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THE *Journal of Wildlife Rehabilitation* is designed to provide useful information to wildlife rehabilitators and others involved in the care and treatment of native wild species with the ultimate purpose of returning them to the wild. The journal is published by the International Wildlife Rehabilitation Council (IWRC), which invites your comments on this issue. Through this publication, rehabilitation courses offered online and on-site in numerous locations, and its outreach to those in the profession, the IWRC works to disseminate information and improve the quality of the care provided to wildlife.



ON THE COVER:

European hedgehog (*Erinaceus europaeus*) a common backyard visitor. This one was cleared of ticks and released back into its urban "wild."

PHOTO © GEORGE KENDAL ON UNSPLASH.

LEFT:

Anna's hummingbird (*Calypte anna*), a winter resident of the Pacific Coast, north into British Columbia. It has been part of the increased patient load in the area as the frequency of extreme cold snaps has increased.

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IWRC

Providing evidence-based education and resources on wildlife rehabilitation to move the field of wildlife rehabilitation forward; to promote wildlife conservation and welfare; and to mitigate human-wildlife conflicts worldwide, through better understanding of wild animal ecology, behavior, and welfare.

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EDITORIAL

Heeding Cassandra

In the essay "How Encanto Explains America" by Tom McTague,[1] the description of the foreseer of the future as a community outcast reminded me of reading about Ariadne's Thread* in a class long ago, in which Cassandra is a stand in for an apocryphal future. A Trojan priestess in Greek mythology, Cassandra was cursed to deliver true prophecies that would never be believed.

This immediately brought to my mind the vociferous reactions to the recent movie "Don't Look Up," reactions possibly fueled by our current "head-in-the-sand" approach to climate change. As I continued the essay, I found the author making the same Cassadric connection.

Over the last several months I've used the excuse of preparing for an upcoming roundtable to read my backlog of books related to climate change. The books investigate the mechanics of climate change, the underlying geology, the history of our scientific knowledge, and explore the social causes and ramifications of our current crisis. Some of the books also tease apart the cultural history and ways of thinking that underlie our actions and inactions.

The current book on my nightstand, **The Great Derangement**, suggests that our collective approach to the climate crisis—or lack thereof—doesn't reflect an unwillingness to face reality, but a cultural inability to perceive the cataclysmic events that science has forewarned for decades. The author, Amitav Ghosh, believes that three factors have contributed to this condition: the modern novel, the Descartian method of reducing a problem to its parts, and 18th century geologic theory. These, he believes, are the underpinnings of this cultural inability to believe in the uncanny.

I am sharing these thoughts in this journal devoted to wildlife rehabilitation because our practitioners and advocates encounter many of the same challenges as climate change communicators. We consistently struggle (and often succeed) to convey the complex relationships that tie our ecosystems together, like Ariadne's famed thread.

But I also share these thoughts here because, like McTague, I see hope for change. Hope in a changing paradigm where One Health is embraced by major NGOs, government agencies, and universities. A paradigm where we see the world not just as the sum of separate parts but where we use Ariadne's thread to acknowledge the interconnectedness of our planet and unravel holistic solutions.

Wildlife rehabilitators are part of the sea change needed to break from our cultural mold of uniformity, accept our present, and work to improve our future.

—Kai Williams
Executive Director

**The myth is cited throughout many disciplines to address solving difficult problems with a logical, multi-pronged approach through the forest of interconnected complexities. It is used in this manner as the title to Mary Clark's 1989 book of the same name.*

In this myth, young humans were sent into a labyrinth occupied by the Minotaur, a half-bull, half-human creature, for sacrifice. Theseus, son of King Aegeus of Athens, volunteered to enter the labyrinth and kill the Minotaur.

The human Ariadne gave him a sword and ball of thread, to tie the end near the entrance of the labyrinth and unroll as he wound his way through the dense, branching paths. Once Theseus succeeded, he followed the thread back to the entrance and Ariadne.

—Source: www.greekmythology.com.

[1]McTague, T. "How Encanto Explains America: All is not lost; the future is not set." The Atlantic. January 16, 2022.

"Biggest Year Ever"

EUGENE, OREGON (February 7, 2022)—Wildlife rehabilitation centers across North America have reported 2021 as their busiest year yet. In Minnesota the Star Tribune reported that the Wildlife Center of Minnesota received a record 19,000 animals; 197 different species. To the West in British Columbia, centers reported moderate to extreme increases, with the Wildlife Rescue Association in Burnaby seeing a 25% increase over 2020 intakes. The Wildlife Rehabilitation Center of Northern Utah also noted record intakes in 2021, a 22% increase over their five year average.

Wildlife Rehabilitators Featured in Award Winning Film

SALT LAKE CITY, UTAH (January 28, 2022)—A film centering around Nadeem Shezad and Mohammad Saud, founders of Wildlife Rescue in New Dehli, India, won the World Documentary Grand Jury Prize at the 2022 Sundance Film Festival in January for their film, "All That Breathes." Learn more on the Sundance Blog, or in reviews including Variety, Indie Wire and The Hindu.

Peruvian Oil Spill Draws Multi-country Response

VENTANILLA, PERU (January 31, 2022)—A damaged ship off the coast of Peru has spilled at least 6,000 barrels of oil after ignoring warnings of tsunamis from the Tonga volcanic eruption.

The spill contaminated two protected areas: the Ancón Reserved Zone and the Pescadores Islets, which belong to the National Reserve System of Guaneras Islands, Islets, and Points. These areas are home to iconic and legally protected species such as the Humboldt penguin, sea otter, Guanay cormorant, and Peruvian booby. The spill has also compromised fishing in the area, threatening the livelihoods of local fishermen.

"The oil spill is wreaking havoc on marine life in an important and biodiverse area of Peru, all while devastating local fishermen and their families," said Daniel Olivares, vice president of Oceana in Peru.

Aiuká is the lead wildlife rehabilitation team responding to this spill. They are working with local organizations and global partners, such as International Bird Rescue, to care for affected wildlife.



PHOTO © GABE GIFFIN, LOUISIANA DEPT OF WILDLIFE & FISHERIES.

Wildlife Response Services' rehabilitator, Justin Murgatroyd, inspects an alligator after washing near the Collins Pipeline diesel spill in Chalmette, Louisiana.

Diesel Fuel Spill in Mississippi River Gulf

ST BERNARD PARISH, LOUISIANA (January 20, 2022)—A corroded pipeline spilled 315,000 gallons of diesel into two ponds December 27th. Louisiana Department of Wildlife & Fisheries response personnel have been on-scene daily since Dec. 28.

Wildlife Response Services (WRS) was brought in to establish and implement wildlife rehabilitation operations on Dec. 28. A wildlife rehabilitation center was set up near the spill site on Dec. 29. All animals brought in by response personnel are given an intake exam. The exam allows response personnel to determine the animal's overall condition and what the individual treatment plan needs to include.

As of January 20th, 169 live animals were captured for rehabilitation. LDWF has released 63 animals back into the wild, including 38 alligators. LDWF has documented that 2,523 fish and 96 animals were killed in the spill.

Alligators make up the largest group of wildlife collected thus far. The alligators range from hatchlings to one 6-foot alligator. No alligators larger than 6 feet have been admitted into the rehabilitation center as of January 20th.

Trial Effort Addresses Unusual Manatee Mortality Event

CAPE CANAVERAL, FLORIDA (December 8, 2021)—The U.S. Fish and Wildlife Service (USFWS) and Florida Fish and Wildlife Conservation Commission (FWC), in cooperation with Florida Power & Light Company (FPL), are enhancing ongoing

efforts to address the unusual manatee mortality event (UME) along Florida's Atlantic coast.

After thorough science, policy, and legal reviews, and substantial coordination, the USFWS and FWC leadership recently approved the Unified Command establishing a Temporary Field Response Station at FPL's Cape Canaveral Clean Energy Center in Brevard County. The Response Station will support several UME response operations already underway in the central Indian River Lagoon, such as manatee rescues, carcass recovery, and limited field health assessments.

In approving the Response Station, USFWS and FWC leadership also approved staff to conduct a short-term feeding trial, referred to by many as supplemental feeding.

The goals of this limited, small-scale feeding trial are two-fold: 1) to reduce manatee mortality and 2) to reduce the number of animals in need of rescue, allowing the limited space in permitted critical care facilities to remain open for animals needing rehabilitation for other reasons.

"We understand the importance of a timely response. Our agencies and Unified Command partners carefully considered all aspects of a short-term feeding trial," said Shannon Estenoz, Department of the Interior Assistant Secretary for Fish and Wildlife and Parks. "It is critical we help manatees in the short term with actions that are compatible with their long-term well-being and resilience."

The Response Station is not a location for mobile veterinary care or rehabilitation. Our partners with the Manatee Rescue and Rehabilitation Partnership will continue to care for rescued animals at their federally permitted rehabilitation facilities.

Unified Command partners still anticipate relatively high mortality along Florida's Atlantic Coast during the winter of 2021–22 due to chronic effects of starvation from the loss of seagrass associated with poor water quality within the Indian River Lagoon.

Because this trial effort is a management action that has not been tried before, we do not know how many manatees will visit the site or how much vegetation individual manatees will consume. The goal of this action is to reduce manatee mortality. It will not eliminate it.

Visit MyFWC.com/Manatee for more information.

Proposed U.S. Rule on Captive Avian Welfare; Public Comment Until April 25

WASHINGTON, DC (February 18, 2022)—The United States Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) is inviting public comments on a proposal to amend the Animal Welfare Act (AWA) to establish new regulations and standards governing the humane handling, care, treatment, and transportation of birds in captivity.

The proposal would ensure each individual bird that is subject to the AWA is raised and maintained in conditions that ensure its good health and well-being and that its physical and behavioral needs are met. The proposed rule outlines how entities with birds can obtain a license, and the standards they would have to follow.

APHIS is asking the public to provide comments on how this proposed rule would impact the regulated community, as well as ways that APHIS might assist regulated entities with implementation of these standards, whether through documents, guides, training, or other means. APHIS also invites comments on the proposed operating standards for facilities, the proposed animal health and husbandry standards, and the proposed transportation standards.

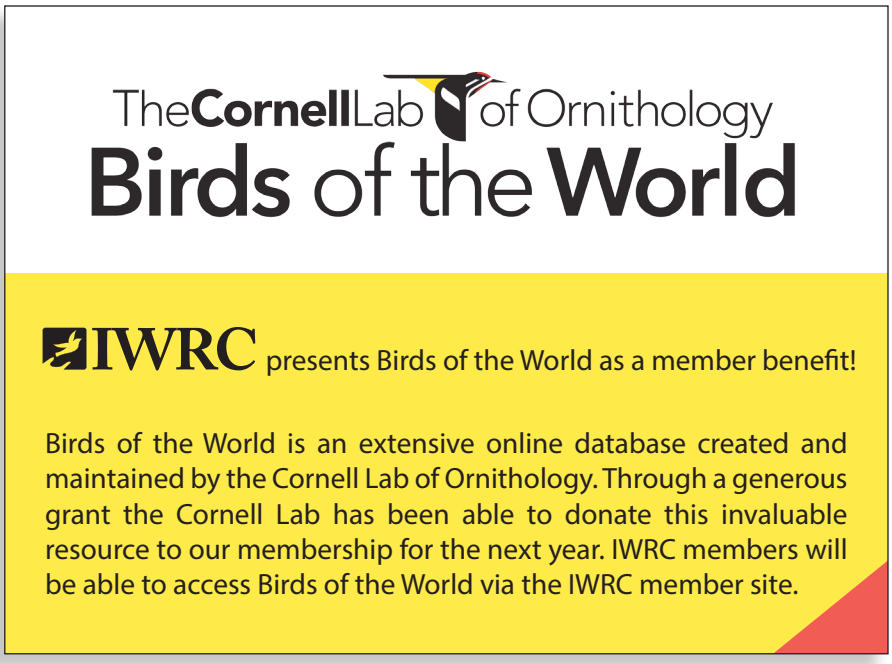
The proposed rule is available in the Federal Register. Public comments are accepted until April 25, 2022.

Tasmania Develops Wildlife Rehabilitation Strategy

HOBART, TASMANIA (January 31, 2022)—The Department of Natural Resources and Environment Tasmania is working with the Tasmanian Wildlife Rehabilitation Council, along with other wildlife rehabilitation and veterinary organizations to develop a strategy plan for wildlife rehabilitation on the island.

"The Government has allocated $460,000 in the 2021–22 Tasmanian Budget towards care and services for injured and orphaned wildlife across the State and to assist the sector to build its capacity and become sustainable over the longer term."

2021 saw a series of meetings, workshops, and a sector survey to develop the strategy. The draft was released for comment in January of 2022. A final strategy will be published later this year. ■



Management of lynx orphans in Switzerland, 1981–2019: a case study

Stéphanie Borel,[1] Andreas Ryser,[2] Mainity Batista Linhares,[1] Anja Molinari-Jobin,[2] Marie-Pierre Ryser-Degiorgis[1]

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Introduction

The Eurasian lynx (*Lynx lynx*) was extinct from most of Western Europe by the end of the 19th century. In Switzerland, the species has been protected by law since 1962 and was reintroduced in the Swiss Alps and the Jura Mountains in the 1970s,[1] where two distinct populations have established. Later on, a small population nucleus was reintroduced to northeastern Switzerland. Lynx in Switzerland are currently increasing in number, with a population estimated to be 251 (+/- 12) independent lynx (subadults and adults) in 2018.[2]

The concept of conservation generally applies to an entity, such as a population.[3] However, in the case of rare or threatened species, for example among felids the Eurasian lynx (*Lynx lynx*) in Bohemian-Bavarian Forest (Germany),[4] the Iberian lynx (*Lynx pardinus*) in Spain,[5] and the jaguar (*Panthera onca*) in Argentina,[6] the management of individuals is also part of conservation.[7–9] Moreover, anthropogenic causes of death may be sufficient to justify this investment.[10] In this context, the question was raised as to whether a wild-born animal such as an orphaned lynx may be a good candidate for a zoo or rehabilitation.

