The distribution and relative numbers in barn owl pellets of the bicoloured white-toothed shrew (*Crocidura leucodon*) in Zeeuws-Vlaanderen; a meta-analysis

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Abstract: Changes in the distribution of the bicoloured white-toothed shrew (*Crocidura leucodon*) in Zeeuws-Vlaanderen (Province of Zeeland, the Netherlands) are described, going back to the first catch of a specimen in 1937. An analysis is made of the relative numbers of this species found in the pellets of barn owls (*Tyto alba*) since 1943. Two white-toothed shrew species, the bicoloured and the greater white-toothed shrew (*Crocidura russula*) are present in this region. The distribution of both species is evaluated with special reference to their simultaneous presence in trap localities and in barn-owl pellets. In four periods (before 1950, 1950-1969, 1970-1988 and 1989-2008) the number of occupied 5x5 km grid cells of bicoloured white-toothed shrew has increased from 2 (first period) to 36 (last period). The increase in their occurrence in 1x1 km blocks (to 78 in the last period) has been almost exponential. Between 1989 and 2008 trappings have been made of bicoloured white-toothed shrew in the area between the Kanaal van Gent naar Terneuzen and the Braakman, where the species has not previously been observed. The percentage of remains of the species found in barn owl pellets between 1943 and 2008 has also shown an increase. Until 1990 this proportion remained far below 2%; after 1995, the percentages were well above 2%, except for 1998 and 2004. Almost all the separate lots of pellets contained both bicoloured and greater white-toothed shrew, meaning that both species are present within the home range of hunting barn owls. The trapping results varied from 0 to more then 2 percent. At the 65 locations where *Crocidura* species were captured, 32 contained only bicoloured white-toothed shrew and 31 contained only greater white-toothed shrew. At two locations both species appeared to be present. The data from Zeeuws-Vlaanderen for 1964-1970 and 1987-2002 is compared to similar data from the bordering provinces in Belgian Vlaanderen. According to the criteria of Red List definitions, the change in the status of bicoloured white-toothed shrew in the Netherlands towards 'least concern' has been justified by the findings presented in this study.

Keywords: bicoloured white-toothed shrew, *Crocidura leucodon*, greater white-toothed shrew, *Crocidura russula*, barn owl pellets, interspecific competition, Zeeuws-Vlaanderen, the Netherlands.

Introduction

The improved status of the bicoloured white-toothed shrew (*Crocidura leucodon*) on the Red List of Mammals in the Netherlands from 'susceptible' in 1994 to 'low risk' (Zoogdiervereniging VZZ 2007) was expected by some insiders. But it surprised many members of the Dutch Mammal Society. One of the few ways to assess the presence of small mammals, such as the bicoloured white-toothed shrew, in a certain area and evaluating its rarity is by analysing barn owl (*Tyto alba*) pellets. Live-trapping is another method, but it is much more laborious to get enough specimens. Evaluating the first year of the Owl Pellet Monitoring Project, La Haye (1998) con-

cluded that it is feasible to track the trend of small mammals through the analysis of skull fragments in the pellets of barn owls, but some years later there still are statistical, methodological and biological flaws in this method (van Engeldorp Gastelaars 2001). In the case of the bicoloured white-toothed shrew, a lack of continuity in the availability of barn owl pellets has made it impossible to make a proper analysis of population trend developments in western and eastern Zeeuws-Vlaanderen and the interconnected north-eastern Overijssel and south-eastern Drenthe regions, the two regions in the Netherlands where the species is known to occur. Moreover, the sensitivity of this method appeared to be low (van Engeldorp Gastelaars 2001). Another problem is the interdependency of prey species: an increase in the ratios of specific prey species in barn owl pellets automatically induces a decrease in one or more other prey species and vice versa. This relation is evident for prey species that can be regarded as staple food, e.g. comparing years with cyclic high and low densities of common vole (*Microtus arvalis*) and greater white-toothed shrew (*Crocidura russula*). However, this effect could not be demonstrated for species with low densities (van Engeldorp Gastelaars 2001).

The population of bicoloured white-toothed shrew in the northwest of Europe extends from Belgium into Zeeuws-Vlaanderen, with a (sub-)population in north-eastern Overijssel and south-eastern Drenthe and adjacent areas in Germany. This group is isolated from the main distribution area in Europe by a distance of more than 150 km (Krapp 1999). Snaak (1999) has extensively described barn owl pellet analysis and trapping results for bicoloured white-toothed shrew in Drenthe and Overijssel. He also included the neighbouring German county of Bentheim in his analyses. He extended his study from 1999 to 2007 (Snaak 2008) and during this period identified 53 5x5 km grid cells with evidence of bicoloured white-toothed shrew presence. The Red List evaluation of the species for the Netherlands needs to take into account the status of these two geographically separate populations. The available population descriptions for Zeeuws-Vlaanderen are also compared with those from the adjacent part of Belgium.

