ABSTRACT: Difficulties in investigating shrews in the wild in winter, especially in trapping them and keeping them alive during live-trapping studies, have been the main reason for serious deficiencies in our knowledge of their ecology. We developed a live-trapping protocol which allowed us to maximise capture rates and minimise mortality of shrews. We used wooden box traps with a nest-chamber, which we set in plywood 'chimneys' with removable roofs. Chimneys facilitated suitable positioning of traps and protected them from being blocked by snow. This resulted in a high trappability (up to 20.2 shrews and 8.2 voles per 1000 trap hours), a large proportion of recaptures (most shrews were recaptured, often repeatedly) and a very low mortality rate (<0.09 shrews and 0 rodents per 1000 trap hours) despite sub-zero temperatures and deep snow cover. This allowed us to pursue an intensive live-trapping study, using the CMR-method, of shrews wintering in the Narewka river valley (north-east Poland). Because of the high trappability and minimal mortality, the presented protocol can be recommended to study winter ecology and conservation biology of such fragile and strictly protected small mammals as shrews.

KEY WORDS: new method, trappability, winter trapping, winter ecology, shrews, voles
Several studies have pioneered the use of shelters to protect traps from snow. Soper (1942) instructed how to set traps under spruce bough cover, under blocks of frozen snow, between two logs or inside hollow logs, but he was interested in an increase of winter snap-trapping to collect more dead specimens for museum collections. Simple wooden shelters for traps were made by Iverson and Turner (1969) and Jannett (1984). Merritt (1995) used lengths of plastic pipe cut longitudinally to cover the traps and Schmid (1984) used inverted plastic waste-bins. Others have constructed rectangular or cylindrical ‘chimneys’ of wood or roofing felt placed vertically to exclude snow, at the bottom of which is placed a trap (Pruitt 1959, Merritt and Merritt 1978, Merritt 1982, 1984, Penny and Pruitt 1984). Keeping small mammals alive in traps for mark-recapture studies presents particular problems, especially for shrews (e.g. Yunger et al. 1992). Trap design, provision of appropriate food and bedding, and trap inspection regimes are all critical to their survival. Various types of live traps have been used in winter studies (see Schmid 1984 for examples) with different degrees of success.

Aspects of shrew winter ecology have been studied in winter in southern and western Europe (e.g. Croin Michielsen 1966, Churchfield 1984, Castién and Gosálbez 1999), but winters are relatively mild there. We needed to study the winter survival strategies of soricine shrews and the functional basis of Dehnel’s effect (Dehnel 1949, Mezhzherin 1964, Pucek 1970) in northeastern Poland, i.e. in the area with winter temperatures regularly falling below –10°C, frozen soils and snow cover for 3 months. This has necessitated the development of a live-trapping protocol that maximises captures and survival, and meets ethical demands about the treatment of these tiny mammals. Details of our methodology with illustrative results are provided here.

Fig 1. Structure and dimensions (in cm) of (A) chimney with removable roof and (B) nest-box trap made of pine or spruce wood.
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We chose to use ‘chimneys’ to protect traps from snow and facilitate their operation, coupled with specially modified box traps which we have trialled very effectively over the course of five winter live-trapping sessions. Protective boxes or ‘chimneys’ were made from plywood treated with waterproofing paint to prevent water-logging. Each chimney measured 30 × 31 cm and 50 cm high and was supplied with a removable lid (roof) to allow inspection of the interior, but no base. Gaps were cut into the walls at the base of the chimney to allow access to small mammals from the surrounding litter layer (Fig. 1A).

The chimney walls were attached to each other on three sides by strips of tough plastic tape stapled at three points along each wall, providing some flexibility during assembly and disassembly. On the fourth side of the chimney, the walls were attached using three strips of ‘velcro’ stapled to the wood (Fig. 1A). Disengagement of the velcro allowed the chimneys to be collapsed and folded flat for carriage and storage, and rapid assembly. VELcro proved resistant to water and retained its adhesive capacity throughout. The cost of one chimney was 90 zł (i.e. about 21 €).

During deployment, a plug of snow equal to the base area of the chimney was removed from the trapping site with a spade, exposing the ground surface/litter layer. The assembled chimney was placed in the resulting gap with its base flush with the ground surface. Care was taken that the access gaps at the base were not blocked by snow or vegetation. Snow was then packed lightly around the outer walls of the chimney to restore a continuous cover and protect small mammals moving through the subnivean space (Fig. 2).

Inside each chimney, on the ground surface, were placed two wooden box traps of modified ‘dziekanówka’ type and size of 21 × 8 × 9.5 cm (Fig. 1B). These were designed to include a small nest chamber at the far end of the trap (and therefore called ‘nest-box traps’), reached by small mammals through a hole of 25 mm diameter so that bedding and food could be supplied without interfering with the trapping mechanism. Traps could be opened from either end by means of a sliding metal strip. Nest chambers were provided with polartec fleece as insulating bedding and food in the form of fly (Calliphora sp.) pupae and minced beef. The cost of one nest-box trap was 40 zł (i.e. about 9.50 €).

