



Interactions between two protected species: *Rhinolophus ferrumequinum* impacting the recovery of *Rhinolophus hipposideros* populations in Britain

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Received: 19 April 2024 / Accepted: 19 January 2026

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Abstract

Rhinolophus hipposideros populations in Britain are recovering from a severe population crash in the mid-20th century. In recent years, substantial declines in *R. hipposideros* numbers, coinciding with the arrival of *Rhinolophus ferrumequinum*, have been observed at summer roosts. Here, we aim to understand whether *R. ferrumequinum* are occurring more frequently in *R. hipposideros* roosts and whether these are impacting population growth. We used *R. hipposideros* summer roost counts from the National Bat Monitoring Programme (NBMP) database to assess this impact. Our findings indicate that *R. ferrumequinum* are increasingly being observed in *R. hipposideros* roosts in summer from 2010 onwards. From 1998 to 2010, *R. hipposideros* population trends increased similarly whether *R. ferrumequinum* were observed or not inside the roost. However, population trends decreased by 15% (6.8–22%) between 2015 and 2023 in roosts where *R. ferrumequinum* have occurred, while populations continued to increase in roosts where they have not been observed. The timing of this decrease also coincides with the rise of *R. ferrumequinum* occurrences in *R. hipposideros* roosts. It is not yet fully understood how these interactions are impacting *R. hipposideros*, but these appear to reduce the recovery of the affected roosts. As both species are highly protected, active management to accommodate the roosts for both species is preferable. However, a clear understanding of the local and national context of each affected roost for both species is required if a species is to be prioritised.

Keywords Chiroptera · Bats · Species coexistence · Reserve management · Population decline

Introduction

The increase in conservation programmes resulting from biodiversity loss can result in conflicting conservation goals between and within programmes where certain management practices can be favourable for certain species whilst being detrimental for others (Jordán and Báldi 2013). Such conflicts will also become more important as many species

distributions are expected to shift as a response to climate change and lead to new interactions (Novella-Fernandez et al. 2021).

Increased predation of a protected species by another is often the main driver behind such conflicts. For example, the recovery of *Delphinium montanum*, a protected endemic plant, is largely influenced by the grazing of *Rupicapra rupicapra pyrenaica*, a species which has undergone important conservation efforts to increase its populations (Simon et al. 2001; Jordán and Báldi 2013). Similarly, the decline of *Cyprinodon bovinus*, an endangered pupfish, was largely driven by egg predation from another endangered species, *Gambusia nobilis* (Gumm et al. 2008). However, the report of increased interactions between recovering syntopic species impeding on one's recovery has rarely been observed. *Rhinolophus ferrumequinum* and *Rhinolophus hipposideros* are bat species which share very similar ranges and ecology in Europe. Having historically evolved to roost throughout

Communicated by Jenna Kohles

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the year in caves, they have also adapted in most parts of their range to also roost in buildings. Both species form maternity colonies in warmer months, comprised mostly of female bats which aggregate in roosts for the purpose of giving birth and rearing pups. In the more northerly parts of Europe, both species favour forming maternity colonies inside buildings and tend to be associated with heterogeneous landscapes comprised of woodlands along with well-connected hedgerows, tree-lines and wooded riverbanks (Schofield et al. 2022).

Populations of both species reached a critical low point in western/northern Europe during the mid-20th century, with dramatic declines being reported in multiple countries (e.g. Belgium, Luxembourg, Britain; Stebbings 1988; Hutson and Mickleburgh 2001; Schofield 2025). The decline of both species has largely been attributed to the loss of roosting sites, remedial timber treatment, loss of feeding habitat and persecution. They are now subject to high levels of protection in Britain and Europe and are included in Appendix II of Bern Convention, Appendix II of the Bonn Convention, Annex II and Annex IV of the European Directive on the conservation of Natural Habitat and of Wild Fauna and Flora. In Britain, milder winters accompanied by increased protection of key bat roosts have contributed towards an increase in populations of both species (Barlow et al. 2015; Bat Conservation Trust 2021, Wright et al. 2022). *R. ferrumequinum*, however, are recovering from a much more severe bottleneck and have notably lower levels of genetic diversity than the rest of the European population (Tournayre et al. 2019). As the species recovers and extends its range, small numbers of individuals are regularly observed roosting in *R. hipposideros* roosts. These observations have been accompanied by sudden population declines of several *R. hipposideros* roosts, which in some cases constitute a severe drop in adult numbers and cessation of breeding (Pers. Observation). While the nature of the disturbance caused by *R. ferrumequinum* is still poorly understood, concerns have been raised regarding the impact that these interactions are having on the population recovery of *R. hipposideros*.