Kruseman (1937) caught the first bicoloured white-toothed shrew found in Zeeuws-Vlaanderen in 1937, near Terneuzen. In 1943, Schreuder (1945) identified the species among 85 mammal preys found in one lot of barn owl pellets collected in Axel, Zeeuws-Vlaanderen. Mulder (1969) mentions three locations where bicoloured white-toothed shrew was found in barn owl pellets: Hoofdplaat (1 specimen), Ossenisse (2 specimens), and Kloosterzande (1 specimen); besides these identified bicoloured white-toothed shrew some *Crocidura* spec. were established: Zaamslag (4 specimens), Ossenisse (17 specimens) and Kloosterzande (14 specimens). In 1965 there was an (unconfirmed) capture of three specimens near the Zevenaarhaven at Terneuzen and Buise & Sponselee (1978) report the capture in 1972 of a female bicoloured white-toothed shrew near Terhole. Van Netten (1976) mentions two locations where bicoloured white-toothed shrew was found in barn owl pellets: Koewacht (1 specimen) and Terneuzen (13 specimens), and from Koewacht also 6 *Crocidura* spec. More inventories and captures have been described by 't Hart & Straetmans (1984) (7 specimens, 7 locations), Kapteyn (1988) (15 specimens, 5 locations) and Keijl (1995) (3 specimens, 2 locations). Buise (1984) mapped the locations (in five 5x5 km grid cells) of the 23 specimens found in barn owl pellets in the eastern part of Zeeuws-Vlaanderen. Hoekstra (1992), describing the distribution of the bicoloured white-toothed shrew in the Netherlands, mapped 20 occupied grid cells in Zeeuws-Vlaanderen; seven of these based on identification by finding or capture. Recently, four new 1x1 km blocks, and two new grid cells were added, based on finding specimens in barn owl pellet material collected in 1984 an 1985 in new locations (J.P. Bekker, unpub-

lished data). In addition, Luciën Boerjan (personal communication) has, with the help of members of the local natural history organisation *'t Duumpje*, analysed barn owl pellets, containing 43 lots with remains of bicoloured white-toothed shrew (excluding two *Crocidura* spec.) in the west of Zeeuws-Vlaanderen. These recent survey results suggest that the gaps in the distribution for the species in Zeeuws-Vlaanderen, as described by Dijkstra (1997) and also mentioned by van Engeldorp Gastelaars (2001), have been filled (Bekker 2007).

Population estimates, in general, are difficult to obtain. This is especially true for small mammals in low densities. Even so, data on the long term population trends of bicoloured white-toothed shrew are limited. Buise's analysis on terrestrial mammals in eastern Zeeuws-Vlaanderen (1984) mentions that about 0.5% of mammal remains found in barn owl pellet lots were those of bicoloured white-toothed shrew.

Schreuder (1945) mentions the result of analyses of barn owl pellets, collected in 1943 in Damme, in the Belgian Province of West-Vlaanderen: besides ten greater white-toothed shrews, no other *Crocidura* species were found among the remains of 26 small mammals. Between 1964 and 1970, Asselberg (1971) analysed barn owl pellets collected in Belgium, including the two provinces bordering Zeeuws-Vlaanderen, West-Vlaanderen and Oost-Vlaanderen. The proportion of bicoloured white-toothed shrew for these two provinces amounted 0.38% (15 specimens out of 3,940 vertebrates) and 0.61% (21 specimens out of 3,460 vertebrates) respectively of the mammal species found. Almost two decades later, Verkem (2003) revealed 201 specimens of the bicoloured white-toothed shrew from 1987 to 2002, in the five provinces of Vlaanderen; half of the data came from barn owl pellets and a considerable number from live trappings.

Crocidura species seem to be parapatric as a result of interspecific competition (Meylan 1967). In Westfalen (Germany), the bicoloured white-toothed shrew seems to live in cultivated areas without connections with human settlements (Vierhaus 1984). Frank (1984) captured this species near Oldenburg in human settlements before the greater white-toothed shrew entered the area. Recently (Kraft 2000) noticed a shift in the distribution of greater white-toothed shrew at the expense of the lesser white-toothed shrew (*Crocidura suaveolens*) in Bayern, Germany. Vogel et al. (2002), investigating range expansion of the greater white-toothed shrew in the lower part of the Rhone valley in Switzerland, found the bicoloured white-toothed shrew to be locally extinct along both banks over 18 (south) and 35 (north) km respectively.

Because both the bicoloured white-toothed shrew and greater white-toothed shrew are present in Zeeuws-Vlaanderen, the distribution of the latter is evaluated with special reference to its simultaneous presence in trap localities and in barn-owl pellet lots. Therefore the ratio of bicoloured white-toothed shrew / total *Crocidura* found in pellets is important. Buise (1984) already mentioned almost all pellet lots contain remnants of both species, which means that both are present within the home range of hunting barn owls. As the size of these home ranges are no more than ca. 925 ha (Bond et al. 2004), we can calculate that the (sub)populations of the white-toothed shrew species live, at maximum, within ca. 2 km of each other. A change in the ratio of bicoloured white-toothed shrew / total *Crocidura* in barn owl pellets will reflect the outcome of interspecific concurrence between the two white-toothed shrew species. On the other hand, the rate of co-occurrence of both species at one trapline locality will reflect the degree of parapatry at a lower level.

This paper presents the changes in the distribution of bicoloured white-toothed shrew in Zeeuws-Vlaanderen over four periods. The ratios of the two species in the pellets of the barn owl since 1989 shows an undulating pattern in the population of the bicoloured white-toothed shrew in Zeeuws-Vlaanderen

(Bekker 2010a) with no definitive indication of a long-term decline or incline. The changes in the relative numbers of this species in this region are described from 1943, the first year when lots of barn owls pellets were collected.

Material and methods

Geography

The study area, Zeeuws-Vlaanderen (Province of Zeeland, the Netherlands), stretches over 61 km from west to east and a maximum distance of 20 km from north to south. It lies south of the Westerschelde. Its southern border area with Belgium partly consists of sandy pleistocene soils, with relatively small-scale plots. The large clay polders, next to the Westerschelde, are relatively new and intersected by numerous creek-rests. Along the Westerschelde new dykes provide a solid demarcation between land and water. Older dykes separate the polders from each other. These dykes, made of clay or sandy soils, form the ecological backbone of this area. Many dykes are planted with poplar (mostly *Populus canadensis*), elm (*Ulmus x hollandica*) or willow (*Salix* spec.) and they are usually managed by extensive grazing (Jacobusse 2010).

