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Original Investigation

# Trends in small mammals derived from owl pellet data using occupancy modelling

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ABSTRACT

The EU Habitats Directive prescribes the monitoring of several small mammals on a national scale. A cost-effective way of monitoring these species is by using owl pellet data. Unfortunately, owl pellet data suffer from several methodological difficulties, all associated with the imperfect detection of the presence of prey species. Occupancy models can overcome the difficulties by taking detection into account, but they require temporal replicates. To supply these, we created replicates by splitting each pellet batch into two equal parts. A pellet batch consists of a number of pellets collected together in the field.

Here we show how occupancy models can be applied to derive trend estimates from owl pellet data using such half batches as temporal replicates. We justify this approach by showing that the results from occupancy models treating half batches as temporal replicates in a test dataset were similar to the results of treating individual pellets as temporal replicates.

The owl species and the number of prey individuals examined were included in the occupancy model applied to all data. We studied eleven small mammal species, two of which showed positive trends in occupancy. The confidence intervals of the trend estimates were satisfactorily small. Our methodological innovations reinforce the usefulness of pellet data for trend estimation in small mammals and increase the feasibility of large-scale monitoring of such species under the Habitats Directive.



## Introduction

The EU Habitats Directive prescribes that each member state must assess the population abundance trend of species of community interest per biogeographic zone (EC 2006). These species include a number of small mammals. In the Netherlands, for instance, the trend of Root vole *Microtus oeconomus arenicola* must be reported to the European Commission every six years, because this species is listed on Annexes II and IV of the Habitats Directive (http://forum.eionet.europa.eu). The Water shrew *Neomys fodiens* and Harvest mouse *Micromys minutus* are listed as typical species of several habitat types under the Habitats Directive in the Netherlands. This implies that their trend is taken into account while assessing the conservation status of particular habitat types (http://forum.eionet.europa.eu). *Micromys minutus* is widespread, but *Microtus oeconomus arenicola* and *Neomys fodiens* are scarce in the Netherlands (Broekhuizen et al. 1992).

Monitoring small mammals on a national scale is challenging however. When using standard survey techniques such as live traps, it requires substantial resources (Balčiauskienė 2005; Cornulier et al. 2013; McDonald et al. 2013). It is cheaper to derive trend estimates using unstandardized sighting records or so called ‘citizen science’ data (Schmeller et al. 2009). But this requires the availability of many sighting records, preferably recorded as an assemblage (van Strien et al. 2013). Unfortunately, there are relatively few sighting records of small mammals, because these species live hidden in the vegetation and below ground and many of them are night-active. A more promising dataset for inferring trends in these species is the use of owl pellets (McDonald et al. 2013). Owls are efficient samplers and even catch small mammal species that are hard to obtain with trapping efforts (Avenant 2005; Balčiauskienė 2005). They regurgitate the indigestible parts of prey, mostly mice, shrews and voles, as pellets. Volunteers collect batches of pellets, i.e., the bulk of pellets from owls in a site in a year (La Haye 1999). In the Netherlands, pellet batches mainly come from Barn owls *Tyto alba* and Long-eared owls *Asio otus*. Pellet batches can be informative about trends in prey species if they are collected over a number of years in a number of sites (McDonald et al. 2013). We examined the possibility of using pellet data for

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distribution trends, i.e., for trends in the number of occupied sites, as a proxy for the population abundance trends.

The use of owl pellet data for inferences on distribution trends is not straightforward because of imperfect detection. The probability that a prey species is in a pellet batch, given the animal's presence at the site, is less than one. Detection is likely to vary among sites depending on factors such as the abundance of the prey species (Korpimaki and Norrdahl 1991) and the food preference of the owl species involved. Barn owls tend to be food generalists, but they undersample woodland rodents (Yom-Tov and Wool 1997; Torre et al. 2004) while Long-eared owls strongly select against shrew species as prey (Love 2009). Furthermore, the sample size of the pellet batches examined affects the detection of species. A standard practice is to examine pellets from a batch until 150 prey individuals are identified (La Haye 1999). However, it is not always possible to yield a batch of pellets that contains so many prey.

Imperfect detection may hamper the assessment of reliable trends in distribution and should be taken into account at every opportunity (MacKenzie et al. 2006). This is especially true if detection probability changes over time. This can easily happen in pellet data, because the detection of a species depends on the abundance of other prey species (Bernard et al. 2010). A species that becomes more abundant over the years will be caught more often by a predator (Korpimaki and Norrdahl 1991). Consequently, other prey species show up less often in the pellet batches, which may be mistaken for declines.

