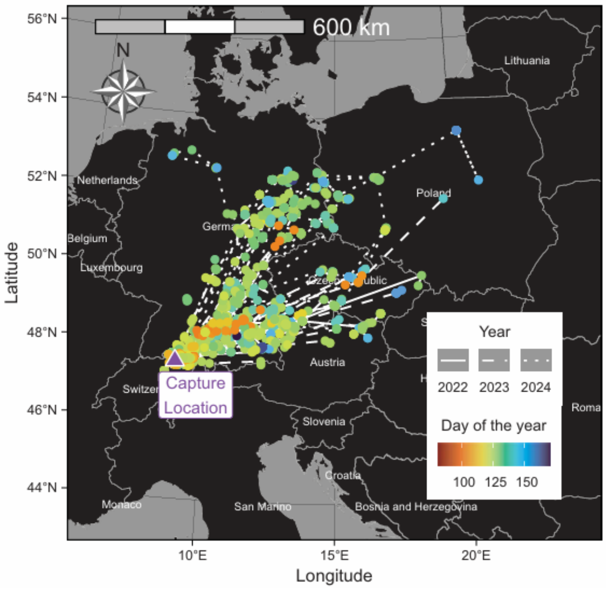

Figure 5 Map of central Europe migratory routes of common noctule females (Hurme et al., 2025).

2. Reasons for Bat Rescue

Free-ranging bats can face a series of issues, mostly related to their proximity to human settlements (e.g., glue traps, wind turbines, predation by domestic cats) (Ancillotto et al., 2013; Mühldorfer et al., 2011a; Ancillotto et al., 2024; Voigt et al., 2024). The most common health issues include emaciation, trauma and disease (Mühldorfer et al., 2011a; Thor & Bielecki, 2021; Salina-Ramos et al., 2023; Colombino et al., 2023).

2.1. Debilitation, Trauma and Disease

In a research sample of more than 900 individuals, it was shown that the majority of individuals required only hydration and feeding. Injuries and disease were the second most common conditions affecting bats (Table 2), with long bone fractures and damage to the patagium membranes being the most frequent injuries (Table 3) (Thor & Bielecki, 2021).

Reason for intervention	Rehabilitation centres	Bat workers	Total cases
Taken without justification	53	24	77
Immediate aid	41	56	97
Weakness/feeding	442	203	645
Injuries/disease	65	72	137
Born in captivity	0	6	6
Total	601	361	962

Table 2 Reasons for intervention (Thor & Bielecki, 2021).

Injuries/diseases	Rehabilitation centres	Bat workers	Total injuries
Inflammation	12	8	20
Long bone fractures	62	11	82
Fractures of the phalanges	19	4	23
Fractures of the spine	-	1	1
Jaw fracture	-	1	1
Damage to the wing membranes	39	9	48
Wounds on the torso	22	5	27
Total	154	39	193

Table 3 List of bat diseases and injuries (sometimes, one individual had several different injuries) (Thor & Bielecki, 2021).

Researchers in Germany were able to assign cause of death for 304 individuals out of 486 bats from different regions, with two thirds of deaths caused by trauma (39%) or disease (primarily respiratory disease due to pneumonia, 40%). Significant age- and sex-dependent differences were found: juveniles and adult females were significantly more affected by disease than adults and adult males respectively (Figure 6). Researchers also noticed peaks of mortality at the end of the maternal season and at the beginning and end of the hibernation period. These situations are associated by the aggregation of numerous individuals in the roosting sites of maternity colonies and hibernacula (Figure 6) (Mühldorfer et al., 2011a).

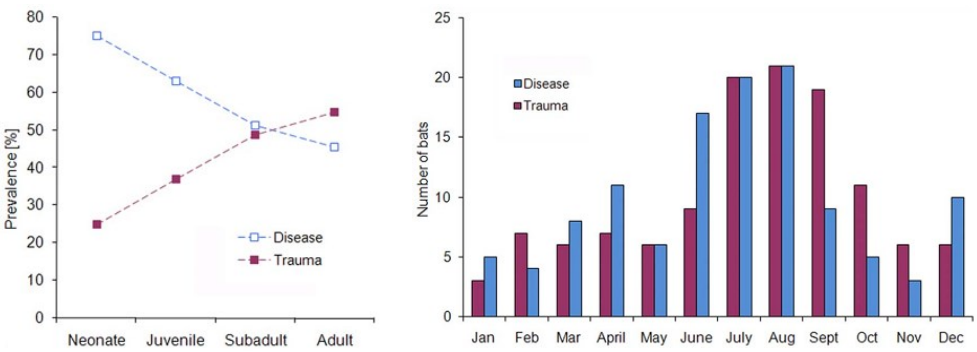

Figure 6 Age-dependent differences and seasonal variations among the general causes of mortality, disease and trauma. Age-specific prevalence and seasonal distribution of trauma- and disease-related mortality cases (Mühldorfer et al., 2011a).

A smaller-scale study conducted on 71 deceased bats from north-western Italy, supports the previously mentioned evidence. Trauma and emaciation were the predominant causes of death. Patagium lacerations (32.4%) and forelimb fractures (21.1%) were the most frequent traumatic lesions. Pneumonia was the most common disease observed (33.8%) and emaciation in absence of any sign of trauma was observed in 18.3% of cases, which can be attributed to chronic illness, hunger, disturbance during hibernation in winter or high environmental temperatures in summer (Colombino et al., 2023).

2.2. Heat Stress, Climate Change and Wind Turbines

Microclimate selection for roosting is essential to lower the expense of homeothermy, particularly for females during the reproductive season. Heat-tolerant bats may take advantage of urban roosts that are subjected to elevated temperatures and optimize their benefits. However, they may find themselves in a deadly trap as a result of climate change and rising temperatures, since a lack of roost diversity or availability may deter them from switching roost to avoid the mortal overheating (Salina-Ramos et al., 2023). Researchers examined the relationship between heatwaves and bat admissions to wildlife rescue centers in Italy, using data covering more than 20 years. Overall, in weeks when the mean temperature exceeded 30°C, a larger number of bats were rescued and admitted for rehabilitation. Most individuals had fallen from the roost and had been injured after, due to exposure to solar radiation, resulting in thermal shock and sudden dehydration, and to predators (Salina-Ramos et al., 2023).

Besides, the use of wind as a renewable energy source to thwart climate change can also pose significant threats to biodiversity (Dai et al., 2015), as bats may collide with the rotating blades of wind turbines, suffer from habitat loss trying to avoid them, or be displaced by the turbine operation (Voigt et al., 2024).

2.3. Glue Traps

The use of glue traps to capture pest insects in anthropogenic habitats may represent a threat for bats. Between 1998 and 2023, 222 occurrences (302 individuals overall) of bats glued to adhesive traps were documented (Ancillotto et al., 2024). According to the same study, smaller bats and gleaner species are more likely to get caught in glue traps, which may be attributed, respectively, to the higher proportion of body/wing surface in contact with the adhesive trap and to the imprisoned insects acting as bait. Species living in urban areas are at particular risk: in fact, the brown long-eared bat (*P. auritus*), a small, gleaning-hunting species that lives near human settlements, is one species that is particularly impacted by glue traps (Ancillotto et al., 2024).

2.4. Cat Predation

According to published data, impact of cat predation on admissions of adult bats to rehabilitation centers ranges from 11% (Ancillotto et al., 2013) to 15.3% (Mühldorfer et al., 2011a). Additionally, the study of Ancillotto et al. (2013) indicates that house-roosting bat species were the most impacted, females were preyed upon more frequently than males and predation incidents occurred more often during the summer months, especially in rural areas (Ancillotto et al., 2013). Bacterial infections have been found in 44% of individuals caught by cats, which may be caused by either the spread of bacteria through cat bites or by the fact that bats that are already weakened by bacterial disease are more vulnerable to cat predators; this suggests that bats may act as vectors for zoonotic pathogens that domestic cats may spread to humans (Mühldorfer et al., 2011a).

3. Infectious Diseases, Zoonoses and Risks for Rehabilitator

Wild animals have always posed a zoonotic risk to humans, representing a major public health concern that affects all continents (González-Barrio, 2022). In recent times, events such as the COVID 19 pandemic increased the researchers' interest in the zoonotic potential of bats (Cheetham & Markotter, 2021). For these reasons, a basic understanding of the infectious diseases and risks associated with bats is essential for wildlife rehabilitators (Souza et al., 2019).

3.1 Virus

Bats may silently host a large number of viruses (both mutated and native versions), which may have been transmitted to other species through spill-over events. Many viruses with interesting phylogenetic relationships to human or animal viruses have been detected in bats, including adeno-, astro-, hepe-, influenza-, orthoreo- or rotaviruses, in addition to agents of undeniable zoonotic importance such as rhabdo-, paramyxo-, and filoviruses (Wibbelt & Torrence, 2012). A summary of the most relevant viral families detected in bats with established or potential zoonotic behavior has been published by Cheetham and Markotter (2021):

- Rabies and rabies related lyssaviruses: Bats are considered lyssavirus reservoirs although canine species are responsible for the majority of human infections globally. Transmission occurs through contact with infected saliva, usually through a bite. Spillovers from bats are uncommon, however, species-specific susceptibility and low public health awareness are some of the reasons why rabies transmission from bats still occur nowadays (Cheetham & Markotter, 2021). Some typical symptoms include hydrophobia, aggressiveness, chewing marks on bedding, dirt or debris in the mouth, difficulty in swallowing, inappetence, paralysis and seizures. However, not all rabies cases manifest violently, others may appear depressed and moribund (Bowen et al., 2019).
- Paramyxoviruses: Direct transmission from bats to humans can occur, as well as through intermediate hosts, such as horses (Hendra virus) or pigs (Nipah virus). Transmission occurs through contact with urine of infected bats and results in severe neurological and respiratory symptoms with high mortality rates and no cure (Cheetham & Markotter, 2021).
- Coronaviruses: Bat coronaviruses are predominantly found in feces but can be found also in saliva and urine. These viruses are airborne and induce respiratory syndromes in humans. Global surveillance for coronaviruses increased significantly after SARS emergence in China in 2002, MERS outbreak in the Arabian Peninsula in 2012, and the recent SARS CoV-2 pandemic in 2019 (Cheetham & Markotter, 2021). In Europe, SARS-like coronaviruses have been detected in

Rhinolophus spp. bats, and MERS-like coronaviruses in vesper bats (mainly *Pipistrellus spp*.) (Lelli et al., 2013).

- Filoviruses: Filoviruses include Ebola and Marburgvirus genera, which manifest as life threatening hemorrhagic fever in humans. Egyptian fruit bat (*Rousettus aegyptiacus*) is known to be a reservoir for Marburgvirus and several bat species in Africa, Asia and Europe have been found to carry Ebolavirus antibodies. However, antibodies are not necessarily a sign of infection but may be due to infection from a related filovirus. Outbreaks are rare and transmission to humans is infrequent (Cheetham & Markotter, 2021).
- Orthomyxoviruses: Influenza viruses are known to undergo frequent genetic reassortment events, giving rise to new pandemic strains (Cheetham & Markotter, 2021).

Researchers examined 210 bat carcasses in Germany for virological investigations. They did not identify any positive samples for influenza A, corona-, hanta- and flaviviruses. However, two serotine bats tested positive for lyssavirus. Additionally, 63 bats were infected with seven of the eight previously identified herpesviruses (Mühldorfer et al., 2011a). In the investigation on 71 deceased bats in northwestern Italy, researchers detected exclusively poxvirus and orthoreovirus, with low to moderate positivity rates (respectively, 2.8% and 16.9%). However, the small sample size and geographic region considered may have affected the results (Colombino et al., 2023).

3.2 Bacteria

Little is known about bats' bacterial flora and the zoonotic hazard it poses (Veikkolainen et al., 2014). There are many individual cases of bacteria being isolated from a wide range of chiropteran species, indicating that our understanding of bat bacterial infection is relatively scarce and quite fragmented (Buckles, 2015). Bats are known to be susceptible to a number of infectious agents that are common in bacterial diseases of humans and domestic animals, such as enteric bacteria (e.g. *Salmonella*, *Shigella*, *Yersinia* and *Campylobacter* spp.), arthropod-borne bacterial pathogens (*Bartonella*, *Borrelia* spp. and members of the family Rickettsiales), and pathogenic *Leptospira* species (Mühldorfer, 2013).

Over half of the 486 vespertilionid bats examined by Mühldorfer et al. (2011b) showed evidence of bacterial-related inflammatory lesions in one or more organs. The most frequent histopathological finding was pneumonia, with an underlying infectious etiology. *Pasteurella*, *Enterococcus*, and *Clostridium* were among the 22 bacterial species evidently associated with pathological lesions. Bacterial infection was determined as cause of death for at least 11% of bats in the study (Mühldorfer et al., 2011b).