The study area comprised a sedge-swamp in the valley of the Narewka river, close to Białowieża village in north-east Poland. This region is characterised by cold winters with January temperatures regularly falling below −10°C (often below −20°C), with frozen soils and snow cover for 3 months (pers. obs.). The vegetation on the study plot was dominated by reeds, grasses and sedges (Phragmites communis, Phalaris arundinacea, Bromus inermis, Carex approprinquata and C. rostrata) plus a diversity of forbs (mostly Urtica dioica, Filipendula ulmata and Angelica sylvestris). Scattered trees and bushes (Alnus glutinosa, Salix spp. and Betula spp.) were also present. The vegetation profile comprised mostly dense

![Diagram and plan of a chimney installed with nest-box traps set inside, showing location of the entrance in relation to the snow, litter and soil layers. (B) View of a chimney installed in deep snow (Photo of S. von Merten).](image-url)
tussocks with additional ground cover of mosses and a litter layer of dried grasses.

In 2006, 50 chimneys were placed in a grid with intervals of 5 m (five rows of 10 trap points). Twenty chimneys contained two wooden box traps, 20 chimneys contained one box trap and one nest-box trap, and 10 chimneys contained one plastic pitfall (25 cm deep and 20 cm in diameter). Additionally, 20 nest-box traps were set singly (also with intervals of 5 m) along other lines without chimneys. Here, box traps were dug into the sides of grass/reed tussocks and protected against further snowfall by metal sheets 250 mm × 250 mm placed as flat roofs over the top of the trap. This gave a total of 70 trap points. All three types of traps were provided with the above mentioned bait and bedding (though only little amount of polartec fleece could be placed in box traps without blocking the closing mechanism).

In winters 2007–2009, two nest-box traps were set in each chimney. In 2007 and 2008, 100 chimneys were placed in the same study area in a grid with intervals of 5 m, giving a total of 100 trap points (10 rows of 10 trap points). Additional chimneys (17 in 2007 and 5 in 2008) were placed at 10 m intervals along the outer edges of the trapping grid, and approximately 10 m from the main grid. The grid and the outer lines covered an area of 70 × 70 m (4900 m²). In 2009, 60 chimneys within the grid (i.e. 6 rows) and 5 chimneys along an outer line were set.

In winter 2006, we compared the effectiveness of the nest-box trap prototypes with standard box traps and plastic pitfalls. Trapping performed in winters 2007–2009 allowed us further assessment of the trapability and mortality of small mammals trapped with nest-box traps set in chimneys.

All traps were open either 24 hr day and night (when data on shrew circadian activity were collected) or during evening and night hours. In both situations, they were checked at 2–3 hour intervals. Trapping was carried out during January and February, and lasted from 8 days in 2007 to 13 days in 2008. During trapping, ambient temperatures under snow (within the leaf litter layer) were measured at midday (once per trapping session) at five points within the study area, using electronic temperature probes. Maximum and minimum air temperatures were recorded daily, using maximum-minimum capillary thermometer. Depth of snow cover at the study site was also noted.

Most trapped animals were released at the place of capture immediately after recording data about them, but some animals were taken to the laboratory for further experiments (Taylor et al. 2010 and papers in prep.). We have obtained permissions (no. DOPog-4201-04-126/05/kl of 7 July 2005 and no. DLOPiK-op/ogiz-4200/IV-7/1331/08/aj of 15 February 2008) from the Minister of Environment for our capturing and temporary keeping of the protected shrews, as well as acceptances from the Local Ethical Commissions for Experiments with Animals in Białystok (no. 2005/46 of 21 December 2005) and Poznań (no. 10/2007 of 22 January 2007) for our experimental methods.

There was a thick (up to 30–42 cm) covering of snow in winters 2006–2007 and below-zero ambient temperatures (minimum –4.9 and –9.0°C, respectively), even on the ground surface beneath the snow (about –1.0°C) during the sampling sessions. Temperatures in winters 2008–2009 were higher (minimum 0.7 and –0.7°C) but, with lacking or little snow cover (see Churchfield et al. 2012), small mammals could also suffer from heat loss. Five species of small mammals were captured, including three species of shrews. Common shrews Sorex araneus were captured more frequently than any other species and bank voles Myodes glareolus were more numerous than root voles Microtus oeconomus (Table 1).

In 2006, the rate of capture (standardised for number of traps and hours of trapping as trappability per 1000 trap hours) tended to be higher when nest-box traps were used and traps were set in chimneys. For example, trappability of S. araneus was six times higher in nest-box traps set in chimneys than in nest-box traps set without chimneys (Table 1). These trappabilities came from captures of 16 and 4 individuals of S. araneus, respectively (chi-square-test: χ² = 7.20, df = 1, \(P = 0.007\); the difference for individuals and not the total number of captures was tested to prevent pseudoreplication; no individual was caught in both types of traps). Interestingly, pitfalls, that are known to be very effective in
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Capturing shrews in summer, appeared to be completely ineffective in winter.

