473
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13th European Vertebrate Pest Management Conference

- Book of abstracts -

Marco Zaccaroni, Emiliano Mori, Jens Jacob

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Preface

The European Vertebrate Pest Management Conference (EVPMC) was founded in 1997 when the first meeting was held in York, UK. Since then, the biennial conference has been the meeting place for scientists, practitioners, regulators, NGOs and industry. After many highly successful previous meetings and an unfortunate break due to the Covid-pandemic, we are happy and proud to host 13EVPMC in Florence, Italy, from 28th August to 1st September 2023.

The meeting focuses on the newest and most exciting topics covering a wide range of disciplines and taxa, including symposia on invasive vertebrates, crops and urban systems, ecology, physiology and behaviour, fertility control, rodenticide resistance, new tools and methods, zoonotic pathogens and parasites and human-animal social conflict.

About 170 participants from 30 countries present 120 talks and posters.

The international community of experts in vertebrate management and conservation share their experience and expertise, the latest advances, renew friendships and increase worldwide collaboration.

The organizers gratefully acknowledge the support of International Pest Control, Pest Management Science, Integrative Zoology, Ecommerce, Pig Bring Trap System, Botstiber Institute for Wildlife Fertility Control and Copyr.

All summaries in this book of abstracts are available online at https://evpmc2023.com.

We thank all partners and colleagues who have contributed in one way or another to the organization of 13EVPMC, especially plenary speakers, symposium chairs, and all presenters. Thank you for making 13EVPMC run smoothly and for such a wonderful experience.

Florence, August 2023

Marco Zaccaroni, Emiliano Mori, Jens Jacob

Table of contents

Ecology, physiology and behaviour – 2

Ecology, physiology and behaviour – 3

Invasive vertebrates – 1

Invasive vertebrates – 2

Invasive vertebrates – 3

Human-animal social conflict – 1

Human-animal social conflict – 2

New tools and methods: a bridge from research to pest control – 1

New tools and methods: a bridge from research to pest control – 2

Fertility control

Crops and urban systems – 1

Crops and urban systems – 2

Rodenticide resistance

Zoonotic pathogens and parasites

POSTERS

Ecology, physiology and behaviour

Invasive vertebrates

Human-animal social conflict

New tools and methods: a bridge from research to pest control

Crops and urban systems

Rodenticide resistance

Zoonotic pathogens and parasites

PLENARY TALKS

Mousy minds: intra-specific variation in behaviour and cognition in small mammals

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Cognitive abilities are part of a species' adaptation to its environment. When environmental conditions present rapid or drastic changes, behavioural and cognitive responses provide an effective buffer against these alterations. Innovation, the ability to produce new behaviours or to apply novel solutions to old problems, is a key determinant in the successful coping with environmental challenges and changes. Behavioural and cognitive trait underlying innovation propensity, however, present high among-individual variation. A better understanding of the drivers of among-individual variation in innovation propensity and its consequences will provide insights into the traits enabling animals to thrive in the face of rapid environmental change. Urban environments offer a unique opportunity to do so, by presenting dramatically altered environmental conditions for which animals lack eco-evolutionary experience. However, current research is heavily biased towards species with high dispersal abilities, namely birds and larger mammals. The potential role of innovation in coping with anthropogenic environments in species that cannot easily elude anthropogenic disturbances remains relatively uninvestigated.

Here, I focus on ground-dwelling rodents, which are often found in urban areas despite being non-commensal. Using standardized tests, I investigate the drivers of within-species behavioural variation in relation to anthropogenic environments, among-individual differences in innovation propensity and its underlying mechanisms, consistency across several types of innovation in wild populations, as well as the role of animal personality in mediating the expression of cognitive performance. Results support the hypothesis that living in human-altered environments favours increased innovation propensity, and that personality mediates cognitive performance. Among-individual variation in behaviour and cognition might thus play a key role in individuals' successful coping with the rapid and recent expansion of human-altered environments.

The role of nature conservation in pest and disease control

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Biodiversity-is-good-for-our-health has become a paradigm in disease ecology. The foundation of this paradigm is the dilution effect, a concept that predicts low disease risk in species-rich communities. The presence and abundance of non-competent reservoirs inhibits pathogen transmission via different mechanisms. For example, non-reservoir competitors can prevent pathogen transmission via encounter reduction and predators can increase mortality of infected hosts. Likewise, in disturbed and degraded habitats that often are low in biodiversity, pest species dominate over specialist species. Hence, there are multiple parallels between disease risk mitigation and pest control, especially considering that multiple pest species are also reservoirs or even hyperreservoirs. Brown rat (*Rattus norwegicus*), house rat (*R. rattus*) and house mouse (*Mus musculus*) are prominent representatives among rodents. While nature conservation is considered important for ecosystem health, there are only few principles or proofs of concepts that could guide measures towards biodiversity recovery that also mitigate disease risk and control pests. In this talk, I will elaborate on the role of biodiversity and biodiversity recovery for pest and disease control in mammals. What are the theoretical and empirical relationships? Which are the most important gaps in knowledge and how can they be filled towards effective nature-based pest and disease control? Or is the concept of nature-based solutions just a myth?

PLENARY TALKS

Global movements of migratory birds – enigmatic phenomena with implications for pest and disease management

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Billions of birds make impressive migratory movements across thousands of kilometers. Their movements link otherwise separated habitats and ecosystems through the transport of nutrients, energy, seeds, and parasites/pathogens and through interacting trophically with the diverse ecological communities along their way. These movements and their transport and trophic effects have a variety of implications for numerous ecological processes, they raise human-wildlife conflicts and provide services (pollination, seed-dispersal, pest control, nature's contribution to people) and disservices (pathogen dispersal, agricultural damage) that are essential to human agriculture, economy and health. Furthermore, in the current biodiversity crisis, many bird populations have experienced alarming declines. Quantifying populations and their movements and understanding the drivers of (changes in) their spatiotemporal distributions is key to preserving aerial and terrestrial diversity. Although the airspace is increasingly recognized as an essential habitat for a large proportion of the global biodiversity, aerial habitats are poorly monitored and largely absent from legislation and policy despite their fragmentation having a similar impact on biodiversity and ecosystem functioning like other habitats.

In my presentation, I will show recent advances in identifying individual migration routes and schedules as well as the large biomass flows of aerial migrants as the basis for understanding and predicting the services and disservices provided by migratory birds. I will take a particular example of the conflicts with agriculture that overabundant migratory bird species cause and show how the setup of management measures can be aided by theoretical models. Furthermore, I will outline the role of migratory birds in spreading parasites/pathogens, notably those with zoonotic potential and take avian influenza as a recent example.

Finally, I will show how human-wildlife conflicts in the transition to CO2-free energy production (wind energy) could be reduced with operational curtailment based on mitigation scenarios.

Too many? Eight reasons for Europe to invest in wildlife fertility control

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As human populations increase and urbanization expands, conflicts between humans and wildlife are growing. Concurrently, public attitudes are shifting, with the main focus moving from the traditional "wildlife management" to "resolution of human-wildlife conflicts" and lately to "coexistence". This is particularly relevant to Europe, where the density of the human population is relatively high and where attitudes to overabundant wildlife, catalysed by increasing wildlife economic and environmental impact such as disease outbreaks, are driving interest to invest in novel tools for mitigating human wildlife conflicts.

Conventional methods to resolve human-wildlife conflicts, such as shooting, trapping and toxicants, may be unfeasible, expensive, harmful to the environment, socially unacceptable or ineffective. In parallel, the number of hunters, traditionally involved in controlling game species like the wild boar, is decreasing throughout most European countries. In this situation, fertility control is often advocated to reduce human wildlife conflicts for several species, including native and non-native wildlife, charismatic birds and mammals and feral livestock, and for contexts such as urban areas and national parks. In recent times, the debate on rewilding has also reignited discussions on humane methods to manage overabundant animal populations.

The first part of this presentation will cover the progress made in applications of contraceptives for wildlife, with particular emphasis on Europe, and illustrate case studies where fertility control has been implemented or is being considered as alternative or complementary to culling. The second part of the talk will discuss opportunities and challenges to meet the demand for effective and safe alternatives to lethal control for managing overabundant wildlife in Europe's 21st century. The talk will end with the presentation of a road map for implementing applications of fertility control and promoting human wildlife coexistence in the landscapes we share.

PLENARY TALKS

Genetics of a common species – diversity, phylogeography and conservation of the European red deer

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The red deer (*Cervus elaphus*) is one of the most iconic and ecologically important large mammal species in Europe. While not globally endangered, a variety of anthropogenic factors contribute to an increasing number of populations becoming isolated and facing the subsequent impacts of inbreeding and genetic drift. Also, European red deer are surprisingly diverse genetically, morphologically and ecologically, which is partly a legacy of the last ice age and survival in refugial areas during the Last Glacial Maximum. In this talk, I will present a summary of the genetic structuring, phylogeography and taxonomy of this fascinating ungulate, highlighting, among other things, the importance of southern Europe, particularly Italy (including Sardinia), as a centre of diversity and endemism as well as a "genetic museum" of lineages that are extinct elsewhere. I will also give a short overview of the consequences of anthropogenic habitat fragmentation, which for red deer is the main driver of genetic depletion and sometimes even inbreeding depression.

The importance of behavioural ecology knowledge in reducing human-wildlife conflicts

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Behavioural ecology uses rigorous evolutionary reasoning to explain how individuals respond to environmental stressors modifying their behavioural patterns. In an analysis involving a group of individuals with the same characteristics, for instance sex or age classes, the variation around this assumption has been supposed to be "noise" caused by bias in data collection or caused by individual differences, which attracted little attention from researchers. In the last decades, studies on wildlife behaviour have abandoned this view and proposed a 'new' approach focused on between-individual variation and within-individual consistency, generally defined as personality. Conversely, management strategies of threatened species, as well as problematic ones, continue to propose one-size-fits-all solutions that do not consider the diverse behavioural responses of individuals. Actually, these strategies are often based on anecdotal knowledge or only partially supported by scientific evidence.

Focusing on large mammal species, this presentation will expose the results of some of the most recent scientific research on aspects of wildlife behaviour that can influence the implementation and success of pest containment strategies and the damage they cause. The examples from different European areas show that only by an increase of the knowledge on the behavioural ecology of populations, involved or not involved in control actions, it is possible to improve the success of management actions, reducing undesirable effects.

TALKS

Ecology, physiology and behaviour – 1

Bird crop depredation in Switzerland: Feeding behaviors and the influence of local and landscape habitat attributes

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Bird damage to spring crops is an increasing concern for some growers in Switzerland. Sunflower and maize are the most vulnerable crops to bird attacks at sowing and emergence, causing yield loss and cost increase due to a second sowing in extreme situations. The main bird species involved are carrion crows and rooks and, in a lesser extent, pigeons. To date, there is no single effective method to prevent bird attacks. Moreover, due to the high dispersal capacity of birds, the distribution of damage is spatially uneven: few fields are affected, but with a high severity. The current research focuses on two key behavioral aspects: 1) birds' field selection according to the habitat characteristics and the location of their nests, together with 2) their food preferences in order to identify a potential repellent.

Historical data, and surveys of rookeries during the period from 1963 to 2019, document an increase in the rook breeding population in Switzerland as well as an urbanization of nesting habitats. The effect of the proximity of rook nests on damage severity was investigated in the canton of Geneva, where a financial compensation for rook damage is available. We found that most of the damaged fields were reported within 0.5–1 km of the nearest rookery. To further identify the influence of spatial context on damage levels to crops, a coordinated field study in the cantons of Geneva, Vaud and Fribourg have started in February 2023. Spatial factors both on the farm and landscape scales such as edge effects and proportions of diverse habitat types of the surrounding landscape (e.g., forests, urban/built, farms) were documented.

The second section of the study describes birds' feeding behaviors by studying food preferences – seed type, color and taste – of wild carrion crows, with the aim of detecting thresholds for bitter tastants and thus developing repellents.

This research is part of a larger project that seeks to improve the understanding of corvid behavior in order to offer durable solutions to prevent damage using diverse approaches including interview surveys and GPS tracking.

Goose accommodation field concept may alleviate human-wildlife conflict in agricultural areas

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Many goose populations have substantially increased in size in Europe over the last decades, which has resulted in human-wildlife conflicts. In particular, the Russia/Germany & Netherlands population of the Barnacle geese (*Branta leucopsis*) has increased from a few tens of thousands of individuals up to 1.5 million birds in just 40 years. They recently have shifted migration route westwards and about ½ of the population stage and browse in the fields of south-eastern Finland in spring and autumn causing substantial damage to crop plants, such as autumn-sowed cereals and sward for dairy cows. Regionally, up to 70% of the fields can be damaged by the geese. Because the Barnacle geese is a tightly protected species, lethal management is not possible. We tested whether goose accommodation field concept – where geese can rest and forage without disturbance, while they are actively repelled from normal production fields – could alleviate the economic and social problems geese are causing to farmers and to the society. We tested the efficiency of the concept by measuring the 1) habitat choice of geese using GPS tagged geese and 2) grazing impact of the geese on accommodation and repelling fields. To examine habitat use, we tagged 70 barnacle geese with GPS collars in 2021 to study foraging habitat choice in general and specifically accommodation field use using hidden Markov models and integrated step-selection analysis. We found that, first, geese generally do not select for accommodation fields during spring and autumn staging, while after a repelling event, geese avoid selecting repelling fields again compared to other fields. Second, active repelling of geese from production fields can substantially decrease the grazing of geese measured as the average sward length in repelling fields compared to accommodation fields. Our results suggest that the accommodation field concept can be one mitigation tool to this conflict. It can reduce agricultural damage and provide income for local people participating in repelling. Recent update in national legislation now includes accommodation field concept as a preventive mechanism that is supported financially. Coming years will show whether this has positive long-term impacts on the coexistence between geese and humans.

Do badgers eat lamb? Using DNA and post-mortem analysis to investigate lamb predation on Scottish farms

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In recent years, concerns have grown in the Scottish farming sector over suspected predation of lambs by badgers. In one survey, badgers were implicated in 11% of livestock attacks and in another, 20% of farmers reported attacks on livestock by badgers. While these surveys reveal strong opinion about the role of badgers in sheep predation, supporting evidence for such attacks remains scarce. To further investigate the potential role of badgers in predation or scavenging on lambs and sheep, a study was conducted in spring 2022, involving 21 farms from across Scotland where farmers suspected they had lost lambs due to predation by badgers.

Post-mortem analysis of 17 lambs found that six had wounds consistent with predation, i.e., evidence of bleeding at the wound site and in surrounding tissues. These wounds were most commonly in the form of small puncture wounds to the head, neck and jaw. Due to extensive scavenging, predation could not be ruled out for two further lambs, and the remainder showed evidence consistent with scavenging after death (i.e., no predation). Wounds associated with scavenging after death included missing head, limbs and/or organs, broken bones, open abdomen and injuries to eyes and tongue.

DNA analysis was carried out on swabs from 22 lambs, of which 17 also had post-mortem results available. Fox DNA was found on swabs from 19 lambs, including the six that exhibited evidence consistent with predation. Badger DNA was obtained from the remains of one lamb. No carcass was available for post-mortem so it was not possible to determine cause of death of this lamb. Dog DNA was present on three lambs. On two occasions, dog DNA was present alongside fox DNA and on one occasion alongside badger DNA. It is likely that this is a result of sample contamination by farm dogs. It was not possible to retrieve predator DNA from two lambs, one of which was stillborn and one of which was alive but was found with facial injuries.

This first year of data has shown the importance of post-mortem in distinguishing between scavenged and predated carcasses. We have also shown that predator DNA can be reliably retrieved from lamb carcasses, that farmers themselves can collect these samples and that the results can help inform suitable predator control. However, sample size was small, and almost half of samples came from one farm so the study would benefit from an additional year of data from a greater number of farms**.**

The magpie and the grapes: increasing ozone exposure impacts fruit consumption by a common corvid in a suburban environment

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Corvids are widely regarded as crop pests. The Eurasian magpie *Pica pica* is a resident bird species and is a widespread species in farmlands and anthropized environments. This corvid shows a wide trophic spectrum, including fruits, invertebrates, small vertebrates, and carcasses. Particularly, vineyards production may be severely affected by the feeding activity of corvids and other birds. Prevention measures are successful with small Passeriformes, e.g., Eurasian starlings *Sturnus vulgaris* and golden orioles *Oriolus oriolus*, whereas the limitation of damages by corvid species often requires direct captures and individual removal to be effective. However, high population densities of corvid species in crop areas may also prevent the success of bird removal operations. In this work, we carried out a camera-trap experiment to test whether different ozone (O_3) concentrations on vineyards result in different grape consumption rates by suburban corvid species. Ozone is a toxic gas, whose atmospheric concentrations are a concern for plant and animal health. Given its local abundance, we used the magpie *Pica pica* as the model species. This test was performed at the Ozone-FACE (Free Air Controlled Exposure) facility located in the city of Sesto Fiorentino (Italy), that consists of nine 5 × 5 × 2 m plots in which the O_3 levels are measured and controlled. In each plot, O_3 is dispersed by a network of vertical vent-pipes across the entire plot (50 m^3) to simulate three ozone treatments, i.e. 1.0, 1.5, and 2.0 times the ambient concentration (denoted as AA, x1.5AA, x2.0AA, respectively). Camera-traps (model Browning SpecOps) were located in front of each treatment area after taking off grapes from tulle bags to protect them on the plant. Cameras were placed at about 130 cm from the ground, oriented towards potted vineyard (*Vitis vinifera* L.) plants, and kept active for 24 hours/day and for 5 days periods throughout a total of 3 months to monitor grape consumption by birds. Camera-traps were controlled once a day to download data and change dead batteries. Each morning, we counted for an hour (07.00-08.00) the number of magpie passages within each vineyard; afterwards, the acini of each bunch were counted to evaluate the daily percentage of consumption. We collected a total of 38 videos: Eurasian magpies were the only grape consumers, with a total of 6.73 ± 3.26 passages (mean ± SD) per hour, with no differences across different vineyards and different O_3 treatments ($c^2 = 102$, $P < 0.01$). All data were compared by RM-ANOVA test followed by Least Significant Difference (LSD) post hoc test, considering all the interactions between the data. The grapes in the AA treatment were consumed significantly faster than those in the x1.5AA treatment, which were, in turn, consumed faster than those in the x2.0AA treatment. For instance, after 3 days of exposure, 94, 53 and 22% of the acini from AA, x1.5AA, and x2.0AA treatments were eaten, respectively. After 5 days (end of experiment), all the acini in the AA treatment were consumed, whereas in the x2.0AA treatment, over 50% of the acini still remained. Finally, acini were eaten in x2.0AA only when the O_3 fumigation was turned off. This study has provided valuable insights to mitigate human-wildlife conflict in agricultural and periurban environments.

Ecology, physiology and behaviour – 2

Population dynamics of rodents in Asia and Europe: patterns and processes

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The population abundance of several rodent species fluctuates within years (seasonal changes) and among years. In contrast to rodent species that populate forests and fields, very little is known about the multi-annual dynamics of commensal rodents that live closely to humans and man-made structures. It is generally assumed that the fluctuation of their population abundance is buffered and regular multi-annual population outbreaks are not to be expected, however, there is no convincing scientific evidence, because of lacking long-term data. Time series of the abundance (indices) of rice field rats from Asia (Indonesia and Vietnam) and urban rodents from Europe (Germany and Switzerland) were compiled. Long-term crop damage data and information about rodent control were collected from the local government office in Indonesia and Vietnam. Existing data on the long-term dynamics of commensal rodents from Germany (Hamburg) and Switzerland (Zurich) were used to estimate the population pattern of urban commensal rodents. For the analysis of the long-term dynamics, the annual absolute values per country were converted into annual growth rates. We tested for auto correlation structures and spatial synchronization among rat populations. Our preliminary time series data analysis revealed that the population fluctuations of *Rattus* sp. in Asia rice field landscape tended to be associated with frequencies toward 2-3 years whilst the commensal rat in European urban setting indicated 2 years frequencies. The next level analysis will focus on the correlation among locations as well as correlation with natural effects (weather) and man-made impact (rodent control activities) to identify environmental drivers of long-term population dynamics. Long-term population data for commensal rats from other countries is being collected to validate our preliminary findings.

Towards the influence of climatic covariates in the spatio-temporal differential expression of common vole abundance in Castilla-Y-León Region (Spain)

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The common vole (*Microtus arvalis* Pallas) is considered one of the most harmful pests for agriculture in Europe, since its natural cyclical outbreaks are linked to risk situations that can lead to significant crop losses. Furthermore, it can also constitute a public health problem as a potential environmental amplifier of zoonotic diseases, some of which are transmissible to humans.

In Castilla-y-León region (Spain), after a quick process of colonization from the mountainous areas that border it, the common vole invaded the agrarian ecosystems of its central plateau. Until the 2007-08 campaign, a cyclicity tending to five years was observed for the general population dynamics, although since then the pattern has been shortened to a three-year trend.

However, both the parameters related to the population abundance curve and the final impact on crops depend on, and are modulated by, a complex system of intrinsic and extrinsic factors. There is no a scientific consensus on the final explanation underlying this intricate system.

In this study we prospect for the possible influence of climatic factors in the expression of this phenomenon in Castilla-y-León. A database of common vole abundance monitored during a decade has been used, linked to reservoir-type and crop-type habitats and distributed in 42 zones across the more than 3 million hectares of arable land in the region. The temporal distribution considered has been the continuous succession of three types of four-monthly periods, summarized as spring, warm and cold periods. The climatic covariates to be considered have been estimated from the daily information of about 100 weather stations located in the vicinity of the study areas.

Main results show a complex pattern in terms of the spatio-temporal differential expression of abundance, with significance both for the zone, period and type of habitat factors as well as for all their possible interactions.

When including the climatic covariates to explain the aforementioned spatio-temporal differential expression of abundance, the influence of temperature and rainfall that occurred up to a year before appeared to be of special interest. In addition, the relationship of these climatic covariates with the evolution of abundance seems to be dependent, even changing sign, on the moment of the population cycle.

Although further studies are needed to deepen into the influence of these covariates, including their inclusion in models considering other types of factors, in the light of our results the expression of temperatures and rainfall seem to be of great interest in terms of predictive modelling of demographic events of the common vole and of the derived risk for crops. The development of this type of predictive tools is one of the objectives pursued to optimize the tasks that, both farmers and the different agents involved, must carry out for a proper Integrated Management of this agricultural and health problem.

Ecology, physiology and behaviour – 3

Chromosomal diversity and evolution of *Nannospalax*, Palmer 1903 (Mammalia: Rodentia) in Anatolia

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Although speciation is difficult to understand when there is no obvious geographic isolation between populations, there are cases where isolation does not occur in the course of of natural selection. Speciation and the demonstration of the separation of existing species, especially in groups that are not understtod as sibling species, endless debates remain and the issue is difficult to study until to find a suitable explanation. However, if studied, they could be ideal model organisms for collecting information about evolutionary processes. This is the case for *Nannospalax* forms in Anatolia. Currently, 24 cytotypes have been defined in Anatolia. Comosome number differs from 36 to 60. Morphologically they are almost impossible to separate from each other. Another important point is that chromosome number can be used as a taxonomic character to separate species and populations. The differentiation of chromosomes brings along genetic differentiation and speciation. Possible reasons for the rapid fixation of the chromosome number in this species are: they live solitary, have limited movement due to living in tunnels they dig underground, show adaptive expansion due to the absence of competitors in the area they live in, and the effect of the small population effect can be seen quickly due to limited sexual selection. When all these factors are evaluated together, the resulting chromosome number differences revealed that the cytotypes of mole rats were different in studies carried out with any method, speciation was faster and cytotypes should be evaluated as separate species. However, the still unanswered question is: What caused the chromosomal evolution that led to differentiation?

Is mowing an effective method to reduce rodent damage in forest plantations?

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Forest trees, especially at a young age in afforestation, periodically experience feeding damage from herbivorous rodents such as voles. Methods to prevent rodent damage are limited. However, mowing herbaceous vegetation is often indicated as a valuable and efficient way of protecting tree seedlings and saplings against small rodents in forest plantations. Unfortunately, no empirical evidence exists supporting the claim that mowing prevents or stops rodent damage to seedlings in a forest ecosystem. In the presented study, we examined the effects of mowing on rodent population dynamics and the extent of damage to saplings in Gościno Forest District (NW Poland). We conducted a field experiment in 20 randomly selected beech (*Fagus sylvatica*) forest plantations, half of which were mowed in summer. Within each plantation, we monitored the population dynamics of small rodents (bimonthly) and the extent of damage they caused to tree saplings (monthly) from December 2019 to April 2021. Damage showed explicit seasonal dynamics with peaks in winter and early spring and varied from 0 to 40% of saplings per plantation. Surprisingly, mowing did not change the pattern of population dynamics of small rodents (including voles) on the plantations, nor did it reduce seedling damage. Our results suggest that mowing is an ineffective method to prevent tree damage by small rodents in forest plantations; therefore, we do not recommend it for forestry practice.

Applying science to increase trapping efficiency

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Most actions involving management of invasive vertebrates require the use of traps. However, making trapping an effective management method remains a major challenge, as it depends on having knowledge of the ecology and biology of the target species as well as on having an appropriate trapping protocol. Regarding the trapping protocol, it is necessary not only to have a suitable trap but also an attractive bait. However, this latter information is often not available. Therefore, exploring prey preference of the target species using scientific methods can robustly contribute to increasing trap attractiveness. An example of this is found in the management of the invasion of the California kingsnake on the island of Gran Canaria (Canary Islands, Spain). An important part of the captures carried out yearly relies on the use of traps baited with live mice. However, the efficiency of these traps is not particularly high, especially considering the resources required for their manufacture and management. In this context, the main objective of this research was to analyze the preference behavior of *L. californiae* against different prey, tested under controlled conditions. In a semi-natural terrarium (2 x 2 m), we exposed a total of 60 individuals of *L. californiae* in 3 different trials (2-days apart to avoid habituation) to a total of 12 different prey items (4 different per trial). We video-recorded the behavior of the snakes for 45 min to later extract variables such as: prey selected, order of selection, tongue flick attack score, and time spent on each prey. The results obtained identified the most attractive prey for the target species, an information that is essential incorporating into control actions to increase trap effectiveness. At global level, this experimental design can be exported to improve trap attractiveness for any other invasive vertebrate elsewhere. Our research highlights the importance of interweaving science and management to promote the effective invasive vertebrate control.

Bluetooth loggers to study spatial behaviour and contact among small rodents

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Small rodents can transmit various pathogens to people and livestock and they can cause considerable damage in farming. Frequent contacts between wild rodents and livestock favour the transfer of pathogens, which can lead to high economic losses. It is therefore important to understand the movement patterns of small mammals on farms in order to be able to develop strategies to prevent damage and pathogen transfer. Miniaturised proximity loggers (Kirkpatrick et al. 2021 https://doi.org/10.4404/hystrix-00430-2021) represent a newly developed tool to monitor spatial behaviour of wild small mammals. Mobile and stationary Bluetooth loggers emit, receive and store individual logger signals with a time stamp. Differences in signal strength give information about the proximity between individuals and to stationary loggers placed at specific points on the farms. This allows deriving contacts among animals and location relative to stationary loggers.
We provide initial experience of the methodology and results of dry runs for testing and calibrating this technology in the field with regard to farming environments. Such tests yield information about the effect of physical barriers such as soil, concrete and metal structures present at livestock farms that may interfere with Bluetooth signal strength. The results will support developing the method further and contribute to apply a validated technique in the field.

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Invasive vertebrates – 1

The Mammalnet citizen science contribution to improve knowledge of invasive mammal species in Europe

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The European framework to monitor wildlife (*ENETWILD*, enetwild.com), supported by the European Food Safety Authority (EFSA), identified gaps in available occurrence data on different taxonomic groups, as well as biases in the inferred spatial distribution for most wild mammal species. Citizen science was deemed to have potential to improve data availability.

Following this, the Mammalnet project (https://mammalnet.com) has used different strategies to assess the potential of citizen science to improve the availability of wild mammal records in Europe. MammalNet uses different information technology tools, such as the *iMammalia app* for ad-hoc occurrence records*, or MammalWeb and Agouti* for camera trap data recorded by citizens and wildlife managers or researchers, respectively. A pilot study was implemented to engage a range of audiences (from citizens to wildlife professionals) in Croatia, Germany, Poland and Spain, which were later expanded to other countries in the Balkans (Serbia, Montenegro, Albania, North Macedonia, Bosnia & Herzegovina), Italy and Portugal. First, we review the spatial and temporal patterns of reports of invasive mammal species, among more than 47,000 mammal occurrence records collected by citizens. Then, we assess the main outcomes of the project considering the contribution that these databases have made to support the generation of new knowledge, and the potential of information technology tools for monitoring wildlife populations and diseases. These

results have only been possible thanks to the contribution of hundreds of citizens and researchers who have kindly participated, giving their time and enthusiasm by sharing their knowledge and experience to improve knowledge about the distribution of European mammals.

Mainland eradication of the invasive raccoon dog (*Nyctereutes procyonoides*) and the evolution of a national task force for invasive alien species

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Invasive Alien Species (IAS) are recognized as one of the main threats to global biodiversity. According to EU-regulation 1143/2014 on IAS, EU-listed species has to be managed, preferably eradicated, by the concerned member states. In Sweden we have approximately 17 out of the 49 EU-listed IAS established or occasionally seen in the country. Out of those 17, 7 are mammals, birds or water turtles (*Trachemys* spp.). The Swedish Raccoon Dog Project has been ongoing since 2008, with the goal to minimize the occurrence of the Raccoon Dog in northern Sweden, where it is invading from Finland, and stop it from dispersing south and west. The Swedish Association for Hunting and Wildlife Management is leading the project in Sweden, contracted by the Swedish Environmental Protection Agency (SEPA). The management has been very successful, and today the raccoon dog population is under control.

The management framework for the raccoon dog is very adaptable, with a core of full time employed professional hunters. Many of the tools developed for the raccoon dog can also be used on other species. To keep the competence of the professional staff SEPA has taken the decision to, instead of lowering the projects resources (since the raccoon dog now needs less work), broaden the mission to cover all mammal and bird IAS, plus water turtles, in the country. In 2014, the raccoon (*Procyon lotor*) was added to the mission, in 2018 the muskrat (*Ondatra zibethicus*), and in 2019 the Egyptian goose (*Alopochen aegyptiaca*) and water turtles (*Trachemys scripta* sp.). The task force should also stand on hold and be prepared to take care of all new mammal and bird IAS discovered in the country. Apart from the EU-listed species, SAHWM also works with eradication of American mink (*Neovision vision*) in valuable bird recruitment areas and from 2021 we have the mission to eradicate a small population of Stone Marten (*Martes foina*) that has emerged in an urban area in Southernmost Sweden.

