



Too small to matter? a call to action for european small mustelid research

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Abstract

Weasel *Mustela nivalis* and stoat *Mustela erminea* are important specialist predators whose populations are suspected to be declining across Europe. Predominantly hunting rodents, they play a key role in shaping the population dynamics of small herbivorous mammals. Despite their ecological significance, these species have remained relatively understudied due to their elusive nature, and many questions regarding their ecology and conservation remain unanswered. In recent years, these small predators have attracted growing attention, supported by new methodologies that allow more effective research. In June 2025, a group of European researchers convened at the first ‘European Small Mustelid Meeting’ to assess the current state of small mustelid research, with a focus on weasels and stoats, and identify priorities for the future. Here, we synthesize the current research on weasels and stoats across Europe and propose six key directions for future small mustelid research: (1) the optimisation of monitoring techniques and data collection protocols; (2) the upscaling of species distribution models to a continental level; (3) the ecological role of small mustelids in the food web; (4) the influence of climate change on their moulting phenology; (5) the impact of environmental contaminants on small mustelids; and (6) the gathering of genetic material to analyze genetic diversity across Europe. We hope these will enable a robust assessment of the conservation status of weasels and stoats across Europe. We invite researchers working on or interested in these fascinating small predators to join our collaborative effort to advance research and conservation of small mustelids in Europe.

Keywords Conservation ecology · Methodology · *Mustela* · Perspectives · Stoat · Weasel

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Introduction

Small mustelids, here with a focus on weasel *Mustela nivalis* and stoat *Mustela erminea* due to their similar ecological role and research challenges, are specialist predators that play a pivotal role in ecosystems as key regulators of rodent populations (Jędrzejewski and Jędrzejewska 1993; Norrdahl and Korpimäki 1995; Korpela et al. 2014; Korpimäki et al. 2025). Weasels and stoats not only shape rodent population dynamics but are among the few predators capable of reducing rodent population density (Sullivan and Sullivan 1980; Mougeot et al. 2020; Korpimäki et al. 2025). During spring, prey switching to eggs and chicks of ground-breeding birds can cause them to negatively affect these species, although the actual impact relative to other species may be limited (Teunissen et al. 2008; Fokkema et al. 2024; Barton et al. 2026). At the same time, weasels and stoats fall prey to larger predators, especially raptors, giving them a unique position within the foodweb (Korpimäki and Norrdahl 1989). Owing to their short lifespans, intermediate trophic position, and broad ecological niche breadth, weasels and stoats have the potential to serve as sentinel species for anthropogenic environmental impacts, as they are expected to exhibit faster and more pronounced responses than taxa at higher, and lower trophic levels (Marneweck et al. 2022; Do Linh San 2024; Jachowski et al. 2024b). However, due to their elusive nature, they have been relatively little studied, and many questions remain about their responses to environmental change, shifts in food-web structure, and potential ecosystem services or disservices to humans (Rosalino et al. 2023).

Traditionally, research on weasels and stoats has focused on habitat use, utilising a combination of live trapping and subsequent tracking of animals equipped with VHF transponders. Early pioneers, such as King (1975), Erlinge (1977), Santos-Reis (1983, 1989), and Debrot and Mermod (1983), laid the groundwork for our understanding of how weasels and stoats utilise their habitat and how this use changes across seasons. This work was further developed by Jędrzejewski et al. (2000), Macdonald et al. (2004), Brandt and Lambin (2005), and Zub et al. (2008). At the same time, Macdonald and Harris (2002) used data on the numbers of animals trapped by gamekeepers to study the population dynamics of weasels and stoats in the UK. Non-invasive methods were especially applied in northern systems, such as Finland, where extensive snow tracking has formed the basis for most work on weasels and stoats (Korpimäki et al. 1991) and in the UK, where some studies used tracking tunnels (Graham 2002). However, these methods had several limitations, including risks to animal welfare with invasive methods (e.g., injuries and deaths during live trapping, handling, and sedation), the need for snow (snow tracking), and

the difficulty of distinguishing weasel and stoat tracks (track tunnels). Therefore, new non-invasive methods have been developed, such as camera-trapping applications, detection dogs, and environmental DNA (eDNA) surveys, which have spurred a new surge in the study of small mustelids (Jachowski et al. 2024a).