In this study, we aim to (1) assess whether the number of cases of *R. ferrumequinum* roosting at *R. hipposideros* summer roosts is increasing over time and (2) evaluate whether the presence of *R. ferrumequinum* in *R. hipposideros* summer roosts is affecting the population growth of these colonies.

Methods

NBMP database

The National Bat Monitoring Programme (NBMP; Barlow et al. 2015; Bat Conservation Trust 2024) Roost Count Surveys started in 1997 and have provided counts of known *R.*

hipposideros summer roosts. This is a citizen science initiative led by the Bat Conservation Trust where trained volunteers undertake two standardised emergence counts between the 6th and 25th June and at least five days apart. During these visual counts, acoustic bat detectors are often used to identify species, but neither these or night vision aids are a requirement of the survey protocol. The presence of other bat species is also recorded, enabling the mapping of roost locations where both horseshoe bat species have been reported. This information allows the inspection of spatial and temporal configuration of the number of cases where both horseshoe species are recorded in roosts. To visually assess spatial trends, all NBMP *R. hipposideros* roosts monitored between 1998 and 2023 were mapped, along with the number of years *R. ferrumequinum* was also recorded at each summer roost.

Data analysis

All analyses were carried out in R version 4.3.2 (R Core Team 2021) implemented in R Studio (RStudio Team 2015). To test whether *R. ferrumequinum* occurrences at *R. hipposideros* summer roosts is increasing over time, we fitted a generalized additive mixed model (GAMM), using the mgcv package (Wood 2017), with a binomial error distribution and logit link function. The response variable was modelled as a yearly ratio of *R. ferrumequinum* occurrences in *R. hipposideros* summer roosts. The model included a smooth term for year to capture nonlinear temporal patterns, and a smooth term for the yearly ratio of detectors used during roost counts as it was thought this could influence the detection of *R. ferrumequinum*. To account for temporal autocorrelation in the residuals due to annual observations, we specified a first-order autoregressive structure applied to the residuals ordered by Year. Model diagnostics, including residual plots and autocorrelation functions (ACF), were used to assess model fit and ensure assumptions were met.

We used the package poptrend (Knappe 2016) to perform generalized additive mixed models (Wood 2017) to estimate population trends at *R. hipposideros* roosts nationally, where *R. ferrumequinum* have never been recorded, then where they have been recorded at least once. We filtered the dataset to keep sites with at least 3 years of data. Log-linear models were fitted with a poisson distribution to the counts on each survey. The method developed by Knappe (2016) allowed us to decompose population change into a long-term population trend (smooth function of time) and short-term fluctuations as temporal random effects. A site term was included as a random effect and we presented results using seven degrees of freedom as suggested by Fewster et al. (2000), which is approximately 0.3 times the number of years. Index values were derived from the fitted curve using 1998 as a base year set at 1 and the goodness of fit of each model was verified.