As a prerequisite for a successful IAS management, SEPA has given the project necessary exemptions from the hunting law and permission to work on all land in the country, even if the land owner does not agree. Outside of Europe the project has been a key part of two successful eradications of Common Myna (*Acridotheres tristis*) on different islands in the Seychelles. The management cost for mammal and bird IAS for the state has dropped from of approx. € 800 000 annually for one species in 2008-2013 to approx. € 100 000 per species today. The national task force for eradication of invasive alien mammals and birds has proven both practically and economically successful in Sweden and could be used as a template for other countries.

Alien parakeets as a potential threat to the common noctule *Nyctalus noctula*

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The ring-necked parakeet *Psittacula krameri* (Aves: Psittaciformes) is a widely distributed species of Asian and African origin, which occurs with over 40 alien populations in the rest of the world. Most established populations of this species are showing a clear trend of territorial expansion and numerical growth. Recent reviews highlighted that one of the main impacts by alien ring-necked parakeets is the competition with threatened bat species using trunk cavities as roosts. In Italy, the only known reproductive population of *Nyctalus* bats (Mammalia: Chiroptera) occurs in an urban area in the central part of the country, surrounded by increasing and expanding populations of ring-necked parakeets. In this work, we updated the population status of both ring-necked and Alexandrine parakeets and breeding noctule bats in the region. Then, we ran a species distribution model using Maxent software to analyze the environmental suitability of the region for the ring-necked parakeet and a connectivity model using Circuitscape software to predict the possibility of its expansion in the area occupied by breeding noctule bats. We recorded a high number of individual parakeets and breeding colonies, together with a remarkable noctule population decline, from about 400 to about 120 individuals, in the last 20 years, possibly due to urban green management practices. Although some ring-necked parakeets have already been observed in the study area, there is no evidence of reproduction in the surroundings of the noctule colony. However, our model showed high environmental suitability for the ring-necked parakeet in the area occupied by breeding noctules. As well, the connectivity model showed the potential for a direct flow of individuals from the main urban centers to the area used by noctule bats. The arrival of alien parakeets to the area occupied by the bat breeding colony should be tightly monitored by surveying the suitable areas for this bird, as well as the identified ecological corridors. Early detection of new invasions, together with a sustainable urban green management practice, may prevent the extinction of the southernmost breeding colony of the common noctule.

Kaput feral hog bait with 0.005% warfarin: product development, efficacy, non-target, human safety and politics

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Destruction of crops and landscape in the United States by wild pigs amounts to $4 Billion each year. Kaput Feral Hog Bait (with 0.005% warfarin) was approved by the US Environmental Protection Agency in 2017 for use against wild pigs in the U.S. Field studies conducted in northern Texas from 2015-2017 using 0.005% warfarin resulted in efficacy averaged >95% with no issues related to primary or secondary toxicity to domestic animals or wildlife. Additionally, laboratory and pen studies were conducted on with warfarin on wildlife species to examine the potential for primary and secondary toxicity to wildlife. Over a 10-year period, non-target risk assessments were conducted for magpies, American alligators, mallard ducks, European ferrets, and bobwhite quail to assess primary and secondary dietary exposure to 0.050, 0.025, or 0.005% warfarin baits. Warfarin-induced morbidity and/or mortality never occurred during any of the studies. Studies have also been conducted to evaluate the ability of the delivery system (HogStopper® feeder) to deter access by non-target wildlife. Feeder modifications have since been made (thickness of metal lids, weight of doors, etc.) to limit access by black Bear and raccoons. Studies have also been conducted to evaluate the usefulness of the blue dye, and indicate the dye is evident at 3 hours after bait consumption and will remain for at least 14 days even if the animal eats >200 g bait, deterring potential human consumption. This bait is a US federally-registered product which, when used properly in conjunction with the HogStopper, reduces feral hog numbers in the United States and elsewhere, while presenting little to no risk to humans and non-target wildlife.

Invasive vertebrates – 2

A new invasive mammal in Britain? The greater white-toothed shrew

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The British Isles are host to one (Ireland) or three (Great Britain) native shrews. The non-native Greater White-toothed (GWT) shrew was reported in Ireland in 2008 and may have been present since 2001. Since then, it has spread quickly and the native pygmy shrew has substantially declined where the GWT is present. In 2022 the GWT was identified and reported in North East England and may have been present since 2015, according to dated photographic evidence.

We do not know how this introduction occurred, not if it will affect the pygmy shrew in England. Since that initial finding some other evidence has been found suggesting other locations where it may be present. We report on the up-to-date findings of survey work, using various methods.

These introductions of small mammals should not be surprising given the paucity of data and we identify improved monitoring approaches for small mammals.

Twenty years of muntjac: monitoring and management of an emerging deer species in Flanders (Belgium)

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Chinese muntjac (*Muntiacus reevesi*) is a small-sized deer of Asian origin. A large population has developed in the United Kingdom, causing significant environmental and economic damage. To avoid a similar scenario on the European continent, muntjac has now been included on the list of species of Union concern (Regulation 1143/2014). In the past decade, muntjac has mainly been reported from Flanders (northern Belgium). The first sighting dates from 2004, but observations increased steeply after 2012 in particular.

In this presentation, we first zoom in on the region-wide spread of muntjac, its causes, and how it is counteracted. To understand the dynamics, we rely on genetic analyses that elucidate the structure between populations using SNPs (single nucleotide polymorphisms). These have shown how both natural processes (e.g., dispersal) and human actions (e.g. exchange) play a role. Though most sites in Flanders are related to some extent, the main population is genetically distinct. The origin of that population has now also been confirmed.

Second, we show how monitoring through camera traps supports site-level management. The recordings illustrate the secretive nature of muntjac, allowing it to thrive well in a suburban park with intense recreation. By inferring activity patterns, and estimating abundance through encounter models, the authorities can more accurately track the effects of their culling efforts.

The situation of muntjac in the European Union deserves to be closely monitored. The current policy in Flanders seems to have averted further spread relatively well so far, albeit with considerable effort. The pressing question is how the species can be sustainably contained and whether eradication is possible at all.

Feral American mink (*Neogale vision*) expanding in Europe: time to harmonize population monitoring

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American mink (*Neogale vison*) is an invasive alien species in Europe that threatens biodiversity and may transmit zoonotic diseases. It was introduced for fur farming and, after escapes and releases, has been expanding its range as a feral species across the entire continent. Control strategies have been implemented by several countries, yet effective control requires recurrent and detailed information on the species. Different data sources can be integrated, each with its flaws and potentialities.

The aim of this study was to update the distribution of American mink and to assess its temporal trends. Furthermore, we aimed to provide recommendations for improving protocols for future monitoring and data collection on distribution and management.

The last original mapping of this species in Europe, at continental scale, dates back to 2007. We gathered and standardized data from 34 sources, covering 32 countries and a diverse set of data resources (hunting bag statistics, records from monitoring programs and opportunistic observations from citizen science). Data was grouped in ranges of 5 years (2007-2011, 2012-2016 and 2017-2021) and then presence/absence mapped for each period, with reference to the spatial resolution of represented data. Changes in range size were calculated as Extent Of Occurrence (EOO) and mapped for each period. We compared the updated distribution with the last published mapping of the species performed in 2007. Hunting bags and capture statistics were analysed to obtain a general trend. We also reviewed the current situation of mink farming in the different European countries and recorded existing population control schemes.

Despite the closure of many mink farms across Europe, American mink is now widespread in the Baltic states, France, Germany, Iceland, Ireland, Poland, Scandinavia, Spain, and the United Kingdom. Information gaps and heterogeneity in data quality are obvious, with data deficiencies for several countries mainly in south-eastern Europe. Over the last 15 years, the species has continued to invade the continent, extending its EOO in some countries by more than 13%.

Our effort to collect and harmonize data across international borders highlighted information gaps and heterogeneity in data quality, in terms of temporal and geographical resolution. We integrated different data sources (hunting bag statistics, records from monitoring programs and opportunistic observations), but still data is lacking for the eastern part of Europe.

The updated distribution data on the species can aid risk assessment and risk management policies. These actions require a coordinated effort for population monitoring at continental level, as well as standards for data recording. Monitoring effort, data collection and data publication should be intensified in eastern Europe to close knowledge gaps on the current distribution of this invasive alien species.

Invasive vertebrates – 3

Trapping of vertebrate IAS coypu (*Myocastor coypus*) and raccoon (*Procyon lotor*) in live traps – preliminary results and conclusions on animal welfare

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In Germany, although being invasive alien species (IAS), coypu and raccoon are listed as game species subjected to hunting law. Live trapping of game species was approached with minimum standards in the European Union with the conclusion of the Agreements on International Humane Trapping Standards (AIHTS). In Germany, these agreements have not (yet) been implemented into applicable law. On an international level, the AIHTS standards are controversially discussed and considered insufficient by experts. Our research highlights animal welfare aspects of live capture of coypu and raccoon in three commonly used live capture systems, guided by the principles of AIHTS regarding the minimum number of target animals as well as AIHTS and ISO 10990 for the performance of pathological-anatomical examinations. Extensive video recordings lead to veritable behavioral analyses during capture. The occurrence of injuries and behavioral abnormalities as well as abnormal hormonal parameters were examined. Behavioral assessments are also assumed in AIHTS, but to the authors' knowledge have not been systematically done in known publications and studies to date. The study design includes three different types of live traps, which are mainly used in Lower Saxony.

Looking at the trap types in terms of suitability for the two species, clear differences are evident: when raccoon traps were evaluated, two traps turned out to be the ones in which the animals sustained fewer injuries. For the coypu, some traps performed better in terms of injuries. We conclude that animal welfare in IAS management should be improved also in live trapping.

Towards an evidence-based spatial prioritization of management efforts to counter a widespread invader

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Prevention and early-detection-rapid-response strategies have received considerable attention in biological invasion management. However, many conservation managers are confronted with species that have already invaded large areas and for which a different set of management strategies are required. In these cases, hands-on management recommendations are often lacking. It may therefore take several years of suboptimal management for the efficacy of the interventions to increase in response to the knowledge acquired along the way. Using the invasion of the American bullfrog (*Lithobates catesbeianus*) in Belgium as a case study, we show that prior analyses based on environmental DNA (eDNA) may smoothen this learning curve that typically presents itself at the onset of an eradication program, and facilitate the prioritization of limited resources. First, we setup mesocosm and field experiments to assess the relationship between eDNA concentrations and number of bullfrogs. We found that eDNA concentrations were not only strongly related to bullfrog population sizes ($R^2_{adj} > 0.8$), but also that natural breeding sites (i.e., source populations) can be distinguished from sink populations. Our results further showed that eDNA-based analyses can reveal the spatial configuration of invasion hubs and hence infer invasion dynamics. Landscape genomic analyses are currently in the pipeline to locate potential barriers to invasive spread by evaluating geneflow between these hubs. We then looked into ecological characteristics of breeding sites to identify ponds that would support breeding populations upon colonization. Permanent water bodies with abundant emergent vegetation and sparse tree cover along the shoreline were strongly associated with breeding sites. Next, we conducted eDNA metabarcoding analyses to quantify the ecological impact of invasive bullfrogs on amphibian communities, and found that spatiotemporal niche overlap mediates severe amphibian declines associated with this invader. By overlaying the distribution of highly impacted amphibian species with the invaded area, invasive spread towards sensitive populations can be prevented. Finally, all the discussed aspects are integrated into one general framework that can facilitate the prioritization of resources to spatially optimize reduction, containment or damage control strategies.

Spatial and temporal patterns of bait uptake by grey squirrels in woodlands

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Invasive alien species (IAS) are the second largest cause of biodiversity loss in the world. The European Commission has drafted a regulation for the prevention and management of invasive alien species. Among the most damaging species is the grey squirrel (*Sciurus carolinensis*), which is considered a pest in newly introduced areas. The introduction of grey squirrels has a two-fold negative effect on new territories: a) the gradual disappearance of the native squirrel (*Sciurus vulgaris*), b) considerable economic losses in the forestry sector. Culling (through trapping or shooting), poisoning and surgical sterilisation are methods currently used to control squirrel populations. As lethal management methods are facing increasing opposition from society, novel non-lethal methods such as fertility control are increasingly preferred for population management in the future. The effective and efficient application of oral fertility control depends on factors that may influence the uptake of a contraceptive bait by the target species. This study investigates the spatial and temporal patterns of bait uptake by microchipped grey squirrels, using bait dispensers equipped with microchip readers. The feeding behaviour of four populations of grey squirrel in woodlands in Yorkshire, UK were monitored in three different woodlands at two different times of the year (summer and winter). Across all study sites a total of 138 squirrels were microchipped, including 61 males and 77 females. A total of 21-24 dispensers were deployed in each wood and the spatial and temporal distribution of individual feeding visits mapped and analysed based on sex, reproductive status and season. The data were then used to optimize resource allocation, in terms of effort and equipment employed, to maximise bait uptake in target populations in the future. The application of the study findings to other bait deployment strategies for wildlife management is discussed.

From invasion to eradication: success story of removing grey squirrels from an urban area in Central Italy

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The LIFE U-SAVEREDS project managed an isolated population of the invasive grey squirrel *Sciurus carolinensis* in the city of Perugia (Central Italy) and surrounding areas, intending to protect the native European red squirrel (*Sciurus vulgaris*) and safeguard biodiversity in Apennines ecosystems.

The invasive species settled in Perugia around yr 2000, and the project's specific aim was to eradicate the population or remove at least 80% of the grey squirrels. During the project, grey squirrels were live-trapped with Tomahawk traps, and then euthanised using carbon dioxide (CO_2). A fraction of the animals was surgically sterilized and released in urban parks.

Overall, between February 2016 and September 2018 (32 months), we removed 1070 animals. Comparing this number with the abundance estimated in 2015 through distance sampling (1510 animals SD 211, 95% confidence interval 1096-1924), and combining the removal data with the results obtained through monitoring, the percentage of removed animals is likely to be 82-98%. Indeed, grey squirrel density was reduced from 3.37 individuals/ha in 2015 to 0.31 individuals/ha in 2017, and in 2018, it was even closer to zero. In 2015, the grey squirrel occurred over 36.9 km^2; at the end of the project, its range was reduced to 3 km^2. Over time, we also detected an increase in the area occupied by red squirrels, from 19 km^2 to 57 km^2.

To date, there is no evidence of the persistence of a grey squirrel population in the area of Perugia. The removal of grey squirrels through trapping was thus successful and facilitated the recovery of the native squirrel.

Human-animal social conflict – 1

Habitat recording and habitat design in forests - key for modern monitoring and management of vertebrates

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The predicted far-reaching climate changes make it necessary to adapt management of forests. Investigating the effects of different management strategies is aim of the project WiWaldI.

The Chair of Forest Protection at Technische Universität Dresden assessing the effects and potentials of regulation measures with regard to the influence of game. For this purpose, the occurring game species, game condition, game management and habitat structures are considered. Strongly distributed herbivores such as roe deer and their influence on forest development are in conflict with human objectives. From the results of the investigations and the comparison of interdisciplinary data collections of the project partners, statements on the ecological and economic evaluation, the forest development influenced by game, an adapted hunting and the implementation of a future-oriented development of forests are to be derived. The new consideration is a multifactorial approach to be able to map dynamic processes approximately.

In the lecture, the embedding of stability factors that can be influenced by humans will be worked on, the experimental design, the methodology for recording influencing factors and preliminary results will be presented.

Ungulates, voles, insects – Why do we have such different management systems in German forests?

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In times of climate change and forest transformation, ungulates are linked to losses of up to one billion Euro per year in German forests. Since the 2018 storms, bark beetles and defoliators have caused about 500,000 ha of clearcut areas that provide habitats for wildlife and voles damaging the young trees of forest regeneration. Furthermore, defoliators in conifer forests and increasingly in broadleaf forests occur in mass outbreaks following forest transformation.

With regard to defoliators, the application of insecticides is sometimes permitted. However, the artificial regulation of voles was often forbidden by administrational bodies. Ungulates are the most important biotic damage factor in forests but are simultaneously an important subject of hunting and forest management.

In this presentation, partly hidden losses caused by these biotic factors are reported and a brief discussion of the different backgrounds, importance und approaches as well as results of hunting and habitat management to avoid voles and regulation by food webs to promote predators and/or parasitoids to regulate insects are described.

Bird pests: How do farmers deal with bird damage to spring crops in Switzerland?

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Bird damage in crops is considered as an increasing problem among farmers, and effective solutions are still scarce. An online survey was sent to Swiss farmers in May 2021 in the three official Swiss languages - French, German and Italian - and received over 500 answers. The answering rate was higher in the eastern part of Switzerland (German speaking), followed by the western part (French speaking), and much lower in the Southern part (Italian speaking). It appeared that sunflower and maize were the most damaged crops by birds, followed by pea and spring cereals. Farmers mentioned corvids, both carrion crows and rooks and, in a lesser extent, pigeons, as the most problematic birds for their crops.

Among the preferred control solutions, seed-coating repellents come first, with the use of a relatively effective substance (Zirame) registered for use on maize. However, the loss of a previously marketed effective product (Methiocarb) worries farmers concerning the long-term reliability of maize seed coating solutions. It is also worth noting that there is no repellent product registered for use on sunflower in Switzerland. Other techniques – scarecrows or sound and acoustic scarers – are commonly used but their effectiveness is limited by rapid habituation of the birds. Population control through shooting or nest destruction is also used by farmers and requires the intervention of wildlife authorities, although its effectiveness has not been evaluated.

In order to investigate more precisely farmers' views on the current threat posed by bird damage and their trust in various management solutions, a series of interviews have started in late winter 2023. Farmers were chosen among the ones who had answered to the previous survey, and contacted by phone to set up a meeting. The interviews assessed diverse aspects including socio-economic characteristics of respondents, an evaluation of their recognition of the crop depredating species present in the area, the strategies used to avoid attacks, whether they used lethal controls such as shooting and nest destruction, as well as their estimation of the benefits of these bird management strategies.

This sociological study takes part in a wider project aiming at developing new and more effective solutions aside from lethal methods for bird damage control that involves agronomic techniques and the study of feeding behaviors and movements of bird species.

New solutions to old problems: can humane non-lethal control be an effective alternative to manage charismatic invasive vertebrates? The case of invasive parakeets in Europe

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Invasive species are one of the main drivers of biodiversity loss. Public collaboration has proven to be a useful asset to successfully manage invasive species, but some invasive species are appreciated by the public, being considered “charismatic species”. The management of these charismatic invasive species rarely rely on public collaboration for management. Invasive parakeets seem to be one of the most charismatic invasive species across Europe, where active opposition to parakeet capture have been recorded in England, Belgium and specially Spain, where this opposition is becoming more and more aggressive (patent). This belligerent scenario, together with the traditional inaction to manage invasive parakeets has created the paradox that, one of the few invasive species stablished in Europe which could be technically removed from most of the invaded countries, has not been removed and is growing exponentially, at least in Mediterranean countries.

To unfreeze this situation, we have developed in Spain a non-lethal framework to manage populations up to 500 individuals of invasive parakeets, consisting in the capture, sterilization and adoption. It required the collaboration of regional authorities, local authorities and the public. The parakeets are captured in the nests with different methods depending on the species. This is the limiting factor given this species are not easy to capture. Then their health is checked and if they are healthy, all of them are sterilized, identified by different methods and donated to adoption to citizens. The owner has to be registered, given they are considered invasive species in Spain and possession of these species need to be authorised by the regional government. This framework is ready to be applied in Spring 2023.

Returning invasive species to captivity is not new, but one of the limiting factors use to be the space when the populations are big. In this case, we took advantage of the illegal networks created in social networks to adopt chicks of invasive parakeets when they were removed from the nest, often with collaboration of the gardening staff, a forbidden activity which the authorities never tried to stopped. We created a new legal circuit to remove the parakeets from the environment and monitor if these parakeets return to the environment again. In captivity, animal welfare indicators will be monitored to decide if captivity can be considered humane management for wild born parakeets.

Effective installation of deer fences in Tsushima Island

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Sika deer (*Cervus nippon*) are Cervini widely distributed in East Asia, and as Bergmann's law states, the difference in body size is very large, ranging from about 120 kg in northern Hokkaido to 35 kg in southern Kerama Island. The sika deer population in the Japanese archipelago was very small from the 19th to the mid-20th century, but excessive postwar protection has led to an explosive population growth, causing significant forestry and agricultural damage. In Tsushima, located between the Korean Peninsula and Kyushu Island, the number of sika deer has also exploded, causing extensive damage to forestry and crops. The local government estimates that there are 20,000 humans in Tsushima today, but about 40,000 deer inhabit the island. In Tsushima, about 10,000 deer are captured annually in order to reduce the number of deer, but this has not led to a reduction in the population. The height of the sika deer in Tsushima is about 130 cm and the maximum weight is about 60 kg. Therefore, in Tsushima, the local government has been distributing deer fences for the past 15 years, and private citizens have been using them. The height of the distributed fences has gradually increased to 100cm, 130cm, and 150cm. On the other hand, fences recommended by the Japanese government are 200 cm in consideration of the Hokkaido population.

However, the effectiveness of these fences of different heights has not been fully verified. Therefore, this study was conducted to determine how to set up an effective deer fence with five conditions of fences and controls. The fences used were 130, 150, and 200 cm. 130 and 150 cm fences were prepared and installed as "fence only" and "fence with horticultural shade curtains". "Fences only" and "fences with nets" of the same height were placed side by side about 10 m apart. One side of the fence was a 10 m square, and a polyethylene net was placed between the posts. Hay cubes were used as bait to attract the deer for at least two weeks before the fence was set up to acclimate them. Bait were placed inside the all fence and control area to attract them even after the fence was installed. Camera traps were set in the study area before the fence was installed, and video was taken of the fence and its surrounding area to observe the behavior of sika deer.

Of the 10,499 videos were taken between November 2021 to May 2022, when the fence was installed, 1,385 showed animals and a total of 587 sika deer were identified. The most sika deer were filmed in the control area without fences, and the number of animals filmed decreased in the order of “fences only” and “fences with curtains” (t teat, $p<0.05$). In other words, there was a difference in the number of individuals approaching between the side-by-side "fence only" and "fence with curtain". GLM analysis examined the factors that reduce the number of approaching sika deer to fences, and found that the height of the fence and the presence of curtains affected the number of shots (number of approaching individuals) and the number of sika deer contacts to the fence. The horticultural shade curtains used in this study are inexpensive and lightweight, so there is a possibility that fences plus curtains can provide cost-effective protection.

Agricultural damage following the recent expansion of wild boar in Finland – farmer perceptions and preconditions

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Wild boar (*Sus scrofa*) numbers have recently increased in Northern Europe, including Finland. This induces both positive and negative human-wild boar interactions, manifesting, e.g., as hunting opportunities and damages to property. Experiences and associated feelings from encounters may shape attitudes towards animals and the support for specific population management. We studied whether attitude groups exist within farmers, and what factors explain the differences between such groups by means of theme interviews and survey data. We also made preliminary estimates of the economic value of wild boar damage in Eastern Finland. Our analysis revealed three main attitude groups among farmers: “hunting resource group” (13% of respondents), "pest-of-concern group” (44%), and “unaware group” (43%). The perceived benefits received from wild boar presence, and their perceived population growth partly explained the division to groups. Surprisingly, only the level of experienced forestry damages differed between the groups, whereas no such effect was discernible in relation to agricultural damage. The total value of wild boar damage in Eastern Finland was estimated at ca. 990 000 € annually. The results indicate that both mitigating damages and promoting the presence of species may support the preconditions of coexistence. While the level of agricultural damages is thus far not substantial compared to that of some other game animals in Finland, wild boar population growth, and undoubtedly increase in levels of damage, will increase the pressure for including wild boar in the national compensation scheme.

Human-animal social conflict – 2

Rodentizide exposure of red fox (*Vulpes vulpes*) in Scotland, before and after the introduction of an industry stewardship scheme

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Since 2016, UK governments have supported an industry led 'stewardship' scheme that aims to reduce anticoagulant rodenticide (AR) contamination, and in particular, second-generation anticoagulant rodenticides (SGAR), in wildlife. Stewardship measures include: best practice guidelines; changes to permitted usage practices; compulsory training for professionals or farmer membership of assurance schemes; 'full strength' products restricted to trained professionals, with associated sales point monitoring; and reduced concentration amateur products in small packs.

Various monitoring projects assess the impact of the scheme on AR contamination. Current residue monitoring uses animals found dead, which may increase the risk of bias towards animals that are contaminated or have higher levels of AR contamination. This research sourced samples harvested through pest control; a source potentially less biased towards the presence of rodenticides.

512 red foxes were sampled from around Scotland during the period 2011 to 2022 and their livers analysed for both presence and concentration of AR residues. Pre 2016 samples were compared to those collected from 2018 onwards, allowing two years for stewardship to be taken up by AR users.

The SGAR's Bromadiolone, Difenacoum and Brodifacoum were the most prevalent ARs detected across all years. There was a small but not significant fall in the percentage of foxes post stewardship containing Bromadiolone and Difenacoum residues (down by 3.2% and 0.5% respectively). Brodifacoum presence increased significantly; it was present in 18% of fox samples pre-stewardship and in 43% post-stewardship. The occurrence of total summed SGAR's increased (up 7.6%) but this was not significant. There were no significant changes in the concentrations of either summed SGAR's (down 0.7%) or individual ARs. Both Bromadiolone and Difenacoum concentrations fell (down 8.5% and 32.6% respectively) and Brodifacoum concentrations remained the same. There was a significant increase in the number of samples post stewardship containing two or more ARs; and in the proportion of samples containing both Bromadiolone and Brodifacoum.

The results of this study concur with results from other species that suggest AR contamination in wildlife has not significantly fallen after the introduction of stewardship, and that occurrences of Brodifacoum have increased. Prior to stewardship Brodifacoum was only permitted for professional use indoors but post stewardship it can also be used 'outdoors around buildings' this change may have contributed both to its increased use and increased exposure to wildlife. The wider permitted use of 'resistance breaking' compounds such as Brodifacoum might allow more efficient control of resistant rat populations and therefore lead to faster control with less product, and subsequently a reduced risk of wildlife contamination, but so far there is no evidence of such an effect in overall SGAR contamination levels post stewardship.

This research has added to the body of evidence showing that the stewardship scheme has not (as of 2022) had the intended impact of reducing overall SGAR contamination in wildlife and that brodifacoum use may be an important factor to consider in any future review of stewardship.

Practical implications of following the non-chemical rodent control guidance for controlling a *Rattus norvegicus* infestation

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In Europe, rodenticides are subject to authorisation under the Biocidal Products Regulation (Regulation (EU) 528/2012) and must undergo human health and environmental risk assessments prior to their being available on the market. Despite the regulatory challenges faced by rodenticides, they continue to be authorised for rodent control due to a lack of efficient and viable alternatives, including non-chemical control methods. In 2018, a European workshop took place on the viability of non-chemical rodent control (NoCheRo), particularly rodent snap-traps, as an alternative to chemical rodent control. One output was the guidance for the evaluation of rodent traps (Part A break back/snap traps) to address the lack of robust field data in this area. BASF undertook a trial at a cattle and sheep farm that was infested with Brown rats (*Rattus norvegicus*) following the principles of the NoCheRo guidance. The purpose of the trial was to assess the efficacy and any welfare impact of a representative market leading snap-trap. There were four aspects of the guidelines which, for practical and justifiable reasons, BASF found difficult to fully adhere to. Firstly, only traps with an acceptable welfare impact according to the NoCheRo guidance should be used for field trial efficacy. However, no such traps were available at the time of the trial and there is no publicly available database to indicate which traps on the market have been tested and meet the NoCheRo guidance criteria. Secondly, comments were received the number of traps used was low. The trial was designed to be a comparative assessment for snap traps versus rodenticide bait. Following after a site survey and from previous experience of the site, 100 bait points would have been used to successfully control the infestation, so 100 rat traps were used. To determine the efficacy of the snap-traps, the size of the infestation was assessed pre- and post-treatment using both census diet takes and tracking activity. Before the treatment with snap-traps, there were approximately 770 rats present on the farm. During the treatment phase only a total of 105 rats were caught. After the treatment period, approximately 930 rats were present on the farm, which is a 21% increase. Therefore, the third stipulation in the guidance that treatment period should be “an appropriate period (normally up to 30 days)” could not be met as the trapping period had to be terminated at 21 days as it was clear that the infestation was not being controlled, despite dead bodies being removed daily. The NoCheRo guidance also states, “if trapping is unsuccessful, switch to alternative professional, non-toxic baits or lures to ensure a variety of scents as rodents vary in their tastes”. Of the 105 rats caught, where bodyweight could be determined (that is not cannibalised) 88% weighed less than 100 g, hence were considered to be juveniles or sub-adults. These juveniles and sub-adults were not of breeding age. However, the neophobic adult rats which survived by avoiding the traps, continued to breed and enhance the neophobic status of the infestation. Therefore, it was decided not to add professional lures for fear of further adding to the neophobic response of the adult rats. This is the fourth aspect where, with justification, the trial deviated from the guidance.

Of note, only 44% of the rats were caught by the head or neck (indicating that death would have been relatively quick) and 6% were complete ‘mis-hits’ with the rats actually caught by either their tail or leg(s). For this 6% death would not have occurred quickly and hence not humanely.

The trial demonstrated that, while non-chemical control is an important tool for controlling rodents, it cannot be considered to be a viable replacement for chemical control and the incidence of ‘mis-hits’ raises humaneness concerns. There are many situations, such as in this trial, where using only non-chemical control would have a detrimental impact on the efficiency of the rodent control programme and subsequent health and welfare of both animals and workers.

