Do set-asides act as small mammal biomass enhancers, and what is their relevance as food reservoirs for nocturnal avian predators?

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Table of Contents

Abstract 3
Introduction 4
Material and methods 5
    Small mammals 6
    Owl radiotracking 7
Results 10
    Small mammals 10
    Owl radiotracking 11
Discussion 12
Acknowledgements 14
References 15
Appendices

Abstract

1. During the past decades agricultural ecosystems have lost biodiversity due to more intensive production methods. In order to promote species diversity, the Swiss Confederation attributes subsidies only to farmers who cultivate at least 7% of their land as ecological compensation areas, such as set-asides and wildflower fields. Several studies have shown that biodiversity is actually higher in those habitats than in other cultivated land. To what extent set-asides and wildflower fields also promote small mammal populations, and therefore contribute to restoring a functioning food chain, remains largely unknown, however.

2. We studied seasonal variation in small mammal populations among eight habitat types, in particular set-asides, and attempted to address patterns of food resources use through habitat selection by a top predator of farmland, the barn owl, which specialises on that prey.

3. Small mammal density was higher in set-asides than in other habitat types throughout the year, with estimated densities increasing from May through July to September (on average 755, 1700, 2120 individuals / ha, respectively).

4. Barn owls ($n = 7$) foraged preferentially in cereal fields and grassland. They avoided maize, cropland (other than maize and cereals), and set-asides. Only two out of seven owls showed significant preferences for longer relative linear habitat features, such as streams and hedgerows.

5. Barn owls do not seem to select their hunting habitat with respect to prey abundance. Rather, prey accessibility may play a more crucial role in habitat decisions. Set-asides seem particularly unsuitable in this respect due to their dense vegetation cover. The exploitation of

set-asides, as outstanding food reservoirs for top nocturnal predators, may be enhanced by creating open foraging corridors between set-asides and adjacent cultures, or by placing perches nearby.

Introduction

In the past decades agricultural ecosystems have become impoverished due to more intensive production methods. Simplification of crop rotation, larger fields and loss of ecological relevant structures caused by land consolidation lead to a decline in plant and animal species richness (Nentwig 2000). In order to promote biological diversity the Swiss Confederation attributes subsidies only to farmers who cultivate at least 7% of their land as ecological compensation areas (ECA). ECAs contain, among others, set-asides and wildflower fields, extensive meadows and hedges (Schweizer Eidgenossenschaft 1998). Such ECAs provide suitable habitats for several species of plants, invertebrates, birds and mammals (Nentwig 2000; www.biodiversity.ch). But, not only beneficial organisms take advantage of such new habitat; the abundance of agricultural pests such as voles (*Microtus sp.*), for instance, may be enhanced too (Airoldi 2004; Aschwanden 2004; Briner et al. 2003; Tattersall et al. 1997, 2000). Small mammals not only favour ECAs for rich food supply, but also for the dense vegetation cover, which protects them from predators (Aschwanden 2004; Baker and Brooks 1981; Bechard 1982; Dickman et al. 1991; Jacob and Hempel 2003; Wakeley 1978). The present study attempts to quantify small mammal population densities in different habitats including set-asides, and to look at patterns of habitat selection in one of their major nocturnal predators, the barn owl, in order to see whether set-asides contribute to restore functionalities along the food chain.

The Barn owl *Tyto alba* has a wide distribution range (Mebs & Scherzinger 2000). In temperate biomes it has followed the spreading of agriculture for it is hunting mostly in open and semi-open habitats (Snow & Perrins 1998). Barn owls prefer habitats harbouring their favourite prey, i.e. small mammals such as microtid rodents and shrews.

There has been a widespread decline of the Barn Owl in the 20th Century due to intensification of farming practices and habitat loss, including suitable breeding sites (Mebs & Scherzinger 2000; Roulin 2002; Snow & Perrins1998). The species is potentially endangered in Switzerland (Burkard and Schmid 2001) with an estimated 1000-1500 breeding pairs (Mebs & Scherzinger 2000). Local density (e.g. at study site) may reach up to 42 pairs per 100 km^2 thanks to suitable farmland and good supply of nest-boxes (Roulin 1999a). Swiss populations fluctuate in synchrony to vole populations (Roulin 2002) as in many avian predators (Korpimaki 1994). Switzerland lies in the hybridisation-zone of the two 'subspecies' *Tyto alba alba* (whitish breast, Southern and Western Europe) and *Tyto alba guttata* (rufous breast, Central and South-Eastern Europe).

This study addresses two main questions: 1) Are abundance and number of small mammals superior in set-asides and wildflower fields than in other agricultural habitats? 2) Are set-aside and wildflower fields so much attractive as prey suppliers that barn owls over-select them compared to other habitat types?

Material and methods

The fieldwork was conducted on the plain of the river La Broye (46°43-56' N; 6°49'-7°02' E, 434-650 m elevation; Appendix 1). This is a broad plain bordered by a hilly landscape (N, NW and SW). Intensive agriculture is dominant in the whole area. The most important crops on the plain and the northwest are cereals, maize *Zea mays*, Sugar beet *Beta vulgaris,* and Tobacco *Nicotiana tabacum*. On the foothill of Mont Vully (N) there is some viniculture, whereas the hills in SW are mainly used for dairy farming. In the north and in the west there are a lot of set-asides and wildflower fields. This region is a classical barn owl study site, with a relatively high population density (Altwegg et al. 2003; Roulin 1999a, 1999b; Roulin et al. 1998, 2000a, 2000b, 2001).

Small mammals

For estimating small mammal abundance, we selected two sites on the plain and two sites in the hilly region. We made sure that all four study sites (see Appendix 1) encompassed the eight following different habitat types within reasonable distance between each other: 1) set-aside fields (>2 years old, because in >2 years old set-asides vole abundance is no longer related to age [Tattersall, 2000]); >1 ha area set-asides to avoid edge effects; 2) banks of canals or ditches; 3) edges of forests or hedgerows; 4) fields of winter wheat *Triticum aestivum*; 5) maize, 6) tobacco; 7) extensive meadows that had not been ploughed for at least five years (permanent meadow); 8) intensively fertilised grassland that is part of the crop rotation (intensive meadow) (Appendix 2).