Since the 1980s, in Switzerland lynx orphans have regularly been found and brought

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ABSTRACT: The management of orphaned lynx since species reintroduction in Switzerland has been very challenging, including both animal welfare and conservation issues. We analyzed data on 120 presumptive orphans (75 found alive and 45 found dead) and described the fate of live individuals taken to a wildlife care center. We assessed the following management options of free-ranging orphaned lynx, which have been successively applied in Switzerland from 1981 to 2019: placement in a zoo, culling, rehabilitation, and feeding in the wild. Out of 42 animals taken to captivity, 18 (42.9%) died before placement or release. Deaths were related to pre-existent health impairments and, in a few cases, to captivity-related injuries. Of eight released orphans, all survived the first month, three the first year, and two reached reproduction age. Lynx orphan management has been driven by the current political situation in Switzerland. Based on this study, we can make two recommendations: 1) it is absolutely necessary to pre-establish procedures and define clear responsibilities; and 2) if the option chosen implies captivity, it is crucial to identify a suitable infrastructure in advance, with competent staff who can respond to all needs of individuals, whether for a temporary or permanent stay.

KEYWORDS: animal care, captivity, conservation, Felidae, health, *Lynx lynx*, management, outcome, rehabilitation.

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to captivity. The management of these animals has remained challenging until today. In 1996 the Federal Office of Environment (FOEN; named the Swiss Federal Office for the Environment, Forests and Landscape until 2005) updated the Hunting Ordinance, stipulating that this governmental institution had to establish protection and management plans for selected protected species, such as the lynx. However, until the year 2000 there were no particular guidelines on how to proceed with injured or orphaned lynx. In the first "Lynx management plan," published in 2000,[11] it was stipulated that abandoned juvenile lynx should be used for future translocation projects in Switzerland or abroad. During the following years, all orphans were brought to captivity to raise them in the hope of release into the wild or, if this was not possible, of placement in a zoo. In case of serious health impairment, orphaned lynx were culled in the field or euthanized by a veterinarian in accordance with Art. 8 of the Swiss Hunting law.[12]

However, releases within the country were hampered by stakeholder pressure (hunters, livestock breeders) as well as the political tensions arising from it.[13,14] Furthermore, during these years orphans were not considered appropriate candidates for ongoing reintroduction projects because they would not reproduce as early as adults and the mortality rate of subadult dispersing lynx is high.[15] Finally, for diverse reasons, it became increasingly difficult to find a zoo willing to adopt these animals. Thus, the responsible governmental agency required the culling of all lynx orphans for which release was not an option and zoo placement was not possible. Importantly, potential zoo placement had to be arranged before capturing an orphan.

In 2004, the "Lynx management plan" was revised[16] to better define the relevant legal framework and promote a uniform application of the legislation. According to this new version (Art. 4.5), abandoned juvenile lynx had to be reintegrated into the population of origin at an appropriate time or used for translocation projects in Switzerland or abroad. If reinstatement was not recommended for veterinary reasons, the orphaned lynx had to be euthanized. This management plan also stipulated that all lynx killed or found dead in Switzerland should be submitted to the Institute for Fish and Wildlife Health (FIWI) at the University of Bern for a thorough post-mortem investigation.[17] Thus, juveniles shot on site, euthanized, or that died after their arrival at a wildlife care center (WCC) were systematically examined by FIWI staff according to a standard protocol applied on all dead lynx.[18]

The management plan was revised again in 2016[19] and the paragraph about care and management of orphans was removed. As the local political situation in many Swiss cantons (i.e., Swiss political subunits) was not favorable to releases, most orphans were culled in the field. However, on the initiative of some concerned cantons, a few orphaned lynx with good chances of survival at first sight were captured and brought to a WCC despite the modified national management framework. Capture of lynx orphans was carried out by professional game wardens or auxiliary rangers, using different methods as best indicated by the situation (with a net, a small box trap, or by distance anesthesia with a blowpipe without previous physical immobilization). Capture was usually easy because the animals were hungry and weakened and had lost their escape behavior.

In addition to placement in a zoo, rehabilitation, and culling, a further option has been recently tested in Switzerland and abroad—to provide care in the wild.[20,21]

Methods

Animal data

We performed a retrospective study based on the FIWI and KORA (Foundation KORA—carnivore ecology and wildlife management) records on free-ranging orphan lynx caught alive in Switzerland since the species was reintroduced in the 1970s, hypothesizing that rescue attempts of orphaned lynx in Switzerland were characterized by poor success. We analyzed available medical records and documentation on their housing conditions and behavior in WCC, focusing on how they had adapted to their captive environment, in particular whether they had developed health impairments or behavioral anomalies. We also studied the various causes of disease in lynx orphans that died or were euthanized at a WCC, and screened the FIWI necropsy reports for lynx orphans found dead or culled in the field. We assessed the circumstances in which these orphans were found, their age and health status at this time. Finally, we described a successful experience with orphan care in the wild.

Orphan definition

For our study, selection criteria for a lynx orphan included age (juveniles dependent on their mother until and including March, i.e. before the peak of dispersal),[22,23] apparent absence of mother, and emaciation.

We determined the age in months, based on field data of KORA or on clinical and post-mortem data of the FIWI, using dentition as classification criteria.[18,24,25] When data required for age estimation were missing (no teeth pictures, n = 22), we arbitrarily set the birth date on May 1st, considering that in Switzerland, young lynx are born from the beginning of May to mid-June.[15]

Based on field observations, juvenile lynx are commonly classified in three categories according to lynx biology:[15] stationary juveniles (May to July: cubs remaining at the den), small juveniles (August to October: cubs becoming mobile, until the end of lactation and change to solid food), and large juveniles (from November to March: mobile immature lynx feeding on their mother's prey, but still dependent on her). For the purposes of this study, these three categories were retained, but age was the determining factor to classify individuals as follows: stationary juveniles (<3 months old), small juveniles (≥3 to <6 months old), and large juveniles (≥6 to <11 months old). The latter was subdivided into large juveniles before the start of dispersal (≥6 to <9 months old) and during the dispersal and mating season (≥9 to <11 months).

Assessment of body condition was based on the animal's general appearance, muscular mass, and prominence of bones at palpation. At post-mortem examination, additional criteria

included the amount and appearance of subcutaneous and visceral adipose tissue, as well as bone marrow consistency and color (only in case of fracture, as the skeleton was left intact for taxidermy). Subsequently, body condition was categorized as: good, mildly emaciated, moderately emaciated, or severely emaciated (including cachectic state).

All available data on the animals included in this study were compiled in an Excel sheet (Microsoft Excel 2010, Microsoft Corporation, Redmond, Washington, USA), including date and season of discovery (lunar calendar) and of first veterinary examination, animal data (age, weight, sex), geographical origin and population (Jura, Alps, or northeastern Switzerland), circumstances of findings, health status at the time of admission or at necropsy, and time spent at a WCC.

Medical records

Seventy veterinary records of clinical exams, performed on 19 lynx from 2000 through 2019 (1–26 exams per animal), were available. All orphans for which clinical examination was documented were examined following the same pre-established protocol (see Appendix 1 for details). Briefly, captured cubs were anesthetized as soon as possible, either right after capture or within the first week upon arrival at a WCC. Drug dosage depended on the estimated weight and varied slightly from the targeted dosage of 0.1 mg/kg medetomidine and 5 mg/kg ketamine.[26] A full clinical examination including records of dentition state, weight, health status, and morphometrics was carried out, followed by age estimation. If needed, wounds were cleaned and disinfected, antibiotics and/or subcutaneous fluids were given, and each lynx received an anti-parasitic treatment. Blood was sampled by venipuncture for genetics and/or hematology, serum biochemistry, molecular diagnostics, and serology as needed, as well as for archiving purposes. Additionally, feces were collected from the enclosure ground for parasitological analysis (flotation and Baermann-Trichter method).

Questionnaire survey among zoos

From October 2008 through August 2009, a questionnaire survey was carried out among the eight zoos that had adopted a rescued lynx orphan from 1981 (first known live orphan) through 2008 (see Appendix 2 for details). Thanks to written reports of observations from the animal keepers, we could gather reliable information on 14/15 orphaned lynx placed in zoos. No response was provided for the female "Aisha," who did not stay long-term (provisory stay in a first zoo, and then escaped from a second zoo, see Results).

Statistical analysis

In order to assess factors influencing the probability of discovering an orphaned lynx in Switzerland, exact binomial and multinomial tests were performed using the free R software (R Core Team, 2015. R: A language and environment for statistical computing. URL: http://www.r-project.org/). We tested the influence of the lynx population (Alps, Jura, northeastern Switzerland), season (spring, summer, autumn, winter), age category (stationary, small, large juveniles), sex (female, male), proximity to human settlements (using two arbitrary categories: ≤500 m and >500 m) and body condition (good body condition vs. emaciated, the latter including mild, moderate, and severe emaciation). For each variable, the category with the highest number of occurrences was used as a baseline for comparisons. The null hypothesis was an absence of association between the discovery of an orphaned lynx and these variables, and the alternative hypothesis was that a link exists between these variables and the probability to find an orphaned lynx. Level of significance was set at $p < 0.05$.

Results

Animal data

In total, we identified 120 presumptive orphans from 1981 through 2019 (38 years), including 75 found alive and 45 found dead. The total number of recorded orphans per year varied from 0–11 (including 0–10 live lynx), with a mean of about three (3.2) individuals per year (Fig. 1). The fate of the orphaned lynx is summarized in Fig. 2.

Mother's death was proven or strongly suspected for six cubs (out of 75 live lynx and of all 120 orphans of this study): a marked

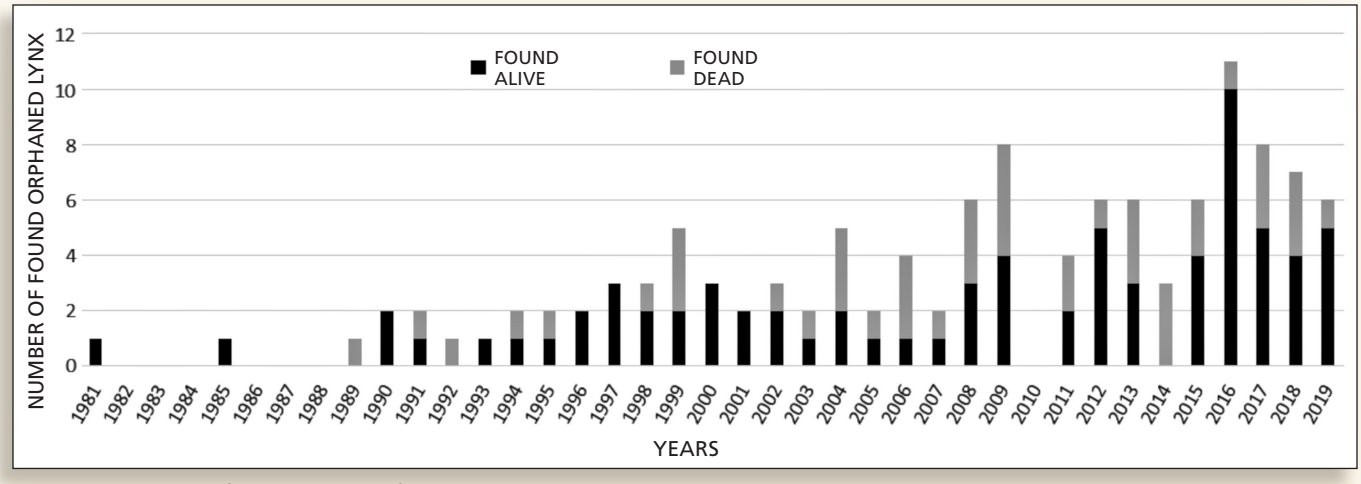


FIGURE 1. Number of orphaned lynx found per year in Switzerland, 1981–2019. The Eurasian lynx was reintroduced to Switzerland in the 1970s but there are no available data prior to the first documented orphan in 1981.