Released beavers in central Italy: story of a recent reintroduction and assessment of human perception

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The Eurasian beaver *Castor fiber* was once present in a large part of the Palearctic from Portugal to Mongolia, throughout all suitable riparian habitat types in forests, tundra, and steppe. In March 2021, wildlife technicians detected for the first time since Medieval times the presence of the Eurasian beaver with two populations in Central Italy. Preliminary field-work confirmed the presence of the species since at least 3 years and the reproduction in all the rivers where beavers were detected. Beavers may represent crop pests and their activities may affect river flowing and human wellness. A project named “Rivers with Beavers” has been therefore financed by the Beaver Trust, aiming also at assessing the social perception towards the presence of the Eurasian beaver in Central Italy through direct questionnaires. We surveyed the human population through standard methods commonly used in social science, for citizens > 18 years old and with respect to national privacy laws. According to the IUCN guidelines, wildlife reintroduction should consider in their feasibility plan also including the impacts on humans. Eurasian beavers *Castor fiber* are reconquering most of their past range, due to protection laws and both authorised and unauthorised reintroductions. As to central Italy, a possibly unauthorised reintroduction has occurred in the last five years leading to self-sustaining, naturalised populations of beavers. We firstly determined the distribution and the consistence of local beaver populations by means of camera-trapping and research of presence signs. Afterwards, a questionnaire to measure whether and how citizens, fishermen, and farmers perceive the presence of the beaver was administered to 1114 respondents (46% women, 52% men, 2% transgender). A link to the questionnaire was posted on the webpage of the research project, asking group members to complete the questionnaire. All surveyed people have been and will be over 18 years old and able to fill the questionnaire autonomously, and they should agree to participate in this research according to the National and International Italian laws on privacy and sensitive data (DL 196/2003; EU Regulation 2016/679). All on-site questionnaires were implemented on paper, were anonymous, and conducted through autocompletion to avoid potential influences by operators. Questionnaires are confidential and take about 10-15 minutes to be completed. We observed a comprehensive awareness of the presence of the beaver in Italy and a high ability to distinguish it from coypus *Myocastor coypus* (92.3%). We also recorded a general high knowledge of issues related to the presence of the beaver (i.e., potential effects on indigenous biodiversity). The majority (65.5%) of the population interviewed was in favor of legally reintroducing the beaver in central Italy, and only 1.2% was firmly against it. The majority of interviewed people was against the removal of beavers from central Italy (65.8%), whereas only 3.7% was in favor, as fearing impacts on the river, crops, and fish populations. This work was financed by Beaver Trust UK.

Perspectives on rodent-human interactions in Nepali communities

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Rodent-human conflict occurs when the behaviours of the former impact on the latter, in terms of crop loss, damage to buildings and food storage, and health issues including zoonotic diseases such as leptospirosis. New and re-emerging zoonotic diseases are an increasing threat to global health, particularly in resource-poor countries like Nepal, which may lack the infrastructure, finances and awareness necessary to address them effectively. This work contributes to a PhD examining community awareness of zoonotic disease in Nepal and aims to identify potential and existing mitigatory activities in communities to address anthropogenic drivers of zoonotic disease spread. We conducted a multimethod study that included 39 in-depth interviews and five focus group discussions with people in rural and urban communities around Nepal, some of whom also took photographs to better illustrate their concerns. We also conducted 20 semi-structured interviews with animal and human healthcare professionals and policy-makers. Themes generated included animals as potential zoonotic disease vectors, beliefs (e.g., traditional medicine), disease awareness, anthropogenic drivers of increased contact (e.g., habitat encroachment, development, climate change), and the ways people experience and are affected by rodents (e.g., house and crop damage, consumption, disease). Community interviewees considered rodents to be the main nuisance animal in their environment, causing illness and destroying property (clothes, furniture, grain) and crops in fields. When interviewees discussed methods of preventing rodent damage, this tended to be perceived as necessary because of financial loss, rather than potential effects on health. People worried about not having enough to eat, without the luxury of worrying about getting ill. Most interviewees had experience of close contact with rodents (bites, crop damage, presence in homes) and some were resistant to the idea that this contact could become a health issue. Rodents were seen as a source of protein by some interviewees, with an interesting distinction between rats present in fields (seen as being clean and healthy, and therefore acceptable as food) while rats in the house were seen as dirty and not to be eaten. Photos taken included homemade rat traps, household damage, faeces in food storage, and disposal of rodent corpses. Health and policy professionals discussed the increasing human contact with rodents and wild animals caused by habitat encroachment and destruction of forest cover, and the fact that people tend not to have a clear understanding of the threats posed by rodents. This is a result of lack of comprehension at governmental levels, so knowledge does not filter down to communities. Rodent-human conflict was perceived as an important concept with much significance for rural and urban settlements in Nepal. Professionals noted that successfully implementing any long-term, transformational change required political attention to the threat of rodent-human conflict before programmes could be funded in communities. Engagement between health professionals and communities, to work with local priorities and co-develop effective solutions addressing drivers of zoonotic disease, rather than ‘parachuting in’ generic programmes was discussed as another positive step toward achieving a workable solution to potential disease spread through contact with rodents. Key learnings and avenues for future exploration will be presented.

European rabbit in north-central Chile: outbreak causes

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The European rabbit (*Oryctolagus cuniculus*) is one of the main invasive species in Chile, where it became naturalized ca. 150 years ago. Their high reproductive capacity, lack of specialist predators, and great adaptability favored the settlement of rabbits in diverse mainland and island ecosystems of the country. Rabbit pests are usual on crops and ecosystems causing severe economic damage. They have complex population dynamics with endogenous and exogenous influence factors, and an absence of a causal explanatory mechanism to predict their outbreaks. We employed seasonal and annual models to understand the increase and decrease of the population through different drivers. The rate of increase was best explained by low evaporation in summer, high cumulative winter rainfall, and abundance of *Geranoaetus melanoleucus* and *Tyto alba* during autumn to winter. We conclude that Rabbit dynamics can be defined as an eruptive dynamic caused by weather triggers that allow the population to obtain more and better resources avoiding being consumed by predators. These results are useful to explain and predict the outbreaks, understanding the mechanisms that cause the rabbit explosion in Chile ecosystems.

Urban fauna management through habitat modification: preliminary report of a pest management project on *Rattus norvegicus* in Genoa (NW Italy)

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About 51% of all the reports on the presence of rodents in the Municipality of Genoa come from the historical center of the city, with a worsening during the national lockdown introduced in 2020. The historical center of Genoa has all the typical features of an urban core of medieval origin: ancient buildings, underground systems (e.g. sewers) and all those factors that favour the proliferation and movement of rodents such as *Rattus norvegicus* (availability of waste, abandoned buildings, etc.).

The evolution of European and national legislation on the management of urban pests and wildlife, with particular attention to biocides and permanent bait, combined with the desire to reduce the environmental impact of disinfestations, make it necessary to implement structural measures for a radical solution to the problem. This can be perceived in an even more ethical vision, which sees the possibility of reducing the rodent population through pest-proofing with a consequent lower use of poisonous substances dangerous for the environment and avoiding the risk that these substances could end up in the sea, as well as a lower animal suffering. The preliminary operations consisted in the punctual maintenance of the territory (aimed at the removal of burrows and breeding/feeding sites), in the installation of ultrasound micro-seismic waves deterrents, in the physical removal of potential sources of edible food (waste) and in the progressive replacement of rodenticide bait stations with models more suited to the species, in view of their progressive elimination.

After a year from the start of data collection, it is possible to provide some preliminary results which, based on what is evidenced by the analysis of the territory, amount of used bait and citizens reports, have highlighted dynamics which, if confirmed in the coming months, will lead to a quick and effective containment of urban rat populations, with a substantial reduction of pollution and enhancement of ecological quality (including animal welfare).

New tools and methods: a bridge from research to pest control – 1

The European observatory of wildlife (EOW): a harmonized approach to estimate wildlife densities

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The need to harmonize wild boar population monitoring at international level to assess risks associated to African swine fever outbreaks and develop science-based polices has materialized a European framework to monitor wildlife (*ENETWILD*, www.enetwild.com) supported by the European Food Safety Authority (EFSA). The 'Observatory' approach (a representative network of intensively monitored sites) can provide long-term systematic insights, based on harmonized wildlife data, to support decision-making. The new-born European Observatory of Wildlife (EOW) (https://wildlifeobservatory.org/) as part of the *ENETWILD* project, is conceived as a network of “observation points” over Europe with common population estimation protocols and data collection standards to facilitate harmonization and interoperability. The main aims of this open collaborative approach, currently present in more than 30 countries, are (i) to provide guidance on methods and protocols for wildlife monitoring, focused on terrestrial mammals, (ii) to generate independent information on population abundance for those involved in developing, adopting, implementing, and evaluating environmental policy in Europe, (iii) to report trends on wildlife population changes in Europe, (iv) to improve density methods, incorporating Information Technology tools (ITs), Artificial Intelligence (AI) and Citizen Science (https://mammalnet.com), and in a further step, (v) to integrate with other environmental monitoring activities in Europe. The *EOW* provides to collaborators training, protocols for wildlife density estimations, continuous assistance on study design, implementation in the field, data processing and networking activities.

Among the activities carried out so far, comparable wild boar (*Sus scrofa*) density estimates were obtained for the first time by following a standardized camera trapping (CT) protocol in 39 areas (18,018 contacts in total). The Agouti app, including photogrammetry methods to estimate CT detection zone size and animal speed of movement using a computer vision process, represented a fundamental tool to reduce the workload, improve objectivity of measurements and enable a collaborative participation in the project. The collected data represent first baseline data for future trend analyses.

Recommendations for reducing environmental impact of pest mammal monitoring in New Zealand

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The introduction of pest mammals and plastic pollution are two significant contributors to biodiversity loss in New Zealand (NZ). My research aims to minimise both these issues by offering a solution to pest mammal monitoring that is more environmentally friendly

Despite NZ's reputation as a 'clean, green' country – we have trouble managing waste, leading to challenges in the fight against climate change. We have already banned plastic bags, and are expanding the ban to include all single-use plastics - targeting items that commonly end up in landfills and pollute soil, waterways and the ocean. It is estimated that more than 2 billion single-use plastics will be removed from our landfills yearly By phasing out unnecessary and problematic plastics, we will reduce landfill, improve recycling systems and encourage reusable or environmentally responsible alternatives.

While the NZ government focuses on removing single-use plastic from many large sectors, such as hospitality, smaller less-recognised sectors, such as conservation and biodiversity, are often overlooked. Instead of waiting until the spotlight turns to the single-use plastic used in pest monitoring and control, we should begin phasing out single-use plastic ourselves. Currently, the most commonly used pest mammal monitoring options are plastic. New biodegradable, environmentally friendly pest mammal monitoring equipment options can be designed and compared with traditional plastic options to determine if they can become the new industry standard. I will also be investigating potential by-products from other larger sectors that could potentially be used to create sustainable monitoring equipment. Complementary research is being done to develop biodegradable traps and long-life biodegradable lures; however, more effort is required for monitoring equipment.

Throughout this study, I will conduct fieldwork that looks at encounter and interaction rates of plastic and biodegradable detection devices – with both free-ranging and captive animals. Current research suggests that biodegradable options have a slightly higher interaction rate than plastic options. This fieldwork will take place at several field sites around New Zealand to ensure biodegradable materials work in all terrains and conditions. Biodegradable materials will be also compared to their plastic alternatives in terms of how well they withstand environmental conditions and how easy animal identifications are on each material (bite marks, footprints etc.). These preliminary results will then be shared at the conference

I will also be taking into account what is valuable to a range of different stakeholders and working alongside different groups, businesses and individuals to ensure all products meet required standards in terms of disposal, durability and cost-effectiveness. Different materials (e.g wood-core pulps, cardboard, natural pulp fibres) will be investigated to find alternatives to the current equipment used in pest mammal monitoring in New Zealand. Recommendations will also be put forward on how they can be utilised to reduce our reliance on plastic in the pest control industry.

The pathway to precision pest control: using genomics data for species-specific toxin development

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Pest control of invasive mammalian species is a key priority for New Zealand to prevent further decline of our native species, and to support the Predator Free 2050 initiative. One limitation of current vertebrate toxins for pest control is that they are relatively broad spectrum, with associated risks to non-target species. With increasing restrictions being imposed on the most commonly used toxins, globally the 2nd generation anticoagulants and in New Zealand sodium fluoroacetate (1080), there is a critical need to expand our toxin toolbox by developing more pest-specific toxins.

The genomes of important New Zealand pest species (stoat, ship rat and possum) have recently been sequenced, providing diverse new research opportunities. Using these genomes and those of non-target species, we are able to computationally compare protein sequences, with the goal of identifying potential novel toxin targets for pest-specific toxin development. Our initial focus is on the protein family of G protein-coupled receptors, as these receptors are commonly used as therapeutic targets for human medicine and as such many are well characterized with associated ligands that could be used as lead compounds in the toxin development process. Applying target identification and validation techniques from drug discovery represent an innovative strategy for the development of new vertebrate toxins, using genomics data.

How to control what is unseen? Analysing capture methods effectiveness and efficiency for an invasive snake

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The number of established populations of invasive snakes is steadily increasing worldwide, posing a serious threat to global biodiversity. However, almost all attempts to manage these organisms has been unsuccessful so far. This is partially explained by snakes' secretive behavior and extremely low capture probability, which cause management programs to yield insufficient captures, leading to invasive snake persistence or even spread. Management programs often try to counter these difficulties by relying on multiple capture methods, although their effectiveness and efficiency (in terms of capture rate and costs) are unknown for all species except two. In this context, we analyzed the effectiveness, efficiency and cost of the different capture methods used to control the invasive California kingsnake (*Lampopeltis californiae*), an invasive species introduced in Gran Canaria for at least 25 years and subjected to successive management programs since 2007. The main aim of this contribution is to provide robust information for better management planning in *L. californiae*, while contributing to reverse the current paucity of information regarding snake management methods effectiveness and efficiency. To do so, we first analyzed capture data collected since 2020 in Gran Canaria to evaluate the effectiveness potential capture limitations and factors affecting the effectiveness of the different traps, artificial cover objects (ACOs) and active searches routinely performed during management actions. Second, we performed a small-scale experiment in a recently invaded area to robustly quantify and compare the efficiency (calculated as captures per unit of effort) of passive capture methods against active methods to capture invasive snakes. Additionally, we used the data provided by the snake management program to quantify the costs associated to snake captures using the different methods available. The results obtained from the capture data provide crucial information on the effectiveness of traps, ACOs and active searches, as well as their limitations. Our small-scale experiment also reveals that active searches, often considered insufficient to control snakes, yield much higher captures per unit of effort than traps or ACOs. We also bring light on the costs associated to the management of *L. californiae*, currently considered the second costliest snake and the fourth costliest reptile worldwide. These results are contributing to design more effective management actions and increase efficiency in the particular case of *L. californiae*, highlighting the importance of incorporating research into invasive species management. Our contribution presents strong evidences over which to build clear recommendations for the management of invasive snakes over the dozens of established populations worldwide.

Novel audio lures to improve interaction and encounter rates of possums (*Trichosurus vulpecula*) with control methods in New Zealand

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The brushtail possum (*Trichosurus vulpecula*), a marsupial native to Australia, was widely introduced in both the North and South Islands of New Zealand between 1890 and 1930 to support the fur industry that was booming in Australia at the time. Possums were one of the many mammalian species that humans introduced when they discovered and settled in New Zealand. Before the settlement of humans in New Zealand, there were no terrestrial mammals; therefore, the local species evolved in the absence of mammalian predators. This resulted in native species populations falling at alarming rates and possibly facing extinction due to numerous predators and species that had not been intended to coexist alongside one another.

The government's initiative to reduce New Zealand's predators (possums, rats, and stoats) by 2050 has significantly expanded efforts to eliminate these pest mammals in recent years. Managing these pest mammal populations is crucial to protect the native bird, reptile, and invertebrate species.

In New Zealand, predator control has been practiced for a long time, but what started with simple trapping has since developed into a thriving industry full of expertise to boost the efficiency of trapping and toxins, including species-specific attractants. The number of traps and bait stations needed to be set up and the associated labour and expense would be significantly reduced if animals could be reliably drawn from a distance to a bait station or trap. Any sound played to encourage or discourage interaction with a control tool/area is known as an audio lure.

This research aims to identify if audio lures can significantly increase possum encounter and interaction rates of control devices and establish an audio lure tool that is durable, easy to use, and cost-effective for the wider public to use.

Preliminary captive trials found that an aggressive possum sound is significantly more attractive to possums than an alarmed possum sound, a beeping sound, or a control (no sound).

Preliminary field trials have found that the audio lure being developed performs similarly to an already established audio lure included as part of the Cacophony Project Thermal Camera. The price point of the audio lure being developed is around $250 (NZD) and should last 30 days in the field.

At the conference, I will present the final captive trial results and more field trial research. The field trial research will investigate encounter and interaction rates of possums feeding in live-capture traps with and without audio lures. I will also, report the final audio lure costings and field life before servicing is required.

Development of a coyote toxicant: PAPP and an antidote

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Research on the potential use of para-aminopropiophenone, PAPP, to control pest wildlife began decades ago; the United States Department of Agriculture (USDA) has been involved in PAPP research since its beginning. PAPP has been registered in New Zealand for the control of stoats and feral cats and in Australia for the control of wild dogs and foxes. The USDA National Wildlife Research Center (NWRC) has maintained an interest in the development of PAPP for coyote control. NWRC investigated the efficacy of PAPP as a means of lethal control in coyotes using multiple routes of administration. In initial studies, animals were orally gavaged with PAPP in an inert carrier to determine LD50 values and test LD100 doses. Coyotes were also offered PAPP in meatballs and allowed to freely consume the food bait. In further trials, NWRC researchers tested the effectiveness of two different doses of toxicant PAPP capsules (880 mg and 400 mg) placed in a spring-loaded ejector device (SLED) to lethally control coyotes. Captive coyote trials occurred at NWRC's headquarters and Utah Field Station. Both doses were 100% lethal to all animals tested. A larger study using 400 mg doses and wild-caught coyotes fitted with GPS collars will allow researchers to monitor coyote activity and movement patterns.

PAPP causes the formation of methemoglobin whereby reducing oxygen delivery to tissues. This mechanism of action is considered humane but, if exposed, non-target species may be affected. We are interested in developing an antidote that could be administered in working or companion dogs that may activate a PAPP delivery device. We have tested two potential antidote compounds in various formulations for delivery in the oral cavity, specifically sublingually and buccally. Antidote formulations were applied to the oral cavities of anesthetized coyotes. Blood was drawn every 10 minutes and circulating antidote concentrations were determined. These data will aide in the development of a field applicable PAPP antidote. Findings from coyote efficacy testing will be presented and antidote development discussed.

New tools and methods: a bridge from research to pest control – 2

Continuing the development, registration and efficacy testing of norbormide against both *Rattus rattus* (Ship rats) and *Rattus norvegicus* (Norway rats)

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Previously we have reported on the registration of para-aminopropiophenone (Predastop®) for predator control, and cholecalciferol with diphacinone (Double-Tap®) for “low-residue” rodent control. Norbormide is a uniquely selective “low residue” rat toxicant with rats being 100 to 150-fold more sensitive to norbormide toxicity than most other mammals and birds, and is our current focus. Lack of susceptibility has been shown in 50 species, including five bird species, numerous mammals, and nine primate species, with acute studies complemented by mechanistic research explaining the species selective effects of norbormide at a vascular and sub-cellular level. We have overcome the taste aversion associated with this a.i when it was first discovered as a candidate rodenticide and established the efficacy of norbormide-containing baits in laboratory studies targeting rat infestations in agricultural settings on poultry farms and achieved 100% reductions of wild Norway rat (*Rattus norvegicus*) populations. In larger scale field trials in conservation settings targeting ship rats (*Rattus rattus*), using the same new 1% norbormide paste baits, and a baiting strategy with prefeeding, independent assessors recorded a 100% reduction in rat abundance at test sites and no reduction at the untreated control site. Plans are progressing to complete product development, scaling production and registration in NZ as a precursor to making the product more widely available.

Rodent hole detection in a typical steppe ecosystem using unmanned aircraft systems and deep learning

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Rodent outbreak is the main biological disaster in grassland ecosystems. Traditional rodent damage monitoring approaches mainly depend on costly field surveys, e.g., rodent trapping or hole counting. Integrating an unmanned aircraft system (UAS) image acquisition platform and deep learning (DL) provides a great opportunity to realize efficient large-scale rodent damage monitoring and early-stage diagnosis. As the major rodent species in Inner Mongolia, Brandt's voles (BV) (*Lasiopodomys brandtii*) have markedly small holes, which are difficult to identify regarding various seasonal noises in this typical steppe ecosystem. In this study, we proposed a novel UAS-DL-based framework for BV hole detection in two representative seasons. We also established the first bi-seasonal UAS image datasets for rodent hole detection. Six models were investigated from three perspectives: accuracy, running speed, and generalizability. Results revealed that DL models based on UAS imagery had satisfactory results in BV hole detection with a high average accuracy of about 90% using Faster R-CNN and YOLOv4 model using Faster R-CNN and YOLOv4 model. The proposed method was demonstrated to utilize automatic, accurate, and efficient BV hole detection in a typical steppe ecosystem. The integration of UAS and DL techniques will have great potential for large-scale multi-seasonal rodent damage monitoring and control.

Evaluation of the Ekomille CO2® device as an animal welfare suppression system for rodent pests management

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Rodentia is the biggest family in the order of Mammalia, with over 40% of the species. The populations of a relatively few species that live in close association with humans sometimes cause economic damage or become threats to the health of humans or domestic animals. A few species of rodents are strictly associated to humans, and they are the cause of serious direct and indirect damage, by consuming or fouling stored products, acting as disease vectors or destroying infrastructure. In this context, rodent management is essential to preserve human safety. The trapping systems available on the market like glue traps, or snap traps, do not guarantee a humane suppression for trapped rodents, however other types like electronic traps or carbon dioxide single catch traps ensure a humane death but can make only a single catch.

In the present work the efficacy in rodent management conducted with the Ekomille CO_2® multi capture device according to the animal welfare guideline for Black rat and Norway rat are reported.

Estimating risk to prevent damage: proposals for management actions to prevent coypu damage to transport infrastructure

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The coypu (*Myocastor coypus*) is an invasive semi-aquatic rodent native to South America. Its negative impacts are mainly due to its digging activity in riverbanks and to the risk of floods and collapse damages to infrastructures. One of the riskiest situations concerns the collapse of roads or railways due to digging activities at intersections with watercourses. Preventive measures should be implemented to avoid collapse damages, but their implementation at all watercourses/transport infrastructures intersections is not economically viable. In this study, we propose the use of model-based analyses of species-habitat relationships to identify the characteristics of areas most susceptible to digging by coypu to guide the selection of priority areas where to develop specific preventive actions. This study was commissioned by the Italian Railway Network to the University of Milano-Bicocca to identify the most susceptible areas to digging by coypu along railway lines. To reach this aim we modeled species-habitat relationships at both landscape and local scale through i) a predictive model of species presence probability in the central area (17,000 km^2) of Lombardy (northern Italy), and (ii) detailed models to identify the environmental characteristics of the railway line-watercourse intersections (RLWIs) that make them particularly susceptible to digging. For the predictive model, we used a presence vs availability approach: coypu presence points (N=1804) were obtained from GBIF and Ornitho platforms (period: 2018-2022), while availability points (N=1804) were generated using a bias map (KD [Kernel density] 95% of presence points). Twenty-two environmental variables were calculated within buffers of different size around presence/availability points and a multi-scale ensemble model was developed to estimate the relationships between species presence probability and environmental variables. For the development of the detailed models, in spring 2022, we visited 61 RLWIs (within the KD50% of presence points) to detect coypu dens occurrence and collect environmental data. We then developed: i) a glm (presence [RLWIs with coypu dens: N=27] vs absence [RLWIs without coypu dens: N=34]) to assess the effect of environmental variables on the probability of coypu digging within a 50m buffer around RLWIs, and ii) a lm to assess the effect of environmental variables on the distance of dens (N=27) from the RLWI.

From the results of the ensemble model (AUC>0.9) we developed a predictive map of the potential distribution of coypu in the whole study area: coypu selected extensive agricultural areas characterized by developed hedgerows and watercourses networks close to rivers and/or marshes, while it avoided intensive agricultural areas with maize cultivation and both woodland and urban areas. The GLM (Explained deviance=43%) stressed that the RLWIs most susceptible to coypu digging were those surrounded by arable lands with interspersed hedgerows locally characterized by high herbaceous vegetation and silty-clayey soil. Conversely, RLWIs locally characterized by shrub vegetation and gravelly soil were significantly avoided. The lm (R^2=41%) showed that at RLWIs located in urban contexts with a poor hedgerow network locally characterized by high shrub cover coypu dens are excavated significantly closer to the railway increasing the risk of collapse damage. Our results provided practical indications to i) prioritize RLWIs where to implement preventive actions, considering both species presence probability at the landscape scale and environmental characteristics of RLWIs at the local scale, and ii) to design effective preventive actions. These actions can include both the installation of devices that discourage excavation (e.g., partially buried wire meshes) and environmental interventions that reduce the suitability for excavation close to the RLWI (e.g., mowing herbaceous vegetation) and increase suitability at a safe distance from the RLWI (e.g., maintaining high herbaceous vegetation).

Controlling *Apodemus sylvaticus* and *Microtus arvalis* that have moved from the field to infesting 'in and around buildings' with a cholecalciferol bait

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Within Europe the three key pest commensal rodent species are *Rattus norvegicus* (Norway or brown rat), *Rattus rattus* (Black or roof rat) and *Mus musculus* (House mouse). Under the EU Biocidal Products Regulation (BPR) these commensal rodents are allowed to be controlled with rodenticide products as their infestations are deemed to be harmful to human or animal health and / or cause damage to materials. Most rodenticide baits approved under the BPR have the use 'in and around buildings' on the label and for some products, uses in sewers and open areas, such as waste dumps and parks, are also included on the label.

There are other pest rodents, such as *Apodemus* species (for example *A. sylvaticus* - wood mouse) and *Microtus* species (for example *M. arvalis* - common vole), which are agricultural pests living in and around fields, damaging crops and orchards. The control of these field rodents is with products authorised under the EU Plant Protection Product (PPP) regulation. All grass-dominated habitats in Europe are inhabited by *Apodemus sylvaticus* and *Microtus arvalis (*Heroldová *et al.*, 2007). However, in certain countries and locations these field rodent species are becoming an increasing problem out of the field. That is, they are migrating away from fields and infesting buildings, spreading disease, contaminating food & feed (Klaudia Ko´ nczyk-Kmiecik et al., 2021) and causing damage. Hence with these infestations, they can be considered as "pseudo-commensal" pest rodents.

Worldwide, anticoagulant rodenticides baits are the fundamental tool used for rodent pest management (Buckle and Eason, 2015). In 2020 BASF registered Selontra®, a 0.075 % cholecalciferol non-anticoagulant rodenticide bait under the BPR. In mammals, cholecalciferol toxicity causes death by hypercalcemia - the calcification of soft tissues such as heart, kidney, liver, stomach (inducing a stop-feeding effect). In 2023, the registration of this product in Europe was expanded to include the pseudo-commensal rodent, *A. sylvaticus* and *M. arvalis*.

The infestations of *A. sylvaticus* and *M. arvalis* that are intended to be controlled with Selontra® are those that demonstrate different behaviour, where they are migrating away from fields and moving towards and infesting buildings. Therefore, in these situations their control now falls under the BPR and rodenticide baits can be used 'in and around these buildings' to treat the infestation. Choice feeding (palatability) and field trial studies were undertaken on Selontra®, where all studies complied with that prescribed in the Guidance on the Biocidal Products Regulation, Volume II Efficacy - Assessment and Evaluation (Parts B+C). Version 3.0, April 2018. Choice feeding (palatability) studies against *A. sylvaiticus* and *M. arvalis* demostrated 100 % control for both species. In both species Selontra® was found to be well accepted, with palatability ratios of 2.1 (62.2 % acceptance) and 2.2 (64.9 % acceptance) for *A. sylvaiticus* and *M.arvalis,* respectively. The mean time to death was 4.1 days for *A. sylvaiticus* and 5.3 days for *M.arvalis*. Field trial studies, undertaken 'in and around buildings' on infestations of either *A. sylvaitics* or *M. arvalis*, demonstrated 100 % control in both species. The baiting period to achieve 100 % control was 12 and 11 days for the *A. sylvaiticus* and *M.arvalis* infestation, respectively.

This paper outlines the difference between use of rodenticides under the BPR and PPP regulation, the reason why products are now approved under the BPR for the control of these pseudo-commensal rodents and control of against *A. sylvaiticus* and *M. arvalis* infestation with Selontra®, a 0.075 % cholecalciferol bait.

Strong phenotype variation as an early warning signal of abundance outbreaks in cyclical common vole (*Microtus arvalis*) populations

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Common vole populations from NW Spain are the only known example of a wild cyclical rodent in the Mediterranean region. These common vole populations constitute a major agricultural pest in the region, and derived impacts on local human populations include economical losses due to cultivated plant damage and a public health burden due to periodical outbreaks of zoonotic tularaemia. Successful management of such conflictive wildlife mostly relies on the availability of basic ecological knowledge about the factors and processes that determine the distribution and dynamics of their populations. Recent theoretical and empirical studies propose that specific combinations of extrinsic and intrinsic factors can generate multiannual population fluctuations and explain biological attributes of rodent cycles. In relation to intrinsic factors, rapid early recruitment during the increase-phase of the population cycle is favoured by a high proportion of genetically related breeding females within vole colonies (kin clusters), which can favour cooperative burrowing and breeding. The spatial clustering of large numbers of breeding females increases competition for fertilizations among males, and most competitive individuals should try to monopolize kin clusters. Access to, and defence of, female groups by large competitive males can optimize fitness and ultimately their breeding performance. Protected females may be safer to grow and increase body size, which is in turn correlated with higher productivity. Under these social circumstances (spatial aggregation of breeding females, including large productive individuals), the largest most competitive males are expected to be found in the population, that is, just prior and during the maximum population growth rate (PGR) of vole populations. Therefore, the intensity of sexual selection among common voles may be phase dependent. In this context, phase-dependent attributes of rodents, such as strong changes in body size, can be used as an effective early-warning signal to population outbreaks. Among cyclical common vole populations from NW Spain, larger males are indeed mostly recorded during years coinciding with the increase-phase of the cycle, and the degree of sexual dimorphism seems to be enhanced over those periods of maximum PGR. This striking pattern may be useful to forecast vole population growth if a greater sexual size dimorphism always precedes population outbreaks. The natural variation of common vole phenotypes can therefore be exploited to predict increases of abundances and aid to prevent rodent-driven impacts. More specifically, analysing changes in body size and degree of sexual dimorphism can provide an effective early-warning signal of vole population growth and its associated risks.

Fertility control

Insights from a 20 years' research on free-roaming cats

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Domestic cats have been widely distributed around the world as pets. Over time, non- domiciliary populations known as free-roaming cats have formed. These cats often suffer from impaired welfare and were shown to cause adverse environmental effects, such as ecological damage, nuisances, and public health hazards. The most commonly used method for managing these populations is trap-neuter-return (TNR), which is considered a humane control method. However, there is ongoing debate among researchers, regulators, and animal organizations about the effectiveness of TNR in reducing free-roaming cat numbers, improving their welfare, and reducing the negative environmental effects they may cause. In our research, we examined various aspects of TNR effectiveness using a unique controlled field experiment over a 12-year period in a 20-km2 urban area. We found a positive correlation between neutering and cat health and survival. High-intensity TNR was able to reverse population growth, achieving an annual reduction of approximately 7%, only when it was applied in a contiguous geographic area. However, this population reduction was limited by a rebound increase in cat reproduction and longevity. We concluded that TNR should be implemented with high intensity, continuously, and in a contiguous geographic area to achieve population reduction. To improve management effectiveness and prevent compensatory effects, we recommend further evaluating an integrated strategy that combines TNR with complementary methods, such as regulating vital resources, euthanasia for sick cats, and adoption.

