Mammal Review

Mammal Review ISSN 0305-1838

SHORT COMMUNICATION

# The scientific profiles of terrestrial mammals in Great Britain as measured by publication metrics

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**Keywords**
biomass, h-index, invasive species, red list species, Web of Science

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Submitted: 25 June 2014
Returned for revision: 16 September 2014
Revision accepted: 19 December 2014
Editor: KH

doi:10.1111/mam.12038

## ABSTRACT

Research on mammals provides the evidence base for their conservation, management and related policy. We assess the effect of study choices on the composition of this evidence base. We derived species *h*-index (SHI) for 67 breeding terrestrial mammals from 2305 publications based on field research carried out in England, Scotland and Wales. Native species had higher SHI than introduced species, but SHI was not related to the level of species conservation concern. SHI was positively related to geographical range and/or population size and to functional group: large herbivores had higher SHI, then carnivores, rodents, small herbivores, bats and insectivores.

## INTRODUCTION

British mammals are particularly well studied so that we have a good understanding of their ecology, and research provides evidence supporting their conservation and management. An understanding of how this evidence base is influenced by human value judgements, species status and ecology is needed to inform decision making, investment and research.

Metrics exist to compare the scientific outputs in different disciplines and of individual researchers, including the *h*-index (Hirsch 2005) – defined as the number of papers *h* with citations $\geq h$. For the first time, we apply this approach to individual species. This allows ranking of species in order of volume and impact of publications, investigation of between-species differences, and a novel exploration of the drivers of research on mammals in Britain. Two further metrics are presented for comparison.

## METHODS

This paper is based on the number of published papers on the ecology of terrestrial mammals in England, Scotland and Wales, and on the number of times they were cited. Both jurisdictions in Ireland were omitted due to complications in the population estimates we used as covariates. The list of 67 terrestrial mammal species was derived from Harris et al. (1995), Battersby (2005) and Harris and Yalden (2008; see Table 1).

We searched the Web of Science (WoS) for the scientific and common name of each species in turn. Where species had alternative or historic scientific names (National Centre for Biotechnology Information; http://www.ncbi.nlm.nih.gov/), each was entered. Searches were restricted by predetermined WoS criteria: research domain (science technology), research area (zoology, environmental sciences, ecology and biodiversity conservation) and countries/territories (UK, England, Scotland and Wales). We extracted title, abstract, authors, source and date. Each paper was then checked for relevance using three criteria. A qualifying paper had to

**1.** Feature the species name (scientific or common) in the title or abstract. This criterion was additional to the initial WoS search.
**2.** Be carried out, at least in part, in England, Scotland or Wales. Field studies conducted entirely elsewhere were excluded.
**3.** Deal with the ecology of the free-living species. Papers dealing solely with anatomy or genetics, and captive or

**Table 1.** Publication metrics for terrestrial mammal species in Britain based on searches in the Web of Science: species *h*-index (SHI), total number of papers per species and mean number of citations (±1 standard error). Where an additional (non-current or alternative) scientific name was included in the search term, this is given in parentheses