In recent years, research interest has shifted from general ecology with a focus on habitat use and population dynamics towards a focus on the conservation status of small mustelids and their interactions with the environment, allowing them to function as sentinels or indicator species (Marneweck et al. 2022; Wright et al. 2022; Granata et al. 2026). While monitoring data for weasels and stoats is lacking across most European countries, several indications suggest that populations are in decline (Torre et al. 2018; van Norren et al. 2020; Coomber et al. 2021; Wright et al. 2022; Llorca et al. 2024). In response, efforts to improve our understanding of the population status of weasels and stoats and how they are responding to human-induced changes in the environment are currently underway in several European countries, primarily using non-invasive (Soininen et al. 2015; Mos and Hofmeester 2020; Konradsen et al. 2024; Hofmeester et al. 2024; Otte et al. 2025; Egloff et al. 2025; Croose et al. 2025; Granata et al. 2025; Dürst et al. 2026).

Here, we first present an overview of current efforts, highlighting recently published studies as well as ongoing efforts by the authors that have not yet been published. Then we present several avenues for future research on small mustelids, addressing pressing research questions. On June 25th and 26th, 2025, we held the first European Small Mustelid Meeting in Groningen, the Netherlands, bringing together researchers from seven European countries working on small mustelids. During that meeting, we synthesised current efforts and explored future directions for international collaboration, which are summarised here. We concluded the meeting by establishing the European Weasel Gang, a collaborative network for researchers with current research projects on weasels and stoats, which is open to new members (www.europeanweaselgang.eu).

Current status of small mustelid research in Europe

Camera-trap-based monitoring methods

Weasels and stoats are notoriously difficult to detect. While traditional monitoring methods relied on live trapping, growing concerns about conservation and animal welfare have led to an increased demand for non-invasive monitoring techniques (Jachowski et al. 2024a). Specialised enclosed camera-trap methods, such as the ‘Mostela’ (Mos

and Hofmeester 2020), were developed to improve detection of small mustelids. Across Europe, their effectiveness has been compared to that of ‘regular’ external camera traps (Barros et al. 2024; Otte et al. 2025; Croose et al. 2025), with mixed results. Detection probabilities are often higher for weasels in Mostelas (Barros et al. 2024; Otte et al. 2025; Croose et al. 2025), whereas findings from the Italian Alps suggest the opposite (Granata et al. 2025). For stoats, detection probabilities have been low in Mostelas in two studies in Britain and Ireland (Croose et al. 2022, 2025). However, results from Denmark (Konradsen et al. 2024), the Italian Alps (Granata et al. 2025), and the Dutch lowlands (Otte et al. 2025), together with unpublished data from the Catalan Pyrenees and the Swiss lowlands, indicate higher success for stoats in Mostelas. The application of Mostelas in the Netherlands and Poland has revealed a clear peak in both relative abundance and daily detection probability during late summer and early autumn, which is likely driven by a combination of increased population densities and more exploratory behaviour (Hofmeester et al. 2024; Mos and Hofmeester 2025). An added advantage of using enclosed camera traps such as the Mostela to study stoats, weasels, and their prey, is that it is easier to apply a clustered sampling approach with cameras at two distinct spatial scales, one related to the spatial scale of rodent movement, the other to the spatial scale of movement of small mustelids, something that was hard to do with more traditional methods such as life-trapping (Kleiven et al. 2023). Currently, these improved monitoring methods enable us to conduct studies to better understand the occurrence and population dynamics of stoats and weasels in relation to landscape features, prey and predator abundance, and human activity, thereby advancing knowledge of their ecology. Furthermore, we can start testing their suitability as sentinel and indicator species, thereby enabling the use of information on stoat and weasel populations to assess the overall health and dynamics of the environment (Do Linh San 2024; Egloff et al. 2025).

Advancing habitat use and population studies through trapping and tagging

To better understand how small mustelids respond to environmental change at finer spatial scales, and to calibrate non-invasive methods for estimating population density, studies using invasive methods can provide essential information. Traditional studies examining the habitat use of weasels and stoats through trapping and tagging have used Very High Frequency (VHF) transmitters (Jedrzejewski et al. 1995; Zub et al. 2008). However, manual radiotracking is labour-intensive, with low temporal and spatial resolution (Thomas et al. 2011). The development of Automated

Radio-Tracking Systems (ARTS) enables the continuous tracking of VHF-tagged small mustelids, potentially providing high-resolution data on their habitat use (Gottwald et al. 2019). This system is currently being tested on stoats by several of the authors in a study in the Netherlands. These data will be used to improve our understanding of fine-scale habitat selection, thereby benefiting landscape-level conservation measures. Furthermore, trapping and tagging of animals allow more accurate population estimates by providing information on home-range locations and sizes, and can be used to determine density through analyses such as spatially explicit capture–recapture (SECR; Efford 2004). By comparing these results with statistical models based on camera-trapping data, such as n-mixture models, we can evaluate the accuracy of non-invasive monitoring tools for population assessment (Hofmeester et al. 2024). Across Europe, several authors are conducting such studies to advance ecological understanding and improve non-invasive monitoring.

