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ORIGINAL PAPER

The German wildlife information system (WILD): population densities and den use of red foxes (*Vulpes vulpes*) and badgers (*Meles meles*) during 2003–2007 in Germany

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Abstract Monitoring the populations of badgers and red foxes may help us to manage these predator species as a matter of wildlife conservation and regulation. To fit the needs of a monitoring programme, the most practicable method has to be selected. Hunting bag statistics deliver large but inaccurate data amounts with low effort. Indirect and also often direct counts might deliver only presence–absence data with high effort. Direct counts with high accuracy are very costly. Den mapping by volunteer local hunters can deliver reliable data on density and additional biological variables while being feasible and cost effective. Within reference areas all over Germany, fox and badger dens and litters were recorded, and spring and summer densities estimated as well as potential annual population increases were calculated for 2003–2007. Habitat preferences for breeding dens were also analysed. Additionally, in 2006, the distribution of badgers was surveyed by a nationwide questionnaire. Fox and badger are distributed all over Germany with some small gaps and regionally differing densities. During the monitoring period, fox and badger densities and reproduction stayed stable, at a high level corresponding to hunting bags. However, densities varied between geographical regions, with lower densities in the sparsely wooded lowland regions. A preference for forest and habitats offering shelter was clear for breeding setts and dens. Badgers especially preferred setts of natural origin.

Keywords Monitoring · Reference areas · Population density · Small game predators · Management · Sett usage

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Introduction

The German wildlife information system "WILD" (Wildtier-Informationssystem der Länder Deutschlands) was founded in 2001 and is the first monitoring programme recording population sizes of huntable game species throughout Germany. The project was initiated on behalf of the German hunting association (Deutscher Jagdschutz-Verband e.V. (DJV)) as a permanent integral part of environmental assessment with the aim of developing strategies for conservation and sustainable use of game populations (see Strauß et al. 2008) by monitoring live animals instead of estimating population sizes from hunting bags. Especially for cryptic or rare species, many detection errors persist within any survey method (Elphick 2008). Therefore, within every monitoring programme, the most practicable method has to be established, as different methods have different levels of cost–benefit ratios, i.e. accuracy and precision versus cost efficiency (Gaidet-Drapier et al. 2006; Lyra-Jorge et al. 2008; Vine et al. 2009). Hunting bag statistics are most practical for large area monitoring, as they deliver area-wide data casually. Hunting bags give a good view on long-term population tendencies; however, they depend very much on the willingness and ability of hunters as well as on weather conditions (Gaillard et al. 2003; Grauer and König 2009). Therefore, WILD established a live survey network of so-called reference areas, in which the densities of the European hare (*Lepus europaeus*, first results presented in Strauß et al. 2008), the red fox (*Vulpes vulpes*), the badger (*Meles meles*), the carrion crow (*Corvus corone*) and the hooded crow (*Corvus cornix*) are recorded using standardised methods (DJV 2003). As the accuracy of such live surveys depends a lot on accessibility to area and interaction with local people (Gaidet-Drapier et al. 2006), the reference areas are monitored by the local hunters. At periodical intervals, other small game species are estimated by querying hunters area-wide all over Germany.

Red fox populations, as indicated by annual hunting bags, decreased in Germany owing to rabies and the gassing of dens in the 1960s. Since gassing stopped in the mid (FRG) and later (GDR) 1970s, the population increased a little but remained stable until the start of vaccination against rabies in 1986 (DJV 1990; Bellebaum 2003; Pegel 2004). Since the late 1980s, the population has increased very rapidly and has varied since 1995 at a high level. The annual hunting bag in Germany increased from about 180,000 in the late 1960s to around 630,000 recently, with a tendency for a slight decrease (DJV 1990, 2009; Bellebaum 2003). Monitoring fox populations is important for the conservation of endangered prey species, management of small game (Reynolds and Tapper 1995; Baker et al. 2006) and for disease control (e.g. rabies or echinococcosis, Bellebaum 2003; König et al. 2008; Vos et al. 2008).

Badger populations, as indicated by annual hunting bags, were reduced much more by rabies and gassing (Schwierz and Wachendörfer 1981) than was fox density. Since the end of gassing of setts, the annual hunting bag has increased from less than 5,000 in the 1960s and 1970s and now remains stable at a high level of about 50,000 since 2003 (DJV 1990, 2009; Pegel 2001). However, reliable large-scale population data are sparse today in most parts of Europe (Griffiths and Thomas 1997; Kowalczyk et al. 2000; Sleeman et al. 2009). Monitoring badgers is important for wildlife management (Eichstädt and Roth 1997; Revilla et al. 2001; Sleeman et al. 2009), agricultural damage (Roper et al. 1995; Moore et al. 1999; Schley 2000; Delahay et al. 2009) and disease control (e.g. bovine tuberculosis in Britain and Ireland, Griffin et al. 2005; Woodroffe et al. 2008).