| Scientific name | Common name | SHI | No. of papers | Mean no. of citations |
|---|---|---|---|---|
| *Cervus elaphus* | Red deer | 54 | 241 | 41 (4.11) |
| *Meles meles* | Badger | 47 | 291 | 25.1 (1.9) |
| *Ovis aries* | Feral sheep | 34 | 83 | 51.82 (8.4) |
| *Vulpes vulpes* | Red fox | 34 | 152 | 22.68 (2.36) |
| *Apodemus sylvaticus* | Wood mouse | 31 | 141 | 18.69 (1.58) |
| *Lutra lutra* | Otter | 30 | 184 | 13.09 (1.48) |
| *Pipistrellus pipistrellus** | Common pipistrelle | 30 | 83 | 30.76 (4.39) |
| *Microtus agrestis* | Field vole | 26 | 99 | 20.09 (2.2) |
| *Neovison vison (Mustela vison)* | American mink | 26 | 98 | 19.59 (2.56) |
| *Oryctolagus cuniculus* | Rabbit | 26 | 125 | 15.41 (1.38) |
| *Capreolus capreolus* | Roe deer | 24 | 72 | 20.49 (2.94) |
| *Myodes glareolus (Clethrionomys glareolus)* | Bank vole | 22 | 58 | 19.12 (2.57) |
| *Sciurus vulgaris* | Red squirrel | 22 | 82 | 17.46 (2.47) |
| *Sciurus carolinensis* | Grey squirrel | 21 | 92 | 13.79 (2.14) |
| *Arvicola terrestris* | Water vole | 20 | 74 | 12.5 (2.08) |
| *Dama dama* | Fallow deer | 20 | 51 | 22.71 (4.18) |
| *Sorex araneus* | Common shrew | 19 | 41 | 24.07 (3.72) |
| *Plecotus auritus* | Brown long-eared bat | 18 | 35 | 29.94 (5.63) |
| *Erinaceus europaeus* | Hedgehog | 17 | 49 | 13.75 (2.02) |
| *Rhinolophus ferrumequinum* | Greater horseshoe bat | 17 | 36 | 26.06 (5.2) |
| *Lepus timidus* | Mountain hare | 16 | 47 | 13.7 (2.56) |
| *Mustela nivalis* | Least weasel | 16 | 33 | 31.36 (6.1) |
| *Lepus europaeus* | Brown hare | 14 | 37 | 19.08 (3.77) |
| *Muntiacus reevesi* | Muntjac | 14 | 44 | 13.66 (2.72) |
| *Muscardinus avellanarius* | Common dormouse | 14 | 45 | 13 (2.92) |
| *Mus musculus (Mus domesticus)* | House mouse | 13 | 23 | 21.52 (3.87) |
| *Myotis nattereri* | Natterer's bat | 13 | 25 | 18.72 (4.31) |
| *Pipistrellus pygmaeus* | Soprano pipistrelle | 13 | 32 | 19.72 (5) |
| *Apodemus flavicollis* | Yellow-necked mouse | 12 | 26 | 16.85 (3.53) |
| *Mustela erminea* | Stoat | 12 | 23 | 15.39 (3.14) |
| *Mustela putorius* | Polecat | 11 | 35 | 11.89 (3.01) |
| *Myocastor coypus* | Coypu | 11 | 20 | 12.95 (4.43) |
| *Cervus nippon* | Sika deer | 10 | 29 | 11.69 (3.44) |
| *Eptesicus serotinus* | Serotine | 10 | 16 | 29.13 (9.56) |
| *Martes martes* | Pine marten | 10 | 33 | 14.36 (3.89) |
| *Rattus norvegicus* | Norway/brown rat | 10 | 32 | 10.25 (2.64) |
| *Sorex minutus* | Pygmy shrew | 9 | 16 | 19.13 (5.93) |
| *Felis silvestris* | Wildcat | 8 | 21 | 11 (3.08) |
| *Micromys minutus* | Harvest mouse | 8 | 16 | 12.25 (2.9) |
| *Rhinolophus hipposideros* | Lesser horseshoe bat | 8 | 19 | 23.32 (7.41) |
| *Capra hircus* | Feral goat | 7 | 17 | 9.94 (2.62) |
| *Myotis daubentoni* | Daubenton's bat | 7 | 11 | 40.09 (12.27) |
| *Nyctalus noctula* | Noctule | 7 | 14 | 23.43 (11.49) |
| *Talpa europaea* | Mole | 7 | 15 | 8.47 (1.83) |
| *Castor fiber* | Eurasian beaver | 6 | 20 | 7 (2.5) |
| *Neomys fodiens* | Eurasian water shrew | 6 | 12 | 7.17 (2.28) |
| *Sus scrofa* | Wild boar | 6 | 12 | 9 (3.16) |
| *Glis glis* | Edible dormouse | 5 | 12 | 4.92 (1.84) |
| *Hydropotes inermis* | Water deer | 5 | 11 | 10.45 (5.23) |
| *Microtus arvalis* | Common vole | 5 | 7 | 17.14 (7.9) |
| *Myotis mystacinus* | Whiskered bat | 5 | 7 | 23.29 (12.03) |
| *Nyctalus leisleri* | Leisler's bat | 5 | 7 | 38.71 (19.51) |
| *Pipistrellus nathusii* | Nathusius' pipistrelle | 5 | 8 | 10.88 (3.81) |
| *Barbastella barbastellus* | Barbastelle | 4 | 6 | 27.67 (14.41) |
| *Bos taurus* | Wild cattle | 4 | 7 | 9.57 (3.09) |
| *Equus caballus* | Wild horse | 4 | 7 | 19.86 (8) |
| *Felis catus* | Feral cat | 4 | 7 | 7.29 (2.97) |
| *Myotis bechsteinii* | Bechstein's bat | 4 | 7 | 32.71 (14.49) |
| *Rattus rattus* | Black rat | 4 | 10 | 7 (3.59) |
| *Mustela putorius furo (Mustela furo)* | Feral ferret | 3 | 6 | 6.33 (2.39) |
| *Myotis brandtii* | Brandt's bat | 3 | 4 | 47.25 (22.62) |
| *Macropus rufogriseus* | Red-necked wallaby | 2 | 4 | 1.5 (0.96) |
| *Plecotus austriacus* | Grey long-eared bat | 2 | 2 | 8.5 (3.5) |
| *Hystrix cristata* | Crested porcupine | 0 | 0 | 0 (0) |
| *Myotis alcathoe* | Alcathoe's bat | 0 | 0 | 0 (0) |
| *Ondatra zibethicus* | Musk rat | 0 | 0 | 0 (0) |
| *Rangifer tarandus* | Reindeer | 0 | 0 | 0 (0) |

