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Raptor morbidity, mortality, and post-release survival tracking: rehabilitation outcomes from a wildlife rehabilitation centre in Cyprus

Chorobnosť, úmrtnosť a sledovanie prežívania dravých vtákov po vypustení: výsledky rehabilitácie z centra pre rehabilitáciu voľne žijúcich živočíchov na Cypre

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Abstract: Raptors as apex predators hold an ecologically important position in biological food webs and historically have faced numerous challenges. Wildlife rehabilitation centres provide an opportunity to understand the regional threats to local raptors. This study details the admissions and recoveries of wild raptors admitted to the Wildlife Rescue and Rehabilitation Center in Northern Cyprus between 2016 and 2022. A total of 1,101 raptors were admitted, comprising 22 species and three families, with a mean rehabilitation success rate of 42.6%. The most common species admitted were common kestrels (*Falco tinnunculus*) (44.1%), little owls (*Athene noctua*) (22.8%), and western barn owls (*Tyto alba*) (11.6%). The prevalent causes of admission were trauma (unknown) (27.2%), orphaned/abandoned (22.6%), and collision (11.9%). Post-release survival rates averaged 368 days ± 407 SD (median = 183, range 2 –1,177). Six birds [four long-legged buzzards (*Buteo rufinus*), one European honey buzzard (*Pernis apivorus*) and one northern goshawk (*Astur gentilis*)] were GPS tracked following recovery, and their average survival time was 319 days ± 334 SD (median =184, range 18–847, and one still transmitting). Additionally, one Bonelli's eagle (*Aquila fasciata*) and four long-legged buzzards were fitted with either a tail-mounted or leg-mounted VHF radio transmitter, which were less successful, with only the Bonelli's eagle being tracked away from its release site. Post-release survival indicates that the release assessment of individuals is professionally managed, while the rehabilitation success rates demonstrate that the centre is delivering effective treatment and care.

Abstrakt: Dravé vtáky ako vrcholoví predátori zaujímajú ekologicky dôležité miesto v biologických potravných reťazcoch a historicky boli vystavené mnohým výzvam. Centrá na rehabilitáciu voľne žijúcich živočíchov poskytujú príležitosť pochopiť regionálne hrozby pre miestne dravé vtáky. Táto štúdia podrobne opisuje prijatia a zotavenia voľne žijúcich dravých vtákov prijatých do Centra na záchranu a rehabilitáciu voľne žijúcich živočíchov na Severnom Cypre v rokoch 2016 až 2022. Celkovo bolo prijatých 1101 dravých vtákov, zahŕňajúcich 22 druhov a tri čeľade, s priemernou úspešnosťou rehabilitácie 42,6 %. Najčastejšie prijatými druhmi boli sokol myšiar (*Falco tinnunculus*) (44,1 %), kuvik obyčajný (*Athene noctua*) (22,8 %) a plamienka driemavá (*Tyto alba*) (11,6 %). Najčastejšími dôvodmi prijatia boli úrazy (neznáme) (27,2 %), osirelosť/opustenie (22,6 %) a kolízia (11,9 %). Miera prežitia po vypustení bola v priemere 368 dní ± 407 SD (medián = 183, rozsah 2–1177). Šesť vtákov [štyri myšiaky hrdzavé (*Buteo rufinus*), jeden včelár lesný (*Pernis apivorus*) a jeden jastrab veľký (*Astur gentilis*)] bolo po zotavení sledovaných pomocou GPS vysielača a ich priemerná doba prežitia bola 319 dní ± 334 SD (medián = 184, rozsah 18–847, jeden stále vysiela). Okrem toho bol jeden orol jastrabovitý (*Aquila fasciata*) a štyri myšiaky hrdzavé vybavené VHF rádiovým vysielačom umiestneným na chvoste alebo na nohe, čo bolo menej úspešné, keďže iba orol jastrabovitý bol sledovaný mimo miesta svojho vypúšťania. Prežívanie po vypúšťaní naznačuje, že hodnotenie vypúšťania je realizované profesionálne, zatiaľ čo úspešnosť rehabilitácie demonštruje, že centrum poskytuje účinnú liečbu a starostlivosť.

Key words: birds of prey, recovery rates, satellite and radio tracking, Accipitriformes, Falconiformes, Strigiformes, survival rates

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Introduction

As apex predators, raptors hold an important ecological position and are often used as flagship species to highlight environmental issues (Donázar et al. 2016). Historically, raptors have experienced numerous threats, ranging from direct persecution to indirect effects such as habitat destruction or chemical contamination (O'Bryan et al. 2022). As providers of critical ecosystem services, their position as apex predators means they suffer from biomagnification of pollutants such as polychlorinated biphenyls (PCBs), pesticides (such as insecticides and rodenticides), Diclofen (medication), and heavy metals (like lead and mercury) (Opdam et al. 1986; Green et al. 2004, González-Rubio et al. 2021). This was most notably highlighted by the decline of some raptor populations due to eggshell thinning caused by dichloro-diphenyl-trichloroethane (DDT) exposure (Rodríguez-Jorquera et al. 2017, Kuo et al. 2022). Electrocution and collisions with energy infrastructure, including wind turbines, have also emerged as lethal hazards for migratory raptors (Kouba et al. 2021, Oppel et al. 2021). Concerted international efforts have been made to protect important sites for migratory raptors, recognising over 7,500 as crucial for their conservation (Birdlife Annual Review 2023). Despite these efforts, the conservation status of many raptor species continues to deteriorate, highlighting the urgent need for increased protection measures and awareness to ensure the survival of raptors and the biodiversity they support.

According to recent estimates, 52% of raptors are in decline and 18% threatened with extinction (McClure et al. 2018). Numerous raptor species have recovered from historical population declines through direct conservation initiatives, including reintroductions, habitat restoration, and legislative changes (Jones et al. 1995, Cruz et al. 2018, Nygård et al. 2019). However, many raptor populations are still in decline, which is concerning given the vital role raptors play in ecosystem services and functioning (McClure et al. 2018). Such population declines can result in top-down trophic cascades, leading to increases in mesopredators and meso-scavengers (Ritchie & Johnson 2009). The consequences of which can lead to population explosions of pest species or epidemiological imbalances of disease reservoir hosts (Prugh et al. 2009, Muñoz-Pedreros et al. 2016).