Since capture probability of small mammals is not equal for every trap type (Airoldi 2004), and we had different types of traps, we always placed three traps, one of each type, at capture locations (Longworth, Penlon Ltd., Abingdon, UK; Sherman, H.B. Sherman Traps, Inc., Tallahassee, USA; Trip Trap, Alana Ecology Ltd., Bishops Castle, UK). As bait, pieces of carrots, pieces of Emmental cheese and grains (Hamster food from Coop, CH) were used (Airoldi 2004). Additionally, a handful of hay was put into the traps to permit a longer survival of the small mammals captured (Airoldi 2004).

Capture design was inspired by Aschwanden (2004), who also investigated small mammals in set-asides. We applied a capture-mark-recapture protocol to estimate population sizes in May, July and in September 2005, respectively. On each field, traps were set in a reticule-pattern with distances of 5 m between trap sets along a double 45 m long transect (Appendix 3). This design defines 20 trap points (Appendix 4), totalling 60 traps per study site. Assuming a capture radius of 2.5 m around traps, the overall catching area of a study site was about 500 m^2. Traps were set for three nights and days and were controlled every eight hours. Installation was at 2 pm on day 1 and removal after 6 am on day 4. The number of traps available and the handling time allowed to set traps on four habitat types simultaneously (4*60 = 240 traps). One complete capture series at one site of eight habitat types lasted seven days. At each control, small mammals were determined, sexed, aged, weighed and marked. Marking consisted of local cutting of the fur on the back and the head at seven different places to make the darker underfur visible. Varied cutting codes enabled individual recognition (Appendix 5). Subsequent trap checks enabled to construct a capture history for each animal. We assumed and found no exchanges between the habitat types sampled at each study site.

Population sizes were estimated using the program Capture (Otis et al. 1978). When no recapture took place, we used the number of caught individuals for determining density. Since those numbers had no standard error, we allocated them the mean of the standard errors gained from the other densities. Density (n/ha, with 500 m^2 as reference area per study plot) was not normally distributed and could not be transformed appropriately. We therefore ran a MANOVA (JMP 4.0.4, SAS Institute Inc. 2001, Cary, NC, USA) on the ranks of densities as response variable. Habitat type and study site were independent variables. As densities were sampled in equal intervals throughout the season, the three consecutive capture series were considered as repeated measures, providing information about seasonal trends. P-values are two-tailed with rejection levels set at 5%. Differences in densities were finally tested with posthoc pairwise comparisons with respect to habitat type and season (Tuckey-Kramer HSD test).

Owl radiotracking

Seven male owls were chosen for the study of habitat selection. They had their nesting site in the vicinity of the small mammal capture sites (Appendix 1). The owls were caught and tagged with radio transmitters (ATS type A1240, 8 g, mortality sensor: 6 h fast, ATS, Isanti, USA, fixed with a Rappole leg-harness with a rubber band that falls off after one year) by Bettina Almasi in the framework of her PHD study on the impact of stress in barn owls. Owls were radio located using a portable receiver (Telonics TR-5, Telonics Inc., Mesa AZ, USA), and a hand-held 3 element Yagy antenna.

The study lasted from June to September 2005 with interruptions during the small mammal capture sessions (see above). I tracked only males, since males are the main food providers in barn owl broods (Mebs & Scherzinger 2000). The tagged owls were radiotracked by car and located by “homing-in on the animal” (White & Garrot 1990). Visual localisations were attempted in open area, where one had a good view on a large area, using an observation spyglass (Aspectem 80/500 with vario ocular, Docter, Eisfeld, Germany), a powerful torch (Maglite, Mag Instrument Inc, Ontario, USA), and a GPS device (eTrex Gecko, Garmin Int. Inc, Olathe, USA).

Exact position of hunting or resting owls was obtained from GPS. We also noted time, behaviour (sitting/flying), hunting activity (“dives” to the ground), habitat type, vegetation height in grassland or cropland (lower or higher than 20 cm, to assess whether the field had recently been mown or harvested), and the type of perches used.

Bearings were used to draw home ranges as Minimum Convex Polygons (MCP; Mohr 1947). MCPs were mapped in the field for agricultural soil utilisation. MCPs were then divided into 1-ha squares according to the official reference grid of the Swiss Federal Topographic Service (Arlettaz 1999). For each 1-ha square we noted the dominant habitat type in the 1-ha grid cell (cereals, maize, tobacco, other crops, grassland, forest, set-aside, riparian and settlement). Set-asides, the habitat type of our interest, are often too small to be the dominant habitat type in a square of 1ha. We therefore noted also all 1-ha cells containing set-asides. We finally estimated the length of different linear structures: forest edges, rivers, set-asides, hedgerows and total linear structures (0 : no linear structure; 1 : 0 – 25 m; 2 : 25 – 50 m; 3 : 50 – 75 m; 4 : 75 – 100 m; 5 : > 100 m).

Within individual home ranges (MCP) we distinguished between visited and unvisited 1-ha square cells. We assumed that visited cells mirrored habitat preferences, whilst non-visited cells were avoided because representing non-suitable habitat. This assumption is realistic since every cell in the MCP was potentially overflown by the owl (Arlettaz 1999). For habitat selection analysis on a population level, we conducted a Compositional Analysis (Aebischer et al. 1993) to test differences between used and available habitats (1-ha cells) within the owls' home ranges (Aschwanden et al. 2005). This non-parametric technique takes into account that the proportional use of one habitat type is dependent on that of other habitat types (Wisler 2006). Compositional Analysis enables to examine only n-1 factors, with n being the number of individuals considered. Our basis habitat matrix had thus to be reduced to six parameters. Maize, tobacco, and other crops were grouped together as cropland, whereas settlements were excluded. According to Aebischer et al. (1993), zero values in the "used" worksheet were replaced by a small number (0.001). Because Compositional Analysis produced satisfying results only at the population level, we had to rely on another statistical method to test for individual patterns. Frequency distributions of visited vs. non-visited cells were computed through randomised contingency table procedures with the program Actus2 (G. F. Estabrook, University of Michigan, Ann Arbor, MI 48109-1048, USA; Estabrook and Estabrook 1989, Arlettaz 1999). This program provides levels of probability for any positive or negative deviation between observed and expected frequencies, depicting habitat selection patterns for every single owl and nine habitat types. Comparing selection trends among the seven individuals enabled us to draw information on general habitat selection pattern. We gained a selection index by subtracting for each habitat type the percentage of owls that avoided a given habitat type from the percentage of owls that showed positive selection. We also ran randomised contingency table procedures to test for differences between the frequency distribution of set-asides between visited and non-visited cells for every owl separately. For the analysis of visited and unvisited structure lengths, we relied on non-parametric statistics because the variables were not normally distributed and could not be transformed appropriately (Wilcoxon-Kruskal-Wallis Test; program JMPIN 4.0.4, SAS Institute Inc. 2001, Cary, NC, USA). Tests were one-tailed since we predicted longer linear structures in visited than non-visited habitat cells.