Results

R. ferrumequinum were recorded at 74 *R. hipposideros* roosts out of the 369 roosts and throughout the species' range overlap with specific clusters visible in southern Wales (Fig. 1). The number of years *R. ferrumequinum* were recorded ranged from 1 (18 sites) to 25 (3 sites > 10; Fig. 1). The ratio of *R. ferrumequinum* occurrences remained stable and below 0.1 from 1998 to 2010, then increased and exceeded 0.2 in 2023 (edf=2.95, $F=17.38$, $p<0.001$; Fig. 2). In contrast, the yearly ratio of detectors used during roost counts did not impact the ratio of *R. ferrumequinum* occurrences (edf=1.96, $F=1.73$,

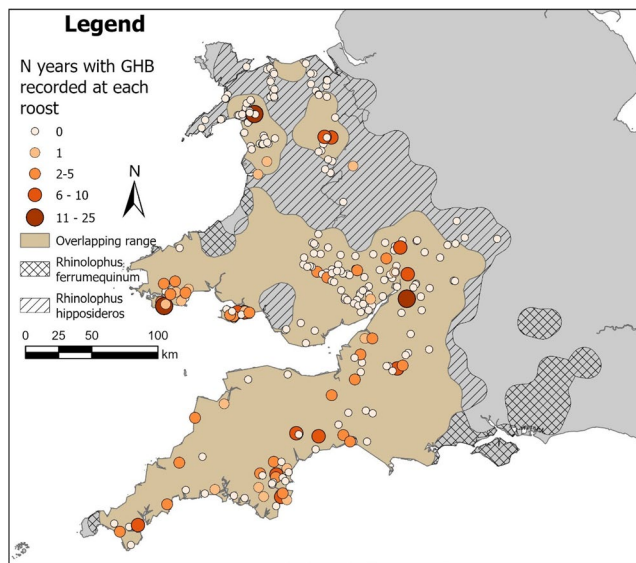


Fig. 1 Map representing the number of years *R. ferrumequinum* (GHB) were recorded at each *R. hipposideros* roost

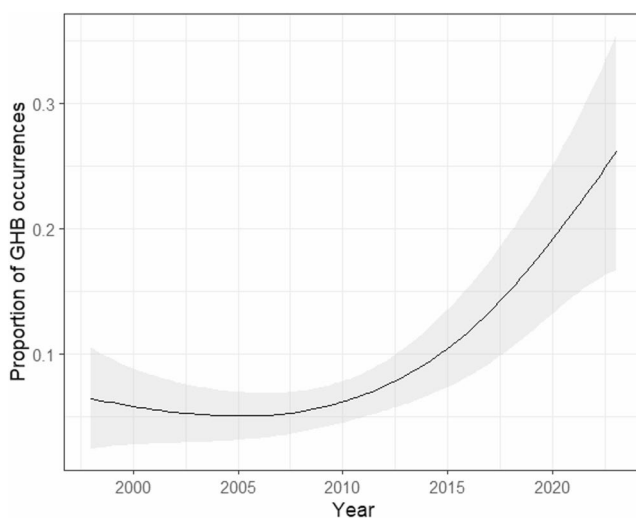


Fig. 2 Predicted proportion of *R. hipposideros* roosts with *R. ferrumequinum* (GHB) records since 1998

$p=0.192$). Therefore, the increased use of detectors did not lead to an increased number of *R. ferrumequinum* occurrences.

Overall, our results showed an 84% increase (CI 68–101%) of the *R. hipposideros* population with a significant increase from 1998 to 2016, the population has remained stable up until 2023 and may show early signs of decline in 2023 ($p<0.001$; Fig. 3A). Population trends of roosts where *R. ferrumequinum* have never been recorded increased by 99% (CI 79–118%) between 1998 and 2023 and the increase was significant throughout most years up until 2019 ($p<0.001$; Fig. 3B). Roosts where *R. ferrumequinum* has been recorded significantly increased by 68% (49%–91%) between 1998 and 2008 but a significant decrease of 21% (8.9–33%) was detected from 2018 onwards ($p=0.12$; Fig. 3C).

