Managing the Natura 2000 network in Cyprus and shaping a sustainable future

ACTION A.5

Study the ecological requirements of key qualifying species for SPAs (Annex I bird species of Directive 2009/147/EC)

DELIVERABLE A5.10

Report on the impact of secondary poisoning from rodenticides and other widely used poisons on diurnal and nocturnal birds of prey

Antaia Christou, Nikos Kassinis

Nicosia, January 2026

LIFE IP PHYSIS - LIFE18 IPE/CY/000006
The project is co-funded from LIFE programme of EU

Comments:

Proposed reference: Christou A., Kassinis N. 2026. Report on the impact of secondary poisoning from rodenticides and other widely used poisons on diurnal and nocturnal predatory species. Deliverable A5.9 for the project LIFE IP Physis - LIFE18 IPE/CY/000006 - Managing the Natura 2000 network in Cyprus and shaping a sustainable future. BirdLife Cyprus, Game and Fauna Service.

Διαχείριση του Δικτύου Natura 2000 στην Κύπρο και διαμόρφωση ενός βιώσιμου μέλλοντος

ΔΡΑΣΗ Α.5

Μελέτη των οικολογικών απαιτήσεων ειδών ορνιθοπανίδας που περιλαμβάνονται στο Παράρτημα Ι της Οδηγίας 2009/147/ΕΕ

ΠΑΡΑΔΟΤΕΟ Α5.10

Αναφορά για τις επιπτώσεις της δευτερογενούς δηλητηρίασης από τρωκτικοκτόνα, εντομοκτόνα και φυτοφάρμακα σε ημερόβια και νυκτόβια αρπακτικά είδη

Ανταία Χρίστου, Νίκος Κασίνης

Λευκωσία, Ιανουάριος 2026

LIFE IP PHYSIS - LIFE18 IPE/CY/000006
Το έργο συγχρηματοδοτείται από το πρόγραμμα LIFE της ΕΕ

Σχόλια:

Προτεινόμενη βιβλιογραφική αναφορά: Χρίστου Α., Κασίνης Ν. 2026. Οι επιπτώσεις της δευτερογενούς δηλητηρίασης από τρωκτικοκτόνα, εντομοκτόνα και φυτοφάρμακα σε ημερόβια και νυκτόβια αρπακτικά είδη στη Κύπρο. Πρόγραμμα LIFE IP Physis (LIFE 18 IP/CY/000006). Διαχείριση του δικτύου Natura 2000 στην Κύπρο και διαμόρφωση ενός βιώσιμου μέλλοντος. BirdLife Cyprus, Υπηρεσία Θήρας και Πανίδας.

Contents

Περίληψη 1

Summary 2

1. Introduction 3

1.1 About the project 3

1.2 Action description 3

1.3 Focal bird species for this report 3

1.4 Objectives of current report 3

1.5 Description of sections of the report 3

2. Target toxic substances of this report 4

2.1 Brodifacoum 5

2.2 Bromadiolone 5

2.3 Difenacoum 6

2.4 Flocoumafen 7

2.5 Carbofuran 7

2.6 Methomyl 7

3. Methodology 8

3.1 Bird sample collection 8

3.2 Toxicological analysis 8

4. Results 9

4.1 Sampling distribution 9

4.2 Cause of injury or death 9

4.3 Species of birds collected 10

4.3.1 Barn Owls 13

4.3.2 Long-eared Owls 14

4.3.3 Common Kestrel 15

4.3.4 Bonelli's Eagle 16

4.3.5 Long-legged Buzzard 17

4.3.8 Scops Owl 20

4.3.9 Little Owl 21

4.3.10 Hen Harrier 22
5. Discussion 24
6. Conclusions 25

Περίληψη

Η παρούσα έκθεση αξιολογεί την έκταση και τις οικολογικές συνέπειες της δευτερογενούς δηλητηρίασης από τρωκτικοκτόνα και άλλες τοξικές ουσίες που χρησιμοποιούνται συχνά, σε ημερόβια και νυκτόβια αρπακτικά πουλιά στην Κύπρο. Η μελέτη εστιάζει σε αρπακτικά όπως το Ανθρωποπούλι, τον Αρκόθουπο, τον Κουκκουφκιάο, τον Κίτση, τον Σπιζαετό,την Αετογερακίνα και έχει στόχο την ποσοτικοποίηση των επιπέδων έκθεσης και την παροχή κατευθυντήριων γραμμών για στοχευμένες δράσεις διατήρησης.

Τα δείγματα των πουλιών συλλέχθηκαν ευκαιριακά μεταξύ τα έτη 2019 και 2024 από την Υπηρεσία Θήρας και Πανίδας και το BirdLife Κύπρου, σε όλη την Κύπρο, σε περιοχές υπό τον αποτελεσματικό έλεγχο της Κυπριακής Δημοκρατίας. Πολλά δείγματα ανακτήθηκαν μέσω αναφορών του κοινού για τραυματισμένα ή νεκρά άγρια ζώα. Τα δείγματα αναλύθηκαν από το Γενικό Χημείο του Κράτους, με έμφαση στα αντιπηκτικά τρωκτικοκτόνα (Brodifacoum, Bromadiolone, Difenacoum και Flocoumafen) και σε απαγορευμένα εντομοκτόνα (Carbofuran και Methomyl). Η έκθεση εξετάζει επίσης το νομικό καθεστώς αυτών των ουσιών στην Ευρώπη και την Κύπρο, τονίζοντας το κενό μεταξύ των νομικών περιορισμών και της περιβαλλοντικής έκθεσης.

Τα αποτελέσματα δείχνουν ευρεία μόλυνση μεταξύ των αρπακτικών πουλιών: περίπου το 89% των πουλιών που αναλύθηκαν βρέθηκαν θετικά σε τουλάχιστον μία τοξική ουσία, ενώ το 65% των οργανισμών είχαν εκτεθεί σε πολλαπλές ουσίες. Τα Bromadiolone και Brodifacoum ήταν οι ουσίες που ανιχνεύθηκαν συχνότερα γεγονός που συνάδει με την κυριαρχία τους στην τοπική αγορά τρωκτικοκτόνων, ενώ οι ουσίες Carbofuran και Methomyl, ουσίες που απαγορεύτηκαν το 2008 και το 2009 αντίστοιχα, βρέθηκαν επίσης σε πολλά δείγματα, γεγονός που υποδηλώνει συνεχιζόμενη παράνομη χρήση ή μακροχρόνια περιβαλλοντική επιβάρυνση. Τα ευρήματα καταδεικνύουν ότι τόσο τα νόμιμα όσο και τα απαγορευμένα βιοκτόνα εξακολουθούν να αποτελούν σημαντικό κίνδυνο για την άγρια ζωή, εισερχόμενα στην τροφική αλυσίδα μέσω βιοσυσσώρευσης και επηρεάζοντας είδη σε πολλαπλά τροφικά επίπεδα.

Η συζήτηση υπογραμμίζει ότι τέτοια επίπεδα δευτερογενούς δηλητηρίασης σε αρπακτικά συνάδουν με τις ευρύτερες ευρωπαϊκές τάσεις και έχουν σαφείς επιπτώσεις στη διατήρηση της φύσης και την νομοθεσία. Τα κενά στην επιβολή, τη ρύθμιση και την ευαισθητοποίηση του κοινού είναι πιθανό να συμβάλλουν στη συνεχιζόμενη έκθεση. Η έκθεση συνιστά την ενίσχυση των μέτρων ελέγχου, τον περιορισμό της πώλησης εξαιρετικά τοξικών αντιπηκτικών, την προώθηση περιβαλλοντικά ασφαλέστερων μεθόδων διαχείρισης παρασίτων και την ενίσχυση της παρακολούθησης της άγριας ζωής που δεν αποτελεί στόχο. Υπογραμμίζει περαιτέρω την ανάγκη ενσωμάτωσης αυτών των μέτρων με δράσεις διατήρησης και διαχείρισης οικοτόπων που αφορούν συγκεκριμένα είδη, ώστε να μειωθούν οι κίνδυνοι δευτερογενούς δηλητηρίασης για τα αρπακτικά πουλιά και άλλα ευαίσθητα είδη στην Κύπρο.

Summary

This report assesses the extent and ecological implications of secondary poisoning from rodenticides and other commonly used poisons on diurnal and nocturnal birds of prey in Cyprus. The study focuses on raptors such as Barn Owl, Long-eared Owl, Little Owl, Common Kestrel, Bonelli's Eagle, and Long-legged Buzzard, with the aim of quantifying exposure levels and informing targeted conservation actions.

Bird carcasses were collected opportunistically between 2019 and 2024 by the Game and Fauna Service and BirdLife Cyprus across Cyprus, in areas under the effective control of the Republic of Cyprus, with many individuals recovered through public reports of injured or dead wildlife. Samples were analyzed by the State General Laboratory, focusing on anticoagulant rodenticides (Brodifacoum, Bromadiolone, Difenacoum, and Flocoumafen) and banned insecticides (Carbofuran and Methomyl). The report also discusses the regulatory status of these substances within Europe and Cyprus, emphasizing the persistent gap between legal restrictions and environmental exposure.

Results reveal widespread contamination among raptors: approximately 89% of all birds tested positive for at least one biocide, and 65% of the individuals were exposed to multiple compounds. Bromadiolone and Brodifacoum were the most frequently detected, consistent with their dominance in the local rodenticide market, while Carbofuran and Methomyl; substances banned from 2008 and 2009 respectively, were also found in multiple samples, indicating ongoing illegal use or long-term environmental persistence. The findings demonstrate that both legal and prohibited biocides continue to pose significant risks to wildlife, entering the food chain through bioaccumulation and affecting species at multiple trophic levels.

The discussion highlights that such patterns of secondary poisoning in raptors are consistent with broader European trends and have clear conservation and policy implications. Gaps in enforcement, regulation, and public awareness are likely contributing to continued exposure. The report recommends strengthening control measures, restricting the sale of highly toxic anticoagulants, promoting environmentally safer pest management methods, and enhancing monitoring of non-target wildlife. It further underscores the need to integrate these measures with species specific conservation and habitat management actions to reduce secondary poisoning risks for raptors and other sensitive species in Cyprus.

1. Introduction

1.1 About the project

Life IP Physis (*Pandoteira*) is a LIFE Integrated Project that aims directly at the improvement of the conservation status of species and habitats of community interest through actions in the whole Natura 2000 (N2K) network in Cyprus (for the areas under effective government control). The project includes actions affecting the whole network and other actions affecting certain species and habitats in specific N2K sites (including both Special Protected Areas (SPAs) and Sites of Community Importance (SCIs) / Special Areas of Conservation (SACs)).

1.2 Action description

Action A5 is a preparatory action under the LIFE IP Physis project. The responsible partners for this action are the Game and Fauna Service (GFS) and BirdLife Cyprus (BC). Under this action, four studies have already been completed and this is the fifth study that was carried out (between 2022 and 2025), with the overall objective of informing conservation actions later during the project (2023-2030). The current report comprises one of these studies and provides information on the extent of secondary poisoning impact on raptor species in Cyprus. The current report will identify the impacts of Second-Generation Anticoagulant Rodenticides (SGARs) and secondary poisoning from rodenticides and other commercially used poisons on diurnal and nocturnal predatory species. This is a recognised problem across the world. However, the full extent of secondary poisoning of raptor species such as the Barn Owl (*Tyto alba*), Bonelli's Eagle (*Aquila fasciata)* and the Long-legged Buzzard (*Buteo rufinus)* is still largely unknown in Cyprus. To understand the degree to which raptors are exposed to and affected by SGARs, the GFS, in collaboration with the State General Laboratory and BirdLife Cyprus, carried out toxicological examinations of raptor carcasses. This is to our knowledge the first study that investigates this issue in Cyprus.

1.3 Focal bird species for this report

This report focuses on raptor species that are more susceptible to secondary poisoning, since they depend on rodents to cover a significant part of their diet. These species include the Barn Owl, the Long-eared Owl (*Asio otus*), the Little Owl (*Athene noctua*), the Common Kestrel (*Falco tinnunculus*), the Long-legged Buzzard, the Goshawk (*Accipiter gentilis*), the Common Buzzard (*Buteo buteo*), the Scops Owl (*Otus* sp.) and the Bonelli's Eagle.

1.4 Objectives of current report

The objective of this report is to quantify the problem by documenting poisoning cases and carrying out systematic sampling of recovered raptor corpses. Based on these results, the project team will propose specific conservation actions to combat this problem.