Results

Small mammals

During the three capturing sessions in May, July and September, we recorded 1’286 capture events, including 224 recaptures. In total we examined 1’062 individuals, of which 1’035 could be identified, belonging to eight species: *Apodemus flavicollis, Apodemus sylvaticus, Mus musculus, Arvicola terrestris, Clethrionomys glareolus, Microtus arvalis, Crocidura russula, Sorex araneus/S. coronatus*. Muridae (*Apodemus* and *Mus*) were the most abundant species in all habitat types except in winter wheat and permanent meadow (Fig. 1). Species richness was highest in set-asides (n = 6), followed by canal bank and wood edge (n = 5 species). The poorest habitat type was tobacco with only two species. Species abundance was dependant on habitat type. The five most abundant species are depicted in Fig. 2. *Apodemus sylvaticus* and *A. flavicollis*, as well as *Microtus arvalis* dominated the sample. Concerning the efficacy of trap types, there were 457 captures with Trip-Traps, 441 with Longworth traps and 388 with Sherman traps ($\chi^2 = 6.211$, df = 2, p = 0.045).

Densities of small mammals varied significantly between habitat types ($F_7 = 195.694$, $P < 0.0001$), throughout the season ($F_2 = 7.471$, $P < 0.0001$), and between study sites ($F_3 = 1.664$, $P = 0.0001$; Fig. 3). The highest average densities were in all three months within set-asides (mean ± SE: 755 ± 11; 1700 ± 5; 2120 ± 16). The highest density ever was reached in a set-aside with an estimated 3260 (± 96, SE) individuals per hectare. The pairwise posthoc comparison of densities among habitat types with seasons separated gave the following trends. In May, small mammal densities were significantly higher in set-asides ($p < 0.05$; Tuckey-Kramer HSD) than in maize, tobacco, permanent meadows, and intensive meadows; densities in canal banks and winter wheat were also significantly higher than in maize, tobacco, and intensive meadows. Finally, densities were significantly higher in wood edges than in maize and tobacco. In July, densities were significantly higher in set-asides and winter wheat than in tobacco, permanent meadows, and intensive meadows. At last, in September, ranks of small mammal densities were significantly higher in set-asides than in winter wheat (Fig. 3).

Owl radiotracking

For foraging activity 158 precise localisations were obtained (mean ± SD: 22.6 ± 5.8, range: 17 – 34, n = 7). There was a large variance in individual home range size (mean = 335.6 ± 234.2 ha; median: 297 ha; range: 93 – 804 ha, n = 7). Compositional Analysis showed that habitat types were not chosen at random, but there was only a significant difference between cereals and other crops ($\lambda = 0.07$, $\chi^2 = 18.58$, $p = 0.0023$; Table 1). Randomised contingency table analyses showed, overall, a positive selection for cereal fields and grassland, whereas set-asides, other crops than maize and cereals, riparian habitat, tobacco and maize were avoided. Regarding the selection indices, we gained the following decreasing order of habitat type preference: cereals > grassland > forest, settlement > riparian > tobacco > maize, other crops >set-aside (Table 2). Two owls showed a significant difference in the frequency distribution of set-asides between visited and non-visited cells; both avoided set-asides (randomised contingency tables, $p < 0.05$) (Table 3).

Regarding structural, linear habitat features, only two owls visited 1-ha cells with longer stream length, longer hedgerow length and longer total linear structures length. There was also a marginally significant selection for cells with longer forest edges in two other owls, and longer total length of linear structures in a 5th owl (Table 4).

Of 24 hunting events observed visually, 22 (92 %) were on the wing and 2 (8 %) from perches.

Discussion

Set-asides, canal banks and wood edges were the species-richest habitat types. This may be explained primarily by their diverse vegetation structure, which offers a lot of niches and refuges, contrary to monocultures. The two habitat types that were ploughed in spring (maize and tobacco) were dominated by the two more mobile *Apodemus* species. Intensive meadows are also ploughed regularly, which implies a high number of wood mice (*A. sylvaticus*). Wood edges were dominated by the yellow-necked mice (*A. flavicollis*). In set-asides, canal banks, winter wheat and permanent meadows voles were the dominant species. Here, voles can develop dense populations because they are not disturbed by ploughing.

Population densities of small mammals apparently depended primarily on the vegetation cover of the habitat. Densities were thus highest in set-asides in all seasons. Canal banks and wood edges were also important reservoirs throughout. In May, this was the habitat offering the best suitable vegetation conditions. In July, wheat and maize were cultivated habitats which also harboured high densities. In September, after harvesting, small mammals had left winter wheat.

Although set-asides were the best food reservoirs across seasons, followed by canal banks and wood edges, habitat selection analyses showed a preference of barn owls for grassland and cereal fields, confirming former studies (Mebs & Scherzinger 2000, Roulin

2002). Except winter wheat in July, the latter two habitats did not support particularly high prey densities. Moreover, set-asides were even among the most avoided habitats! We therefore conclude that prey detectability or accessibility is more crucial than prey abundance for selecting optimal foraging grounds in barn owls, as shown in other raptors (Aschwanden et al. 2005, Baker and Brooks 1981, Bechard 1982, Dickman et al. 1991, Jacob and Hempel 2003, Wakeley 1978). In this respect, open habitats such as cereal fields and grassland are likely to provide an optimal compromise between prey supply and detectability and/or accessibility. Set-asides, with their dense vegetation, are probably not easy to exploit, particularly given that Swiss barn owls search for prey almost exclusively on the wing (this study), contrary to findings reported by Taylor (1994). High and dense stalks, or barbed and inflexible plants like Teasel (*Dispacus fullonum*) may complicate hunting within set asides for raptors, despite that they potentially constitute important food reservoirs.