Fertility control in common voles – sperm analysis and residues of an anti-fertility compound

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Overabundant pest rodents can lead to significant damage in agriculture, forestry, food storage, and to infrastructure. Additionally, these rodents can transmit zoonotic pathogens to both humans and livestock, making them a global threat. The common vole (*Microtus arvalis*) is widespread in Europe and during outbreaks, which occur every 3-5 years, their numbers can grow to an alarming level. Bait-based fertility control using environmentally safe compounds and appropriate baiting techniques could contribute to effectively manage the excess population of common voles.

We conducted a pilot study with wild and F_1 generation common voles, which were live trapped and individually housed. A liquid bait, containing 4-Vinylcyclohexene diepoxide (VCD) and Triptolide (TP) was offered daily to male voles for 14 or 28 consecutive days. In order to examine the sperm quality and residues in liver and testes, the animals were euthanized for dissection after the baiting period.

First results indicate that daily bait consumption between the 14 and 28-day treatments was similar and that the treatments had no effect on testes weight, sperm counts and sperm motility. However, there was an increased number of morphological sperm defects in treated voles. There were no TP residues in testes, few and low TP residues and no VCD residues in liver tissue.

The results show that the treatment with the compounds VCD+TP seems to have a minor effect on the reproductive organs of male voles (increased morphological defects) without an unwanted accumulation of the compounds in liver and testes tissues. However, further studies are needed to evaluate the effect of the treatment on females and on the reproductive success of common voles.

The work was supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the Federal Programme for Ecological Farming and Other Forms of Sustainable Agriculture (FKZ 2815NA113).

Collaboration, communications and fertility control to effectively manage a well-established, invasive non-native squirrel

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Invasive non-native species (INNS) are among the biggest global threats to biodiversity. In the UK, the grey squirrel, *Sciurus carolinensis*, is a well-established INNS. Now in the millions, its growing populations have caused local extinctions of native red squirrels, *Sciurus vulgaris*. As well as significant damage to and loss of countless ecologically and economically important young broadleaf trees, costing millions of pounds each year. Traditional, lethal wildlife management methods are increasingly unpopular, require much time and effort, and fail to have a sufficient impact on grey squirrel numbers.

In 2015, the UK Squirrel Accord (UKSA) was established; bringing together a range of stakeholders to more effectively tackle grey squirrel management to protect red squirrels and trees at a national scale. The partnership currently has 43 signatories, including conservation and forestry organisations, government agencies and companies. Partners work collaboratively by funding key research areas, disseminating knowledge, raising awareness, and increasing effective stakeholder involvement.

In 2017, UKSA began funding research to develop a grey squirrel oral contraceptive and design a species-specific feeding hopper. A range of contraceptive formulations are being explored, including oral immunocontraceptives. Along with a variety of methods to ensure the resulting contraceptive formula is only delivered to grey squirrels and does not impact non-target species.

Public support for this work is increasing. Grey squirrels are charismatic mammals with which many people connect and engage. Communicating their negative impacts and offering a future, non-lethal management alternative is turning the tide of opinion in favour of their removal from the UK.

This presentation aims to cover the main challenges of developing oral contraceptives for grey squirrels and how they are addressed; outline the model of UKSA as a blueprint for INNS management; and highlight stakeholder engagement and landscape-scale trials

An effective contraceptive bait delivery system for small mammals

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Rodents and other small mammals cause an increasing number of negative economic and environmental impacts worldwide, including losses to the food industry, damage to property and the transmission of disease. For example, in England and Wales, the grey squirrel *Sciurus carolinensis* causes an estimated £37 million in tree damage per annum and is also responsible for the decline of the native red squirrel *S. vulgaris*. Baits can be used to deliver biocides and contraceptives to reduce wildlife populations and as vehicles for vaccines to control disease outbreaks. Suitable bait delivery systems are required to ensure wildlife management is targeted, practical and cost-effective. The Animal and Plant Health Agency is currently developing oral contraceptives to manage grey squirrel populations in the UK and an important part of the research is to develop an effective bait delivery system. This system includes 1. a novel method to estimate small mammal population sizes to inform the number of bait devices to deploy for effective delivery; 2. a novel species-specific bait feeder that can be used to monitor patterns of bait uptake and the amount of bait consumed by individual animals. For study 1, we demonstrated that a camera-trap based method could accurately predict the density of squirrels in ten woodland areas of between 6 and 18 ha in size with densities of between 2 and 10 squirrels per hectare. For study 2, we demonstrated that a novel bait feeder was target-specific and could accurately measure patterns of bait uptake in four woodlands where squirrels were microchipped. Data from the feeders revealed that both male and female squirrels fed from hoppers and most of the individuals recorded made at least 70 visits over a minimum of 9 days, consuming at least 8 g of bait per day. These data provide important information on the amount of bait that would need to be deployed for most individuals to receive an effective contraceptive dose. Our system could be adapted to other rodent species and other bait delivery scenarios.

African lessons for Europe in developing contraceptives for rodent management

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Anti-coagulant rodenticides remain the main tool for rodent pest management across the world. Because of growing problems with environmental accumulation and development of resistance in target species, many countries increasingly restrict the use of anti-coagulant poisons, whilst some jurisdictions are considering outright bans on their use. Other options to control rodents in sustainable and humane ways are lacking, where the absence of poisons to control pests could lead to increased problems with zoonosis spillover to livestock and new disease pandemics of rodent origin as well as higher economic losses in most farming systems. Fertility limiting hormones levonorgestrel and quinestrol have been successfully and safely used to limit reproduction in humans and several wildlife species over many years. We present evidence that these synthetic estrogen and progesterone (EP-1) hormones can be highly effective against a number of different rodent pest species including cosmopolitan pest species such as *Rattus rattus* as well as regionally important pest species such as *Mastomys natalensis*, the main rodent pest across sub-Saharan Africa. Laboratory assessments have shown that the fertility of both males and females of these two species are adversely affected. Observed effects in males are reduced size of testes and other sex organs, with reduced sperm production and sperm viability. In females the effect is to induce prolonged uterine edema. Mating trials where both sexes or just females are fed a bait containing EP-1 can prevent pregnancy and where only the male is fed the contraceptive, it can reduce rate of pregnancy and litter size. Field trials in Africa comparing the use of EP-1 contraceptive bait compared to using an anticoagulant rodenticide bait have shown comparable population reductions where the impact of a single baiting event in an agricultural field can reduce rodent numbers in comparison to untreated control field areas. Evidence of using EP-1 for rodent control in field studies in China suggests its use should be safe for the environment. Based on evidence of efficacy, available human safety data and published environmental breakdown and non-target impact data, EP-1 is now registered for use in Tanzania to control rodent pests. Using EP-1 in a European context will remain challenging under current absolutist policies to prevent environmental contamination with synthetic hormones; however, rodenticide restrictions may necessitate a re-evaluation of EU rules where EP-1 should be a more environmentally sustainable alternative than anticoagulant use.

Controlling urban pigeon (*Columba livia*) population humanely

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Feral pigeons (*Columba livia*) are common in urban areas, where city buildings replace the rocky cliffs inhabited by their wild counterparts. Worldwide, pigeons have a significant economic impact. Pigeons' fouling, as well as being unsightly, can deface and accelerate the deterioration of buildings by eroding stonework, can block gutters and downpipes and cause potential slipping hazards on pavements, thus increasing the cost of maintenance. In addition, fouling has potential for diseases transmission.
Management tools such as netting, spikes, gels, and other approaches such as flying birds of prey can help, but these methods generally move the problem elsewhere. Products containing nicarbazin are an effective approach to reduce pigeon numbers through fertility control.

Already registered in Italy, Belgium, Hungary, Malta, and Spain as a veterinary medicine, as a means of reducing and controlling pigeon numbers, nicarbazin-treated bait has been shown to reduce pigeon numbers by 30% year on year for up to five years and maintain low pigeon numbers. This presentation will illustrate the results of applications of nicarbazin-treated bait for multiple, consecutive years, in many European cities, from 2002 to 2021. In cities like Florence, Genoa, Barcelona, Valentia, Brussels, just to mention the best known, the consistent use of nicarbazin-treated bait for at least 3 consecutive years led to a visible and documented reduction of the number of pigeons. In turn, the number of public complaints and accidents had a documented reduction.

The talk will also discuss potential issues encountered by practitioners in delivering nicarbazin-treated bait, illustrate evidence-based solutions to overcome these issues and compare advantages and disadvantages of different methods to resolve human-pigeon conflicts. Combined with other pigeon population management methods, fertility control represents a modern, integrated solution to mitigate this man-made wildlife problem.

Crops and urban systems – 1

Humane management of rodents

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Rats (*Rattus rattus* and *Rattus norvegicus*) and mice (*Mus musculus*) thrive near human settlements. Because of this they can become a nuisance or cause damage, and are therefore controlled. There are different ways for controlling rats and mice, each with its own advantages and disadvantages. This presentation will focus on the animal welfare aspect of the various methods used in Belgium and the integrated approach necessary to achieve animal-friendly control.

Integrated Pest Management (IPM) means that, after a thorough study of the problem, one chooses the most suitable method to solve the problem. Preference is given to animal-friendly and non-chemical methods. The aim is always to prevent damage, and within IPM it is therefore also possible not to proceed with the control if an animal does not cause damage. This is a departure from the classic thinking about pests, which is illustrated by legislation that always obligates control.

The most important step within IPM is to take preventive measures. By preventive measures we mean all methods that discourage an animal from appearing in a certain place. After all, the animals are so numerous that, if we would only focus on killing them, conspecifics would very quickly take their place. Rats and mice are mainly attracted to readily available food sources and access should be limited as much as possible.

However, sometimes control might still be needed. To assess the impact on animal welfare of lethal and non-lethal control methods the Sharp and Saunders welfare assessment model was used by an expert panel, scoring eleven control methods and three dispatch methods.

Mechanical traps range widely in their animal welfare impacts. For example, clamps, electrocution traps, captive bolt traps and live trapping cages for one animal can be described as animal-friendly. However, they must all be placed correctly and monitored regularly. Glue traps and live trapping cages for multiple animals are strongly discouraged from an animal welfare perspective.

Our own research and the literature clearly show that anticoagulant rodenticides are not animal-friendly. In addition, their use poses risks to humans, and the environment, and can lead to secondary intoxication. Therefore, these resources should only be considered as a last resort in the context of IPM. Other rodenticides such as chloralose or certain fumigants may offer a more animal-friendly alternative.

If rodenticides are nevertheless chosen, correct use thereof is very important. It is therefore important that private individuals find sufficient information and support when using these resources and, if necessary, be assisted by a professional pest controller.

Zinc phosphide for phytosanitary use against common voles (*Microtus arvalis*) population outbreaks: literature review and environmental perspective on the risks and impacts derived from its use

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The use of chemical rodenticides for the control of vole population outbreaks in crop fields is a common management option promoted by governments. Specifically, second generation anticoagulant rodenticides have been the main management tool used in pest control programs in Spain, even in the first decades of the twenty-first century

The global opposition of the international scientific community and environmental groups has led to the prohibition of these products in many countries, demonstrating their high toxicity and persistence and their effects of primary and secondary poisoning.

This is the case of Spain, where since 2019 a new chemical is available for the phytosanitary control of voles. This product is zinc phosphide, a non-anticoagulant rodenticide that hydrolyzes in contact with acidic environments such as the stomach, releasing phosphine gas and free radicals. Its commercial presentation is in the form of lentils made of cereal flour or grain impregnated with poison and a special applicator for the introduction of the product into the vole burrows.

Fortunately, since its approval, massive applications of the product in agricultural fields in Spain have not yet been necessary. Therefore, this is considered a good time to capture attention of regional governments through a literature review of environmental perspective on the risks derived from the application of zinc phosphide in agricultural crops.

Some technical observations from the manufacturer and data sheet about poisoning risks, contrast with available scientific literature about this topic. Although this product causes fewer secondary poisoning problems than anticoagulant rodenticides, many international studies show that there is a high risk of primary poisoning of wild animals, livestock and pets. This significant given that wildlife of agricultural environments is recognized as the most threatened group of species due to the use of phytosanitary products and habitat destruction.

Continue deepening in ecologically based rodent pest management (EBRM) strategies (i.e., non-chemical management options such as control with predatory birds) is necessary to restore biodiversity and balanced agricultural landscapes so they are able to minimize the effect of vole population outbreaks by keeping a manageable and more stable vole population, with the objective of keeping agricultural damage at bay in the long term.

Biological control as a tool for integrated management of common vole (*Microtus arvalis*) pests in agricultural environments in Spain: evolution of the project

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The Biological Control Pest of Common Vole (*Microtus arvalis*) Project started in Northwestern Spain in 2009 as an alternative to traditional measures applied to manage population outbreaks.

In that context, the systematic use of second-generation anticoagulant rodenticides and the burning of vegetation cover susceptible to harbouring possible reservoirs of the rodent were the main tools used to combat the population increase of the common vole. These, contributed to loss of refuge, habitat destruction, loss of biodiversity and simplification of agricultural ecosystems, thus aggravating the problem in the medium and long term.

The basic foundation of this project is to provide structures that serve as a refuge and breeding place for the potential native predators of the common vole, in this case Barn Owl *(Tyto alba*), Common Kestrel (*Falco tinnunculus*) and Little Owl (*Athene noctua*). This measure also contributes to the conservation of the target species and thus to re-establishing the predator-prey relationships that exert significant pressure on common vole populations and their reproductive potential.

The complexity of this project is due to the variety and diversity of the actors directly involved. This is why in these fourteen years different lines of work have been developed, depending on the constantly changing conditions and requirements, such as dissemination, implementation of new study areas, monitoring of the refuges installed, scientific studies, active presence in the territory, joint work with different administrations and institutions, as well as the development of other measures to support biodiversity in agricultural environments. Nowadays the project is developing in 77 localities belonging to 7 regions (Comunidades Autónomas), including private initiatives. It has about 2600 nest boxes in place, 1700 of which are being monitored with the aim of increasing knowledge of the species under study and their trophic and reproductive dynamics.

Among the achievements are, on the one hand, the compliance of the primary objectives of this project, which are the prohibition of the phytosanitary use of second-generation anticoagulant rodenticides and the burning of semi-natural linear spaces (ditches, boundaries, streams, etc.). Likewise, there has been an increase in the willingness of the agricultural and hunting community to implement measures that help to enhance the biodiversity of agricultural ecosystems as part of an integrated management of the presence of common voles in crops.

On the other hand, the demonstration of the potential that biological control and its associated recommendations have as a management tool is other important achievement. Which is why it has been included in the regional regulatory framework included in the ORDEN AYG 96/2019 by which the "Strategy of integrated management of risks arising from the presence of common vole in Castilla y León" prepared by the Junta de Castilla y León in view of the continued presence of the rodent in the agricultural land of the region. Its purpose is to protect crops against the risks arising from the evolution of the populations of common vole, acting always from the perspective of a preventive, integrated and environmentally friendly management, compatible with agricultural productivity and wildlife conservation.

Common vole biological control in agricultural ecosystems of Castilla-y-León (Spain): reproductive productivity of raptors in artificial nest-boxes in relation to abundance fluctuations of the pest species

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The common vole (*Microtus arvalis* Pallas) is an arvicoline rodent whose distribution in Spain was limited to the mountain systems into the Iberian Peninsula northern half. From the 1970s onwards, a fast and progressive colonisation of this species took place towards the Duero river basin, until common vole became to be present in the whole of the Northern Plateau. This area in Castilla-y-León region, has large tracts of cereal steppe (>3 million hectares of arable land), where periodic common vole population outbreaks occurs causing important damages to crops. Biological control by promoting its natural predators is one of the types of action contemplated within the integrated management strategy for this species in Castilla y León. Biological control is considered an interesting ecologically-based rodent pest management (EBRM) tool, that seeks to reduce the impact of the common vole in an accessible and sustainable way through the knowledge of its ecology and that of its predators. In this study, more specifically, we propose the promotion of native raptors highly specialized in the capture of rodents, through an environmental enrichment based on the placement of nest boxes, which serve as a substrate for shelter, nesting and reproduction of these birds in agricultural areas with high risk of recurrent vole outbreaks. The results presented here correspond to five years monitoring experiences (2018-2022) in experimental areas (more than 600 nest boxes distributed in 8 municipalities) located in one of the most severely affected agricultural counties of Castilla y León. The installed nest boxes were specifically designed for occupancy by the common kestrel (*Falco tinnunculus*), barn owl (*Tyto alba*) and, to a lesser extent, little owl (*Athene noctua*). Nest boxes have been yearly monitored during the raptors breeding season, recording their occupancy by these species, breeding pairs, clutch size and number of hatched chicks. In parallel, the abundance of common vole in the study areas was monitored, in order to establish the relationship between raptors reproductive productivity and common vole population fluctuations. The obtained results point to an adjustment of the birds of prey reproductive capacity in the nest boxes in response to the availability of voles in the environment. Beyond the density of adult barn owls and kestrels and number of breeding pairs in the study areas, these variations are manifested in the size of their clutches and chicks hatched throughout the different years, although other factors not already considered in our study may also have some influence. The variations observed in these parameters are consistent with the hypothesis of a greater predatory pressure when the common vole increases its population size, both due to the number of raptors present and the effort required by each pair to raise their broods. Although further studies are needed to clarify all this, environmental enrichment by providing artificial nest boxes for rodent specialized raptors would contribute to reestablishing the prey-predator balance in agricultural areas with risk of common vole incidence.

Field size as a determinant of common vole population densities

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Landscape heterogeneity has long been implicated in mechanisms proposed to explain differences in the observed patterns of population dynamics in small mammals, with the more homogenous landscapes promoting higher vole population densities and cyclicity in vole dynamics. This mechanism has always been difficult to test rigorously. In an agricultural landscape, one method of testing may be based on the relationship between population density and field size. From the vole perspective, the larger the field size, the greater the homogeneity of the landscape it inhabits. The farmland in the Czech Republic is particularly suitable for accomplishing this task because the field size ranges from less than 1 ha to vast fields much above 50 ha in size. Between 2015 and 2021, I collected data on population densities of the common vole in 22 districts of the Czech Republic twice a year in more than 220 fields with fodder crops, namely alfalfa, clover and permanent grass fields. The size of each field was measured to the nearest tenth of a hectare using the map application OneSoil. Fitting the generalized linear mixed models revealed that consistent with the hypothesis, vole population densities increase with field sizes. However, the relationship is highly nonlinear, with the highest rate of change observed in fields up to 10 hectares in size. Above this threshold, the increase in population density is negligible. These findings contribute to ecological theory and have implications for agricultural practice.

Rodent management and rice production in Southeast Asia – balancing food security and biodiversity goals

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Rodents are a major issue impacting food security in Southeast Asia where smallholder farming families, who typically cultivate less than 1.5 ha, dominate and are particularly vulnerable. We briefly review recent developments in ecologically-based rodent management (EBRM). Then we will take a broader view and consider two Sustainable Development Goals (SDG 2 and 15) and the context of developing rodent management approaches that balance food security and halting of biodiversity loss in agricultural landscapes.

In Southeast Asian countries, EBRM significantly increased rice yields (6-15%) and income (>15%) of smallholder families. We summarize recent case studies on EBRM in Cambodia and on interactions between rodent pests and weeds in Myanmar. We then consider the importance of modified wetlands for biodiversity and rodent pest management. We identify ten challenges for the next decade. For example, quantifying post-harvest impacts of rodents is increasing but more research is needed on benefit-cost analyses of recommended interventions. A related research gap is the assessment of human health impacts following a reduction of rodent densities in and around houses. We also need to understand better the interactive effects of cropping intensification, conservation agriculture and climate change. More research is needed on the modelling of long-term population data to address these issues. Also, new management approaches such as fertility control need to be considered in the context of smallholder cereal farming systems. Finally, there are many native rodent species and other vertebrate fauna that are not pests of cereal production but are often at risk through indiscriminate rodent control approaches. Rapid changes in intensification of agriculture coupled with an increase in occurrence of extreme climatic events are likely to lead to an increase in pest rodent population outbreaks. These need to be anticipated and the pest populations managed without compromising faunal biodiversity, particularly in flooded rice cropping systems that provide important wetlands. Often, these faunae can provide an important positive ecosystem service in such systems.

Crops and urban systems – 2

Collection of pest management data used to improve rat control in Denmark

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The Danish legislation (the Danish Statutory Order on prevention and control of rats) has made it mandatory for citizens to report actual or suspected occurrences of rats to the local authorities. The rat controls are most often carried out by the local authority - for free, but citizens can also choose a private PCO, this however is not free of charge and will be covered by the citizen. Whether rat control is done by the local authority or a private PCO, there is a requirement that rat control may only be carried out by an authorized person. When carrying out rat control, the authorized person must make a mandatory report (online). The reported data are automatically transferred to a central database and here the data are available for local authorities and the Danish Environmental Protection Agency (DEPA). The database is own by DEPA and all the Danish municipalities. DEPA and the municipalities supervises that all rat control (the municipal or the private) comply with this requirement.

The same legislation furthermore requests that all municipalities, as a preventative measures for invasion of sewer rats, install rat blockers on all sewer lines leading into institutions such as schools, nursing homes and hospitals.

Together, this gives opportunity to extract various and adequate data for the control of rats in Denmark, at local and national level and use these data to suggest improvement for rat control in general

We will present data that provides detailed and valid information about:

- The development in reports of rat occurrences from 2015 until 2022
- The distribution of rat control carried out by either municipals or private PCO's
- The most common causes to rat occurrences
- The development in use of chemical and non-chemical control methods
- The effect of preventative measures against sewer rats seen as the numbers of reports of rats from institutions

Rat (*Rattus norvegicus*) management in the city of Zurich, Switzerland

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According to the hygiene decree of the canton Zurich from 1967, rodents in the communities have to be controlled, as they are potential carriers of diseases and cause damage in and around buildings. In the city of Zurich, the Urban Pest Advisory Service (UPAS) is responsible for the control on public grounds. Private pest control companies control rodents on private properties. From 1997 to 2022 the control of Norway rats (*Rattus norvegicus*) on public ground in Zurich has gradually changed to an efficient rat management with different improvements and continuing efforts to increase the efficiency. Our data show that covid-19 has not influenced the rat situation significantly, however in 2021 we had a wet year and a very strong storm in the summer and more rat control than usual was necessary.

Sewer baiting of rats was taxed as inefficient in 1994 and abandoned without a significant increase of rat problems as the city sewers are in good condition and are regularly cleaned, inspected and renewed. After a reorganisation in 2003 the UPAS gave up practical insect control and delegated it to private companies. This left more time to improve the rat control on public ground, public relations and other prevention projects. After 2004 stationary bait boxes were placed in public «rat areas». A regular monitoring interval was defined for all designated public rat areas and is adapted from time to time. This and reports by city staff and private people allow early detection and efficient control of rat populations. Since 2007, the city Waste Disposal & Recycling Department has successively equipped parts of the city with closed underground waste containers, which are rat-safe. Rat proof litterbins have also been installed in strongly frequented areas. Additional waste containers are stationed to keep the areas clean during the summer. A long-lasting problem has been deliberate bird feeding by a group of bird lovers offering abundant food for the rodents as well. Since beginning of 2023, a new cantonal law forbids the feeding of wildlife and the gamekeepers of the Gardening and Nature department (GSZ) have the possibility to fine excessive feeders. On the long run, this should reduce available food and ease the rodent situation in some of the public places. We inspect private houses or properties when rat problems appear. This is necessary in backyards of house blocks, where often nobody feels responsible. The causes are usually inappropriate waste disposal, bird feeding and/or broken sewer drains. Based on the cantonal law, we can enforce the repair of damaged sewers. We check new baits for their attractiveness and efficient use and now mainly use the following baits on public ground: coumatetralyl paste bags, cholecalciferol blocks (Selontra) and difenacoum grains for direct baiting. They all have a fairly low toxicity for non-target animals. Until today, no problems have turned up concerning resistance and all of these baits have worked successfully.

We present data concerning the rat situation of the last 25 years, the decrease in the amount of rat bait used and the improved work efficacy. The 41 «rat areas» defined in 1998 were reduced to 27 areas by 2022. Maintenance and repair measures of local sewer lines and renewal of the surroundings have led to this reduction. In 2009, we implemented a web-based Arc-GIS programme to visualize all registered rat cases on the city map. This helps to solve continuous rat problems. In 2014, the city created a mobile phone app «Züri wie neu», similar to the British «fix my street», where people can easily report infrastructure damages. In 2018, we added the possibility to report pests and rat or other pest sightings can be reported this way. Since then, citizen science enhances our reporting network.

For birds and humans: unforeseen challenges and additional benefits of rat eradications on inhabited islands

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Eradication of rats from islands is a very effective tool that can free species and entire ecosystems from the pressure of alien predators. However, in prioritising which islands to operate on, great emphasis is placed on the benefits to target species and communities, while less (or no) attention is paid to the benefits to resident communities. On the contrary, the presence of resident communities is often seen as an additional obstacle to the implementation of the action, particularly due to the presence of ship connections that could allow the recolonisation of rats. Actually, a quantification of the benefits for resident communities should be an additional element of interest for the implementation of interventions. In this study we present the case study of the island of Ventotene, which to date is by far the island with the largest number of inhabitants ever freed from rats. The intervention – carried out in the framework of the Life PonDerat project, co-financed by European Union - was preceded by a thorough preparatory survey, which covered both the species present on the island and the presence of economic and pathogenic damage related to the rat population. In addition, the presence of anticoagulant-resistant mice and rats and the genetic proximity between the rat populations on the neighbouring islands (Ponza and Palmarola) and the mainland opposite was verified. The results demonstrated the convenience of the action, not only from the point of view of ecosystem restoration, but also from that of reducing rat impacts. The overall economic cost to the community for the presence of rats was quantified at approximately €20,000 per year, while several pathogens were detected in the rat population prior to eradication. A large reduction in the number of rodenticides distributed annually on the island was also estimated. Identifying the source from the present population allows the development of more targeted and effective biosecurity measures. However, genetic analyses on the VKork genes that confer resistance to anticoagulants have confirmed the presence of mutations associated with resistance to anticoagulants in domestic mice, suggesting that this aspect must be carefully considered in the planning stages of interventions on these islands. Furthermore, greater difficulties are certainly present, because domestic animals are present on the islands, however in the case study not impacted (affected) by the treatment, and the need to carry out treatments in urbanised areas, with particular attention to poultry houses and sewers.

Rodenticide resistance

Structural mechanism of anticoagulant rodenticides resistances: Identification of a hydrophobic cluster responsible for the affinity between inhibitors and the target protein

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Vitamin K antagonists (VKAs) rodenticides have been used for the past decades for rodent populations management. These molecules act by inhibiting the vitamin K epoxide reductase (VKORC1) enzyme, an endoplasmic reticulum resident protein. VKORC1 catalyzes vitamin K epoxide reduction to vitamin K quinone then hydroquinone, the latter state being the exclusive cofactor of gamma-glutamyl-carboxylase (GGCX) enzyme. GGCX is responsible for the activation of clotting factors II, VII, IX and X. Inhibition of VKORC1 by VKAs thus prevents the reduction of vitamin K epoxide to quinone, inducing a disruption of the blood coagulation cascade. However, two main issues have arisen from the use of VKAs: resistances and ecotoxicity. Many anticoagulant resistances were described for both rats and mice, that led to the development of second generation VKAs. Although they were more potent, these molecules have caused some wildlife poisoning cases: secondary poisoning of rodent predators – such as foxes and raptors – was reported. Despite the use of VKAs since the 1950s, the *Vkorc1* coding gene was only identified in 2004, so VKAs resistances have been first characterized at genetic and enzymatic levels over the last decade. Many VKORC1 mutations have been identified as resulting in resistances, with frequencies that can locally reach 100%: L120Q, Y139C and Y139F mutations have been widely described in rats, as well as W59G, L128S and Y139C in mice. Nevertheless, the structural mechanisms of resistances induced by these mutations remained unclear since no 3D data was available for VKORC1 enzyme, due to its membrane location. But the publication of the experimentally solved VKORC1 structure in 2021 has provided reliable and valuable new data for exploring and explaining the structural mechanisms of VKAs resistances induced by VKORC1 mutations.

In the present work, we investigated the effects of the five VKORC1 mutations mentioned above on the enzyme structure: W59G, L120Q, L128S, Y139C and Y139F. Molecular modelling studies led us to identify a hydrophobic cluster ensuring VKORC1 structure integrity and encompassing W59, L120, L128 and Y139 residues. The mutation of a single amino acid in this structural region totally disrupts the hydrophobic pattern, leading to a loss of structure of VKORC1-VKAs binding site. The W59G mutation even triggers a disruption of the whole enzyme, also preventing the binding of vitamin K epoxide, the VKORC1 natural substrate. These results allowed us to explain the structural consequences of VKORC1 mutations and to characterize the mechanisms that decrease affinity between the mutated enzyme and VKAs. In an other hand, we also studied the role of the phospholipidic membrane towards VKAs. Variations of membrane permeability to anticoagulants was investigated, considering two types of lipids (phosphatidylcholine and phosphatidylserine, the major species in endoplasmic reticulum membrane). The obtained results indicated that lipid bilayers are less permeable to second generation VKAs, but show higher variation towards first generation VKAs depending on their lipid composition. These preliminary results might therefore imply a role for the endoplasmic reticulum membrane in VKAs selectivity/retention, thus its involvement in ecotoxicity issues – the lipid profile being variable over species, mammals and raptors for example. Taken all together, our results help at understanding structural mechanisms underlying resistances and ecotoxicity issues relative to VKAs. It also paves the way for the development of new, efficient and less ecotoxic VKORC1 inhibitors, which would allow the management of rodent populations while preserving wildlife.