Over the long west-eastern axis there are three main barriers that restrict the movement of small terrestrial mammals. To the west, the Braakman, formerly a creek running into, but now blocked off from, the Westerschelde, runs south to the Belgian border via the Isabellakanaal. In the centre, the Kanaal van Gent naar Terneuzen completely splits Zeeuws-Vlaanderen, with four bridges providing crossing points. To the east the Otheense Kreek forms a smaller barrier, stretching almost five kilometres inland from the Westerschelde. Zeeuws-Vlaanderen shares 97 km frontier with the Belgian province of Oost-Vlaanderen and the most western tip of Zeeuws-Vlaanderen shares a 13 km frontier with the province of West-Vlaanderen.

Barn owl pellets

Barn owl and tawny owl (*Strix aluco*) regularly take shrews, as shown by pellet-analysis. However, the tawny owl is rare in Zeeuws-Vlaanderen and pellets from this species have never been collected in this region. Although little owl (*Athene noctua*) sometimes takes shrews, the numbers involved are small. The other owl species found living in the area, long-eared owl (*Asio otus*) and short-eared owl (*Asio flammeus*) almost never take shrews (Mostert 1993). Up to now, in Zeeuws-Vlaanderen there have been no reports of remnants of bicoloured white-toothed shrews found in pellets other than barn owls. Barn owl pellets seem the best option for analysing the distribution and numbers of bicoloured white-toothed shrew. Barn owls often breed in barns in Zeeuws-Vlaanderen and have regularly been enticed to breed in human made nestboxes. This makes it relatively easy to collect their pellets. During the severe winter of 1962/63, the number of breeding barn owls in the Netherlands almost completely collapsed (Texeira 1979). Since then a slow recovery has been reported, both in the Netherlands and in Zeeuws-Vlaanderen. When close monitoring started in this region in 1985 there were four breeding pairs – which has risen gradually to a maximum of 74 in 2007 (M. Buise, personal communication).

The gathered lots of barn owl pellets over Zeeuws-Vlaanderen are unevenly distributed. There are also gaps in the continuity of lots collected from one locality. The density of the distribution, as well as the number of serial lots, is higher in the eastern part of Zeeuws-Vlaanderen.

Period categorisation

For the analysis the history of biogeography of bicoloured white-toothed shrew in Zeeuws-Vlaanderen has been divided into four periods: before 1950 (period 1), 1950-1969 (period 2), 1970-1988 (period 3) and 1989-2008

(period 4). These four periods are closely related to investigation activities and key publications: van Wijngaarden et al. (1971) covered the period to 1969 and Hoekstra (1992) described period 3. Although the periods are not exactly equal (- , 20 years, 18 years and 20 years), the time span is long enough to avoid misleading results arising from annual fluctuations in field vole years.

Based on the information described by the literature cited in the introduction, the catches have been related to the trapping effort and presented as ratio of used traps per night. The presence of bicoloured white-toothed shrew, measured for captures, finds and remains in owl pellets together, has been scored for each period in 1x1 km blocks (also visible in grid cells of 5x5 km). The number of occupied 5x5 km grid cells forms the basis for assessing trends in population at the national level. The number of occupied 1x1 km blocks gives a more detailed picture, often used for regional purposes.

Red List criteria

The IUCN does not provide quantitative criteria for the categories 'susceptible' or 'near threatened'. As a result the Dutch Mammal Society adopted criteria for the Netherlands, based on the Basisrapport voor de Rode Lijst Vogels (Zoogdiervereniging VZZ 2007). These adopted criteria for the categorie 'near threatened' are: 1. a decline in the population: a 20-30% reduction in the last ten years or last three generations; 2. area of occupancy fragmented: <2,000 km^2 and ≤10 locations or a continuing decline; 3. area of occupancy fragmented: <4,000 km^2 and ≤10 locations and a continuing decline; 4. population: <15,000 individuals and a decline of at least 10% in the last ten years or last three generations; 5. very small or restricted population: 1,000-1,500 individuals. We do not have any data on absolute numbers for the bicoloured white toothed shrew, but only have data on the (relative) population size and on the area of occupancy.

Statistical analysis

Spearman's rank correlation test was used to test for correlation of pairs of values (Boon 1979), with the upper and lower limits of the coefficients retrieved from tables compiled by Diem & Lentner (1968). χ^2 statistics were used to test differences in categorical data. For all tests, the significance level was set at $P<0.05$.

Results

Analysis of barn owl pellets

Table 1 summarises an account of all the barn owl pellet lots analysed by individuals, organisations or cited from literature references over the four periods. The figures from the first two periods are mainly based on the literature, and show 85 and 3,253 mammal preys respectively. In the third period the total number of analysed lots increased to 107, and the mammal prey items amount to 14,927. For this period the results consist of compiled information kept mainly by Luciën Boerjan (personal communication) for the western part of Zeeuws-Vlaanderen, by Marc Buise (personal communication) for the eastern part and partly by others. Several preserved lots from this period were analysed in the second half of the 1990s, by Kees Mostert and/or the author. The analysis of barn owl pellet lots for this last period is presented here for the first time. The total number of analysed lots in this period almost tripled to 293, while the total number of mammal prey items doubled to 29,791.

