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Authors: Rozycka, Danielle, Lim, Jia M., Trout, Roger C., and Brooks, Sarah

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# Have feral boar significantly impacted hazel dormouse populations in Sussex, England?

**Danielle ROZYCKA[1], Jia M. LIM[2], Roger C. TROUT[3]* and Sarah BROOKS[4]**

[1] *Flat 2, 69c Netherhampton Road, Salisbury, Wiltshire SP2 8NA, England; e-mail: danielle.roz05@yahoo.co.uk*
[2] *Ecology Consultancy, Beckett House, 72 Borough High Street, London SE1 1XF, England; e-mail: jasmine@ecologyconsultancy.co.uk*
[3] *Rabbitwise-plus Consultancy, Holtside Bungalow, Batts Corner, Dockenfield, Farnham, Surrey, GU10 4EX, England; e-mail: rabbitwise@hotmail.co.uk*
[4] *21 Pavillion View, Scholes Lane, Cleckheaton, West Yorkshire BD19 6NL, England; e-mail: brooks.se@googlemail.com*

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**Abstract.** Wild boar, *Sus scrofa* have been extinct in the wild in Britain for about 300 years. However, escapees from farm enclosures have been noted for over 20 years in parts of Southeast England, and populations of free-living feral boar have now established. Boar root for food on the woodland ground where hazel dormice, *Muscardinus avellanarius* hibernate in fragile nests and thus may impact on their population through predation. A group of twelve woodland sites assessed as suitable for supporting dormice and where wild populations of boar were known to have been present for ca. 20 years were chosen in Sussex (boar-positive sites). An additional twelve sites without boar presence (boar-negative) were chosen in the same region from the National Dormouse Monitoring Programme (NDMP). Fifty nest boxes were erected in early spring 2009 at each new site and all were inspected in June and October until the end of 2012. The numbers of individual dormice, empty nests found, and nest boxes used by dormice annually were compared between the two groups. The correlative GLM comparisons (using a negative binomial model) for all three indices were significantly higher in the boar-negative sites, suggesting that boar have negatively impacted on, but not eliminated, dormouse populations. Potential confounding variables including soils and woodland classification were investigated and were similar between the groups. Since the study was over a four year period any initial neophobic reaction to new nest boxes on the boar-positive sites would be unlikely to influence the result. We had no data for boar densities so could not evaluate boar versus dormouse density.

**Key words:** *Sus scrofa*, *Muscardinus avenallarius*, interspecific interaction

## Introduction

The hazel dormouse *Muscardinus avenallarius* is a native species in Britain protected under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended) and Schedule 2 of the Conservation of Habitat and Species Regulations 2010 (as amended). There has been a marked decline in their distributional range over the past 100 years in Britain, largely due to loss and fragmentation of woodland habitat as a result of changes in forestry management, urbanisation and agricultural practices (Bright et al. 1994, Amori et al. 2008, Juškaitis 2008, Trout et al. 2012a). Extensive measures are taken to monitor and conserve this charismatic species, including the National Dormouse Monitoring Programme (NDMP). Work by Trout et al. (2012b) indicated, using data from 1000 nestboxes from 20 sites, that the amount of shrub vegetation (between 20-80 % cover) correlated with increasing dormouse presence in nestboxes.

Wild boar are historically a native species of Britain but are believed to have been driven to extinction twice in British history; in the 13th century and, despite reintroductions again in the 17th century (Goulding et al. 1998, Yalden 1999, Goulding 2009). They have thus been absent in the wild for around 300 years. Feral boar (escaped farmed stock of various origins, Goulding et al. 1998) are currently found free-living in a few areas of England (Natural England 2011). The potential for boar to spread widely within Britain, as have woodland deer (Harmer et al. 2010), due to its high fecundity, adaptability to different habitats and lack of predators (Goulding et al. 1998) has not been fully recognised.

* *Corresponding Author*



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Both boar and dormice occupy primarily woodland habitats and so there may be direct and/or indirect interactions between the two species, particularly predation by boar when dormice are hibernating (Juškaitis 2008, Juškaitis & Büchner 2013). In their study on the interactions of ungulates and rodents, Muñoz et al. (2009) found ungulates to modify the habitat and thus the spatial distribution and space used by rodents; in oak forests rodents were found concentrated under shrubs in the presence of ungulates, for shelter against disturbance from trampling and rooting. Additionally, boar rooting behaviour in Britain has been found to modify ground flora in subsequent years (Sims 2006, Harmer et al. 2011), and also has the potential to alter shrub vegetation structure.