Vkorc1 polymorphisms in the Norway rats from the ancestrally distributed area indicate independent evolution of anticoagulant resistance

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Anticoagulant rodenticides have been widely used in China for nearly 50 years. Mutations in the vitamin K epoxide reductase complex subunit 1 (Vkorc1) can cause anticoagulant resistance in rodents. However, the Vkorc1 polymorphisms were unclear for Norway rats in most areas in China. To understand the anticoagulant resistance level in Norway rats in China and whether the Vkorc1 polymorphisms reported in European Norway rats could be traced in the ancestrally distributed area of Norway rats, e.g., China, we analyzed the Vkorc1 polymorphisms of 494 rats in China and compared them to the VKORC1 polymorphisms in global Norway rats out of China. We identified three nonsynonymous mutations Ala26Thr, Cys96Tyr and Ala140Thr in three populations in China. The Ala26Thr had been fixed in a population that used anticoagulant rodenticides frequently, indicating a strong selection by anticoagulant rodenticides. Using the bioinformatic methods, we found the binding affinities of VKORC1 protein to the anticoagulant rodenticides, such as brodifacoum, bromadiolone, coumatetralyl, difenacoum, had been changed by the three mutations, indicating they could be responsible for anticoagulant resistance in the Norway rats. No Vkorc1 nonsynonymous mutations were detected in the remaining 39 of 42 populations, indicating a low resistance level in most areas of China. The first generation of anticoagulant rodenticide is still effective in these areas. We also collected the Vkorc1 nonsynonymous mutations in Norway rats out of China and found all 18 mutations except Ala26Thr were absent in China, indicating independent evolution of Vkorc1 mutations in Norway rats during their dispersal from their ancestrally distributed area.

Investigating invasive roof rat resistance by screening for genetic mutations

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Rats (*Rattus* spp.) are a common and very damaging invasive pest found throughout much of the world, with one projection of damage caused by rats in the USA estimated at $19 billion annually. Although much of the damage they cause occurs in residential areas, they are also common agricultural pests. Rats are also a significant public health threat as they are linked to the spread of numerous diseases in humans and animals. They are also often implicated in food safety risks in crops through contamination with their urine and feces.

Anticoagulant rodenticides are the most common method of control of rodents worldwide and act through the inhibition of the vitamin K epoxide reductase (VKOR) enzyme. Inhibition of this enzyme results in the depletion of available vitamin K and subsequent blocking of the clotting cascade. The initial success of controlling rodent populations using first-generation anticoagulant rodenticides (FGARs) led to their widespread use and the emergence of resistance. As populations of rodents that were not susceptible to first generation anticoagulants became more prevalent, second-generation anticoagulants (SGARs) were brought to the market. SGARs are now integral to pest management programs safeguarding human and animal health and global food security.

Anticoagulant compounds pose risks to non-target species through both direct consumption of bait and through carcasses of anticoagulant-exposed animals. These risks have led to increased pressure to limit the use of this class of compounds, especially SGARs. The future impacts of these regulations are unknown. It is also uncertain if an overreliance on FGARs for structural pest management could impact the effectiveness of these active ingredients used for agricultural applications. Where resistance to certain anticoagulant rodenticides is widespread, the inability of pest management professionals to use any of the effective active ingredients (potent resistance-breaking anticoagulants) for rat control has adversely affected the control of resistant rat infestations. It may also have played a part in accelerating the spread of anticoagulant resistance and the proliferation of resistance mutations.

The objective of our study was to investigate the prevalence of rodenticide resistance in *Rattus* species in agricultural and urban areas in California, USA. We used a combination of field and lab work. The field work involved trapping (snap and live) rats in agricultural and urban areas in California to collect samples from geographically distinct locations. The lab work involved genetic analysis for identification of mutations of the VKORC1 gene that may confer anticoagulant resistance. Our genetic analysis looked for both known and novel mutations that may be unique to rat populations in California. We will also test the metabolic activity of liver microsomes that may be affected by alterations the VKOR enzyme. *In-vitro* work is critical as it will demonstrate the functional metabolic changes related to genetic mutations for specific active ingredients (first or second-generation anticoagulants). No applied research related to resistance in *R. rattus* has been conducted in the USA. Findings of our study will be presented and thoughts for future studies discussed.

Rodenticide resistance in Norway rats and house mice in Ireland

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Norway rats (*Rattus norvegicus*) and house mice (*Mus musculus*) spread pathogens, spoil foodstuffs and gnaw property. Anticoagulant rodenticides are the primary control method. Anticoagulants inhibit the VKORC protein in the liver and kidneys, leading to haemorrhaging and anaemia mortality. These rodenticides have a delayed action that helps overcome feeding shyness, and the widespread availability of an antidote (Vitamin K1) reduces the risk to people, pets and livestock. The genetic basis for resistance is linked to single nucleotide polymorphisms (SNPs) in the *Vkorc1* gene. Globally, rodent populations are developing genetic resistance to the less potent anticoagulants. Increasingly, resistance to the more potent anticoagulants is also being discovered. The aim of this study was to determine the prevalence of resistance in Irish rodents. A national survey has been conducted to obtain tissue samples, focusing on high-risk areas. The Polymerase Chain Reaction (PCR) and Sanger sequencing were used to reveal the DNA code of individuals. This established the prevalence of resistance-linked *Vkorc1* SNPs. The survey results are being used to inform Ireland's national evaluation of rodenticides under S.I. 427 (2013) European Union (Biocidal Products) Regulations. This may lead to regulatory modifications on the use of highly potent resistance-breaking rodenticides. Rodenticides with reduced efficacy have been identified, and their authorisation is being considered.

A brief overview of the Vkorc1 gene mutations related to anticoagulant rodenticide resistance in Turkish populations of *Rattus rattus* and *Rattus norvegicus*

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Rats include the most known rodent species and have importance for public health due to the spread of zoonotic diseases. First- and second-generation anticoagulant rodenticides are used to control these rodents, especially in urban areas; however, studies show that anticoagulant rodenticide resistance associated with *Vkorc1* (vitamin K epoxide reductase complex subunit 1) gene exists in rats. Mutations in the *Vkorc1* gene causing changes in the enzyme structure prevent the binding of anticoagulant rodenticide to the enzyme and reduce the anticoagulant efficacy significantly. Black rat (*Rattus rattus*) and Brown rat (*Rattus norvegicus*) native to southeastern Asia have have been spreading to Turkey via shipping or highway transportation for years. In the present study, in addition to the previously identified Ala21Thr (*R. rattus*) in Exon 1 region, Ile90Leu (*R. rattus, R. norvegicus*) in Exon 2 region and Leu120Gln (*R. norvegicus*) in Exon 3 region, newly identified Ser74Asn, Gln77Pro (*R. rattus*) and Ser79Pro (*R. norvegicus*) mutations were found as “missense mutations” causing amino acid changes. While Leu120Gln is the only detected mutation related to resistance based on previous studies, the relevance of other mutations to resistance is unclear. In order to obtain precise results, future studies are needed for applied rodenticide resistance studies to be carried out especially in specimens with missense mutations. In any case, the results obtained will contribute to rodent control studies in Turkey.

This study has been accepted as an article in “PeerJ Life & Environment” under the title “*Vkorc1* gene polymorphisms confer resistance to anticoagulant rodenticide in Turkish rats”.

Widespread distribution of resistance-conferring mutations in the Vkorc1 gene among populations of invasive house mice in the oceanic archipelagos of Azores and Madeira

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Synanthropic rodents, including house mice, are responsible for huge economic losses worldwide, with impact on human dwellings, agricultural production, and food spoilage, also constituting a public health concern. On islands, invasive rodents pose an additional challenge for biodiversity conservation due to their ability to outcompete and even extirpate some native species.

Resistance to anticoagulant rodenticides can be a major problem in attempts to manage and/or eradicate house mouse populations and their negative effects. Over the last decade, numerous studies, particularly in Europe, have detected the presence of several mutations in the vitamin K epoxide reductase complex subunit1 gene, *Vkorc1*, associated with resistance to different anticoagulant rodenticides in synanthropic mice and rats. Here, we characterized the status of genetic resistance to these biocides within *Mus muscuslus domesticus* populations inhabiting both Portuguese Atlantic archipelagos, Azores and Madeira, comprising a total of 12 islands. House mouse samples from continental Portugal and Southern Spain were also included in the analyses.

A total of 241 house mice distributed throughout the study area were genotyped for the 3 exons of the *Vkorc1* gene. Overall, eight mutations were identified, seven of which non-synonymous. Among these variations, two of the most geographically widespread mutations in house mice, L128S and Y139C, were detected, particularly in the insular settings. Additionally, four substitutions in exon 1 and one substitution in exon 2, constituting the *Vkorc1*^{spr} genotype, were identified at very high frequency in the mainland populations. This sequence variant is resultant of adaptive introgression between *Mus musculus* and *Mus spretus* due to the hybridization between both species, that co-occur in sympatry in the Iberian Peninsula.

Both mutations, L128S and Y139C, as well as the *Vkorc1*^{spr} genotype are all associated with high levels of resistance to first-generation anticoagulant rodenticides and some resistance to some second-generation rodenticides like bromadiolone and difenacoum. These findings are in line with the informal feedback from farmers from Madeira and Azores regarding the difficulties in controlling house mouse populations. These results highlight the need for adaptation of standard rodent management practices to prevent the inefficient use of anticoagulant rodenticides in resistant populations. Likewise, it emphasizes the need to assess the resistance status of island populations of synanthropic rodents before pest management/eradication actions are set in place.

Widespread resistance to anticoagulant rodenticides in *Mus musculus* domesticus in the city of Barcelona

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Control of rodent populations is a big challenge because of the rapid evolution of resistance to commonly used rodenticides and the collateral negative impacts that these products may have on biodiversity. Second-generation anticoagulants are very efficient but different single nucleotide polymorphisms (SNPs) in the *Vkorc1* gene may confer resistance in rodents. We sequenced exons 1, 2 and 3 of the *Vkorc1* gene from 111 mice (*Mus musculus domesticus*) captured across the city of Barcelona and found SNPs associated with resistance to first- and second-generation anticoagulants in all of them. Although most of the SNPs were associated with resistance to bromadiolone, we also found SNPs associated with resistance to brodifacoum. Out of all the individuals analyzed, 94.59 % carried mutations associated to introgression events with *Mus spretus*, a sympatric rodent species. Currently most of the chemical products for rodent control commercialized in the area are based on bromadiolone, although recent public control campaigns have already shifted to other products. Thus, the widespread occurrence of resistant mice to bromadiolone represents a challenge for rodent control in Barcelona and may increase the risk of secondary poisoning of animals preying on this species. Public health managers, pest control companies and citizens should be aware that the use of bromadiolone based products is ineffective and represents a risk for the environment, including human and animal health.

Management of resistant Norway rats: measures to minimize rodenticide applications

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If genetic resistance occurs in Norway rats, anticoagulants, which are classified as toxic, bioaccumulative and persistent, are commonly used for control. These agents are harmful to the environment and to non-target species, so they should be used as little as possible. In the ResRaMa project, we investigated the extent to which rat-related sanitary measures, rat-sniffing dogs, and toxin-free monitoring can help minimize rodenticide applications on farms. The results were summarized in a guidance for farmers and pest control operators. The study clearly showed that by using dogs to detect current infestation sites, the time required for infestation detection can be reduced. Alternatively, both sands to detect rat tracks and non-toxic monitoring baits, such as rolled oats, can be used to record actual rat distribution during control and limit poison baits to boxes with rat activities.

Sanitary measures delayed rat establishment by an average of 85 days and supported control success. While more rats with resistance were observed inside than outside buildings prior control, there were generally significantly fewer animals with resistance after control. All of the measures tested can result in less anticoagulant agents use in the resistance area, reducing the risk to the environment and non-target species. To prevent resistant rat establishment, the project digiWRaP is now underway to develop a digital early warning system for farms with resistance.

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Zoonotic pathogens and parasites

RodentGate: future rodent management for pig and poultry health

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Apart from consuming and spoiling animal feed, and damaging infrastructure in and around buildings, rodents are a considerable threat to animal and human health. They can cause direct stress in pigs and poultry but are mainly important as carriers of pathogens. They can pick up the infection from infected pigs or poultry and spread it within and between farms, act as a bridge between wild fauna and livestock, and maintain the infection locally when a farm is emptied and decontaminated after a disease outbreak or livestock turnover. An important approach for on-farm rodent control is the use of rodenticides but new restrictions on their use pose new challenges for efficient rodent management on farms. Project RODENTGATE investigates rodent-related risks for animal health in the pig and poultry industry and how this might change with altered rodent control.

For two years, the RODENTGATE consortium has trapped rodents on pig and poultry farms in different parts of the UK, Belgium, Netherlands, Germany, and Poland. A preliminary molecular screening using PCR has revealed that rodents harbour various pathogens known to infect poultry and pigs, including *Brachyspira* sp., pathogenic *Leptospira* species and *Lawsonia intracellularis*, which could be spread to pigs and poultry on these farms. A small subset of the rodents trapped in Belgium was screened by metagenomic sequencing, revealing that the diversity of viruses and bacteria was drastically higher in the rodents trapped in pig farms than in poultry farms. This has potentially severe consequences for livestock health, especially in the pig industry, where, based on our survey, almost 50% of the owners manage the rodents themselves.

The next step within the project is to extend the molecular screening of various other pathogens and include them in an individual-based epidemiological model, which will ultimately allow us to propose appropriate evidence-based and economically sustainable strategies for the ecologically-based management of rodents and rodent-borne infections around farms.

Changes in forest management intensity predict the presence of Puumala-orthohantavirus (PUUV) in bank voles (*Clethrionomys glareolus*)

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Anthropogenic alterations to the environment can negatively affect natural ecosystem integrity. In the process, shifted ecosystem properties have led to the disturbance of many fundamental ecosystem services. For zoonotic pathogens, habitat degradation may alter host abundance, diversity, community composition as well environmental conditions associated with pathogen transmission. There are very few experimental studies dealing with mechanisms of transmission of pathogens in response to different forest management intensities. To make informed recommendations on combating emerging zoonoses, it is important to establish how different forest management strategies contribute to the persistence or absence of certain zoonotic pathogens.

Here we present results of a trapping campaign in Central Germany from 2020 to 2021. A total of 25 forest sites were sampled for small mammals. Sites were chosen to represent the range of forest management intensities based on the silviculture management index (SMI). A total of 815 individuals showed a mean PUUV prevalence of 4.1% (ranging site-specific from 0-28.9%). Bank vole abundance was positively associated with SMI and the probability of detecting PUUV significantly increased with increasing SMI. These results are of particular importance, as they highlight that a reduction in management intensity can potentially help to mitigate PUUV presence.

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Lymphocytic choriomeningitis virus, a neglected zoonotic pathogen in Europe?

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Lymphocytic choriomeningitis mammarenavirus (LCMV) is a globally distributed zoonotic pathogen with the house mouse (*Mus musculus*) as an important reservoir. The virus causes callitrichid hepatitis in New World primates (family Callitrichidae) and symptoms ranging from flu-like to meningitis and encephalitis in humans. Four lineages of LCMV are currently recognized, with lineages I and II being the most common found worldwide. Little is known about the current distribution of LCMV in Europe. In Germany, LCMV has been absent in the literature for more than 20 years. Here we report on the re-emergence of LCMV in a diseased golden lion tamarin (*Leontopithecus rosalia*) and wild house mice (*Mus musculus domesticus*) in a German zoo. Phylogenetic analysis of the entire coding regions of the RNA polymerase, nucleocapsid protein and glycoprotein reveal the presence of one LCMV lineage (I) in the golden lion tamarin, and two LCMV lineages (I and II) in wild house mice from the zoo. The sequences found in the golden lion tamarin and one of the house mice were nearly identical, suggesting cross-species virus transmission. These findings do not support the previously proposed host specificity of LCMV lineages in *Mus musculus* subspecies. Ongoing studies are dedicated to evaluate the geographical distribution of LCMV in house mouse populations in Europe.

Rodent control by rodenticide and trapping to fight Lassa virus in Upper Guinea: a six years longitudinal study and possible pool table effect

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Lassa fever is a viral haemorrhagic fever caused by a Lassa arenavirus (LASV). This zoonotic disease is endemic in West African countries, including Guinea. *Mastomys natalensis* has been identified as its reservoirs in Guinea. Without vaccine, rodent control and human behavioural changes are the only options to prevent Lassa fever in highly endemic areas. Rodenticides were used to quickly reduce *Mastomys populations* and reduce LASV transmission among individuals. However, similar densities were observed 2-3 months after treatment and LASV circulation persited. We tested the hypotheses: (i) prevalence of LASV in *M. natalensis* population is negatively influenced by a long-term yearly chemical control (ii) intensive trapping can complete the chemical control (iii) LASV infected *M. natalensis* are unevenly distributed in the rodent population. The village of Brissa (1500 inhabitants), located in the Lassa virus endemic area of Upper Guinea, was used for a 6-year (2013-2019) annual chemical rodent control with anticoagulant rodenticides (Bromadiolone and Difenacoum) during the dry season (November-April) each year in all open houses. The duration of chemical treatment was 10 days during the first 2 years and 30 days during the last 4 years. To evaluate the control efficacy, trapping sessions of three consecutive trap nights were performed before and after intervention. Additionally, an intensive trapping lasting 3 months was tested in 2019 to complete the annual control. Each rodent trap was geo-located. Our analyses were based on the infection status: IgG tested by immunofluorescence assay and LASV tested by RT-PCR. The prevalence between sessions were tested (before/after each chemical control) and after the intense trapping session. Clusters of positive individuals for LASV (IgG and LASV) were determined by Cuzick-Edwards test and geographically defined with Kulldorff statistic. 434 rodents were trapped including 420 *M. natalensis* with 88% (369/420) before and 12% (51/420) after chemical control. Chemical control efficacy was 73-89% (mean = 80.2 ±6.2) according to the session. Before treatment, IgG and LASV prevalence varied from 12 (7/58) to 79% (78/99) with a plateau at 36-40% during years 1-4, then decreased during year 5, to finally reach the highest level at the end of year 6. After treatment, IgG and LASV prevalence varied 7-83% showing a chaotic pattern due to the peak during year 2. As before treatment, the infection raised during the year 6. There was no difference before/after each session, but IgG prevalence was significantly lower after treatment when we consider the whole study. Because no rodents were LASV positive after treatment except for the year 2 (prevalence = 35%), we expect that chemical treatment decreased temporally the number of infectious rodents but did not stop the virus circulation. Despite 2477 rodents trapped during 3 months of intensive trapping, IgG and LASV-prevalence exceed the levels observed, since six years. The majority of infected rodents were trapped in a few houses and most houses were rodent-free at a specific point in time. Spatial analyses defining trapping success hotspot combined to the clusters of positive rodents are in progress and will be presented during the conference. Such spatial information can help to describe what higher exposure conditions are for humans and define risk assessment preconisations.

Pathogen risks posed by humans to urban rats: campylobacteria in Helsinki, Finland

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Humans are the most prolific spreaders of parasites and pathogens across the globe. Many animal species are in risk of acquiring anthroponotic diseases from humans, but none are in such a great risk as the synanthropic species. Indeed, urban or other synanthropic rats have a long-documented history from plague pandemics in acquiring pathogens from human vectors. Nevertheless, there is still surprisingly few studies assessing the infectious disease risk that is posed by humans to rats. We have studied in Helsinki Urban Rat Project pathogens and parasites in urban rats and the overlaps in their habitats and human movement. We have collected tissue samples, adult helminths and fecal samples from carcasses obtained through pest management companies and fecal and blood samples from live rats from the Helsinki city area. We have found a number of pathogens or parasites that are potentially transmitted between humans and rats, but it is difficult to assess which pathogens and parasites are in reality transmitted between these species. Nevertheless, a pathogen – *Campylobacter jejuni* which is the most prevalent gastrointestinal symptom causing pathogen in humans in Finland – was common in rats. We cultured the bacteria from the fecal samples and performed a whole-genome sequencing of any positive occurrence. The sequencing revealed that urban rats in Helsinki harbour both human-associated and mice-associated sequence types of this pathogen, suggesting for a possibility of interspecific transmission. Based on our studies, the transmission risks are highly asymmetrical: whereas humans rarely are exposed to rat feces, rats in Helsinki area commonly move within the sewage system and are thus exposed to human excrement. Our results strongly suggest that *C. jejuni* can be added to the list of pathogens commonly transmitted from humans to rats. Due to the age of sewer infrastructure in the city of Helsinki, it is difficult to stop rats from entering the sewer system in the city center area, thus making it difficult to disrupt interspecific transmission. We suggest that the pathogen prevalence in rats could be decreased by reducing the amount of edible waste in the sewage and by reducing the prevalence of *C. jejuni* in humans.

TALKS

Why account for biodiversity for mitigating tick-borne disease risk? Insights and perspectives from eastern Italian Alps

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The biodiversity crisis is one of the most critical environmental issues of our time. Species losses affect ecosystem functioning by depriving those services - such as carbon sequestration, nutrient cycling and resistance to drought - on which also humans rely. Among these, control of infectious diseases is a highly valuable service provided by biodiversity with implications for human health. Habitat degradation and the resulting biodiversity loss, alter the ratio among generalist species and specialist, thus increasing the risk of zoonotic emergence since many generalist species are competent reservoirs. Currently, scientific studies considered either the role of anthropogenic changes (e.g., climate and land-use) on disease emergence or how biodiversity affects dynamics of endemic diseases. Indeed, a multitude of studies performed in the Eastern Italian Alps (Autonomous Province of Trento, Italy) unveiled what are the environmental and climatic factors driving risk of tick-borne zoonoses emergence. In particular, findings from a systematic review evidenced that temperature-dependent variables were negatively associated to the variation of Tick borne encephalitis (TBE) across Europe. Further, habitat diversity seemed to also dilute TBE virus (TBEv) incidence. Conversely, covariates related to the presence of competent hosts (i.e., rodents) and forest cover had a positive role in TBEv circulation, while incompetent hosts (i.e., deer) showed a hump-shaped effect. These patterns were confirmed also through empirical studies. Specifically, a study found that TBEv detection was related with number of co-feeding ticks carried by rodents, which in turn is negatively correlated with autumnal cooling rate and increased with tick burden on rodents, deer and rodent abundance. Therefore, a specific combination of climatic conditions and certain rodent and deer densities resulted the principal determinants of the TBEv incidence. Similarly, another study highlighted the strong relation between TBEv cases and air pollen abundance, a proxy for seed production. This suggested the major role of rodents as amplifying hosts, being favored by the availability of seeds and thus by pollen quantities. Similar insights were observed in experimental research evaluating the role of artificial ungulate feeding sites in disease spreading. Here, food availability promoted the density of mice, while favoring revisitation patterns of roe deer and interspecific competition among rodents' species. Co-occurrence of roe deer and mice at these sites affected infectious pathogen transmission, with lower prevalence of tick-borne pathogens (*Borrelia burgdorferi s.l.*, *Babesia microti*, *Anaplasma phagocytophylum* and *Hepatozoon* spp.), while the opposite was found for rodent-borne ones (hantaviruses). Beyond hosts, also land-use plays a crucial role in driving disease circulation. In this sense, a study investigating the effects of land-use type on acarological hazard for *Ixodes ricinus* and on its infection rate found a positive effect of climate on relative abundance of questing nymphs, while no differences were observed among land-use categories. However, when considering the density of infected nymphs (DIN), the effect of land-use emerged with the natural habitats having the highest DIN values for *B. burgdorferi s.l.*, the urban habitats the highest ones for *A. phagocytophilum*, while for *Rickettsia* spp., no differences were observed. Overall, this provides evidence for complex ecological factors to consider for predicting microbial hazard. However, so far, few studies have tried to reconcile the relationship between biodiversity, anthropogenic change, circulation of endemic pathogens and risk of disease emergence. By considering the cascading eco-epidemiological processes occurring in ecosystems with different degrees of naturalness we aim

to identify the anthropogenic impacts on biodiversity, and the role of the latter in driving infectious disease circulation and emergence.

The combined effect of bromadiolone and ivermectin (iBr) in controlling both rodents and their fleas

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Rodent pests not only cause severe agricultural loss, but also spread zoonotic pathogens to human beings. Anti-coagulant rodenticides are widely used to decrease population densities of rodents, but often lead to the spillover of ectoparasites because fleas and ticks may gather on surviving rodents. Therefore, it is necessary to kill fleas and ticks before culling rodents to minimize the risk of disease transmission. In this study, we used a mixture of ivermectin (an anti-parasite drug) and bromadiolone (an anti-coagulant rodenticide) to control both rodent and flea/tick abundances. We found, in a laboratory test, 0.01% ivermectin bait was not lethal for Greater long-tailed hamster after 7 days of treatment, while 0.1% ivermectin baits was lethal for approximately 33% of treated rodents. In a field test, bait containing 0.001%, 0.005%, 0.01%, and 0.05% ivermectin decreased the number of fleas per vole of Brandt's voles to 0.42, 0.22, 0.12, and 0.2, respectively, as compared with 0.77 in control group, indicating 0.01% ivermectin bait performed best in removing fleas. In another laboratory test, the bait containing 0.01% ivermectin and 0.005% bromadiolone mixture caused death of all voles within 6-14 days after the intake of the bait. In the field test, the bait containing 0.01% ivermectin and 0.005% bromadiolone reduced the average of fleas per vole to 0.35, significantly lower than 0.77 of control group. Our results indicate 0.01% ivermectin and 0.005% bromadiolone mixture could be used to control both rodents and fleas in minimizing the spillover risk of disease transmission using traditional rodenticides.

POSTERS

Ecology, physiology and behaviour

Poster 1 – Analysis of bear-stripping behaviour using video images taken by automatic camera

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The damage caused by black bears to the bark of planted forests (bear stripping) is problematic from both a forestry and forest management perspective, as the damage occurs at the base of the trees, where timber value is high, and often several trees are affected at the same time. Research has been carried out on methods to control bear stripping, but it is difficult to observe the site of bear stripping, so sufficient countermeasures have not yet been considered.

In August 2008, automatic cameras with infrared sensors were installed in a small area of about 0.1 ha in the University of Tokyo Chichibu Forest, where bear stripping has been occurring since the 1950s, and attempts were made to film bear stripping. As a result, by the end of the research in 2020, we were able to take videos of bears stripping five times: in June 2013, July 2017, June 2018, May 2020 and June 2020. In the Chichibu region, bear stripping is said to occur from late May to early July. All of the bear stripping incidents photographed this time occurred between late May and early July, which is in accordance with previous experience.

Analysis of the five videos revealed that the bears strip bark horizontally or vertically using their claws and teeth, that they use their teeth and tongue to feed on the surface of the wood beneath the bark, and that the time per bear attack can range from around five minutes to nearly an hour. Bear-stripping behaviour could be carried out by one bear alone or several bears together, and the number of trees damaged at any one time varied from one to more than 10 cubs were also observed stripping bark at a height of more than 6 m while climbing trees.

There were also indications that bear cubs working with mother bears may learn to strip bark by imitating their mother's behaviour, and that stripping bark skill may improve as the cubs grow older, that are thought to prolong damage as bear stripping behaviour is passed on from mother to cubs.

Poster 2 – Digital quantitative evaluation of rodent hair tubes for activity indices

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Activity indices such as hair index derived from hair tube use are utilised to determine small mammal activity. This can be less labour intensive and is less invasive than trapping animals, and hence seems a suitable alternative to trapping campaigns when purpose and setting allow it. Usually, hair tubes are deployed in transects or grids in the habitat of interest according to standard procedures and checked after several days for hair left by small mammals in the tubes.

Collected hair can be used to assess small mammal activity based on presence of hair or the number of hair/hair density. Estimating the latter can be tedious and requires considerable effort when many tubes are used by small mammals.

Our hair tubes consist of plastic tubes of different diameters, open at both ends, with double-sided adhesive tape fixed to the inner side of each tube. After the session, the adhesive strip is collected and scanned with a standard commercial scanner. The image is then assessed with a newly custom-developed computer program that allows to distinguish background and adhesive tape from hair automatically, and provides a quantitative measure for the hair density, which can be used for further analysis. This will facilitate an easy-to-use non-invasive determination of small mammal activity. The first results will be presented and discussed.

This project is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the Federal Programme for Ecological Farming and Other Forms of Sustainable Agriculture (2819OE179).

Poster 3 – Red fox den sites' environmental characteristics

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The red fox (*Vulpes vulpes*) is one of the most widespread mesopredators in Europe, and this species is relevant to game management and mammal conservation across the continent. The fox has shown great adaptation within human dominated landscapes and now inhabits urban areas as a result of boosted population sizes. This has led to an increasing conflict between this species and human activities, particularly hunting and poultry farming. For this reason, the red fox is considered a pest species by several local and regional administrations, and it is now included in many management control plans. Gaining information of behaviour, habitat selection, and particularly the selection of den sites could improve the management of the species and reduce conflict. We disentangled some environmental variables driving red fox den-site selection, during springtime, in a hilly area (~ 46 km2) in northern Tuscany, Italy. We considered a "den" an enclosed site, such as a burrow in the ground or hollow log, used by foxes for shelter and/or reproduction, after ascertaining fox presence in this site with direct observation or non-invasive camera trapping. We did not distinguish between dens used for reproduction, for birthing, or only for shelter, and we recorded the GPS location of each den. To determine the den characteristics selected by foxes, we subdivided the study area into equal polygons of 0.5 km2 each, where we randomly selected 98 points to be field visited to verify the absence of a fox den and record the environmental characteristics in the same way they have been recorded at fox dens. Vegetation type, distance from water streams and distance from roads were extracted for each site (den and random points) using GIS land cover map layers (50x50m resolution - Tuscan Regional Government). Finally, in both fox dens and random points, we sampled the visibility of habitat for each point using a red fox shape. Specifically, we placed the shape of a standard-sized red fox in each point and determined its visibility in terms of the percentage of squares observed out of the total squares constituting the shape. The visibility was assessed by observations from the four cardinal points, at about 50 cm above the ground, from 10 metres distances. We model den presence-absence data using a Generalized Linear model with binomial error distribution and land use type, visibility, distance to water streams and roads as predictors, including quadratic effects for numeric predictors to account for non-linear effects. Our pilot study included 13 den sites and 98 random points where the absence of a den site was confirmed. After model simplification we found that fox dens were more likely to be located at greater distances from water streams and roads, when compared to random points. Moreover, fox den sites were characterized by lower visibility when compared to absences. Habitat type was not deemed statistically significant in our model, but we highlight a strong tendency of foxes to select for deciduous forests which will be reassessed by future research with increased sample size. As a result of the high undergrowth and reduced visibility caused by the den location, our findings indicate that it is possible to predict where fox dens are more likely to be located and this will be further explored by increasing sample sizes and detail in the habitat type data collection. The low visibility, especially of the den entrance, which provides greater safety for the individuals using it, is unquestionably the most crucial consideration taken by foxes when choosing the location of the fox's den.