1.5 Description of sections of the report

This report will provide a comprehensive overview of the impact of secondary poisoning on key bird species, particularly those vulnerable to secondary poisoning through their diet preferences. The report will provide information on species sampled, geographic locations of the samples, and the types of poisons detected, highlighting the high prevalence of certain anticoagulant rodenticides. Data gathered through opportunistic samples of bird carcasses and lab analysis will be presented in the form of graphs to enable visualization of possible connections between bird

species and certain rodenticide chemicals, as well as to highlight the vulnerability of certain species through increased exposure due to their dietary preferences.

In addition, the report will explore specific chemicals, their regulatory status, and their relevance to the environmental context in Cyprus. It explains the distinction between legally available substances such as Brodifacoum, Bromadiolone, Difenacoum, and Flocoumafen, and banned substances like Carbofuran and Methomyl, emphasizing the ongoing environmental exposure despite regulatory bans.

2. Target toxic substances of this report

Second-Generation Anticoagulant Rodenticides (SGARs) have been widely applied in Cyprus for rodent control, usually for the protection of crops, agricultural trees, mostly Carob (*Ceratonia siliqua*), but also for public health purposes. Carbamate insecticides, namely Carbofuran and Methomyl were also applied in the past to control agricultural pests. Their high toxicity, rapid action, and frequent misuse have been strongly associated with intentional and unintentional poisoning incidents, particularly affecting birds of prey and scavenging species and their use was banned in Europe. Given the heavy reliance on biocides for pest management in agricultural and peri-urban landscapes, understanding their secondary effects on non-target species is critical for wildlife conservation and public health. This section of the report focuses on key chemical substances involved in pest control and their regulatory status within Europe. These substances include anticoagulant rodenticides, such as Brodifacoum, Bromadiolone, Difenacoum, and Flocoumafen, as well as insecticides like Carbofuran and Methomyl, which are banned substances in Europe but are still used in Cyprus as evidenced within this report. These compounds have been shown to cause severe toxic effects on wildlife, leading to secondary poisoning, population declines in predatory birds and mammals, and bioaccumulation in food webs. Moreover, their persistence in the environment poses serious risks to human health, including contamination of soil, water, and food sources. Furthermore, a 2010 study in Cyprus showed that 5.7% of hospital admissions of children were due to accidental consumption of rodenticides[1]. Understanding these chemicals' properties, uses, and the regulatory frameworks governing them is crucial for assessing their environmental impact, public health implications, and the measures required to mitigate associated risks.

It is also worth mentioning that Brodifacoum, Bromadiolone, Difenacoum, and Flocoumafen are legal poisons and commercially available in Cyprus. Unpublished data from the Department of Agriculture quantified the private market of these chemicals to between 40,662.24 kg -52,916.83 kg a year. Meanwhile the Department of Agriculture also produces and disseminates an additional 117,600 kg - 120,150 kg per year (Figure 1). Carbofuran and Methomyl on the other hand are illegal poisons which have been banned since 2008 and 2009, respectively.

[1] Koliou, M., Ioannou, C., Andreou, K., Petridou, A. and Soteriades, E.S., 2010. The epidemiology of childhood poisonings in Cyprus. European journal of pediatrics, 169(7), pp.833-838.

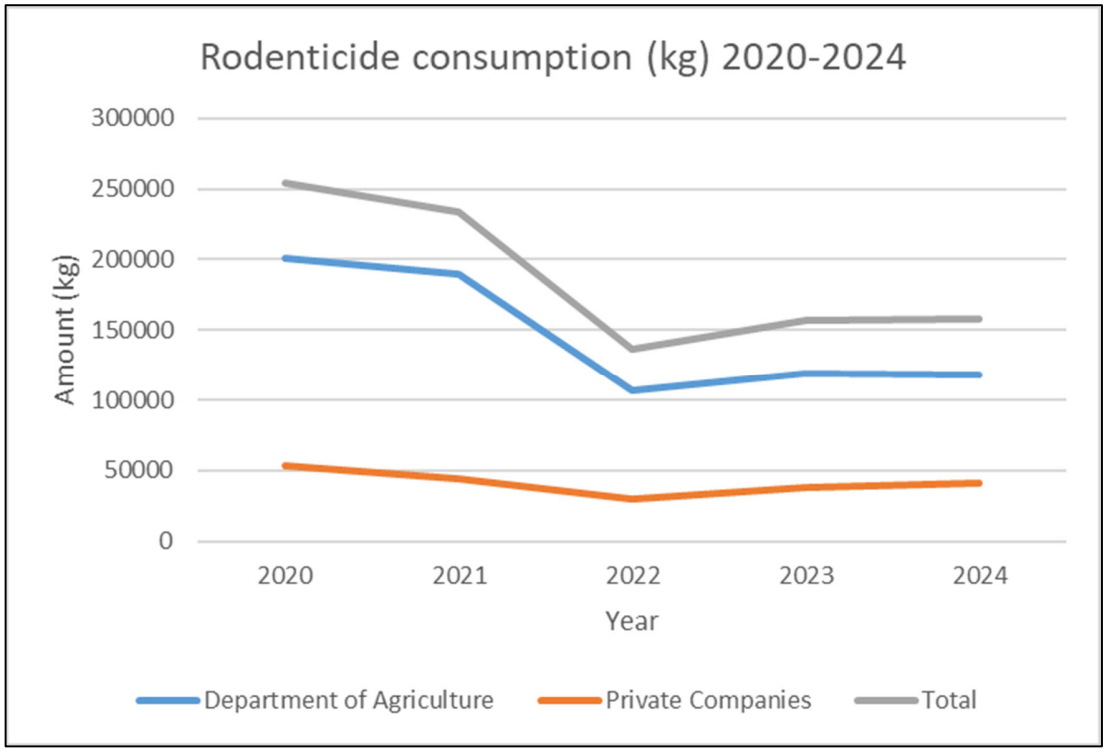


Figure 1: Line graph shows consumption of rodenticides produced and disseminated by the Department of Agriculture as well as Private Companies. Data provided by: Department of Agriculture.

2.1 Brodifacoum

Brodifacoum is a potent anticoagulant rodenticide used to control rodent populations. It is highly toxic to mammals and birds and is classified as a restricted substance under European regulations[2], with its use limited to authorized professional pest control operators due to environmental and health concerns. Brodifacoum is the most popular chemical in the market in Cyprus. It is only available for commercial use through authorised companies, and its sales make up between 60-72% of the rodenticide market in Cyprus. This number ranged between 20,368.75 kg – 31,958.4 kg during 2020 – 2024 (Figure 2)[3].

2.2 Bromadiolone

Bromadiolone is another anticoagulant rodenticide employed for rodent management, which is subject to strict regulation in the European Union. Classified as a restricted substance under EU law[2], its sale and use require authorization to prevent accidental poisoning of non-target species. Bromadiolone is the only substance used by the Department of Agriculture in Cyprus to produce the rodenticide that it then provides freely or at low cost to community councils, farmers or hunting groups across the island, for public health, crop protection and game protection purposes[3]. The Department has significantly reduced the production and dissemination of this rodenticide in the past 5 years, dropping by 41.5% between 2020 and 2024 (Figure 3).

[2] Regulation (EU) 528/2012. Regulation concerning the making available on the market and use of biocidal products.

[3] 2025, personal communications of authors with the Department of Agriculture (Unpublished data).

Bromadiolone is also sold by private companies to individuals for personal use and makes up between 7-9% of the poisons sold to the public, amounting to sales ranging from 2,263.75kg to 4,754.85 kg in the period 2020 - 2024[4].

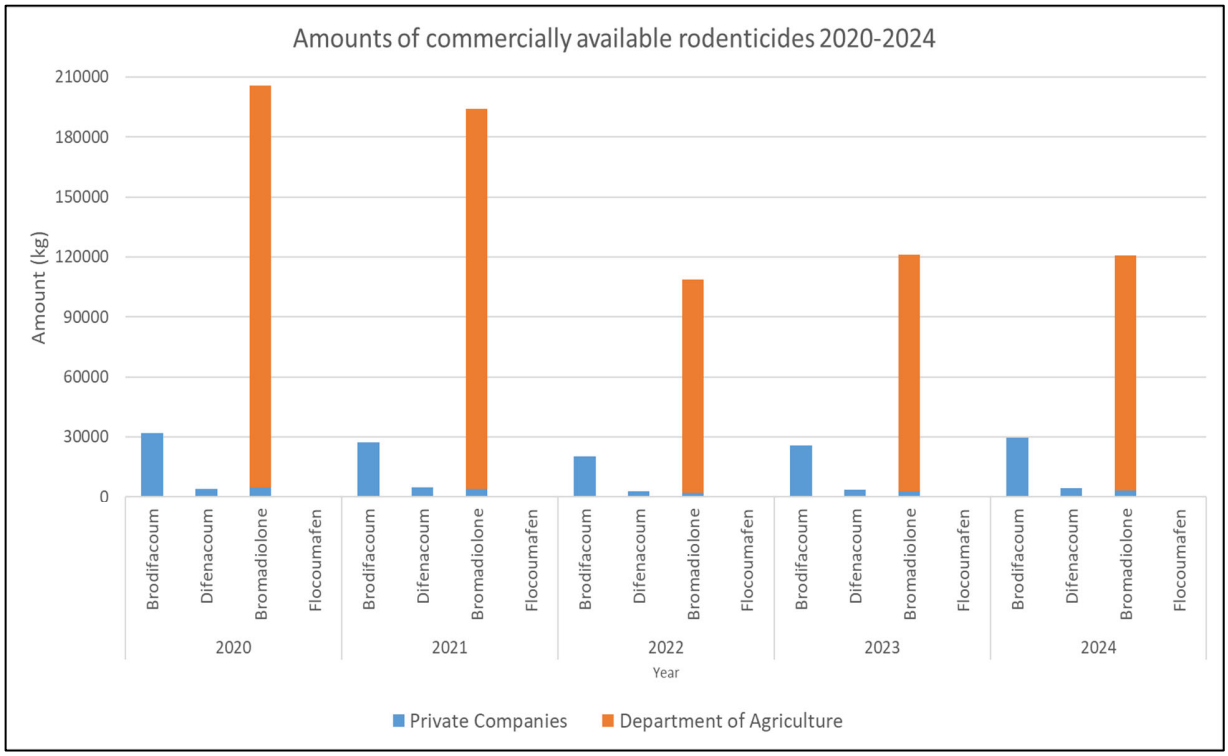


Figure 2: Combined bar graph showing the quantity of the different types of commercially available rodenticides sold or provided legally by the Department of Agriculture during 2020-2024.

2.3 Difenacoum

Difenacoum is a second-generation anticoagulant rodenticide commonly used in pest control products. It is regulated as a biocidal product under the EU Biocidal Products Regulation[2] and is available only under authorized conditions to minimize risks to non-target species. Difenacoum is only available for commercial use through authorised companies, and its sales make up between 7-10% of the rodenticide market in Cyprus, amounting to sales of 2,935 kg – 4,636 kg during 2020 – 2024 (Figure 2)[5].

[4] 2025, personal communications of authors with the Department of Agriculture (Unpublished data).
[5] 2025, personal communications of authors with the Department of Agriculture (Unpublished data).