It could be argued that most set-asides were too small to appear as the dominant habitat type within a 1-ha reference grid, which may bias the results. However, our study of small mammal density took place on set-asides larger than 1 ha. As we know nothing about abundance of small mammals in small set-asides at the study site, our results are conservative. Moreover, the frequency distribution of set-asides between visited and unvisited cells differed in only two owls, which both avoided set-asides.

Our results confirm the findings by Aschwanden et al. (2005) that set-asides cannot be exploited directly by raptors. However, those authors could demonstrate a preference for grassland adjacent to grassland in common kestrels (*Falco tinnunculus*) and long-eared owls (*Asio otus*). The apparent discrepancy between our studies could be explained by the fact that, in our study area, most set-asides were not placed directly adjacent to grassland or cereal fields, the latter two being the main hunting habitat of barn owls.

The apparent avoidance of riparian habitats may be purely artefactual, it could be explained by the linear character of rivers and canals. Although there were many such streams, their area was usually too small to make them the dominant habitat within our 1-ha squares. In the end, the fact that the 1-ha cells visited by several owls had longer linear structures (streams, hedges, forest edges, etc.) than non-visited cells supports the view that the apparent avoidance of these linear features by barn owl is primarily artefactual.

Common voles do usually not leave harvested cereal fields, in contrast to wood mice (Jacob and Hempel 2003, Tew and Macdonald 1993). Harvesting and mowing therefore contribute to increasing temporary prey accessibility and/or detectability for Barn owls.

Abundance of small mammals was actually highest in set-asides, but that habitat was not selected for due to a low prey detectability and/or accessibility. The exploitation by barn owls of these extraordinary food reservoirs might be enhanced if set-asides were placed along linear landscape features, which are used as hunting perches (hedges, forest edge, pylons, etc.). Artificial perches could also be placed along set-aside borders to facilitate hunting by avian predators (Buner 1998). However, given that Swiss Barn owls seem to hunt mostly on the wing (this study, contrary to the findings by Taylor 1994), which may be explained by an absence of sufficient perches within the landscape matrix, the best option for rending this crucial prey accessible would be to systematically create open corridors, of several metres breadth, between set-asides and adjacent fields. That way the carrying capacity of the barn owls' habitat could be greatly improved. Experiments with radiotagged owls could be envisioned to test if these measures could operate properly. If so, agricultural policies could promote new adequate management practices of set-asides for the attribution of subsidies.

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Table 1: Results of compositional analysis pinpointing differences in relative habitat use of seven barn owls, and ranking habitat types according to the percentage of visited and available 1-ha cells within their home ranges. Signs indicate direction of selection (+ : preferred; - : avoided). Three symbols express a significant selection ($p < 0.05$).

	Cereals	Crops	Grassland	Set-aside	Forest	Riparian	Rank
Cereals		+++	+	+	-	+	4
Crops	---		-	+	-	+	2
Grassland	-	+		+	-	+	3
Set-aside	-	-	-		-	-	0
Forest	+	+	+	+		+	5
Riparian	-	-	-	+	-		1

Table 2: Results of randomisation tests of habitat selection in seven barn owls. For every owl the probability of a deviation between visited and unvisited 1-ha squares according to habitat type within individual home ranges was tested. “+” shows a significant positive selection and “-“a significant avoidance. “0” stands for not available in the home range of that owl and “ns” means no significant selection.

Owl	Cereals	Grassland	Forest	Settlement	Riparian	Tobacco	Maize	Other crop	Set-aside
1	+	-	ns	-	+	+	ns	-	-
2	+	ns	-	ns	0	-	ns	ns	ns
3	+	ns	ns	ns	ns	-	ns	-	+
4	-	+	ns	+	-	-	-	ns	-
5	ns	ns	+	+	+	0	-	+	ns
6	ns	ns	0	ns	-	+	ns	ns	ns
7	ns	+	0	-	-	0	ns	-	-
Index	28.6%	14.3%	0%	0%	-16.7%	-20%	-28.6%	-28.6%	-33.3%

Table 3: Comparison of the frequency distribution of set-asides between visited and unvisited 1-ha cells within the individual home ranges of seven male barn owls (randomised contingency table procedures). ---: significant avoidance ($p < 0.01$), 0: set-asides not present in the home range of that owl, ns: no significant selection.

Owl	Presence of set-asides				
	visited		unvisited		Randomisation
	set-aside	no set aside	set aside	no set-aside	
1	2	21	21	164	ns
2	0	17	0	76	0
3	1	21	42	740	ns
4	1	20	27	332	ns
5	3	17	23	171	ns
6	0	18	3	398	---
7	0	34	7	187	---

Table 4: Differences between average ($\bar{x}$ ± SD) structure lengths in used vs. unused 1-ha squares in the home ranges of seven barn owls. N indicates the number of 1-ha cells, “-“ indicates that there was no such structure within the home range of that owl. P: probability (Wilcoxon-Kruskal Wallis Test)