Ecological issues associated with native wild boar are less obvious in continental Europe, where they have remained widespread. Therefore, the situation in Britain is somewhat unique and raises the question: if current feral boar populations persist and spread, what will the consequences be? This study investigates their possible impacts on hazel dormouse populations (a European protected species) by comparing three population indices from a group of sites in Southeast England without boar (boar-negative) and another group where boar have been present for circa 20 years (boar-positive).

## Material and Methods

Site selection for the group of boar-positive sites was primarily based on a long-term (20 year) boar presence in woodlands in the Beckley and Peasmarsh area of East Sussex, England. Sites with a long term presence were chosen due to an increased likelihood of detecting any effects boar may have on both dormice and vegetation rather than using recently invaded sites. Twelve boar-positive sites were selected within different one kilometre square areas to obtain a spread of sites. Twelve boar-negative sites in the NDMP were selected from a list of sites within Sussex and Kent obtained from the People's Trust for Endangered Species (PTES). Only sites with similar soil types were selected for both groups. Soil types of this area are Curtisden and Wickham 1; stagnogley subsoils that become seasonally waterlogged, typically during wet winters (Jarvis et al. 1983, Burnside et al. 2006). The locations of all 24 sites are shown in Fig. 1.

Chosen sites were of similar woodland habitats – ancient semi-natural woodlands (ASNW) or planted ancient woodland sites (PAWS), where evidence remains of former ancient woodland vegetation (Goldberg et al. 2007, The Woodland Trust 2009). Using the National Vegetation Classification Field

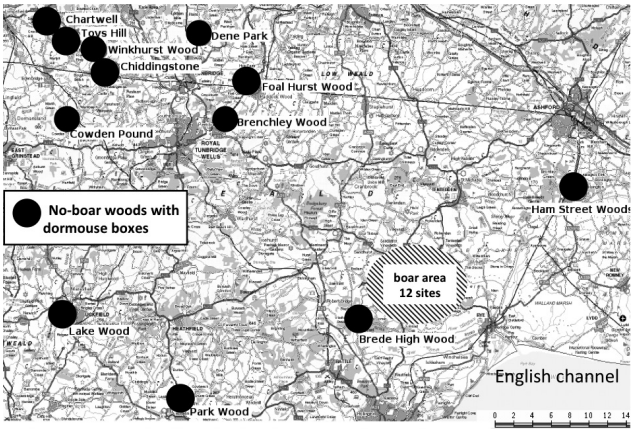



**Fig. 1.** Map showing the 12 no-boar sites (filled circles) and the 12 boar-present sites (hatched area).

**Table 1.** Woodland size, soil type (specific identity code) and national vegetation classification (NVC) of the two groups of study sites.

| Site name | Size (ha) | Geology (U.K. soil classification) | NVC |
|---|---|---|---|
| Boar-positive sites | | | |
| Little Dennis | 20 | Curtisden (572i) | W10 |
| Kings | 2.7 | Wickham 1 (711e) | W10 |
| Garland | 7.5 | Curtisden (572i) | W10 |
| Great Sowden | 39 | Curtisden (572i) | W10 |
| Mill Wood | 17.5 | Curtisden (572i) | W10 |
| Burnthouse | 15 | Curtisden (572i) | W10 |
| Waterfall | 20 | Wickham 1 (711e) | W10 |
| Flatropers North | 35 | Curtisden (572i) | W10 |
| Flatropers South | 35 | Curtisden (572i) | W10 |
| Twist Wood | 12 | Curtisden (572i) | W10 |
| Spring Wood | 4.5 | Curtisden (572i) | W8 |
| Great Shelley | 2.5 | Curtisden (572i) | W10 |
| Boar-negative sites | | | |
| Lake Wood | 8.5 | Curtisden (572i) | W10 |
| Park Wood | 60 | Curtisden (572i) | W8 |
| Chartwell | 7.5 | Wickham 1 (711e) | W10 |
| Dene Park | 33 | Wickham 1 (711e) | W10 |
| Toys Hill | 7.5 | Curtisden (572i) | W10 |
| Ham Street | 32 | Wickham 1 (711e) | W10 |
| Brede High | 9 | Wickham 1 (711e) | W10 |
| Foal Hurst | 17.5 | Wickham 1 (711e) | W10 |
| Cowden Pound | 7.5 | Curtisden (572i) | W10 |
| Winkhurst | 17.5 | Curtisden (572i) | W10 |
| Brenchley | 13 | Wickham 1 (711e) | W10 |
| Chiddingstone | 59 | Wickham 1 (711e) | W10 |