Discussion

Here, we present evidence showing that *R. ferrumequinum* can negatively affect the population recovery of *R. hipposideros* summer roosts, and that increasing cases of heterospecific roost use may even be affecting the national recovery of the species. Tackling conflicting priorities in conservation programmes requires a detailed understanding of the ecological mechanisms that generate conflicts between heterospecifics so that conservation practitioners can make any necessary adjustments to the interventions that are applied. While the interactions between both species inside roosts show a detrimental impact on *R. hipposideros* colony trends in this study, we have yet to understand the nature of these interactions. Competition by interference has been suggested as *R. ferrumequinum* have been observed chasing *R. hipposideros* (Salinas-Ramos et al. 2020 & Pers. Observation.), and it is also thought that *R. ferrumequinum* could predate on juvenile *R. hipposideros*. That said, it is also known that *R. ferrumequinum* will readily roost with other species, such as *Myotis emarginatus*. In Britain, *R. ferrumequinum* populations are rapidly recovering from a historic bottleneck and certain roosts may be reaching carrying capacity. As a result, certain, potentially stressed individuals may need to disperse and prospect other roosting sites, which may in turn result in aggressive behaviour towards *R. hipposideros* and/or a form of eavesdropping for resources (Li et al. 2014).

A better understanding of the structure of roosts that are impacted or not by the presence of *R. ferrumequinum* should also be investigated as building modifications may be a plausible route to mitigating *R. hipposideros* colony declines. It has been observed that some of the roosts where *R. hipposideros* suffer drastic declines can be limited in space (Pers. Observation), whereas those that do not appear to be