Owl	Forest edge length							Stream length							Set-aside length							Hedgerow length							Total structure length						
	used			unused			P	used			unused			P	used			unused			P	used			unused			P	used			unused			P
	$\bar{x}$	SD	n	$\bar{x}$	SD	n		$\bar{x}$	SD	n	$\bar{x}$	SD	n		$\bar{x}$	SD	n	$\bar{x}$	SD	n		$\bar{x}$	SD	n	$\bar{x}$	SD	n		$\bar{x}$	SD	n	$\bar{x}$	SD	n	
1	1.4	2.1	26	1.2	2	185	0.56	0.5	1.4	26	0.5	1.4	185	0.73	0.1	0.4	26	0.3	1	185	0.54	0.5	1.4	26	0.3	1.1	185	0.19	2.6	3.8	26	2.3	3.6	185	0.64
2	0.4	1.2	17	0.2	0.8	76	0.21	0.6	1.2	17	0.6	1.4	76	0.70	-	-	-	-	-	-	-	0.9	1.7	17	0.4	1.2	76	0.10	1.9	2.1	17	1.1	1.8	76	0.09
3	1	1.8	22	0.6	1.6	782	0.20	1	2	22	0.6	1.5	782	0.14	0.2	1.1	22	0.2	0.8	782	0.89	0	0	22	0.2	0.8	782	0.32	2.2	2.8	22	1.5	2.3	893	0.18
4	0.9	1.8	20	0.3	1.1	194	0.08	0.7	1.7	20	0.6	1.5	194	0.92	0.6	1.4	20	0.4	1.2	194	0.67	0.3	1.1	20	0.2	0.9	194	0.31	2.4	3	20	1.5	2.4	194	0.18
5	0.5	1.4	21	0.2	1	359	0.10	1.1	2	21	0.2	0.9	359	0.00	0.1	0.4	21	0.3	1.1	359	0.60	0.5	1.4	21	0.1	0.7	359	0.01	2.2	3	21	0.8	2	359	0.00
6	-	-	-	-	-	-	-	2.9	2.3	18	0.8	1.7	401	0.00	0	0	18	0	0.3	401	0.71	0.9	1.9	18	0.2	0.8	401	0.00	3.9	2.7	18	1	1.8	401	0.00
7	0.1	0.9	34	0.1	0.5	194	0.56	-	-	-	-	-	-	-	0	0	34	0.1	0.7	194	0.26	-	-	-	-	-	-	-	0.1	0.9	34	0.2	0.9	194	0.60

Figure Captions

Fig. 1: Mean (+ SE, showing inter-site variation) number of rodents (Muridae, Arvicolidae) and shrews (Soricidae) caught with pitfalls in May, July and September in eight different habitat types.

Fig 2: Mean (+ SE, showing inter-site variation) number of dominant species of rodents and shrews caught in May, July and September at four study sites in eight different habitat types.

Fig. 3: Mean densities of small mammals (n/ha + SE, showing inter-site variation) in eight habitat types in May, July and September. Significant differences are depicted by an asterisk ($p < 0.05$, Tuckey-Kramer post hoc pairwise comparison).

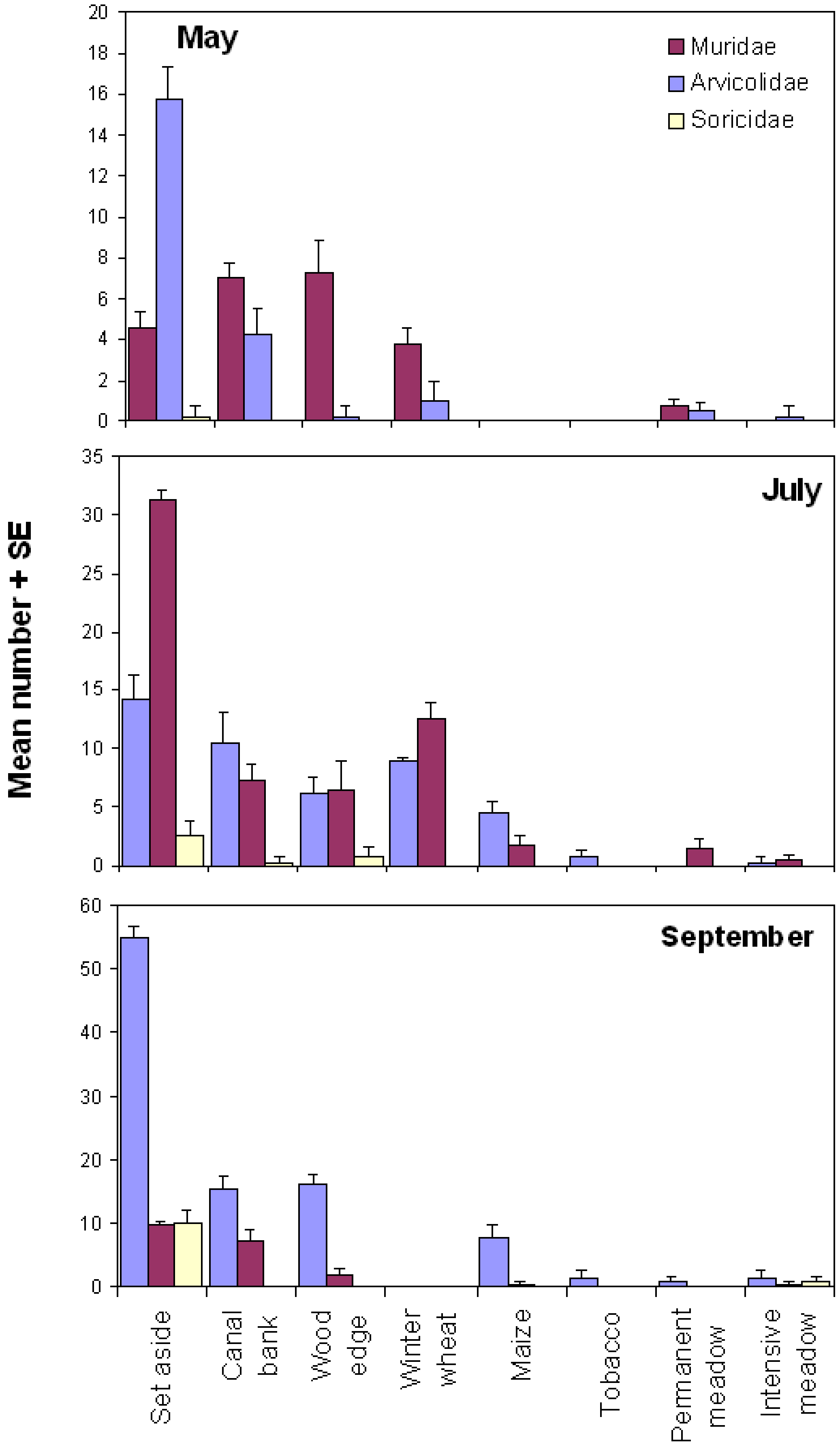
May
July
September
Muridae
Arvicolidae
Soricidae
Mean number + SE
20
18
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
60
50
40
30
20
10
0
Set aside
Canal bank
Wood edge
Winter wheat
Maize
Tobacco
Permanent meadow
Intensive meadow