Distribution

Since the first period the distribution of bicoloured white-toothed shrew in Zeeland was restricted to south of the Westerschelde (figure 1). In the four periods (figure 1a-1d), the number of occupied 5x5 km grid cells increased from 2 (in the first period), to

Table 1. Account of the numbers of analysed barn owl pellet lots and the total mammal prey items in Zeeuws-Vlaanderen provided by individuals, organisations or published references; *: see reference list; **: referred to as the analyser of pellets in a special edition of *De Bosmuis 1969 7 (5): 1-20*, ***: referred to as the analyser of pellets in a special edition of *De Bosmuis 1976 14 (1): 1-20 and I-XVI*; #: Owl pellet analysing group of *'t Duumpje* consisting of core volunteers LB and AdZ together with HB, GvD, JJ, PS and HvdV (see 'Acknowledgements' for abbreviations); ##: VWG & ZWZ: members of the Field Study Group of the Dutch Mammal Society and members of the Zoogdierwerkgroep Zeeland, see 'Acknowledgements'. Period 1: before 1950; Period 2: 1950-1969; Period 3: 1970-1988; Period 4: 1989-2008.

Individual, organisation or published reference	Lots	Number of prey animals
Period 1		
* A. Schreuder 1945	1	85
Period 2		
** Arie Bijl	7	1,725
*** Jack Groefsema	1	232
** Mieke de Haan & Gerhard Glas	1	554
* W. Krommenhoek 1967	1	47
** Jaap Mulder & Mieke de Haan	1	378
** Eduard Osieck & Jaap de Vlas	1	174
** Jaap de Vlas	1	143
Period 3		
Jan Piet Bekker	5	1,146
Lucien Boerjan	14	2,466
*** Flip Bossenbroek	2	107
Marc Buise	15	3,529
*** Rob Bijlsma	1	288
Henk Castelijns & M. Ploegaart	1	129
*** Rudy van Diggelen	1	88
H. van Iwaarden	1	41
*** Reyer Kommer	1	7
J. Molenaar	8	1,021
Kees Mostert	20	2,861
Kees Mostert & Jan Piet Bekker	2	357
Luud Persijn	18	1,072
Arthur Schotman	8	547
Arthur Schotman & Lucien Boerjan	1	131
Wies Vonck	7	452
Rob van Westrienen	2	685
Period 4		
Jan Piet Bekker	250	26,292
Lucien Calle	2	21
Pepijn Calle	1	53
Arnoud van der Meulen	4	177
Kees Mostert	2	255
# Barn owl pellet analysing group of *'t Duumpje*	29	2,558
## VWG & ZWZ	5	435

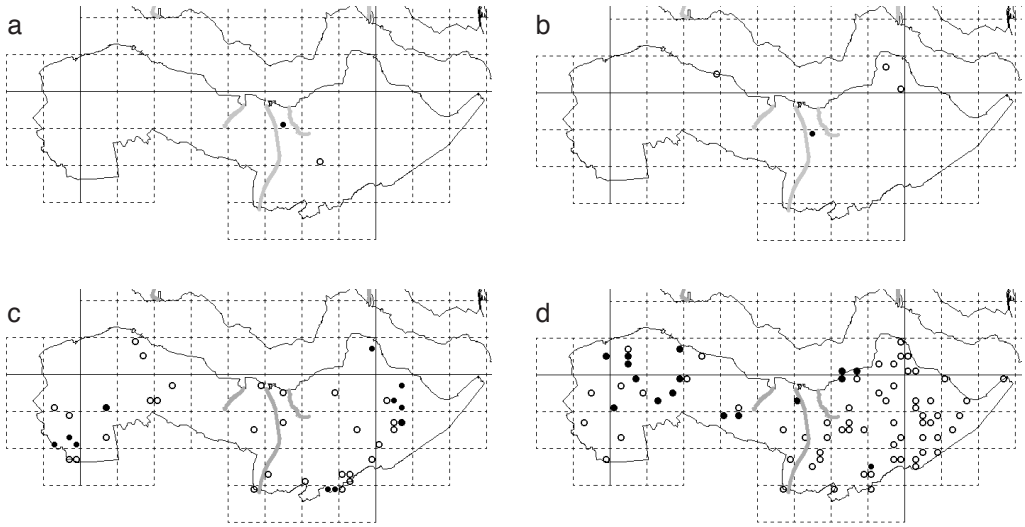

Figure 1. Distribution of bicoloured white-toothed shrew (*Crocidura leucodon*) in Zeeuws-Vlaanderen, the Netherlands. a: to 1950, b: 1951-1969, c: 1970-1988, d: 1989-2008; solid dots = catches, open circles = remains in barn owl pellets.

3 (period 2), 23 (period 3) and 36 (period 4). The increase in 1x1 km blocks is even more impressive: from 2 (in the first period), to 4 (period 2), 39 (period 3) and 78 (period 4). This is an almost exponential growth.

Until 1969 there appeared to be a distribution gap for bicoloured white-toothed shrew between the Kanaal van Gent naar Terneuzen and the Braakman (figure 1a and 1b). This seems to have been filled in during the period 1970-1988 (figure 1c). However, the open circles are based on analysis of barn owl pellets (figure 1c). During the period 1989-2008 bicoloured white-toothed shrew has only been captured at one location between these ecological barriers (figure 1d).

Population

Table 2 presents data on the numbers of bicoloured white-toothed shrew and mammalian preys in barn owl pellets for the four periods. A significant difference exists between periods 2 and 3, 2 and 4, and 3 and 4 ($P<0.001$). Comparisons with period 1 could not be made, because there were less than five expected observations for bicoloured white-toothed shrew and this figure is too small to meet the criteria for a χ^2 test.