3.3 Parasites

The presence of ectoparasites is common and they are generally removed during grooming activity. Usually, they are only present in significant numbers if the animal is debilitated (Bowen et al., 2019). Species-specific parasites (e.g., fleas, ticks, mites, true bugs and parasitic flies) are found in specific parts of the body: for example, wing mites will only be found on patagial membranes or along the bones of the wing, while other species of mites will only be found on the bat's torso (Lollar, 1994). Most of these ectoparasites are hematophagous and so are presumed to be potential vectors of diseases (Couper, 2011); in fact, some recent findings describe bat parasites as possible carriers for zoonotic pathogens, both bacteria as *Mycoplasma haemohominis* and viruses as *Lloviu virus* (Szentiványi et al., 2024). However, many ectoparasites are species-specific and consequently do not constitute a direct threat for people; yet, in certain cases, they can cause allergic reactions in sensitive individuals, such as eczema (EUROBATS, 2022).

Bats also harbor endoparasites, including protozoans (*Eimeriidae* and *Sarcocystidae* species) and helminths (nematodes, cestodes and trematodes). About 30% of bats in the study of Mühldorfer et al. (2011a) had endoparasites. The parasitic load was found to be positively correlated with age and size, with larger species as noctule and serotine bats carrying higher endoparasite numbers (Mühldorfer et al., 2011a). Even though some human and domestic animal helminths have been discovered in bats, the majority of these species are unique to bats and they do not seem to be a reservoir for any human endoparasite (Lollar, 1994).

3.4 Fungi

Pseudogymnoascus destructans is a recently described fungus, which is the causative agent of White-Nose Syndrome (WNS), which has killed millions of bats in the US and Canada (Bowen et al., 2019). Transmission likely occurs in cold caves where bats are hibernating, and clinical signs include white spots around the hairless portion of the body (nose, ears, tail and wings, with the latter being most affected), with scars or defects that persist even if the bat survives hibernation (Buckles, 2015). The fungus causes irritation to the bat, leading to repeated arousal episodes that cause dehydration and starvation from the rapid depletion of energy (Bowen et al., 2019).

According to recent evidence, European bats are infected with *G. destructans* but show little to no mortality: the introduction of European strains of the fungus into hibernacula of naïve bat populations seems to be the cause of the north American outbreak (Warnecke et al., 2012). No zoonotic risk has been documented after exposure to *P. destructans*. Human skin and core temperature exceed those that allow the fungus to grow, so it does not constitute a direct threat to human health (Blehert & Lankau, 2022).

3.6 Safety Measures

Basic disease prevention techniques work against most, if not all, health and zoonotic risks (Terrell, 2005). These consist of:

- Wash hands with disinfectant soap and warm water or with alcohol-based sanitizers. It prevents zoonotic disease exposure and transmission from one patient to another, preventing >95% of fecal-oral transmission of bacteria and parasites (Terrell, 2005).
- Wear personal protective equipment (gloves, boots, coveralls, and masks). Gloves are essential when dealing with fecal matter or bodily fluids. Coveralls and boots help prevent contamination of personal clothing and shoes. Surgical masks are uncommonly used, since they are designed to protect the patient rather than the wearer of the mask (Terrell, 2005).
- Avoid disease vectors. Minimizing exposure to insects and ectoparasites reduces the risk of infection with vector-borne diseases (Terrell, 2005).
- Limit animal contact. Direct interaction with potentially infected animals should be minimized to reduce exposure risk. Only trained, properly equipped and vaccinated personnel should handle high-risk animals (Terrell, 2005).
- Awareness and education: individuals working with wildlife must be informed about both personal and species-specific risk factors. Immunological state, pregnancy, advanced age or concurrent illness are personal risk factors. Individuals facing particular risk factors should be aware that they may be more susceptible to contracting specific diseases (Terrell, 2005).

Only personnel who have received rabies and tetanus vaccinations should handle bats, and appropriate puncture-proof gloves should always be worn to mitigate the risk of being bitten (Mullineaux & Brash, 2009; Bat World Sanctuary, 2010; Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016). However, while gloves provide protection, they may also interfere with handling, physical exams, medical procedures and with maintaining a clean hand-feeding environment (Lollar & Bat World Sanctuary, 2012). The Bat Conservation Trust provides a list of recommended gloves according to bat species and the nature of handling tasks (Table 4).

Species of bat	**Type of handling required**	**Suggested type of glove***
Large bats, e.g. noctule, serotine, greater horseshoe bat, Leisler's bat.	Minimal handling (e.g. placing in a box, placing on vertical surface for take-off).	Thick leather gloves
As above.	Examination, measuring, sexing, weighing, etc.	Thick leather glove on hand most likely to be bitten, thinner leather glove on "examining" hand. Consider wearing surgical type gloves underneath.
As above but where bat is used to being handled and is calm.	To administer first aid.	Thinner leather gloves. Consider wearing surgical type gloves underneath.
Medium sized bats, e.g. long-eared bats, barbastelle, Daubenton's bat, Bechstein's bat, and Natterer's bat.	Minimal handling (e.g. placing in a box, placing on vertical surface for take-off).	Thick leather gloves.
As above.	Examination, measuring, sexing, weighing, etc.	Thinner leather gloves. Consider wearing surgical type gloves underneath.
As above but where bat is used to being handled and is calm.	To administer first aid.	Showa Grip Lite or similar, consider wearing surgical type gloves underneath.
Small bats, e.g. pipistrelles, whiskered bat, alcathoe bat and Brandt's bat.	Minimal handling (e.g. placing in a box, placing on vertical surface for take-off).	Thinner leather gloves, Showa Grip Lite or similar.
As above.	Examination, measuring, sexing, weighing, etc.	Showa Grip Lite or similar.
As above but where bat used to being handled and is calm.	To administer first aid.	Showa Grip Lite or similar.

Table 4 List of suitable gloves according to the bat's species and handling task (Bat Conservation Trust, 2016).

Regardless of vaccination status, anyone bitten or scratched by a bat should have their wound immediately irrigated and cleaned with soap or suitable disinfectant, and medical assistance sought immediately (Mullineaux & Brash, 2009; Couper, 2011). Wildlife rehabilitators should also avoid handling bats in case of positivity or symptoms of diseases (EUROBATS, 2022), as their goal as One Health practitioners is to release *healthy* animals back to their habitats (Deem, 2024).

4. Bat Care Guidelines

Several manuals exist for rehabilitators, regarding the care and captive management of insectivorous bats. The following chapter provides a review and comparison between various management standards and protocols derived from these resources (Bat World Sanctuary, 2010; Couper, 2011; Lollar & Bat World Sanctuary, 2012; Bat Conservation Trust, 2016; Mullineaux & Keeble, 2017; Global Federation of Animal Sanctuaries, 2019; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

4.1. Clinical Assessment, Handling and First Aid

Once a bat has been rescued, it is extremely important to assess its general conditions. A clinical examination should be conducted in a secure environment, with no possibility for the animal to escape, after appropriate first aid has been administered (Couper, 2011). Most rescued bats are torpid, cold and immobile; therefore, an accurate evaluation of their physical state can only be possible once they have warmed up (Bexton & Couper, 2010). Before handling the casualty, the rehabber should examine visually the bat in its container (Bat Conservation Trust, 2016) or on the horizontal surface of the examination table (Couper, 2011). A paper towel can be put underneath to help notice any eventual anatomical defects, discharges and droppings (Couper, 2011; Bat Conservation Trust, 2016). Posture, behavior and motility should also be noted (Bexton & Couper, 2010), as abnormalities may indicate neurological impairment or signs consistent with rabies infection (Lollar & Bat World Sanctuary, 2012). The physical examination should be systematic, ordered and complete (Couper, 2011; Bat Conservation Trust, 2016), to decrease time of handling (Mullineaux & Brash, 2009). They should be restrained in a way that minimizes the chances of being bitten or scratched yet ensuring that the animal experiences minimal stress or discomfort (Lollar & Bat World Sanctuary, 2012). A bat should never be handled by its wings during the examination (Bat Conservation Trust, 2016). It is vital to restrain the wings to avoid injury in attempts to fly and ensure that only sufficient pressure is placed on the chest or abdomen, to avoid impairment of respiration (Mullineaux & Brash, 2009). Figure 7 illustrates different restraining methods of small bat species.

Figure 7 Correct way to handle a bat (left: Couper, 2011, middle: Bat Conservation Trust, 2016, right: Lollar & Bat World Sanctuary, 2012).

A thorough physical examination of the bat should include close inspection of the head, body and wings in order to identify signs of trauma such as skin lesions, hematoma, fractures or dislocation. (Couper, 2011). Eyes appearance and respiratory patterns are key indicators of a bat's overall condition. The eyes should appear clear and alert. Normal respiration is observed in the pelvic region, whereas labored breathing is visible in the thoracic area. When at rest and alert, a bat's heart rate is comparable to that of other small mammals (e.g., mouse), averaging between 500 and 600 beats per minute, and increases notably during flight. During daily torpor, it may drop to 40-60 bpm, and during hibernation it can fall as low as 10 bpm. Bats' body temperature can vary significantly, so it is not a reliable indicator of clinical status (Lollar & Bat World Sanctuary, 2012). Gently stimulating the bat's jawline with a cotton swab typically causes most bats to open their mouth as a defensive response, allowing a check of the teeth. By raising the lip, color of the gums can be assessed too (Lollar & Bat World Sanctuary, 2012).

Determining the sex and age of the bat patient can assist in diagnosis and treatment (Lollar & Bat World Sanctuary, 2012). The two sexes are easily distinguished by the penis of the male; the testes are intra-abdominal but can become swollen and visible during the mating season in autumn. The mammary glands are located in the axillary area and are evident only during lactation (Couper, 2011). In females, the rehabilitator should check for abdominal distention (indicating pregnancy) or look for oval areas beneath the skin of the breasts (signs of a lactating female that has recently given birth) (Lollar & Bat World Sanctuary, 2012). The age of the bat can be assessed visually (Figure 8). Very young bats are easily distinguished by their small size, underdeveloped wings and sparse pelage, while differentiating adults from juvenile bats that have recently become independent is more difficult on visual inspection (Couper, 2011). Scrutiny of the epiphyses of the finger joints by transillumination (using a light source behind the wing membrane) can help in the distinction. Elongated cartilaginous finger joints indicate a bat born in the previous spring or summer, while adults have rounder, ossified joints. Elongated sections at these joints on a fully furred bat indicate the bat is a juvenile (Figure 9).

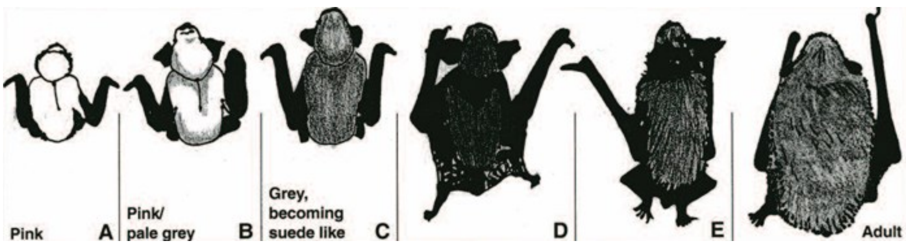

Figure 8 Bat's growth stages, from newborn to fully grown adult (Bat Conservation Trust, 2016).

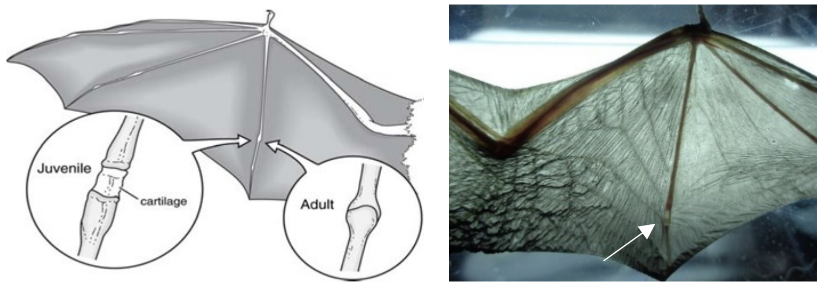

Figure 9 Left: finger joints of a juvenile and adult bat (Lollar & Bat World Sanctuary, 2012); Right: finger joints of a juvenile bat (https://64.media.tumblr.com/63efebd472fbcd17fd1b53133ca05ace/6112469c80df2450-fa/s1280x1920/8c1f3c4f8cec00510cbbc05d3e0c7efd4669c4b0.pnj).