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**Table 2.** Dormouse indices from the boar-present and no-boar groups of sites. In June 2009 the nestboxes had only recently been placed in the boar positive sites. Key: HDm = hazel dormouse.

| Year | Month | Sites surveyed that month | Sites with positive evidence of HDm | HDm found in boxes | Nests | All nestboxes used by HDm |
|---|---|---|---|---|---|---|
| Boar-positive | | | | | | |
| 2009 | June | 12 | 0 | 0 | 0 | 0 |
| 2009 | October | 12 | 7 | 19 | 8 | 22 |
| 2010 | June | 12 | 7 | 14 | 0 | 10 |
| 2010 | October | 12 | 10 | 45 | 11 | 33 |
| 2011 | June | 12 | 8 | 14 | 5 | 16 |
| 2011 | October | 10 | 8 | 22 | 20 | 43 |
| 2012 | June | 10 | 8 | 6 | 5 | 10 |
| 2012 | October | 10 | 7 | 26 | 28 | 42 |
| Totals | | | 61 % | 146 | 77 | 176 |
| Boar-negative | | | | | | |
| 2009 | June | 12 | 6 | 15 | 8 | 20 |
| 2009 | October | 12 | 9 | 46 | 20 | 56 |
| 2010 | June | 10 | 8 | 24 | 9 | 27 |
| 2010 | October | 10 | 9 | 77 | 25 | 73 |
| 2011 | June | 11 | 6 | 21 | 17 | 36 |
| 2011 | October | 10 | 8 | 58 | 36 | 70 |
| 2012 | June | 9 | 5 | 23 | 7 | 23 |
| 2012 | October | 10 | 7 | 17 | 28 | 42 |
| Totals | | | 69 % | 281 | 150 | 347 |

Guide to Woodland (Hall et al. 2004), sites were also chosen by their woodland type to ensure the two groups of sites were similar. Canopy and shrub vegetation at each site was surveyed to provide a standardised measure of vegetation surrounding each nest box. This method was adapted from a study by Bousfield (2001). A 5 m radius was taken around every alternate tree with a nest box attached in order to sample a large portion of the site. Within this radius, vertical and a horizontal vegetation density was measured visually using a Domin scale measurement whereby the abundance measures increased from 1-5, with "no presence" depicted by a zero count. The data were compared after arc-sin transformation to determine whether the two groups of woods were broadly similar in three dimensional structure, i.e. similarly likely to be suitable for dormice.

Fifty wooden nest boxes were installed within each of the twelve boar-positive sites between April and June 2009, the boar-negative sites were already set as part of the NDMP. Where possible, the nest boxes were installed in grid formation at 20-25 m apart (along and between rows). Nest boxes were generally surveyed once a month, with surveys for June and October occurring at all 24 sites from June 2009-October 2012, creating a database of potentially 96 sample points for each group. Nestbox monitoring followed the methodology within the Dormouse Conservation Handbook (Bright et al. 2006). Data recorded included the number of individual dormice out of 50 boxes; number with a dormouse nest and the number of boxes with any sign of dormouse. Comparative analyses using the statistical package R were used to explore potential differences between the two groups of sites. The explanatory variable is boar absence versus presence and the response variables are dormouse numbers, dormouse nests and all nest boxes used by dormice. A generalised linear model (GLM) was constructed with negative binomial errors to produce the lowest Akaike Information Criterion (AIC), due to a skew in the data towards low numbers. The variance for each dataset indicated that there was unlikely to be a Poisson distribution.

## Results

The woodland size, soil geology and woodland classification of each site of the two groups are shown in Table 1, showing the woodland sites to be broadly similar in these aspects. The canopy and shrub vegetation comparisons (both the horizontal and



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vertical aspects), showed no significant differences between the two groups, indicating generally similar woodland structures.

Only a few of the boar-positive sites were surveyed in June 2009 as the nest boxes had only just been positioned. Unfortunately, dormouse evidence was not always collected from all the boar-negative sites between 2009 and 2012, causing several gaps in the data (Table 2). Two of the boar-positive sites had to be withdrawn before the end of the study due to clear felling forestry operations. All sites except one boar-positive site had evidence of dormice, confirming our general approach to choosing potentially reasonably dormouse-friendly sites. A chi-squared test shows boar presence does not significantly affect the basic presence of dormouse ($\chi^2 = 0.43$, $p = 0.51$). AIC values for GLM using poisson distribution were all higher than the equivalent negative binomial models.