The presence of bicoloured white-toothed shrew as a percentage of all mammal preys in barn owl pellets for each year are shown in figure 2. These percentages increased between 1943 and 2008 (Spearman rho: 0.79, $P<0.001$). Until 1990 the percentages remain far below 2, except for in 1973 and 1986, when the figures were 2.0 and 2.3 respectively. After 1995 the situation is quite different: all the percentages, except in 1998 and 2004 (1.9 and 1.4 respectively) were well above 2, even rising to 4.9, 4.8 and 4.8 in 2000, 1997 and 2001 respectively (figure 2).

Competition

Almost all the separate lots of pellets contained both bicoloured and greater white-toothed shrew, meaning both species are present within the home range of hunting barn owls. The percentages of bicoloured white-

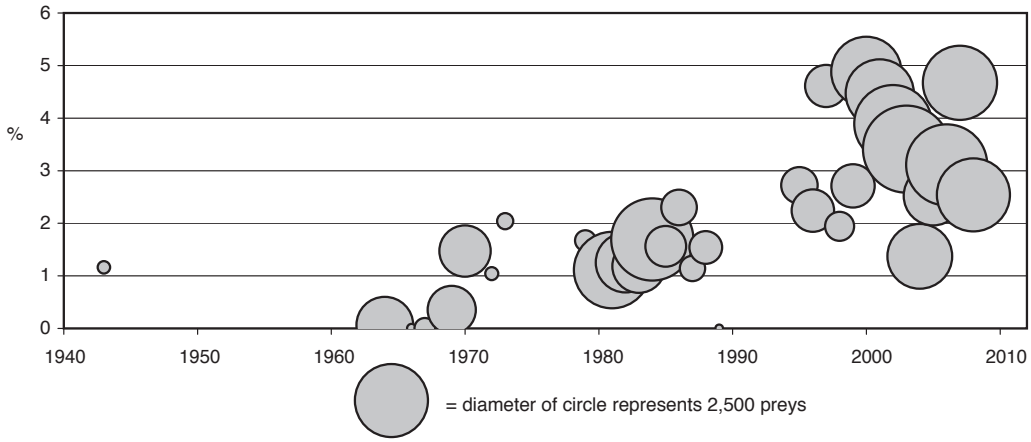

Figure 2. Percentages of bicoloured white-toothed shrew (*Crocidura leucodon*) found in all pellets of barn owl between 1943 and 2008 in Zeeuws-Vlaanderen; the diameter of the circles represents the total number of mammalian prey items in these pellets in each year.

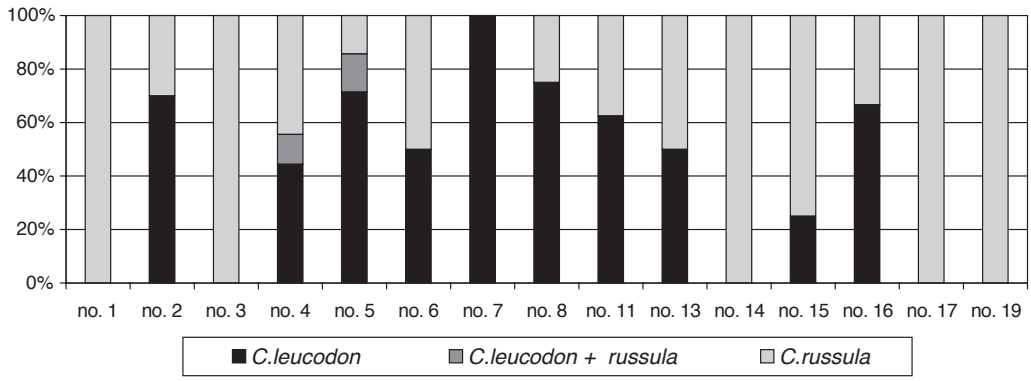

Figure 3. Studies describing trappings of *Crocidura* species: bicoloured white-toothed shrew (*Crocidura leucodon*) and / or greater white-toothed shrew (*Crocidura russula*) at the same spot (numbers on x-axis refer to table 4; studies without trapping *Crocidura* species have been omitted).

toothed shrew in barn owl pellets over the four periods vary from 0.24 to 14.29, while in greater white-toothed shrew these figures vary from 0.65 to 83.3 (table 3). The percentages of greater white-toothed shrew preys found in barn owl pellets increased from 1943 to 2008 (Spearman rho: 0.37, $P<0.001$), but at a lesser rate than bicoloured white-toothed shrew. This difference is also expressed in the ratio of bicoloured white-toothed shrew to all *Crocidura* between 1943 and 2008 (Spearman rho: 0.59).

The trapping result, as ratio of the number of successful trappings of bicoloured white-toothed shrew to trapping effort (number of traps per night), varies from 0 to more than 2 percent. The total number of trapped specimens was rather low (table 4). At the 65 locations where *Crocidura* have been caught, 32 exclusively contain bicoloured white-toothed shrew and 31 greater white-toothed shrew exclusively. Both species appeared to be present at two locations (figure 3). These species evidently show a parapatric occurence at the trap location sites ($P< 0.001$).

Table 2. Distribution of bicoloured white-toothed shrew (*Crocidura leucodon*) and mammal preys in barn owl pellets, by period; χ^2 test between periods: * $P<0.001$, # $P<0.001$, $ $P<0.001$ (definition of periods: see table 1).

	Crocidura leucodon in all lots	Mammal preys
Period 1	1	85
Period 2 (*, #)	5	3,253
Period 3 (*, $)	216	14,927
Period 4 (#, $)	1,056	29,791
Total	1,278	48,056

Comparison with the Belgian border area

This section adjusts some of the data and the periods from Zeeuws-Vlaanderen, in order to make a proper comparison possible with the two Belgium provinces, bordering Zeeuws-Vlaanderen, West-Vlaanderen and Oost-Vlaanderen.