Evaluation of habitat structures as compensation measures for small mustelids

Land-use change in Europe is homogenising agricultural areas, reducing linear features such as hedgerows and stone walls that stoats and weasels use for shelter, reproduction, predator avoidance, and prey (Macdonald et al. 2004). In Switzerland, branch and stone piles, once traditionally built during field and hedge maintenance and now artificially re-established in homogeneous agricultural landscapes, function as safe ‘stepping stones’ within the home range and have been shown to positively affect stoat occurrence at both local (Egloff et al. 2025) and landscape scales (Dürst et al. 2026). These practical mitigation strategies are promising tools for small mustelid conservation and should be tested across a wider range of habitats and countries to evaluate their broader effectiveness (e.g., Sullivan and Sullivan 2023).

Eradication programmes for introduced small mustelids

While the suggested decline of weasels and stoats is raising conservation concerns across Europe, there are also places where these species are less welcome. In 2010, stoats were introduced to the Orkney archipelago off the coast of mainland Scotland, where they pose a threat to local wildlife, including ground-breeding birds and endemic Orkney voles (Zub et al. 2022). Similar to issues in New Zealand, where stoats were introduced in the 1880s, and eradication programmes have not been entirely successful (King 2025). Eradication initiatives present a valuable opportunity to

gather invaluable information on the biology (e.g., population dynamics, age structure, sex ratio, body-size variation, and prey selection), genetics, and evolutionary adaptations (e.g., moulting phenology) of stoats. It also represents the world's largest stoat eradication effort in an inhabited landscape, serving as a testing ground for diverse monitoring techniques (e.g., tracking dogs, AI-assisted thermal cameras, and drones) that may be applicable elsewhere to improve the detection of elusive small mustelids. Although the transferability of biological trait data remains uncertain, work from New Zealand by King (2025) has yielded relevant information for stoat research in Europe.

Distribution models to predict how land-use change and climate change will affect small mustelids

Species distribution models (SDMs) are considered valuable tools in ecology to understand how environmental changes affect species distributions, and are increasingly applied in small mustelid research (Cheeseman et al. 2024; Granata et al. 2026). Climate change is thought to affect mustelids through range contractions (Cheeseman et al. 2024) and altitudinal shifts (Granata et al. 2026), but remains understudied in Europe (Wright et al. 2022; Valdez et al. 2025). Additionally, land-use change, particularly the intensification of agriculture, is considered to negatively impact their distribution as habitat becomes more fragmented (Cheeseman et al. 2024) and linear features become scarcer (Petit et al. 2003). Currently, efforts are underway to use observational data from local, national, and open-source databases (e.g., iNaturalist, GBIF, Observation.org) to model how climate and land-use change affect the distribution of weasels and stoats across Europe. In Iberia, Italy, and the Netherlands, several authors aim to predict how environmental change, such as climate and land-use change, shapes the distribution of small mustelid species and assess their future range contraction or expansion. Through the application of SDMs, we aim to better understand which factors are most important in explaining the suggested decline in stoat and weasel populations.

Applying molecular and genetic methods to study small mustelids

Recent advances in molecular techniques have expanded opportunities to study small mustelids using non-invasive genetic sampling. DNA obtained from scats, hair, or other biological material can be used to confirm species presence and improve detection of these elusive predators (García and Mateos 2009; Vigués et al. 2021; Egloff et al. 2025; Dürst et al. 2026). Genetic analyses have further enabled investigations of dispersal and fine-scale population genetic

structure in weasel populations (McDevitt et al. 2013), as well as comparative genomic analyses within the Mustelinae lineage (Totikov et al. 2025, preprint). For example, ongoing work by one of the authors in Switzerland uses tissue samples from road-killed animals together with scats and hair samples to investigate the population genetic structure of stoats and establish baseline data for future monitoring. More recently, eDNA has emerged as a promising tool for detecting carnivores from various environmental samples, such as rivers (Sales et al. 2020; Bolton 2021; Croose et al. 2023) or snow (Kinoshita et al. 2019). eDNA-based surveys from river systems have successfully detected both weasel and stoat (Bolton 2021; Broadhurst et al. 2021), demonstrating the potential of this approach for monitoring elusive carnivores.