In Cyprus, 46 species of raptors have been reported, 13 of which have not been seen in 20 years or can be classed as vagrant species (Flint & Richardson 2024). Twelve of these species are current regular residents or migrant breeders, with the remaining being passage migrants or winter visitors (Flint & Richardson 2024). Three breeding raptor species in Cyprus have become locally extinct, with 3–4 species having population levels which could be classified as precarious (low number of breeding pairs) due to a range of human-induced threats such as habitat loss through urbanisation and agricultural expansion (Flint 2019). Illegal poisoning, often aimed at controlling predator populations for livestock protection, has inadvertently led to a decline in raptor numbers, with non-target species like the griffon vulture (*Gyps fulvus*) and Bonelli's eagle (*Aquila fasciata*) falling victim (Tsiakiris et al. 2021). Trapping and shooting also significantly impact many raptor species (Brochet et al. 2016).

During the early 20th century, individuals began to take and rehabilitate injured and distressed wild animals. These pioneers operated out of their homes, often with makeshift facilities, relying on their instincts and compassion to care and rehabilitate these creatures before returning them to the wild (Williamson 2013). Over the last 50 years, there have been advances in the treatment, housing, rehabilitation and release protocols in the field of wildlife rehabilitation, with the formation of dedicated wildlife rehabilitation programs across the globe, including facilities specialising on specific animal groups (Paterson et al. 2021). One such animal group is birds of prey, or raptors, with resources targeted at their treatment and welfare (including humane euthanasia).

Despite advances in rehabilitation practices, survival outcomes for released raptors remain difficult to assess, underscoring the need for comprehensive post-release evaluation. Rehabilitation facilities often use metal rings to identify released birds, including raptors, but these generally have low recapture rates (Bildstein & Peterjohn 2012, Lutmerding et al. 2012). Radio-tracking enables researchers to monitor released individuals periodically; however, it faces challenges in range, topography and workforce. Satellite tracking, which offers near real-time location and movement data, is potentially the most effective method for tracking raptors. However, it can be the costliest, which makes it prohibitive to many centres and generally results in small sample sizes.

This study reports admission causes and the final outcomes of all raptors admitted to Cyprus's Wildlife Rescue and Rehabilitation Center (WRRC). Also documented are the recapture events of previously treated and released raptors (2016–2022), including their post-release survival and movements, through ringing, satellite and radio tracking methods.

Materials and Methods

WRRC was established in July 2016 and now falls under the umbrella organisation, the Cyprus Wildlife Research Institute (CWRI). It is located approximately 10 km north of Nicosia. WRRC staff rescue and treat any sick, injured, or orphaned wild animal, aiming to return them to the wild. A new admission number is assigned if a patient undergoes subsequent readmissions; however, these admissions are cross-referenced with prior records for continuity and accuracy. Additionally, it has become a sanctuary for any confiscated animal illegally imported or kept in captivity.

This study includes all raptors admitted to the centre from 2016 to 2022. Raptors were collected by the centre team, delivered by the public, or confiscated by government officials. A trained wildlife biologist or veterinarian examined all raptor admissions to determine an animal's condition and whether any specialist interventions were required. All raptors that were successfully rehabilitated were fitted with a metal leg ring and released close to where they were collected (if known) following morphometric measurements, ageing and sexing (if possible). Migratory species that missed their migration window were kept until the next available migration season. Individuals who survived but were not releasable were placed in a purpose-built sanctuary complex.

One Bonelli's eagle and four long-legged buzzards (*Buteo rufinus*) were fitted with a tail-mounted or leg-mounted VHF radio transmitter (Biotrack Inc., UK; model TW-3-10-28). After that, they were tracked daily using a hand-held receiver and binoculars (x10). However, given the poor results and limited workforce, it was decided to use GPS tracking technology to track rehabilitated raptors instead.

Six released raptors [four long-legged buzzards, one northern goshawk (*Astur gentilis*), and one European honey buzzard (*Pernis apivorus*)] were fitted with solar-powered GPS-GPRS telemetry transmitters (Manufacturer – Ornitela, Lithuania, Models OrniTrack-20-4G, OrniTrack-25-4G, OrniTrack-30-4G) which possess GPS modules for receiving GPS data and transmitting via the 4G cellular system. Transmitters were fitted to the six raptors using a permanent 5-mm-wide Teflon tape backpack wing harness described by Thaxter et al. (2014). Individual devices' data recording and duty cycles were optimised according to solar irradiance capture and battery charging levels. Location data was downloaded as "csv." files and filtered to optimise figure presentations, with at least the first location for each day shown. When the data was required to highlight a specific incident or behaviour, that specific data was left unfiltered. When location data did not show individual movement for 24–48 hours, the location was visited (only possible for locations in Cyprus) to determine the reason and retrieve any carcasses for necropsy. Device failure was determined if the device suddenly stopped providing location data for no logical reason (i.e., previous adequate battery levels, location altitude/travel speed). All map figures were constructed using ArcGIS Pro version 3.5 (Esri, USA).

Results

Species admissions

A total of 1,101 raptors were admitted between 2016 and 2022, comprising 22 species from 3 families (Table 1). The three most common raptor species admitted were common kestrels (*Falco tinnunculus*) 44.1%, little owls (*Athene noctua*) 22.8% and western barn owls (*Tyto alba*) 11.6%, accounting for 78.6% of all raptor admissions. Eleven of the twelve regular resident or migrant breeding species (except the griffon vulture) have also been admitted to the centre.

Reason for admission

The three most common reasons for admission were trauma (unknown cause) 27.2%, orphaned/abandoned 22.6%, and collisions (car, building, or other) 11.9%

Tab. 1. Total counts of admission reasons and outcomes for all raptor species admitted to the Wildlife Rescue and Rehabilitation Center between 2016 and 2022. Overall percentages for each admission reason and outcome are also provided.
Tab. 1. Celkový počet dôvodov prijatia a výsledky všetkých druhov dravých vtákov prijatých do Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov v rokoch 2016 až 2022. Uvedené sú aj celkové percentuálne podiely pre každý dôvod prijatia a výsledok.