If the rescued bat is an infant, initial first aid should involve gradually warming it to approximately 30°C, administering an oral electrolyte solution, and performing a clinical assessment for signs of injury or illness. If the pup appears healthy and there is no indication of roost disturbance (e.g., predation by a cat) or maternal mortality, efforts should be put in place to reunite it with its mother. If all attempts fail, hand-rearing is possible (Bexton & Couper, 2010).

Three key parameters should be assessed during the physical examination: nutritional status, hydration level, and the presence or absence of ectoparasites (Couper, 2011; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

Body condition can be estimated visually, by palpation, and with weighting. In short-haired bats, the nutritional status is visible at first glance (Figure 10), while in other species the rehabilitator may need to palpate the site between the scapulae and neck, and the lumbar region to check the amount of fat present (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

- Well-fed condition: “Tube-shaped” body without depressions and sufficient fat reserves, suitable for hibernation (only bats with sufficient fat reserves should be hibernated) (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).
- Normal condition: Slight depressions in the lumbar region (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).
- Lean condition: Apparent depressions in the lumbar region and little to no fat (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).
- Emaciated/dehydrated condition: Pronounced depressions in the lumbar region, no palpable fat (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Dehydration can be detected by reduced skin turgor (Bexton & Couper, 2010); signs of severe dehydration include generalized weakness, dry wing and tail membranes, and dry, drooping eyelids or failure to open the eyes (Lollar & Bat World Sanctuary, 2012).

- Over-fed condition: "Pear-shaped" body with excessive and sometimes prominent fat deposits. In female bats, always ensure that the shape of the body is not due to pregnancy (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

Bats in well-fed, normal and lean conditions become active and exhibit normal behavior after warming up, while emaciated bats are not able to warm themselves at room temperature and are commonly observed laying inactive at the bottom of the enclosure (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

Figure 10 Left: a common noctule in lean condition; Right: a well-fed common noctule bat in condition ready for hibernation (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

EUROBATS' guidelines suggest that the bat should also be weighed, although optimal body weight can vary depending on the season, regional differences in hibernation duration, and individual body size (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). In contrast, Bat World Sanctuary's guidelines advise weighing after the bat is fully rehydrated, as dehydration can lead to inaccurate measurements (Lollar & Bat World Sanctuary, 2012).

Dehydration should be a primary concern (Bat Conservation Trust, 2016). Mild dehydration can typically be addressed by administering frequently small amounts of water or electrolytes orally with a paintbrush, small catheter or pipette (Couper, 2011; Bat Conservation Trust, 2016). In more serious cases, oral rehydration solutions formulated for small animals are effective (e.g., Royal Canin® Rehydration Support sachets) (Bat Conservation Trust, 2016). The Bat Conservation Trust does not recommend subcutaneous fluid administration for bats (Bat Conservation Trust, 2016). In contrast the BSAVA Manual of Wildlife Casualties suggests subcutaneous administration of sterile Ringer lactate solution at a dosage of 0.1 ml per 5 g of body weight (20 ml/kg), injected into the lower dorsal region (Couper, 2011). Once the bat is capable of drinking independently, a small amount of water or oral electrolyte solution should be made available in a shallow dish within the enclosure (Couper, 2011).

Bats should also be treated for ectoparasites upon intake (Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). As previously mentioned, bats usually carry one or two ectoparasites of little significance (Table 5), while heavy ectoparasitic burdens are common on young bats during summer or when grooming activity is impaired by injury or disease (Bexton & Couper, 2010).

Ectoparasites of bats

Ectoparasite	Significance
Mites (Macronyssidae, Spinturnicidae and Trombiculidae)	Common, especially on juvenile bats
Fleas (Ischnopsyllidae)	Quite common, usually only one or two
Bat flies (Nycteribiidae)	Wingless, often difficult to spot
Bat bugs (Cimicidae)	Rarely found on bats but live in roosts, climbing onto bats for a blood meal
Ticks (Argasidae, occasionally Ixodidae)	Some bats have large burdens. May transmit *Babesia* species
Blowfly larvae (Calliphoridae)	Usually secondary to wounds or debility

Table 5 Ectoparasites of bats and their significance (Bexton & Couper, 2010).

For severe infestations, a cotton swab dipped in 70% isopropyl alcohol can be used to gently dampen the fur around the head and neck, to encourage parasites to migrate away from the facial area towards the torso (Lollar & Bat World Sanctuary, 2012), where they can be manually removed using tweezers (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). To remove ectoparasites from the wing membranes, a gauze pad moistened with isopropyl alcohol can be used. Following this, each wing should be carefully rinsed using a gauze pad soaked in warm water. Throughout the procedure, care must be taken to keep the bat warm and dry (Lollar & Bat World Sanctuary, 2012). Fly eggs are best removed by grooming with a fine comb (Couper, 2011). Manual removal of ectoparasites is considered the safest approach (Bexton & Couper, 2010; Couper, 2011). However, chemical antiparasitic treatments may also be used with caution, provided they are administered in appropriate doses suitable for such small mammals, and only in bats that are in well-fed, normal or lean nutritional condition (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Permethrin powder may be applied topically between the scapulae or directly onto larger parasites such as ticks (Bexton & Couper, 2010). In cases of heavy tick infestation, treatment with fipronil is effective; however, it should never be applied directly to the bat. Instead, the product should be sprayed into a dish and applied with a paintbrush to the area behind the neck or directly onto the parasites (Bat Conservation Trust, 2016). Selamectin can also be used topically to eliminate residual external parasites and is also effective against roundworms (Lollar & Bat World Sanctuary, 2012). Regardless of the treatment, chemical antiparasitic agents should only be administered once the bat has recovered from the initial debilitation and is clinically stable (Lollar & Bat World Sanctuary, 2012). As the bat's condition improves, it will begin to groom and remove any remaining ectoparasites naturally, while environmental parasitic stages can be managed through daily changes of the substrate and proper enclosure hygiene (Couper, 2011).

As the physical examination continues, assess of the bat's body and patagial membranes for signs of trauma or abnormality, including fractures, perforations, hemorrhage, foreign bodies, ulceration, contamination, and other eventual defects (Bat Conservation Trust, 2016). In some cases, bats that are minimally injured or healthy may attempt to fly, allowing an evaluation of flight capability (Couper, 2011). The most commonly encountered injuries include:

- Injuries of patagial membranes: Holes in wings patagium usually heal over time, allowing the bat to regain flight capability (Figure 11). However, significant tears or slits in the membrane often result in permanent flight impairment (Couper, 2011; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Surgical repair may be attempted but is technically challenging and not always successful (Bexton & Couper, 2010).

Figure 11 Wing repair observed over a four-month period (Bat Conservation Trust, 2016).

- Fractures: Fractures affecting joints or involving bone exposure often have a poor prognosis, as repair must be near perfect to regain the full ability to fly again. Surgical intervention may restore function in some cases, and flight exercise is essential for rebuilding the necessary strength prior to release (Bexton & Couper, 2011). In case of open fractures to the limbs, amputation is the only viable option, and euthanasia should be considered based on welfare implications (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

- Dried wings' tips: In winter wing membranes may dry out, particularly at the distal tips of the third digit. In the worst cases, the phalanx bone may become exposed and eventually break off. Bats with missing wingtip segments are generally considered unlikely to be released back into the wild (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

- Cat predation: Injuries from predator attacks commonly include bruises, fractures and puncture wounds. Due to the risk of septicemia from bacteria transmitted via cat saliva (e.g., from *Pasteurella multocida*; Mühldorfer et al., 2011b), routine antibacterial treatment is recommended (Bexton & Couper, 2010). Subcutaneous emphysema may also occur, and, if it compromises respiration, it can be deflated. Severe internal trauma often remains undetected until postmortem examination of non-surviving cases (Bexton & Couper, 2010). When multiple signs are present, such as bite marks, torn membranes, fractures and inactivity, euthanasia is advised (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

- Blunt trauma: It may result from attempts to catch a flying bat indoors, leading to severe injuries such as spinal damage with hindlimb paralysis, rib fractures, or pneumothorax. Hindlimbs may get injured when legs are trapped or crushed by a door, which impair grooming and roosting. Trauma to the thumb of the wing can interfere with climbing, roosting and feeding (Bexton & Couper, 2010).
- Poisoning: Bats are susceptible to toxins through direct exposure in the roost via inhalation or ingestion during grooming, or indirectly through bioaccumulation from consuming pesticide-affected insects. Clinical signs of toxicity are non-specific (Bexton & Couper, 2010).
- Skin/fur contamination from oil, flypaper adhesives, dust, paint, soot and spiderwebs: Ingestion of these substances during grooming can lead to toxic effects, which likely contribute to the exhaustion commonly observed in chronically affected bats; in such cases, euthanasia should be considered (Couper, 2011). Cobwebs and dust can be removed with a soft brush, while water-soluble contaminants are cleaned with a mild diluted washing-up liquid (industrial degreasing agents are too severe), using warm water. Oils and adhesives are loosened with butter, margarine or vegetable oil, followed by washing and thorough drying with a cloth, to prevent cooling and loss of energy. The process may need repetition, with rest and rehydration between washes. Oral kaolin and pectin gel can be used as adsorbent to reduce the effects of ingested oils, and affected bats should be monitored for up to two weeks for toxic effects (Bexton & Couper, 2010; Couper, 2011).
- Burns: Bats can sustain burns when coming down of chimneys, with the affected skin becoming dry and brittle, and wing membranes darkened. Respiratory distress from smoke inhalation generally indicates a poor prognosis (Brexton & Couper, 2010).

Diagnostic ancillary techniques in bats are limited due to their small size. Radiography is helpful for detecting fractures, particularly of the pectoral or pelvic girdle, which may not be visible during the clinical examination. Blood samples can be obtained from the vein in the interfemoral membrane of the uropatagium in larger bats, though this is technically challenging and provides insufficient volumes for most tests. Endoparasites can be detected through microscopic fecal examination but are rare and of limited clinical significance (Bexton & Couper, 2010; Couper, 2011).

4.2. Therapeutics and Euthanasia

Manual restraint is usually sufficient for bat examination, but pharmacological restraint may be necessary for diagnostic procedures and surgery. Due to their narrow safety margin, most injectable anesthetics are unsuitable for bats; alternatively, volatile anesthetics are preferred and relatively safe (Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016). Modern inhalational agents, such as isoflurane or sevoflurane, may be administered via induction chamber and anesthesia can be maintained using an improvised facemask, such as endotracheal tube connector (Couper, 2011). Bats are therapeutically challenging, due to their small size and fluctuating heterothermic metabolism, and, currently, no veterinary drugs are licensed for use in these animals (Bexton & Couper, 2010; Bat Conservation Trust, 2016).

During rehabilitation, bats are generally kept warm to prevent torpor and promote recovery, particularly when under medication, as torpor slows metabolism, making drugs pharmacokinetics unpredictable (Bexton & Couper, 2010; Bat Conservation Trust, 2016). Oral administration using a small catheter or pipette is considered the safest route of drug delivery in bats. Small volume can also be administered subcutaneously using 27-to-30-gauge, 1.25 cm needles, whereas other routes are either inaccessible due to their small size or carry an increased risk of iatrogenic damage or overdose (Bexton & Couper, 2010). Topical medications must be used with caution due to the risk of ingestion during the grooming activity (Bexton & Couper, 2010), and all antibiotics should be administered orally (Bat Conservation Trust, 2016). A list of medications used in bats is provided in Table 6 (Couper, 2010); however, veterinary advice is essential whenever surgical procedures or pharmacological treatments are required. Rehabilitators should always consult a veterinarian for diagnosis and therapeutic decisions (Bat Conservation Trust, 2016).