Some authors have included sample size in their analysis of pellet data (e.g., Torre et al. 2004), but few make efforts to overcome the detection difficulties in this type of data. Here we propose to analyze pellet data in an occupancy modeling framework (MacKenzie et al. 2006). By accounting for differences in detection, occupancy models estimate the 'true' proportion of sites where a species occurs. These models enable us to correct for differences in detection due to the different owl species and to the different numbers of prey individuals examined. Also, systematic changes in the detection of a species provoked by changes in the abundance of other species are taken into account, though implicitly. In an occupancy model, a higher share of a prey species in pellet batches leads to a lower detection of other prey species but not to a higher occupancy.

Occupancy models require detection/non-detection data from temporal replicates arranged in so-called detection histories per site in the season, such as '01' if the study species was detected in the second replicate, but not in the first replicate. For a multiple year study, a full site detection history may contain something like 01-11-11-11-00 etc. The frequency of the detection histories over many sites provides information about detection probability (MacKenzie et al. 2006). Unfortunately, the application of temporal replicates in pellet data is not straightforward. There are several ways to define temporal replicates in pellet data:

(i) Entire batches. However there are few replicates of batches available, mainly those from different owls in the same site.
(ii) Separate pellets. These form the natural temporal replicates in pellet data as each pellet is the result of catches of several prey during a night or a part of the night. However, there are mainly records from the bulk results available and not many per-pellet data.
(iii) Half batches. By splitting the entire batch data afterwards into two equal parts, two replicates can be created out of each batch. This generates sufficient temporal replicates to apply occupancy models to all available pellet data. These replicates are artificial, yet we believe this approach is defendable.

In this paper we show how occupancy models can be applied to derive trend estimates from owl pellet data by using half batches as temporal replicates. To test whether our 'half batches' approach is justified, we used a second, smaller dataset for which we had species records per separate pellet. We compared the annual occupancy estimates based on treating half batches as temporal replicates with those from treating pellets as replicates. Then we applied occupancy models to all survey data and assessed trends in occupancy for eleven small mammal species in the Netherlands.

**Table 1**
Characteristics of the two datasets analysed.

| | Survey data | Test data |
|---|---|---|
| No. of pellet batches | 7654 | 184 |
| Period | 1995–2012 | 2004–2013 |
| Predator species | Mainly Barn owl (82%) | Only Barn owl |
| Geographical coverage | Entire country (Fig. 1) | Biased to north and east Netherlands |
| No. of $1 \times 1\,km^2$ sites | 3185 | 165 |
| No. of prey items | 1,006,528 | 15,620 |
| Mean no. prey/batch | 130.8 | 90.6 |
| Replicate description | Half batch + owl species | Pellet or half batch |
| Mean no. of replicates | 2.3 | 25.9 (pellet) or 2 (half batch) |
| Mean no. of prey items/replicate | 65.4 | 3.5 (pellet) or 45.3 (half batch) |

## Material and methods

### *Study species*

We assessed the trend in the Netherlands for 11 mammal species for which we had sufficient data, i.e., from more than a few hundred sites (McKann et al. 2013): Pygmy shrew *Sorex minutus*, Water shrew *Neomys fodiens*, Greater white-toothed shrew *Crocidura russula*, Bank vole *Myodes glareolus*, Common pine vole *Microtus subterraneus*, Common vole *Microtus arvalis*, Field vole *Microtus agrestis*, Root vole *Microtus oeconomus arenicola*, Harvest mouse *Micromys minutus* and Wood mouse *Apodemus sylvaticus*. Common shrew *Sorex araneus* and Millet's shrew *S. coronatus* were hard to distinguish and were treated as one species *Sorex araneus/coronatus*.

### *Survey data*

We used $1 \times 1\,km^2$ as the definition of a site where pellets were collected. These sites were not selected by using a formal sampling design, but by taking the opportunity to collect pellet data from all over the country (Fig. 1). This poses the risk of site-selection bias, giving biased trend results (Yoccoz et al. 2001). To reduce this bias, we conditioned the analysis to historic sites, i.e., sites where a species had been recorded at least once in the available time series data (Kéry et al. 2010). The survey data consisted of species records from more than 7,000 pellet batches collected between 1995 and 2012 containing over a million prey individuals (Table 1). The annual number of batches grew from about 200 in the first years to about 500 in later years. Batches came mainly from Barn owls (82%), and were collected in and near their nests mostly after the breeding season. The batches of the second most important predator, the Long-eared owl (13%), were collected under winter roost trees. The remaining 5 percent of batches came from other birds of prey such as the Tawny owl *Strix aluco*.

The batches were collected at more than 3,000 $1 \times 1\,km^2$ sites, but 55 percent of these sites were examined for only one year (Fig. 1). Consequently, for many year-site combinations data is missing. This was also because Barn owls were absent in some years. Pellet batches were examined by volunteers who determined the number of individuals of each prey species per batch.