Comparative analysis of dormouse numbers, using June and October data for 2009-2012 (excluding incomplete June 2009 data), indicated that feral boar presence had a significant negative effect on dormouse numbers handled (AIC = 494, z = –2.51, df = 177, $p = 0.0122$). Analysis of the results for each October only showed an almost significant effect on dormouse numbers handled as a result of boar presence (z = –1.85, $p = 0.065$).

Analysis of the presence of dormouse nests in boxes using June and October data for 2009-2012 (excluding incomplete June 2009 data), also indicates feral boar presence had a significant negative effect on the number of dormouse nests found (AIC = 810, z = –2.47, df = 146, $p = 0.0135$). Where only October results were used, analysis still showed a significant effect on dormouse nests as a result of boar presence (z = –2.21, $p = 0.027$).

Using data of overall nest boxes used (boxes with dormice or nests) for June and October data for 2009-2012 (excluding incomplete June 2009 data), boar presence has a very significant negative effect on overall nest box usage (AIC = 810, z = –3.28, df = 172, $p = 0.0010$). Where only October results were used, analysis also showed a significant effect on nest box use as a result of boar presence (z = –2.23, $p = 0.026$).

## Discussion

The objective of this study was to determine whether long term boar presence has affected local dormouse populations by direct or indirect means, as determined by nest box activity. Our simple measure of vertical and horizontal shrub cover showed no significant difference between the two groups of sites, suggesting no overall major shrub habitat change due to boar. The presence of boar did not affect the actual presence of dormice at the site (11/12 *vs.* 12/12) so, importantly, they had not made dormice extinct on these sites. Analyses indicated that boar presence is significantly negatively correlated with each of the three dormouse population indices. Thus boar appear, over the last 20 years, to have reduced the numbers of dormice using artificial nest boxes, and by implication their density. We did not have data on feral boar densities so cannot relate boar density indices to dormouse density indices.

A likely impact on bluebells by boar in the same area was found by Harmer et al. (2011) who similarly concluded that whilst there was an impact, the plant would not become extinct in that area of Sussex. However, both his and our studies were correlative, not experimental. We deliberately tried to overcome several potential confounding factors between our two groups of sites. For soil type by choosing sites with similar soils; by choosing only similar woodland type and the woodland structure – especially shrub layer density; against potential dormouse neophobia towards new nestboxes by monitoring for four years; choosing boar-positive sites with ca. 20 years of boar presence rather than only recently invaded woods. Whilst we know from marking studies (Trout et al. 2012b) that not all dormice use nestboxes all the time (so the animal count data is an index measure), we used a standardised methodology across all sites so the data can justifiably be compared. Moreover, the negative correlation result is similar when comparing the presence of nests, thus demonstrating a difference unrelated to the presence of a dormouse during an individual inspection. Since nestboxes are the standard method of evaluating dormice, a major change in dormouse behaviour to not use nestboxes in the presence of boar would negate our results. However we cannot find any empirical evidence for this, nor propose an implicit evolutionary advantage for such a change in dormouse behaviour that would take only 20 years to occur.

Predation of hazel dormice by wild or feral boar is most likely to occur during winter months due to boar rooting behaviour whilst dormouse are hibernating at ground level. Schley & Roper (2003) found no dormouse remains within boar faecal analyses in Spain and no published studies recording boar predation of hazel dormice are reported by Juškaitis & Büchner (2013). However due to the rare availability and small size of this potential prey species this is unsurprising. Boar were not seen during field work, but fresh signs such as rooting, wallows, footprints and tree rubbings were seen on all boar-positive sites during each year.



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Occupied dormouse nests constructed during their active season near the ground might also be taken by feral boar. Our horizontal shrub vegetation index measures were based at one to five metres above ground. It is possible that boar impact may relate more to the herb layer, where dormice take some nesting material, or the lowest shrub layer below 1 m.

Recent evidence suggests dormouse populations to be generally (not exclusively) greater in southern Britain than most of Europe (Juškaitis & Büchner 2013). Since wild boar populations have seen an increase across Europe in recent decades even in the presence of hunting pressure (Sáez-Royuela & Tellería 1986, Massei et al. 2015), there is the potential for boar to further impact dormice (and other parts of the ecosystem directly or indirectly) in the U.K. Feral boar are virtually certain to increase and spread further from the few current "hot-spots" (as they can disperse across the countryside more easily than deer) and especially if there is a lack of adequate population management. Whether the impact of boar on dormice is by direct predation or is indirect through alteration of ground vegetation composition and/or structure is yet to be determined.

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