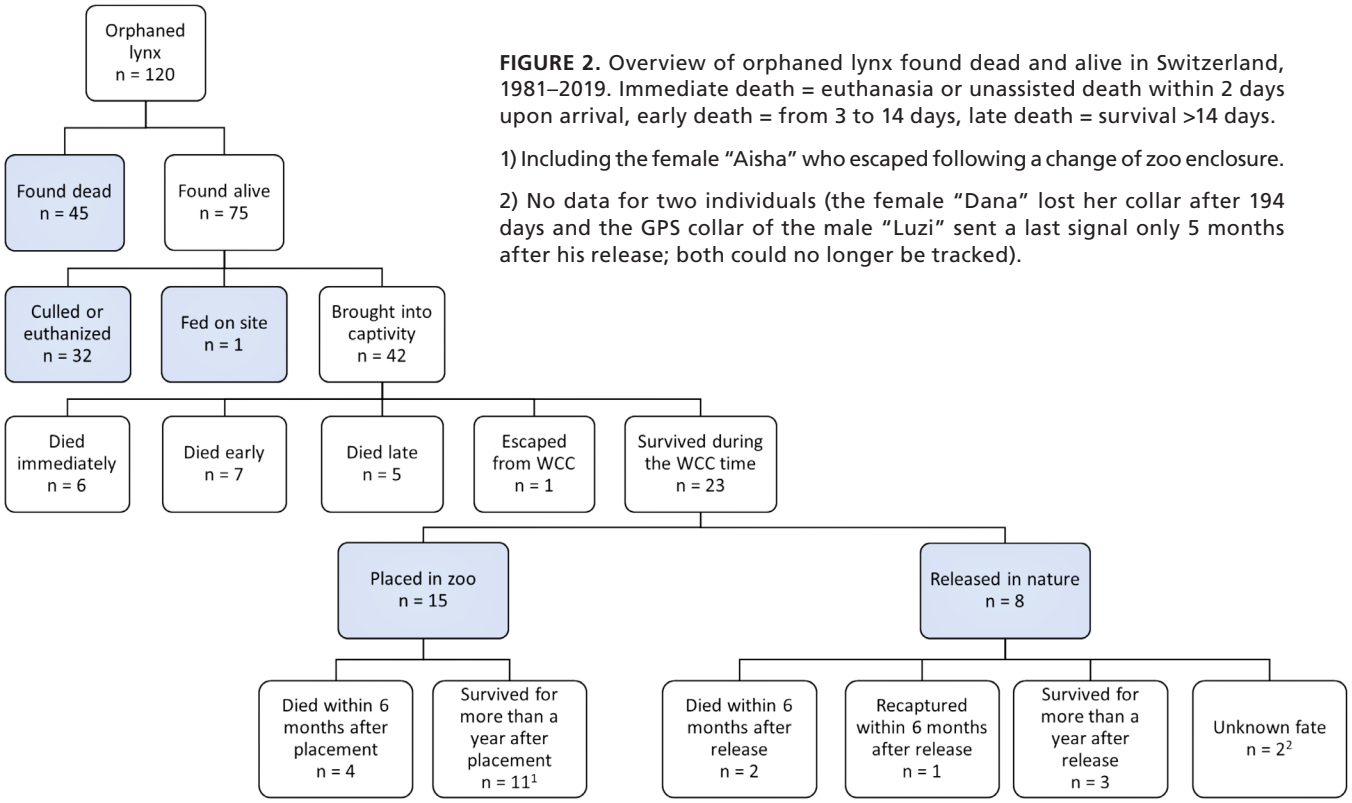


FIGURE 2. Overview of orphaned lynx found dead and alive in Switzerland, 1981–2019. Immediate death = euthanasia or unassisted death within 2 days upon arrival, early death = from 3 to 14 days, late death = survival >14 days.

1) Including the female "Aisha" who escaped following a change of zoo enclosure.

2) No data for two individuals (the female "Dana" lost her collar after 194 days and the GPS collar of the male "Luzi" sent a last signal only 5 months after his release; both could no longer be tracked).

female was killed by car (three cubs), another one vanished while her collar was found in a lake (two cubs, named "Cora" and "Cass"), and a third mother was found dead (unknown cause of death) 4 km from a cub.

Mean age of orphans, alive or dead, at the time of discovery was 5 months (range: 1–9 months). Small juveniles (age based on dentition) were slightly more numerous (n = 68, 56.7%; including 56 found from August to October, 10 in November and one each in January and February) than large juveniles of the first subcategory (n = 39, 36.7%; including three found in October and 36 from November to January). Both were significantly more numerous than stationary juveniles (n = 10, 8.3%, $p < 0.001$; including five found in June, four in July and one in September) and large juveniles of the second subcategory (n = 3, 2.5%, $p < 0.001$; including three found in February) (Table 1). In agreement with this observation, orphans were significantly more frequently found in autumn (n = 88, 73.3%) than in spring (n = 3, 2.5%, $p < 0.001$), summer (n = 20, 16.7%, $p < 0.001$) or winter (n = 9, 7.5%, $p < 0.001$) (Fig. 3). There was no significant difference between females (n = 69, 57.50%) and males (n = 50, 41.67%; $p = 0.05$). Information on sex was missing for an animal that was fed in the wild.

In accordance with our definition, most orphans (n = 101, 91.82%, $p < 0.001$) were moderately to severely emaciated (partly cachectic). Information on body condition at the time of discovery was missing for 10 individuals found alive. The initial weight of live orphans (at the time of capture, euthanasia, culling, or at maximum a week after admission at the WCC) ranged from 0.7 to 2.0 kg for stationary juveniles, from 0.9 to 6.2 kg for small juveniles, and from 2.9 to 6.7 kg for large juveniles. The weight of 18 live individuals was missing in the database or taken after more than seven days at the WCC.

One hundred orphans (83.3%), alive or dead, were found at ≤ 500 m from human settlements, which was significantly more than those found at > 500 m (n = 20, 16.7%, $p < 0.001$). Among all individuals, twenty orphans (16.7%) were found within an anthropogenic structure (barn, pen, chicken coop, garage, wash house). No data were available for two individuals. Fourteen cases of predation by orphans were reported at or shortly before capture, affecting chicken (five lynx), ducks and lambs (three lynx each), a domestic cat, sheep and goat (one lynx each). Three fights were reported: with a fox, with cats, and with a dog.

Orphaned lynx originated significantly more often from the Alps (n = 82, 68.3%) than from the Jura (n = 28, 23.3%, $p < 0.001$) or northeastern Switzerland (n = 10, 8.3%, $p < 0.001$) (Fig. 3).

Health status

Of the 42 orphans brought to captivity, 29 were emaciated, sick and/or injured, and three were apparently in good health, including a good nutrition state. Data were missing for 10 individuals. Nine of 19 animals with clinical examination records (47.4%) showed superficial, sometimes infected, subacute or chronic skin wounds of the claw bed, the lips and/or the forehead. Ectoparasites were found on 13 lynx at arrival (ticks, lice, fleas and/or ear mites).

During subsequent anesthesia or at necropsy, numerous captivity-related lesions were observed, such as split claws (n = 14),

TABLE 1. Orphaned lynx found (alive or dead) in Switzerland, 1981–2019.

SEX	JUVENILE AGE CATEGORIES				TOTAL
	STATIONARY <3 MO	SMALL JUVENILE ≥3 TO <6 MO	LARGE JUVENILE ≥6 TO <9 MO	≥9 TO <11 MO	
Female	8 (8)[1]	38 (23)	21 (17)	2 (1)	69 (49)
Male	2 (1)	30 (13)	17 (11)	1 (0)	50 (25)
Unknown	0 (0)	0 (0)	1 (1)	0 (0)	1 (1)
Total	**10 (9)**	**68 (36)**	**39 (29)**	**3 (1)**	**120 (75)**

[1]Individuals found alive are indicated in parentheses.

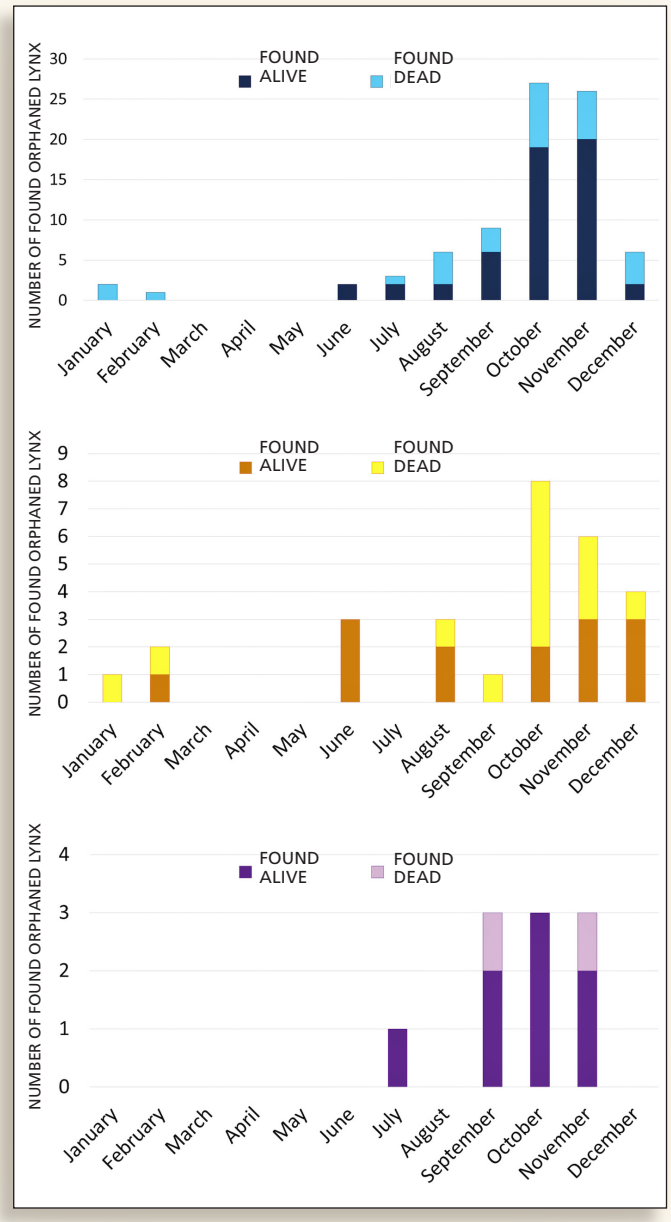


FIGURE 3. Population of origin of orphaned lynx found (alive or dead) in Switzerland, 1981–2019. Colors refer to the lynx population (blue = Alps, yellow = Jura, purple = northeastern Switzerland).

abnormal tooth wear (n = 4), and pulpitis and/or osteomyelitis (n = 4). Among those with severe dental pathologies, the female "Jla"was euthanized after 133 days at the WCC (Table 2) and the male "Talo" had surgery. Prior to euthanasia, "Jla" had undergone 26 anesthesias for antibiotic injections and wound care because of a severe paw injury. The stress caused by these interventions had likely triggered biting of hard structures in the enclosure, causing the dramatic dental lesions.

Eighteen of 42 orphaned lynx (42.9%) died at the WCC (see Table 2 for pathological findings). They died either from pre-existent health impairments (n = 16, including five with a congenital malformation; Table 2) or from injuries resulting from suboptimal enclosures (n = 4). Two animals (Orphan 8 and the female "Behtli") are mentioned in both groups because the direct cause of death, an intestinal perforation, was related to wood split ingestion (i.e., captivity-related) but pelvis malformation (an obviously pre-existent health impairment) was thought to have contributed to the disease process. Indeed, considering the recurring enclosure damages, it is very likely that other lynx also ingested wood pieces without negative health effects.

Management in wildlife care centers

Facilities

Lynx orphans had been admitted in eight different structures playing a role as a WCC, including a stand-alone wildlife rehabilitation center, three zoos having a rehabilitation structure in addition to the animal display, and four zoos offering temporary housing before a decision was taken concerning orphan management. Of the 42 orphaned lynx brought to captivity, data on housing conditions and behavior were available for 13 lynx, but these data were incomplete due to a lack of documentation.

Most lynx (32/42, 76.2%) were kept at the stand-alone WCC, in partially sheltered outdoor enclosures with concrete ground of 18.5 m^2. There were four such distinct concrete enclosures that could be connected with each other, and it was possible to connect one of them with an uncovered outdoor enclosure with natural ground and wire mesh fence of approximatively 50 m^2. A second enclosure with concrete or natural ground was made accessible to the orphans in care as soon as possible.

This WCC was originally built as a pheasant breeding station and the enclosures designed accordingly. Until 1999, the enclosure walls were made of unprotected wire mesh mounted on a cement base associated with a cement ground. The top of the enclosures also consisted of wire mesh. In 2000, the wire mesh of the walls was covered with wooden panels and the cement ground was overlaid first with sand, then later on with rough wood chips, to decrease the risk of lip abrasions (likely related to feeding on carcasses placed on the ground) that were noticed in quarantined adults temporarily housed in the same enclosures. There were

TABLE 2. Cause of death or reason for euthanasia and main pathological findings in orphans that died at a wildlife care center (WCC).