Poster 4 – Effects of inhabit and life patterns on the UV spectral properties of small mammalian herbivores' urine

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It is well known that avian predators can use prey excretions such as urine and feces to track their prey, and the urine and feces of small mammalian herbivores can reflect ultraviolet (UV) light and emit fluorescent light. There is still some debate as to whether UV visibility of small mammalian herbivore's urine is used as a hunting cue by avian raptors. Some studies in Europe have demonstrated that diurnal raptors are capable of utilizing these cues to target key prey species. However, researchers in Australia have argued that raptors do not use the UV visibility of urine while hunting. To our knowledge, there are no reports from Asia concerning the ultraviolet spectral characteristics of small mammal herbivores urine.

This study examined the UV spectral properties of urine from 6 small mammal herbivores species by comparing the UV reflectance and fluorescence spectra of urine from small mammalian herbivores living in plateau meadows, plateau shrubs, open marshland, farmland, and semi-desert grassland in China. In addition, we compared the UV spectral properties of urine from ground-dwelling species of rodents and subterranean species to determine whether ultraviolet visibility of small mammal herbivores urine could be used as a visual signal by Asian vole-eating raptors.

The results showed that (1) the SC_{370} values of urine from five small mammal herbivores species were ordered as plateau pika (plateau meadow) > root voles (plateau bush) > reed voles (swampland) > Brandt's vole (desert grassland); and (2) UV fluorescence peak intensity and the wavelengths of urine from ground-dwelling species (such as the root vole, plateau pika, or Brandt's vole) were significantly higher than those of subterranean-dwelling species (mandarin vole and plateau zokor). These results indicate that UV visibility of small mammal herbivores urine may act as a visual cue for raptors.

Poster 5 – Voles - a hidden threat to forest regeneration in Germany

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Climate change-driven forest damage caused by storms, droughts and bark beetle outbreaks have led to an increase of deforested areas in the federal state of Saxony in Germany. Sites that require reforestation are regularly covered with fast growing grass and herb species promoting the occurrence of vole species and thus increasing the feeding damage on forest regeneration. The complex temporal and spatial mosaic of such areas complicates the management of voles as potential forest pests.

One of the biggest challenges with regard to voles in forestry is an early regulation of the population density. However, due to restrictions on the use of rodenticides since 2019, short-term control is increasingly difficult, which is why more attention has to be paid to precise monitoring procedures.

In this context, the KuSaMWET research project at the Chair of Forest Protection at Technische Universität Dresden conducted a number of field experiments studying habitat conditions to predict the colonization probability of voles and show present deficits of currently applied methods in vole management.

Invasive vertebrates

Poster 6 – Ungulate as pests: DNA analyses reveal a widespread occurrence of sika deer genes in north-western Italy

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All ungulate species may severely affect the floristic structure of ecosystems through selective browse of palatable species, and most of them are responsible for the local disappearance of a number of plant species. Particularly, alien species are not coevolved with native vegetation and their early detection and removal should be recommended to limit potential impacts including increased browsing and hybridization with native species. Sika deer *Cervus nippon* are native to Japan and the Far East, but have been introduced to several European countries as an attraction for urban parks and for meat. As to Italy, the most recent checklist of mammals reports the sika deer as occurring only in small non-reproductive groups in Northern Italy, as escaped or released from farms.

The identification of hybrids *C. elaphus* x *C. nippon* can be morphologically and bioacustically possible only for individuals of the first generation, which shows intermediate phenotypes between parental species, whereas the identification of further generations and backcrosses require genetic analyses. Despite the current lack of research effort in determining the distribution of sika deer and hybrids, the Italian prioritization list of alien species (excluding those of European concern included in the EU Regulation 1143/2014) reports that the sika deer is the second most harmful alien mammal species to Italian native biodiversity. The current state of our knowledge of sika distribution in Italy is insufficient to provide the basis for sound management in the near future. Thus, in our work, we aimed at clarifying the current status and distribution of the sika deer in North-Western Italy. In this work, we conducted genetic analyses on mitochondrial DNA COXI gene on a sample of Northern Italian peninsular populations of “deer”. Differently from what previously suggested, we confirmed the presence of sika deer genes in deer populations from three Italian regions (Emilia Romagna, Liguria and Tuscany). This finding suggests that the escaped individuals may have resulted in an expanding *C. elaphus* x *C. nippon* population, which needs to be rapidly identified and removed, to limit potential impacts on native environment and the genetic pollution of Italian native red deer nuclei.

Poster 7 – The Life MICA project: managing aquatic invasive species across borders

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Aquatic invasive species can spread rapidly within and across regions connected by watercourses. This is especially true for muskrat (*Ondatra zibethicus*) and coypu (*Myocastor coypus*), two semi-aquatic rodents that have long been present and managed in Western Europe. To facilitate cross-border management of these invasive species, Flanders, the Netherlands and Germany work together in the MICA project (Management of Invasive Coypu and muskrat in Europe), co-funded by the Life+ programme of the European Union. The project aims to reduce coypu and muskrat populations to a manageable size in order to prevent damage to waterways and biodiversity.

Life MICA develops and tests several innovative techniques such as the use of eDNA and wildlife camera traps for monitoring and detection. Furthermore, to facilitate the flow of information across (inter)national administrative boundaries, data on the occurrence and management of the species from the three regions were standardized and brought together in an open, interactive online dashboard.

Poster 8 – Patterns of activity of the invasive species *Myocastor coypus* through camera trapping in a northern Italy reserve

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The study of the activity rhythms of invasive species can help in their management and eradication programs. Coypu *Myocastor coypus* is a South American rodent that has been introduced in Italy for fur farms. It is one of the most invasive species in the world that causes huge damages to ecosystems, like bank collapse and crop damage. In this study, the phenology of *M. coypus* has been analyzed through one year of camera trapping in the "Riserva Regionale Vallazza" (MN) (45.133°N, 10.825°E). 1132 images of *M. coypus* have been collected by 5 camera traps to examine their activity rhythms during the different months and hours of the day. The specie is more active during February (11%), March (12%) and from October to December (36%). The greatest number of births in the area take place mainly in late spring but it is possible to meet very young specimens throughout the year.

Regarding the night and day activity, coypus are often considered diurnal by the rivers' managers and the monitoring are mostly performed in the mornings. The observation underlined that 55% of the movements were recorded from 4 pm to 9 pm. Another peak in activity was evident during night hours, at 12 pm (8%).

The behaviors of coypus were categorized by classes during image and video classification: passing, stationing, eating, sniffing, and interaction between individuals. The highest percentage of behavior analyzed (68%) has been "moving in front of the camera traps" as 4 of the traps were placed far from their dens systems and between areas of alimentation and only one close to den in a bank. All other behavior were also, in decreasing percentage: stationing (15%), eating (11%), sniffing (5%) and interaction (1%).

Nocturnal activity is also confirmed in this protected area where there is currently no pressure on the population by culling and leads us to reflect on the importance of monitoring even at night for the evaluation of numbers and the activation of control plans. The wide range of activities, movements and foraging at distance from the burrow systems underlines how complex it is then to make the control plans of the species effective. Coypus are very numerous in the plains of northern Italy as well as in many other areas in Italy.

Poster 9 – Will the expansion of *Callosciurus finlaysonii* in Basilicata and Calabria regions worsen the condition of the endemic *Sciurus meridionalis*?

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The extreme south of the Italian peninsula is an area of particular biogeographical value in the Mediterranean and there is the endemic Calabrian black squirrel *Sciurus meridionalis*. This species is present in all the major mountain reliefs of Calabria region and in recent years we have been monitoring an effective expansion to north of its range, mainly thanks to extensive plantations of pine trees, mainly *Pinus nigra* and *P. halepensis* woods, on ridges and slopes of all the main mountain systems. In the north of the area, a population of *Callosciurus finlaysonii* is also rapidly expanding, originated more than 30 years ago from 3-4 pairs from a private garden. *C. finlaysonii* is responsible for large decortications on numerous natural and cultivated trees species, causing considerable damage, sometimes even to power lines and buildings.

Despite the repeated alarms, an adequate plan has not yet been developed to counteract the expansion of the Finlayson's squirrel which is now starting to occupy part of the Apennine areas in the southern slope where it has already come into contact with the endemic species.

The study is aimed at monitoring and evaluating the potential niche overlap, getting more information about the distribution and food choices of the two species and verifying Calabrian black squirrel disappearances from sites recently occupied by the Finlayson's squirrel. In field investigations the signs of presence were evaluated, such as eaten pine cones, tracks, nests, camera traps data and decortications as well as surveys of the public and stakeholders. Increased range and new sites in areas previously occupied by the Calabrian black squirrel. The need to operate adequately to preserve *Sciurus meridionalis,* a species with a very small range and relevant biogeographic interest, is becoming increasingly urgent.

Poster 10 – A successful rapid eradication of emerging African clawed frog (*Xenopus laevis*) in Flanders (northern Belgium)

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The African clawed frog *Xenopus laevis*, native to Sub-Saharan Africa, has been introduced to natural systems around the globe from escapes or releases linked to the pet trade and from biomedical laboratories that use animals as model organisms in research. This largely aquatic species can adapt to a wide range of aquatic habitats (rivers, streams and ponds) and tolerates high levels of pollution. Its capacity to disperse through the water as well as over land and its propensity to burrow into the substrate represent particular management challenges. Despite it being listed as an invasive species of Union Concern (as of 2 August 2024), new introductions still occur. In 2018, a new population of *X. laevis* was discovered in northern France, far outside the known range of the species further southwest in the country. Subsequent observations across the Belgian border, triggered surveillance and response actions, integrating conventional monitoring, environmental DNA (eDNA) sampling and the application of calcium oxide as a control method. To assess the invasion extent of the species and to establish a baseline distribution, eDNA sampling campaigns were executed in 2020 and 2022, resulting in the discovery of three pond sites (1100m^2, 600m^2, 500m^2) with reproduction in Mesen (Flanders, border region with Wallonia and France). These ponds are located in arable fields and pastures along a brook where adult frogs had been detected using electrofishing. Also, the spatial configuration of eDNA concentrations in the landscape suggests this brook might serve as a dispersal corridor for *X. laevis* from Wallonia and France. Authorities acquired agreement with site owners and quickly initiated action. In January 2023 the ponds were fenced with a screen and drained. The remaining water and pond edges were subsequently treated with quicklime (calcium oxide) at 0.6–3.1 kg/m3. There are several reasons why this method was chosen. First, it is presumed to be highly effective. African clawed frogs have a pH amplitude of 5-9. A quicklime treatment bringing pH >12 for 24 hours should suffice for killing any aquatic organism. Second, the method is fast which was necessary to convince the farmers to allow action on their land. Third, when everything is oxidized, the situation should be entirely back to normal with no effect on soil properties after a few weeks, so ponds could return to their normal agricultural use for cattle drinking and be used by native amphibians again. Lastly, the method is legally allowed for disinfection purposes. One disadvantage of the method is the production of quicklime itself involves an environmental cost. Also, the product is highly corrosive and implies health and safety risks for operators. During and after application, the pH and the number of (dead) frogs and other organisms were monitored. Although classic field monitoring suggests all three reproducing populations were entirely eradicated, we intend to explore the value of post-intervention eDNA to quantify eradication success. Considering the risk of reinvasion from neighbouring areas, there is a need to upscale the surveillance and intensify management where needed. The case of this *Xenopus* eradication illustrates the challenges of rapid eradication in the face of invasion across administrative boundaries, and the difficulties of rapidly mobilizing the necessary scientific follow-up of actions. To our

knowledge, this represents the first documented case of using calcium oxide for rapidly eradicating an invasive amphibian in Europe.

Poster 11 – Estimating the size of a feral cat population prior to its removal from a long-inhabited Mediterranean island

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Feral cats (*Felis catus*) i.e., free-ranging cats of domestic origin which have minimal or no reliance on humans, represent a major threat to biodiversity worldwide, especially on islands. In 2017, the LIFE project "RESTO CON LIFE" (LIFE13 NAT/IT/000471, https://www.restoconlife.eu) successfully removed a feral cat population from the island of Pianosa (Tuscan Archipelago National Park, Italy) by live-capturing. The first step of the eradication program included an estimate of population abundance: twenty camera traps were placed all over the uninhabited part of the island, and individual detection histories were analyzed with spatially explicit mark–resight models (SEMR). The total number of cats that moved during the day on the uninhabited part of Pianosa was estimated at 28.5 ± 7. The second step included the physical capture of the animals using cage traps with two spring-loaded doors and daily baited with fresh mackerels or canned cat food: with a trapping effort ranging from 53 to 262 traps (mean = 192; SD = 45) kept active and checked every day for 99 days, 57 feral cats were removed in total. To ensure the full eradication success, camera-traps were left active on the island and regularly checked for two years after the last cat was captured in January 2017. Moreover, several cage traps continued to be active and baited all over the island until June 2018.

Camera-trap data gave us an indication of the population size, needed in order to establish the necessary effort to eradicate Pianosa cats. The difference between the total number of cats removed and those estimated to be present was probably due to higher density of cats in non-monitored areas (e.g., the village), sex-biased detectability by camera-traps and/or variable elusiveness between individuals.

Poster 12 – A manual for the management of vertebrate invasive alien species of Union concern, incorporating animal welfare

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Since 2015, invasive alien species (IAS) have been regulated at the EU level by EU Regulation 1143/2014 on the prevention and management of the introduction and spread of invasive alien species. This Regulation which, as of early 2022 listed 22 vertebrate species of Union concern, requires that animal welfare is taken into consideration when managing these invasive alien species. It acknowledges that '*eradication and management of IAS may induce pain, distress, fear or other forms of suffering to the animals, even when using the best available technical means*'. It further states that, when applying management measures, '*Member States shall ensure that animals are spared any avoidable pain, distress or suffering, taking into account as far as possible the best practices in the field and without compromising the effectiveness of the management measures*'. Under an EC-funded project ran by IUCN, together with a consortium of six partners, a manual for the management of the 22 vertebrate IAS of Union concern that explicitly assesses the impacts to animal welfare, alongside effectiveness and costs of lethal and non-lethal measures that are available to eradicate, control, or contain these species, has been produced. This was done in consultation with a large number of European experts and stakeholders, by running a number of workshops across the EU. The goal of this manual is to support Member States and any other interested parties in deciding which measures to use for the humane management of the vertebrate IAS of Union concern, or similar species. The manual describes management measures along an axis of welfare impact to permit decision-making that selects the methods producing the least negative welfare impacts. Alongside the manual, a variety of freely available dissemination materials have also been produced under the project, with the aim of making the information within them reach the widest range of users possible (such as scientists, practitioners and policy decision makers).

Poster 13 – Successes and challenges for the conservation of one of the rarest birds in the world

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Since 2003, the Society of Ornithological Studies of Reunion Island has been working intensively on the monitoring and conservation of the Reunion Cuckooshrike (*Lalage newtoni*). This insectivorous passerine bird, endemic to Reunion Island, is only present over ca. 1,200 ha of the Roche Ecrite massif, an indigenous tropical rainforest.

To date, the main conservation action carried out consists in rat population control using rodenticides. Indeed, these introduced and invasive predators can eat eggs, chicks or nesting adults.

Our results indicated a link between our rat control campaigns and the population dynamics of the Reunion Cuckooshrike. Thus, for several years, the distribution and size of this population have seemed to be increasing.

This addresses major new challenges for the monitoring and the conservation of this species to:

- involve local populations to maintain conservation actions at sustainable costs

- develop methods of rodenticide aerial dispersal by drone to treat the most difficult-to-access areas of the species in a homogeneous manner

- initiate standardised monitoring of Reunion Cuckooshrike's population in order to better infer benefits/limitations of the methods used to control predators (optimal threshold for the rodenticide amount of per hectare, evaluation of the efficiency and costs of alternative methods, such as mechanical control or combined chemical and mechanical control, and simultaneous control of feral cats)

- identify immediately the areas without predator control actions where the Reunion Cuckooshrike occurs, using automatic acoustic recorders.

Our current actions are on the way to meet these challenges.

Poster 14 – Lessepsian invasions in the Mediterranean Sea: health problems arrive

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The Suez Canal is a navigation channel that connects the Mediterranean and the Red Sea through the Isthmus of Suez in Egypt. The invasion of non-indigenous marine species in the Mediterranean is four times greater in the Red Sea than in the Atlantic Ocean, and concerns more than 1000 different species since the 19th century. Some of these species are venomous and/or poisonous, and cases of severe poisoning have already been published in the medical literature.

The aim was to collect data on marine envenomations and poisoning from 2015 to 2022 among Poison Centers (PC) of countries bordering the Mediterranean See. Questionnaires were sent to PC of countries bordering the Mediterranean in October 2018 and December 2022. Calls related to fish or jellyfish intoxication especially those which are unusual, and cases of ciguatera or tetrodotoxin poisoning were used. Results show:

- 16 out of the 21 countries around the Mediterranean have a Poison Center (PC).
- PC of France, Greece, Israel, Egypt, Italy, Slovenia, Morocco, Spain, Tunisia and Croatia have answered the questionnaire.
- Results by categories of toxic or venomous species between 2015 and 2017:
  - Fish envenomations and intoxications: Israel was the most involved with 120 envenomations between 2015 and 2017, mainly by *Plotosus lineatus*, 3 cases of tetrodotoxism (TTX) by *Lagocephalus sceleratus* and 4 cases of ciguatera (fish not mentioned). Italy was concerned with only one envenomation by stonefish. No other country has recorded lessepsian envenomation. Greece has recorded 14 cases of TTX poisoning by *Lagocephalus sceleratus* and Spain mentioned 24 TTX intoxications. No other country has recorded lessepsian intoxication.
  - Jellyfish envenomations: Israel was the most involved with 72 envenomations between 2015 and 2017, mainly by *Rhopilema nomadica* and *Cassiopea*. No other country has recorded lessepsian envenomation.
- Results by categories of toxic or venomous species between 2018 and 2022:
  - Fish envenomations and intoxications: Greece was the most involved with 63 envenomations between 2018 and 2022, mainly by *Pteroïs miles*. Italy has recorded 6 envenomations by *Pteroïs miles* and one by stonefish. Morocco has recorded one intoxication by *L. sceleratus* and one envenomation by stonefish.
  - Jellyfish envenomations: Israel was the most involved with 82 envenomations between 2018 and 2022, mainly by *Rhopilema nomadica*. No other country has recorded lessepsian envenomation.

It is concluded that despite few records of envenomations or intoxications by lessepsian species in European PC compared to the incidence of these species in the literature, health consequences occur in human beings. The two periods of study clearly show a progression of lessepsian species – and health problems – from the Levantin basin to the West part of the Mediterranean See. All these trends are converging towards an increase in poisoning and envenomations by dangerous marine species in the Mediterranean Sea in the years to come, and European toxicologists and emergency physicians should be working together with marine biologists aware of the toxicological risks associated with this Lessepsian invasion.

Human-animal social conflict

Poster 15 – The role of training in the evolution of pest control companies in Italy

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Professional disinfestation is a sector that has become complex and requires adequately trained personnel. Not only the approach to containing mouse and rat infestations has become more complex, due to the different situations where it has become necessary, of the increasingly diversified field of construction, production and customers who have to deal with, but also, or perhaps above all, due to the complexity of the institutional rules that need to be considered. The types of products used, the capture and suppression devices, that must respect the animals, the rules to try to prevent the risks of contamination of the anticoagulant in the food, people's health and environment, as well as the careful management of waste, make it necessary to have a company prepared, conscious and certified in its activities. In this context, training is obviously a key element. The Association of Italian Professional Pest Control Companies – A.I.D.P.I. [Associazione Imprese Disinfestazione Professionali Italiane] has been operating nationally for a comprehensive approach to this issue. The association, born at the end of 2018, organizes courses of various levels, involving all the professionals in this sector and, until today, has trained over 2400 technicians. In addition to lectures and learning, national meetings and events are promoted between operators and specialists exams to certify of the various sectors, with training values but also of contact and general cultural growth of the sector.

The specialization courses on vertebrate control include, above all, synanthropic rodents, where the three species for Italy are *Mus domesticus*, *Rattus norvegicus* and *Rattus rattus*. For these, training focuses on the use of new active ingredients in anticoagulants, resistance management and device use protocols. The management of waste, both technological and the carcasses, was then greatly demanded by the professionals. If initially regarding birds, the training has been mainly focused on problems related to town pigeons, focusing on the techniques of dissuasion, management of numbers, cleaning of guano and prevention of zoonoses, today gulls, starlings and corvids are also tackled, with the relative technical and legislative difficulties, that face multiple intervention requests from different sectors. In all cases, attention to non-target species and the support of natural predators are underlined. The effects on companies are demonstrated by a rapid change of attention, management and awareness that is verified by the national meetings organized by the Association.

Poster 16 – MaxEnt as management tool of a problematic species: the case of the fallow deer (*Dama dama*) in the Oasis of Pixina Manna Is Cannoneris

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Fallow Deer (*Dama dama*) is an allochthonous species in Italy, as well in Sardinia. The species was present in Europe and became extinct with the last ice age. It was reintroduced by the Phoenicians in 1,000 B.C. in Sardinia, and in the rest of Europe by Romans. In Sardinia, in 1960, the Fallow Deer became extinct again due to hunting activity and it was reintroduced in the 80's.

Nowadays, the Sardinian population is stable and well settled. His impact with anthropic activities, as agriculture, and on the natural environment, has made it necessary to control the population for preventive purposes.

In 2022, a monitoring project of the Fallow Deer in the Oasis of Pixina Manna Is Cannoneris was started, with the aim to check the distribution of the species and its impact with human activities. The most probable distribution trend was evaluated with the help of MaxEnt software, to identify possible suitable areas for the species, his potential impact on the territory and optimize its management.

A grid composed by 120 plots (1 km x 1 km) has been overlapped on the entire surface of the Oasis and on the surrounding areas. In each one, signs of presence of the Fallow Deer were sought detected by applying different census techniques: vantage point counts, roaring census, camera trapping, spot light census, census with thermal cameras, analysis of damages on agricultural crops and wildlife traffic accidents.

A prediction model of presence, on the entire territory, was elaborated by using the MaxEnt Software with the aim to analyse the most probable trend of the distribution of the population. Twelve environmental variables, like land use, hydrography, viability and the Digital elevation model (DEM), were compared with the collected signs of presence.

The data were not affected by the presence of the Corsican Red Deer (*Cervus elaphus corsicanus*), because the collected data could be attributed with certainty to the Fallow deer, and the dubious ones were discarded.

A total of 183 signs of presence were collected in 14 plots. The population is concentrated in a little area of the Oasis and outside its boundaries, near agricultural activities.

The analysis shows how the most important variables are altitude (DEM), the animals are more attracted by areas with low elevation, and presence of arable land.

The model represents the basis for the future management of the species. The knowledge about its real distribution, its impact on the territory and its environmental preferences, allows to develop a management plan that is applicable to unmonitored territories, operating mainly on the concept of prevention.

New tools and methods: a bridge from research to pest control

Poster 17 – The Life-Biorepem project, a new approach in ecological IPM

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Life BIOREPEM (Life19 ENV/IT/000358) is a 40-month project co-funded by the European Commission through the LIFE program. It is coordinated by the Municipality of Fiumicino and has a total budget of 1,525,713 euros. Other project partners are the Municipality of Francavilla al Mare, the Higher Institute for Environmental Protection and Research (ISPRA), AGEI, Natur-Lab, Fondazione Ecosistemi. The project aims to help European municipalities reduce the rodenticides used by partner municipalities by 50% over a 2-year period, through the implementation and testing of an innovative, digital and ecological approach to pest control. The BIOREPEM project will demonstrate the effectiveness of the latest generation electromechanical rodent traps, used in digitally managed networks, for the management of rat infestations (*Rattus norvegicus, Rattus rattus, Mus musculus/domesticus*). The project adopts an integrated approach to pest management, thus combining preventive and control measures with monitoring and planning activities. At the heart of the new approach is the use of technological traps for the mass capture of rats, digital monitoring devices (which signal the passage of a rat without actually catching it) and a web portal developed *ad hoc* for management and monitoring purposes. Green public procurement criteria were also developed to support new procurement procedures for municipal rat control services. The implemented portal is able to archive and manage numerous information and georeferenced data. Data are collected directly from traps and monitoring devices, from the web, or are uploaded via a mobile application by field operators and municipal staff. The portal allows the territorial analysis of the information, therefore the monitoring of the infestations and the evaluation of the interventions carried out. Digitizing rat control enables informed decision-making and improves the overall effectiveness of municipal action. The project takes place in two Italian partner municipalities, Fiumicino (Lazio) and Francavilla al Mare (Abruzzo). A total of 102 monitoring and capture devices were used in the two municipalities. The traps and monitoring devices were placed in critical locations (such as schools, markets, senior centres, gardens and other public spaces) selected through an ex-ante analysis. Some traps have been kept to deal with possible and unpredictable events or needs. In fact, traps and monitoring devices can be moved to monitor, prevent and control infestations according to the needs detected or foreseen thanks to the portal, which transforms the data collected by all the devices into heat maps. Non-chemical alternatives for rodent control are already available on the EU market, including biological control, mechanical systems and natural substances, often combined in an integrated approach. However, their use, both professionally and privately, is still limited for some often-interconnected reasons: Reliability/feasibility, Cultural barriers, Resistance to change, Knowledge/information, Cost – Sustainable and green approaches are often more expensive or, at least, may be perceived as such if environmental/health concerns and long-term prospects are not considered. Having developed and managed two networks of digitally controlled traps in 2 municipalities for a year and a half, we can state that the objectives set for reducing the use of biocides have been achieved.

Poster 18 – ProVeBirD – Protection of vegetables from bird damages

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Bird damage is an unresolved problem in plant protection. While there is little scientific evidence of damage caused by bird feeding and droppings, there are many experiences and reports from vegetable producers. The damage can be so severe that the cultivation of individual crops is questioned. According to producers, bird feeding heavily affects cabbage vegetables, as well as leaf and fruit vegetables. This relates to all plant stages from freshly sown seeds to seedlings and young aboveground biomass. For example, maize seedlings can be impaired or uprooted, so they often shrivel, but also cobs can be heavily damaged by feeding. For peas, a seed premium of about 10 % is considered reasonable in the event of expected bird feeding, with seed costs accounting for a large part of production costs. According to experience, the main species causing feeding damage are crows, followed by pigeons, but also geese, gulls and cranes. In addition, wild birds pose a health risk as they can transmit pathogens such as salmonella through feces to humans and animals. This creates a potential source of danger for producers and consumers, aside from the aesthetic aspect. Despite its high relevance to vegetable farming, there is a lack of overview of effective and economically feasible protection measures to regulate bird damage. Covering the crops with fleece and growing young plants early are common practices. There are also traditional measures such as bird scarecrows, perches for raptors and reflective objects, as well as innovations such as acoustic systems that imitate the warning calls of birds. However, these protection measures are time-consuming, only feasible for small areas, expensive or can be a noise nuisance for residents. The aim of the ProVeBirD project is to identify potential losses in main and special crops. This will be achieved by i) collecting data on damages and possible protection measures through interviews with producers, ii) collecting species and crop-specific damages on practical farms, and iii) determining the effectiveness of established and innovative methods for avoiding bird damage through field trials. The focus is on developing a practical guide for the production systems of organic vegetable farming.

The project is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the Federal Programme for Ecological Farming and Other Forms of Sustainable Agriculture.

Poster 19 – Long-term spatial distribution of the common vole abundance in Castilla y León (Spain): a GIS-based analysis of hot-spots

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The common vole (*Microtus arvalis*) is a cricetid rodent that invades agricultural habitats, a fact that is especially noticeable during the cyclical population outbreaks, causing serious economic damages and human health risks. Cycles occur each two to five years, but their temporal and spatial dynamics are far to be clear. The study period here covered up to three cycles related to outbreaks. This work explores a long-term database of >100,000 records of common vole abundance from 12,450 plots of Castilla-y-León region (Spain). The period of observations was 2012-2022 covering 90,000 km^2 over the land uses categories: a) Crop plots (CPlot), typically annual herbaceous crops, b) Crops reservoirs (CRes), such as alfalfa or other pluriannual herbaceous crops, c) Reservoirs plots (Res) with natural covers, such as grasslands, meadows, etc., and d) Dispersal pathways (Paths), such as road ditches, stream banks and margins. Cplot and CRes are the most sensitive areas to be protected. CRes also acts as a reservoir of the rodents, providing continuous food and shelter. In the Res areas, there is not direct economic damages, but, as CRes do, they represent a vole reservoir for the future. Paths are also reservoirs with no losses, but they connect the rest of habitats and spread the plague. The vole abundance index (VAI) was based in the common vole presence along 99 m transects divided in 33 monitored units of 3*1.5 m^2 in which the presence of common vole-like burrowing linked to signs of recent excavations, fresh latrines and/or feed accumulation in the burrow entrance was recorded. VAI was calculated as the percentage of positive units related to the total monitored in each plot. The temporal scale of the analysis was related with the seasonality conditions in the area, resulting in three periods of four months corresponding to the spring season (mid-February to mid-June), hot season (mid-June to mid-October) and cold season (mid-October to mid-February). To examine the spatial patterns of the VAI distribution either at the time evolution and the different land scenarios, we propose a Geographical Information System (GIS)-based analysis using the so-called Optimized HotSpot tool, which is able to identify significant spatial clusters of extreme values of the variable. Given incident points or weighted features (points with VAI values, in this case, separated by habitat), this tool creates a map of statistically significant hot (accumulation of plots with high VAI) and cold (accumulation of plots with small VAI) spots using the Getis-Ord Gi* statistic. The VAI observed during the period of study at each habitat followed a non-random spatial pattern with a confidence level of 99%. The local patterns of the vole activity (local measurement and its neighbors) resulted statistically significant from the global pattern (all features); thus, it was proven that the spatial distribution of the common vole abundance is a spatially clustered process. The hotspots tend to be accumulated for Cplot and CRes over a specific area of the north center of the region, whereas they were much less concentrated for Res and Paths, being spread along the whole region (especially Paths). Interestingly, it should be noted that in areas where high abundances for crop-related plots (CPlot and CRes) were detected, there was a high incidence of Paths hotspots up to three periods in advance (i.e., one year), which was especially remarkable in 2014 and 2016. Although more test should be done with agroclimatic and topographic attributes, it could be preliminarily inferred that common vole integrated management stakeholders should paid special attention to the dispersion paths, which act as an important spatial source for future dissemination.

Poster 20 – A tool for a systematic asessment of properties of mechanical and electrocution traps for non-chemical rodent control

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In the past years, non-chemical pest control measures have received increasing attention in the industry but also in the society. At present, snap traps and electrocution traps are the most important devices for non-chemical management of rodent pests. Traps should catch effectively and do not cause unnecessary suffering of animals during capture. However, there are no harmonised, systematic test methods available to assess rodent traps and it is not always clear which mechanical forces or electrical parameters are optimal to achieve swift unconsciousness and death.