	Admission Reasons													Final Outcomes				
Species	**Collisions**	**Dog/Cat Predation**	**Gunshot**	**Trapped/ Relocation**	**Captivity**	**Born in Centre**	**Orphaned/ Abandoned**	**Infectious Disease**	**Nutritional**	**Toxicosis**	**Neurological**	**Unknown Trauma**	**Undetermined/ Other**	**Released**	**Sanctuary**	**Died / Euthanised**	**Total Admissions**	**Success Rate %**
barn owl (*Tyto alba*)	27	1	2	17	1	1	19	10	4	1	0	32	13	43	12	73	128	33.6
black kite (*Milvus migrans*)	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	100
Bonelli's eagle (*Aquila fasciata*)	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	2	50
common buzzard (*Buteo buteo*)	1	0	7	1	2	0	0	1	1	1	0	4	3	6	5	10	21	28.6
common kestrel (*Falco tinnunculus*)	40	3	16	16	48	5	138	35	12	1	2	136	34	240	35	211	486	49.4
Cyprus scops-owl (*Otus cyprius*)	3	2	0	3	0	0	5	0	0	1	0	10	3	9	2	16	27	33.3
Eleonora's falcon (*Falco eleonorae*)	0	0	0	0	0	0	0	0	2	0	0	1	0	1	0	2	3	33.3
Eurasian hobby (*Falco subbuteo*)	0	0	1	0	0	0	0	2	2	0	0	5	0	3	2	5	10	30
Eurasian sparrowhawk (*Accipiter nisus*)	4	0	8	2	0	0	0	0	0	0	1	12	1	3	3	22	28	10.7
European honey-buzzard (*Pernis apivorus*)	1	0	2	0	2	0	0	2	0	0	0	7	1	2	1	19	15	13.3
hen harrier (*Circus cyaneus*)	1	0	10	0	1	0	0	0	0	0	0	10	0	9	1	5	22	40.9
little owl (*Athene noctua*)	41	11	1	30	5	0	83	8	6	0	6	43	17	121	23	107	251	48.2
long-legged buzzard (*Buteo rufinus*)	1	0	5	5	1	4	0	1	0	0	0	6	0	11	5	7	23	47.8
merlin (*Falco columbarius*)	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2	0
Montagu's Harrier (*Circus pygargus*)	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	4	4	0
northern goshawk (*Astur gentilis*)	1	0	4	1	0	0	0	0	0	0	0	0	0	2	2	2	6	33.3
northern long-eared owl (*Asio otus*)	7	0	1	3	1	0	4	2	5	0	2	14	2	8	5	28	41	19.5
pallid harrier (*Circus macrourus*)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0
peregrine falcon (*Falco peregrinus*)	1	0	3	0	2	0	0	3	0	0	0	7	0	4	1	11	16	25
red-footed falcon (*Falco vespertinus*)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
short-eared owl (*Asio flammeus*)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
western marsh harrier (*Circus aeruginosus*)	0	0	2	1	0	0	0	1	0	1	0	7	0	5	3	4	12	41.7
Total	**131**	**17**	**64**	**80**	**64**	**10**	**249**	**65**	**32**	**5**	**11**	**299**	**74**	**469**	**100**	**532**	**1101**	**42.6**
Percentage	**11.9**	**1.5**	**5.8**	**7.3**	**5.8**	**0.9**	**22.6**	**5.9**	**2.9**	**0.5**	**1.0**	**27.2**	**6.7**	**42.6**	**9.1**	**48.2**		

(for each species admission percentages, see Supplementary Table S1). Other common reasons for admission were trapped/relocation (7.3%), infectious diseases (5.9%), gunshot (5.8%), and captive confiscations (5.8%). However, certain injuries predominantly affected specific species; for example, dog/cat predations were primarily seen in the smaller owl species, with little owls providing the most admissions for this category. For northern goshawks and hen harriers (*Circus cyaneus*), injuries from gunshots made up the highest proportion of their admissions at 66.7% and 45.5%, respectively. Most collision-related admissions were attributed to vehicle collisions, accounting for 72.5% of the total collision cases. Notably, 93.7% of these incidents involved five species only (Table 2).

Final outcomes

The total number of birds released from the centre between 2016 and 2022 was 469 (42.6%). One hundred birds were deemed non-releasable and transferred to the sanctuary (9.1%). The remaining 532 raptors (48.3%) either died or were euthanised. The species with the highest success rates (excluding species with < 10 individuals) were common kestrel (49%), little owl (48%), long-legged buzzard (48%), western marsh harrier (*Circus aeruginosus*) (42%), and hen harrier (41%).

Ringing recaptures / Resightings

There were seven ringing recaptures or resightings during the study period, a recapture rate of < 1% (Table 3). The time between release and resighting ranged from 2 to 1,177

Tab. 2. Comparison of vehicular and non-vehicular collision admissions. The top five species admitted with collision-related injuries.
Tab. 2. Porovnanie prípadov prijatia v dôsledku zrážky s vozidlom a inej zrážky. Päť najčastejších druhov prijatých v dôsledku zranenia spôsobeným zrážkou.

	Collision (non-vehicle)	Collision (vehicle)	Total	% vehicle collisions
little owl	7	34	41	82.9
barn owl	6	21	27	77.8
northern long-eared owl	2	5	7	71.4
common kestrel	13	27	40	67.5
Cyprus scops owl	1	2	3	66.7
Total	**29**	**89**	**118**	

days, which is related to a little owl and common kestrel, respectively (Table 3). A juvenile peregrine falcon (*Falco peregrinus*) released in the Karpaz peninsula was later confiscated by the Royal Society for the Conservation of Nature in Jordan after being illegally trapped near Aqaba in southern Jordan. The bird was subsequently released at the Rift Valley of Jordan close to the Dead Sea coast.
In addition to the cases shown in Table 3, a long-legged buzzard rescued after being kept in captivity for two years was released, only for the centre to be called again as the bird was perched in a garden close to WRRC. It was decided that this bird had become imprinted and could not be released back into the wild. It was consequently readmitted to the sanctuary to later become part of the long-legged buzzard breeding program. Another released long-legged buzzard did not fare so well, as following its release, it was electrocuted after perching on some overhead power lines.