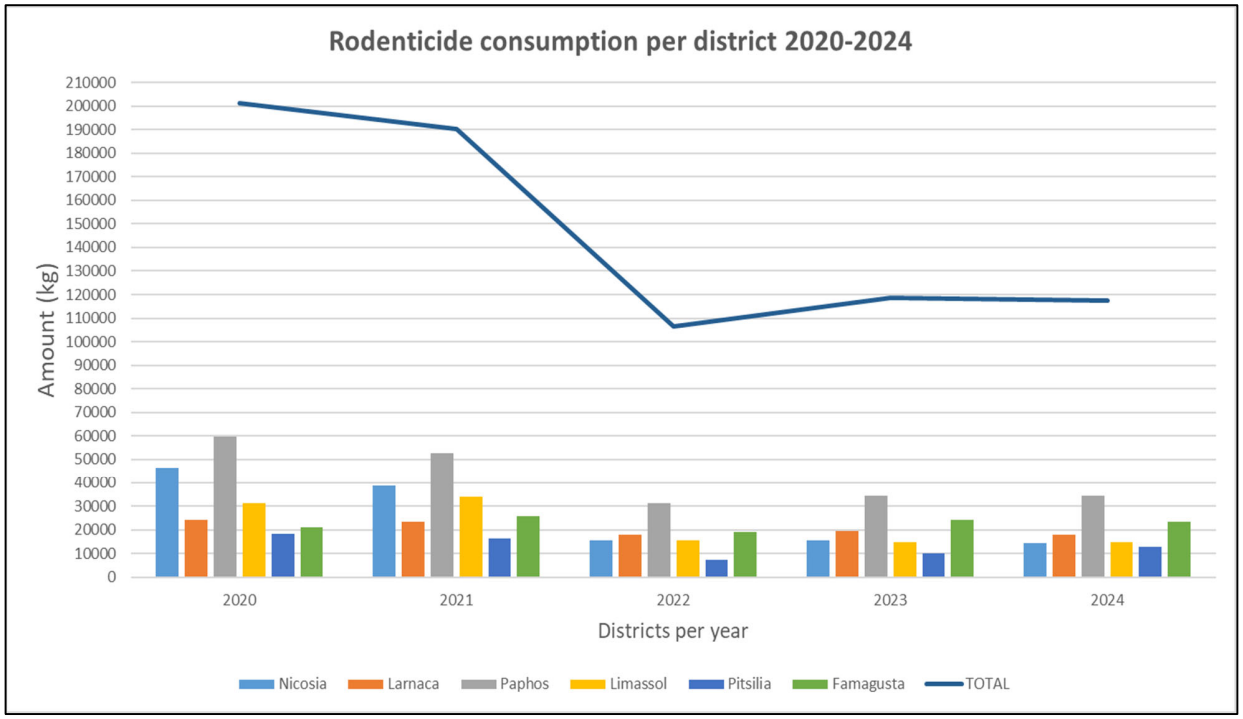


Figure 3: Rodenticide consumption per district between 2020-2024. The data per district are only available for the rodenticide provided by the Department of Agriculture.

2.4 Flocoumafen

Flocoumafen is a potent anticoagulant used in rodent control, often in bait formulations. Its use is tightly regulated in Europe, classified as a restricted biocidal product, with specific authorization requirements to prevent environmental contamination and accidental poisoning. Flocoumafen is only available for commercial use through authorised companies, and its sales make up 1% of the rodenticide market in Cyprus, amounting to sales of 370 kg – 680 kg during 2020 – 2024 (Figure 2)[5].

2.5 Carbofuran

Carbofuran is a highly toxic carbamate insecticide (chemicals that affect the nervous system) and acaricide (substance poisonous to mites or ticks) used in agriculture and pest control in the past. Its use has been banned or severely restricted across Europe (Regulation (EC) No 1107/2009) since 2008 due to its high toxicity to humans, wildlife, and the environment.

2.6 Methomyl

Methomyl is also a carbamate insecticide used to control a variety of pests (mainly arthropods). In Europe, it is banned under EU pesticide regulations since 2009 (Regulation (EC) No 1107/2009) due to its high toxicity to humans, non-target organisms, and potential environmental hazards.

3. Methodology

3.1 Bird sample collection

The methodology for bird collection was opportunistic. Birds were either located and collected by the Game and Fauna Service or BirdLife Cyprus staff members or collected after reports by the public. Birds were either injured or dead. Bird carcasses were stored at –18°C until necropsy by the Veterinary Services and analysis at the State General Laboratory. Biological samples used for toxicological screening included liver, intestine, stomach, brain, and heart. If the birds were found injured, they were transferred to the wildlife rehabilitation centre of the Game and Fauna Service. Birds were collected only in the areas under the effective control of the Government of the Republic of Cyprus.

3.2 Toxicological analysis

The State General Laboratory (Toxicology Lab) tested the biological samples of the birds. The samples (mainly gastric content and liver) were homogenized and then divided into two parts.

One part of the sample was screened for presence of carbamates (Methomyl and Carbofuran) on Shimadzu GCMS-EI-QP 2010, in scan mode using a simple extraction method with Ethyl Acetate and a separation column DB-5MS (30m 0.250mm x0.25µm).

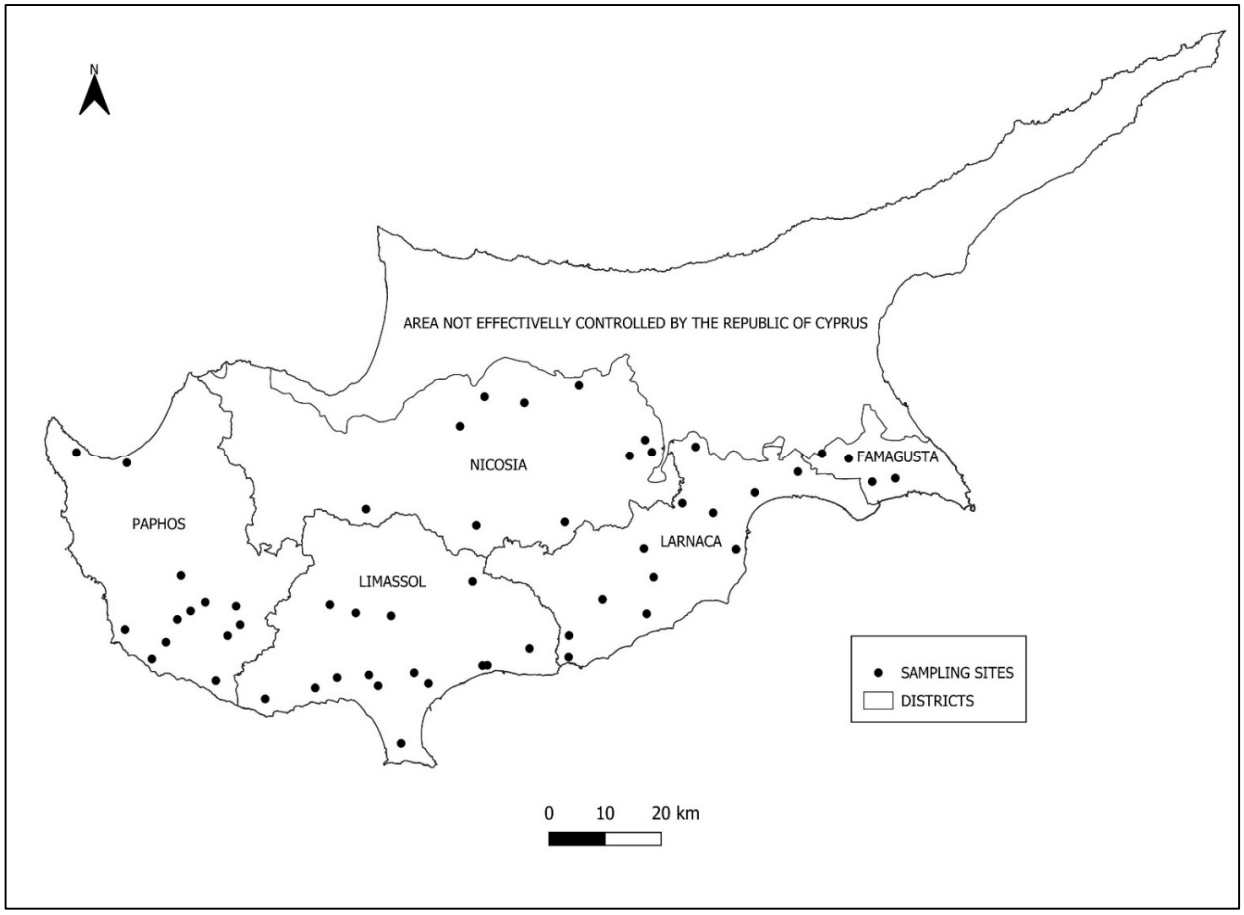
The second part of the sample was subject to targeted testing for the presence of traces of carbamates (Methomyl, Carbofuran) and anticoagulant rodenticides (Brodifacoum, Bromadiolone, Difenacoum, Flocoumafen).

Targeted analysis was performed on an LC-MS/MS system (Sciex QTRAP 6500+) using an electrospray ionization (ESI) probe, operated in both negative (ESI-) and positive (ESI+) polarity modes. Homogenized samples from stomach content/liver were spiked with 20 µl of warfarin-d5 as internal standard (concentration:200 ng/ml) and extraction was performed with 5 ml Ethyl Acetate with the addition of 200 µl of phosphate buffer pH 3, mixed, vortexed for 10 min and centrifuged for 10 min at 4500 rpm at 7°C. The upper organic layer was evaporated to dryness under nitrogen stream. Extracts were reconstituted in 100 µl of methanol and vortexed well prior to analysis. Chromatographic separation of analytes was achieved using 10mM Ammonium acetate pH 7.5 (mobile phase A) and Methanol (mobile phase B) and a Zorbax Eclipse Plus, 1.8 µm RRHD, 2.1 x 50 mm column.

4. Results

4.1 Sampling distribution

Since the sampling was opportunistic, the geographical distribution of samples was not uniform across all districts. A total of 118 wild bird samples were collected, with some locations having multiple birds. Map 1 shows that while sampling locations were distributed throughout the island, there was a noticeably higher concentration in the western and southern regions, particularly within the Paphos and Limassol districts. This pattern may reflect either a greater prevalence of incidents in these areas or higher public awareness and reporting activity. Distinguishing between these factors lies beyond the scope of this report.



Map 1: Map showing all sampling locations.

4.2 Cause of injury or death

In most cases (92 samples), the cause remained unknown, representing nearly four-fifths of all records and highlighting the difficulty in determining precise mortality factors for many individuals. Among the identified causes, roadkill was the most frequent, accounting for 13 cases, suggesting that vehicle collisions continue to pose a significant threat to birds, particularly those using roadside habitats. The extensive road system on the island, within agricultural but also

natural habitats increases the collision risk, especially for nocturnal species. Illegal shooting was confirmed in 4 cases, while weakness or emaciation was reported in 3 individuals, likely reflecting underlying ecological stress or secondary poisoning effects. Single cases were also attributed to wing fracture, bruising, collision with windows, industrial oil contamination, poisoning, and electrocution, each representing isolated but important causes of injury or mortality. Overall, while the high number of unknown cases limits detailed interpretation, the results indicate that anthropogenic factors such as road traffic and illegal shooting remain notable sources of bird mortality in Cyprus.

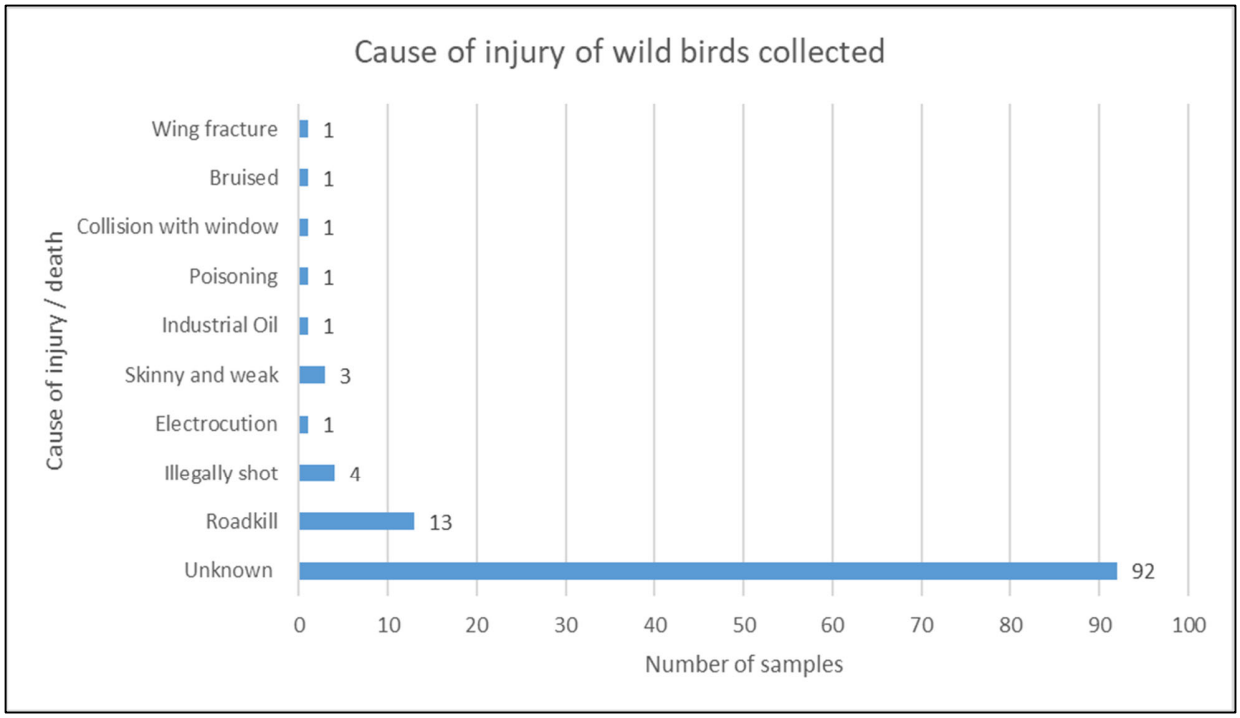


Figure 4: Bar graph showing the causes of injury / death that lead to the collection of bird samples.