We categorised snap traps and electrocution traps for house mice and Norway rats available on the market according to trigger types and dimensions. Based on these findings we constructed an apparatus to measure spring energy, triggering force, impact momentum and clamping force of snap traps and we developed an arrangement to measure voltage, amperage and power frequency of electrocution traps to calculate the current and energy taking effect on rodent bodies. Finally, we performed measurement series to generate descriptive data of trap characteristics. Measurements were run without animals.

All measured forces showed a high variability among snap traps within and among models. Mean forces were similar between new and multi triggered snap traps and between trap models with different triggering modes. In electrocution traps, the time pattern of emitting high voltage differed between the models but not within the traps of one model. The effective current and energy impacting on trapped rodents decreased with lower voltage input but the traps indicated weak battery by LED lights and one model switched of automatically when voltage is insufficient.

With the apparatus and the electronic arrangement, the majority of snap traps and electrocution traps available on the market can be assessed in a standardised and repeatable way. Matching the dataset with results from animal experiments and experiences from pest control practitioners allows relating properties of traps to effectiveness and animal welfare issues. This can support further development and optimisation of trapping devices for non-chemical rodent pest control.

Poster 21 – DURBAN Project - Management of grass strips in cropland to increase common vole control by vertebrate predators

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In cropland, common vole (*Microtus arvalis*) outbreaks can reduce yields in areas managed for soil conservation. At low densities, common voles are mainly found in the grass strips where their predation may be limited by high grass cover and the absence of perches for raptors. It is therefore possible to manage the grass strips at low vole densities to limit their increase and consequently, the colonisation of agricultural parcels. Several studies have sought to assess the ability of predators to limit vole population and consequent crop damages but the majority of these were short term and therefore not able to evaluate the long-term sustainable suppression of rodent pest population. The project DURBAN aims to enhance common vole predation by both carnivorous mammals and raptors by (1) limiting the height of the cover only in the parts of grass strips colonised by common voles, (2) installing perches for raptors in these grass strips. Twelve experimental plots (from 2 to 5 parcels under conservation agriculture per plot) corresponding to 6 “control” and 6 “managed” plots were defined. In each plot, common vole densities in grass strips and parcels were assessed twice a year (February and November) and the grass strips with vole density > 30% (transect index method) were managed as reported above, mowing and installation of perches for raptors. The time spent by raptors and the visitation rate of carnivores were assessed in each plot ten times and four times per year, respectively. The results obtained during the first two years of DURBAN on population dynamic of voles in both grass strips and parcels and on the activity of predators will be presented at the conference.

Crops and urban systems

Poster 22 – Influence of red deer (*Cervus elaphus* L.) grazing on yield reduction and changes in the chemical composition of grassland forage: experiences from three organic cattle farms in the southeastern Slovenia

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With more than 60 % of forest cover, Slovenia is the third most forest abundant European country. In Slovenia far most harmful species of game are wild boar (*Sus scrofa*) and red deer (*Cervus elaphus*) and our presentation deals with the yield loss due to red deer grazing on permanent grassland at three organic farms. Grassland experiments were conducted in 2013 and 2014 at three locations (Novi Lazi, Kačji Potok, Stari Breg) in Kočevje region (SE Slovenia). In both years, at all locations, the grassland experiments lasted from the end of the first decade of May, when we mounted iron cages for the first time, till October 14 in 2013 and October 3 in 2014, when we carried out the last (third) cut. Considering the results of all three cuts at all three locations we determined that an average optimal yield of dry matter on grassland in Kočevje region was 8.1 to 8.2 t/ha and total yield loss due to red deer grazing accounted from 48-52 % (3.9-4.3 t/ha). Among locations we also confirmed differences in optimal productivity on permanent grassland and yield loss due to red deer grazing. The lowest optimal total yield of forage dry matter (6.7-7.2 t/ha) occured in Stari Breg, where we also confirmed the largest yield loss of herbage dry matter (56-75 % or 4-5 t/ha). In Novi Lazi, the total optimal yield was 8.3-9.3 t/ha and 33-40 % (2.7-3.7 t/ha) was the yield loss and in Kačji Potok we measured 7.7-9.6 t/ha of forage dry matter and 47-53 % (3.6-5.1 t/ha) for yield loss. Red deer graze on permanent grassland in Kočevje region through the whole year but consequently the yield loss varies during the growing season with highest forage consumption in spring time (at first cut we determined the yield loss of 1.7-1.9 t/ha of dry matter) with a decrease to the end of the growing season (at the third cut we assessed yield loss of 0.9 t/ha of dry matter). Due to the intensive growth of grass sward on permanent grassland in spring, yield loss at the first cut was 38-40 % and at the third cut as far as 75 %. On permanent grassland at all three locations before cuts, there were no differences in abundance and foliage cover of grasses, legumes and herbs. The major output of such surveys was namely indication of species poor grassland on organic cattle farms in Kočevje region. The content of crude protein in treatment control was always higher than in fenced treatment. This was due to red deer grazing which rejuvenate grass sward with progressive defoliation and removal of herbage and force grasses to form new leaves which also hold the most important part of fodder quality. Crude fibre was the highest in herbage in treatment. Nutritional value of conserved feed at all locations was low (<5 MJ/kg dry matter) even at the first cut. This we attribute to poor floristical composition of grassland. Economical analysis showed that costs for feed on farm by presumption that farm breeds livestock in extent which is allowed by the inputs and considering the damage done by wildlife are higher because of primary production costs and feed purchases outside the farm which both lead to the current farm existence. The average additional cost per unit of land ranges from 182-344 EUR/ha – a consequence of different levels of intensity in red deer grazing on individual locations and different production capacity of grassland. We discovered that as a society we are lucky that permanent meadows in Kočevje are, despite the heavy red deer grazing from early spring, later on still cut. On the contrary the land will get abandoned and overgrown by bush vegetation.

Poster 23 – Efficacy of rodenticides in the sewer system of Berlin to manage Norway rats (*Rattus norvegicus*)

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When rodenticide baits applied in sewers come into contact with water, the anticoagulant active ingredient can enter the aquatic ecosystem. Then, anticoagulants accumulate, for example, in fish and their predators, such as otters, due to their persistent and bioaccumulative properties. Additionally, it is questionable if rodent control using anticoagulant rodenticides in the sewer system is suitable to sustainably control the whole rat population present. Behind this background, we wanted to scientifically investigate the efficacy of rodenticide control in the sewers. Up to now, in three out of five areas which we chose for our study in Berlin, the size of rat infestation was determined using two non-invasive monitoring methods in the sewer system and adjacent parks, backyards or waste disposal sites. Before and after rodenticide application, we used wildlife cameras and a feeding census in the sewers. Above ground, we used a feeding census and counted the rats with a thermal camera. A comparison of these censuses before and after the rodenticide control in the sewers can show whether this measure is effective and to what extent the above and sewer populations can be reduced. Furthermore, approximately five rats were captured both above and underground in each study area before and after the rodenticide application. We took muscle tissue samples for genetic analysis. The comparison of genotypes at sampling sites before and after the measures will reveal whether local genepools have changed. Furthermore, it is determined if individuals from above ground and sewers form a connected population or are rather reproductively separate. To be able to genotype a lot of samples in a short time and with low costs, we decided to use the SNP panels provided by Standard BioTools (formerly Fluidigm). From the available publications, we could not identify SNPs from wild rat populations. Therefore, we applied a method (called MIG-seq) for SNP genotyping to discover a set of polymorphic putative loci using 89 samples. We detected 1677 putative loci, which were filtered for several criteria to get a robust set of candidate SNPs (144 SNPs) which will be tested and validated on the Fluidigm platform. Using an initial diverse test sample set of 92 samples, out of these 144 SNPs the best 96 SNP markers will be determined for application on all remaining samples using the SNP panels provided by Standard BioTools (formerly Fluidigm). In May 2023, six months after the rodenticide application, rats are again monitored and captured in the same study areas to answer the question how fast the populations recover through reproduction or migration. The results on efficacy of rodenticide control in the sewers as well as the insights on the ecology of city rats will be considered to develop a more sustainable urban rat management in order to use rodenticides only where necessary and meaningful.

This project is funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (grant number: 3721674020; project duration: 10/2021 – 10/2024).

Poster 24 – Study of the fixation of birds of prey populations in agricultural territories equipped with nest boxes for the promotion of biological control of common vole (*Microtus arvalis*) population outbreaks

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The Biological Pest Control of Common Vole Project (Proyecto de Control Biológico de plagas de Topillo Campesino) is a project established as a useful and necessary prevention tool to combat the recurrent common vole population outbreaks in the agricultural crops of the Douro Valley.

It has also been recognized as such by the different public administrations competent in agriculture, either by financing its implementation and monitoring or through the issuance of official recommendations based on data provided thanks to different research teams.

One of the main lines of action of the Biological Pest Control of Common Vole Project is to recover the nesting habitat in the short and medium term for three species of raptors specialized in the predation of this small rodent that causes so much damage to agriculture in Europe. This is through the installation of nest boxes specially designed for Common Kestrel *(Falco tinnunculus*), Barn Owl (*Tyto alba*) and little owl (*Athene noctua*).

The nest boxes are installed on 4m high poles on the margins of crops such as alfalfa, wheat, barley, sunflower (among others) and in streams. To increase scientific knowledge in this regard and to continue progressing in the study of the effect of the installation of nest boxes on birds of prey populations, a monitoring system has been developed through scientific banding in five provinces of northwestern Spain.

Thanks to this, in the study period between December 2, 2021 and July 29, 2022, a total of 106 birds of prey where ringed (63 owls, 35 owls and 8 common kestrels) including adults and chicks and where registered 24 recaptures of birds already ringed (13 owls, 10 owls and 1 common kestrel), including exclusively adults.

This work has allowed expanding knowledge on the behavior, breeding pairs, dispersion and other ecological patterns of these vole predators in the five study areas of this research.

With this, it has also been possible to demonstrate the fixation of predators to the study areas, one of the objectives of the project necessary to maintain a stable population of avian predators that can exert continuous pressure against the detrimental demographic oscillations of the rodent. That is to say, to keep common vole populations low and stable so they cannot cause damage to crops.

Poster 25 – Comparison of baiting strategies in common vole management

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Pest rodents can cause extensive damage to agriculture, forestry, food storage, and infrastructure while also posing a significant risk to public health and livestock due to the spread of zoonotic pathogens worldwide. In Europe, the most common pest rodent species is the common vole (*Microtus arvalis*), especially during periodic outbreaks every 3-5 years. Current management largely relies on rodenticidal bait. A possible alternative method to manage the excessive numbers of common voles might be the use of environmentally safe compounds and suitable baiting methods for fertility control delivered through baits. In either case, a sufficient proportion of the population needs to consume an effective dose of bait.

In a laboratory experiment, we developed a bait with the quantitative marker Iophenoxic acid (IPA) for common voles to evaluate baiting strategies in a series of enclosure experiments. Wheat-based bait with IPA was placed in bait boxes or directly into the tunnel system entrances at different seasons and common vole abundances. Voles were live-trapped, individually marked and blood samples were collected to relate IPA blood residues to bait uptake.

First results indicate that voles that consumed bait offered in bait boxes have higher IPA blood residues and hence ate more bait than voles that lived in the enclosures where bait was inserted into the tunnel systems. Furthermore, heavier and therefore older voles are more likely to have IPA blood residues than animals with a lower weight.

The results of this study might help to improve baiting techniques to manage overabundant rodent pest species regardless of the compounds to be delivered.

The work was supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the Federal Programme for Ecological Farming and Other Forms of Sustainable Agriculture (FKZ 2815NA113).

Poster 26 – Wildboar management in urban areas: a challenge in the city of Perugia, Umbria (Central Italy)

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The city center of Perugia develops in a sprawling shape on a series of converging ridges, separated from each other by deep incisions covered by dense vegetation of trees and shrubs. These areas in recent decades have been progressively recolonised by natural and dense vegetation following the abandonment of the rural landscape due to the social and economic deep transformations of post-second world war in Umbria.

The most obvious result is that these new natural areas had been used first by wild boars and roe deer and then by wolves as useful ecological corridors to re-establish themselves in an unused space and today they are sites of refuge, feeding and reproduction throughout the year. From 2017 onwards, the social instances that ask for removal intervention of wild boar have multiplied due to the presence of the species (even in large groups) close to houses and public urban parks, both at night and in broad daylight, with the risk of road casualties.

On the basis of current regulation and a dedicated management plan for wild boar in urban areas (approved by the Prefecture in March 2021), inspections and removal were carried out. During 2020, 38 wild boars were removed, 50 in 2021 and 127 in 2022. In 2022, the techniques used were trapping (40% of the animals removed), shot by firearm by points (32%), search with a specialised dog (28%), while in only two cases we implemented drive hunts.

It is not always easy to manage the multiple social instances and the relations with citizens, who sometimes do not realize the need for interventions and in some cases there have also been acts of sabotage the traps. To facilitate trapping and shooting authorization procedures in 2021 an urban wild boar management unit was established. In this management unit is not allowed the collective wild boar hunting.

Unfortunately, the maintenance of these “new” natural areas used by wild boars is a weak link in the chain of management useful for limiting the presence and movement of wild boars, since they represent a heavy cost for both public bodies and private citizens.

Poster 27 – Sustainable rodent control in sugarcane fields using barn owls (*Tyto alba*): program development and monitoring

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Rodents pose a significant threat to sugarcane crop productivity in Florida (USA), leading to a decrease in both cane and sugar yield. To combat this problem, a program, which utilizes barn owls (*Tyto alba*) as a sustainable biological control method has been implemented. Since its inception in 2016, the barn owl program has made remarkable progress and is one of the largest in the world. Currently, the rodent control program is based on the thriving barn owl population, complemented by diurnal predators and cultural practices such as weed control, canal cleaning, and field maintenance.

Research has demonstrated the effectiveness of plastic boxes in attracting and maintaining owl populations. These boxes are strategically installed near canals, supported by 9-10 feet tall wooden poles. However, various pole designs and anchoring methods are being evaluated to enhance support and prevent leaning. These efforts began with the installation of 50 boxes in 2016, and now expanded to a total of 1900 boxes throughout the entire farm. The distribution of boxes ensures that there is approximately one box for every two fields (30 hectares) in organically grown sugarcane fields and one box for every four fields (60 hectares) in conventional sugarcane areas.

Since 2019, 2 to 3 barn owl censuses per year have been conducted. Historical data reveals that the September census consistently yields lower percentages of nested boxes, while the March census consistently records the highest numbers, with rates reaching up to 94% in two consecutive years. During the census, the number of owls, including adults and owlets, as well as the number of eggs are recorded. Furthermore, the owl population dynamics have been analysed by evaluating nesting throughout the year in 85 boxes.

Overall, this sustainable approach to rodent control using barn owls has proven successful, with the installation of owl boxes and monitoring of population dynamics. Even though, these efforts contribute to a reduction of rodent damage and promote sustainable crop production practices, more studies are needed to understand the predator / prey interaction. The magnitude of this barn owl program offers an immediate opportunity for numerous research projects.

Rodenticide resistance

Poster 28 – Developments in control strategy and resistance in Norway rats in Denmark

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In Denmark rat control has been dictated by an Act of law since 1907. The first-generation anticoagulant rodenticides (FGARs) came into use during the early 1950s and revolutionised rodent control. The second-generation anticoagulant rodenticides (SGARs) were introduced to overcome resistance to the first-generation compounds, which was observed in Denmark for the first time in 1962.

Since the late 1980's and beginning of the 1990's it has been recommended that when using anticoagulants for controlling rats, that the lesser potent anticoagulants should be used first (e.g., Coumatetralyl). If this did not result in effective rat control, the PCO should switch to a stronger anticoagulant (e.g., Bromadiolone) and so on. However, since 2012 use of first- generation anticoagulants as first substance was no longer a recommendation but mandatory, according to the statutory Order "Preventative measures and control of rats" and with the use of SGARs only to be used in case of resistance.

With the genetic knowledge we have today on anticoagulant resistance this approach could be accused of promoting resistance rather than delaying resistance.

In 2019 the Danish resistance strategy from 2012 was supported by a ministerial guideline on when and how PCO's are to use anticoagulants when controlling rats, but which also emphasized that the SCARs; bromadiolone and difenacoum no longer was an alternative when rats survived treatment with coumatetralyl.

By presenting results from various studies on anticoagulant resistance in Denmark prior to and after the changes in the Danish legislation in 2012 and 2019, we will demonstrate to what extent the chosen strategy has influenced the occurrence and spreading of anticoagulant resistance in Denmark.

- The before scenario is represented by the historical data on anticoagulant resistance from the periods of 1962 to 1994, from 1994 to 2001 and from 2001 to 2008. The data were made and earlier published by the Danish Pest Infestation Laboratory (DPIL)
- The after scenario is represented by data form 2012-2018 and from 2019 and forward. The rat samples were collected by Danish PCO's and analysed by us. Since 2015 approximately 600 rat samples have been analysed by ARMS-PCR. The studies were focused on municipal level and collection of rat samples was from randomly selected locations within the municipalities.

Poster 29 – Development of a digital early warning system for resistant rat infestation on farms

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To overcome poison resistance, highly toxic, persistent and bio accumulative anticoagulant rodenticides are commonly used to control Norway rat (*Rattus norvegicus*) populations on farms. Such control activities usually begin when the resistant rat populations are already established and there is a significant risk of pathogen infection of livestock. Hygiene measures can delay a new settlement by about 85 days and contribute to successful rat management. Nevertheless, immigration of new individuals and the establishment of resistant populations on farms cannot be prevented.

The aim of digiWRaP is to develop a digital warning system that detects the migration of individual animals onto the farm at an early stage and reports it to a mobile device. This warning system should enable local and targeted control of individual animals before resistant populations become established in buildings. Rodenticide applications and the risk to non-target species are reduced.

In a first step, the acceptance of the sensor technology by the rats will be optimized. It should be clarified where and how the sensor technology available on the market guarantees reliable rat detection on farms. Afterwards, the use of the developed digital warming system will be evaluated and summarized in a guidance to be tested by farmers for its practicability and then published in a comprehensible form. Such an approach will contribute to the establishment of a farm-wide warning system in the future.

The project is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany. The Federal Office for Agriculture and Food (BLE) provides coordinating support for future farms and future regions as funding organisation, grant number 28DE209X21.

Poster 30 – Screening of anticoagulant resistance-related mutations in the VKORC1 gene in *Mus domesticus* in four Italian islands

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Mice are among the most important pests worldwide due to their severe impact on urban areas, businesses, and animal husbandry, as well as on the risk of zoonoses transmission. It is also widely recognised that human commensal rodents can be extremely harmful to small islands biocenoses where control or eradication of invasive pest species is generally recommended to mitigate the impact on autochthonous species. Using anticoagulant rodenticides (ARs) is a common practice during eradications worldwide. Thus, the phenomenon of resistance to ARs can cause low efficiency in the management of invasive rodents. Resistance to ARs is mainly due to Single Nucleotide Polymorphisms (SNPs) in the vkorc1 gene but the occurrence and the frequency of this mutations is poorly known for the house mice *Mus domesticus* populations in the Mediterranean islands. We analysed the vkorc1 gene sequences in four islands of central and southern Italy and we found resistance-related mutations in all of them. A total of 30 tissue samples of *M. domesticus* were collected between May 2021 and October 2022 from Ventotene, Pantelleria, San Domino and San Nicola islands. Genomic DNA was extracted and the three exons composing the vkorc1 gene were amplified through PCR. Sequences were aligned and checked for the presence of SNPs conferring resistance to ARs. Seven missense mutations were found: Arg75Lys, Tyr139Cys, Ser149Ile, Ser149Asn, Gln151His, Glu155Lys, and Lys157Asn. Among these, Tyr139Cys, Ser149Ile and Glu155Lys were the only mutations that had already been detected in rodents by previous studies. Particularly, Tyr139Cys is one of the most frequent amino acid substitutions occurring in the vkorc1 gene in resistant mice and rats in Europe, and it is known to confer resistance to ARs also in heterozygous condition. This mutation was already detected in mice in Ventotene prior to the eradication of rats which started in January 2018 and ended in September 2022. Ser149Ile and Glu155Lys were only detected in *Rattus norvegicus* in Lebanon and France respectively so far and this is the first record of these mutations in house mice. There is no data on their effects in heterozygous condition. All the other mutations we found are newly described ones. Furthermore, we also detected two silent mutations in Pantelleria Island. These results suggest a wide distribution of known resistance-related mutations in insular Italy. This could be due to the continuous use of ARs on the studied islands (eradication of rats in Ventotene, rodent control activities to protect houses and businesses carried out on a continuous basis). Therefore, there is an urgent need for a safer, more conscious use of ARs to be considered for future eradication plans. Moreover, the occurrence of novel missense mutations will require further investigations to understand if resistance-related mutations have been positively selected by an intense use of ARs.

Poster 31 – Bioaccummulation of rodenticide residues in two populations of susceptible rats as determined by Vkorc1 genotyping

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Invasive rats are considered major pests around the world, posing growing economic risks and being vectors of numerous zoonotic diseases. Since the 1950s, exhaustive efforts have been made to control or eradicate these animals by using anticoagulant rodenticides. These compounds act by blocking the normal blood clotting cascade in vertebrates, interfering with the VKOR enzyme, leading to massive internal bleeding and eventually death. At first, first-generation anticoagulant rodenticides (FGARs) such as warfarin were developed and widely used with promising success. However, as resistance to these started to emerge, more potent and bio-accumulative second-generation rodenticides (SGARs) were developed. Over the last decade, several studies, particularly in Europe, have detected the presence of mutations in the *Vkorc1* gene linked to varying degrees of resistance to various anticoagulant rodenticides in synanthropic rodents. As these biocides become less effective due to resistance, the likelihood of rodenticide over usage increases and, consequently, bioaccumulation in target and non-target species. Terrestrial carnivores, birds of prey, and scavengers are predominantly affected through predation, raising concerns about biomagnification across trophic levels.

Herein, we aim to characterize the status of genetic resistance to anticoagulant rodenticides in two species of synanthropic rats, *Rattus rattus* and *Rattus norvegicus* inhabiting the urban areas of Lisbon (mainland Portugal) and Ponta Delgada (São Miguel island, Azores archipelago, Portugal). In both cities, the proximity to a major harbor facilitates the arrival of invasive rats from worldwide locations, increasing the risk of introduction and dissemination of resistant animals into the resident populations. Tissue samples from rats live-trapped within a 10 km radius from both city's ports were used for DNA extraction, PCR amplification and sequencing of exon 3 of the *Vkorc1* gene in the search for non-synonymous resistance-conferring mutations described in the literature.

To determine the bioaccumulation levels and compare them with the information obtained from the *Vkorc1*-mediated resistance, a highly sensitive LC-MS/MS analytical method was used to simultaneously detect and quantify five anticoagulant rodenticides, including one first-generation (coumatetralyl) and four second-generation rodenticides (brodifacoum, bromadiolone, difenacoum and difethialone), in the liver of both rat species inhabiting both study cities.

A total of 203 samples, 122 *Rattus norvegicus* and 81 *Rattus rattus* were screened for the third exon of the *Vkorc1* gene. Notably, the absence of known resistance-conferring mutations (Tyr139Cys, Tyr139Phe, Tyr139Ser, Leu120Gln, Leu128Gln) suggests that anticoagulant rodenticides could still be effective in controlling rat populations in both cities and surrounding areas. Six *Rattus norvegicus* and one *Rattus rattus* from Lisbon exhibited three silent mutations previously identified in the literature as haplotype C (Ile107Ile, Thr137Thr, and Ala143Ala). Rodenticide residues' quantification is currently under analysis and will provide valuable insights regarding other putative mechanisms of resistance to anticoagulant rodenticides in synanthropic rats besides the *Vkorc1*-mediated. Nonetheless, further research is required to assess the implications of these findings for the management and control of invasive rats and the environmental impacts on non-target species.

Poster 32 – Exposure and resistance to anticoagulant resistance in urban rodent pest in Chad

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Rodent pest management involves the widespread use of anticoagulant rodenticides (AR) worldwide. This use has resulted in the selection of numerous resistance alleles in the Vkorc1 gene, encoding the target enzyme of anticoagulant rodenticides. Mutations have been widely reported in brown rats, house mice and black rats in Europe, the United States and Asia. In Africa, while rodents are a major problem because of the transport and transmission of zoonotic pathogens and the damage they cause to crops, the use of ARs and the spread of resistance alleles are poorly documented. Through sampling of rodents captured in urban areas of Chad, one of the largest countries in Africa located at the crossroads of North and Central Africa, spreading from the Sahara Desert to the Sudan region, we have tried to make progress on resistance to ARs in endemic and invasive rodent pests in Africa.

653 rodents were captured in Chadian urban areas. Mitochondrial cytochrome b sequencing enabled us to relate them to 5 species of rodents belonging to the Muridae family, i.e., *Mastomys kollmannspergeri* (36.3%), *Mastomys natalensis* (15.4%), *Arvicanthis niloticus* (19.3%), *Rattus rattus* (28.7%). *M. kollmannspergeri* was the predominant species caught and was found widespread in the Sahelian and Sudanese zones, in all Chadian cities and in all types of trapping sites. *M. natalensis* appeared to be less abundant in Chad with a more limited distribution. The distribution of *A. niloticus* was limited to urban areas in the Sahelian zone. Remarkably, *R. rattus* was only found in southwestern urban areas with a decreasing abundance gradient between the cities of N'Djaména, Moundou, Doba and Sarh, suggesting a current migration of this species in Chad.

Exposure to ARs was analyzed by measuring ARs in the liver of rodents. These analyses demonstrated the use of ARs in Chadian cities, but in a moderate manner with very limited exposure of endemic rodents and a more frequent exposure of *R. rattus*. Both generations of ARs were observed.

The presence of resistance alleles was analyzed by sequencing *Vkorc1* gene. The total sequence of *Vkorc1* could be obtained in the 3 endemic rodent species. Sequencing of *Vkorc1* in *M. natalensis* revealed two different haplotypes in this species that may lead to a difference in susceptibility to AR. Sequencing of Vkorc1 for the other 2 endemic rodent species, *M. kolmanspergeri* and *A. niloticus*, did not reveal presence of mutations between individuals of the same species. Finally, three new missense mutations were detected in *R. rattus*, V29E, V69E, D127V. These mutations could disrupt the structure of the enzyme. Therefore, consequences of these mutations were analyzed by protein engineering and enzymology.

These results should argue for the implementation of a reasoned management of rodent populations in Africa to avoid the spread of ARs resistance alleles.

Poster 33 – Variation in the Vkorc1-gene and anticoagulant rodenticide resistance in brown rats on the Faroe Islands

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Anticoagulants are widely used to eradicate the invasive brown rat (*Rattus norvegicus*) on the Faroe Islands. In this study, we investigated variations in the rat Vkorc1-gene in these populations that could lead to resistance against these rodenticides.

In samples from 137 rats from the Faroe Islands, none of the earlier reported non-synonymous mutations in the Vkorc1-gene from Scandinavia, Belgium and Britain were found, but seven new ones were identified. None of those could be linked with functional resistance, but some have a potential based on their position in the enzyme. The calculated dN/dS ratio (0.81) suggests the Vkorc1 gene in Faroer is undergoing negative selection. The low frequency in mutations and the dN/dS ratio suggest that resistance is not widespread and not spreading on the Islands. Further research is needed to link the newfound mutations with possible functional resistance.

Zoonotic pathogens and parasites

Poster 34 – Belgrade experience in control of contamination of public places with dogs parasites

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In urban environment the largest population of animals are dogs. Contaminated faeces of dogs in urban environment usually were found at public places like children sand boxes, green area of parks or at street. Parasites of dogs with their own pathological effect can negatively influence health of their hosts so the dogs can present a potential source of human infection. Examination performed at numerous cities worldwide importing that dog was presence main environmental contaminant with eggs of zoonotic parasitosis, especially geohelminths like *Toxocara canis* and *Ancylostomidae* sp. In order to monitor the contamination in the Belgrade area since 1993 continuously monitors the contamination of public areas for the presence of parasites originating from dogs. Samples of grass and soil with green areas in our climate condition were collected from march to october. Material for examination was taken on the basis of indicators of bioclimatic conditions prevailing in the same area leading to the method of bioclimatograme by Uvarov which the components have temperature and humidity in the average values for the studied area. This is of particular importance in assessing the results with respect to embryonation of geohelminths in soil (become infective), under certain conditions like the of optimum temperature and humidity. The examination is carried using native preparation, with sedimentation method, the flotation method, and the sedimentation - flotation method and determination of eggs, oocysts and adult parasites is performed morphometric analysis based on morphological characteristics.

On the basis of the control of parasitic contamination of land from parks and other green areas during 1993-2003 parasite eggs was found 65.90% of the examined samples. Followed by the reactive in terms of cleaning the playgrounds and public places. After that the contamination has been established at 45.90%. The following progress has been made by introducing during 2008-2009 in central city districts has taken root system of baskets with plastic bags from dog feces (Dogi-pot system). This reduced the contamination to 30.45%

During 2011 in some parks are form of eco zones or parks for dogs. A special segment of solving this problem in Belgrade has been the adoption of problem-solving strategies non-owner of dogs and cats in the city of Belgrade, which was adopted at the Belgrade City Assembly held 2011. In developing this strategy for the City of Belgrade and its implementation was guided by the principle of humanity, combining the method of euthanasia without (no kill strategy) and CNR method "catch - treat - let " (CNR - catch - neuter -release), with special emphasis on the protection of human and animal health, and applying measures of education, control and sanctions against irresponsible owners whose negligence and disregard of positive legal rules and moral principles directly cause an increase in the number of abandoned dogs. The city of Belgrade has become one of the few cities that has a strategy to solve the problem of non-proprietary dogs and it is a document that defines the principles, objectives and measures to solve the problem in terms of non-owner dogs carry out administration of local government. The present results indicate that the implementation of this strategy has been to stabilize the population of stray animals on the streets and implementation of mass sterilization, gave as a result 50 % smaller increase of abandoned dog’s full cooperation with them and with all the other organizations that animal welfare goal. During the 2022 presence of parasite eggs was found in public places over 65% less than in the period before introduction of all these preventive measures.