Tracking results

The GPS tracking produced a variety of outcomes (Table 3), the summaries of which are given below. The average time at large from the GPS-tracked birds was 319 days ± 334 SD (median = 184, range 18–847 days).

European honey buzzard (RC2363): Following release on 29/11/2021 from WRRC in Northern Cyprus, the bird travelled south-easterly across Cyprus and crossed the Mediterranean Sea before reaching land in Israel. This southerly directed journey continued across Israel and into Saudi Arabia, where the transmissions ceased after 18 days just south of Al Wajh, in north-west Saudi Arabia (Fig. 1).



Fig. 1. Post-release positions (yellow circles) of the European honey buzzard (RC2363) released from Northern Cyprus (R) and monitored to the Red Sea coast of Saudi Arabia, where transmissions ceased (E) on 17/12/2021.
Obr. 1. Pozície včelára lesného (RC2363) po vypustení (žlté body) zo severného Cypru (R) a sledovaného až po pobrežie Červeného mora v Saudskej Arábii, kde 17. 12. 2021 došlo k prerušeniu prenosu (E).

Northern goshawk (RC2443): This bird was released on 30/4/2022, close to the village of Koruçam where it was found initially (Fig. 2). As this species is a resident in Cyprus it remained in the general vicinity, holding a territory where it was released for 4 months never moving further than a few kilometres at any one time (marked A in Fig. 2). It then moved 5 km south, where it remained for 18 days (marked B in Fig. 2), before returning the previous area. During the following week, it spent time shuttling between the two sites, spending a couple of days at a time within each location. During the final 5 days of the transmission, the bird moved to a new area near Geçitköy reservoir, where it was later found dead (marked C in Fig. 2).

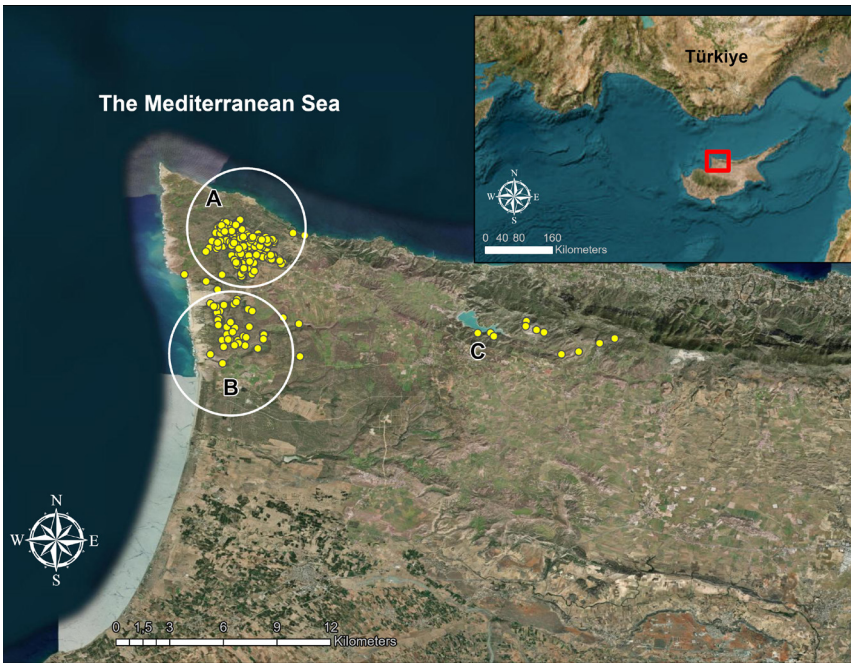


Fig. 2. Post-release positions (yellow circles) of areas (A and B) inhabited by the northern goshawk (RC2443) in the region of Cape Kormakitis. It was released in area A on 30/4/22, and was later found dead on 9/10/22 at location C.
Obr. 2. Pozície sledovaného jastraba veľkého (RC2443) po vypustení (žlté body) v oblastiach (A a B) v regióne Cape Kormakitis. Jedincec bol vypustení v oblasti A dňa 30. 4. 2022. Neskôr, 9. 10. 2022 bol jedinec nájdený uhynutý na mieste C.

The bird may have been shot, as the birds' movements ceased following a designated official hunting day. The carcass and transmitter were recovered a few days later, but only the bird's wings and legs remained, probably due to post-mortality foraging by scavengers (Fig. 3).

Long-legged buzzards: Four individuals have been tracked to date, two died after 65 and 205 days respectively (Table 3; Figs. 4 and 5), one ceased to transmit locations on 11/7/2024 and the final one, of which at the time of writing 28/2/2025, was still at large, with transmitter functioning (Table 3; Figs. 6 and 7).

Long-legged buzzard (RC2321): Released from the rehabilitation centre on 15/11/21 and remained in the Kyrenia mountains close to the release site for three days. It then flew for 30 km southerly and spent three days close to Tamassos reservoir. It then flew south a further 30 km before stopping and spending two days near the village of Pentakomo. Over the next few days, it flew east; then northeast a total of 70 km before settling in an area between the villages of Boğaziçi and Mormenekşe (area marked with a black box in Fig. 4). It remained in this location (except for a couple of brief excursions to Larnaca and Kaleburnu) until its death (reason unknown) on 8/6/2022.



Fig. 3. The northern goshawk (RC2443) tracked post-release for 162 days. The carcass had been scavenged, with only wings and legs remaining.
Obr. 3. Jastrab veľký (RC2443) sledovaný 162 dní po vypustení. Kadáver bol nájdený obžratý, zostali len krídla a nohy.