Our aims were to assess densities and density changes of foxes and badgers in Germany between the years 2003 and 2007 as well as to monitor differences of densities between geographical regions. We discuss the reliability of the methods and data. Additionally, we queried the distribution of badgers from every German hunting ground. Besides population data, also habitat parameters for breeding dens were evaluated from the mapping data. The data from WILD may serve as a basis for further research.

Material and methods

Since 2002, the project has established more than 800 reference areas, randomly distributed over all German agricultural regions. The mean size of these reference areas is 738 ha (minimum 95, maximum 4,500 ha). For several reasons (e.g. organisational matters and weather), the number of reference areas providing data differs between years. In total, 360 reference areas delivered density data for fox and badger populations.

Hunters monitoring the reference areas were instructed and trained according to the WILD manual, which includes detailed descriptions of the methods used (DJV 2003). The local hunters familiar with their hunting grounds map all fox dens and badger setts every winter. Therefore, the hunters visit every known den and sett. Additionally, they search for dens and setts systematically. Unknown dens might be found by following fox and badger tracks in winter (Briedermann and Dittrich 1982; Stubbe 1989), especially during fox mating and in snow (January and February). In spring, during rearing of puppies (April–June), the hunters control the mapped dens and setts and noted several parameters: type, location and habitat of den, number of entrances, inhabited or not, species inhabiting, breeding den or not, litter size and additional notes.

The sex ratio of red foxes is male biassed (Goretzki and Paustian 1982; Tryjanowski et al. 2009). Thus, for calculating the minimum spring fox density, we multiplied the number of litters by the factor 2.5, adding non-reproductive females and surplus males to the litters' parents (Wandeler and Lüps 1993; Stubbe and Stubbe 1995). Potential minimum summer densities were calculated by adding the spring adult density and cub density. The cub density was the observed mean number of cubs per litter at the breeding den multiplied by the number of observed litters.

For calculating badger densities, every sett was observed carefully during spring and early summer, to record the litter density and size. The sex ratio of badgers was assumed to be 1:1 (Macdonald and Newman 2002), although populations are often slightly female biassed (Do Linh San 2002). As badgers live in their setts all the year, the potential minimum spring density was calculated by multiplying the litter density by the factor 2 (number of parents) and adding non-reproductive animals represented by the number of inhabited outlier setts without litters (Stubbe 1989; Noack and Goretzki 1999), although the relationship between the number of setts and the number of group members still remains unclear (Tuyttens et al. 2001; Rogers et al. 2003; Wilson et al. 2003; Sadlier et al. 2004). Admittedly, non-reproducing badgers use more than one sett (Brøseth et al. 1997; Loureiro et al. 2007). The minimum summer density was the spring density plus the number of litters multiplied by the mean number of cubs per litter. All densities were calculated per 100 ha hunting ground.

Estimating density by mapping and counting active setts, number and size of litters, and numbers of reproductive and non-reproductive animals may be more precise than calculating densities from hunting bags, line transects and other methods, especially in low densities (Stiebling and Schneider 1999; Heydon et al. 2000; Tuyttens et al. 2001). However, with these calculations, only minimum densities are estimated, as unknown numbers of undetected dens, litters and non-reproducing animals exist depending on habitat and landscape structure (Stiebling and Schneider 1999; Good et al. 2001). Especially for badgers in large setts, two litters of two females might be possible (Diezel 1983), and several non-reproducing animals might live within large families, which utilise outlier setts in different proportions (e.g. Roper et al. 2001; Rogers et al. 2003; Sadlier et al. 2004). For these reasons, spring and summer densities have to be figured more as indices.

Additionally, in 2006, the distribution of badgers was surveyed by a nationwide questionnaire, querying badger occurrence in hunting grounds all over Germany. The questionnaire was sent to every owner, tenant or manager of private or state forest hunting grounds by the regional hunting associations and forestry offices and vice versa.

Habitat preferences for breeding dens and setts were calculated from their location compared to the availability of forest and agricultural areas within reference areas for the year 2006 (maximum participation) with Jacobs' selection index (Jacobs 1974). Dens and setts were divided into three categories: (1) natural dens, (2) artificial dens specifically constructed mostly for foxes and (3) others dens of mainly anthropogenic origin, such as culverts, bunkers, stacks of wood or straw bales.