Future directions for small mustelid research in Europe

Although considerable research on small mustelids has been conducted across Europe in recent years and is currently ongoing, there is potential for new studies and ideas to further advance our understanding of their ecology and conservation. Below, we present a selection of future research directions (also shown in Fig. 1) along with collaborative efforts that could support this field. Through these, we hope to strengthen our understanding of how weasels and stoats interact with their environment and, ultimately, reassess their conservation status at national and international (European) levels. Globally, both species are assessed as 'Least Concern' on the IUCN Red List. However, several studies have documented declines in both species (Hellstedt et al. 2006; Sidorovich and Solovej 2007; Coomber et al. 2021). Also, both weasel and stoat have recently been red-listed in the Netherlands (van Norren et al. 2020), while only the weasel is red-listed in Switzerland (Capt 2022), and the stoat is considered Near Threatened in Wales, following an IUCN-compliant Red List for Britain's Terrestrial Mammals (Mathews and Harrower 2021). We propose reviewing the status of stoats and weasels, adopting a similar approach to that taken for the European polecat (*Mustela putorius*; Croose et al. 2018), and recommending changes to the conservation status of stoats and/or weasels where deemed necessary.

1. Streamlining methodology and data collection to enable a better comparison of data and for meta-analyses to be conducted. Despite a concerted effort by researchers across Europe to monitor stoats and weasels, there are significant differences in data-collection methodologies and data-management practices. By agreeing

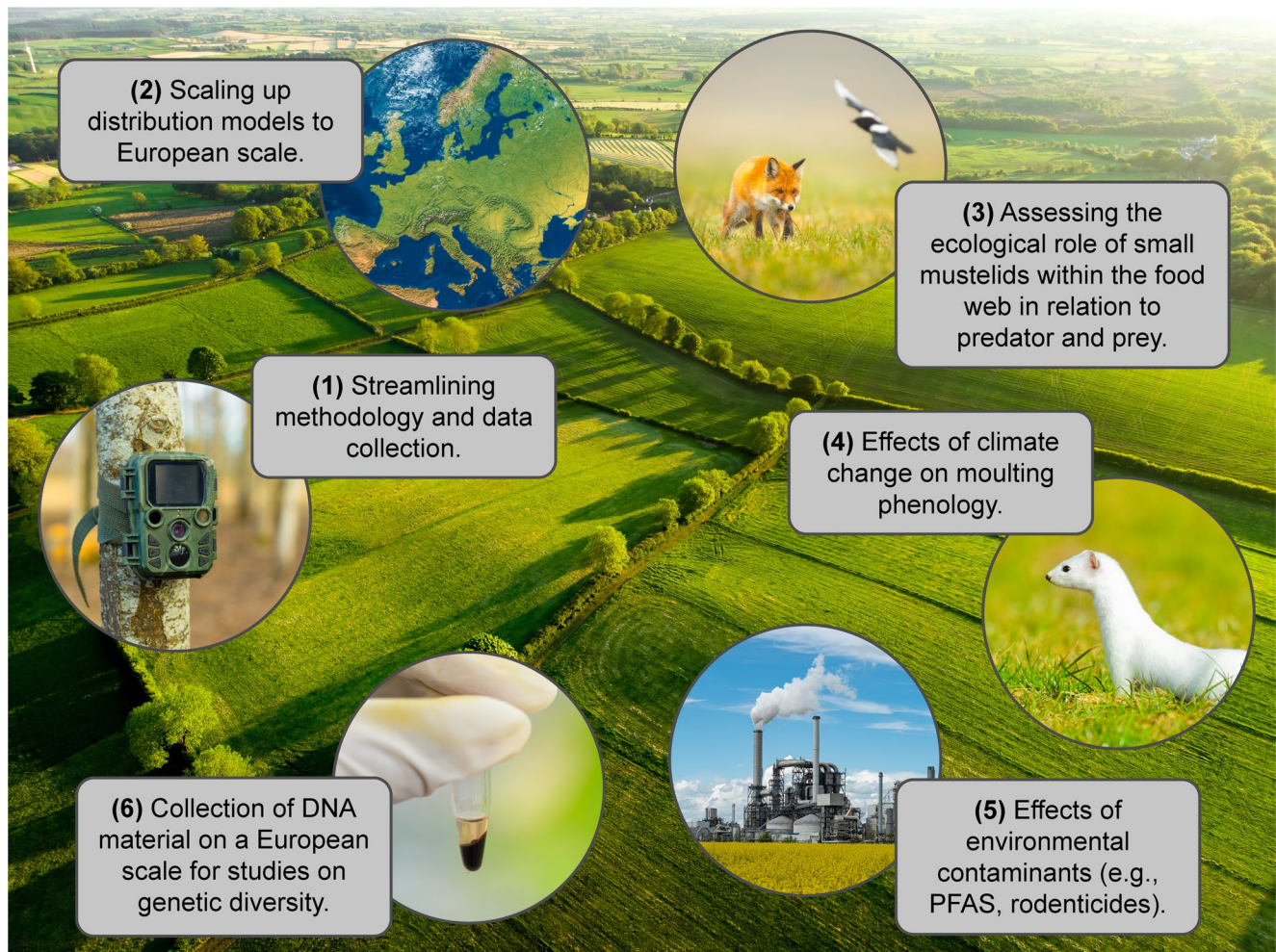


Fig. 1 An overview of the future research directions we envisage for small mustelid research in Europe. The numbers correspond with the points from the section 'Future directions for small mustelid research in Europe'