ORPHAN ID (NAME)	LENGTH OF STAY AT A WCC (DAYS)	STATE OF NUTRITION AT TIME OF DEATH	MANNER OF DEATH	CAUSE OF DEATH OR REASON FOR EUTHANASIA	MAIN PATHOLOGICAL FINDINGS[1]
1	7	Cachexia	Exitus	Starvation	Necro-suppurative laryngitis, rhinitis and bronchopneumonia Ulcerative stomatitis Pulmonary and renal calcifications
2	< 1	Cachexia	Exitus	Starvation	None
3 ("Samo")	192	Good body condition	Euthanasia	No data	Dislocation olecrani Congenital malformation (lordosis, scoliosis)
4	5	Cachexia	Exitus	Starvation	Congenital malformation (peritoneopericardial diaphragmatic hernia) Anemia
5	< 10[2]	Cachexia	Exitus	Trauma	Meningeal hemorrhage (traumatic) Bacterial infection *(Salmonella typhimurium)*
6	< 1	Cachexia	Exitus	Starvation	None
7	4	Cachexia	Exitus	Trauma-induced bacterial infection	Septicemia *(Salmonella canis)* Suppurative skin and musculature injuries
8	55	Good body condition	Exitus	Intestinal perforation	Colitis, necrotizing proctitis and peritonitis following ingestion of foreign body Congenital malformation (pelvis malformation)
9 ("Jla")	133	Good body condition	Euthanasia	Trauma	Pulpitis, periodontitis and osteomyelitis with fistule (both inferior canines)
10	7	Moderate emaciation	Exitus	Suspected suffocation (hernia)	Congenital malformation (diaphragmatic defect in area of esophageal hiatus, with suspicion of diaphragmatic hernia) Suppurative bronchopneumonia, with foreign body (aspiration pneumonia)
11 ("Behtli")[3]	171	Good body condition	Exitus	Intestinal perforation Bacterial infection	Septicemia (*Yersinia pseudotuberculosis*) Peritonitis, with bacteria, foreign body and abdominal effusion Necrotizing proctitis with rectal perforation Congenital malformations (lumbar vertebra, pelvis and sternal malformation)
12	< 1	Moderate emaciation	Euthanasia	Stationary juvenile dependent on milk-feeding	None
13	10	Cachexia	Exitus Starvation	Kidney failure	Multisystemic mineralization Suppurative dermatitis Tooth damage with necrotizing stomatitis
14	4	Cachexia	Euthanasia	Tooth damage with necrotizing stomatitis Starvation	Bacterial infection (*Yersinia pseudotuberculosis*) Necrotizing hepatitis
15	61	Good body condition	Exitus	Trauma	Fracture, bilateral (metatarsi) Myocarditis Suppurative bronchopneumonia Fracture with callus (tarsus)
16	1	Cachexia	Exitus	Bacterial infection	Suppurative bronchopneumonia Periodontitis, alveolitis and tooth fractures
17	1	Cachexia	Exitus	Starvation	Tubular nephrosis and interstitial fibrosis, with renal, pulmonary and gastric calcification
18	1	Cachexia	Exitus	Starvation	Tubular degeneration with necrosis, mineralization, interstitial nephritis and fibrosis Tooth fractures

[1]Poor nutrition state excepted (including muscle atrophy and serous fat atrophy). [2]Exact length of stay not specified in the necropsy report. [3][51,52].

small holes in the wooden panels along the corridor accessing the enclosure entrances to allow visual inspection of the inside while minimizing disturbance by the observer. Later on, walls were covered from the ground to the roof by long wood logs, to prevent access to hard prominent structures such as the cement part of the walls, which nervous lynx tended to bite, resulting in teeth injuries. The enclosure structure consisted of a mid-height platform; of a second, low platform on which there was a transport box (adult size) with hay on the bottom, which could be used as a hide; and of a few tree trunks on which the animals could climb. The hide underneath the platform was partly hidden by conifer branches and the top of the platform was limited by a wooden panel with a window open to the front, enabling the lynx to look at the door and the keepers to partly observe the lynx. At zoos acting as WCC, enclosures measured 56 m^2, 160 m^2, and 5000 m^2 respectively, with natural ground and offering many hiding places and climbing opportunities. However, in most cases the enclosures were located in the public area.

Nearly all orphaned lynx were kept alone, as they arrived at a WCC independently from each other. Exceptions were two females ("Luna" and "Dana") that arrived a few months apart in 2012, which were placed in the same enclosure after a period of acclimation, and two siblings (the females "Cora" and "Cass") found at the same place in 2016, which were also kept together. In both cases, a third orphan was subsequently added to the group (see below).

Behavior

During their stay at a WCC, 7 of 13 orphans for which data were available (53.8%) tried to find a way out. Several bite and scratch marks on the enclosure walls were repeatedly noticed in the morning, suggesting that attempts had happened at night. However, intensity and duration of this behavior varied among individuals. During the day, they were mainly alert but calm, using the high wooden platform for resting or sleeping. Some of them were very difficult to observe, using the hide below the platform (WCC) or hiding in trees (large zoo enclosures). They also showed behaviors recorded in nature, such as covering their feces[27] and their "prey" (whole carcass)[28] with wood chips from the ground or hay from the transport box.

Orphans sharing the same enclosure appeared to be less stressed than those kept alone. "Luna" and "Dana" in 2012 were gradually habituated to each other over a week, first by providing them alternating access to a common enclosure (where there was a wild ungulate carcass for feeding) and secondly by placing feces from each lynx in the other one's enclosure. Finally, they were given simultaneous access to several enclosures including the larger one with natural ground. Video-surveillance documented that the first contact between these lynx occurred quickly and easily, as they immediately ran to each other to rub their noses, tails upwards. They often rested together and kept body contact (Fig. 4). This good relationship persisted until the end of their stay at the WCC. However, "Luna" was more nervous, with signs of stereotypy such as pacing along the fence of the larger enclosure, which was fenced



FIGURE 4. Two orphaned sisters ("Luna" and "Dana") resting together, illustrating the positive effect of housing orphans in a social group.



FIGURE 5. Lynx orphan (the male "Talo") with severe captivity-related dental lesions and associated tissue damages: Lateral view (A) and frontal view (B) of oral cavity. Abnormal wear of the two lower canines with greyish discoloration of the lower right canine (yellow arrow) indicating devitalization and pulpitis and associated focal proliferative gingivitis (orange arrow). C) Same animal, same day, ventral view of the inferior jaw. Bilateral fistule openings (arrows). D) Same animal, later time point, ventro-lateral view of the inferior jaw. Extensive crust formation due to dried purulent exudate that accumulated on the chin after spread of dental infection to the inferior jaw (osteomyelitis).

by wire mesh only with view on a sheep pasture. During the same period, "Talo" was quarantined alone in a single enclosure. He remained in isolation for several weeks due to disagreement between stakeholders about the strategy to adopt after detection of a potential health issue. Video-surveillance revealed intense distress signals, such as screaming, scratching and biting the walls, and his health progressively deteriorated: he broke a canine tooth, which resulted in severe pulpitis (Fig. 5) and developed a severe lice infestation with pruritus and poor hair coat. After his tooth lesion was treated by surgery and his coat improved thanks to anti-parasitic drug application, he was introduced into the enclosure of "Luna" and "Dana." Group housing was initially difficult, in particular because "Luna" showed aggressive behavior and finally bit him, which required additional handling for treatment. However, they

could remain together, and the general health status and behavior of "Talo" greatly improved.

A second attempt at group housing was made in a 5,000 m^2 enclosure. "Cora" and "Cass," two sisters less than 2 months old, were placed there in June 2016. They had positive interactions, played and ate together. In October, a third female ("Alosa"), previously kept alone at a different institution, was released in the same enclosure. The arrival of "Alosa" did not disturb the relationship of "Cora" and "Cass," but "Alosa" always stayed away, was shyer, and often dwelled in high trees during the day. At the pre-release veterinary check, "Cora" and "Cass" did not present any injury. By contrast, "Alosa" had a broken canine that was intact at arrival. This suggests that in absence of human observers, probably during the night, her stress-influenced behavior changed from a calm anxiety to nervousness with physical reactions such as biting into hard enclosure structures.

Feeding

Most of the animals arrived severely emaciated, sick, or injured. The food amount was gradually increased, with wet cat food (common commercial food, brand not documented) during the first week, starting with 2 x 100 g daily and increasing the total amount from 100 g to 200 g twice a day. Multi-vitamin cat supplement (veterinary product in form of paste, brand not documented) was added to the food portions. From the second week, roe deer muscle pieces were offered while reducing the amount of cat food. As soon as the lynx ate regularly and digested well (sometimes from the first day of care), parts of roe deer carcasses, and later on whole roe deer with all internal organs except the digestive tract (i.e. carcasses of approximatively 10–25 kg) were given, with minimal contact between keepers and animals. The feeding rate was one carcass a week, which corresponded to the consumption of an adult. In the wild, a family group composed of a female and two juveniles consumes between 3.2 kg (in June) and 4.9 kg (in February) of meat per night against 3.2 kg for a single female,[29] i.e. about 850 g per large juvenile per night. As juvenile lynx normally feed on entire carcasses, it was considered important for the rehabilitation process to feed them as naturally as possible. Carcass remains were removed when a new one was provided. Dead mice and chicks sold as animal food, hares found dead in the wild, or slaughterhouse waste were offered only when roe deer meat was unavailable, which rarely happened. Feeding orphans with roe deer meat was considered particularly important for animals to be released into the wild, as roe deer is the main prey of the Eurasian lynx in Switzerland.[29] By contrast, livestock meat or organs (slaughterhouse remnants) were avoided. Hares and rodents were finally banned because of the risk of bacterial infections.

Among the medical records, 10 contained information about the initial weight of the orphan as well as the final weight measured after death, before transfer to a zoo (maximum one week before) or before release. Eight orphans gained weight, and showed good digestion, normal feces, and improving body condition. Two individuals had gastro-intestinal disorders and anorexia since their arrival, did not respond to therapy, and died.

Captivity duration at wildlife care centers

The average time at a WCC was 110 days (range: <1 to 561 days, 38 individuals). Four orphans were not considered because two did not require veterinary care and were directly integrated in a zoo for the long term; one escaped from the stand-alone WCC within 2 weeks of placement; and information was missing for the last case.

Captivity duration ranged from <1 to 171 days for natural death (n = 14), <1 to 192 days for euthanized animals (n = 4), 7 to 561 days for orphans placed in a zoo (n = 12) and 162 to 399 days for released animals (n = 8). Four individuals (including "Alosa" and "Aisha") stayed for a prolonged time at the stand-alone WCC (150, 399, 482, and 561 days, respectively) waiting for the decision of the authorities on their future. Two were finally moved to a zoo, "Alosa" was released, and "Aisha" escaped after her transfer from a first zoo to a second one.

Fate of live orphans

Zoo

After a period of care and rehabilitation, 15 orphans were placed in a zoo. Integration was partly challenging (see Appendix 2 for details on 14 orphans). The majority of these orphans (11/14, 78.6 %) remained hidden most of the time. Four died within the first 6 months of aggression by conspecifics, ten remained in the zoo (half of which reproduced), and the 15th animal, "Aisha," escaped from the enclosure 2 days after arrival. She had been first kept for 561 days at a WCC, waiting for a decision about her future placement because there was no political will to release her into the wild, while the WCC continued to aim for it. She was transferred to a first zoo after 1.5 year, where she stayed for 199 days in a better pen (larger and forest-like), before being moved to an even larger enclosure, from which she escaped. She was not radio-collared, but one of her kills was found by chance 74 days after her escape and she reproduced at least three times in the wild. "Aisha" had not been taken care of in view of a release despite the WCC rehabilitation intentions. She showed a reduced fear of humans, both in captivity (nearly threatening reactions towards animal keepers) and in the wild, as she was observed multiple times by forest walkers. She was photographed for the last time almost 3 years after her escape.

Release

Eight orphaned lynx were radio-tagged and released into the wild (hard release method) between 2012 and 2019. In five cases, the release site was close to the initial capture site, in two cases it was 20 to 50 km away, and in one case, "Alosha," 200 km away as a contribution to a reintroduction program in a neighboring country. These three last cases were not released close to the capture sites because local stakeholder conflicts did not allow it. Within Switzerland, releases took place from May 13th to July 13th (i.e., at the age of 12–14 months). "Alosa" was released in late December

(at approximatively 19 months of age).

All released orphans survived more than a month and managed to hunt except "Alosa," who was recaptured after 44 days and euthanized due to a fracture of a front limb that had likely occurred soon after release. "Luna" was recaptured after 71 days and placed in a zoo because she had killed sheep. She then behaved abnormally, was constantly stressed, and died at the zoo of pneumonia about 11 months later. The closed collar of "Cass" was found without carcass remains in an avalanche corridor 2 weeks after the collar emitted a mortality signal, raising the question of whether she might have been poached or killed in an avalanche and consumed by scavengers. The GPS collars of two other lynx ("Dana" and the male "Luzi") sent a last signal only 5 and 6-and-a-half months after release, respectively. Therefore, they could no longer be tracked. Overall, at least three ("Heia", "Talo," and "Cora") of eight orphans survived in the wild the first year after release. "Talo" was hit by car after 1 year and 7 months, but "Heia" and "Cora" reached sexual maturity and reproduced several times.



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FIGURE 6. Orphaned lynx fed in nature, standing on a wild boar carcass ("Chaffrou").

Care in the wild

In October 2016, an adult female with a cub ("Chaffrou") were observed leaving a sheep enclosure where two lambs had been killed. "Chaffrou" was identified based on its coat pattern[30] and estimated to be approximatively 5–6 months old. The same night, it was spotted without its mother in the village and later photographed feeding alone on the lamb carcasses. The mother was never found despite active search. "Chaffrou" was subsequently fed in nature during 2.5 months with carcasses of apparently healthy wild ungulates (roe deer and a few wild boar) that had been traffic-killed or culled for population control (Fig. 6). "Chaffrou" regularly consumed these "prey." Camera traps set at the carcasses indicated that the lynx was gaining weight and looked healthy. "Chaffrou" was observed for the last time in December 2016 and never came back, although carcasses were offered until mid-February 2017. It was photographed again in France mid-June 2017 and at the end of January 2018, 70 km further south. The last observation occurred in January 2019 when "Chaffrou" was at the age of almost 3 years, over 95 km away from its place of origin (A. Rauss, pers. comm., 2020).

Discussion

Our study provides a first overview of the management of orphaned lynx in Switzerland, revealing all its complexity and raising a number of issues. Several orphans remained in captivity for a long time due to an uncertain future. The fate of orphaned lynx was strongly influenced by the political situation of the moment. The lack of an unambiguous agreement among wildlife managers, biologists, veterinarians, and WCC collaborators, including procedures to follow and a clear attribution of responsibilities and duties, resulted in prolonged captivity for a few lynx. This emphasizes the need for developing guidelines for the management of orphaned lynx, which should be discussed with and agreed upon by the authorities in advance. The importance of good and early communication with authorities for the success of rehabilitation programs has previously been underlined.[6]

Animal data

While there was no ambiguity regarding the selection of live lynx for this study, sorting out orphans among dead lynx was challenging because it was sometimes uncertain as to whether an illness or trauma preceded or followed separation from the mother (abandonment of weakened offspring or mother's death/weakness, respectively). However, it seems unlikely that a healthy young lynx able to follow its mother would be emaciated. According to our orphan definition, all traffic-killed, well-nourished dead juvenile lynx were excluded from this study. As case history was often very limited and evidence of mother's absence was extremely rare, it is possible that we excluded orphans in good body condition that had died of an accident shortly after separation from the mother.