We divided Germany into six geographical regions (GR, see Fig. 1) according to the habitat and land use mapping of the German Federal Nature Conservation Agency (BfN 2008): North-Western Lowlands (NWL), North-Eastern Lowlands (NEL), Western Low Mountain Range (WLMR), Eastern Low Mountain Range (ELMR), South-Western Low Mountain Range (SWLMR) and the German Alpine Foothills (AF). These regions and the observed years were analysed for differences in litter densities and litter size with the analysis of variance (ANOVA) function in SPSS 11 (© SPSS Inc.).

Results

The participation of reference areas and, thus, the number of surveyed dens and setts as well as observed litters changed during the years due to organisational matters (Table 1). The fox and badger are distributed all over Germany with the exception of some small gaps and subject to regionally differing densities.

Foxes occurred in every reference area; however, not every reference area reported fox litters. During the years 2003 to 2007, the densities of fox litters in Germany remained mainly stable (Fig. 1) and differed only between the years 2003 and 2006 (ANOVA, F=2.889, p=0.021). The potential minimum spring density of foxes was 0.7

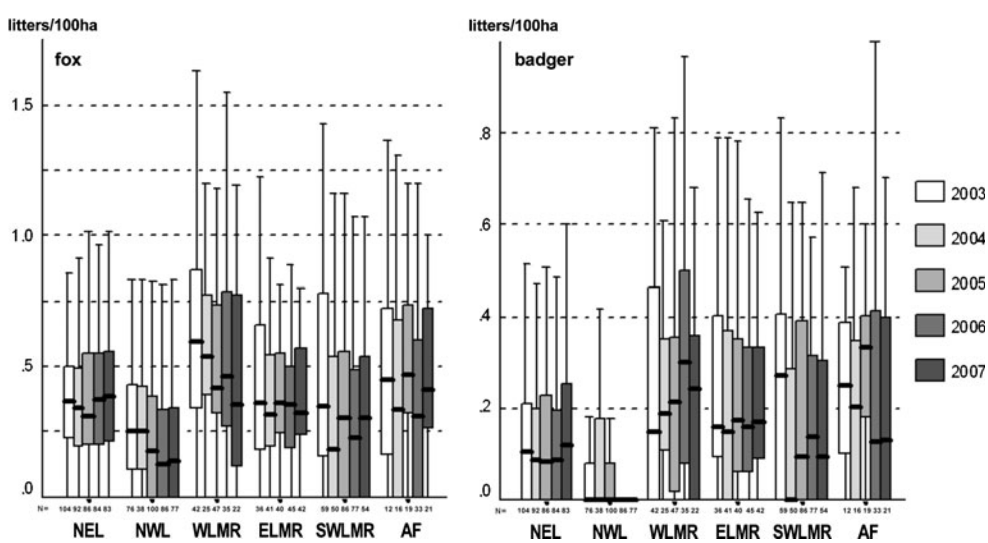

Fig. 1 Litter densities of foxes and badgers within WILD reference areas in Germany and its geographical regions 2003–2007 (for description of regions, see text). *Box* and *whisker plots* show median (*horizontal line within box*), 25% and 75% percentiles (*box*) and range (*whiskers*); statistical outliers and extreme values are excluded

Table 1 Numbers of participating reference areas, mapped dens as well as fox and badger litters in the German geographical regions during the years 2003–2007

GR		*N*	2003	2004	2005	2006	2007
NEL	RA		104	92	86	84	83
	Dens		971	937	811	819	792
	Litters	Badger	96	100	81	94	108
		Fox	306	302	274	292	285
		Both	21	10	16	26	21
		Sum	444	422	387	438	435
NWL	RA		76	38	100	86	77
	Dens		591	407	720	529	383
	Litters	Badger	25	25	34	25	33
		Fox	140	92	152	119	122
		Both	8	4	9	4	4
		Sum	181	125	204	152	163
WLMR	RA		42	25	47	35	22
	Dens		367	239	392	266	120
	Litters	Badger	37	28	46	41	25
		Fox	115	79	112	72	43
		Both	23	11	27	27	6
		Sum	198	129	212	167	80
ELMR	RA		36	41	40	45	42
	Dens		394	402	368	477	391
	Litters	Badger	59	58	52	64	58
		Fox	115	112	127	126	113
		Both	13	9	13	11	11
		Sum	200	188	205	212	193
SWLMR	RA		59	50	66	77	54
	Dens		539	248	573	480	342
	Litters	Badger	49	31	41	52	26
		Fox	115	66	107	96	83
		Both	28	8	20	23	15
		Sum	220	113	188	194	139
AF	RA		12	16	19	33	21
	Dens		90	141	187	254	182
	Litters	Badger	15	17	23	27	16
		Fox	30	33	43	50	54
		Both	2	2	8	12	8
		Sum	49	54	82	101	86
WILD total	RA		329	262	358	360	299
	Dens		2,952	2,374	3,051	2,825	2,210
	Litters	Badger	281	259	277	303	266
		Fox	821	684	815	755	700
		Both	95	44	93	103	65
		Sum	1,292	1,031	1,278	1,264	1,096