Fig. 1

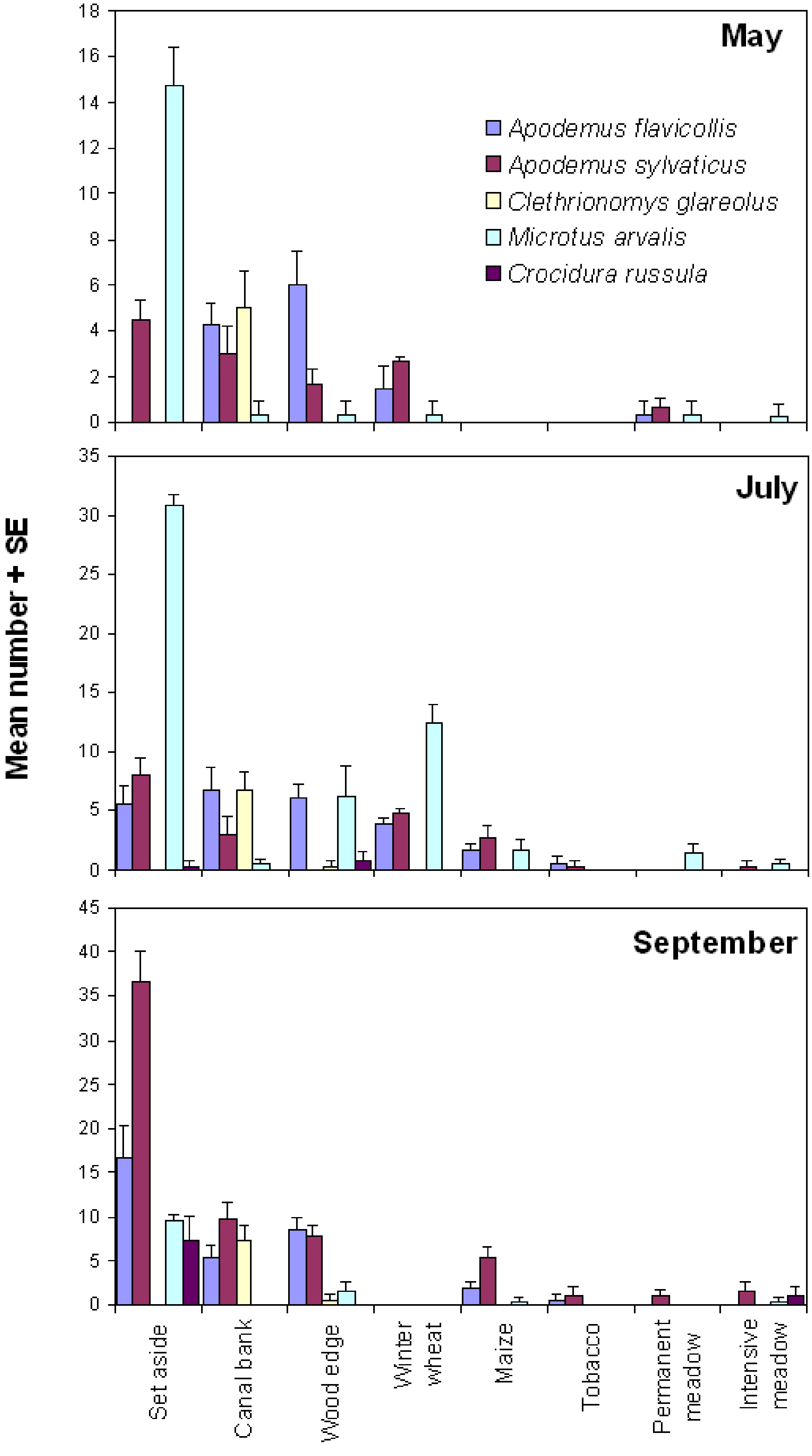

Mean number + SE
May
July
September
Apodemus flavicollis
Apodemus sylvaticus
Clethrionomys glareolus
Microtus arvalis
Crocidura russula
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
0
5
10
15
20
25
30
35
40
45
Set aside
Canal bank
Wood edge
Winter wheat
Maize
Tobacco
Permanent meadow
Intensive meadow