Drug	Formulation	Dose rate	Dilution	Volume of diluted product per 5 g bat	Comments
Antimicrobials					
Amoxicillin/ clavulanic acid (co-amoxiclav)	Dry powder containing 150 mg clavulanic acid plus 600 mg amoxicillin	30 mg/kg orally q12h	Reconstitute by adding 100 ml of water to dry powder Refrigerate after reconstitution and discard after 7 days	0.02 ml	Broad spectrum Duration of treatment according to response (minimum 5–7 days)
Enrofloxacin	2.5% oral solution	10 mg/kg orally q12h	Dilute 0.1 ml of solution with 0.9 ml of water	0.02 ml	Broad spectrum Duration of treatment according to response (minimum 5–7 days) Not to be used in growing animals Make up a fresh dilution daily

Anti-inflammatories/analgesics					
Meloxicam	0.5 mg/ml oral suspension for cats	0.2 mg/kg orally q24h	Dilute 0.1 ml of suspension with 0.9 ml water	0.02 ml	NSAID for treatment of inflammation and mild to moderate pain Avoid use in dehydrated animals Avoid use in pregnant animals Make up a fresh dilution daily
Buprenorphine	0.3 mg/ml solution for injection	0.1 mg/kg s.c., orally q6–12h (Lollar, 2010)	Dilute 0.05 ml of solution with 0.95 ml of water	0.03 ml	For treatment of moderate pain
Miscellaneous					
Simethicone	40 mg/ml oral suspension	400 mg/kg orally q6h	Use undiluted	0.05 ml	For use in animals with bloat
Kaolin suspension	0.99 g Kaolin Light per 5 ml oral suspension	1 ml/kg as total daily dose Given as divided dose orally q6h	Dilute 0.05 ml of suspension with 0.95 ml of water Refrigerate after reconstitution and discard after 7 days	0.02 ml	For use in animals with non-specific diarrhoea

Table 6 Medications used in bats (Couper, 2011).

While recovery and release should always be the primary goals of a rehabilitator, euthanasia must be considered when the welfare cost to the bat outweighs the potential benefit (Bat Conservation Trust, 2016). When specific health issues occur, the only alternative to euthanasia is permanent captivity, which is rarely in the best interest of the animal (Bexton & Couper, 2010). Euthanasia should be viewed as a positive welfare decision rather than a negative veterinary action (Couper, 2011). Appropriate methods of euthanasia include both the use of drugs and physical means; chemical methods involve anesthetic overdose with either inhalational or injectable agents (Bexton & Couper, 2010; Couper, 2011; Lollar & Bat World Sanctuary, 2012). Unacceptable methods of euthanasia include carbon dioxide (due to bat's high tolerance to it), T-61 (whose curariform action causes paralysis, including of the respiratory muscles, potentially leaving the animal conscious while suffocating), tiletamine and ketamine-based combinations (which can induce an excitatory phase marked by tremors and vocalizations before loss of consciousness), diazepam (Lollar & Bat World Sanctuary, 2012) and freezing of alive bats (Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Bats are usually anesthetized within minutes; however, the bat should be left undisturbed and safely contained in a quiet environment for several hours; always confirm death by checking respiration and heartbeat (Lollar & Bat World Sanctuary, 2012). Due to their small size, the euthanasia of bats by physical means is both efficient and humane (Couper, 2011). Methods such as cervical dislocation (Bat Conservation Trust, 2016) or a sharp blow to the cranium (Couper, 2011) can be used to terminate suffering as soon as possible. However, these methods may compromise the cadaver's suitability for post-mortem analysis, including rabies testing (Couper, 2011). EUROBATS' guidelines emphasize that such techniques should only be used in compliance with national legislation (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

4.3. Housing

Housing for bats during rehabilitation must meet some essential requirements: it should be easy to clean and sterilize, escape-proof and well-ventilated with adequate air holes. Additionally, it must provide enough space for the bat to fully extend its wings, crawl around and exercise. Plastic fauna boxes, also known as “faunariums” are ideal for this purpose (Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). The container can be furnished with a soft net with small mesh (1 mm) and a cloth or paper towel partially hanging over it to provide the bat a place to cling and hide within; the latter should be replaced daily to maintain a hygienic environment (Bat World Sanctuary, 2010; Bexton & Couper, 2010; Couper, 2011). The use of hard mesh is discouraged by Bat World Sanctuary (Bat World Sanctuary, 2010). The cloth must be intact to avoid the risk of entanglement and light colors are preferred to allow highlighting any discharge that can indicate a change in the bat’s health conditions (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). The cloth also serves as a visual barrier to reduce social stress in case of housing multiple individuals together (Bat World Sanctuary, 2010). A representation of this kind of housing configuration is visible in Figure 12.

Figure 12 Setup of plastic fauna boxes for temporary housing of bats (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

Wooden boxes made from untreated timber are a good alternative as they offer a more natural environment and are less acoustically harsh, but they are more difficult to disinfect and rough surfaces may harbor parasites and cause abrasions to the bat (Couper, 2011). Another alternative consists of pop-up mesh enclosures (e.g., Bat Hut), which are available in different sizes, are collapsible and inexpensive (Lollar & Bat World Sanctuary, 2012). Styrofoam coolers should never be used to transport or house bats due to the risk of ingestion of their particles during grooming, which can result in illness or death (Lollar & Bat World Sanctuary, 2012).

According to the Bat Conservation Trust and EUROBATS, as a general guideline, the size of a rehabilitation enclosure should be twice the length of the bat's wingspan (e.g., for small species approximately 40 x 25 x 25 cm, for larger species around 46 x 30 x 17 cm) (Bat Conservation Trust, 2016; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). For injured individuals, the size of the enclosure should be determined based on veterinary advice and is typically smaller to restrict movement and allow for recovery (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). For juvenile bats that are not yet very mobile, a small container measuring 18 x 11 x 11.5 cm is considered adequate for housing a single individual, yet it should increase in size following the bats development (Bat Conservation Trust, 2016). Regardless of the size and type of enclosure, every box should be visibly marked by symbols that indicate the species, number, sex and other important information about the bats housed within (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

Bat casualties should be kept away from domestic species such as cats and dogs and should be housed in a warm, quiet area, with supplementary heating, if required, and only handled when necessary (Bexton & Couper, 2010). The recommended temperature range for housing bats lies between 25°C and 35°C (Bexton & Couper, 2010; Couper, 2011; Lollar & Bat World Sanctuary, 2012), however, 20-25°C is still considered to be acceptable (Bat World Sanctuary, 2010). The heat source (e.g., heating pad, heat-retaining stone or hot water bottle) should be positioned at one end of the enclosure to create a thermal gradient, allowing the bat to regulate its own body temperature by moving to warmer or cooler areas as needed (Bexton & Couper, 2010; Bat Conservation Trust, 2016). It is important to note that heating pads should not be placed at the base of the enclosure but rather on the top or side to avoid direct contact (Lollar & Bat World Sanctuary, 2012). Infant bats require constant warmth to support proper digestion and development. It is crucial that juvenile bats have the option to move away from excessive heat too, but they should not be allowed to become cold or torpid (Bat Conservation Trust, 2016). Relative humidity should ideally range between 60% and 90%, although levels around 50-60% are generally acceptable. Insufficient humidity may lead to dehydration, resulting in appetite loss and dermatological issues. Orphaned, ill or weak bats require enhanced environmental conditions to support recovery. For unfurred neonates of many species, optimal temperatures range from 32°C to 37°C, with humidity levels at 70-90% (Lollar & Bat World Sanctuary, 2012). These conditions allow to maintain an optimum body temperature and aid digestion (Bat Conservation Trust, 2016), which are essential for maintaining health and appropriate growth rates (Lollar & Bat World Sanctuary, 2012). A natural day-night cycle should be imitated as it is essential for the regulation of the bat's internal metabolic functions and the maintenance of overall health. When possible, natural light should be prioritized over artificial sources. An artificial light cycle of 12 hours of light followed by 12 hours of darkness is recommended, with transitions ideally managed through a dimming system to mimic natural light changes. At night, the enclosure should be covered to create a darker and more secure environment (Lollar & Bat World Sanctuary, 2012). In cases where the enclosure receives significant sunlight, it is important to provide several shaded areas to allow bats to rest undisturbed during daylight hours (Bat World Sanctuary, 2010). Bedding material should never be dusty or toxic. Certain types of cat litter may be suitable for healthy individuals, while soft and easily changeable paper towels are more appropriate for injured bats (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022), since they can help adsorb waste products such as urine and feces (Lollar & Bat World Sanctuary, 2012). Newspaper and puppy training pads should be avoided, due to the noise and scent exposure (Lollar & Bat World Sanctuary, 2012). Regardless of the material, the floor should always be padded or soft in texture to reduce the risk of injuries, particularly for bats that are grounded (Bat World Sanctuary, 2010).

Fresh water should be always available in a shallow container (e.g., 1 cm height), while food dishes should be added based on the individual needs of each bat (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Dishes must be deep enough (typically 2.5-5 cm) to hold a substantial number of mealworms while remaining shallow enough to allow bats to easily enter and exit. Smooth surfaces are recommended to prevent escape of live mealworms (Lollar & Bat World Sanctuary, 2012). Food dishes should be positioned near enclosure walls or vertical surfaces to allow bats to cling from above or climb out easily if they eat sitting inside the dish. To ensure hygiene, food should never be placed directly beneath roosting sites where it could be contaminated by urine or feces (Lollar & Bat World Sanctuary, 2012). Water dishes can be made from various materials, yet hard plastic, glass or stainless steel is to be preferred as soft plastic may promote bacterial overgrowth. Recommended water depth ranges from 0.5 cm to 2 cm; deeper dishes may be used if filled with marbles to prevent the bat from falling completely into the water. Water dishes should be kept in consistent, clean locations away from potential contamination zones and should be accessible at all times to prevent undue thirst, since dehydration is a common issue in captive bats (Lollar & Bat World Sanctuary, 2012). Everyday cleaning routines are crucial. Uneaten food and droppings should be removed (Bat World Sanctuary, 2010) and roosting materials should be replaced (Lollar & Bat World Sanctuary, 2012). Consistency in the shape and positioning of roosting items is important to maintain a sense of security and environmental familiarity for the bat. Cleaning of surfaces should be performed using only hot water, to avoid stressful scent exposure unless preparing the space to house new bats. Food and water dishes must be washed daily with soap and water, thoroughly rinsed and the water bowl should be immediately refilled and returned to the enclosure (Lollar & Bat World Sanctuary, 2012).

In addition to standard housing enclosures, flight cages are essential for the physical rehabilitation of bats, providing both space for exercise and an environment to assess a bat's ability to fly and forage prior to release (Bat Conservation Trust, 2016). Every flight session should be preceded by appropriate warming of the individual and can be conducted in a hazard-free, enclosed room without escape routes (Bexton & Couper, 2010; Bat Conservation Trust, 2016). Bats that have spent prolonged periods in captivity require more intensive flight training in a purpose-built flight enclosure (Bexton & Couper, 2010) and a minimum of three weeks of practice is generally necessary to build sufficient flight muscle strength and refine echolocation abilities, to ensure readiness for independence (Bat Conservation Trust, 2016). In contrast, adult bats with established survival skills may need shorter sessions to rebuild muscle tone and flight endurance (Bat Conservation Trust, 2016). It is essential that flight opportunities are offered regularly and frequently. Although initial attempts may appear weak or uncoordinated, the rehabilitator should actively encourage and support flight practice. A bat that is apparently uninjured but fails to fly within several days may be suffering from undetected injuries and should be reassessed (Couper, 2011). The importance of pre-release flight conditioning is further supported by telemetry studies, which show that hand-reared bats exhibit improved survival if housed in a flight aviary before being released (Kelly et al., 2008). Bat Conservation Trust recommends a minimum flight cage dimension of 8 x 4 x 2 m, while Bat World Sanctuary considers a minimum size of 1.8 x 1.8 x 1.8 m to be sufficient. The frame should be covered with washable mesh or netting (Lollar & Bat World Sanctuary, 2012). A proper flight cage should offer sufficient space for flight, multiple roosting options such as bat boxes (Couper, 2011) and constant access to food and water (Bat Conservation Trust, 2016). Insects can be lured into the flight cage using attractants like standing water, rotting vegetables or moth lamps (Couper, 2011). Maintenance of the flight enclosure includes sweeping and mopping the floor with a 10% bleach solution, while the structure's frame and netting can be cleaned with soapy water and rinsed in place. The mesh covering should be removed and washed periodically to maintain hygiene (Lollar & Bat World Sanctuary, 2012).

Ideally, pre-release housing for adult bats and independent juveniles should be located at the actual release site. This allows the animals to acclimate to the local environment, improving their chances of successful release (Global Federation of Animal Sanctuaries, 2019).

4.4. Nutrition

Although insectivorous bats have specialized dietary requirements, centered around insects and some arachnids, some species can adapt well to human formulated diets in captivity (Bat World Sanctuary, 2010). Insects generally provide a high-protein food source, although the nutritional content varies across species (Lollar & Bat World Sanctuary, 2012). It is therefore essential to provide high-quality food and appropriate nutritional content in sufficient quantity to maintain health and proper weight (Bat World Sanctuary, 2010), even if precise caloric requirements for many bat species are still undocumented (Lollar & Bat World Sanctuary, 2012).