Poster 35 – Wild rodents as reservoir of (re)emerging tick-borne diseases in natural areas: a novel integrated wildlife monitoring approach

Flavia Occhibove[1*], Rachele Vada[1], Patricia Barroso[1,2], Pablo Palencia[1,2], Amir Reza Varzandi[1], Ezio Ferroglio[1], Stefania Zanet[1]

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Wild rodent species – pest of agroecosystems and other terrestrial habitats – harbour a large variety of endemic pathogens, including a remarkable proportion of widespread zoonotic ones. This, coupled with anthropogenic environmental changes, predicted to profoundly alter their population dynamics, makes understanding rodent-associated disease transmission paramount from an applied disease-control perspective. In particular, rodents are crucial tick hosts and competent reservoir of currently (re)emerging tick-borne diseases, especially in the context of environmental changes. In areas with high degree of nature-based recreation, such as La Mandria Park (Torino), tick bites represent a public health concern, but zoonotic risk has not been formally assessed. In fact, epidemiological dynamics of tick-borne diseases are challenging due to multiple host species contributing to tick life cycle, and differential reservoir potential of tick and host species. Capturing real tick population, disease prevalence, and assessing human disease risk is therefore extremely complex. Yet, it is critical from a public health and wildlife management point of view. Research on ticks and associated pathogens too often focuses on charismatic host species or on a single epidemiological aspect. Therefore, here, we present a novel integrated approach – considering all epidemiological compartments – to shed light on the heterogenous contribution in transmission of multi-host tick-borne pathogens. Our aim is to provide better understanding of tick-borne diseases ecoepidemiology to preserve wildlife and human health through an improved disease management, decreasing wildlife-human conflict. Several sites in La Mandria Park, differing in habitat features and human utilisation, have been regularly sampled for environmental ticks and wild ungulates (the latter via camera trapping). At the same sites, we additionally designed a yearlong (starting this spring) small mammal removal trapping to investigate the missing epidemiological link. Investigating different community assemblages means unveiling potential heterogeneity in the transmission pool that each rodent species represents for different pathogens. We tested rodents and relative ectoparasites, along with environmental ticks, for *Anaplasma* spp., *Babesia* spp., *Bartonella* spp., *Borrelia* spp., *Ehrlichia* spp., *Hepatozoon* spp., and *Rickettsia* spp. Thus, we contribute to uncover pathogens' infection patterns, exploring relationships between prevalence, degree of infestation, rodents' population dynamics, ungulate population abundance, host community composition, and other elements responsible for tick dynamics, as well as reservoir competence in different rodent species. Preliminary results on wild ungulates showed a variable community composition and abundance among sites. Abundance of environmental ticks also varied, being differentially correlated to the diverse ungulate species, suggesting that different species of ungulates might represent either diluter or amplifier species for tick-borne diseases. Preliminary data on rodent species will have the potential to reveal patterns of correlation between prevalence and competent host relative abundance, which in turn is likely to be linked to ungulate populations and habitat features. In addition, prevalence of infection of environmental ticks showed variability and a significant prevalence of the tested pathogens. Rodent data will provide an insight in explaining this variability, as well as patterns of co-infections, and the final piece of the puzzle on the interconnectedness between habitat, wild ungulates, small mammals, and environmental tick dynamics. At the end of the study, our data will provide a holistic picture of tick-borne disease dynamics at the investigated sites, allowing a better assessment of zoonic risk, which will inform public health and wildlife management actions.

Poster 36 – Leptospirosis of rodents in Miyakojima island, Japan (progress)

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Leptospirosis is a zoonotic disease that is endemic throughout the world and an important public health problem in tropical areas of Latin America and Asia. In Japanese archipelago, more than 200 deaths were reported annually until the 1960s, mostly among rice farmers. In the past few decades, improvements in environmental sanitation have reduced the number of infected people, with only about 20 outbreaks per year. A recent trend in domestic outbreaks is characterized by the fact that most outbreaks have occurred in Okinawa prefecture. Today, infection has been confirmed in the northern region of the main island of Okinawa and in Yaeyama region, but there have been no cases of human infection on Miyakojima Island. However, in October 2021, two cases of the leptospirosis infection in humans were reported for the first time, and it is imperative to clarify the source of infection. Pathogenic *Leptospira* (*Leptospira* spp.) is mainly transmitted by rodents such as rats and mice. Pathogenic *Leptospira* are carried in the kidneys of the vectors, and the bacteria are discharged with urine, and are transmitted percutaneously and transmucosally through contact with the vector's urine or soil or water contaminated with urine. To clarify the situation of pathogenic *Leptospira* carrier, trapping rodent in Miyakojima Island and the neighboring Shimoji Island. Sherman traps were used to capture, and oatmeal, rice, and corn-flavored snack food were used as bait to attract rodent. So far, trapping were conducted over four periods, in May, August, and November 2022 and February 2023. 29 rodents were captured in Miyakojima Island and 8 in Shimoji Island, and the species of these rodents were brown rat (*Rattus norvegicus*), black rat (*Rattus rattus*) or eastern black rat (*Rattus tanezumi*), and yonakuni house mouse (*Mus musculus yonakunii*). Kidneys were then collected from the captured rodents and DNA analysis was conducted to investigate the pathogenic *Leptospira* carrier state. Whole kidneys were used and total DNA was extracted for analysis. Shotgun sequencing was performed in the analysis using an illumina next-generation sequencer. To identify the species, read data that obtained from shotgun sequencing were mapped to rodents and *Leptospira* genome sequences. In this study, DNA analysis of 37 rodents captured in the Miyako area was conducted to survey the occurrence of leptospirosis, and the occurrence of interbreeding of *Rattus rattus* and *Rattus tanezumi*, which has been pointed out in previous studies, through genome analysis. Then discussing the history of rodents and infectious diseases brought with farming culture to Miyakojima Island.

Poster 37 – Distribution of *Leptospira* spp. in Norway rat population in Belgrade, Serbia

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Leptospirosis is a bacterial infection, a disease of global concern which is directly transmittable to humans and animals by many rodents, of which Norway rat (*Rattus norvegicus*) is one of the most important. The fact that Norway rats are exceptionally adaptable to a variety of habitats, especially to those in close proximity to humans, creates a high risk of bacterial transmission.

The idea of this study was to examine the presence of *Leptospira* spp. bacteria in populations of Norway rat in the broad environs of Belgrade City. Animals were collected predominantly in their urban and suburban habitats over the past three years. The bacterium was identified by molecular analyses of kidney tissues from the collected animals. After homogenization, bacterial DNA was isolated using the commercial isolation kit Quick DNA MiniPrep. Primers and specific sequence probe were used to detect the bacteria in Real Time PCR. A total of 278 specimens of Norway rat were analysed. Samples with the highest concentrations of bacteria were selected for further analysis and sequencing.

The analyses included animals of different stages of growth with body weight ranging from 30 to 490 g. Considering the sampling periods (2020, 2021 and 2022), the percentage of Norway rats infected with *Leptospira* bacteria was steady, ranging between 31.73 and 40 %. In total, bacterial presence was detected in 35.61 % of the animals.

The present study was funded by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia (Grants No. 451-03-47/2023-01/200214 and 451-03-47/2023-01/ 200031).

Poster 38 – Could rodent damage survey in forestry help in predicting possible zoonotic disease outbreaks?

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Zoonoses are infectious diseases transmitted between animals and humans via direct or indirect contacts. There are different pathways from inhalation, direct contact and vector-borne inoculation through the skin injuries. In this study we analyse three common zoonotic diseases which are all in some way connected to small rodents and considered endemic in continental parts of Croatia. First is a disease caused by rodent-borne hantaviruses (HTV) causing hemorrhagic fever with renal syndrome (HFRS) or hantavirus pulmonary syndrome (HPS), second is Lyme disease which is caused by the bacterium *Borrelia burgdorferi* and third is Tick-borne encephalitis (TBE) virus causing inflammation of the central nervous system. HTV are rodent born and can be transmitted direct or indirect, whereas second two are transmitted via bites of infected ticks which mostly get infected from other ticks while cofeeding on the same rodent host. Data on human cases for all three diseases are available publicly via Croatian health statistics yearbooks. There is no national rodent and tick population monitoring in Croatia which makes predictions of possible zoonotic disease outbreaks impossible. To compare annual human infections with rodent data here we use annual rodent damage per hectare reported annually from forestry offices in continental parts of Croatia. Available data on all three diseases and rodent damage was analysed for the period of year 2002 to 2018. For comparison of variables, Pearson's correlation coefficient (r) was used. For the whole 17-year period there was a moderate correlation for rodent damage and HTV infections (r=0.337) as well as for rodent damage and Lyme disease (r=0.318). Week correlation (r=0.165) was found for rodent damage and TBE. From the analysed data we conclude that use of indirect methods such as intensity of rodent damage in forestry can be useful tool for predicting possible outbreaks of zoonotic diseases.

Poster 39 – Exploring natural variation in wild boar immunity and susceptibility to African Swine Fever Virus

Niek Barmentlo[1*], Mirte Bosse[1], Jacintha Ellers[1], Timothy Smyser[2], Vienna Brown[3]

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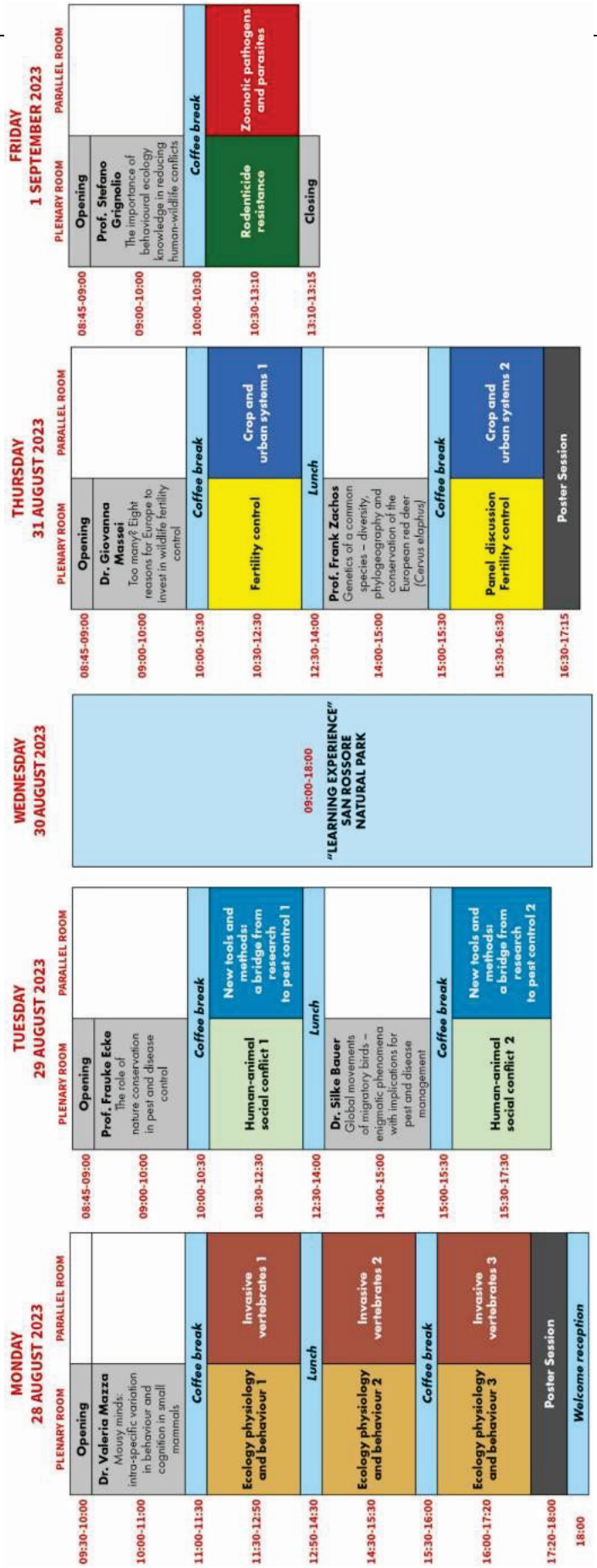
Due to the influences of climate change and globalization, epizootic diseases are becoming more prevalent. Climate change for instance influences host abundances while globalisation allows for increased host-hopping of pathogens. African Swine Fever (ASF) is one such epizootic disease that started to affect different continents in the previous and present century, with detrimental consequences for pig breeders and wild boar populations. It is hypothesised that this disease is so successful in new ranges in part due to the recent wild boar population increases, as a consequence of climate change, as well as the increased degradation time of carcasses due to the increased average body size. The current project aims to discover factors influencing susceptibility of wild boar to African Swine Fever in order to add to the list of environmental, genetic and physiological factors affecting epidemic occurrence. My goals are to assess the life-history drivers and evolutionary forces affecting wild boar immune function and be able to predict susceptibility to ASF of naïve populations. To accomplish this, I will use a combination of genomics, transcriptomics, environmental modelling, microbiome assessments, body conditional measuring and immunoassay-based tools to feed a predictive model. This data will be collected from wild boar in countries with and without ASF to generate baseline data for different countries in order to make comparisons. In the infected range, I will sample naïve and recovered boar to show disease progression and characteristics of survivors in natural systems. I expect to find that a strong baseline investment in inflammation responses is associated with survival as controlled infection experiments have already indicated this. Additionally, I expect to find population differences in innate responses, in part, due to the strong life-history plasticity of wild boar. Here, I present the experimental outline of the project and the first results from a pilot study in the field to test the proposed state-of-the-art ecological immunology tools.

Program


MONDAY
28 AUGUST 2023
PLENARY ROOM
PARALLEL ROOM
09:30-10:00 Opening
Dr. Valeria Mazza
Mousy minds: intra-specific variation in behaviour and cognition in small mammals
10:00-11:00
11:00-11:30 Coffee break
11:30-12:50 Ecology physiology and behaviour 1
Invasive vertebrates 1
12:50-14:30 Lunch
14:30-15:30 Ecology physiology and behaviour 2
Invasive vertebrates 2
15:30-16:00 Coffee break
16:00-17:20 Ecology physiology and behaviour 3
Invasive vertebrates 3
17:20-18:00 Poster Session
18:00 Welcome reception
TUESDAY
29 AUGUST 2023
PLENARY ROOM
PARALLEL ROOM
08:45-09:00 Opening
09:00-10:00 Prof. Frauke Ecke
The role of nature conservation in pest and disease control
10:00-10:30 Coffee break
10:30-12:30 Human-animal social conflict 1
New tools and methods: a bridge from research to pest control 1
12:30-14:00 Lunch
14:00-15:00 Dr. Silke Bauer
Global movements of migratory birds – enigmatic phenomena with implications for pest and disease management
15:00-15:30 Coffee break
15:30-17:30 Human-animal social conflict 2
New tools and methods: a bridge from research to pest control 2
WEDNESDAY
30 AUGUST 2023
09:00-18:00
"LEARNING EXPERIENCE"
SAN ROSSORE
NATURAL PARK
THURSDAY
31 AUGUST 2023
PLENARY ROOM
PARALLEL ROOM
08:45-09:00 Opening
09:00-10:00 Dr. Giovanna Massei
Too many? Eight reasons for Europe to invest in wildlife fertility control
10:00-10:30 Coffee break
10:30-12:30 Fertility control
Crop and urban systems 1
12:30-14:00 Lunch
14:00-15:00 Prof. Frank Zachos
Genetics of a common species – diversity, phylogeography and conservation of the European red deer (Cervus elaphus)
15:00-15:30 Coffee break
15:30-16:30 Panel discussion Fertility control
Crop and urban systems 2
16:30-17:15 Poster Session
FRIDAY
1 SEPTEMBER 2023
PLENARY ROOM
PARALLEL ROOM
08:45-09:00 Opening
09:00-10:00 Prof. Stefano Grignolio
The importance of behavioural ecology knowledge in reducing human-wildlife conflicts
10:00-10:30 Coffee break
10:30-13:10 Rodenticide resistance
Zoonotic pathogens and parasites
13:10-13:15 Closing

Program

MONDAY, 28th AUGUST 2023

PLENARY ROOM | 10:00-11:00

PLENARY SPEECH - 1

10:00 Mousy minds: intra-specific variation in behaviour and cognition in small mammals. Valeria Mazza, page 15

11:00 *Coffee break*

PLENARY ROOM | 11:30-12:50

ECOLOGY PHYSIOLOGY AND BEHAVIOUR - 1

Chairs: Valeria Mazza, Emiliano Mori

11:30 Bird crop depredation in Switzerland: Feeding behaviors and the influence of local and landscape habitat attributes. Amal Chantoufi, page 22

11:50 Goose accommodation field concept may alleviate human-wildlife conflict in agricultural areas. Jukka Forsman, page 23

12:10 Do badgers eat lamb? Using DNA and post-mortem analysis to investigate lamb predation on Scottish farms. Sheila George, page 24

12:30 The magpie and the grapes: increasing ozone exposure impacts fruit consumption by a common corvid in a suburban environment. Andrea Viviano, page 25

PARALLEL ROOM | 11:30-12:50

INVASIVE VERTEBRATES - 1

Chairs: Tim Adriaens, Paolo Sposimo

11:30 The Mammalnet citizen science contribution to improve knowledge of invasive mammal species in Europe. Joaquin Vicente, page 32

11:50 Mainland eradication of the invasive raccoon dog (*Nyctereutes procyonoides*) and the evolution of a national task force for invasive alien species. P-A Ahlen, page 34

12:10 Alien parakeets as a potential threat to the common noctule *Nyctalus noctula.* Silvia Giuntini, page 35

12:30 Kaput feral hog bait with 0.005% warfarin: product development, efficacy, non-target, human safety and politics. Richard Poche, page 36

12:50 *Lunch*

PLENARY ROOM | 14:30-15:30

ECOLOGY PHYSIOLOGY AND BEHAVIOUR - 2

Chairs: Valeria Mazza, Emiliano Mori

14:30 Population dynamics of rodents in Asia and Europe: patterns and processes. Nyo Me Htwe, page 26

14:50 Towards the influence of climatic covariates in the spatio-temporal differential expression of common vole abundance in Castilla-y-Leon Region (Spain). Constantino Caminero-Saldana, page 27

PARALLEL ROOM | 14:30-15:30

INVASIVE VERTEBRATES - 2

Chairs: Tim Adriaens, Paolo Sposimo

14:30 A new invasive mammal in Britain? The greater white-toothed shrew. Graham Smith, page 37

14:50 Twenty years of muntjac: monitoring and management of an emerging deer species in Flanders (Belgium). Bram D'Hondt, page 38

15:10 Feral American mink (*Neogale vison*) expanding in Europe: time to harmonize population monitoring. Rachele Vada, 39

15:30 *Coffee break*

Program

MONDAY, 28th AUGUST 2023

PLENARY ROOM | 16:00-17:20

ECOLOGY PHYSIOLOGY AND BEHAVIOUR - 3

Chairs: Valeria Mazza, Emiliano Mori

16:00 Chromosomal diversity and evolution of *Nannospalax*, Palmer 1903 (*Mammalia: Rodentia*) in Anatolia. Şakir Onder Ozkurt, page 28

16:20 Is mowing an effective method to reduce rodent damage in forest plantations? Zbigniew Borowski, page, page 29

16:40 Applying science to increase trapping efficiency. Marta Lopez-Darias, page 30

17:00 Bluetooth loggers to study spatial behaviour and contact among small rodents. Florian Huels, page 31

PARALLEL ROOM | 16:00-17:20

INVASIVE VERTEBRATES - 3

Chairs: Tim Adriaens, Paolo Sposimo

16:00 Trapping of vertebrate IAS coypu (*Myocastor coypus*) and raccoon (Procyon lotor) in live traps – preliminary results and conclusions on animal welfare. Friederike Gethoffer, page 41

16:20 Towards an evidence-based spatial prioritization of management efforts to counter a widespread invader. Teun Everts, page 42

16:40 Spatial and temporal patterns of bait uptake by grey squirrels in woodlands. Cristiano Tiberi, page 43

17:00 From invasion to eradication: success story of removing grey squirrels from an urban area in Central Italy. Valentina La Morgia, page 44

17:20 Poster session

18:00 *Welcome reception*

Program

TUESDAY, 29th AUGUST 2023

PLENARY ROOM | 09:00-10:00

PLENARY SPEECH - 2

09:00 The role of nature conservation in pest and disease control. Frauke Ecke, page 16

10:00 *Coffee break*

PLENARY ROOM | 10:30-12:30

HUMAN-ANIMAL SOCIAL CONFLICT - 1

Chairs: Stefano Grignolio, Andrea Viviano

10:30 Habitat recording and habitat design in forests - key for modern monitoring and management of vertebrates. Claudia Jordan-Fragstein, page 45

10:50 Ungulates, voles, insects – Why do we have such different management systems in German forests? Michael Müller, page 46

11:10 Bird pests: how do farmers deal with bird damage to spring crops in Switzerland? Alice Baux, page 47

11:30 New solutions to old problems: can humane non-lethal control be an effective alternative to manage charismatic invasive vertebrates? The case of invasive parakeets in Europe. Jose Luis Postigo Sanchez, page 48

11:50 Effective installation of deer fences in Tsushima island. Daisuke Waku, page 49

12:10 Agricultural damage following the recent expansion of wild boar in Finland – farmer perceptions and preconditions. Otso Huitu, page 50

PARALLEL ROOM | 10:30-12:30

NEW TOOLS AND METHODS: A BRIDGE FROM RESEARCH TO PEST CONTROL - 1

Chairs: Dario Capizzi, Marco Zaccaroni

10:30 The European Observatory of Wildlife: a harmonized approach to estimate wildlife densities. Tancredi Guerrasio, page 57

10:50 Recommendations for reducing environmental impact of pest mammal monitoring in New Zealand. Katie Pitt, page 58

11:10 The pathway to precision pest control: using genomics data for species-specific toxin development. Brian Hopkins, page 59

11:30 How to control what is unseen? Analysing capture methods effectiveness and efficiency for an invasive snake. Julien Piquet, page 60

11:50 Novel audio lures to improve interaction and encounter rates of possums (*Trichosurus vulpecula*) with control methods in New Zealand. Brittany Graham, page 61

12:10 Development of a coyote toxicant: PAPP and an antidote. Katherine Horak, page 62

12:30 *Lunch*

PLENARY ROOM | 14:00-15:00

PLENARY SPEECH - 3

14:00 Global movements of migratory birds – enigmatic phenomena with implications for pest and disease management. Silke Bauer, page 17

15:00 *Coffee break*

Program

TUESDAY, 29th AUGUST 2023

PLENARY ROOM | 15:30-17:30

HUMAN-ANIMAL SOCIAL CONFLICT - 2

Chairs: Stefano Grignolio, Andrea Viviano

15:30 Rodenticide exposure of red fox (*Vulpes vulpes*) in Scotland, before and after the introduction of an industry stewardship scheme. Steve Campbell, page 51

15:50 Practical implications of following the non-chemical rodent control guidance for controlling a *Rattus norvegicus* infestation. Sharon Hughes, page 52

16:10 Released beavers in Central Italy: story of a recent reintroduction and assessment of human perception. Emiliano Mori, page 53

16:30 Perspectives on rodent-human interactions in Nepali communities. Anna Durrance-Bagale, page 54

16:50 European rabbit In North-Central Chile: outbreak causes. Paola Correa, page 55

17:10 Urban fauna management through habitat modification: preliminary report of a pest management project on *Rattus norvegicus* in Genoa (NW Italy). Giorgio Chiaranz, page 56

PARALLEL ROOM | 15:30-17:50

NEW TOOLS AND METHODS: A BRIDGE FROM RESEARCH TO PEST CONTROL - 2

Chairs: Dario Capizzi, Marco Zaccaroni

15:30 Continuing the development, registration and efficacy testing of norbormide against both *Rattus rattus* (Ship rats) and *Rattus norvegicus* (Norway rats). Charles Eason, page 63

15:50 Rodent hole detection in a typical steppe ecosystem using unmanned aircraft systems and deep learning. Mingzhu Du, page 64

16:10 Evaluation of the Ekomille CO2R device as an animal welfare suppression system for rodent pests management. Giuseppe Spina, page 65

16:30 Estimating risk to prevent damage: proposals for management actions to prevent coypu damage to transport infrastructure. Olivia Dondina, page 66

16:50 Controlling *Apodemus sylvaticus* and *Microtus arvalis* that have moved from the field to infesting 'in and around buildings' with a cholecalciferol bait. Sharon Hughes, page 67

17:10 Strong phenotype variation as an early warning signal of abundance outbreaks in cyclical common vole (*Microtus arvalis*) populations. Juan Jose Luque Larena, page 68

WEDNESDAY, 29th AUGUST 2023

9:00-18:00 Learning Experience San Rossore Natural Park

THURSDAY, 31st AUGUST 2023

PLENARY ROOM | 09:00-10:00
PLENARY SPEECH - 4
09:00 Too many? Eight reasons for Europe to invest in wildlife fertility control. Giovanna Massei, page 18

10:00 *Coffee break*

PLENARY ROOM | 10:30-12:30
FERTILITY CONTROL
Chairs: Giovanna Massei, Jens Jacob
10:30 Insights from a 20 years' research on free-roaming cats. Idit Gunther, page 69
10:50 Fertility control in common voles – sperm analysis and residues of an antifertility compound. Jens Jacob, page 70
11:10 Collaboration, communications and fertility control to effectively manage a well-established, invasive non-native squirrel. Kay Haw, page 71
11:30 An effective contraceptive bait delivery system for small mammals. Sarah Beatham, page 72
11:50 African lessons for Europe in developing contraceptives for rodent management. Steven Belmain, page 73
12:10 Controlling urban pigeon (*Columba livia*) population humanely. Marco Pellizzari, page 74

PARALLEL ROOM | 10:30-12:30
CROPS AND URBAN SYSTEMS - 1
Chairs: Ann-Charlotte Heiberg, Grant Singleton
10:30 Humane management of rodents. Emma Cartuyvels, page 75
10:50 Zinc phosphide for phytosanitary use against common voles (*Microtus arvalis*) population outbreaks: literature review and environmental perspective on the risks and impacts derived from its use. Carlos Cuellar Basterrechea, page 76
11:10 Biological control as a tool for integrated management of common vole (*Microtus arvalis*) pests in agricultural environments in Spain: evolution of the project. Carlos Cuellar Basterrechea, page 77
11:30 Common vole biological control in agricultural ecosystems of Castilla-y-Leon (Spain): reproductive productivity of raptors in artificial nest-boxes in relation to abundance fluctuations of the pest species. Miriam Bascones Reina, page 78
11:50 Field size as a determinant of common vole population densities. Emil Tkadlec, page 79
12:10 Rodent management and rice production in Southeast Asia – balancing food security and biodiversity goals. Grant Singleton, page 80

12:30 *Lunch*

PLENARY ROOM | 14:00-15:00
PLENARY SPEECH - 5
14:00 Genetics of a common species – diversity, phylogeography and conservation of the European red deer *(Cervus elaphus).* Frank Zachos, page 19

15:00 *Coffee break*

Program

THURSDAY, 31st AUGUST 2023

PLENARY ROOM | 15:30-16:30
15:30 PANEL DISCUSSION - FERTILITY CONTROL
Chairs: Giovanna Massei, Jens Jacob

PARALLEL ROOM | 15:30-16:30
CROPS AND URBAN SYSTEMS - 2
Chairs: Ann-Charlotte Heiberg, Grant Singleton
15:30 Collection of pest management data used to improve rat control in Denmark. Kirsten Sondergaard, page 81
15:50 Rat (*Rattus norvegicus*) management in the city of Zurich, Switzerland. Marcus Schmidt, page 82
16:10 For birds and humans: unforeseen challenges and additional benefits of rat eradications on inhabited islands. Dario Capizzi, page 83

16:30 Poster session

Program

FRIDAY, 1st SEPTEMBER 2023

PLENARY ROOM | 09:00-10:00
PLENARY SPEECH - 6
9:00 The importance of behavioural ecology knowledge in reducing human-wildlife conflicts
Stefano Grignolio, page 20

10:00 *Coffee break*

PLENARY ROOM | 10:30-13:10
RODENTICIDE RESISTANCE
Chairs: Andrew Brigham, Virginie Lattard
10:30 Structural mechanism of anticoagulant rodenticides resistances: Identification of a hydrophobic cluster responsible for the affinity between inhibitors and the target protein. Nolan Chatron, page 84
10:50 Vkorc1 polymorphisms in the Norway rats from the ancestrally distributed area indicate independent evolution of anticoagulant resistance. Ying Song, page 85
11:10 Investigating invasive roof rat resistance by screening for genetic mutations Katherine Horak, page 86
11:30 Rodenticide resistance in Norway rats and house mice in Ireland. Anthony Murphy, page 87
11:50 A brief overview of the Vkorc1 gene mutations related to anticoagulant rodenticide resistance in Turkish Populations of *Rattus rattus* and *Rattus norvegicus*. Derya Cetinturk, page 88
12:10 Widespread distribution of resistance-conferring mutations in the Vkorc1 gene among populations of invasive house mice in the oceanic archipelagos of Azores and Madeira. Sofia Gabriel, page 89
12:30 Widespread resistance to anticoagulant rodenticides in *Mus musculus domesticus* in the city of Barcelona. Jordi Figuerola, page 90
12:50 Management of resistant Norway rats: measures to minimize rodenticide applications. Alexandra Esther, page 91

PARALLEL ROOM | 10:30-13:10
ZOONOTIC PATHOGENS AND PARASITES
Chairs: Frauke Ecke, Rainer Ulrich
10:30 RodentGate: future rodent management for pig and poultry health. Herwig Leirs, page 92
10:50 Changes in forest management intensity predict the presence of *Puumalaorthohantavirus* (PUUV) in bank voles (*Clethrionomys glareolus*). Jens Jacob, page 93
11:10 Lymphocytic choriomeningitis virus, a neglected zoonotic pathogen in Europe? Rainer Ulrich, page 94
11:30 Rodent control by rodenticide and trapping to fight Lassa virus in Upper Guinea: a six years longitudinal study and possible pool table effect. Alicia Lame, page 95
11:50 Pathogen risks posed by humans to urban rats: campylobacteria in Helsinki, Finland. Tuomas Aivelo, page 96
12:10 Why account for biodiversity for mitigating tick-borne disease risk? Insights and perspectives from Eastern Italian Alps. Giulia Ferrari, page 97
12:30 The combined effect of bromadiolone and ivermectin (iBr) in controlling both rodents and their fleas. Liu Ming, page 99

POSTER SESSIONS
Monday 28 August 2023 17:20-18:00 and Thursday 31 August 2023 16:30-17:15

List of Participants

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Kristof Baert, Belgium
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Niek Barmentlo, Netherlands
Damien Barrau, France
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Alice Baux, Switzerland
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Regis Bedry, France
Steven Belmain, United Kingdom
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Linda Bjedov, Croatia
Matteo Boccamazzo, Italy
Paolo Bongi, Italy
Zbigniew Borowski, Poland
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Nolan Chatron, France
Giorgio Chiaranz, Italy
Henrik Svaneberg Christiansen, Denmark
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Paolo Colangelo, Italy
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