*Until 1999, *Pipistrellus pipistrellus and P. pygmaeus* were classified as a single species. This means that up to this date, papers classified as relating to *Pipistrellus pipistrellus* may include papers concerning *P. pygmaeus*. If such papers were found to mention the 55 Hz phonic type of *Pipistrellus pipistrellus*, however, they were classified as *P. pygmaeus* papers.

laboratory studies, were excluded, unless the authors directly related these to the ecology of the species.

In ca. 85% of papers, the extracted data were sufficient to assess the criteria; if not, the full paper was sourced.

We calculated species *h*-index (SHI) as the largest number *h* such that *h* publications had at least *h* citations (Hirsch 2005). For example, if a species has three identified papers with 10, 3 and 1 citations, SHI is 2, as two papers have two or more citations. Two additional species publication metrics were calculated: the total number of papers and the mean number of citations per paper.

Covariates likely to influence SHI were collated. Most population estimates were derived from Battersby (2005) or Harris et al. (1995). For non-native species eradicated during the 20th century, we used peak numbers prior to eradication (see Table S1 for full details and sources). Typical body weights were taken from Harris and Yalden (2008) and TraitBank (Anonymous 2014a). Body weights and population estimates were combined to calculate national biomass. The percentage of occupied 10 km squares (the geographical range) was extracted from the National Biodiversity Network (Anonymous 2014b) between 1960 and 2013.

Additional variables included whether species were introduced or native (recent reintroductions were classed as introduced for this analysis; Harris et al. 1995, Battersby 2005) and species functional group (large and small herbivores, carnivores, insectivores, rodents and bats). The presence of a UK Biodiversity Action Plan (BAP; Anonymous 2014c) and status on the International Union for Conservation of Nature's Red List (Anonymous 2014d) were considered indicative of national and international threatened status and the requirement for conservation action.

Statistical comparisons were made between SHI and selected covariates in turn – native/introduced, functional group, BAP and Red List status. SHI was then used as the response variable in a general linear model (R version 3.0.0, www.r-project.org). Model variable selection was based on *a priori* predictions (see Table S1) and data exploration. Predictors included national biomass, population size and geographical range, along with functional group, introduced/native, BAP and Red List status. Continuous variables were transformed (log + 1) before analysis. We repeated the analysis using the total number of papers and the mean number of citations as response variables.