In captivity, adult insectivorous bats are most commonly fed live mealworms (Bat World Sanctuary, 2010; Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016; Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). These are widely available and, although not a natural part of bats diet, typically accepted quickly by the animals (Bexton & Couper, 2010; Couper, 2011). However, they are nutritionally unbalanced, in particular regarding the calcium:phosphorus ratio, and therefore must be supplemented to meet dietary requirements (Couper, 2011; Bat Conservation Trust, 2016). Several methods exist to improve the nutritional value of mealworms. These include "dusting" with commercially available vitamin and mineral powders and "gut loading" (i.e. feeding the mealworms with a nutrient-rich diet before offering them to the bats) with chick starter feed (used for poultry), non-citrous fruit and milk replacer powder (Bexton & Couper, 2010; Couper, 2011). According to Bat World Sanctuary guidelines, a balanced nutritional medium consists of 60% powdered poultry feed, 38.5% wheat bran and 1.5% calcium carbonate. Additional moisture is provided by placing thin sliced fresh fruits and vegetables directly on the surface medium, such as apples, sweet potato, squash, carrot, green beans, etc. Foods that are too sticky or juicy such as banana or cucumber should be avoided, as well as bitter foods such as banana peel (Lollar & Bat World Sanctuary, 2012). To slow the mealworms' development and reduce the risk of parasitic contamination, they should be refrigerated in the medium in a ventilated container. Before being offered to the bats, the larvae should be cleaned and sprinkled with supplements such as Missing Link® or Vionate® vitamin powders, organic spirulina, powdered canine DDS dental biscuits, coenzyme Q10 (CoQ) powder (Bat World Sanctuary, 2010; Lollar & Bat World Sanctuary, 2012). It is also worth noting that some rehabilitators may experience allergic reactions to mealworms: while severe responses, such as respiratory symptoms, are rare, localized skin irritation is a more common issue (Couper, 2011).

Wild bats admitted into care are typically unfamiliar with alternative types of food and must initially be hand-fed (Bat Conservation Trust, 2016) and gradually trained to accept new feed items such as mealworms (Couper, 2011; Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Initially, the bat should be gently restrained, and a mealworm can be run along its jawline using forceps to encourage it to open its mouth, allowing the caretaker to insert the worm. If the animal refuses to eat a whole worm, a decapitated one may be offered and the visceral content can be extruded into the bat's mouth (Couper, 2011; Lollar & Bat World Sanctuary, 2012). As the bat gets accustomed to this feeding method, decapitated mealworms can be offered using tweezers (Couper, 2011). Progressively, the bat should be encouraged to self-feed by being positioned over a tray of mealworms, either while being held or freely clinging to the enclosure wall, and forceps can be used to pick up mealworms and present them close to the bat's mouth until it begins to reach into the tray independently (Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). The bat should ultimately progress to self-feed from a food dish (Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016). Gleaner species that forage insects on the ground may adapt more quickly compared to aerial feeders that capture prey during flight; Molossid bats also present additional challenges, as their facial morphology appears to hinder their ability to grasp insects from flat surfaces. In some cases, bats may never learn to feed independently and must be hand-fed twice daily for the duration of their care (Lollar & Bat World Sanctuary, 2012). It is essential that bats are warm and active during feeding sessions, as warmth promotes proper digestion and supports overall recovery (Bat Conservation Trust, 2016). Forcing a bat to feed while it is still emerging from torpor or visibly shivering poses an increased risk of aspiration or choking. Additionally, bats should never be held in an upright position during feeding (Lollar & Bat World Sanctuary, 2012).

The daily intake depends on various factors, including species, body size, overall health, activity level, and the nutritional value and size of the mealworms offered. As a general reference, an adult pipistrelle bat may eat up to 40 mealworms per day (Bexton & Couper, 2010). Smaller mealworms are more appropriate for smaller bat species, whereas larger or giant mealworms are often used when feeding only the viscera to the bat (Lollar & Bat World Sanctuary, 2012). Feeding frequency recommendations vary among sources: Bat World Sanctuary advises that insectivorous bats should have continuous access to food, 24 hours a day (Bat World Sanctuary, 2010), whereas EUROBATS guidelines suggest that bats in normal conditions should be offered food once a day in the evening (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). For bats that are not feeding independently, Bat World Sanctuary recommends handfeeding twice daily, approximately 12 hours apart, once in the morning and again in the evening (Lollar & Bat World Sanctuary, 2012). Portion sizes may be estimated based on the bat's weight: bats weighing between 10 and 20 grams generally consume 10-20 mealworms (approximately 2.5 cm in length) per feeding session; smaller species may eat 5-10 worms per feeding, while larger species may consume 5-10 giant mealworms. Nevertheless, Bat World Sanctuary recommends feeding the bat as many worms as it will accept and check abdominal distension throughout the feeding session (Lollar & Bat World Sanctuary, 2012).

In some species, additional insect species are required to complement the diet, such as crickets (*Acheta domestica*), wax-moth larvae (*Galleria mellonella*), or “superworms” (larvae of *Zophobas morio*) (Bat World Sanctuary, 2010; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). While crickets are a natural part of the diet of some wild bat species, their lower nutritional value and limited potential for gut loading or supplementation make them suitable only as dietary supplements rather than main food source (Lollar & Bat World Sanctuary, 2012). Particular attention must be paid to the origin of these insects, as pesticide contamination of wild-caught specimens may pose significant risks to the health of captive bats (Lollar & Bat World Sanctuary, 2012). Many weak bats cannot be forced to eat live mealworms, but most can be persuaded to eat soft food. Tinned cat food or convalescent recovery diet (e.g., Hill’s Prescription Diet a/d®), mixed with water to make a paste and offered on a paintbrush, can be used as an interim measure for debilitated individuals (Couper, 2011; Bat Conservation Trust, 2016). Bat World Sanctuary has created a specialized soft food formula for insectivorous bats, which recipe is shown in Figure 13 (Lollar & Bat World Sanctuary, 2012). Severely ill or starving bats, and those refusing mealworms, may be syringe-fed with small volumes (0.2-2 ml) of the soft paste several times daily (Bexton & Couper, 2010; Lollar & Bat World Sanctuary, 2012). Food residue should be carefully wiped off the bat and the rehabilitator’s hand using a damp paper towel or gauze, ensuring to dry any fur that becomes wet. Unremoved residues may lead to fur loss and potentially fatal skin infections. The use of gloves may interfere with keeping a clean hand-feed environment (Lollar & Bat World Sanctuary, 2012). Although soft diets can support short-term recovery, they lack the chitinous exoskeleton of insects, which provide dietary fiber and is therefore essential to promote healthy digestion and prevent dental plaque buildup (Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

1 cup frozen mealworms (about 1,200 large mealworms) or a combination of frozen mealworms & wax worms
1/3 cup of very cold water (80ml)
2 tablespoons of organic baby food
2 tablespoons of organic or non-gmo corn oil
1 teaspoon Missing Link® (Well Blend)
1 teaspoon of Vionate®
1/4 teaspoon organic spirulina

Figure 13 Soft food recipe; feeds 15-20 medium-sized insectivorous bats (Lollar & Bat World Sanctuary, 2012).

Before feeding emaciated or dehydrated bats, it is recommended to first administer Ringer’s solution or glucose either by infusion or orally. If the bat shows interest in drinking, feeding can start with a small amount of soft food or mealworms, and the process can be repeated after some time (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

In infants, artificial feeding with milk replacement is necessary, as in the wild the pup would normally nurse from its mother's milk (Bat Conservation Trust, 2016; Novak & Szenci, 2024). Orphaned infants that are furless or have small, hooked milk teeth should be fed an appropriate milk formula after being initially rehydrated with an electrolyte solution. Feeding can start as soon as the bat is rehydrated, generally within 10-20 minutes (Lollar & Bat World Sanctuary, 2012). According to Bat World Sanctuary, the formula should never be diluted with fluids in an attempt to combine hydration and feeding in a single step, since this would reduce the caloric density and may increase the risk of nutritional deficiencies such as metabolic bone disease, particularly in emaciated infants who require highly concentrated nutrition to address caloric deficits (Lollar & Bat World Sanctuary, 2012). However, new research suggests that milk replacers can be additionally adapted in concentration and nutritional values depending on the species and age of the baby to approximate their natural milk and thus limit side effects connected to the use of inappropriate milk (Novak & Szenci, 2024). Mean values of milk components in bats and in artificial milk replacers are visible in Table 7.

Order	Species	DM	Ash	TP	TF	CH/Lactose	Ca	P	Mg	Other	References
Chiroptera	**Bat** *(Leptonycteris nivalis)*	12.1	0.63	4.37	–	-/5.39	–	–	–	–	Huibregtse, 1936

DM: dry matter, TP: total protein, TF: total fat, CH: carbohydrate

Order	Species	DM	Ash	CP	TF	CH/Lactose	Ca	P	Mg	References
Monotremata	**Echidna milk replacer**	–	–	34.0	38.0	16.0/0				Wombaloo, 2020
Marsupialia	**Kangaroo 0.6 milk replacer**	–	–	32.0	28.0	32.0				Wombaloo, 2020
	Koala milk replacer	–	–	32.0	43.0	14/-				Wombaloo, 2020
Carnivora	**Baby dog milk Royal Canine**	–	6.0	33.0	39.0	18.50	1.10	0.8	0.06	[1]
	Kitten milk replacer KMR	–	–	40.0	28.0	–				[2]
	Zoologic 30/52 diluted 1:1	30.8	–	9.2	16.0	-/1.6				Treiber et al., 2021
	Cow	12.5	0.7*	3.3	3.3	-/4.7	0.112	0.091	0.011	Verduci et al., 2020 *Nishikawa et al., 1976
Artiodactyla	**Horse**	10.5	0.42	2.14	1.29	-/6.37				Oftedal et al., 1983 Jastrzebska et al., 2017
	Goat	12.13	–	3.07	3.41	4.54				Jenness, 1980
	Pig milk replacer	–	7.5	22.0	14.0	–	0.8	0.7	–	Taylor Picard et al., 2017
Primates	**Human**	12.5	0.20*	1.0	4.4	6.9	0.032	0.014	0.003	Verduci et al., 2020 *Nishikawa et al., 1976
	Soy formula Soy based infant formula regulated by EU (mean values)	–	–	1.66	3.42	-/0	0.064	0.039	0.007	Verduci et al., 2020

DM: dry matter, CP: crude protein, TF: total fat, CH: carbohydrates

Table 7 Mean values of milk components in bats. Milk components in selected milk replacers (Novak & Szenci, 2024).

In general, a suitable milk replacer should be low in carbohydrates and high in protein and fat content (Bat Conservation Trust, 2016). Bat milk is quite similar to goat milk; however, it is 1.42 times higher in protein and 1.18 times higher in lactose (Novak & Szenci, 2024). EUROBATS guidelines recommend using commercial milk formulas for cats and dogs, while the Bat Conservation Trust specifically recommends Royal Canin Babydog® as a suitable alternative to maternal milk (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022; Bat Conservation Trust, 2016). However, Bat World Sanctuary warns that most commercial replacers designed for other mammals often fail to meet the specific nutritional needs of bat pups (Lollar & Bat World Sanctuary, 2012).

The milk replacer should be offered to bat infants at a warm temperature (Lollar & Bat World Sanctuary, 2012; Bat Conservation Trust, 2016). Bat pups typically prefer milk of approximately 46-48°C. It is essential to maintain the pup's body temperature during feeding. Crevice-roosting species should be placed on a warm, clean cloth over a heating pad, while tree-roosting species should be held in the hand (Lollar & Bat World Sanctuary, 2012). Since infants are naked, the stomach contents can usually be seen through the skin of the abdomen. Depending on the pup's size, age and condition, a single feeding may range from a few drops up to 1 ml per feeding; to prevent gastric disturbances associated with overfeeding, the pup should not exceed this amount. Pups that ingest this maximum amount should be limited to four feedings per day, approximately six hours apart (Lollar & Bat World Sanctuary, 2012). After feeding, the abdomen should be slightly rounded but not distended. A visibly distended abdomen suggests overfeeding, which can be fatal. Feeding frequency should be individually adjusted based on how long it takes for the infant's stomach to return almost empty. Between feedings, the stomach should not be allowed to become fully concave, and the abdomen should be slightly rounded or flat. The pup should be fed again when the milk is nearly gone. In furred individuals where visual inspection is not possible, the handler will need to rely solely on tactile examination (Lollar & Bat World Sanctuary, 2012). Most bat orphans initially require feeding every four to six hours, for four to six times a day, depending on their individual condition. However, for very young or emaciated individuals, the stomach may empty in as little as two hours, necessitating more frequent feeding than older healthy pups (Lollar & Bat World Sanctuary, 2012). For example, pipistrelle bat neonates may initially take as little as 0.1 ml of formula every two hours (Couper, 2011). As pups mature and get healthier, the frequency of feeding typically decreases (Lollar & Bat World Sanctuary, 2012). Once rehydrated, milk can be offered using a fine paintbrush, a small plastic syringe or a Pasteur pipette. It is advisable to practice this method using water first to avoid aspiration while the pup is still learning how to nurse in this way. Feeding should begin with small volumes at regular short intervals and a shallow, clean dish with a few drops of water should be left in the enclosure to allow the bat to drink between sessions. As the pup grows and approaches weaning, the frequency of feeding may be reduced as it will drink a larger volume of formula at each meal (Bat Conservation Trust, 2016). Most bat pups will instinctively back away when they are satiated; however, dehydration must always be considered, as a thirsty neonate may overfeed or intentionally dribble excess liquid. In such cases, extra water should be offered using the same techniques (Bat Conservation Trust, 2016).