Survival rates of all small mammals captured in nest-box traps set in chimneys were very high. For the whole period 2006–2009, the only casualties were three *S. araneus* and one *S. minutus*, despite the large numbers of trapping hours (48 670) and captures of small mammals (513 in total). For comparison, only 5490 trap hours of trapping with box traps without nest chamber resulted also in three dead *S. araneus* (Table 1). Thus, the mortality of this species for capturing in nest-box traps was 6–9 times lower than for capturing in box traps without nest. Recapture rate for both box trap types set in chimneys was high. In particular, most shrews were recaptured, and some of them repeatedly (even 20 times).

The design of our trapping chimneys made them easy to operate and resulted in high capture rate of small mammals, particularly shrews. The flat-pack style of design and easy assembly allowed them to be installed rapidly. In order to avoid damage from human, wild boar or beavers (all occasionally entering our study plot) we chose not to install them before the snows came (as had Pruitt 1959), but instead to install them when and where needed. This practice also preserved them for future use (since they were constructed only of plywood).

The dimensions of the chimneys were such that it was possible to see if traps had been sprung without handling them and, if sprung, traps were within arm’s reach. Other designs of chimneys have been taller and required additional aids to reach the traps, on account of greater snow depths (Pruitt 1959, Merritt and Merritt 1978). While snow did occasionally cover our chimneys, frequent trap inspections allowed us to brush excess snow from the lids so that they could be found easily. Freezing of the trap mechanism is a frequent problem in winter, especially when traps are exposed to snow and wet. This was rarely a problem in the protective environment of the chimneys.

Wooden box traps are preferable to metal traps for minimising mortality of captures, and survival was enhanced by provision of

Table 1. Numbers of captures and dead captures as well as trappability and mortality of small mammals captured during four winters using three types of live-traps set in chimneys and without chimneys.

<table>
<thead>
<tr>
<th>Parameter or Winter</th>
<th>Total for</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nest-box traps set in chimneys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of traps</td>
<td>20</td>
<td>10</td>
<td>60</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Number of trap hours</td>
<td>1830</td>
<td>915</td>
<td>5490</td>
<td>1830</td>
<td></td>
</tr>
<tr>
<td>Number of captures (dead captures in brackets):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sorex araneus</em></td>
<td>6</td>
<td>0</td>
<td>74 (3)</td>
<td>37</td>
<td>52 (1)</td>
</tr>
<tr>
<td><em>Sorex minutus</em></td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><em>Neomys fodiens</em></td>
<td>1</td>
<td>0</td>
<td>13</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><em>Myodes glareolus</em></td>
<td>11</td>
<td>0</td>
<td>30</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td><em>Microtus oeconomus</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Trappability (mortality in brackets) per 1000 trap hours:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sorex araneus</em></td>
<td>3.3</td>
<td>0</td>
<td>13.5 (0.55)</td>
<td>20.2</td>
<td>3.3 (0.06)</td>
</tr>
<tr>
<td><em>Sorex minutus</em></td>
<td>1.1</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td><em>Neomys fodiens</em></td>
<td>0.5</td>
<td>0</td>
<td>2.4</td>
<td>1.6</td>
<td>0</td>
</tr>
<tr>
<td><em>Myodes glareolus</em></td>
<td>6.0</td>
<td>0</td>
<td>5.5</td>
<td>8.2</td>
<td>0</td>
</tr>
<tr>
<td><em>Microtus oeconomus</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
</tr>
</tbody>
</table>
insulating bedding and food for the shrews. Despite this precaution, frequent trap checking is needed to further reduce mortality, especially when ambient temperatures plummet. In our study, trap visits were made every 2–3 hours. The result was a total mortality of only 1.7% of all shrew captures and 0% of rodents. Shrews may have survived for longer in traps but we were seeking information on 24-hour activity patterns of shrews, requiring frequent and regular checks.

To conclude, our protocol of winter trapping chimneys and traps provided with nest-boxes for bedding and food resulted in many captures of small mammals, especially shrews, with minimal mortality rate. This allowed us to pursue an intensive live-trapping programme, using the CMR-method, for the collection of new information about foraging habits, changes in body mass, population dynamics, space use, and circadian activity of shrews wintering in north-eastern Poland (Taylor et al. 2010, Rychlik et al. 2011, Churchfield et al. 2012). Therefore, we recommend the present protocol to study winter ecology and conservation biology of such fragile small mammals as shrews, which are strictly protected in Poland and many other countries.

ACKNOWLEDGEMENTS: We are very grateful to J. Chilecki (the producer of chimneys and traps; pulapki@op.pl), A. Arasim, B. Lewończuk (technicians), I. Both, W. Hütz, P. Kreitschmann, D. Matuszak, S. von Merten, E. van Nes, R. M. Ricardo Nunes, A. M. Guimaraes Nuno, J. Tapisso, and C. van den Tempel (students of different universities) for field and technical assistance. This study was supported by the grant no. N304 094 31/3385 of the Polish Ministry of Science & Higher Education and the budget of the Mammal Research Institute of the Polish Academy of Sciences in Białowieża.

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Received after revision April 2012