4.3 Species of birds collected

Samples (total 125) from 15 different bird species were collected and analysed (Figure 5). Apart from one Night Heron (*Nycticorax nycticorax*), the rest of the samples were raptors. Most of the samples were Barn Owls (n=51), followed by Long-eared Owls (n=20), Common Kestrels (=9), Bonelli's Eagle (n=7) and Long-legged Buzzard (=7). Fewer samples were also collected from Goshawk (n=6), Common Buzzard (n=6), Scops Owl (n=5), Sparrowhawk (*Accipiter nisus*) (n=4), Little Owl (n=3), Hen Harrier (*Circus cyaneus*) (n=3), Black-winged Kite (*Elanus caeruleus*) (n=1), Eleonora's Falcon (*Falco eleonorae*) (n=1) and Peregrine Falcon (*Falco peregrinus*) (n=1).

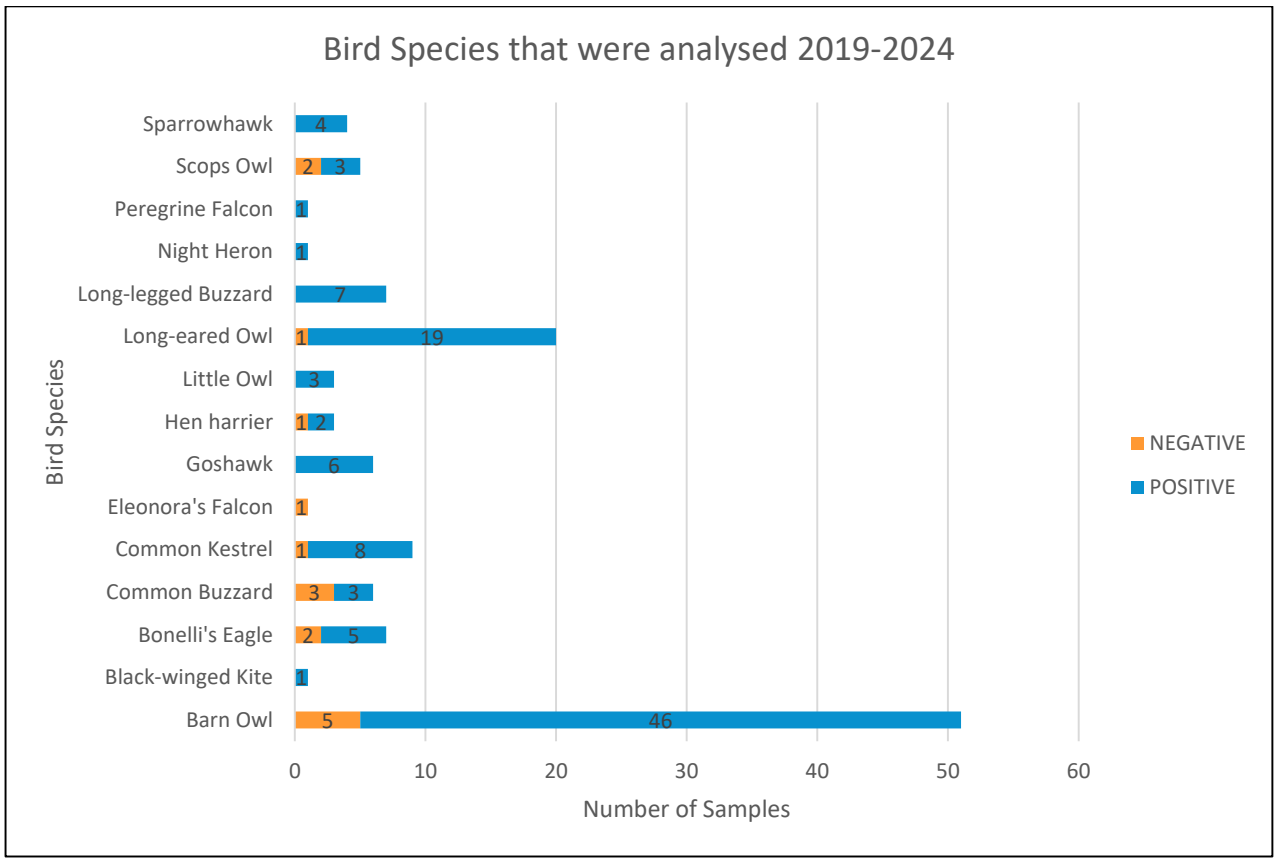


Figure 5: Bar graph showing how many individuals of each species from those collected produced or positive results when analysed for targeted toxic substances between 2019-2024.

Most birds (89%) tested positive for at least one type of poison (Figure 6). Among these, 24% contained residues of a single biocide, while 18% showed exposure to two types, and 22% to three different compounds. A further 21% tested positive for four types of poison, and 4% contained residues of five biocides. Notably, no sample tested positive for all six biocides. These results indicate widespread multi-compound exposure, suggesting that most individuals were subjected to complex contamination scenarios rather than isolated poisoning events.

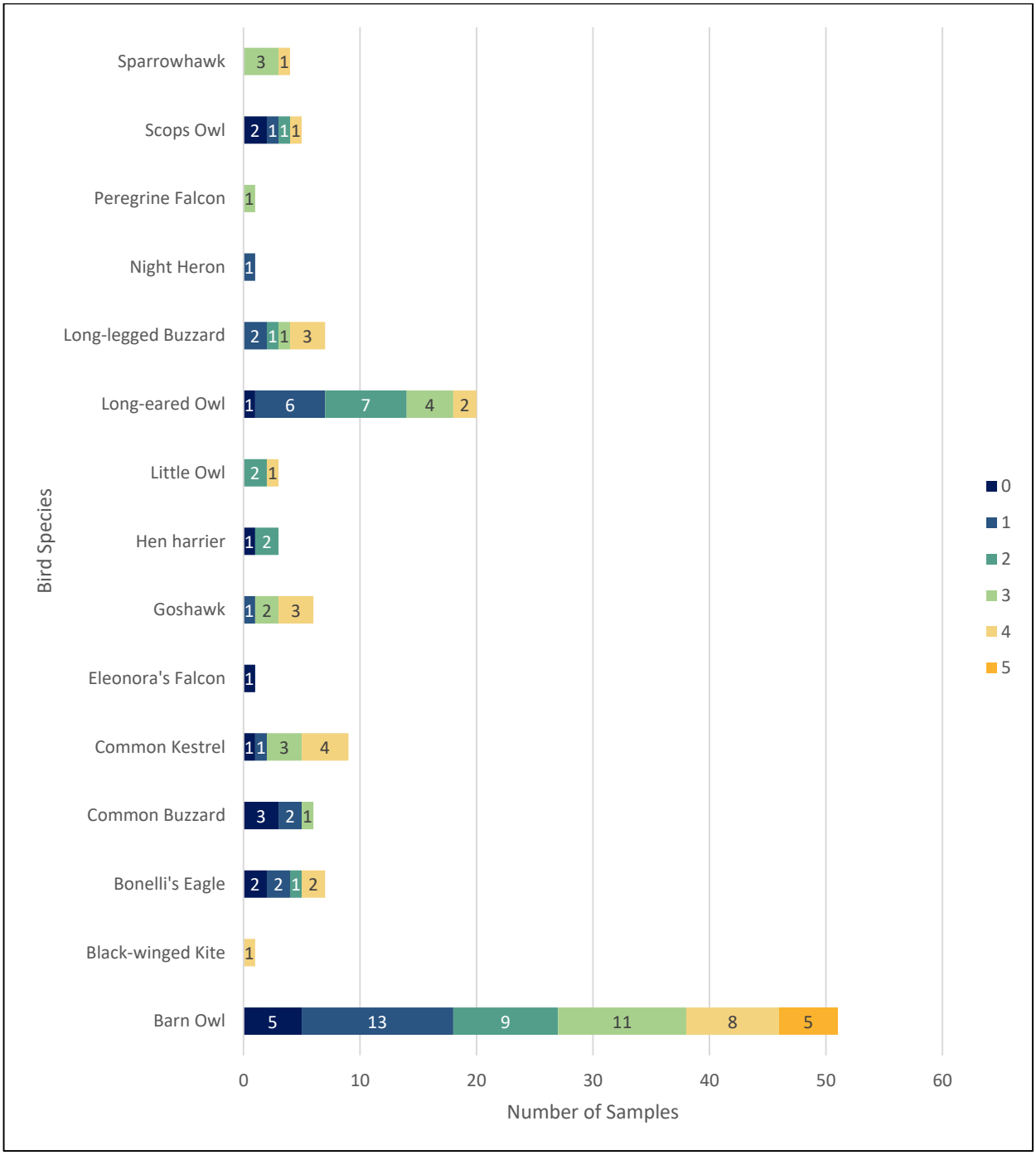


Figure 6: Bar graph showing the frequency of biocide detections across bird species, indicating the number of different SGAR substances detected per sample.

The most frequently detected biocide was Bromadiolone and Brodifacoum with 78 and 68 detections respectively (Figure 7). This pattern is consistent with market data, as these two compounds together account for 67–81% of the rodenticide market in Cyprus (Figure 2). Bromadiolone, is also distributed directly by the Department of Agriculture, with annual quantities ranging from 201,150 kg in 2020 to 117,600 kg in 2024 (Figure 3), which are additional

to the amounts available privately in the market. Of particular concern is the detection of Methomyl in 45 samples, despite its ban on use and sale since 2009, indicating that illegal use and / or possible persistence in the environment exists. Flocoumafen was detected more frequently than expected, considering that it represents only about 1% of the national market, with private sector sales ranging from 370 kg – 680 kg between 2020-2024 (Figure 2). These findings highlight both the dominant environmental presence of the most widely used anticoagulants and the ongoing risks posed by banned substances that possibly remain in circulation.

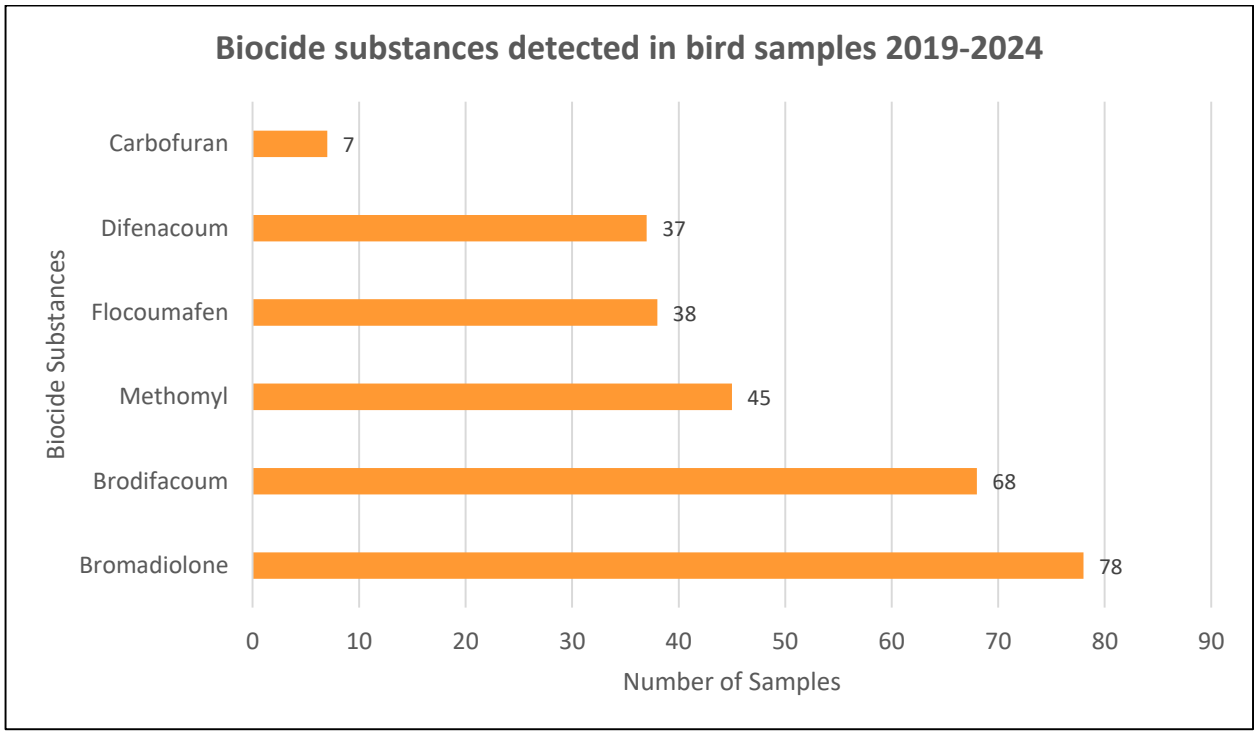


Figure 7: Bar graph showing the different biocides that were detected in bird samples between 2019-2024.