In the period 1964-1970 4,242 vertebrata were collected from barn owl pellets in Zeeuws-Vlaanderen. They contained the remains of 13 (0.31%) specimens of bicoloured white-toothed shrew. An equivalent analysis over the same period for West-Vlaanderen and Oost-Vlaanderen gave results of 0.38% (15 specimens out of 3,940 vertebrates) and 0.61% (21 specimens out of a total number of 3,460 vertebrates) (Asselberg 1971).

Verkem (2003) compared the percentages of the number of grid cells where specimens of bicoloured white-toothed shrew were found in barn owl pellets between 1987 and 2002, using Asselberg's data from 1964-1970. This comparison revealed almost equal percentages over time in West-Vlaanderen (between 38% and 36%), but a decline in Oost-Vlaanderen (from 54% to 28%).

During the period 1964-1970 the number of analysed barn owl pellet lots in Zeeuws-Vlaanderen was low: in five of the ten grid cells (50%) with pellets, bicoloured white-toothed shrew was present. During the period 1987-2002 bicoloured white-toothed shrew was present in 22 of the 26 grid cells (85%) with barn owl pellet lots. Thus, there were more bicoloured white-toothed shrews occupying grid cells with barn owl pellets in Zeeuws-Vlaanderen in the periods 1964-1970 and 1987-2002, compared with the bordering provinces in Vlaanderen (Belgium).

Discussion

According to the percentages of bicoloured white-toothed shrew found in pellets of barn owls, this species has shown a remarkable increase during the four time periods: up to 1950, 1951-1969, 1970-1988 and 1989-2008. According to the species' presence in 1x1 km blocks the increase holds for all four consecutive periods; although the research effort has also increased in more recent periods. The number of 5x5 grid cells with bicoloured white-toothed shrew in the last period amounted 36. There has also been a notable increase over time in the ratio of bicoloured white-toothed shrew to the total number of *Crocidura*.

Table 3. Presence (% ranges) in barn owl pellets of bicoloured white-toothed shrew (*Crocidura leucodon*), greater white-toothed shrew (*Crocidura russula*) and all lots with range of number of prey animals; columns 2 and 3, in brackets: number of lots, only with percentages >0; for definition of periods: see table 1.

	% *Crocidura leucodon* (*n*)	% *Crocidura russula* (*n*)	All lots (range of prey numbers)
Period 1	1.18 (1)	17.65 (1)	1 (85)
Period 2	0.36-1.41 (3)	3.18 – 35.21 (12)	13 (47-553)
Period 3	0.24-7.69 (51)	1.37 – 66.67 (96)	107 (2-1560)
Period 4	0.46-14.29 (183)	0.65 – 83.33 (268)	293 (1-563)
Total	0.24 – 14.29 (227)	0.65 – 83.33 (341)	414 (1-1560)

Table 4. Details of trapping results (%) of bicoloured white-toothed shrew (*Crocidura leucodon*) in relation to trapping effort in Zeeuws-Vlaanderen for individuals, organisations or published references; *: see References; 'casual trappings' not included; (definition of periods: see table 1).

No.	Individual , organisation or published reference	Year	Trapped *Crocidura leucodon*	Traps per night	*Crocidura leucodon* / traps per night
	Period 2				
1	Erik Van der Straeten (personal communication)	1965-74	neg	291	Neg
	Period 3				
2	* 't Hart & Straatmans 1984	1980	7	1055	0.66
3	* Buise & Vonck 1985	1984	neg	2804	Neg
4	* Kapteyn 1988	1988	15	759	1.98
5	* Keijl 1995	1988	3	2083	0.14
	Period 4				
6	* Calle 1998	1992-98	1	244	0.41
7	Erasmus SBB (unpublished inventaries)	1999	1	345	0.29
8	Calle & Bekker (unpublished inventaries)	1999	6	276	2.17
9	Oranjedijk/Turkye (unpublished inventaries JPB)	1999	neg	63	Neg
10	Kriekeputten SBB (unpublished inventaries)	2000	neg	280	Neg
11	* Bekker & Honingh 2001	2000	7	1175	0.60
12	Sandra Dobbelaar (personal communication)	2002	neg	160	Neg
13	Akkerranden (unpublished inventaries JPB)	2002	1	800	0.13
14	Saeftinghe (unpublished inventaries JPB)	2002	neg	120	Neg
15	RWS N58 (unpublished inventaries JPB)	2004	3	600	0.50
16	* Bekker 2007	2006	5	580	0.86
17	Glacisweg (unpublished inventaries JPB)	2007	neg	250	Neg
18	Boschkreek (unpublished inventaries JPB)	2008	neg	224	Neg
19	* Bekker 2010b	2008	neg	620	Neg
Total			49	12729	0.38

To make changes to the status of species on Red Lists it is important to distinguish between changes in actual population trends and distributions and those that originate from an increase in research effort. Even taking this into account for the period 1999-2008, the last ten years of this study, there is evidence of 36 occupied grid cells in Zeeuws-Vlaanderen, together with a further 53 grid cells in north-eastern Overijssel and south-eastern Drenthe. Together these make up 2,225 km^2 of distribution, albeit fragmented between two regions. Snaak (2008) does not provide an analysis of the numbers of bicoloured white-toothed shrew found in barn owl pellets in the north-eastern part of the Netherlands; but his findings do not suggest a decrease of this northern population. The increase over years in the relative numbers of bicoloured white-toothed shrew found in barn owl pellets from Zeeuws-Vlaanderen, indicates an increase in the population.