Tab. 3. Successful release and recapture events recorded at the Wildlife Rescue and Rehabilitation Center between 2016 and 2022.
Tab. 3. Úspešné prípady vypustenia a opätovného odchytu zaznamenané v Centre pre záchranu a rehabilitáciu voľne žijúcich živočíchov v rokoch 2016 až 2022.

Species and mark type	ID No	Admission Date	Release Date	Recovery/ Final Date	Survival Days	Notes	
						Admission Reason	Resighting details
Metal ringed							
common kestrel	65	23.2.2018	10.7.2018	13.10.2020	826	Found in a garage, feather damage, probably kept captive.	Readmitted after being shot and later died.
little owl	1121	30.4.2020	19.6.2020	21.6.2020	2	Admitted as juvenile/orphan.	Found dead (skull injury).
western barn owl	1423	4.7.2020	15.7.2020	16.11.2020	124	Sticky substance on feathers.	Found dead.
common kestrel	1462	1.1.2017	20.4.2017	10.7.2020	1177	First admission fractured wing.	See second admission reason.
—	—	10.7.2020	23.2.2021	—	—	Second admission, infection weak/ underweight.	
peregrine falcon	2093	8.6.2021	15.11.2021	10.2.2022	87	Admitted due to a collision, released in Karpaz.	Confiscated from trappers in Jordan.
long-legged buzzard	2866	6.6.2022	25.6.2022	17.9.2022	84	Rescued from irrigation pond, released Doganci.	See second admission reason.
GPS tracked							
European honey buzzard	2363	29.9.2021	29.11.2021	17.12.2021	18	Confiscated, poor condition.	Ceased transmitting.
northern goshawk	2443	28.11.2021	30.4.2022	9.10.2022	162	Ulna's fractured, shot gun pellets	Found dead possibly shot
long-legged buzzard	2321	3.9.2021	15.11.2021	8.6.2022	205	Emaciated, high ectoparasite load.	Found dead after release.
long-legged buzzard	2881	BP*	7.7.2022	20.7.2022	13	Born in sanctuary.	See second admission reason.
—	—	20.7.2022	23.7.2022	13.9.2022	52	Rescued from sea and later released.	Found dead (shot).
long-legged buzzard	2866**	17.9.2022	4.11.2022	still at large	847+	2nd admission, shotgun pellets, fractured ulna and femur.	Still transmitting
long-legged buzzard	3262	15.10.2022	4.11.2022	11.7.2024	615	Rescued from irrigation pond. No major injuries.	Ceased transmitting, device lost power.
Radio tracked							
Bonelli's eagle	376	20.11.2018	20.12.2018	12.7.2019	204	Trapped in partridge breeding cages.	Later tracked to nesting location.
		Mean days at large			**368**		

*breeding program identifies an individual born in the centre. **An end date of 28/2/2025 was used to calculate the survival days for the long-legged buzzard (2866).

Long-legged buzzard (RC2881): On its release from the rehabilitation centre (07/7/2022), it flew north to the coastline before heading easterly to the tip of the Karpaz peninsula. Next, it flew a few kilometres west to the village of Dipkarpaz, where it remained for 8 days (green circles, Fig. 5). On the morning of 20/7/2022 (yellow circles, Fig. 5), it flew back to the tip of the Karpaz peninsula and out of the Khleides Islands. Tracking data showed its GPS locations and altitude to be in the sea and drifting in a south-westerly direction (marked A in Fig. 5). Approximately three hours later, the bird was rescued (marked B in Fig. 5) and returned to the rehabilitation centre, where it was observed for a few days before its second release on 23/7/2022. Following its second release, it again returned to Dipkarpaz village (green circles, Fig. 5), where it died 52 days later after being shot (x-ray confirmation).

Long-legged buzzard (RC2866): Released from the rehabilitation centre on 4/11/2022, and over the next few days, it first flew south and then west, before reaching Güzelyurt on 7/11/2022. After spending approximately two months in the agricultural fields surrounding Güzelyurt (area B in Fig. 6), it flew south to the foothills of the Troodos mountains (area A in Fig. 6), where it remained for the next two weeks before returning to the Güzelyurt region (24/1/23). During the next three months, it shuttled between these two regions, spending 1 to 6 days at each (areas labelled A and B in Fig. 6). From 29/4/22, the bird flew from Güzelyurt back to Troodos, where it remained until the autumn. On 1/10/23, the bird flew back to Güzelyurt until it returned to Troodos on 13/11/2023. This bird has continued this movement pattern while the device still functions.



Fig. 4. Long-legged buzzard (RC2321) post-release positions (yellow circles) after released from the Wildlife Rescue and Rehabilitation Center (R) on 15/11/21. The white square encompasses the area where the bird spent 95% of its time. Finally being found dead (D) on 8/6/22. The bird visited the following locations described in the discussion: 1 = Tamassos Reservoir, 2 = Pentakomo, 3 = Boğaziçi, 4 = Mormenekşe, 5 = Larnaca and 6 = Kaleburnu.

Obr. 4. Pozície myšiaka hrzdavého (RC2321) po vypustení (žlté body) z Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov (R) 15. 11. 2021. Biely štvorec zahŕňa oblasť, kde vták strávil 95 % svojho času, až kým bol 8. 6. 2022 nájdený mŕtvy (D). Vták navštívil nasledujúce miesta opísané v diskusii: 1 = vodná nádrž Tamassos, 2 = Pentakomo, 3 = Boğaziçi, 4 = Mormenekşe, 5 = Larnaca a 6 = Kaleburnu.