Geographical regions (GR): North-Western Lowlands (NWL), North-Eastern Lowlands (NEL), Western Low Mountain Range (WLMR), Eastern Low Mountain Range (ELMR), South-Western Low Mountain Range (SWLMR), Alpine Foothills (AF)

RA reference areas, *MD* mapped dens, *both* one litter of each species in one sett/den

(median) and 1.0 (mean) adult foxes per 100 ha, and the potential minimum summer density was 2.1 (median) and 2.7 (mean) foxes per 100 ha for Germany in 2007. The highest density within a single reference area was 7.1 adult foxes per 100 ha in spring and 20 foxes per 100 ha in summer. Fox litter densities differed slightly within the GR (Fig. 1), remaining stable in NEL and ELMR, and decreasing slightly in NWL and WLMR (n.s., p=0.175 for NWL and p=0.518 for WLMR; Fig. 1). Differences between the GR were significant every year (ANOVA, 2003, F=3.252, p=0.007; 2004, F=3.726, p=0.003; 2005, F=7.719, $p \leq 0.001$; 2006, F=6,513, $p \leq 0.001$; 2007, F=4.829, $p \leq 0.001$). Especially in NWL, litter densities were comparatively low (Fig. 2).

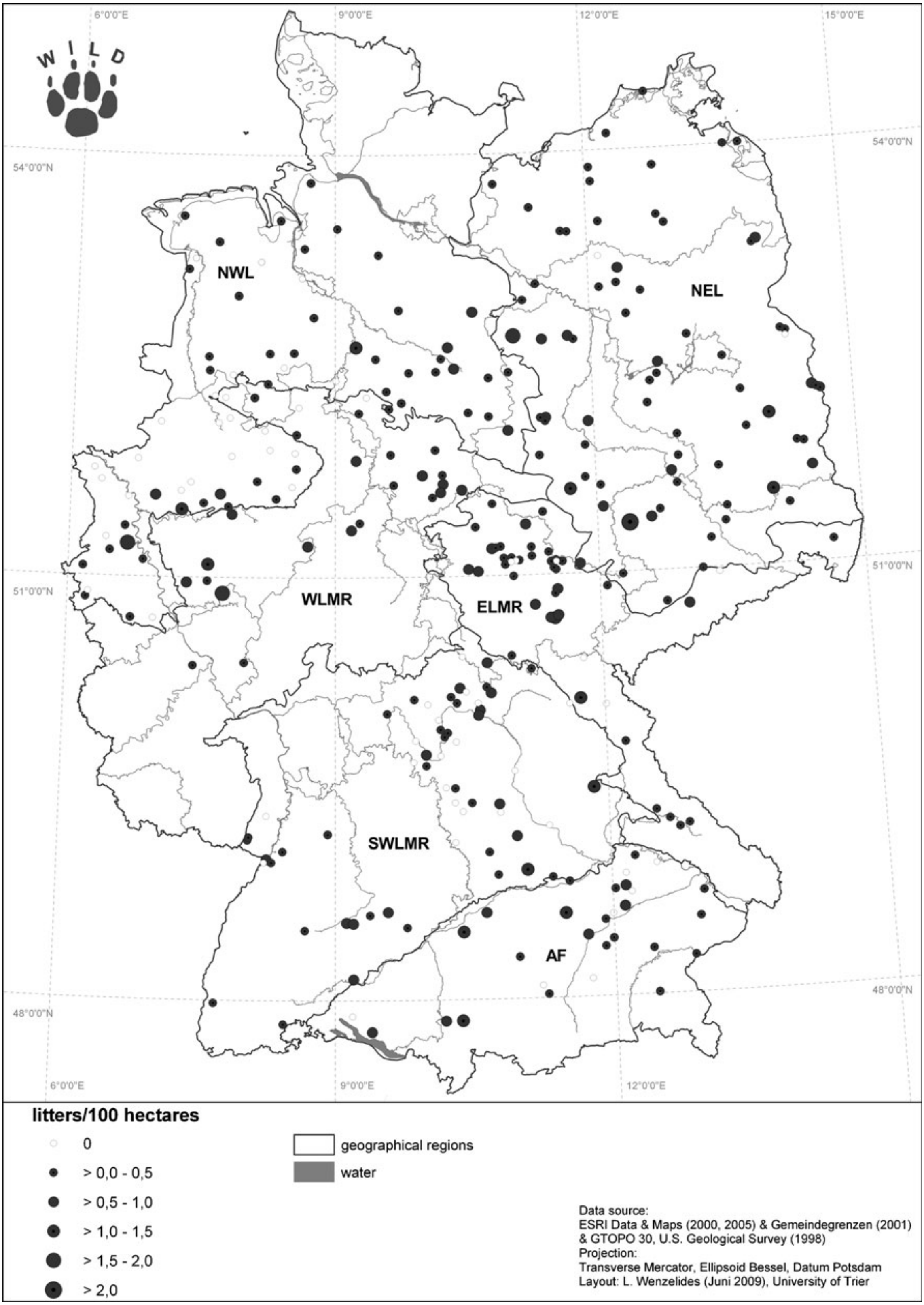

Fig. 2 Fox litter densities within the German reference areas for 2006. Geographical regions: North-Western Lowlands (NWL), North-Eastern Lowlands (NEL), Western Low Mountain Range (WLMR), Eastern Low Mountain Range (ELMR), South-Western Low Mountain Range (SWLMR), Alpine Foothills (AF). For description of geographical regions, see text

Fox cubs averaged 4.4 per litter (mean; median=4, N=1,273 litters, Fig. 3). At 9% (N=141) of the breeding dens, cubs were reported to have been killed. On average, 3.6 (median 3) cubs were shot per litter. The mean numbers of cubs per litter fluctuated during 2003–2007 around this overall average (mean, 4.21–4.49) and were not significantly different between years (ANOVA, F=1.238, p=0.293), but within the GR (ANOVA, F=4.996, $p \leq 0.001$). Litter size was higher in NWL (mean, 4.6) and ELMR (mean, 4.7) than in the other GR.