## RESULTS

### SHI calculation

The initial WoS extraction produced 7176 papers, many of which related to captive animal studies or were conducted outside Great Britain. The refined database consisted of 2875 references based on 2305 publications (some referred to more than one species), which attracted 49163 citations with an overall *h*-index of 87 (see Fig. S1 for numbers of papers per year).

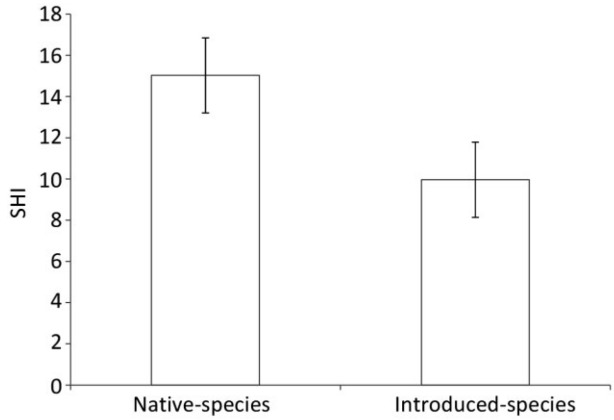


**Fig. 1.** Mean species *h*-index (SHI) of native ($n = 42$) and introduced ($n = 25$) terrestrial mammals; each bar represents the mean value of SHI, and the error bars show ±1 standard error. The difference between the means of the two groups is statistically significant ($F = 7.575$, $P < 0.01$).

SHI (Table 1) ranged from 0 to 54; the total number of papers and the mean number of citations are also shown. SHI was highly correlated with both of the other publication metrics (total number of papers: Pearson's coefficient = 0.931, $P < 0.001$; mean number of citations: 0.530, $P < 0.001$).

### The effect of covariates on SHI

In single-variable comparisons, native species had significantly higher SHI than introduced species (Fig. 1, $F = 5.24$, $P < 0.05$). There was no significant relationship between the SHI of introduced species and the number of years since their introduction ($T = 0.644$, $P = 0.526$), and between 1973 and 2014, new papers on established introduced species appeared at only 59% of the rate associated with native species (Fig. S2). SHI did not differ significantly among functional groups ($F = 1.112$, $P = 0.363$). SHI was not significantly associated with BAP ($F = 1.71$, $P = 0.196$) or red-list status ($F = 0.005$, $P = 0.942$). Many of these patterns were repeated when the alternative metrics were tested (see Table S2 for details).

Population size and geographical range were highly correlated (Pearson's coefficient = 0.711, $P < 0.001$) and interchangeable in the model. Using population size as a covariate, the best-fit model for SHI contained two significant variables – species population size ($T$ value = 5.727, $P < 0.001$) and functional group (ANOVA between models with and without this variable were significantly different, $P < 0.005$). Introduced status was close to significance,

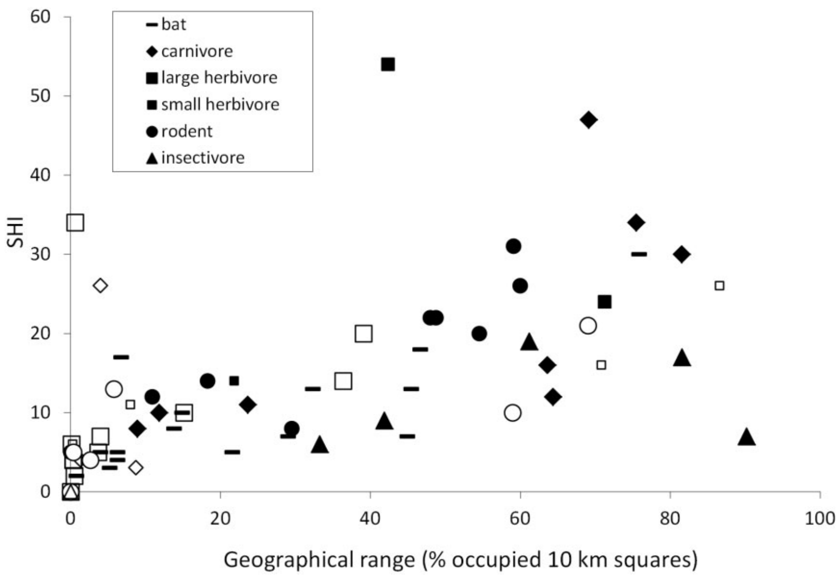


**Fig. 2.** The size of a species' national geographical range (percentage of occupied 10 km squares) plotted against species *h*-index (SHI); different functional groups are identified by different symbols. Closed symbols indicate native species, and open symbols introduced species.