Species-specific feeding techniques:

- Vespertilionid pups should be held upside down during feeding to prevent aspiration. A small amount of warm formula placed on the mouth typically stimulates lapping. The milk should be dispensed drop-by-drop as the bat drinks (Lollar & Bat World Sanctuary, 2012).
- Molossid pups do not lap milk and must be fed using soft foam sponge tips (e.g., eye-shadow applicator tips). The foam tip should be removed from the plastic wand and cut into a wedge shape (Figure 14). The bat should be placed abdomen down in a warm cloth, on a heated surface. The sponge, soaked with warm milk, should be inserted into its mouth using tweezers. When the pup starts nursing, the sponge should be released and milk should be added drop-by-drop until it is saturated (Lollar & Bat World Sanctuary, 2012).

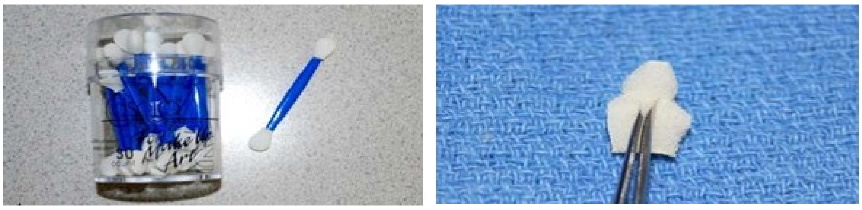

Figure 14 Foam eye-shadow applicators cut into wedge shape to nurse bat pups (Lollar & Bat World Sanctuary, 2012).

- Tree-bat pups should be hand-fed while held under a heat source. The bat should lie prone on the rehabilitator's thumb, with the dropper and mouth forming a "V" shape (Figure 15). This setup prevents air bubbles and keeps the pup clean during feeding (Lollar & Bat World Sanctuary, 2012).

Figure 15 Correct position for a bat pup drinking milk formula from a glass medicine dropper (Lollar & Bat World Sanctuary, 2012).

It is essential to prevent food or water from entering the bat's nostrils. Moreover, spillage of food or fluids down the bat's chin or chest should be avoided and gently cleaned with a tissue or similarly adsorbent material if it occurs (Lollar & Bat World Sanctuary, 2012; Bat Conservation Trust, 2016). In the event of fluid aspiration during hand-feeding, the bat should be held with its head down and its abdomen resting against the palm. Firm but gentle tapping between the shoulder blades can help expel fluids from the airway. To clear liquid from the nasal passage, apply light pressure with a cotton swab from just below the eye down along the bridge of the nose. Any expelled fluid should be wiped away and the process repeated until the nose is clear. Normal breathing should resume immediately, but if liquid or food has entered the lungs the bat may develop aspiration pneumonia and show signs of respiratory distress (Lollar & Bat World Sanctuary, 2012). As with other young mammals, urination and defecation must be stimulated at each feeding (Couper, 2011; Lollar & Bat World Sanctuary, 2012). This can be done by gently rubbing the anogenital area with a soft piece of gauze moistened with warm water; cotton swabs are typically too abrasive for this purpose (Lollar & Bat World Sanctuary, 2012).

The bat should be monitored regularly to assess its condition and progress, and care protocols should be adjusted accordingly (Bat Conservation Trust, 2016). Due to their small size and highly social nature, the use of surrogates such as puppets is impractical. According to Lollar's experience, insectivorous bats do not imprint on human caregivers. Bat neonates naturally spend a significant amount of time in close physical contact with their mothers and conspecifics; thus, direct handling is recommended to promote their wellbeing and a sense of security. For the same reason, pups should never be housed alone (Lollar & Bat World Sanctuary, 2012). Hand-rearing bat pups is a challenging task, and the most common complications are illustrated in Table 8 (Bexton & Couper, 2010; Couper, 2011; Lollar & Bat World Sanctuary, 2012).

Condition	Predisposing factors	Prevention and treatment
Bloat (gastric tympany and delayed gastric emptying), and/or constipation	Many factors, including low body temperature, unsuitable milk composition or temperature, inconsistencies in the feeding regimen and timing, and aerophagia	Husbandry problem(s) should be identified and corrected. It is important to ensure pups are hydrated first, and subsequently gradually introduced to milk feeds Simethicone is useful for alleviating symptoms
Diarrhoea	Usually dietary in origin, or similar factors to those listed above for bloat. Infection is rare	As above, plus probiotics, and antibacterial therapy if there is infection or dysbiosis
Inhalation pneumonia	Insufficiently warmed milk may increase the risk. Also, feeding pups too quickly might result in milk going up the nostrils	Ensure milk is adequately warmed before feeding Keep the pup's head slightly below the body and introduce the feed utensil from below
Nutritional metabolic bone disease	Relative or absolute calcium (vitamin D) deficiency due to unsuitable or insufficient diet	Provide feed milk replacer (eg, Esbilac; PetAg) in sufficient quantities based on the experience of bat carers. Only mild or early changes are reversible

Table 8 Common medical issues encountered when hand-rearing pups (Bexton & Couper, 2010).

A frequent complication is gastric distention which can result from improper feeding practices or overfeeding, which is common in captivity, and may provoke subsequent circulatory shock due to cardiac failure (Colombino et al., 2023). Metabolic bone disease is frequently observed in hand-reared bats and a result from a dietary calcium:phosphorus imbalance and appears more common in individuals weaned onto mealworms too early (Couper, 2011).

Weaning should not be rushed and typically begins when young bats show the muscle strength needed for flight (e.g., by doing "push-ups") and develop some real flight (Couper, 2011; Bat Conservation Trust, 2016). Signs of readiness also include biting feeding tools and fully developed canine teeth. At this stage, juveniles will require extra calories to support increased energy demands. Bats usually start accepting soft food between four and six weeks of age, consuming 0.5 to 1 ml per feeding, two to three times daily, yet with milk offered after each feeding (Lollar & Bat World Sanctuary, 2012). Juveniles accept soft food or mealworms when they have reached the appropriate developmental stage (e.g., when canines are fully grown), regardless of their age and size. However, they often continue to supplement their diet with milk, both in captivity and in the wild, especially if they have been nutritionally deprived as orphans. It is therefore normal for adult-sized juveniles to continue drinking milk. Those refusing mealworms or soft food should not be forced to wean: some bats may oscillate between milk and solid food for weeks and should be allowed to follow their natural pace. Full weaning occurs when the bat no longer accepts milk (Lollar & Bat World Sanctuary, 2012).

4.5. Continual Assessment and Socialization

Throughout rehabilitation and captivity, continuous assessment is of great importance (Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016). Many bats are taken into care underweight and suffer from starvation. Therefore, weight and condition should be compared to normal species-specific values for the time of the year. Monitoring food intake is also critical, as a lack of appetite may indicate underlying injuries not initially obvious (Bat Conservation Trust, 2016). On the other hand, obesity is a known issue in captive bats. Further dietary adjustments are necessary as the bat transitions from a sedentary, convalescent state to an active, pre-release stage involving regular flight (Bexton & Couper, 2010; Couper, 2011). Additionally, the conditions of the bat's coat, wings and other physical features provide valuable insight into its overall fitness and response to treatment and captivity (Bat Conservation Trust, 2016).

Regarding socialization, as previously mentioned, bats are highly gregarious animals (Couper, 2011; Lollar & Bat World Sanctuary, 2012). However, opinions on social housing during rehabilitation vary. Bexton and Couper advise housing bats individually (Bexton & Couper, 2010), while BSAVA guidelines suggest that although bats are social, group housing is not necessary during hospitalization due to the need for individual care and the risk of disease transmission between individuals (Couper, 2011). In this case, group housing is recommended for long-term captive bats or when rehabilitating multiple individuals from the same roost (Couper, 2011). When housing multiple bats together, private areas such as individual pouches should be provided, to allow each bat its own space (Bat

Conservation Trust, 2016). For neonate and juvenile bats group housing may be beneficial, as pups kept together tend to progress more quickly by observing and learning from one another (Bat Conservation Trust, 2016). The Global Federation of Animal Sanctuaries recommends housing dependent young bats in nursery units, preferably with conspecifics (Global Federation of Animal Sanctuaries, 2019). If introducing adult bats, insectivorous adults generally accept new roost mates with little or no conflict. In fact, newly arrived crevice bats often adjust more quickly to captivity when housed with an established colony and are accepted with little or no conflict. If there is uncertainty about a bat's behavior toward a new roost mate, placing the newcomer in an "introductory" enclosure within the colony's roosting area at night is recommended. Leaving the bat in this enclosure overnight usually provides sufficient time for acclimation. Differently, hand-raised, unweaned juveniles should never be introduced into an existing colony of adult bats (Lollar & Bat World Sanctuary, 2012).

4.6. Release

The primary goal of bat care and rehabilitation should be the successful release of healthy individuals (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022), and only individuals with a good chance of survival and reintegration into the wild should be considered for release (Bexton & Couper, 2010). Release candidates must be in good body condition, with species- and season- appropriate weight, and demonstrate ability to fly, forage, roost, and respond appropriately to conspecifics, predators, and environmental hazards (Bat World Sanctuary, 2010; Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016; Lollar & Bat World Sanctuary, 2012). To evaluate flight abilities, BSAVA guidelines recommend conducting a flight assessment in the evening, after the bat has had the possibility to warm up and become fully active. The bat should then be encouraged to take off from a height of approximately 1.5 m and, after an initial drop, it should be able to climb above head height and circle the room/flight cage (Couper, 2011). Bats deemed fit for release must be able to fly continuously for at least 5-10 minutes without showing signs of fatigue (Couper, 2011; Bexton & Couper, 2010; Bat Conservation Trust, 2016; Lollar & Bat World Sanctuary, 2012) and must land and roost on elevated surfaces such as the ceiling or upper walls; bats that repeatedly land on the floor are not yet ready for release (Lollar & Bat World Sanctuary, 2012). To assess echolocation abilities, a bat detector may be used: this device captures with a microphone the ultrasonic calls that bats emit and converts them into human-audible frequencies, allowing for real-time evaluation of echolocation activity (Couper, 2011).

Bats should be released during or shortly after sunset (Couper, 2011; Bexton & Couper, 2010; Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and

Rehabilitation, 2022), only under favorable weather conditions (wind below 4 m/s, no rain, nighttime temperatures above 5 °C, and a stable forecast) (Bat Conservation Trust, 2016; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Ideally, the bat should have had a warm-up flight and a meal earlier the same evening at the rehabilitation facility (Couper, 2011). Whenever possible, bats should be released at the exact location where they were originally found. Even if their original roost has changed, it is presumed to remain within the individual's home range, allowing the bat to orient successfully in the release area (Couper, 2011; Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). If this is not possible, a suitable alternative must be selected based on known species-specific roosting and foraging requirements (Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Hard release methods are generally appropriate for adult bats (Bexton & Couper, 2010). These include allowing the bat to launch from an open hand (Bexton & Couper, 2010; Couper, 2011) or from an open transport box positioned at 1.5 m above the ground (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Bats should never be placed directly on tree trunks or building walls for release, as they would be vulnerable to predation before being able to fly away (Lollar & Bat World Sanctuary, 2012). For hand-reared juvenile bats, soft release techniques are recommended. These involve allowing the bat to gradually acclimate to the new environment while providing access to food and shelter post-release (Bexton & Couper, 2010; Couper, 2011; Lollar & Bat World Sanctuary, 2012). While the independent survival of hand-raised pups was debated in the past, recent post-release monitoring studies (using radiotelemetry, metal bat banding and PIT tags) indicate that juveniles can survive both in the short and long term, provided they have had sufficient opportunity to develop essential skills such as flight, echolocation, insects catching and social interaction (Bexton & Couper, 2010; Kelly et al., 2008; Kelly et al., 2012; Serangeli et al., 2012; Lollar & Bat World Sanctuary, 2012).