Categorization of orphans based on discovery month is sometimes less accurate than categorization based on age determination from dentition. Indeed, month-based aging disregards both the

range of the birth dates[15] and the occurrence of occasional late births.[15,31] Fifteen individuals would have been misclassified if the month of discovery had been taken as reference instead of the teeth, and it also may have been the case for the 22 individuals whose age was unknown and for whom there were no tooth pictures. As there are no morphological measurements available to age lynx in growth, it was not possible to estimate age based on body size either.

There has been a steady slight increase in the number of orphans found per year from 1981 to 2019. This was in agreement with a population increase[2] (no statistical analysis), but this trend continued despite population stagnation between 1984 and 1994.[1] The cause of this stagnation is still unknown but could have resulted from poaching in some parts of Switzerland,[32] which would also explain the increase of orphans in absence of population growth.

Most orphans were small and large juveniles found in late summer and autumn. During the "stationary phase," juvenile lynx spend most of their time in the den[15,31] and are unlikely to be found, whether abandoned or dead. From August to October, lynx cubs become more mobile. Lactating mothers prolong their absences to expand their hunting ranges and satisfy the increasing energy needs of growing cubs.[15] The increasing mobility of larger juvenile lynx can explain why orphans are mainly found in late summer. However, in Switzerland, this period also corresponds to the hunting season. Increased human presence in lynx habitat may raise the number of recorded orphans, either due to increased likelihood of discovering abandoned cubs or through intensified poaching of mothers.

The average weight of undernourished orphans of the most affected age group (5–6 months old) was just above 4 kg, while traffic-killed, well-nourished lynx of that age showed an average weight of 6.2 kg (FIWI necropsy database, n = 12). In contradiction with our nutrition state criterion, we included nine live juveniles in good body condition in our dataset because they were found alone without evidence of mother's presence. They had likely been separated from her only recently.

Most orphans were discovered in poor body condition near human settlements, likely because these malnourished animals were looking for easy food sources and were thus more easily found by people. Searching for food associated with human presence is a behavior that is also observed in diseased adult lynx,[33] although healthy lynx can occasionally also be observed close to human settlements.[34,35] Nevertheless, orphaned lynx are certainly more likely to be found near human infrastructures than in the forest, suggesting that the number of orphans in this study may be underestimated.

Orphans originated predominantly from the Alps, reflecting the occurrence and abundance of adult lynx in the wild.[2,36] Other factors likely influencing the number of orphaned lynx found in the different populations were their geographical origin (the largest part of the Jura population is in France) and reintroduction history (the northeastern population was founded in the early 2000s, i.e., nearly three decades after the two others).

Management in wildlife care centers

Facilities and orphan behavior

Several orphans developed abnormal behavior with resulting self-induced tooth damage and other health impairments. The inability of wild-born animals to adapt to captivity is known to lead to physical injuries, behavioral deficiencies, and even neurological damage,[37–42] as well as to generalized poor health.[39] Most of the orphans kept alone showed signs of stress. By contrast, orphans kept in pairs were obviously calmer, and distress signals from "Talo" clearly diminished when he was introduced into the enclosure of "Luna" and "Dana." These observations need to be interpreted with caution because they concerned only a few animals. However, behavioral differences were marked and the observations of two separate situations were congruent, suggesting that the observed reactions were not just specific to the concerned individuals. Although interactions with conspecifics are very important, particularly for cubs,[43] our study suggests that adding a third animal to pairs may disturb a pre-existing balanced group and cause integration difficulties for the third animal.

Thus, behavioral issues encountered with captive lynx are likely due to multiple factors, including enclosure size, enclosure structure, and group composition (manageable), as well as individual character and tolerance to captivity stress (non-manageable).[44]

Feeding

Most of the orphans were over 9 weeks old at the time of admission and therefore able to digest meat.[15] Only "Cora" and "Cass" were younger (about 6–8 weeks old). Slow and progressive refeeding is a key element in the management of malnourished animals due to the risk of clinical signs and metabolic disturbances. For this reason, most lynx orphans were gradually refed with cat food, with progressive addition of meat until complete replacement. The total amount of food offered to lynx orphans was often less fractioned and much higher than the published recommended starting amount for the first week of refeeding (5–10 kcal/kg/day, divided into four to six meals).[45] The goal was to limit the number of comings and goings in the enclosure and thus the contact between staff and orphans. It is important to minimize the risk of habituation to humans and human-associated activities during captivity. Especially when wild mammals get used to human presence and noises associated with food, this habituation may result in a loss of fear of humans, a greater likelihood of getting close to human settlements, inability to hunt, and therefore decreased survival skills upon release.[46–49]

Although the relatively large amount of food given in a few meals could have led to gastrointestinal impairment, this was not observed or recorded during this study. "Cora" and "Cass," which were found at the age of nursing, were only fed traffic-killed ungulates and the early weaning did not seem to affect their weight gain or release success. These experiences suggest that lynx orphans may adapt to abrupt dietary changes and are already able to feed on carcasses 2 to 3 weeks before weaning.

Feeding live prey is not allowed by Swiss law and offering

carcasses of natural prey is the most judicious choice under these circumstances. Although the lynx is considered an obligate predator,[50] juvenile lynx eat their mother's kills until they are able to hunt by themselves.[15] Therefore, it is natural for an orphan to feed on carcasses until it reaches the age of independence.

Captivity duration and welfare aspects

We documented that nearly half of the lynx orphans admitted at a WCC died before placement in a zoo or release. Most of them had a pre-existent health impairment and a few deaths were related to injuries resulting from suboptimal enclosures. "Behtli" and the male "Samo," who have remained at a WCC for several months, could have been euthanized earlier if their malformations had been detected. Initial in-depth veterinary examinations shall allow defining a prognosis. X-rays, for example, could contribute to identifying life-threatening malformations, such as those affecting the lynx pelvis (Table 2, orphans 8 and "Behtli").[51,52] Had "Behtli" not died of an infection before release, the malformation could have caused dystocia and death at parturition.[53,54] In this regard, it is also worth underlining that young wild animals may be rejected by their mother due to reduced fitness.[55] The veterinarian's role is to euthanize individuals that are not viable, will not be able to reproduce due to anatomic defects, or may pose a health risk to the population. Unfortunately, it is often difficult to evaluate this at the time of admission. Possibilities of in-depth veterinary investigations remain limited in wildlife medicine due to financial reasons and because stress-inducing manipulations are detrimental to the animal. Thus, final diagnoses are often only made at necropsy.[56]

"Jla" and "Talo" were manipulated multiple times under anesthesia and their cases illustrate well that the care of orphaned, injured, or sick wildlife is a major challenge, even if a health impairment has been identified and seems treatable. Well-meant repeated manipulations may generate a vicious circle: stressful events can result in signs of distrust and aggressiveness, higher disease susceptibility (e.g. parasites), or development of captive-related injuries (e.g. dental lesions), which may require additional treatments. Others have also reported that human presence, manipulations and anesthesia cause significant stress to wild animals[57,58] and may offset the benefits of therapy. Despite the fact that time spent in captivity is one of the determining factors of rehabilitation success,[38,59,60] it is often difficult to make a prognosis, and hope for recovery encourages continuing care. Specifically for Switzerland, legal protection of the lynx and lack of clear responsibility attributions resulted in wildlife managers avoiding the decision of whether to euthanize a lynx orphan. "Behtli," "Samo," and "Jla" died or were euthanized at the stand-alone WCC after a long period of care, and although "Talo" eventually recovered and was released, he died as a roadkill before reaching sexual maturity (despite a successful adaptation to the wild). Though such fatal events cannot be foreseen, the fate of these animals raises questions regarding the cost and benefit of repeated medical interventions. It also underlines the need for considering welfare issues and making timely decisions.

Several orphans suffered dental trauma and associated local infections. This is a recurring problem of carnivores in captivity.[61–63] A complete, intact dentition is a very important criterion for carnivore rehabilitation, as healthy teeth increase the animal's chances to hunt and feed properly upon release.[60] In case of pulpitis with ascending infection, dental extraction (as performed on "Talo") is the therapy of choice if root canal treatment cannot be performed.[64] The replacement of a broken canine tooth with a dental implant has been previously described in a Eurasian lynx[65] but this is a controversial treatment option for wildlife.[66] Prevention is always to be preferred, especially in terms of animal welfare.

Fate of live orphans

Zoo

Orphaned lynx placed in zoos were shy and inactive most of the time. This behavior may result from stress but could also be compared to boredom.[67] It may negatively impact the animal,[68] and long-term captivity of a lynx with such behavior is therefore questionable from an animal welfare point of view. Furthermore, this passive behavior is not interesting for the public, which is contrary to the purpose of zoos that primarily aim at public education. Additionally, the reproduction rate of orphans placed in zoos was relatively low. In line with our results, there seem to be a significant number of non-breeding lynx in zoos.[44,69,70] It has been suggested that stress may influence reproduction success in captive lynx.[44] The integration of wild-born lynx orphans into life-long captivity settings primarily for display purposes can be interesting from a genetic point of view but raises ethical questions.

Zoos can play an important role in conservation, by ensuring survival of a species extinct in the wild, by participating in public education, or by conducting captive breeding programs to contribute to reintroduction or re-stocking projects.[71,72] For example, successful captive breeding of the Iberian lynx (*Lynx pardinus*) has shown that captivity in adequate settings can successfully serve lynx conservation.[73] However, housing needs of some species are difficult to satisfy, especially in the case of carnivores that normally cover long distances daily.[74] With a territory of 50–300 km^2,[15] the Eurasian lynx is undoubtedly one of them. Although lynx are apparently less subject to stereotypies than other carnivores, they can develop depression-like behavioral changes[37,75,76] and self-inflicted injuries.[18] This is particularly an issue for wild-born animals. Therefore, placement of free-ranging orphans in zoos is ethically questionable.

Release

The seven rehabilitated orphans in Switzerland were released between May and July. This time window coincides with the period following dispersal, which is therefore deemed to be most adequate to release wild carnivores because it mimics normal behavior.[6,77–81] Lynx dispersal occurs mainly from March to April, when juveniles are 10–11 months old.[15,22] Although some individuals already separate from their mother at 9 months old,[22] most are not yet independent at that age. This is illustrated by the

case of an individual that was found severely emaciated and alone in a barn in February and therefore fulfilled the criteria of an orphan. However, although dispersal is the most suitable release time from a biological point of view, this period is also associated with a high mortality rate in juvenile lynx in the wild.[15]

Ability to hunt should ideally be tested before release but it is not allowed in Switzerland. All released orphans were radio-tracked to verify that they were able to survive on their own. Except for "Alosa," who had a leg injury, all rehabilitated orphans demonstrated their ability to hunt in the wild, in agreement with former experiences.[4,82,83] This may have been favored by the fact that all released orphans, except "Cora" and "Cass", had been found at an age when they had already followed their mother to feed on prey (small juveniles) and, for some of them, likely even accompanied her on the hunt (large juveniles). Close monitoring, at least in the initial phase after release, is highly recommended to ensure that the animal can survive on its own.[84]

When comparing with published release success in other species (Table 3), post-release survival within the first month was excellent for lynx orphans (100%). However, interspecies differences, including body size, diet, and varying survival ability in general, may account for varying, species-dependent success rates. As previously stated, the lynx orphans of this study were found at a relatively advanced age. Thus, older age may, on the one hand, be a cause of higher susceptibility to stress in captivity, but on the other hand, it could be an advantage for rehabilitation into the wild.

Excluding "Aisha," whose return to the wild was an accidental event, only "Heia" and "Cora" reproduced. If rehabilitation shall serve population conservation, reproduction should be the main goal and most important indicator of success. Based on this criterion, the success of lynx rehabilitation in Switzerland has apparently been low. However, despite systematic radio-tracking, post-release follow-up has partly been interrupted due to premature signal loss, and the fate of "Dana" and "Luzi" remains unknown. Furthermore, the total number of rehabilitated orphans was very low, as most of those taken to captivity could not be released. To

TABLE 3. Survival rate of rehabilitated juveniles of other species.

SPECIES	MONITORING TIME	SURVIVAL RATE
European Hedgehog (*Erinaceus europaeus*)	[85]2.5 mo	30%
Black-footed ferret (*Mustela nigripes*)	[86]1 mo	30%
	9 mo	20%
White-tailed deer (*Odocoileus virginianus*)	[87]1 mo	40%
		58% (year 2001)
Tawny owl (*Strix aluco*)	[88]1.5 mo	65%
European mink (*Mustela lutreola*)	[89]21 days	75% (male)
		25% (female)
Polecat (*Mustela putorius*)	[78]1 mo	50%
Wombat (*Vombatus ursinus*)	[90]42 days	50%

TABLE 4. Advantages and disadvantages of the four management methods applied on Eurasian lynx in Switzerland, 1981–2019.

MANAGEMENT	ADVANTAGES	DISADVANTAGES
Culling	√ Easy to manage √ Minimal time investment √ Cheap	x No contribution to species conservation x Bad acceptance by the public
WCC and release	√ Contribution to species conservation (locally or for translocation)	x Time-consuming (surveillance, care) x Expensive x Ethically questionable if infrastructure and staff requirements not fulfilled x Limited success
WCC and Zoo	√ Contribution to species conservation if animal integrated into a reproduction program with genetic plan (reintroduction, restocking)	x Risk of bad adaptation to captivity (shyness, hiding) x Ethically questionable if infrastructure and staff requirements not fulfilled
Care in the wild[1]	√ Contribution to species conservation (locally) √ Easy to manage √ Cheap √ Ethically uncontestable √ No infrastructure required √ High chance of success if the health status of the orphan is good √ No risk of captivity-related injuries and other negative impact on health or behavior	x Limited possibilities of veterinary intervention x No marking, i.e., limited follow up after leaving the feeding site x No contribution to translocation programs

[1]For this last option there is not enough experience yet to provide an exhaustive list of disadvantages.