The following subsections summarize the main findings for each species, emphasizing differences in exposure patterns according to diet and ecology.

4.3.1 Barn Owls

Out of 51 Barn Owls samples, 46 tested positive to toxic substances and just 5 were negative for detection of biocides. This is especially worrisome when we consider that 97 % of the species diet comprises of rodents[6], making Barn Owls particularly susceptible to rodenticides.

The analysis of rodenticide and insecticide residues in Barn Owls showed notable differences in exposure patterns (Figure 8). Bromadiolone shows a high frequency of occurrence, with over three quarters of the samples testing positive, indicating significant exposure to this anticoagulant rodenticide. Brodifacoum is also frequently detected, with more than half the samples testing

[6] Moysi, M., Christou, M., Goutner, V., Kassinis, N. and Iezekiel, S., 2018. Spatial and temporal patterns in the diet of barn owl (Tyto alba) in Cyprus. Journal of Biological Research-Thessaloniki, 25, pp.1-8.

positive, suggesting consistent exposure to multiple anticoagulant compounds. This is not surprising, as Bromadiolone and Brodifacoum are the most used chemicals on the island. Flocoumafen exhibits a near equal distribution with almost half the samples testing positive, implying high exposure levels, relative to the chemicals availability in the market. Difenacoum is detected less frequently (37% positives), indicating lower exposure or less use in the environment. In contrast, insecticides such as Methomyl and Carbofuran show significantly lower detection rates, with Methomyl being positive in only 11 samples and Carbofuran detected in just 2 positives. However, both these substances are illegal to use, therefore their detections, (even if in relative low numbers when compared to the other substances) present a worrying trend. These findings suggest that Barn Owls are predominantly exposed to anticoagulant rodenticides, likely due to their predation on contaminated prey, while insecticide exposure appears comparatively minimal. This pattern underscores the ecological risk associated with anticoagulant rodenticides in the environment, as well as the toxicity of the already banned substances which are still available in the environment, despite their ban 16 and 17 years ago.

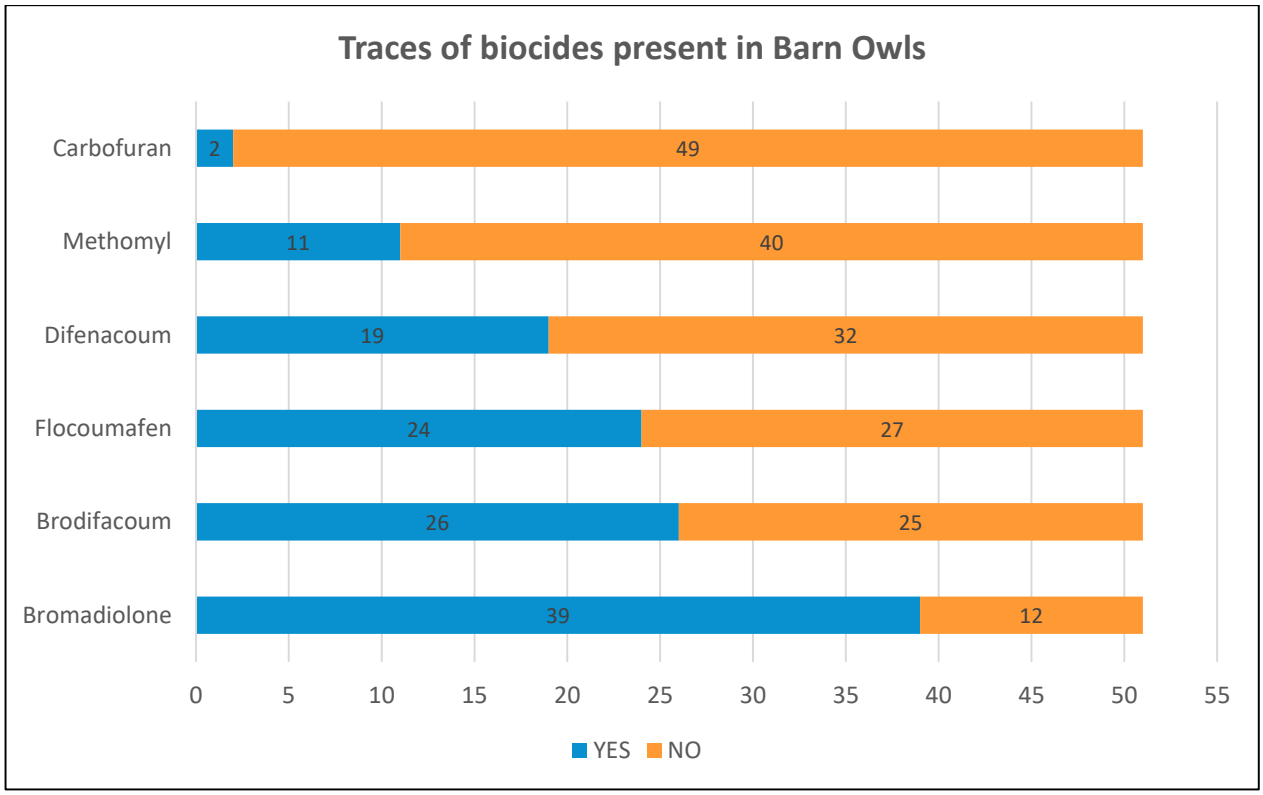


Figure 8: Combined bar graph showing the different types of biocide substances detected in the samples of Barn Owls.

4.3.2 Long-eared Owls

Out of 20 samples of Long-eared Owls, only 1 was negative (Figure 5). This is particularly concerning as the species is known to primarily feed on rodents[7]. Although no diet studies are available for this species in Cyprus, it is expected that their diet does not vary significantly from

[7] Birrer, S., 2009. Synthesis of 312 studies on the diet of the Long-eared Owl *Asio otus*. Ardea, 97(4), pp.615-624.

that in other parts of the world. Most of the samples tested positive for Bromadiolone and Brodifacoum (Figure 9) which are the most used rodenticides in Cyprus (Figure 2). High numbers of Methomyl detection (n=8) highlights the risk that top predators face through bioaccumulation, as well as the presence of these substances in the environment, many years after their prohibition.

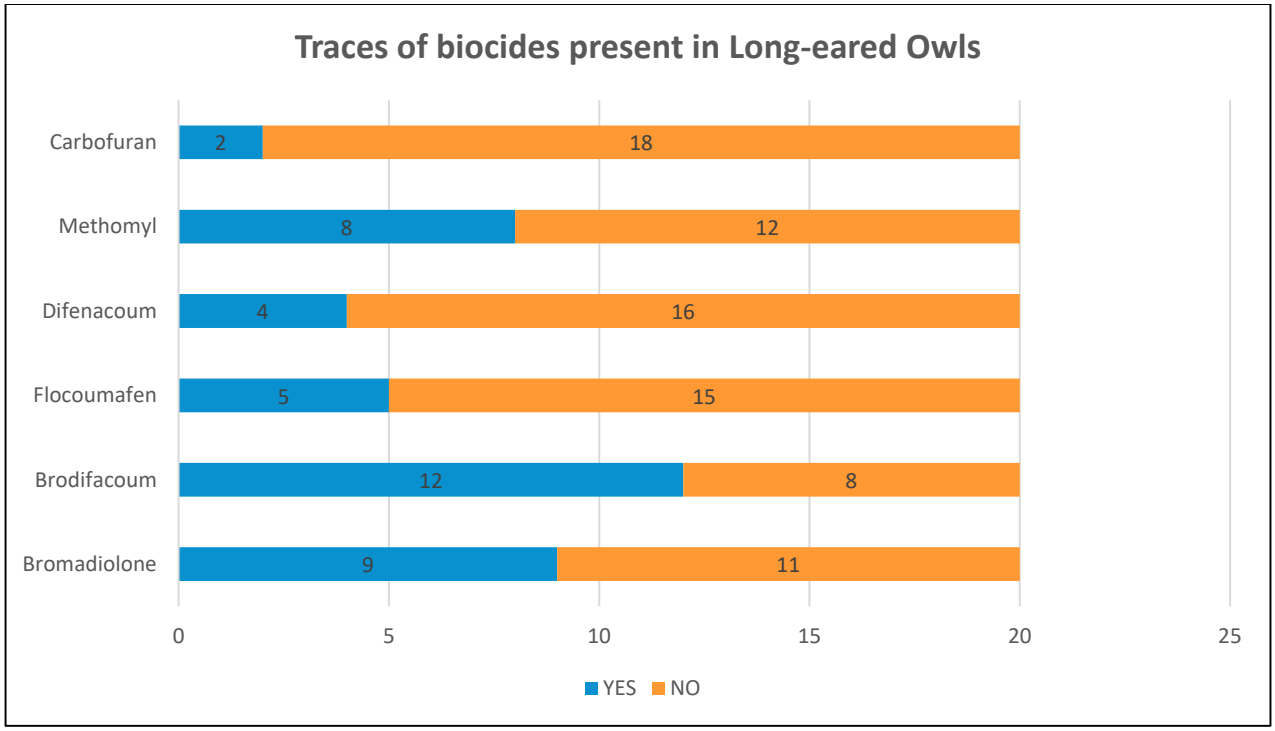


Figure 9: Combined bar graph showing the different types of biocide substances detected in the samples of Long-eared Owls.

4.3.3 Common Kestrel

Out of 9 Common Kestrel samples, only 1 was negative (Figure 10). This result is surprising, since the diet of the species comprises mostly of insects (89.9% in South East Spain, 89% in Tenerife).[8,9] Although no diet studies are available for this species in Cyprus, it is not expected that the diet varies significantly from those in other Mediterranean countries. It is particularly concerning that 7 samples tested positive for Methomyl, a substance that is forbidden to buy and use in Cyprus since 2009. Furthermore, Common Kestrels in Cyprus are more frequent in urban areas, therefore the fact that this species was exposed to many biocide chemicals, shows that the use of rodenticides spans into urban areas as well.

[8] Orihuela-Torres, A., Perales, P., Rosado, D. and Pérez-García, J.M., 2017. Feeding ecology of the Common Kestrel *Falco tinnunculus* in the south of Alicante (SE Spain). Revista Catalana d'Ornitologia, 33, pp.10-16.
[9] Carrillo, J., González-Dávila, E. and Ruiz, X., 2017. Breeding diet of Eurasian kestrels *Falco tinnunculus* on the oceanic island of Tenerife. Ardea, 105(2), pp.99-111.