Long-legged buzzard (RC3262): Released from the WRRC on 4/11/2022, after which, similar to the previous bird, it flew south and west before settling on 12/11/2022 near the village of Gaziveren. It remained in the agricultural fields surrounding this village for the next three months. On 10/2/2023, the bird flew 18 km south to the foothills of the Troodos mountains and over the next two weeks, it spent time shuttling between these two locations (marked A and B in Fig. 7), spending 1 to 3 days at each location. After returning to Troodos

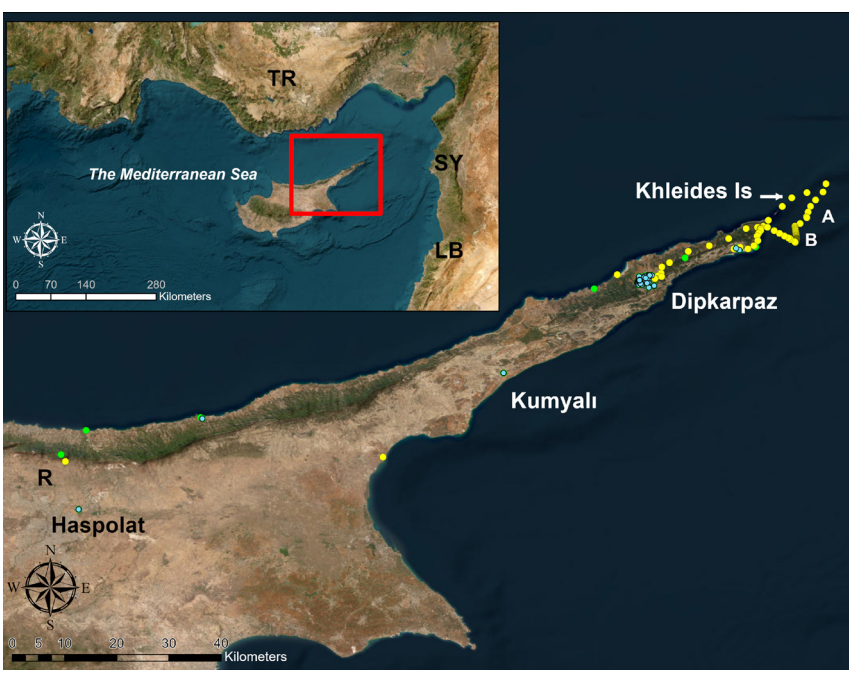


Fig. 5. Long-legged buzzard (RC2881), post-release positions (green circles) after release from the Wildlife Rescue and Rehabilitation Center (R) on 7/7/22. Movements (yellow circles) on 20/7/22 before and during the sea rescue. The bird entered the water at location A and was rescued at location B. Movements following the 2nd release on 23/7/22 from the centre (R) (blue circles), the bird returned to Dipkarpaz, where on 13/9/2022 was found dead (shotgun wounds).

Obr. 5. Pozície myšiaka hrzdavého (RC2881) po vypustení (zelené body) z Centra pre záchranu a rehabilitáciu (R) dňa 7. 7. 2022. Pohyby (žlté body) dňa 20. 7. 2022 pred a počas záchrany na mori. Vták vošiel do vody v mieste A a bol zachránený v mieste B. Pohyby po druhom prepustení 23. 7. 2022 z centra (R) (modré body), vták sa vrátil do Dipkarpazu, kde bol 13. 9. 2022 nájdený mŕtvy (zranenia po brokovnici).

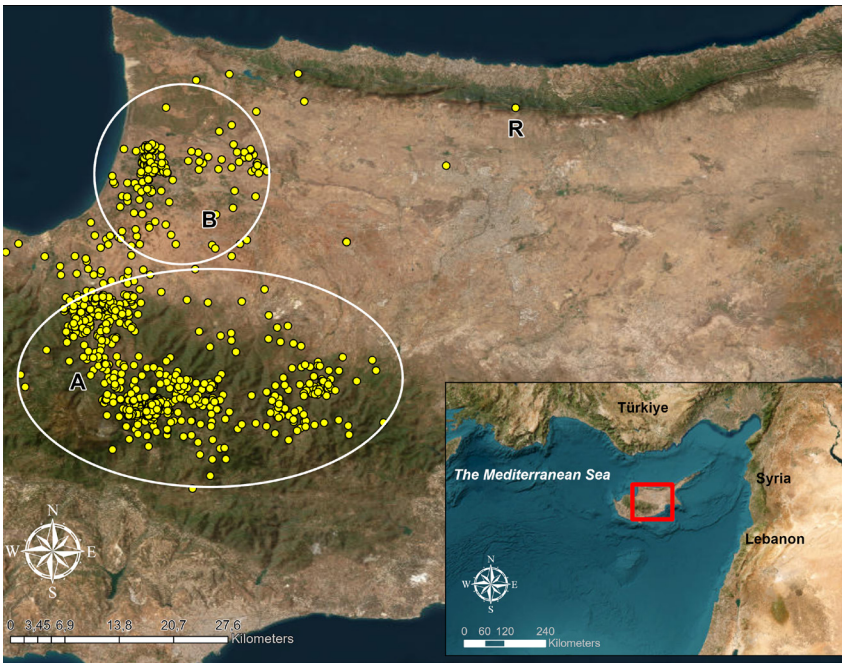


Fig. 6. Long-legged buzzard (RC2886), post-release positions (yellow circles) 4/11/22 – 19/11/23, after release from the Wildlife Rescue and Rehabilitation Center (R), the bird predominantly spent most of its time in either the forested foothills of the Troodos mountains (A) or agricultural fields around Güzelyurt (B). This pattern of movement continues, with the device still transmitting.

Obr. 6. Pozície myšiaka hrdzavého (RC2886) po vypustení 4. 11. 2022 – 19. 11. 2023 (žlté body) z Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov (R). Vták trávil väčšinu času v zalesnených výbežkoch pohoria Troodos (A), alebo na poliach v okolí Güzelyurtu (B). Tento pohybový vzorec pokračuje, pričom zariadenie stále vysiela signál.

on 25/2/23, the bird remained in this region for the next 23 days before resuming the shuttling behaviour between the two locations with slightly extended stays (1–10 days) between shuttling events. On 2/7/2023, the bird flew from Troodos to Gaziveren, where it remained almost two months, before resuming the shuttling behaviour between the two regions until 21/11/23. The exceptions to these two central locations were a couple of trips to Astromeritis and south Nicosia, where the bird remained for one and two days, respectively. The bird continued to