According to the criteria of Red List definitions, the change in status of bicoloured white-toothed shrew to 'least concern' for the Netherlands is justified by the findings presented in this study. Yet the situation of this species in the Netherlands remains peculiar: it is almost completely restricted to a split distribution in the north- east of the country and one in the south-west. If the population in either part of Zeeuws-Vlaanderen experienced a sharp decline, the possibilities of a smooth recolonisation will be hampered by the almost total ecological barrier

posed by the Kanaal van Gent naar Terneuzen. At the same time a spontaneous recolonisation from Belgium is currently not obvious, given the decline of the population on the other side of the border. Therefore ongoing monitoring of bicoloured white-toothed shrew populations is highly recommended.

Although the results seem to show an increase in the population of bicoloured white-toothed shrew, there are some flaws in the data yielded by the barn owl pellet analysis that have to be considered. Several years of results are missing from the series of analyses of barn owl pellets (see figure 2), resulting in a lack of continuity. In addition the total number of analysed prey-items did not always reach 150, a desirable level for calculating trends of populations of small mammals (La Haye 1999).

Historically incorrect determinations of white-toothed shrews, at the cost of the proportion of bicoloured white-toothed shrew, could also have contributed to lower figures for the latter species being reported in the past (J.P. Bekker, unpublished data). Re-examination of the barn owl pellet remains of bicoloured white-toothed shrew is sometimes possible; however most of the time the remains of greater white-toothed shrew have been thrown away directly after analysis. In the following years Husson (1962) suggested to differentiate skulls of the two white-toothed shrews in the Netherlands with size differences between the 3rd praemolar and the front lobe of the 4th praemolar and the ante-orbital breadth; specimens that could not be assigned to the right category then were labeled '*Crocidura* spec.'. If all the specimens in the 1960s and early 1970s, then labeled '*Crocidura* spec', were assigned to bicoloured white-toothed shrew, the relative numbers found in barn owl pellets from Zeeuws-Vlaanderen for this species can be calculated as 3.1% in 1969, 1.5% in 1970, and 7.4% in 1972; these relative numbers will drop by approximately 50% if adjusted for the calculated misinterpretation based on measurements of the ante-orbital breadth (J.P. Bekker, unpublished data). After the results of the studies of Richter (1963, 1964) became widely available, this differentiation problem gradually faded away.

The scale, in which interspecific competition of white toothed shrews expresses itself, is well within the home range of a barn owl and the area of a trap line (ca. 700-1800 m^2). Although large parts of Zeeuws-Vlaanderen are probably occupied by populations of greater white-toothed shrew, there is also an intricate network of connections for populations of bicoloured white-toothed shrew which survives a range of threats. Detailed mapping of these connections and the threats can help ensure proper support and achieving nature conservation objectives. Large scaled plots, sandy soils near the Belgian border, inland dykes and differences in the densities of humans all seem to influence the unbalanced distribution of bicoloured white-toothed shrew over Zeeuws-Vlaanderen. Further research is needed to determine the contribution that these factors make.

Kraft (2000) and Vogel et al. (2002) both observed that the greater white-toothed shrew was dominant to both the lesser and bicoloured white-toothed shrew. Although the origin of the change in interspecific competition is not known, both authors suggest climatic change is responsible for the diminishing populations of lesser white-toothed shrew and bicoloured white-toothed shrew relative to greater white-toothed shrew, which has expanded its range. These observations and the explanation seem to be in conflict with the long term findings in Zeeuws-Vlaanderen. As white-toothed shrews originate from Africa, it is conceivable that bicoloured white-toothed shrew could benefit from climate change. An explanation for this conflict could be the change in outcome of interspecific competition, due to altitude differences, between greater white-toothed shrew and bicoloured white-toothed shrew, in favour of the latter, which could contribute to a higher population of bicoloured white-toothed shrew in Zeeuws-Vlaanderen during the last period. The effect of climate variables (if any exist) on the populations of bicoloured

and greater white-toothed shrew in Zeeuws-Vlaanderen still needs to be explored.

Conclusions

During four study periods (up to 1950, 1951-1969, 1970-1988 and 1989-2008), the percentage of bicoloured white-toothed shrew found in the pellets of barn owls in Zeeuws-Vlaanderen has shown an increase. Over the four study periods the number of grid cells occupied by bicoloured white-toothed shrew has risen from 2, to 3, 23 and 36 respectively. Their presence in 1x1 km blocks has shown a steady increase from two in the first period to 4 in the second, 39 in the third and 78 in the fourth. In addition an increase over time has been noted in the ratio of bicoloured white-toothed shrew to the total number of *Crocidura*. The continual increase in the ratio of bicoloured white-toothed shrew in barn owl pellets over time indicates an increase in the population in Zeeuws-Vlaanderen. According to the criteria for Red List definitions the downgrading of bicoloured white-toothed shrew towards the status of 'least concern' in the Netherlands is justified by the findings presented in this study.