Fig. 2

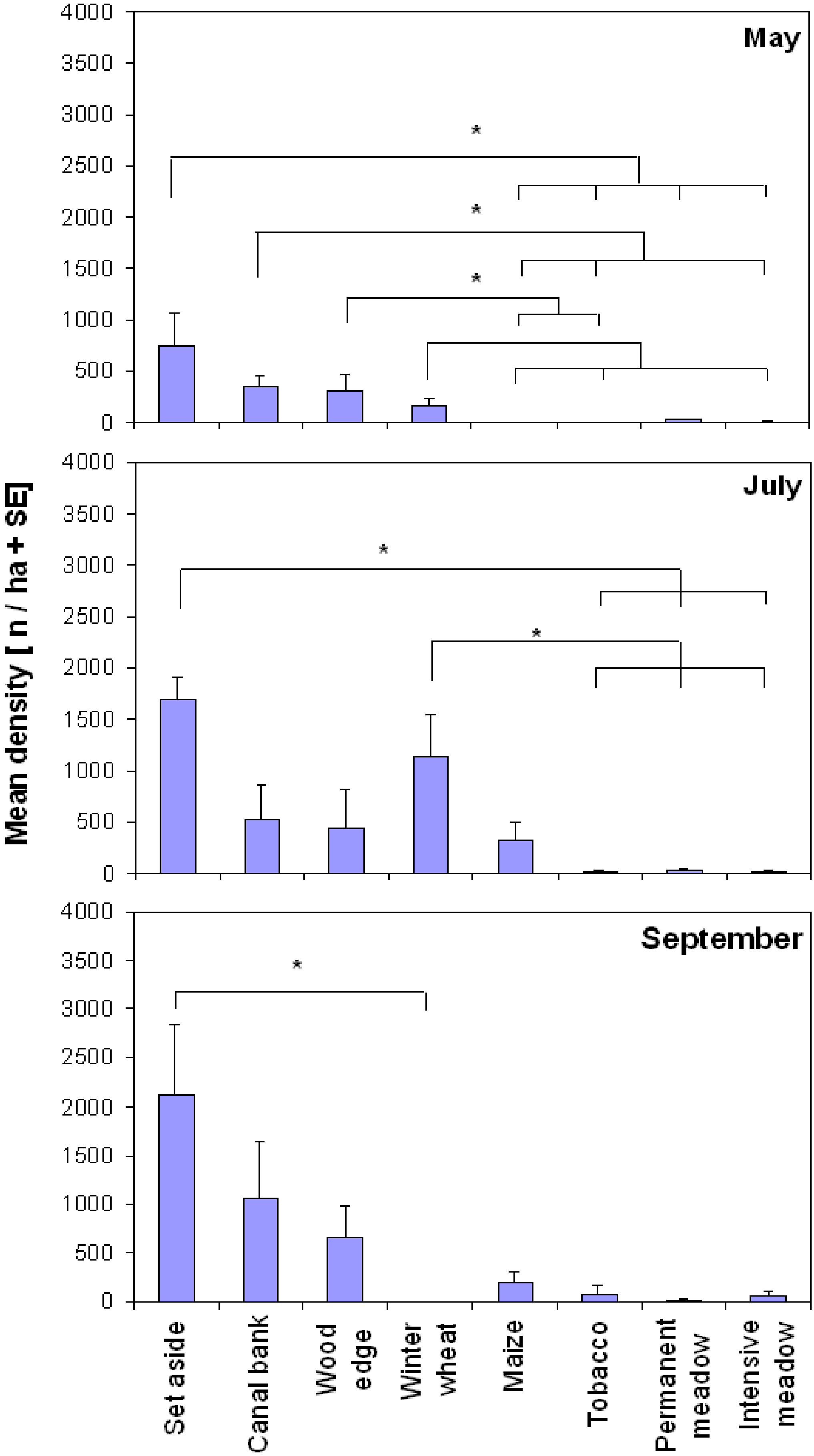
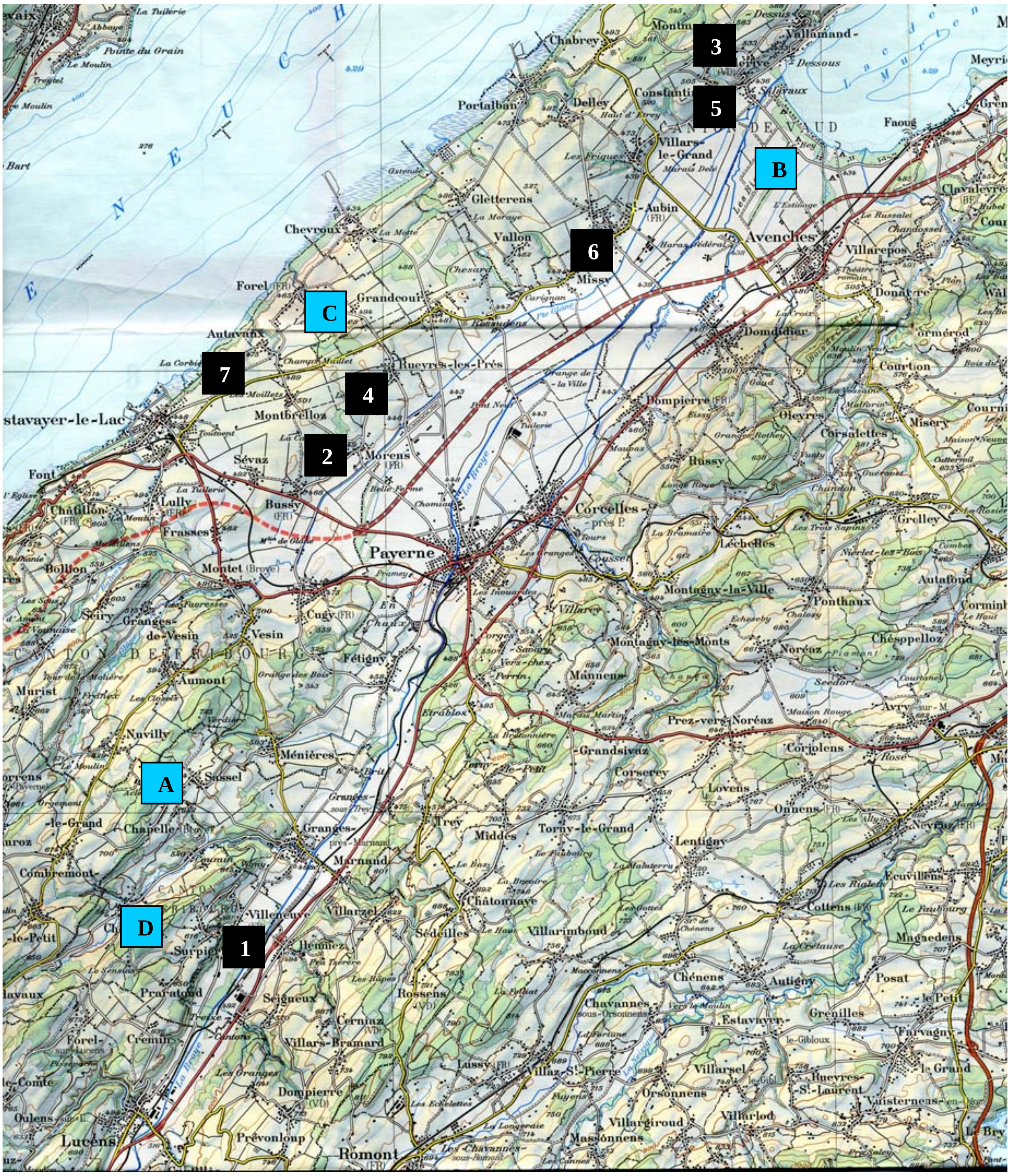

Mean density [n / ha + SE]
May
July
September
4000
3500
3000
2500
2000
1500
1000
500
0
*
Set aside
Canal bank
Wood edge
Winter wheat
Maize
Tobacco
Permanent meadow
Intensive meadow