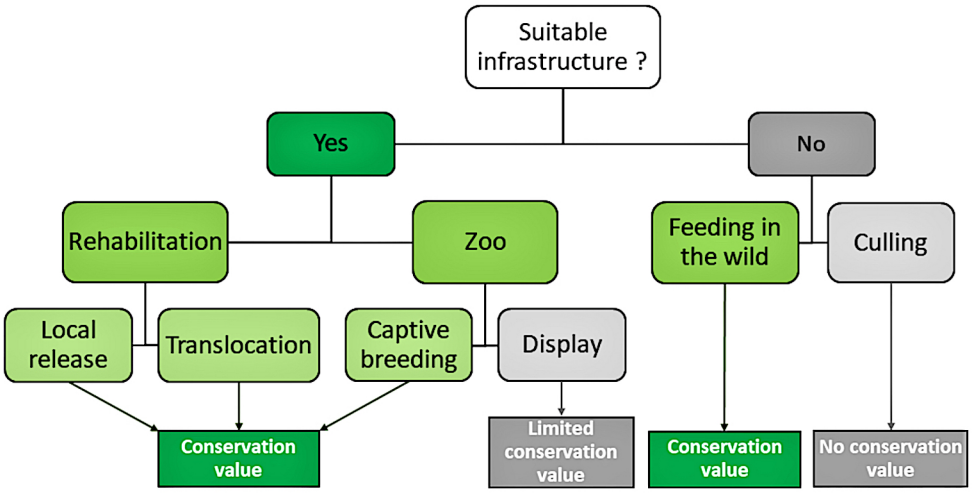


FIGURE 7. Decision tree proposal for the selection of management options for orphaned lynx.

our knowledge, data on reproduction of rehabilitated wild animals in general is not available, as post-release monitoring is generally of short duration (Table 3). Overall, it appears that there is a need for standards to evaluate the success of wildlife rehabilitation.

Care in the wild

Support of the orphaned lynx that remained in the wild until its independence owes its success to three determining factors: the cooperation and motivation of local wildlife services; the short distance between the lynx and a forest road closed to the public (for food deposition); and the participation of motivated game wardens (A. Rauss, pers. comm., 2020). "Chaffrou" was also in a good health status and had not been separated from its mother for long when it was found, which was certainly an advantage in terms of fitness and chances of survival. "Chaffrou" definitely reached sexual maturity because it was seen again 2.5 years after its discovery, i.e., when it was about 3 years old..

Although anecdotal, this successful attempt to support an orphan in its natural habitat adds evidence to former similar experiences, showing that lynx orphan care in the wild represents an additional management approach, with the particularity that it does not require direct animal handling. It may not always be feasible, but may be an alternative to culling when no suitable infrastructure is available (Fig. 7), or an alternative to provisory captivity if the animal's health status seems sufficient. Further experiments of this kind should be carried out to better assess the feasibility and success of such a procedure, which seems very promising compared to other management methods (Table 4).[20,21]

Conclusion

We showed that premature separation from the mother is a major cause of juvenile lynx loss in Switzerland, and that orphaned lynx management is a complex and extensive conservation challenge. We evaluated four management methods: placement in a zoo, culling, rehabilitation after provisory captivity, and feeding in the wild. Given that the majority of the orphans did not survive, the data supported our working hypothesis that lynx orphan rescue attempts in Switzerland have had poor success so far. Nevertheless, releases have largely been hampered by political issues associated with human conflicts, and the few rehabilitations that could occur were successful, which sounds promising. Lessons learned include 1) the imperative need for a pre-established management plan approved by the competent authorities, which defines the rehabilitation goal, includes stakeholder contact data and a list of potential captive settings, sets processes for media outreach, indicates criteria for release, and describes release procedures; 2) the importance of establishing clear stakeholder roles as well as financial and communication directives to favor timely decisions; and 3) in case of provisory captivity, the need for an infrastructure that is respectful of animal welfare and run by competent staff; 4) the value of a careful veterinary assessment at admission (initial triage based on pre-defined criteria) and follow-up with systematic documentation; and 5) the absolute necessity of a committing agreement on a future release. In other words, like for any other wildlife species, lynx rehabilitation should only be carried out in optimal conditions. If the listed conditions are not met, euthanasia or culling seems preferable and ethically justified. Alternatively, taking care of an animal in the wild by providing food until it can survive on its own looks like a promising approach. Relatively simple and inexpensive, this last method deserves to be re-applied and carefully documented in the future. Another useful piece of information generated by this study is that even young orphans before weaning age may accept solid food.

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APPENDIX 1

Medical records Protocol

All orphans were examined under anesthesia following the same protocol. Cubs already in captivity were caught with a hand net before being administered an intramuscular injection of 0.1–0.22 mg/kg medetomidine (Domitor®, 1 mg/ml, Orion-Corporation, Espoo, Finland) followed by 3.14–6.46 mg/kg ketamine hydrochloride (Ketasol®, 100mg/ml, Graeub AG, Bern, Switzerland), which varied from the targeted dosage of 0.1 mg/kg medetomidine and 5 mg/kg ketamine[1] because the weight was estimated.

Wounds were cleaned by curettage and disinfected with a topical antiseptic (povidone-iodine, Betadine®, Mundipharma Medical Company, Basel, Switzerland). When clear signs of infection were present, a subcutaneous injection of antibiotics was administered (mainly long-acting Amoxicillin 15 mg/kg, Betamox®, 150 mg/ml, Norbrook Laboratories Ltd., Carlisle, UK). If the orphan seemed dehydrated, a crystalloid fluid (Ringer's lactate) was given subcutaneously. Blood was sampled by venipuncture in the cephalic vein, and feces were collected from the enclosure ground for parasitic analysis (flotation and Baermann-Trichter method).

Each individual also received an anti-parasitic treatment consisting of a subcutaneous injection of doramectin (Dectomax®, 10 mg/ml, Zoetis, Parsippany, New Jersey, USA, 1 mg/kg) or ivermectin (Ivomec®, 10 mg/ml, Merial, Duluth, Georgia, USA, 1 mg/kg) against nematodes and ectoparasites, and praziquantel (Droncit®, 56.8 mg/ml, Bayer Corporation, Shawnee Mission, Kansas, USA, 5.7 mg/kg) against cestodes and trematodes.

Atipamezole (Antisedan®, 5 mg/ml, Orion Corporation, Espoo, Finland) was given intramuscularly for reversal, according to the given dose of medetomidine.

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APPENDIX 2

Questionnaire survey among zoos and fate in zoos

Questionnaire survey

From October 2008 through August 2009, a questionnaire survey was carried out among the eight zoos that had adopted a rescued lynx orphan from 1981 through 2008, of which seven were located in Switzerland and one in the Czech Republic. The questionnaire was first submitted to KORA collaborators for evaluation, tested with one Swiss zoo and modified as appropriate before being mailed to the other seven zoos. The final version consisted of a mixture of open and closed questions (with the possibility to write additional comments) about group size and composition; enclosure size and configuration; behavior of the individuals towards conspecifics, keepers and visitors; food, feeding method and frequency; health status and health history; undertaken veterinary prophylaxis; and reproduction success. For five of the seven Swiss zoos, the questionnaire was filled on site by conducting interviews of lynx curators. In total, we could gather information on 14/15 orphaned lynx placed in zoos.

Facilities and behavior

In the eight zoos involved in this study, the smallest enclosure covered an area of 40 m^2 whereas the largest one was 75 ha large. At the time of the orphans' introduction, the group size per enclosure varied from one to seven animals, including the orphan. Twice, two orphans were introduced in an enclosure already occupied by an adult couple. Subsequently, group composition changed due to the arrival of additional individuals, transfers to other zoos, or deaths.

Most of the orphans (11/14) showed similar behavior, i.e., they were shy and nervous towards zookeepers and visitors and remained hidden most of the time. Four individuals seemed quite acclimated to human presence; however, they did not approach visitors either.

Fate in zoos

Four orphans died due to aggression by conspecifics (three bite injuries and a fall from a tree during a fight after 8, 83, 110 and 151 days, respectively). All other orphans were successfully integrated into the group. Orphans victim of conspecific aggression were female, aged between 9–18 mo, and introduced into groups of at least three animals in which both sexes were represented in different combinations. In three of these four cases, the deadly conflict involved an adult male; no data were available for the fourth case. These three attacks occurred a few months after the introduction of orphans and around the start of the breeding season. As male lynx become more active and nervous during the early breeding season,[1] these aggressions may have been related to the timing of the introduction. Furthermore, individual behavior may also play an important role in interactions between captive lynx. Intraspecific interactions can be influenced by both intrinsic (individual tolerance to captivity)[2] and extrinsic factors (temperature, time of day, or moon phase).[1]

Four females and one male reproduced during their stay at the zoo. They gave birth to one (n = 2), two (n = 2) and four (n = 1) litters of one to five cubs each. Four females died before reaching sexual maturity. Among the survivors, one female was kept alone, another was housed with a male during seven years but never reproduced, and a third female ("Aisha") escaped from the zoo shortly after her introduction. She was not pregnant at the time but had several litters in the wild. Three orphaned males kept with zoo-born females never reproduced although they reached sexual maturity.

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Juvenile European hedgehogs (*Erinaceus europaeus*) at rescue centers and their release rate depending on their weight on admission

Gabriela Lukesova, Eva Voslarova, Vladimir Vecerek



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Introduction

The European hedgehog (*Erinaceus europaeus*) is one of two hedgehog species occurring in the Czech Republic.[1] Hedgehogs often live in the vicinity of towns and villages as these provide greater protection against predators including badgers and foxes that tend, in contrast, to avoid these places.[2] Hedgehogs also like to use gardens and parks in towns and villages to search for their food,[3] which is comprised mainly of invertebrates. The public is often aware of the fact that hedgehogs occur in their vicinity and that they can support the presence of hedgehogs in their gardens by feeding them, by making gardens accessible, or by playing a part in their protection in other ways. Anthropogenic activity may also harm hedgehogs in the form of mortality on the roads,[4] predation by domestic animals,[5] habitat fragmentation,[6] and possible habitat loss resulting from greater use of land for agricultural purposes.[7] These factors contribute widely to the mortality of individuals, have a negative effect on populations, and pose a threat to many animal species.[8]

Hedgehogs are one of the most frequently admitted mammals in European rescue centers as documented by e.g. Kirkwood[9] in Great Britain and Molina Lopez[10] in Spain. Also, in the Czech Republic, European hedgehogs (most often young) are frequently admitted to rescue centers but only about half of the young can be subsequently released

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ABSTRACT: This study aimed to assess the numbers of juvenile European hedgehogs admitted to rescue centers in the Czech Republic from the viewpoint of weight on admission, the reason for admission, and the success rate of release back into the wild. The results of our study show varying levels of success in the rearing of hedgehogs admitted at different ages (weights) and a varying period required for their rehabilitation. The greatest chance of release was seen in hedgehogs with admission weight of 500–599 g (64.22% released) and 400–499 g (63.31% released). In contrast, the smallest number successfully rehabilitated and released was seen in hoglets weighing 200–299 g (35.24% released) on admission, which corresponds to the weight of hedgehogs at weaning. Time spent at a rescue center may pose an undesirable threat to the lives of animals in some categories. Hedgehogs weighing up to 99 g on admission spent the longest period time at rescue centers (median 48 days), while hedgehogs weighing 500–599 g on admission spent the shortest time (median 7 days). The majority of hedgehogs in the lowest weight categories were admitted due to their inability to survive on their own. A large percentage of hedgehogs of greater weight, in contrast, were juvenile hedgehogs brought to rescue centers needlessly. The percentage of released animals did not exceed 65%, however, even for entirely independent categories of older juveniles. From this perspective, the fact that hedgehogs are often brought to rescue centers in the belief that they are not self-sufficient, though they are actually juvenile or even adult individuals that do not require human care, can be considered a significant finding.

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back into the wild.[11] Similarly, young make up a large proportion of admitted hedgehogs in Great Britain[12] or Portugal.[13] Since European hedgehogs inhabit a large part of Europe, their breeding season may vary in different areas depending on the climatic conditions. The breeding season is also closely associated with the length of hibernation, which also depends on the climate. Hibernation is shorter in warmer areas and the breeding season begins earlier and ends later,[14] meaning that females may have two litters in a single year.[15] In colder areas, in contrast, hibernation is longer and ends later, and just a single litter a year is usual.[16] In some parts of Europe, such as Britain, there is also speculation about the possibility of two litters. Another possibility is that young born later than usual are young from a later replacement litter of a mother that has mated again after losing the young from a previous litter.[17] The mating period differing under different climatic conditions is also confirmed by the fact that female hedgehogs are only receptive to mating when the climatic conditions are suitable[18] as this is associated with a greater chance of survival of the young. The mortality rate is generally high in young hedgehogs. Morris[19] reported mortality of as much as 20% in a litter, resulting primarily from the choice of an unsuitable birth den or the unsuitable timing of birth. Rasmussen et al.[20] reported 70% of hedgehogs surviving their first year of life in residential areas. Hibernation is another critical period in the life of a hedgehog, and preparing properly for the first hibernation is a critical task for young animals. Later-born young may seem to have a lower chance of surviving hibernation due to insufficient weight, though this theory has been refuted by Bunnell.[17] It is, according to this author, possible that young born at a later time of year do not have a lower chance of successful hibernation because they put on weight faster than hedgehog young born earlier. According to Yarnell et al.,[21] even the release of young in the winter does not reduce their chances of survival. The ideal weight given in the studies differs. Jensen,[22] for example, considers a minimum of 513 g the ideal weight before the first hibernation. The determination of age in hedgehogs is complicated by not entirely clear indicators, though certain physical parameters, such as the length of the body, the limbs and the jaw, can be considered suitable parameters.[23]

This study aimed to analyse the number of juvenile European hedgehogs admitted to rescue centers in the Czech Republic in the period 2010 through 2019 and to assess the success of their rearing and release back into the wild, depending on their weight measured on the admission of these juvenile hedgehogs to rescue centers.