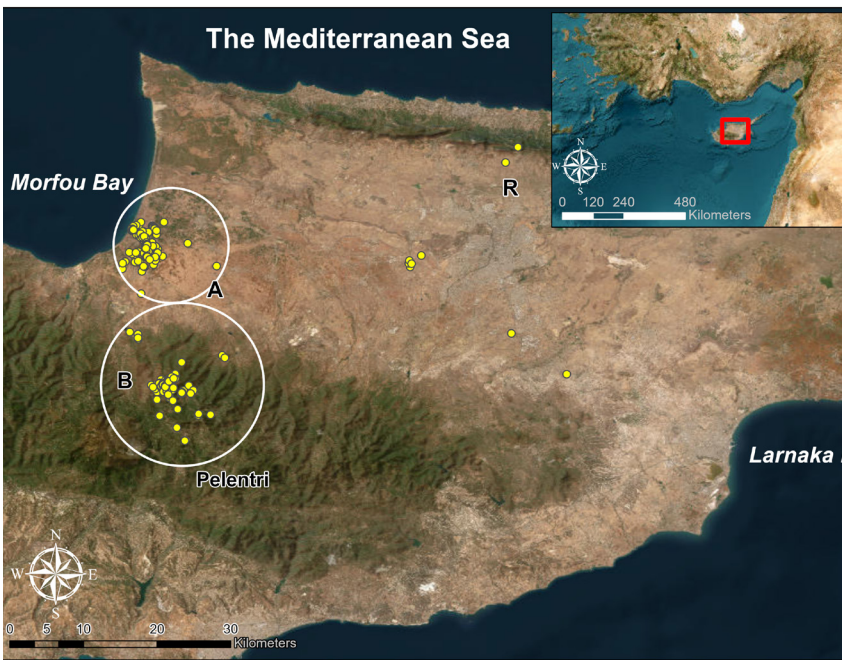


Fig. 7. Long-legged buzzard (RC3262), post-release positions (yellow circles) 4/11/22–11/7/24, after release from the Wildlife Rescue and Rehabilitation Center (R), the bird pre-dominantly spent most of its time either in agricultural fields around the village of Gaziveren (A) or the forest foothills of the Troodos mountains (B). The bird continued to inhabit the two main areas (A and B) until the device lost power on 11/7/2024 near the village of Pelentri.

Obr. 7. Pozície myšiaka hrzdavého (RC3262), 4.11.2022 – 11.7.2024 (žlté body) po prepustení z Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov (R). Vták trávil väčšinu času na poliach v okolí dediny Gaziveren (A), alebo v lesnatých podhoriach pohoria Troodos (B). Vták naďalej obýval tieto dve hlavné oblasti (A a B), až kým sa zariadenie nevybilo 11/7/2024 v blízkosti dediny Pelentri.

inhabit the two main areas (A and B) until the device lost power on 11/7/2024 near the village of Pelentri in zone B (Fig. 7).

Radio tracking results

The results from the radio-tracked birds were generally poor, with only the Bonelli's eagle being tracked for more than a couple of days (see Table 3 for details). Following its release on 20/12/2018, the Bonelli's eagle flew south towards Haspolat, then took an easterly direction and spent a couple of days around the village of Vadili in the Mesaoria plain. By January, his location had shifted to the southern slopes of the west part of the Kyrenia range, and he had settled around the village of Göçeri, where he was observed with his mate by mid-January. In late February, their nesting site was discovered in a rock crevice on the southern face of the Pentadactylos range (Fig. 8).

The nest was monitored three times using a drone: 26/2/2019 February – 2 eggs were present, 19/4/2019 April – 2 chicks were active in the nest, and finally on 26/5/2019 May – there was only one nestling left in the nest. On the final day of nest observation, the female was flying with another bird, potentially the other fledgling and not the tracked male, as no signals were detected from the flying couple. The final signal was detected in July, from a nearby quarry 2 km west of the village of Göçeri, with no sightings of the bird, leading us to believe that the transmitter was lost, possibly through the moulting of its tail feathers.

Discussion

Threats to wildlife populations, raptors included, are diverse and encompass both natural and non-natural hazards. Raptor populations can be critical ecological indicators for ecosystem health, highlighting an array of factors which can endanger both wildlife and humans alike. Identifying specific threats to raptor populations can aid conservation efforts by targeting those particular threats through legislation, enforcement and education (Arroyo & Ferreiro 1997, Sarasola et al. 2018). This study constitutes the first analysis of raptor mortality or morbidity cases admitted to a rehabilitation facility in Cyprus. Descriptive studies related to wildlife mortality and morbidity provide essential insights into the threats wild animals face. The major causes of admission found in this study are also those commonly reported in studies from other countries. Wendell et al. (2002) reported trauma as the major reason for raptor admissions to Colorado State University Veterinary Teaching Hospital, together with numerous other studies stating it as the primary reason for admission (Molina-López et al. 2011, Montesdeoca et al. 2016, Cococcetta et al. 2022,



Fig. 8. Radio tracking positions of Bonelli's eagle (RC0376) from its release site at the Wildlife Rescue and Rehabilitation Center on 20/12/18 through the vicinity of the villages of Haspolat, Vadili and Göçeri and finally to its later discovered nesting location in February 2019. The final location, 2 km west of Göçeri village, was recorded on 12/7/2019.

Obr. 8. Pozície radiovo sledovaného orla jastrabovitého (RC0376) (od miesta vypustenia žlté body) v Centre pre záchranu a rehabilitáciu voľne žijúcich živočíchov 20. 12. 2018 cez okolie obcí Haspolatu, Vadili a Göçeri až po miesta hniezdenia, ktoré bolo objavené vo februári 2019. Konečná poloha, 2 km západne od obce Göçeri, bola zaznamenaná 12. 7. 2019.

Pahl 2024). Admissions of orphaned or abandoned birds were the second most frequent reason (22.6%) for admission and are usually seasonal, principally occurring during the spring and summer months. However, they can place enormous pressure on wildlife rehabilitation facilities due to the considerable time demands on those caring for young orphaned or abandoned chicks (Molina-López et al. 2017). Nevertheless, well-intentioned public members can confuse recently fledged, poorly flying individuals with orphaned birds, which can elevate the number of admissions, with those individuals requiring no rehabilitation. Public education initiatives can help inform communities regarding best practices when dealing with orphaned individuals or nestlings.