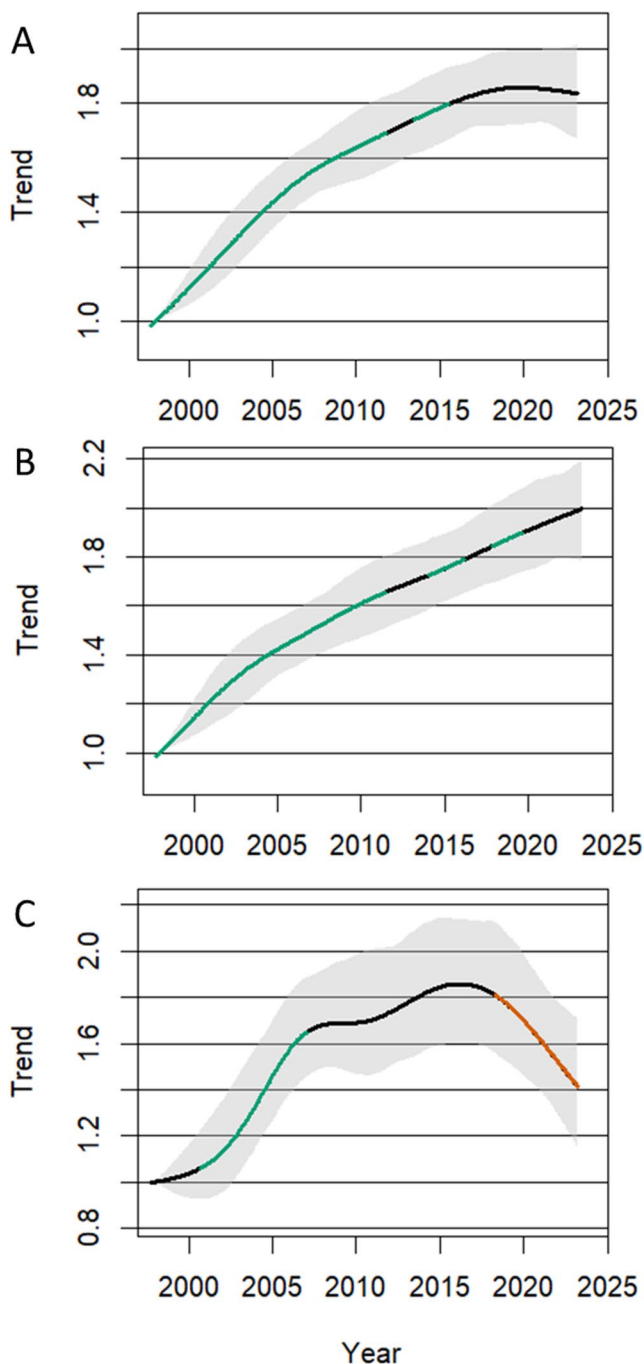


Fig. 3 Effect of *R. ferrumequinum* occurrences on *R. hipposideros* population trends in Britain – A. national trend ($n = 282$), B. trends based on roost counts where *R. ferrumequinum* have never occurred ($n = 218$), C. trends based on roost counts where *R. ferrumequinum* have occurred at least once ($n = 64$). The solid line in these panels is the estimated long-term component of the trend with 95% confidence intervals (shaded area). A green trend line represents a significant increase at the 5% level, while a red line represents a significant decline.

impacted tend to allow for spatial segregation between both species through compact sections in the roost. Therefore, further research is needed to identify the most vulnerable *R.*

hipposideros roosts to disturbance from *R. ferrumequinum*, so that appropriate structural modifications can be made and tested to facilitate within-roost segregation of both species. Fortunately, unlike many conflicts between species conservation programmes, a single stakeholder, with the best interest of both species in mind, tends to be responsible for the management of such roosts. This greatly facilitates any form of decision making needed to modify roosts.

In order to avoid conservation dilemmas between two species, holistic approaches to conservation management, focusing on larger units of study (e.g. landscapes, habitat fragments) are also often recommended (Jordán and Báldi 2013). *R. hipposideros* have a sedentary nature and their relatively low dispersal abilities compared to *R. ferrumequinum* means that roost availability is a significant determinant on the conservation of the species (Tournant et al. 2013). Despite the continued growth of the national *R. hipposideros* population, regional variations in the accessibility and number of suitable roosts could further impact the effect of *R. ferrumequinum* on *R. hipposideros* colonies and result in regional declines. Ideally, conservation efforts and prioritisation in Britain should be informed by knowledge of the local landscape, roost availability and population size of both species. Populations of *R. hipposideros* are likely to be more vulnerable in areas where there are few roosts providing optimal conditions for rearing young. However, in regions where *R. hipposideros* are abundant with plenty of accessible roosts, *R. ferrumequinum* could be prioritised, as their national populations are much lower in size (Mathews et al. 2018), provided their impact on *R. hipposideros* is low and large maternity roosts are not severely impacted. In such scenarios, the creation of additional roosts nearby as mitigation for *R. hipposideros* would be recommended to ensure the colony has optimal resources nearby and that any disturbance is less likely to impact population growth.

Our study demonstrated that instances of *R. ferrumequinum* roosting inside *R. hipposideros* roosts are increasing and occurring throughout the species' overlapping ranges. While the nature of the disturbances that *R. hipposideros* undergo are not fully understood, we have found that these interactions negatively impact the recovery of the affected roosts. As both species are highly protected and still recovering, it is essential to have a clear understanding of the local and national context of an affected roost before making decisions affecting its management. In addition, the provision of numerous roosting sites allowing segregation should be beneficial to both species.

Acknowledgements We would like to thank the Bat Conservation Trust for sharing data from the National Bat Monitoring Programme (NBMP). The NBMP is run by Bat Conservation Trust, in partnership with the Joint Nature Conservation Committee, and supported and steered by Natural England, Natural Resources Wales, Northern

Ireland Environment Agency, and Scottish Natural Heritage. The NBMP is indebted to all volunteers who contribute data to the programme.

We are very grateful to the Bat Conservation Trust and all the volunteers who contribute towards the yearly counts. We are also grateful for Dr Anita Glover & Dr Henry Schofield's support in the development of the project and the early efforts of Colin Morris and Peter Chapman in the reporting of these interactions.

Author contributions All authors contributed to the study conception and design. Data collection and analysis were performed by PW, TK & MBP. The first draft of the manuscript was written by PW and revised by MA, MBP, DH & TK. Final revision was performed by PW & DH. All authors have read and approved the final manuscript.

Declarations

Conflict of interest The authors state that there are no conflicts of interest.

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