Materials and Methods

We obtained data on juvenile European hedgehogs admitted to rescue centers from the database of the Ministry of the Environment, which coordinates the work of rescue centers in the Czech Republic. This database included information on juvenile European hedgehogs admitted to 34 rescue centers falling under the National Network of Rescue Centers of the Czech Republic in the period from 2010 through 2019. The subject of the evaluation was data relating to the numbers of juvenile European hedgehogs admitted, their weight, and the dates on which they were admitted to and left the rescue centers. Since the age of the hoglets admitted to rescue centers was usually unknown, it was only estimated based on some physical indicators by a veterinarian during the admission process. Only data on individuals recorded as hoglets/juvenile hedgehogs were analysed in our study.

For evaluation, the animals were divided into groups by the year in which they were admitted and the month in which they were admitted to rescue centers. The juvenile hedgehogs whose weight at the time of admission to rescue centers was given were divided into groups of animals weighing up to 99 g, 100–199 g, 200–299 g, 300–399 g, 400–499 g, 500–599 g, 600–699 g and 700–799 g. The number of hedgehogs in each weight category that was released back into the wild and the length of time they spent at the rescue center was calculated in the individual weight categories. Evaluation of the length of time spent at rescue centers dependent on weight was performed only for those individuals for which weight on admission, date of admission to the rescue center, and date on which their stay at the rescue center came to an end were stated. The median length of stay for the individual weight categories was calculated from these data. The maximum, minimum, median, and average period spent in days was also determined in individual weight categories for hedgehogs that were released back into the wild following their stay at the rescue center. The percentage of hedgehogs taken to rescue centers because they needed human care due to being orphaned, due to starvation, or having been late-born young, due to injuries (caused by dogs, cats, other animals, cars, or garden equipment), infections or parasites, falls into pits, and hedgehogs captured needlessly (as determined by a veterinarian) or for other reasons (entanglement, intrusion, or unknown reasons) were also studied in the individual weight categories.

The data were evaluated in the statistical program UNISTAT 6.5 for Excel (Unistat Ltd., London, UK). Spearman's coefficient, according to which a rank correlation coefficient was determined, was used to assess development in the number of juvenile European hedgehogs admitted by year and to determine the relationship between the period spent at rescue centers and the weight category. A Fisher exact test using the 2×2 contingency table methodology was used for the statistical evaluation of differences in frequencies among groups of hedgehogs admitted in different months and the frequencies among groups of hedgehogs according to their weight. Kruskal-Wallis ANOVA (and multiple comparisons for t-distribution) was used for evaluation of the period spent at rescue centers for individual weight categories. A value of $p < 0.05$ was determined as statistically significant in all tests used.

Results

A total of 12,514 juvenile European hedgehogs were admitted to 34 rescue centers in the Czech Republic in the period from 2010 through 2019. The number admitted in individual years is depicted in Fig. 1. An increase is evident in the figure in the years 2014 through 2018 in particular. A rising trend in the number of

juvenile European hedgehogs admitted to rescue centers in the Czech Republic in the studied period was found (rSp = 0.8667, $p < 0.05$), despite a slight decline in 2019.

Table 1 shows the number and percentage of juvenile European hedgehogs by the month in which they were admitted.

The largest numbers of juvenile European hedgehogs were admitted to rescue centers in the autumn in September (27.88%) and October (24.49%). The months with the lowest number of admissions were March (0.34%), April (0.51%) and February (0.66%), i.e. the end of winter.

Data on weight on admission were available for 5,304 juvenile European hedgehogs admitted to rescue centers, making it possible to analyse the effect of weight on the release rate and the length of time spent at rescue centers. Table 2 shows the number of juvenile European hedgehogs admitted to rescue centers in the Czech Republic in individual weight categories (for those hedgehogs whose weight was known) and the proportion of those released back into the wild in the studied period of 2010 to 2019. Overall, around a half of the juveniles admitted could be subsequently released (49.38%), with the highest release rate seen in the categories of hedgehogs weighing 400–499 g (63.31%) and 500–599 g (64.22%) and the lowest release rate in hedgehogs weighing 200–299 g on admission to rescue centers (35.24%).

The length of stay at the rescue center before release was also evaluated depending on the weight in 2,619 juveniles with known weight at the time of admission (Fig. 2).

Juvenile European hedgehogs weighing 400 g and more spent a statistically significantly shorter period at rescue centers than juveniles in lower weight categories. The longest period was spent at rescue centers by young animals weighing up to 99 g (median 48 days) before they could be released. A decreasing trend (rSp = -0.4738, $p < 0.001$) was found in the number of days spent at the rescue center with the increasing weight of young.

Table 3 shows the average, median, the minimum and maximum length of time spent at rescue centers in individual weight categories.

While the minimum number of days spent at rescue centers is the same in all categories, the longest stay on average was seen in hedgehogs in lower weight categories (up to 99 g and 100–199 g).

Table 4 depicts categories of hedgehogs by weight and the percentage of juveniles admitted to rescue centers needlessly and juveniles truly requiring human care. The results indicate that the majority of hedgehogs in the lowest weight categories were admitted for reasons that truly demanded human care for their survival, while the proportion of hedgehogs taken to rescue centers needlessly increased with their increasing weight.

Discussion

The number of European hedgehogs admitted to rescue centers has been increasing over the last ten years[11] and a similar trend can also be seen in many other animal species.[24-27] Various studies have also found an extremely high rate of admission of young animals to rescue centers.[28,29] This fact may be explained

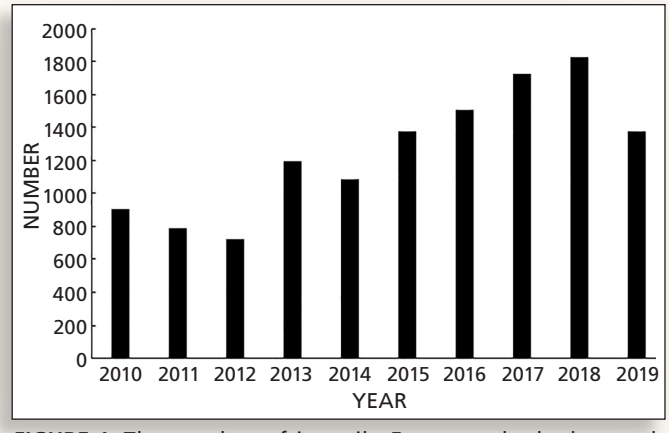


FIGURE 1. The number of juvenile European hedgehogs admitted to rescue centers in the Czech Republic in the period from 2010 through 2019. https://doi.org/10.1371/journal.pone.0258273.g001

TABLE 1. Number and percentage of the total number of juvenile European hedgehogs admitted to rescue centers by individual months in the period from 2010 through 2019. https://doi.org/10.1371/journal.pone.0258273.t001

	ADMITTED HOGLETS (N = 12,514)	
MONTH	NUMBER	%
January	189	1.51[h]
February	82	0.66[i]
March	43	0.34[e]
April	64	0.51[e,i]
May	120	0.96[d]
June	293	2.34[f]
July	379	3.03[g]
August	1,863	14.89[k]
September	3,489	27.88[a]
October	3,065	24.49[b]
November	2,043	16.33[c]
December	884	7.06i

[a–k]The values with different superscript letters in a column are significantly ($p < 0.05$) different (Fisher's exact test).

TABLE 2. Number of juvenile European hedgehogs admitted to rescue centers depending on weight and release rate.

WEIGHT (g)	NO. OF ADMITTED	NO. OF RELEASED	% OF RELEASED
up to 99	598[t]	291	46.88[a]
100–199	1,564[u]	886	56.44[b]
200–299	1,155[v]	407	35.24[c]
300–399	1,017[w]	465	45.72[d]
400–499	477[x]	302	63.31[e]
500–599	204[y]	131	64.22[f]
600–699	149[z]	85	57.05[g]
700–799	140[z]	52	37.14[g]
Total	**5,304**	**2,619**	**49.38**

[a-g]The values with different superscript letters in a column (% of released) are significantly ($p < 0.05$) different (Fisher's exact test).
[t-z]The values with different superscript letters in a column (no. of admitted) are significantly ($p < 0.05$) different (Fisher's exact test).

in several ways. Increasingly intensive anthropogenic impact on the natural world and on changing the landscape and its use by animals may play a part in the increasing number of animals admitted.[30] Another aspect may be the fact that the public is now better acquainted with the issue of permanently disabled animals and is making greater efforts to help these animals. Unfortunately, these efforts sometimes have the opposite effect in the case of animals, and young animals, in particular, being taken needlessly from their natural habitat.[11]

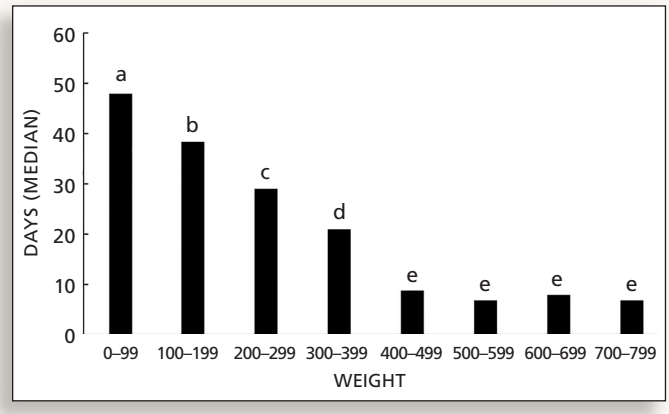


FIG 2. Median of time for individual weight categories of juvenile European hedgehogs released from rescue centers in the Czech Republic back into the wild in the period from 2010 to 2019. *a–e different letters indicate a statistically significant ($p < 0.05$) difference (Kruskal-Wallis ANOVA).

TABLE 3. Minimum, maximum, median, and average length of stay (days) of juvenile European hedgehogs released from rescue centers in the period from 2010 to 2019.

	LENGTH OF STAY (DAYS)			
WEIGHT(g)	MINIMUM	MAXIMUM	AVERAGE	MEDIAN
up to 99	1.0	236	60.78	48.0
100–199	1.0	232	53.39	38.5
200–299	1.0	239	43.26	29.0
300–399	1.0	192	35.53	21.0
400–499	1.0	210	24.01	9.0
500–599	1.0	195	19.09	7.0
600–699	1.0	175	23.90	8.0
700–799	1.0	372	27.28	7.0

Our results show that the largest numbers of juvenile hedgehogs were admitted to rescue centers in the Czech Republic in the autumn months, i.e. at the time they are preparing for hibernation. Hedgehogs lose body weight during hibernation[31] and low body weight before hibernation begins may result in the death of a hedgehog due to insufficient energy reserves needed to survive this period. The public might be aware of this risk but the average member of the public can hardly distinguish between juveniles and adult hedgehogs, and concerns about hedgehogs found in the autumn may lead to their being taken to rescue centers even if they do not need human care. In contrast, the lowest number of hedgehogs admitted in our study was seen in the period from February to April. In the winter and spring months, these may be individuals found out in the open during cold weather. This occurs rarely, however, as hedgehogs are still hibernating in the winter months and at the beginning of spring when temperatures are not suitable for them[32] and they appear only very rarely in gardens and other open spaces.[21,33] Young hedgehogs admitted to rescue centers in the spring months, i.e. at the time when hibernation is coming to an end, may be animals born in the year in question, although because of their reproductive strategy and the birth of young this tends to occur later in the spring when conditions are more suitable for reproduction.[18]

Rescue centers endeavour to release admitted animals back into the wild as soon as possible, i.e. as soon as this is possible from the viewpoint of the condition of the animal and the environmental conditions. The length of stay at the rescue center generally corresponds to the period required for convalescence and the attainment of optimal condition for release. Young animals up to 99 g in weight spent the longest period at rescue centers in the Czech Republic (median 48 d) during the monitored period even though the success rate from the viewpoint of their release

TABLE 4. Percentage of hoglets unnecessarily brought and those requiring human care admitted and subsequently released from the rescue centers depending on weight.