on methods and providing clear data standards (e.g., for *Mustela* data based on the camtrap DP; (Bubnicki et al. 2024), or shared data collection protocols), we aim to compare and combine data collected in different countries and ecosystems.

2. Scaling up distribution models to a European scale to assess how the range of weasels and stoats will change over time in the light of a changing environment. As previously mentioned, SDMs are currently being developed to predict the future distribution of stoats and weasels at the national level; however, at a larger scale, the observed patterns might prove more informative about how these species will change across Europe.
3. Assessing the ecological role of small mustelids within the food web. The number of studies investigating the role of small mustelids within the mammalian assemblage as a whole is limited (but see, e.g., Sidorovich and Solovej 2007; Korpela et al. 2014). Advances in technology have made it easier to study a large set of species

simultaneously. These advances enable examination of small mustelids in relation to their predators and competitors, as well as a range of prey species. One crucial outstanding research question is the effect of larger predators on small mustelid populations, and how this influences the relationship between small mustelids and their prey populations (especially rodents and ground-breeding birds). Molecular dietary analyses (e.g., metabarcoding of feces or stomach contents) could now be applied at larger scales to better understand these trophic interactions.

4. The moulting phenology of small mustelids is being affected by climate change. The seasonal colour change to white for winter, which is common in weasels and stoats, leads to camouflage mismatch, a significant cause of mortality (Atmeh et al. 2018; Otte et al. 2024). Data from trapping and camera-trapping across Europe can help monitor adaptive moulting changes, which could mitigate the negative impacts of climate change.

5. The effect of environmental contaminants (Per- and polyfluoroalkyl substances (PFAS), second-generation anticoagulant rodenticides (SGARs), and heavy metals) on small mustelids. While environmental contaminants are identified as a significant threat to small mustelids (Sainsbury et al. 2018; Wright et al. 2022), to our knowledge, no studies have examined how these pollutants affect the survival of weasels and stoats. In other mustelid species, a range of heavy metals has been found in both stone martens *Martes foina* (inhabiting urban areas), and pine martens *Martes martes* (inhabiting rural areas) (Goretti et al. 2018). In Denmark, traces of rodenticides were found in 95% of weasels and 97% of stoats, with a negative effect on their body condition (Elmeros et al. 2011), while the increasing amount of PFAS coming from industries are found in natural systems suggests that these contaminants may become a concern for small mustelids; however, baseline data are lacking.
6. Collection of DNA samples across Europe to study the genetic diversity of stoats and weasels between countries and to place populations within a broader genetic context. Advances in genomics have enabled the study of population genetic structure and dynamics at large spatial scales using low-quality samples, such as scats and hair samples (von Thaden et al. 2017). Tissue samples could be collected from road-killed animals and from animals killed in eradication programmes. This opens the opportunity to investigate the genetic structure of small mustelid populations throughout Europe using samples collected during other research activities, as well as through targeted sampling. Additional DNA material extracted from stomach contents or fecal matter could support dietary studies through metabarcoding, strengthening our understanding of the ecological role of small mustelids within the food web, as mentioned in point 3 (Vigués et al. 2021; Shively et al. 2025). Protocols for genetic and carcass sampling of small mustelids have been added to the supplementary material as a general guideline to enable standardisation of data collection (Supplementary S1 & S2).

Conclusions

Across Europe, several ongoing projects are currently investigating different aspects of the biology of weasels and stoats, investigating their potential role as sentinels of environmental change as well as assessing their conservation status. By bringing together the expertise from these projects, providing a pan-European network for knowledge exchange, and enabling the sharing of samples and data, we

believe there is significant potential to further our understanding of the ecology and conservation status of these fascinating, smallest carnivores. We therefore urge anyone with a current or upcoming research project on weasels and/or stoats in Europe to get in touch to join the European Weasel Gang (www.europeanweaselgang.eu), a network of researchers working on weasels and stoats.

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Declarations

Competing interests One of the authors of the paper (Karol Zub) is an editor of 'Mammal Research'.

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