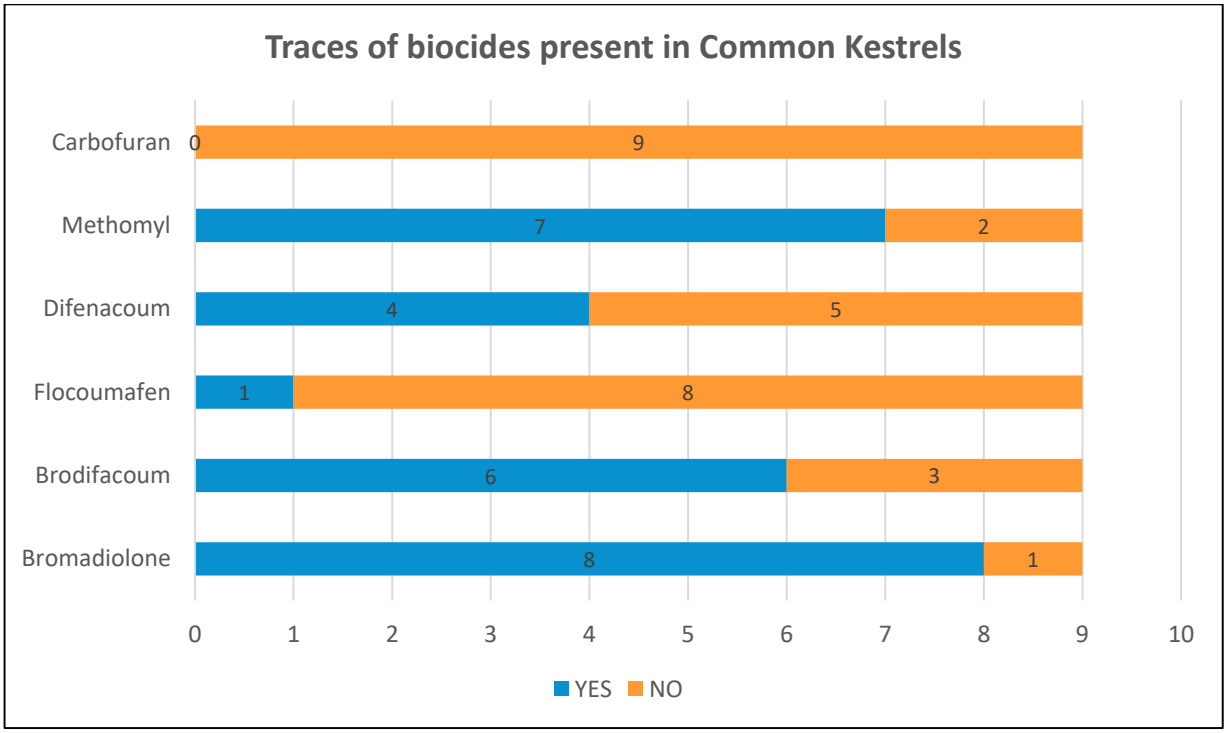


Figure 10: Combined bar graph showing the different types of biocide substances detected in the samples of Common Kestrels.

4.3.4 Bonelli's Eagle

Out of 9 Bonelli's Eagles samples, 6 were positive (Figure 11). This finding is particularly worrying given that Bonelli's Eagle is a top predator and a flagship raptor species for Cyprus, occupying the highest trophic level in the food chain. Considering that Black Rat (*Rattus rattus*) represents around 15-30% (depending on the season) of the species' diet[10][11], the presence of Bromadiolone in 5 samples and Brodifacoum in 4, indicates a significant exposure to SGARs, reflecting the species' diet and potentially the longevity, as well as the bioaccumulation capacity of these chemicals. Flocoumafen was detected in 2 samples, while Difenacoum, Methomyl, and Carbofuran were each detected once. The simultaneous detection of multiple biocides, points to the prevalence of these chemicals in the environment. Given the relatively small population size and territorial habits of this species, exposure to multiple biocides could have serious implications for long-term survival and reproductive success.

[10] Iezekiel, S., Bakaloudis, D.E. and Vlachos, C.G., 2004. The diet of the Bonelli's eagle *Hieraaetus fasciatus* in Cyprus. Raptors worldwide, pp.581-587.

[11] Panta, E. et al. (2025) The diet of the Bonelli's Eagle (*Aquila fasciata*) in Greece and Cyprus. In: Book of abstracts of the 16th International Congress on the Zoogeography and Ecology of Greece and Adjacent Regions. (Eds Pafilis P., Georgiadis Ch., Valakos E.D.) 2025: p.145

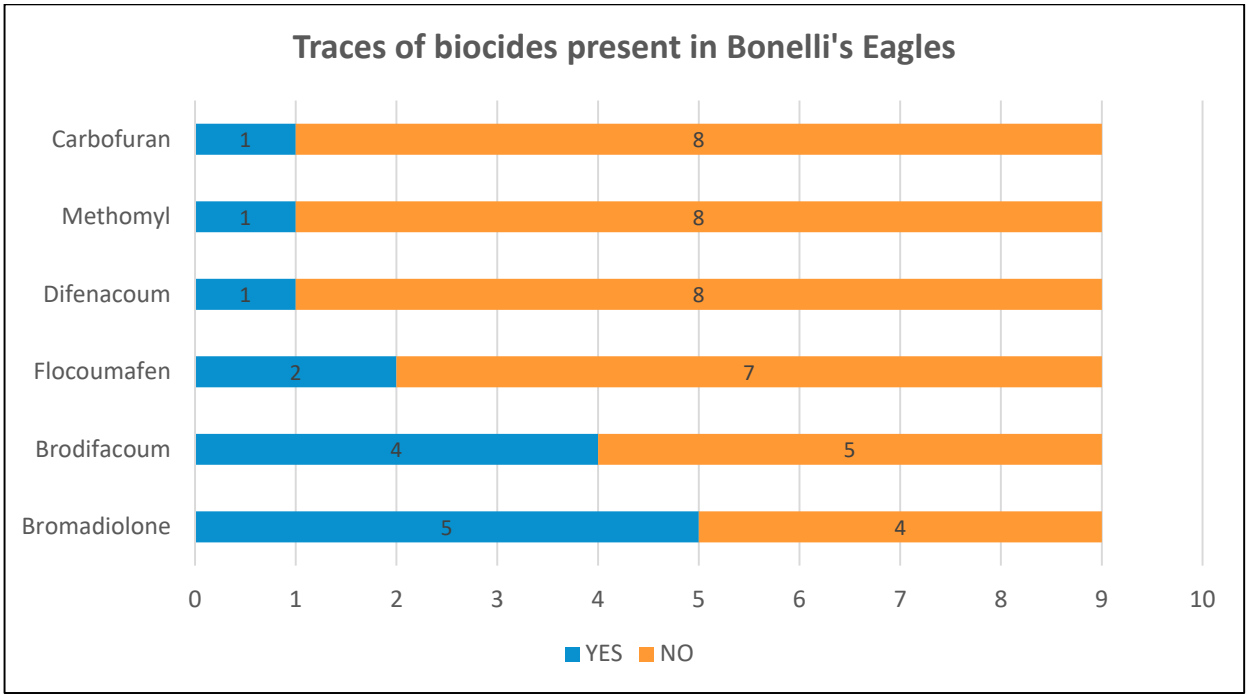


Figure 11: Combined bar graph showing the different types of biocide substances detected in the samples of Bonelli's Eagles.

4.3.5 Long-legged Buzzard

Out of 7 Long-legged Buzzard samples, none were negative (Figure 12). Bromadiolone and Difenacoum were most frequently detected (n=5), followed by Brodifacoum (n=4), Methomyl (n=3) and Flocoumafen (n=2). These results are particularly worrying, as studies in Cyprus indicate that rodents comprise 63% of the species' diet[12].

[12] Kassinis, N.I., Tzirkalli, E., Miltiadou, M., Moysi, M., Charalambidou, I., Roulin, A. and Vogiatzakis, I.N., 2022. Feeding ecology of the long legged buzzard and diet overlap with sympatric Bonelli's eagle on Cyprus. Journal of Raptor Research, 56(3), pp.333-345.

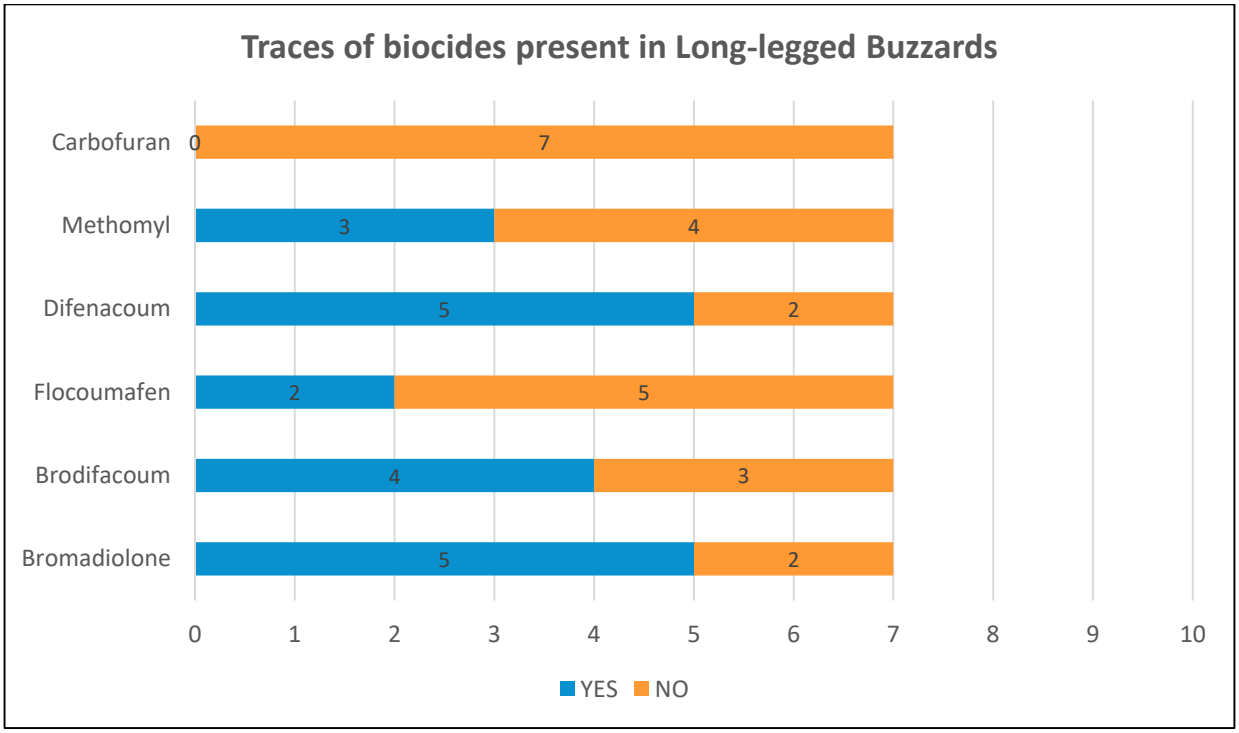


Figure 12: Combined bar graph showing the different types of biocide substances detected in the samples of Long-legged Buzzards.

4.3.6 Goshawk

All of the Goshawk samples (n=6) were positive (Figure 13). This result is particularly noteworthy considering that the diet of the species consists primarily of other birds, with mammals making up around 42% of their diet[13] (studies from Spain). Based on studies in Spain, Goshawks' main mammalian prey is European Rabbit (*Oryctolagus cuniculus*) and Red Squirrel (*Sciurus vulgaris)*, while rats (*Rattus* sp.) represent less than 2% of their diet, and in more recent studies, as low as 0.2%[14]. To our knowledge, there isn't any publication focusing on the diet of the species in Cyprus. Although it is ecologically specialized for avian prey, evidence shows that the Goshawk can adapt to changes in prey species abundance and may consume non-preferred prey at low frequencies. Therefore, SGAR exposure in Cyprus could reflect either increased rodent consumption relative to other regions or bioaccumulation. Notably, all individuals tested positive for one or more SGAR substances.

More specifically, Bromadiolone was detected in all 6 samples, and Brodifacoum in 5, Flocoumafen and Difenacoum were each detected in 3 samples, while Methomyl was

[13] Manosa, S., 1994. Goshawk diet in a Mediterranean area of northeastern Spain. Journal of Raptor Research, 28(2), p.3.

[14] Rebollo, S., García-Salgado, G., Pérez-Camacho, L., Martínez-Hesterkamp, S., Navarro, A. and Fernández-Pereira, J.M., 2017. Prey preferences and recent changes in diet of a breeding population of the Northern Goshawk *Accipiter gentilis* in Southwestern Europe. Bird Study, 64(4), pp.464-475.

found in 2. No detections of Carbofuran were recorded. These results indicate that Goshawks are likely exposed by consuming contaminated avian prey rather than rodents directly. The high frequency of multiple anticoagulant detections suggests that biocide residues are pervasive across trophic levels, reaching even bird specialist predators. This is alarming, as it demonstrates that non-target species with minimal dependence on rodent prey are nonetheless accumulating these toxic substances.