introduced species having lower SHI than native species ($T = -1.972$, $P = 0.0537$; Fig. 2, Appendix S1a). The ranking of functional groups was large herbivores > small herbivores > carnivores > rodents > bats > insectivores. Body weight was not included in the final model as it was confounded by functional group ($F = 8.40$, $P < 0.001$). The output of the model using geographical range was similar (Appendix S1d).

The pattern of results was repeated with total number of papers and mean number of citations as the response variables: population size/geographical range (both number of papers and number of citations $P < 0.001$) and functional group (population size and geographical range models: total number of papers $P < 0.001$, mean number of citations $P < 0.005$) and introduced status (for mean number of citations using the population model $P < 0.05$; Appendix S1b,c,e,f) were significant.

## DISCUSSION

Scientific interest in a species is a composite measure. It reflects species' attractiveness to researchers, ease of study, the importance of the questions, the species' societal value, associated damage or risks, funding availability, the number and contribution of individual scientists, journal profiles, and public interest in the results. We cannot separate these, but differences in SHI show their cumulative effect. The most studied species were native, with large population size and were most likely to be large herbivores or carnivores.

Native species had higher SHI than introduced species. SHI was not associated with the level of national or international conservation concern. SHI was best predicted by the extent of a species' national geographical range or national population size, and by functional group; large herbivores and carnivores had relatively high SHI.

Large, numerous and widely distributed species may preferentially attract study. Their size and abundance may facilitate effective study and make them available to more researchers. They may also have greater impacts and potential conflicts with human interests. Three of the most intensively studied mammalian species (red deer *Cervus elaphus*, badger *Meles meles* and red fox *Vulpes vulpes*) may be in conflict with humans and have economic impacts (Anonymous 2010), although there is no consensus on the resolution of conflict. Introduced species had lower SHI, and this was not related to the length of time since introduction. Given the high and increasing impact of invasive species on ecosystems (Manchester & Bullock 2001, Simberloff et al. 2013), this was surprising. The lack of relationship between SHI and conservation status may reflect the difficulty of studying scarce or declining species and the fact that reports describing conservation actions may not appear in the scientific literature. It also raises questions about the strength of the evidence base underpinning some conservation actions.

This is the first use of *h*-index to measure scientific publication impact for individual species. Unlike the total number of papers and mean number of citations, per species, it is not influenced by the size of the 'tail' of less cited papers on a species (Hirsch 2005). Here, SHI was positively correlated to the two other metrics used, but this may be less likely if searches are effort based, or if search engines are used in which the probability of identification is linked to citation number (Bar-Ilan 2008). We suggest that SHI provides a more reliable quantitative method to compare the volume and impact of publications than numbers of papers or numbers of citations.

Comparison of species publication metrics provides a novel method of assessing the profile of species in a geographic region. Such an approach can help us to assess the effect of human choices and value judgements on the strength of the evidence base, guide future research decisions and inform priorities for future funding.

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## SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

**Table S1.** Description of covariates with sources.
**Table S2.** Results of simple statistical comparisons between categorical variables and each of the three publication metrics.
**Fig. S1.** Numbers of papers in the database for each year of publication (1973–2014).
**Fig. S2.** The cumulative number of papers published per native and introduced species.
**Appendix S1.** Output from the best fit general linear model for each publication metric. Six tables (a–f) present best fit general linear models for each publication metric; species *h*-index (SHI); total number of papers and mean number of citations per species; these repeated for models using either population size or geographical range as covariates.