Fig. 3

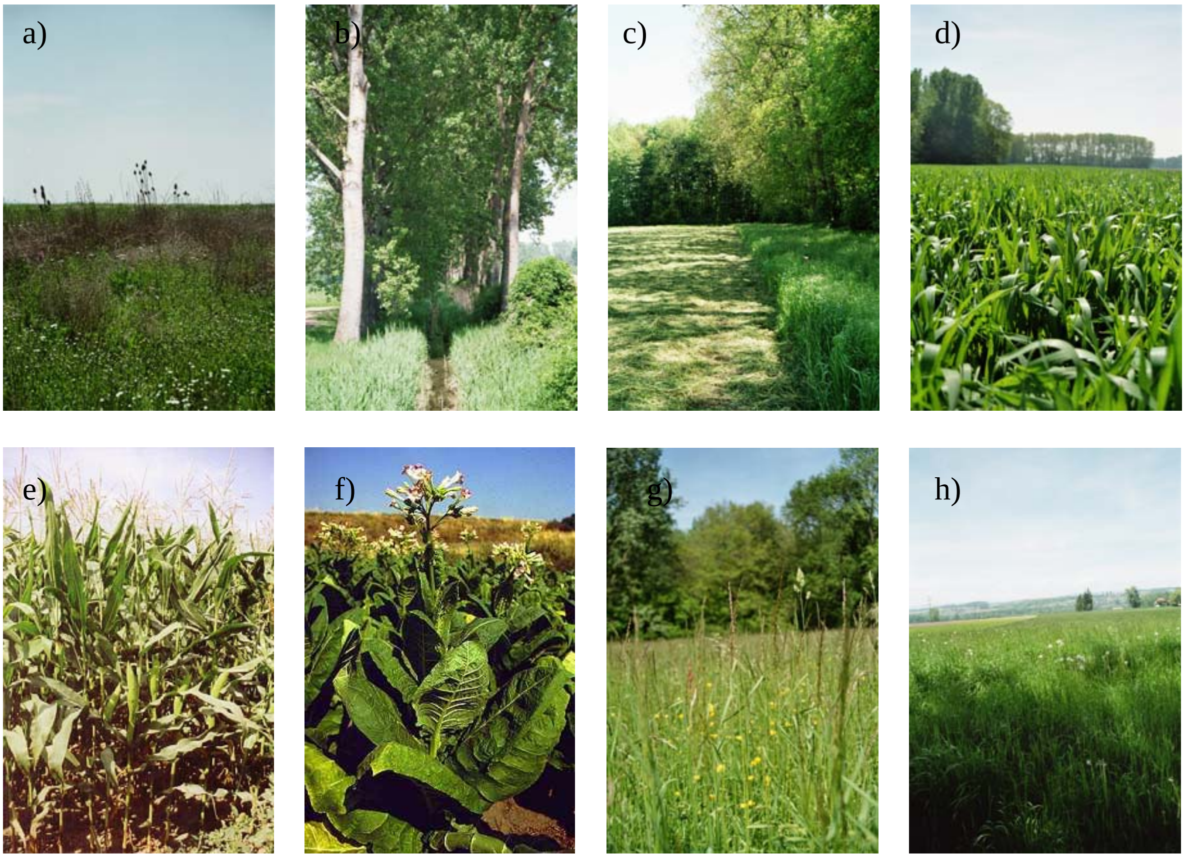
Appendix 1

Study site in the plain of the Broye River (1:100000). Blue boxes with letters show the four study sites for the small mammal captures and black boxes with white numbers show the nesting sites of the seven tracked barn owls. A: Sassel, B: Salavaux, C: Forel, D: Surpierre, 1: Villeneuve, 2: Morens, 3: Bellerive, 4: Rueyres-Palud, 5: Salavaux T, 6: Missy, 7: Autavaux



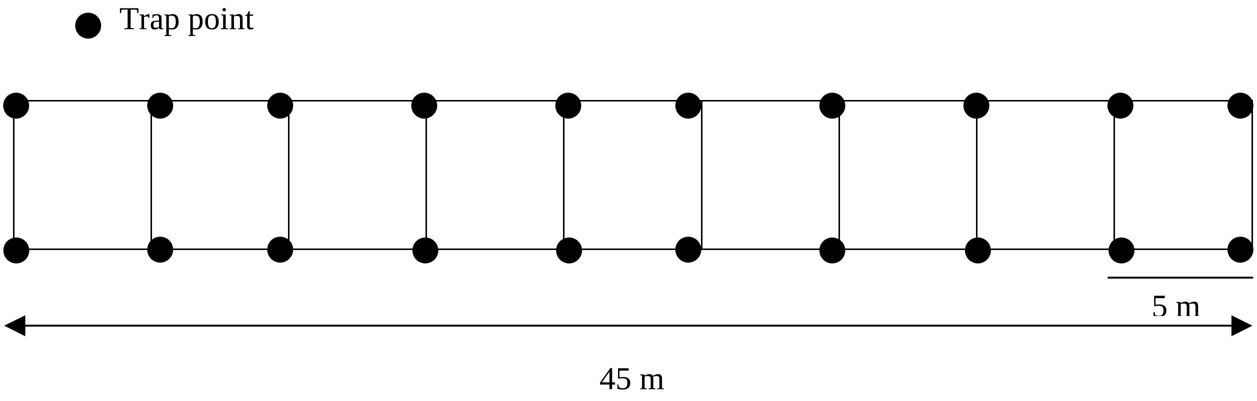
Appendix 2

The eight habitat types used for the assessment of densities of small mammals: a) set-aside; b) canal bank; c) wood edge; d) winter wheat; e) maize; f) tobacco; g) extensive meadow; h) intensive meadow.



Appendix 3:

Reticule-pattern of the 20 trap points for the small mammal capture in a given habitat type.

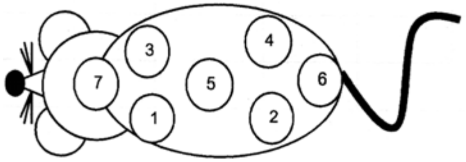


Appendix 4

A trap point in a set-aside in Forel in May 2006, showing a Sherman trap (left), a Longworth trap (middle) and a Trip-Trap (right).

Appendix 5

Form for capture of small mammals

Date: Catching session:				Area No.:		Land use type			Marking schema(2): 
No.	Control	Species	Sex	Weight	Marks at capture	Marks at release(1)	Trap-Type	Remarks	Sketches:
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

(1): For control if all went the right way
(2): By Janine Aschwanden (2004)