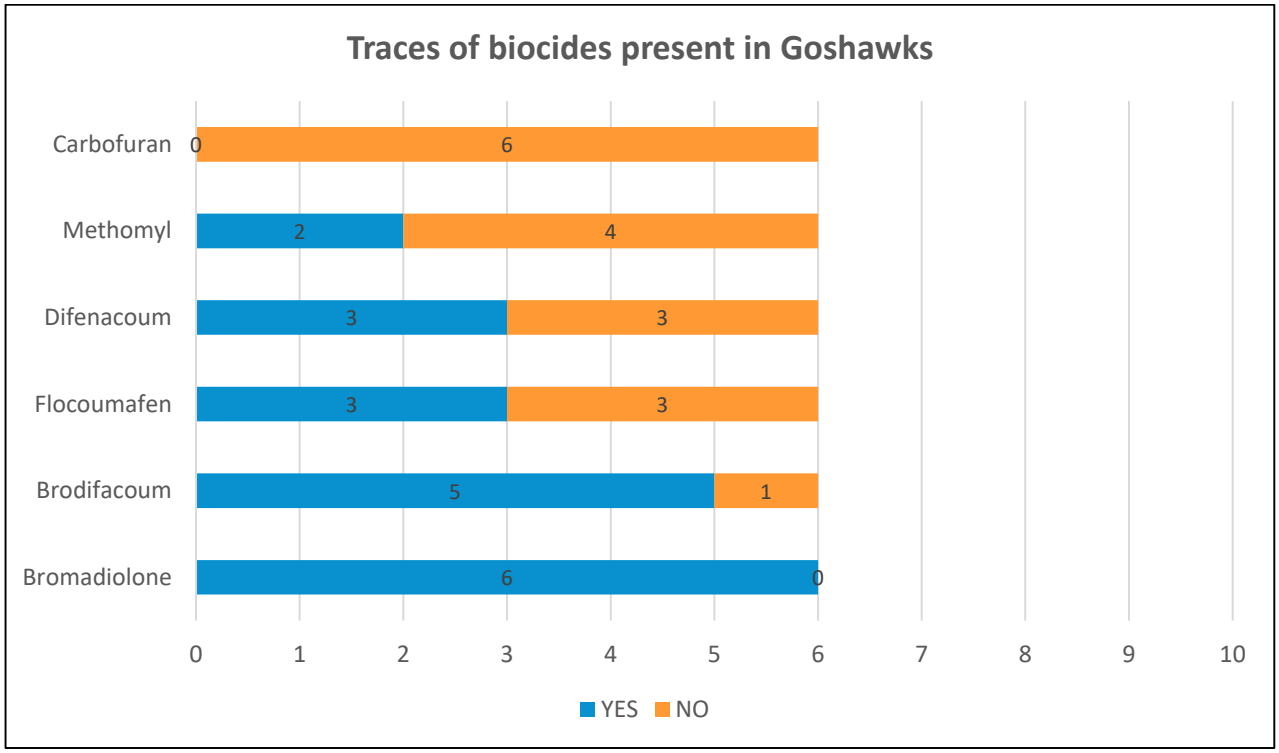


Figure 13: Combined bar graph showing the different types of biocide substances detected in the samples of Goshawks.

4.3.7 Common Buzzard

Out of 6 Common Buzzard samples, 3 tested positive (Figure 5). Bromadiolone and Brodifacoum were each detected in 2 samples, while Flocoumafen, Difenacoum, and Methomyl were not detected in any. The relatively low detection rate of biocides in this species may be explained by its feeding ecology, as arthropods constitute approximately 73% of the Common Buzzard's diet, while small mammals such as mice and rats account for less than 3%[15]. Consequently, exposure to rodenticides through contaminated prey is expected to be limited. However, given the small sample size, these results should be

[15] Manosa, S. and Cordero, P.J., 1992. Seasonal and sexual variation in the diet of the common buzzard in northeastern Spain. Journal of Raptor Research, 26(4), p.5.

interpreted with caution, as they may not fully reflect the true level of exposure within the wider population.

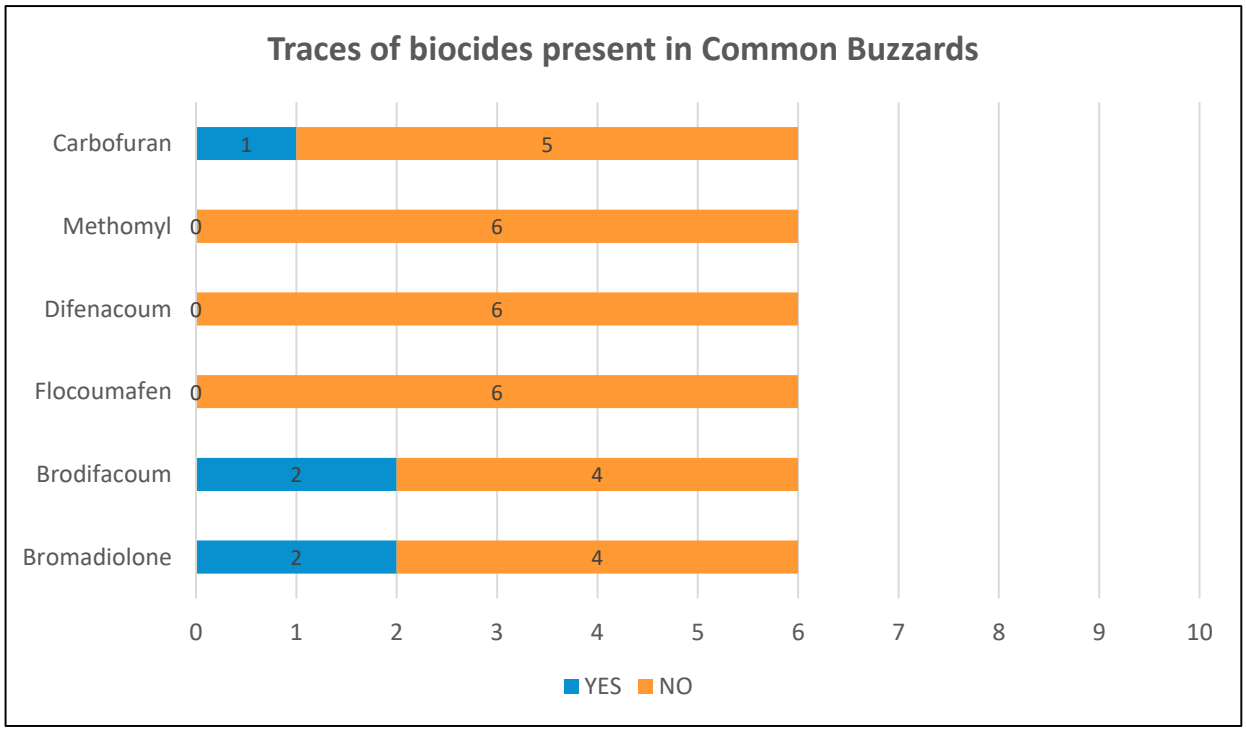


Figure 14: Combined bar graph showing the different types of biocide substances detected in the samples of Common Buzzards.

4.3.8 Scops Owl

It was not possible to confidently distinguish between the Cyprus Scops Owl (*Otus cyprius*) and the European Scops Owl (*Otus scops*), as samples were found in different levels of decomposition, but since their dietary composition is broadly similar[16], the results are presented collectively in this report.

Out of 5 Scops Owl samples, two tested negative for all substances (Figure 5). Given that the diet of Scops Owls consists of a combination of small mammals, reptiles, and insects[17,18], it is not surprising that both rodenticides and insecticides were detected among the positive samples (Figure 15). Due to the small sample size, the findings should be interpreted with caution. Nevertheless, the presence of biocide residues even in this limited dataset highlights potential exposure risks for the species. Further studies, particularly focused on the endemic Cyprus Scops

[16] Latková, H., Sándor, A.K. and Krištín, A., 2012. Diet composition of the scops owl (*Otus scops*) in central Romania. Slovak Raptor Journal, 6(2012), pp.17-26.
[17] Kassinis, N., Alivizatos, H., Christou, A., Charalambides, M. and Tölgyesi, Z., 2024. Food habits of the endemic Cyprus scops owl (*Otus cyprius*) during the breeding season. Slovak Raptor Journal, 18(1), pp.1-7.
[18] Jusztin B 2022: Eurasian Scops Owl (*Otus scops*) (Linnaeus, 1758) 40–61. In: Haraszthy L & Bagyura J (eds): Birds of Prey and Owls in Hungary. Volume 2. Falconiformes and Strigiformes. BirdLife Hungary, Budapest.

Owl, are required to better assess contamination levels and understand the potential implications for local populations.

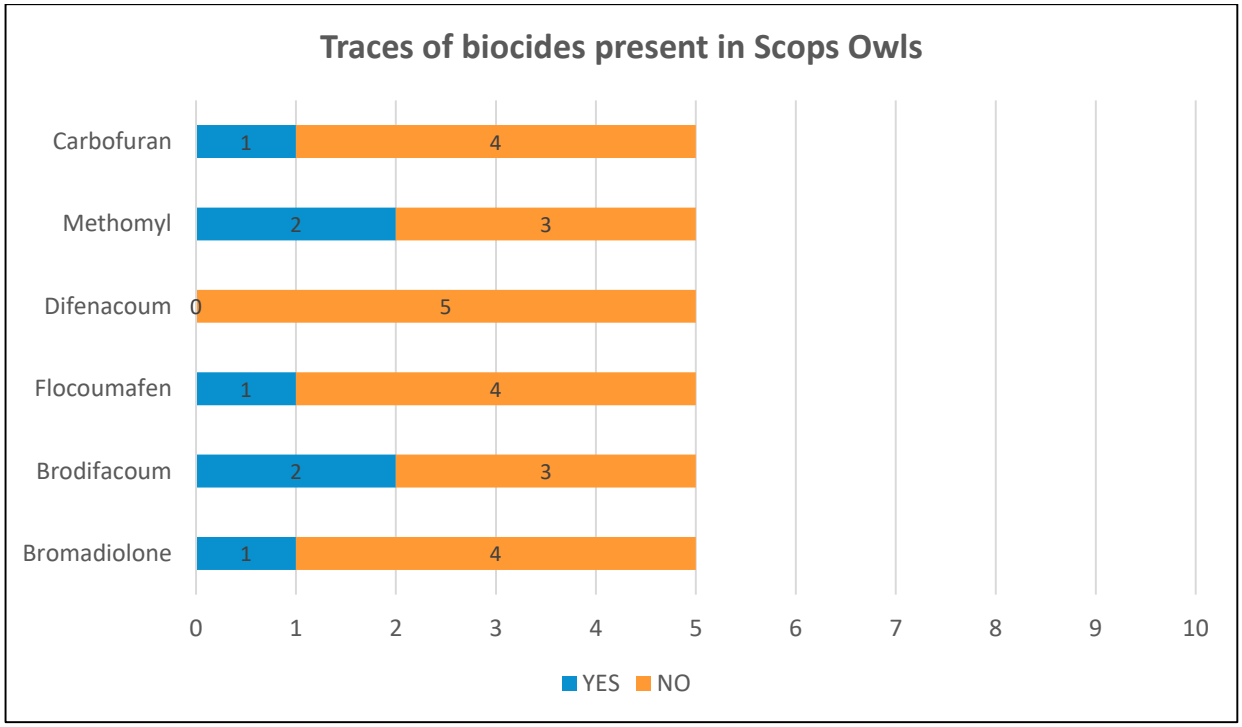


Figure 15: Combined bar graph showing the different types of biocide substances detected in the samples of Scops Owls.

4.3.9 Little Owl

All 3 Little Owl samples, tested positive for at least one biocide (Figure 5). Bromadiolone and Brodifacoum were each detected in two individuals, while Flocoumafen and Difenacoum were detected once each. Methomyl was found in two samples, whereas Carbofuran was not detected (Figure 16). Although no diet studies are available for the species in Cyprus, research from other regions indicates that mammals constitute between 37%[19] and 71%[20] of its diet, with small birds such as House Sparrows (*Passer domesticus*) making up around 12%, and the remainder consisting largely of insects. Given its partly rodent-based diet, exposure to anticoagulant rodenticides is plausible, likely occurring through the consumption of contaminated prey. The detection of Methomyl further suggests secondary exposure to banned insecticides still present in the environment. However, the very small sample size limits the ability to draw firm conclusions.

[19] Saada, I., Hammouda, A., Romanowski, J. and Selmi, S., 2024. Autumn diet of Little Owls (*Athene noctua*) in southern Tunisia. Ornis Hungarica, 32(2), pp.278-286.
[20] Chenchouni, H., 2014. Diet of the Little Owl (*Athene noctua*) during the pre-reproductive period in a semi-arid Mediterranean region. Zoology and Ecology, 24(4), pp.314-323.