Acknowledgements: I express special thanks to Lucien Boerjan and Awi de Zwart, the core of the group of volunteers with the natural history organisation *'t Duumpje,* together with their colleagues Henk Bondewel, Gerard van Daele, Jan Janssens, Pieter Simpelaar and Herman van de Voorde, for providing their results of their analysis of barn owl pellets from the western part of Zeeuws-Vlaanderen. I also thank Marc Buise, the co-ordinator of the provincial Barn Owl Protection Foundation and the members Jan Asselman, Corry Dentz, Oscar van Dorselaer, Eddy Matthijs, Rob Remmerts, Els Renema, G.Verwilligen, B. Vroegindeweij and Alex Wieland who collected barn owl pellets in eastern Zeeuws-Vlaanderen. Also I appreciate the support of the members of the Field Study Group of the Dutch Mammal Society and the members of the Zoogdierwerkgroep Zeeland: Theo Aernoudtse, Hans Bekker, Jan Boshamer, Lucien Boerjan, Elias de Bree, Tiny Breusegem, Lucien Calle, Wannes Castelijns, Mark Dobbelaar, Sandra Dobbelaar, Jan Alewijn Dijkhuizen, Eelco Groenendaal, Menno Haakma, Raymond Haseleger, Ruth Hesseling, Nanning-Jan Honingh, Albin Hunia, Rob Koelman, Kees de Kraker, Peter van der Linden, Kees Mostert, Freek Otte, Janny Resoort, Piet van der Reest, Froukje Rienks, Hanneke Seegers, Marijn Seegers, Kamiel Spoelstra, Eric Thomassen, Joost Verbeek, John van Vliet, Anke van der Wal, Alex Wieland, Jeroen Willemsen, Gerard van Zuilen and Awi de Zwart who took part in field studies mostly aimed at live-trapping of the bicoloured shrew. I acknowledge the support provided by Jaap Mulder and Pieter Slim in searching for 'grey' literature. After more then 40 years Rob Bijlsma precisely revealed his reference resource of owl pellet analyses in those days; specials thank to him for sharing this with me. I would also like to thank two anonymous reviewers for their critical yet constructive reading of the manuscript.

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Samenvatting

De verspreiding en relatieve aantallen in kerkuilbraakballen van de veldspitsmuis (*Crocidura leucodon*) in Zeeuws-Vlaanderen; een meta-analyse

De veranderingen in de verspreiding van de veldspitsmuis (*Crocidura leucodon*) in Zeeuws-Vlaanderen gedurende de afgelopen 70 jaar worden beschreven. Daarnaast wordt voor deze soort met behulp van analyses van kerkuilbraakballen een aantalsontwikkeling geschetst. Het onderzochte tijdvak is opgedeeld in vier perioden: vóór 1950 (periode 1), 1950-1969 (periode 2), 1970-1988 (periode 3) en 1989-2008 (periode 4). Omdat van de *Crocidura*-soorten zowel de veldspitsmuis als de

huisspitsmuis (*Crocidura russula*) in Zeeuws-Vlaanderen voorkomen, wordt de ontwikkeling van de laatste soort ook geëvalueerd. Hiertoe wordt aandacht besteed aan de gelijktijdige aanwezigheid van de beide soorten in valraaien en in kerkuilbraakballen. In de vier perioden nam het aantal bezette uurhokken van veldspitsmuis toe van 2 tot 36. De toename in de vierkante kilometerhokken tot 78 in de laatste periode is bijna exponentieel; hierbij heeft ook de onderzoeksinspanning een rol gespeeld. Gedurende de periode 1989-2008 is het voorkomen van de veldspitsmuis tussen het Kanaal van Gent naar Terneuzen en de Braakman door vangsten aangetoond. De percentages veldspitsmuis in kerkuilbraakballen per jaar laten over de periode 1943 tot 2008 een stijging zien: tot 1990 blijven de percentages onder 2, na 1995 stijgen de percentages ruim boven 2, met uitzondering van 1998 en 2004. De percentages huisspitsmuis in braakballen over de periode 1943 tot 2008 laten ook een stijgend verloop zien, zij het minder uitgesproken dan die van de veldspitsmuis. Veel van de afzonderlijke braakbalpartijen bevatten veldspitsmuis en huisspitsmuis. Dit betekent dat beide soorten aanwezig zijn binnen de home-range van kerkuilen, maximaal ca. 2 km van elkaar. Het vangresultaat in de inloopvallen varieert van 0 tot meer dan 2 procent. Op de 65 locaties met *Crocidura*-soorten, werden op 32 uitsluitend veldspitsmuis en op 31 alleen huisspitsmuis gevangen; op slechts één locatie bleken beide soorten aanwezig te zijn. Binnen de perioden 1964-1970 en 1987-2002 vertoont de veldspitsmuis in Zeeuws-Vlaanderen een opmerkelijk hoog aantal bezette uurhokken op basis van de analyses van kerkuilbraakballen, vergeleken met de aangrenzende provincies in Vlaanderen (België). Volgens de criteria van de Rode Lijst is de opwaardering van veldspitsmuis naar 'thans niet bedreigd' voor Nederland gerechtvaardigd door de feiten en cijfers in deze studie. Toch is de situatie in Nederland merkwaardig doordat de soort nu letterlijk een marginaal voorkomen vertoont: in Drenthe en Overijssel, en in Zeeuws-Vlaanderen. Dit onderzoek vertoont een aantal gebreken. Zo zijn er in de serie analyses van kerkuilbraakballen enkele jaren zonder resultaten van braakbalanalyses, waardoor een gebrek aan continuïteit ontstaat. Ook wordt niet altijd het gewenste totale aantal van 150 geanalyseerde prooidieren bereikt. Onjuiste determinaties in het verleden van *Crocidura*-soorten ten koste van het aandeel van veldspitsmuis kan hebben bijgedragen tot lagere aantallen. De interspecifieke competitie tussen veldspitsmuizen en huisspitsmuizen speelt zich af tussen 0,7 en 925 ha. Of en hoe klimaatvariabelen van invloed zijn op de populaties van veldspitsmuis en huisspitsmuis in Zeeuws-Vlaanderen, zal nader moeten worden onderzocht.

Received: 17 March 2011
Accepted: 17 May 2011