	REASON FOR ADMISSION					
WEIGHT(g)	NO APPARENT REASON (%)	ORPHANED, EXHAUSTED OR LATE-BORN (%)	INJURIES (%)	INFECTION, PARASITES (%)	FALL INTO PITS, ETC (%)	OTHER (%)
up to 99	1.72	92.76	4.14	0.00	1.38	0.00
100–199	1.84	92.18	4.02	0.23	1.49	0.23
200–299	6.09	82.23	2.03	0.51	2.03	7.11
300–399	7.28	73.51	1.77	1.32	4.86	11.26
400–499	27.21	49.12	6.36	1.77	4.24	11.31
500–599	35.45	39.09	2.73	4.55	1.82	16.36
600–699	28.57	19.48	14.29	7.79	10.39	19.48
700–799	32.60	8.70	19.57	6.52	6.52	26.09

was not high (just 48.66% of young in this weight category were subsequently released). In contrast, of all the categories the release rate was highest (64.22%) in hedgehogs weighing 500–599 g, which also spent the shortest period at rescue centers (median 7 d). The results indicate that weight and condition on admission have a greater influence on survival and the ability to return to the wild in juvenile European hedgehogs than the length of time spent at the rescue center and the care provided. This corresponds to the fact that the majority of young weighing up to 99 g (98.28%) were brought to rescue centers because they were truly abandoned, malnourished, or otherwise handicapped (injured, diseased, etc.). In contrast, a life-threatening handicap was found in only 64.55% of hedgehogs weighing 500–599 g when admitted to rescue centers, while 35.45% of young in this weight category were taken to rescue centers needlessly. These animals did not require any care and could be returned to the wild in a short time. As the percentage of the released young animals in this category shows, however, a large number of those that needed care were also successfully treated and prepared for release. In the smallest hedgehogs, in contrast, the attempt to save and raise them often failed and a higher mortality rate was recorded in this category. Care for these young animals at rescue centers consists primarily of providing suitable conditions and correct nutrition and minimising stress. Stress, in particular, can have a negative effect on the possibilities for the convalescence and rearing of young and their release back into the wild, as it has a great effect on processes in the organism and its resilience.[34] It is not always particularly easy to raise young on a milk diet properly given the quality of milk, and this is a problem in many animal species.[35] The young may also be non-viable from birth in some way, for which reason they have been abandoned by their mother.[36] Another reason for the differing success rates in the rearing of young hedgehogs at rescue centers may be the greater resilience of older young to the stress to which they are exposed at rescue centers in the proximity of humans or their ability to survive hibernation at rescue centers.

It is difficult to tell with any certainty whether juvenile European hedgehogs are young from the first or second litter of the given year because of the difficulty of determining their age, and it is, therefore, hard to estimate what chance a given individual has of successful rearing or survival at a rescue center. Pregnancy in female European hedgehogs lasts an average of 35 days, with the first litter born in May or June and any second litter in August or September,[37] though these dates are of only limited applicability and there is also always the possibility of a delayed first litter in the case of a female who has lost her first young. Several other factors may also have an effect on the weight of hedgehogs during the year, such as the period after hibernation and mating.[38] The weight categories in this study reflect the age of the hedgehogs to a certain extent. According to Haigh et al.,[23] a correlation exists between weight and other parameters according to which the approximate age of a hedgehog may be determined. Deanesley[39] reported the onset of puberty in female hedgehogs at a weight of around 400 g, and this weight category can be considered the period of adolescence. Mullineaux[40] based a division into age categories according to certain parameters such as the state of the teeth and the appearance of the spines and also reported the weights typical of these age categories. According to that, young are born at a weight of 12–20 g and attain a weight of 100 g at the age of 3 weeks and a weight of 200 g at the time of weaning which is around the 5th or 6th week of life. According to this division, the category of hedgehogs weighing up to 99 g would be young that have so far been on a milk diet, while hedgehogs weighing 100–199 g would be hedgehogs at the time of weaning and the transition to solid food and an independent way of life. Hedgehogs weighing around 400 g are adolescent individuals, while those weighing 600–800 g are young adult individuals. According to Kristiansson,[41] the availability of food and environmental factors have a greater influence than age as far as the mortality rate in young hedgehogs in the wild is concerned. According to our results, however, weight is a fundamental factor influencing the success of care for juvenile hedgehogs at rescue centers. Juveniles up to the weight of 200 g, i.e. young on a milk diet and at the time of weaning, demand specific care that rescue centers are often incapable of providing, in contrast to adolescent and adult hedgehogs.

The length of stay at rescue centers differed in the individual weight categories, with the longest period (median of d) seen in the youngest weight categories, which reflects the fact that these young require longer care until they are capable of looking after themselves and being released into the wild. We attribute the minimum length of stay of one day primarily to cases in which young were admitted to rescue centers needlessly with no evident health problem and were subsequently released back into the wild, or re-joined with their mother in the case of unweaned young, after being examined by rescue center staff. They may also have been animals from nests threatened by destruction, for example. Such cases occurred in all weight categories. The average length of time spent at rescue centers differed significantly depending on their weight at the time of admission in those hedgehogs that stayed for longer periods. Differences were also found in the percentage of hedgehogs released in individual weight categories. The lowest success rate from the viewpoint of the percentage of animals released (35.24%) was, surprisingly, found in the category of young admitted at a weight of 200–299 g, i.e. probably at the time of weaning. These young should no longer be so dependent on human care, and their nutrition in captivity is not as demanding as it is in young on a milk diet for which the percentage of animals released was, however, significantly higher (56.44%). This result may confirm the assumption that the weaning period is a critical time for wild animals, and even human care need not help individuals survive this period, while certain other circumstances such as the death of the mother and premature weaning may reduce the chance of survival of these young still further.[42] Moreover, young animals admitted in an impaired state of health predominated significantly in this weight category. However, even in the 700–799 g category, only 37.14% of hedgehogs were

released. Most of these hedgehogs (67.40%) were admitted due to injuries, infections, exhaustion, or falls into pits, thus the low release rate in this category may result from the consequences of their impaired health rather than the fact that almost adult animals could not take care of themselves. Overall, it can be said that the number of releases was higher in hedgehogs of greater weight on admission, though the differences were not as high as might have been expected. Overall, it proved possible to release less than a half of the juvenile hedgehogs and the proportion of animals released did not exceed 65% even in hedgehogs whose weight indicated adolescent or almost adult animals.



PHOTO © CALLE EKLUND/V-WOLF, CC 2.0 LICENSE.

An urban mother European hedgehog and her young in Avesta, Sweden.

From the viewpoint of evaluating the success of the work of rescue centers, it is important not merely how many admitted animals can be released back into the wild, but also how many of them then survive in the wild and are capable of reproducing, i.e. actually contributing to maintaining the population of the given species. Preparing them for life in the wild is no less important from this perspective since young animals brought to rescue centers during the first days of life will not necessarily be capable of looking after themselves in the future. Selecting the ideal release site is the final step in the survival of reared young, though the most important. There have been a few studies devoted to survival rates in animals following release from rescue centers. The survival of hedgehogs released from rescue centers seems to be relatively high,[43] even in the case of hedgehogs released during the hibernation period.[20] Rasmussen et al.[20] found 59% of females and 79% of males surviving their first hibernation in Denmark. Similar results were reported by Kristiansson[41] in Sweden. The mortality of hedgehogs during or after hibernation in the wild is more often a result of factors connected with human activity (e.g. mortality on the roads) and predation, rather than an inability to look after themselves.[33,44] Rautio et al.[45] also reported road mortality as the most common cause of hedgehog mortality in the wild in Finland. The time spent at a rescue center may be beneficial for injured or diseased hedgehogs.[46] Natural patterns of behaviour need to be preserved in juvenile European hedgehogs reared at rescue centers although the time spent in the rescue center does not appear to have a negative impact on natural patterns of behaviour.[21] The time of release also plays a role in addition to the site of release, though it is thought that releasing hedgehogs in the autumn or spring poses no problem. Still, the period following hibernation is risky.[21] In addition to the possibilities for rearing juvenile European hedgehogs and the factors that reduce or increase mortality in the lowest weight categories, further research must also be devoted to maximising their survival in the wild following their release from rescue centers.

Conclusion

Juvenile European hedgehogs are often admitted to rescue centers and their survival may depend on many factors preceding their admission as well as on the care given at the rescue center. The results of our study indicate differing success rates in the rearing of hedgehogs admitted at various ages (weights) and differing periods required for their rehabilitation. Rearing the youngest categories appears to be particularly problematic with the lowest release rate (35.24%) found in hedgehogs weighing 200–299 g on admission to rescue centers. However, the release rate was not much higher even in the heavier categories. From this perspective, the finding that hedgehogs that are thought to be young and not yet independent, though they are in reality adolescent or adult individuals that do not require human care, are often brought to rescue centers is also alarming. Members of the public who want to provide help to animals often cannot correctly identify hedgehogs that truly require human care. The results of this and other studies indicate that even animals brought to rescue centers healthy and in good condition need not necessarily cope with conditions in captivity, for which reason it is essential to eliminate such cases of wild animals being brought to rescue centers unnecessarily as much as possible.

Author Contributions

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Competing Interests

The authors have declared that no competing interests exist.

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Surviving the wildlife trade in Southeast Asia: reforming the "disposal" of confiscated live animals under CITES

SN Rivera, A Knight, and SP McCulloch. *Animals,* 2021;11(2):439. https://doi.org/10.3390/ani11020439.

Increased focus on the illegal global wildlife trade has resulted in greater numbers of live animals confiscated by authorities, increasing the need to manage these animals responsibly. Most wildlife seizures take place in Southeast Asia, with global demand for live animals fuelling much of the trafficking. Guidelines for the "disposal" of live specimens are provided by the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), although individual Parties must implement provisions through national laws and regulations. "Disposal" is the term used for the management of illegally traded wildlife upon confiscation. Confiscated live animals can be euthanised (i.e., killed), repatriated to their native country and released, or kept in captivity. This study investigates barriers to proper care and disposal of confiscated live animals in Southeast Asia, where roughly one quarter of the global multibillion dollar illegal wildlife trade takes place. Interviews were conducted with 18 professionals working within conservation, wildlife crime, and confiscated live animal management. Eight limitations to the proper care and disposal of confiscated wildlife were identified: (1) political will, (2) policy, (3) funding, (4) capacity, (5) expertise, (6) attitudes and behaviours, (7) exploitation, and (8) corruption. Based on interviews, we propose seven key reforms to support the efficient and humane management of illegally traded wildlife for national authorities and CITES parties. These are wildlife seizure management, legislative support, enhanced political will, demand reduction, global participation, registry of rescue centres, and terminology change. This research highlights major barriers to the proper care and disposal of live confiscated animals and proposes key reforms to improve the conservation of threatened species and the welfare of millions of illegally traded animals.

Population-level effects of wildlife rehabilitation and release vary with life-history strategy

JE Paterson, S Carstairs, CM Davy. *J Nature Conservation*, 2021;61:125983. ISSN 1617–1381. https://doi.org/10.1016/j.jnc.2021.125983. https://www.sciencedirect.com/science/article/pii/S1617138121000303.

Wildlife rehabilitation is the treatment and subsequent release of injured wildlife. Wildlife rehabilitation benefits individual animals receiving care, but also supports Conservation Medicine approaches by providing opportunities to monitor wildlife health, contaminant loads, and disease prevalence. However, it is typically considered to have negligible effects on population growth, and has not traditionally been acknowledged as an effective tool for wildlife conservation. To explore whether rehabilitation and release could directly support population recovery in some cases (i.e., increase population growth rates), we considered five case study species along a spectrum of life-history strategies (raccoon, painted turtle, Blanding's turtle, snapping turtle, and little brown bat). We simulated populations over 200 years, while varying two parameters: 1) the rate of severe injury (0, 1, 2, or 5% of the population); and 2) how many of these injured animals are successfully rehabilitated (0, 10, 25, or 50%). The effect of the rehabilitation scenarios was largest when additive severe injury rates were highest (5%). Species that were most sensitive to increased adult injury rates (turtles and bats) also exhibited the greatest population-level responses to rehabilitation and release interventions. We conclude that wildlife rehabilitation can support in situ recovery and help stabilize declining populations when 1) injury is an ongoing source of high additive mortality, 2) the target population is small, 3) the species exhibits a K-selected life-history strategy, 4) rehabilitation can be combined with other interventions, including in situ threat mitigations, and 5) rehabilitation efforts do not jeopardize or limit in situ conservation interventions.

Early detection of wildlife morbidity and mortality through an event-based surveillance system

TR Kelly, PS Pandit, N Carion, DF Dombrowski, KH Rogers, SC McMillin, DL Clifford, A Riberi, MH Ziccardi, EL Donnelly-Greenan. *Proceedings of the Royal Society B*, 14 July 2021;288:1954. https://doi.org/10.1098/rspb.2021.0974

The ability to rapidly detect and respond to wildlife morbidity and mortality events is critical for reducing threats to wildlife populations. Surveillance systems that use pre-diagnostic clinical data can contribute to the early detection of wildlife morbidities caused by a multitude of threats, including disease and anthropogenic disturbances. Here, we demonstrate proof of concept for use of a wildlife disease surveillance system, the "Wildlife Morbidity and Mortality Event Alert System," that integrates pre-diagnostic clinical data in near real-time from a network of wildlife rehabilitation organizations, for early and enhanced detection of unusual wildlife morbidity and mortality events. The system classifies clinical pre-diagnostic data into relevant clinical classifications based on a natural language processing algorithm, generating alerts when more than the expected number of cases is recorded across the rehabilitation network. We demonstrated the effectiveness and efficiency of the system in alerting to events associated with both common and emerging diseases. Tapping into this readily available unconventional general surveillance data stream offers added value to existing wildlife disease surveillance programmes through a relatively efficient, low-cost strategy for the early detection of threats. ■

TAIL ENDS



Hold up, y'all. I think Chester saw a chicken again.

Common mallards

Anas platyrhynchos

PHOTO ©MAUREEN BARLIN. CC BY-SA 2.0.

INSTRUCTIONS FOR AUTHORS

POLICY Original manuscripts on a variety of wildlife rehabilitation topics (e.g., husbandry and veterinary medicine) are welcomed. Manuscripts that address related topics such as facility administration, public relations, law, and education are invited as well.

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Include an abstract that does not exceed 175 words and choose several (up to 14) key words.

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A black kite (*Milvus migrans*), one of many surveying the Indian cityscape below. The raptors are featured in "All That Breathes," the award-winning documentary on the challenges they face coexisting with humans in New Delhi, and the brothers who stepped up to meet those challenges.

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