Conclusions

This review has examined the management of insectivorous bat casualties in wildlife rescue centers, aiming to collect and compare best practices from a variety of sources to support successful rehabilitation and reintroduction into the wild. The focus included both adult and juvenile bats native to the European region, drawing from recent studies and authoritative sources such as the BSAVA Manual of Wildlife Casualties (Mullineaux & Keeble, 2017), Bat World Sanctuary (Lollar & Bat World Sanctuary, 2012), Bat Conservation Trust (Bat Conservation Trust, 2016) and EUROBATS guidelines (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

The initial chapters covered an overview of the Chiroptera order, followed by a discussion on the primary causes that lead bats to require care in wildlife rehabilitation centers. Special attention was given to anthropogenic threats and the growing impact of climate change on the well-being of native bats. The review also addressed the zoonotic risks posed by bats and emphasized the importance of safety protocols for rehabilitators when handling potentially infected animals. In fact, reports on the zoonotic potential of bats vary greatly: for example, although rabies are still widely perceived by the public as a major threat, current studies do not support this view. Researchers investigating the zoonotic risks associated with bats after pandemics such as SARS CoV-2 in 2019 have shown that, while bats can silently carry various potentially pathogenic microorganisms, actual transmission to humans is quite infrequent (Cheetham & Markotter, 2021).

All key aspects of bats rehabilitation were covered, from clinical assessment and emergency care to eventual release. Critical aspects such as nutrition and housing were discussed in detail, considering the specific needs at each life stage of the bat (Table 9). Additional guidance on appropriate therapeutic interventions and, when necessary, euthanasia was provided, to ensure that management during captivity remains as humane and ethical as possible.

Unfurred neonate	Initial housing in a small container (18 x 11 x 11.5 cm; Bat Conservation Trust, 2016). Optimal environmental conditions include a temperature range of 32°C to 37°C and relative humidity between 70-90% (Lollar & Bat World Sanctuary, 2012). Rehydrate the pup before feeding; the milk replacer should be administered 10-20 minutes after rehydration (Lollar & Bat World Sanctuary, 2012). While specialized bat milk formulas are not available, commercial milk formulas for puppies and kittens, such as Royal Canin Babydog®, are commonly used (Bat Conservation Trust, 2016). The milk should be warmed to 46-48°C and the pup must be kept warm during feeding (Lollar & Bat World Sanctuary, 2012). Feeding can be performed using

	a fine paintbrush, a small syringe or medicine dropper, or a soft foam tip. The caretaker should rely on visual and tactile cues to assess satiety (milk can be seen through the abdomen skin). The pup should be fed again once the stomach contents have almost emptied, which may occur in as little as two hours in very young or emaciated individuals. Post-feeding care includes stimulation of urination and defecation (Lollar & Bat World Sanctuary, 2012).
Juvenile	As the bat matures and becomes more active, housing conditions must be adjusted to ensure enough space for exercise and movement, still providing a thermal gradient that allows the bat to move away from excessive heat while still ensuring it does not become cold or torpid (Bat Conservation Trust, 2016). Fresh water must always be available in a shallow container (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). In the early stages, the bat requires milk feedings every four to six hours, for four to six times per day (Lollar & Bat World Sanctuary, 2012); as the pup grows older, feeding frequency can be gradually reduced, as the animal begins to consume larger volumes per feeding (Bat Conservation Trust, 2016). Flight practice and weaning should start when the bat has developed adult canine teeth, demonstrates muscle strength and begins to bite at feeding tools (Couper, 2011; Bat Conservation Trust, 2016). At this point, solid food (e.g., mealworms and soft foods) can be introduced. Some bats alternate between milk and solid food over several weeks, and they should be allowed to progress at their own pace. Full weaning is achieved when the bat no longer accepts milk (Lollar & Bat World Sanctuary, 2012). To ensure independent survival in the wild, it is essential for the bat to practice for a minimum of three weeks in a flight enclosure, where it can develop key survival skills such as flight, echolocation, predation and social interaction (Kelly et al., 2008; Bexton & Couper, 2010; Kelly et al., 2012; Serangeli et al., 2012; Lollar & Bat World Sanctuary, 2012; Bat Conservation Trust, 2016).
Adult	Housing should be appropriately furnished to provide opportunities to cling and hide (Bexton & Couper, 2010; Couper, 2011; Bat World Sanctuary, 2010). The size of the enclosure should be at least twice the length of the bat's wingspan to allow for adequate movement and exercise; however, for injured individuals, smaller spaces are preferable to restrict movement and facilitate healing (Bat Conservation Trust, 2016; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). Temperature should range between 25°C and 35°C and relative humidity

	between 60-90%, though levels around 50-60% are generally acceptable (Bexton & Couper, 2010; Couper, 2011; Lollar & Bat World Sanctuary, 2012). Fresh water must always be accessible in a shallow container (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). The bat should be fed "gut-loaded" or "dusted" mealworms to enhance nutritional value. Initial handfeeding may be necessary, followed by training to encourage self-feeding behavior (Bexton & Couper, 2010; Couper, 2011; Bat Conservation Trust, 2016; Bat World Sanctuary, 2010; Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022). For debilitated individuals, tinned cat food or convalescent diets may be used temporarily (Couper, 2011; Bat Conservation Trust, 2016). Bats requiring handfeeding should be fed twice daily, 12 hours apart (Lollar & Bat World Sanctuary, 2012), whereas healthy, self-feeding bats can be given continuous access to food (Bat World Sanctuary, 2010). For adult bats with established survival skills, short sessions in a flight enclosure may be necessary to rebuild muscle tone and flight endurance prior to release (Bat Conservation Trust, 2016). Whenever possible, bats should be released at the exact location where they were initially found (Couper, 2011; Lollar & Bat World Sanctuary, 2012; EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022).

Table 9 Recommended management practices for bats according to life stage.

Different guidelines and valid approaches exist to manage bats in wildlife rescue centers. Among European sources, a generally consistent approach can be observed, whereas some notable differences emerge between European and North American practices. The Bat World Sanctuary guidelines, for instance, are particularly detailed, offering precise specifications for housing structures (e.g., the Bat Hut), enclosure and pre-release flight cage dimensions, as well as carefully developed recipes for bat nutrition, including a soft diet (Lollar & Bat World Sanctuary, 2012). Overall, while various management protocols are available, a focus on bat nutrition is lacking, especially for neonates and developing bats. Bat World Sanctuary has developed its own milk formulas, whereas European protocols often rely on more generalized milk replacers formulated for domestic species (e.g., Royal Canin Babydog®) (Bat Conservation Trust, 2016). Although artificial feeding of orphaned bat neonates can be supported using artificial milk replacers (Novak & Szenci, 2024), scientific data on the nutritional composition of bat milk remains limited, with key studies dating back to the last century (Huibregtse, 1963; Kunz et al., 1983; Kunz et al., 1995).

Guidelines from the United States (e.g., Lollar & Bat World Sanctuary, 2012; Global Federation of Animal Sanctuaries, 2019) and the United Kingdom (e.g., Bat Conservation Trust, 2016; Mullineaux & Keeble, 2017) may be considered the most detailed literature. In contrast, Europe currently lacks a centralized and finalized set of guidelines. The main reference, the EUROBAT guidelines document (EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation, 2022) remains a draft. There underlines the need for more cohesive standards for bat rehabilitation within European wildlife rescue centers. However, another crucial aspect to consider is the funding of wildlife rescue centers. Most of these centers operate as NGOs, relying heavily on volunteer work and receiving minimal or no financial support from national governments (https://www.kodami.it/fondi-statali-ai-cras-in-arrivo-un-emendamento-per-renderli-accessibili-a-tutti/). This financial constraint often limits the ability of bat rehabilitators to implement the best management practices, necessitating compromises between optimal animal welfare and the available resources.

Despite the challenges, wildlife rescue centers remain an essential resource for the care and rehabilitation of European insectivorous bats. They play a vital role not only in the direct support of injured or orphaned individuals, but also in the collection of valuable data on wild bat populations. Moreover, they play an important educational role by raising awareness among the public and future generations about the importance of protecting wildlife and preserving biodiversity.

Bibliography

Altringham, J. D. (2011). *Bats: From Evolution to Conservation*. Oxford University Press.

American Society of Mammalogists. (2024). *Mammal Diversity Database*. Retrieved 04/06/2025, from https://www.mammaldiversity.org

Ancillotto, L., Serangeli, M. T., & Russo, D. (2013). Curiosity killed the bat: Domestic cats as bat predators. *Mammalian Biology: Zeitschrift Für Säugetierkunde*, *78*(5), 369–373. https://doi.org/10.1016/j.mambio.2013.01.003

Ancillotto, L., Cosentino, F., Festa, F., & Mori, E. (2024). Adhesive traps for suppressing pest insects represent a serious threat to bats across Europe. *European Journal of Wildlife Research*, *70*(6), 119–119. https://doi.org/10.1007/s10344-024-01872-6

Ancillotto, L. (2025). Monthly variation in bat abundance across different roost sites. In *Proceedings of the Seminar "I Chirotteri – Biologia – Etologia – Monitoraggio"*. Ente Nazionale U.N.I.N.

Anderson, S. C., & Ruxton, G. D. (2020). The evolution of flight in bats: a novel hypothesis. *Mammal Review*, *50*(4), 426–439. https://doi.org/10.1111/mam.12211

Associazione Teriologica Italiana. (2018). *Il ciclo biologico*. https://www.mammiferi.org/pipistrelli/biologia/

Bat Conservation Trust. (2016). *Bat care guidelines: A guide to bat care for rehabilitators* (2nd ed.). https://cdn.bats.org.uk/uploads/images/Photo-Gallery/Bat-Care/Bat_Care_Guidelines_2016_final.pdf

Bat World Sanctuary. (2010). *Insectivorous bat care standards* (Version 1.0). https://batworld.org/wp-content/uploads/2011/03/BWS-Standards_Bats_-in_Captivity1.pdf

Bexton, S., & Couper, D. (2010). Handling and veterinary care of British bats. *In Practice (London 1979)*, *32*(6), 254–262. https://doi.org/10.1136/inp.c2899

Blehert, D., & Lankau, E. (2022). Infection with Pseudogymnoascus destructans in bats (white-nose syndrome). *CABI Compendium*. https://doi.org/10.1079/cabicompendium.119005

Bowen, L. E., Aguilar, R. F., Yabsley, M. J., Hernandez, S. M., Barron, H. W., & Miller, E. A. (2019). Natural History and Medical Management of Chiroptera. In *Medical Management of Wildlife Species* (pp. 353–362). John Wiley & Sons, Inc. https://doi.org/10.1002/9781119036708.ch27

Boyles, J. G., Cryan, P. M., McCracken, G. F., & Kunz, T. H. (2011). Economic Importance of Bats in Agriculture. *Science (American Association for the Advancement of Science)*, *332*(6025), 41–42. https://doi.org/10.1126/science.1201366

Brualla, N. L. M., Wilson, L. A. B., Tu, V. T., Nojiri, T., Carter, R. T., Ngamprasertwong, T., Wannaprasert, T., Doube, M., Fukui, D., & Koyabu, D. (2024). Comparative anatomy of the vocal apparatus in bats and implications for the diversity of laryngeal echolocation. Zoological Journal of the Linnean Society, 202(3). https://doi.org/10.1093/zoolinnean/zlad180

Buckles, E. L. (2015). Chiroptera (Bats). In *Fowler's Zoo and Wild Animal Medicine* (Vol. 8, pp. 281–290). Elsevier eBooks. https://doi.org/10.1016/b978-1-4557-7397-8.00035-9

Cheetham, S., Markotter, W., Kurta, A., Ortega, J., Brigham, R. M., Lim, B. K., Mistry, S., Russell, A., Fenton, M. B., & Gillam, E. H. (2021). Bats as Reservoirs of Viral Zoonoses. In *50 Years of Bat Research* (pp. 313–330). Springer International Publishing. https://doi.org/10.1007/978-3-030-54727-1_19

Colombino, E., Lelli, D., Canziani, S., Quaranta, G., Guidetti, C., Leopardi, S., Robetto, S., De Benedictis, P., Orusa, R., von Degerfeld, M. M., & Capucchio, M. T. (2023). Main causes of death of free-ranging bats in Turin province (North-Western Italy): gross and histological findings and emergent virus surveillance. *BMC Veterinary Research*, *19*(1), 200–200. https://doi.org/10.1186/s12917-023-03776-0

Couper, D. (2011). Bats. In E. Mullineaux, D. Best, & P. Cooper (Eds.), *BSAVA manual of wildlife casualties* (pp. 248–263). British Small Animal Veterinary Association. https://www.bsavalibrary.com/content/book/10.22233/9781910443316

Dai, K., Bergot, A., Liang, C., Xiang, W.-N., & Huang, Z. (2015). Environmental issues associated with wind energy – A review. *Renewable Energy*, *75*, 911–921. https://doi.org/10.1016/j.renene.2014.10.074

Deem, S. L. (2024). One Health and the wildlife rehabilitator. *Wildlife Rehabilitation Bulletin*, 42(1), 1–5. https://doi.org/10.53607/wrb.v42.272

Dietz, C., & Von Helversen, O. (2006). *Illustrated identification key to the bats of Europe*. Bloomsbury Publishing.