The most frequently admitted species to the centre were common kestrel, little owl, and western barn owl, amounting to over 75% of all admissions. This is to be expected given their high population levels in Cyprus and their propensity to nest and live near human agropastoral landscapes (Tomé 2011, Flint & Richardson 2024). Gunshot wounding, saw common kestrels as the most frequent species admitted; however, the next most frequent were hen harrier and Eurasian sparrowhawk (*Accipiter nisus*) respectively. These levels are unexpected when considering neither is a common species in Cyprus. One of the main reasons for this is that little owls and western barn owls, typically the most common admissions, are nocturnal in their habits, significantly reducing the likelihood of being shot. This was also seen in a study from Central Italy, where no nocturnal raptors were admitted as a result of gunshot wounds (Cococcetta et al. 2022).

As seen in many Mediterranean countries, Cyprus has a tradition of bird trapping, predominantly using glue or nets to trap migratory songbirds (Bhattacharya 2016, Brochet et al. 2016, Sebastianelli et al. 2020). As with most trapping methods they tend to be indiscriminate in the species they trap, therefore a number of those admitted to the centre were those rescued from glue traps, which required intensive cleaning to remove glue residues, frequently also causing extensive feather damage, which sometimes required veterinary intervention (pulling feathers under anaesthesia) and a long period of rehabilitation.

Toxicosis and infectious diseases, often through the lack of specialist equipment and difficulties in diagnosis, are commonly difficult to identify and are generally under-represented in many wildlife morbidity and mortality studies. That is probably the case here, as with the establishment of any new wildlife rehabilitation facility there is a steep learning curve, generally involving primarily learning on the job, especially in this case when there is little or no local expertise to draw from when dealing with a wide variety of taxa (Wendell et al. 2002, Panter et al. 2022).

Post-release survival

One of the main challenges for wildlife rehabilitation is understanding their post-release survival. For birds of prey, as apex predators, their visual acuity and flying agility are paramount to their survival. Therefore, all individuals before release are placed in the centre's largest indoor aviary and tested with live prey (mice, rats, or quail as appropriate for the species) to ascertain their suitability for release. Low re-encounter levels of conventionally ringed non-targeted raptors, of between 2–10% (Bildstein & Peterjohn 2012, Lutmerding et al. 2012), led to the use of radio or GPS tracking devices to understand the post-release survival. Radio-tracking was only successfully deployed on a single Bonelli's eagle, unveiling a previously unknown nesting location for the species. All other radio tracking (long-legged buzzards) was less successful, with individuals being lost after only a day or two. The reasons for this are possibly related to the limited suitability of the species for such tracking, the limited workforce, and the terrain involved. The radio tracking devices had an estimated range of ca 20 km, and given the distances these birds can travel post-release, they can quickly move out of range. Mountain ranges can also lead to poor tracking results, requiring multiple personnel to improve coverage. Following these early radio-tracking attempts, satellite tracking devices provided far greater post-release information. With almost real-time location and movement information, and significantly reduced workforce requirements to track the animal, it was even possible in one incident to enable the recovery of a long-legged buzzard from the sea.

Post-release survival of the GPS-tracked birds in this study averaged 319 days, which far exceeds the accepted 4–6 weeks of post-release period used to ascertain the successful survival of an individual bird in the wild (Duke & Redig 1981, Martell et al. 1991). From the acquired tracking data, the rehabilitated birds from the WRRC were fit for release, demonstrating the ability to travel long distances and survive for extended periods in the wild. This implies that rehabilitation methods utilised at the WRRC prepared the birds to a level of fitness required to survive in the wild. Thus, it highlights the importance of rehabilitation centres in preparing injured or sick raptors for survival in the wild. In the case of locally threatened species, they

can provide essential additions to the breeding population (Rozsypalová et al. 2024).

Only one bird failed to meet this criterion, a juvenile European honey buzzard released relatively late in the season for this migratory species. However, due to the relative difficulty in keeping this species in captivity, mild weather forecast and the fact that juvenile honey buzzards do not make return spring northerly migrations in their second and sometimes third year (Strandberg et al. 2012), it was decided best to release this bird rather than wait until the subsequent autumn. The transmission ceased after 19 days during which the bird migrated from Cyprus, across the Mediterranean Sea to Israel and later, to the Red Sea coast. Transmission termination could have been due to a lack of or blocked GSM, although this is likely temporary. Given that the cessation of transmission signal was not temporary, it is likely to be due to a device or transmission malfunction (Monti et al. 2018), because if the bird had died, multiple transmissions would have been received from the same location, so the fate of this individual will remain unknown. All other GPS-tracked individuals survived beyond the prescribed six-week period, with one long-legged buzzard still at large some 2.5 years later.

This study provides the first comprehensive insight into the threats affecting raptor populations in Cyprus through the lens of a wildlife rehabilitation facility. The successful rehabilitation of raptors is particularly evident in its structured release procedures and post-release tracking results, demonstrating that with adequate care, rehabilitated birds can survive extended periods in the wild. These outcomes point to such facilities' value and importance in monitoring specific threats, public education, and investment in diagnostic capabilities.

Ultimately, this study contributes to a broader understanding of the dynamic threats facing raptors in Cyprus and the efficacy of rehabilitation centres in mitigating these risks. Strengthening data collection, refining release strategies, and fostering awareness among the public and policymakers will be key to ensuring the long-term survival of these iconic avian predators.

Ethics Approval

The Department of Environmental Protection in Northern Cyprus authorised all raptor interactions in this study. Handling and rehabilitation activities were carried out under official protocols (No. 116/01/7-154) issued by the relevant environmental authorities, which include authorisation for wildlife rehabilitation, and extend to handling, providing medical treatment, ringing and tracking device attachments. Where recovery was deemed unfeasible due to the severity of injury or illness, euthanasia was performed following ethical and legal guidelines.

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