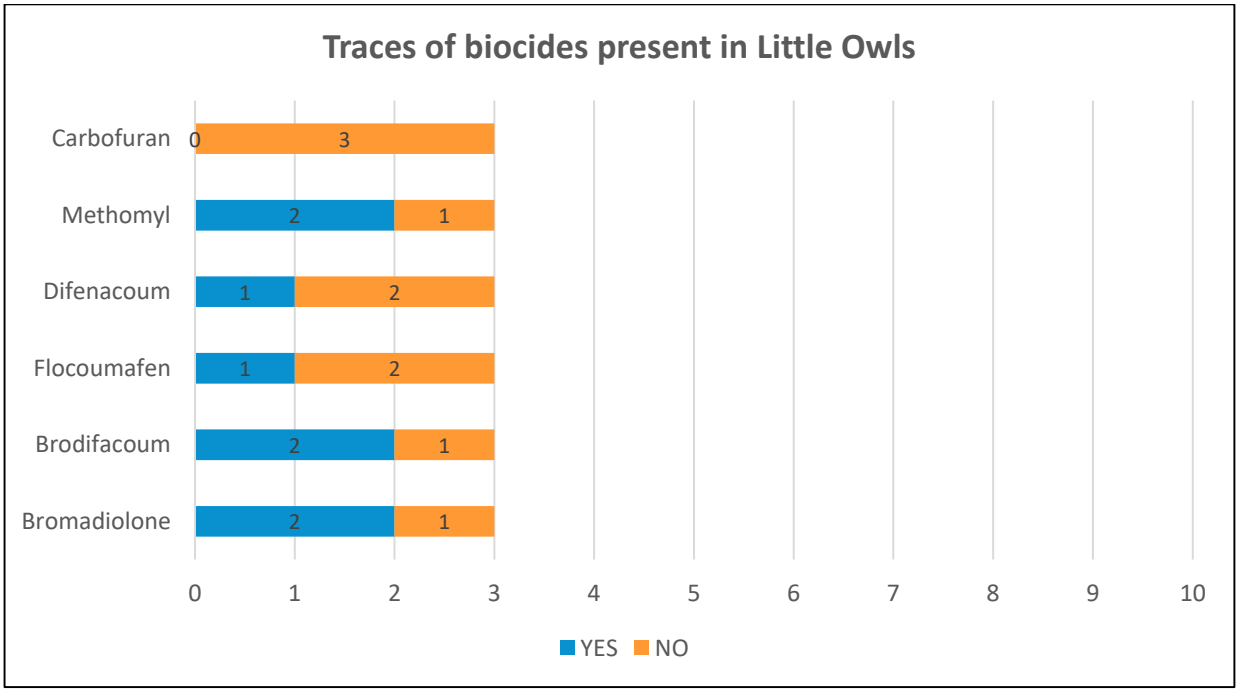


Figure 16: Combined bar graph showing the different types of biocide substances detected in the samples of Little Owls.

4.3.10 Hen Harrier

Out of 3 Hen Harrier samples, one tested negative to biocides (Figure 5). Residues of Brodifacoum and Difenacoum were each detected in one individual, while Methomyl was found in two. No detections of Bromadiolone, Flocoumafen, or Carbofuran were recorded (Figure 17). The absence of Bromadiolone, despite it being the most used rodenticide in Cyprus, is unexpected and may reflect differences in exposure pathways linked to the species' ecology. Hen Harriers are winter visitors and passage migrants, and their limited residence time on the island may reduce their likelihood of contact with locally applied rodenticides. Their diet, which includes 4–16% small mammals[21] and a large proportion of birds such as passerines (21–24%)[22], suggests that exposure is more likely to occur indirectly through avian prey rather than rodents. The detection of Methomyl, a banned insecticide, is particularly concerning, as it indicates that even transient raptors can encounter persistent or illegally used biocides. It is worth noting that since Hen Harriers are only migrating through Cyprus, it is plausible the individuals consumed biocides elsewhere. Given the very small sample size, these results should be interpreted with caution, nonetheless, they highlight the potential for contaminant exposure in migratory raptors using Cyprus as a stopover or wintering site.

[21] Redpath, S.M., Clarke, R., Madders, M. and Thirgood, S.J., 2001. Assessing raptor diet: comparing pellets, prey remains, and observational data at hen harrier nests. The condor, 103(1), pp.184-188.

[22] Ludwig, S.C., McCluskie, A., Keane, P., Barlow, C., Francksen, R.M., Bubb, D., Roos, S., Aebischer, N.J. and Baines, D., 2018. Diversionary feeding and nestling diet of Hen Harriers *Circus cyaneus*. Bird Study, 65(4), pp.431-443.

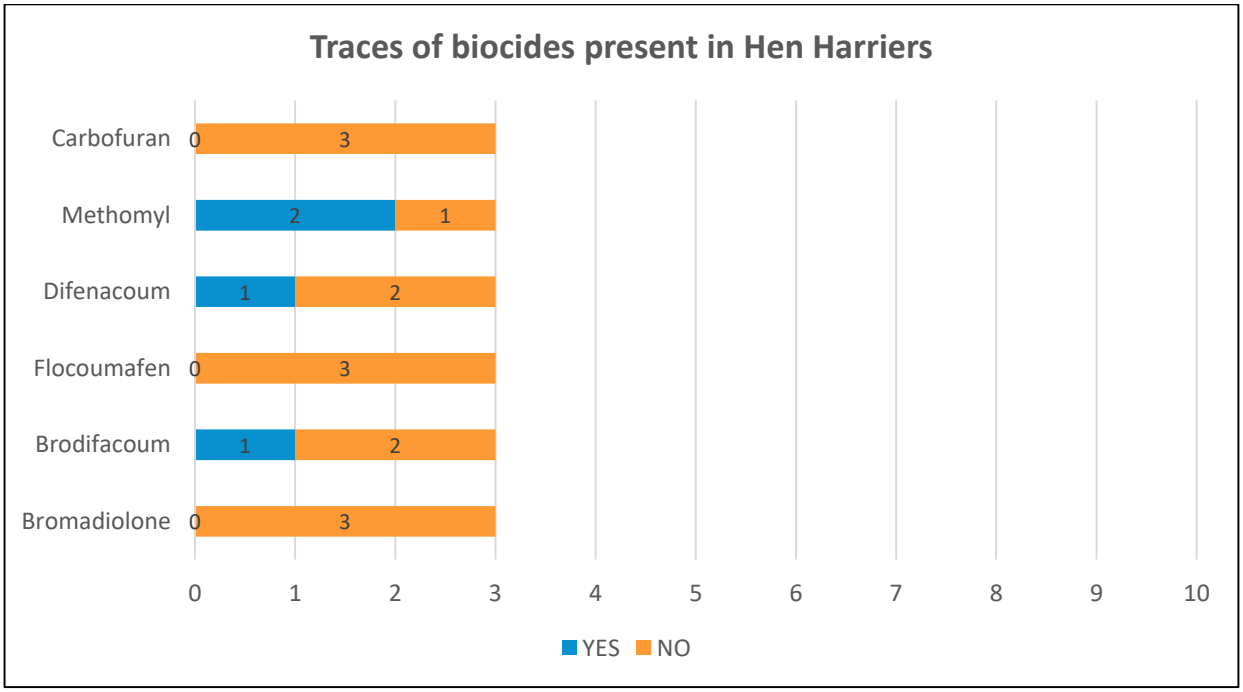


Figure 17: Combined bar graph showing the different types of biocide substances detected in the samples of Hen Harriers.

5. Discussion

These results provide important insights into the prevalence and diversity of biocides detected in raptor species in Cyprus; however, it should be emphasized that these results primarily show qualitative evidence of exposure rather than definitive proof of cause of death. Qualitative screening does not determine whether an individual died immediately following acute poisoning, was exposed to a sub-lethal dose that contributed indirectly to mortality, or accumulated residues over time through repeated low-level exposure.

Within this qualitative study, approximately 89% (106 out of 118 samples) of analysed raptors tested positive to at least one type of rodenticide, while 8% tested positive to all four SGAR substances (Figure 6). High prevalence of rodenticide in Barn Owl carcasses reflects the rodent-heavy diet of the species. SGAR residues were frequently detected in Long-eared Owls but also in larger raptors, such as Goshawks, Long-legged Buzzards, Bonelli's Eagles, and smaller species, such as Scops-owl (*Otus* sp.) and Little Owl, whose diet only partly consists of rodents. Additional necropsies (carried out before this study) conducted on Bonelli's Eagles and Long-legged Buzzards revealed secondary poisoning from SGARs as the cause of death for two individuals. The results show that rodenticide use in the Cyprus environment is widespread and affects protected species throughout the island. These findings are consistent with broader European studies showing widespread environmental persistence of SGARs, even where their use is regulated.

Each species may be vulnerable to different types of poisons depending on its ecology. For example, the Barn Owls, being a top predator that feeds primarily on rodents (97%), can be exposed repeatedly through their diet, and be susceptible to bioaccumulation. Other species, such as Long-legged Buzzards also have a high percentage of rodents in their diet (63%)[23]. This makes these two species particularly vulnerable to rodenticides.

Several types of chemicals were detected in samples, such as Bromadiolone, Brodifacoum, Flocoumafen and Difenacoum. In most cases, more than one poison was detected in the same bird individual (Figure 6). It is worth noting, that even though the most detected SGARs were Bromadiolone and Brodifacoum, which are the most numerous in terms of availability and sales (Figure 2), other chemicals had high detections, even though their availability is relatively low in comparison with Brodifacoum and Bromadiolone. For example, Flocoumafen had only 390-680 kg sales on the island during the period of 2020-2024, but 32% of our samples were found positive to Flocoumafen. This shows that even a relatively small quantity of rodenticides can still enter the food chain.

These findings have clear implications for nature conservation in Cyprus. The prevalence of legally available rodenticides (Brodifacoum, Bromadiolone, Difenacoum, and Flocoumafen) combined with the continued presence of banned substances (Methomyl and Carbofuran) points to gaps in regulation, enforcement, and public awareness. Awareness raising activities should also highlight the toxicity of these substances, not only to wildlife but also to human health. Given the urban occurrence of some exposed species (e.g., Common Kestrel) and the significant market of

[23] Kassinis, N.I., Tzirkalli, E., Miltiadou, M., Moysi, M., Charalambidou, I., Roulin, A. and Vogiatzakis, I.N., 2022. Feeding ecology of the long-legged buzzard and diet overlap with sympatric Bonelli's eagle on Cyprus. Journal of Raptor Research, 56(3), pp.333-345.

rodenticides, actions should include tightening sales authorizations, restricting access to highly toxic anticoagulants, promoting safer pest control alternatives, and enhancing monitoring of effects to non-target wildlife. Furthermore, it is necessary to integrate the above measures with species specific conservation actions, such as habitat management, to reduce the need for rodent-driven pest control.

6. Conclusions

These findings identified which SGARs were most frequently detected in raptor species in Cyprus and provide evidence to support recommendations for legal limitations on their use. Through these results, it is obvious that even banned biocides still enter the food chain, after more than a decade of prohibition. Therefore, more caution should be taken even with legally available SGARs. Stricter measures in applications could include restrictions on the amounts that non-professionals are allowed to purchase, together with requirements for more comprehensive and frequent training for professional users. Increased enforcement can also help reduce the misuse of these chemicals in the countryside, as they not only affect wildlife, but also pose a risk to human health. Further studies could also explore the examination of which rodenticides are the most toxic to wild birds, through detailed quantitative analysis to better establish causal links between chemical exposure and mortality. Ultimately, reducing secondary poisoning in Cyprus will require coordinated action combining stricter regulation, enhanced monitoring, and increased public awareness to safeguard both wildlife and human health.

Acknowledgements

The project team would like to thank the Cyprus State General Laboratory for their commitment to this project and generally for their support in nature conservation. Namely we would like to thank Katerina Liveri, Christiana Cosma, Fotini Christofi and Haris Krassos for carrying out the analysis of all the samples stated in this report. The team would also like to thank Stalo Leontiou for providing support in map creation Melpo Apostolidou and Christina Ieronymidou for reviewing earlier versions of this report.

Acknowledgment of surveyors

The completion of this work would not have been possible without the dedication of BC volunteers and staff and GFS wardens, who carried out the collections of the bird carcasses during the period 2019 – 2024: Antaia Christou, Haris Hadjistyllis, Nikos Kassinis, Pantelis Pourgouras, Romina Constantinou, Markos Charalambides, Michalis Zaharia, Zoltán Tölgyesi. We also wish to express our sincere appreciation to all members of the public who reported injured or dead birds, enabling their inclusion in this study. Their awareness and willingness to act represent a valuable contribution to citizen science and wildlife conservation efforts in Cyprus.

DISCLAIMER

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.