Dietz, C., & Kiefer, A. (2016). *Bats of Britain and Europe*. Bloomsbury Publishing.

Eiting, T. P., & Gunnell, G. F. (2009). Global Completeness of the Bat Fossil Record. *Journal of Mammalian Evolution*, *16*(3), 151–173. https://doi.org/10.1007/s10914-009-9118-x

EUROBATS Intersessional Working Group on Bat Rescue and Rehabilitation. (2022). *Bat rescue and rehabilitation for bat conservation, research and monitoring: Guidelines* (Draft version). https://www.eurobats.org/sites/default/files/documents/pdf/Advisory_Committee/Inf.StC19-AC26.5_BatReR_guidelines.pdf

European Union. (1992). *Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive)*. Official Journal of the European Communities, L206, 7–50.

Global Federation of Animal Sanctuaries. (2019). *Standards for bat sanctuaries* (Version December 2019). https://sanctuaryfederation.org/wp-content/uploads/2020/02/Bat-Standards-2019.pdf

González-Barrio, D. (2022). *Zoonoses and Wildlife: One Health Approach*. MDPI - Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/books978-3-0365-3735-1

Huibregtse, W. H. (1963). *The composition of bat milk; a chemical analysis*. http://hdl.handle.net/10150/319468

Hurme, E., Lenzi, I., Wikelski, M., Wild, T. A., & Dechmann, D. K. N. (2025). Bats surf storm fronts during spring migration. *Science (American Association for the Advancement of Science)*, *387*(6729), 97–101. https://doi.org/10.1126/science.ade7441

Hutterer, R., Ivanova, T., Meyer-Cords, C., & Rodrigues, L. (2005). Bat migrations in Europe: A review of banding data and literature. *Naturschutz und Biologische Vielfalt*, *28*, 3–162. https://www.researchgate.net/publication/311443225_Bat_migration_in_europe_A_review_of_banding_data_and_literature

Jones, G., & Teeling, E. C. (2006). The evolution of echolocation in bats. *Trends in Ecology & Evolution (Amsterdam)*, *21*(3), 149–156. https://doi.org/10.1016/j.tree.2006.01.001

Kelly, A., Goodwin, S., Grogan, A., & Mathews, F. (2008). Post-release survival of hand-reared pipistrelle bats (*Pipistrellus* spp.). *Animal Welfare*, *17*(4), 375–382. https://doi.org/10.1017/S0962728600027871

Kelly, A., Goodwin, S., Grogan, A., & Mathews, F. (2012). Further evidence for the post-release survival of hand-reared, orphaned bats based on radio-tracking and ring-return data. *Animal Welfare*, *21*(1), 27–31. https://doi.org/10.7120/096272812799129420

Kunz, T. H., Stack, M. H., & Jenness, R. (1983). A Comparison of Milk Composition in Myotis lucifugus and Eptesicus fuscus (Chiroptera: Vespertilionidae). *Biology of Reproduction*, *28*(1), 229–234. https://doi.org/10.1095/biolreprod28.1.229

Kunz, T., Oftedal, O., Robson, S., Kretzmann, M., & Kirk, C. (1995). Changes in milk composition during lactation in three species of insectivorous bats. *Journal of Comparative Physiology B*, *164*(7). https://doi.org/10.1007/bf00261395

Kunz, T. H., & Fenton, M. B. (2005). *Bat Ecology*. University of Chicago Press.

Lawrence, B. D., & Simmons, J. A. (1982). Echolocation in Bats: The External Ear and Perception of the Vertical Positions of Targets. *Science (American Association for the Advancement of Science)*, *218*(4571), 481–483. https://doi.org/10.1126/science.7123247

Lelli, D., Papetti, A., Sabelli, C., Rosti, E., Moreno, A., & Boniotti, M. (2013). Detection of Coronaviruses in Bats of Various Species in Italy. *Viruses*, *5*(11), 2679–2689. https://doi.org/10.3390/v5112679

Lollar, A., & Bat World Sanctuary. (2012). *The rehabilitation and captive care of insectivorous bats* (2nd ed.). Bat World Sanctuary. https://batworld.org/wp-content/uploads/2023/01/E-Book-The-Rehabilitation-and-Captive-Care-of-Insectivorous-Bats.pdf

Mühldorfer, K., Speck, S., & Wibbelt, G. (2011). Diseases in free-ranging bats from Germany. *BMC Veterinary Research*, *7*(1), 61–61. https://doi.org/10.1186/1746-6148-7-61

Mühldorfer, K., Speck, S., Kurth, A., Lesnik, R., Freuling, C., Mueller, T., Kramer-Schadt, S., & Wibbelt, G. (2011a). Diseases and causes of death in European bats: Dynamics in disease susceptibility and infection rates. *PloS One*, *6*(12), e29773–e29773. https://doi.org/10.1371/journal.pone.0029773

Mühldorfer, K. (2013). Bats and Bacterial Pathogens: A Review. *Zoonoses and Public Health*, *60*(1), 93–103. https://doi.org/10.1111/j.1863-2378.2012.01536.x

Mullineaux, E., & Keeble, E. (2016). *BSAVA Manual of Wildlife Casualties* (2nd ed.). John Wiley & Sons. https://www.bsavalibrary.com/content/book/10.22233/9781910443316

Mullineaux, L., & Brash, M. (2009). How to... Handle bats. *BSAVA Companion*, 50(6), 8–11. https://pubmed.ncbi.nlm.nih.gov/19536917/

Novak, M., & Szenci, O. (2024). Artificial milk for wildlife orphaned neonates. *Veterinarska Stanica*, *55*(1), 111–123. https://doi.org/10.46419/vs.55.1.5

Salinas-Ramos, V. B., Tomassini, A., Ferrari, F., Boga, R., & Russo, D. (2023). Admittance to Wildlife Rehabilitation Centres Points to Adverse Effects of Climate Change on Insectivorous Bats. *Biology (Basel, Switzerland)*, *12*(4), 543-. https://doi.org/10.3390/biology12040543

Serangeli, M., Cistrone, L., Ancillotto, L., Tomassini, A., & Russo, D. (2012). The post-release fate of hand-reared orphaned bats: Survival and habitat selection. *Animal Welfare*, *21*(1), 9–18. https://doi.org/10.7120/096272812799129510

Shen, Y.-Y., Liang, L., Zhu, Z.-H., Zhou, W.-P., Irwin, D. M., & Zhang, Y.-P. (2010). Adaptive evolution of energy metabolism genes and the origin of flight in bats. *Proceedings of the National Academy of Sciences - PNAS*, *107*(19), 8666–8671. https://doi.org/10.1073/pnas.0912613107

Simmons, N. B., Seymour, K. L., Habersetzer, J., & Gunnell, G. F. (2008). Primitive Early Eocene bat from Wyoming and the evolution of flight and echolocation. *Nature*, *451*(7180), 818–821. https://doi.org/10.1038/nature06549

Simpson, G. G. (1945). *The principles of classification and a classification of mammals*. American museum of natural history.

Souza, M. J., Aguilar, R. F., Yabsley, M. J., Hernandez, S. M., Barron, H. W., & Miller, E. A. (2019). Human Safety and Zoonoses. In *Medical Management of Wildlife Species* (pp. 11–21). John Wiley & Sons, Inc. https://doi.org/10.1002/9781119036708.ch2

Sulser, R. B., Patterson, B. D., Urban, D. J., Neander, A. I., & Luo, Z.-X. (2022). Evolution of inner ear neuroanatomy of bats and implications for echolocation. *Nature (London)*, *602*(7897), 449–454. https://doi.org/10.1038/s41586-021-04335-z

Szentiványi, T., Szabadi, K. L., Görföl, T., Estók, P., & Kemenesi, G. (2024). Bats and ectoparasites: exploring a hidden link in zoonotic disease transmission. *Trends in Parasitology*, *40*(12), 1115–1123. https://doi.org/10.1016/j.pt.2024.10.010

Sztencel-Jabłonka, A., Jones, G., & BogdanowicZ, W. (2009). Skull Morphology of Two Cryptic Bat Species: Pipistrellus pipistrellus and P. pygmaeus — A 3D Geometric Morphometrics Approach with Landmark Reconstruction. *Acta Chiropterologica*, *11*(1), 113–126. https://doi.org/10.3161/150811009X465730

Terrell, S. P. (2005). Zoonotic disease concerns for the wildlife rehabilitator. In *Proceedings of the North American Veterinary Conference*. Orlando, FL: Walt Disney World Animal Programs. https://doi.org/10.5555/20053197495

Thor, K. A., & Bielecki, W. (2021). Issues in bat (Chiroptera) treatment and rehabilitation: the scale of the problem, reasons and effects of interventions. *Journal of Vertebrate Biology*, *70*(2), 21013.1-7. https://doi.org/10.25225/jvb.21013

UNEP. (1979). *Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)*. Bonn, Germany.

UNEP/EUROBATS. (1994). *Agreement on the Conservation of Populations of European Bats (EUROBATS)*. Bonn, Germany.

Veikkolainen, V., Vesterinen, E. J., Lilley, T. M., & Pulliainen, A. T. (2014). Bats as Reservoir Hosts of Human Bacterial Pathogen, Bartonella mayotimonensis. *Emerging Infectious Diseases*, *20*(6), 960–967. https://doi.org/10.3201/eid2006.130956

Veselka, N., McErlain, D. D., Holdsworth, D. W., Eger, J. L., Chhem, R. K., Mason, M. J., Brain, K. L., Faure, P. A., & Fenton, M. B. (2010). A bony connection signals laryngeal echolocation in bats. *Nature (London)*, *463*(7283), 939–942. https://doi.org/10.1038/nature08737

Voigt, C. C., Frick, W. F., Holderied, M. W., Holland, R., Kerth, G., Mello, M. A. R., Plowright, R. K., Swartz, S., & Yovel, Y. (2017). Principles and Patterns of Bat Movements: From Aerodynamics to Ecology. *The Quarterly Review of Biology*, *92*(3), 267–287. https://doi.org/10.1086/693847

Voigt, C. C., Bernard, E., Huang, J. C.-C., Frick, W. F., Kerbiriou, C., MacEwan, K., Mathews, F., Rodriguez-Duran, A., Scholz, C., Webala, P. W., Welbergen, J., & Whitby, M. (2024). Toward solving the global green–green dilemma between wind energy production and bat conservation. *Bioscience*, *74*(4), 240–252. https://doi.org/10.1093/biosci/biae023

Warnecke, L., Turner, J. M., Bollinger, T. K., Lorch, J. M., Misra, V., Cryan, P. M., Wibbelt, G., Blehert, D. S., & Willis, C. K. R. (2012). Inoculation of bats with European Geomyces destructans supports the novel pathogen hypothesis for the origin of white-nose syndrome. *Proceedings of the National Academy of Sciences - PNAS*, *109*(18), 6999–7003. https://doi.org/10.1073/pnas.1200374109

Welman, S., Tuen, A. A., & Lovegrove, B. G. (2018). Using thermoregulatory profiles to assess climate change vulnerability in an arboreal tropical bat: heterothermy may be a pre-adaptive advantage. *Climate Research*, *74*(2), 161–170. https://doi.org/10.3354/cr01496

Wibbelt, G., & Torrence, M. (2013). Editorial. Bats and zoonoses. *Zoonoses and Public Health*, *60*(1), 1–1. https://doi.org/10.1111/zph.12004

https://64.media.tumblr.com/63efebd472fbcd17fd1b53133ca05ace/6112469c80df2450-fa/s1280x1920/8c1f3c4f8cec00510cbbc05d3e0c7efd4669c4b0.pnj

https://www.kodami.it/fondi-statali-ai-cras-in-arrivo-un-emendamento-per-renderli-accessibili-a-tutti/