In total, 880 specified breeding dens were reported in 2006, 88.2% of which were natural dens, 6.9% artificial dens and 4.9% other dens. Analysis of locations of 610 natural breeding dens out of 220 reference areas revealed a preference for forest and habitats offering shelter (Fig. 4).

In the nationwide questionnaire of 2006, the badger was present in 93.6% of the participating (62.5%) municipal areas (Fig. 5) and in 74.7% of participating (N=31,403) hunting grounds (Fig. 5). However, in NWL, the badger occurred in far fewer hunting grounds per municipal area than in other GR (Fig. 5).

Densities of badger litters within the reference areas remained stable since 2003 (Fig. 1, ANOVA, F=0.552, p=0.698). The potential minimum spring density was 0.2 (median) and 0.4 (mean) adult badgers per 100 ha, and the minimum summer density was 0.5 (median) and 0.8 (mean) badgers per 100 ha for Germany in 2007. The highest density within one reference area was 2.4 adult badgers per 100 ha in spring and 5.9 badgers per 100 ha in summer.

Litter densities differed significantly between the GR (Fig. 1, ANOVA, F=36,974, $p \leq 0.001$); this outcome is mainly based on the distribution of badger densities (Fig. 5). Especially in NWL, litter density was low, based on a high proportion of reference areas without litters. A mean of 3.0 (median 3, Fig. 3) badger cubs were observed per litter (N=319 litters). The mean numbers of cubs per litter was similar for all GR and all years.

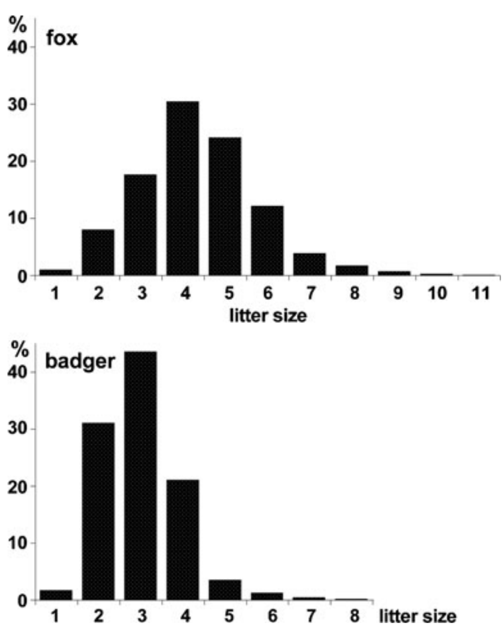

Fig. 3 Percentage (%) of occurrence of litter sizes within all observed litters for fox (N=1,273) and badger (N=319)

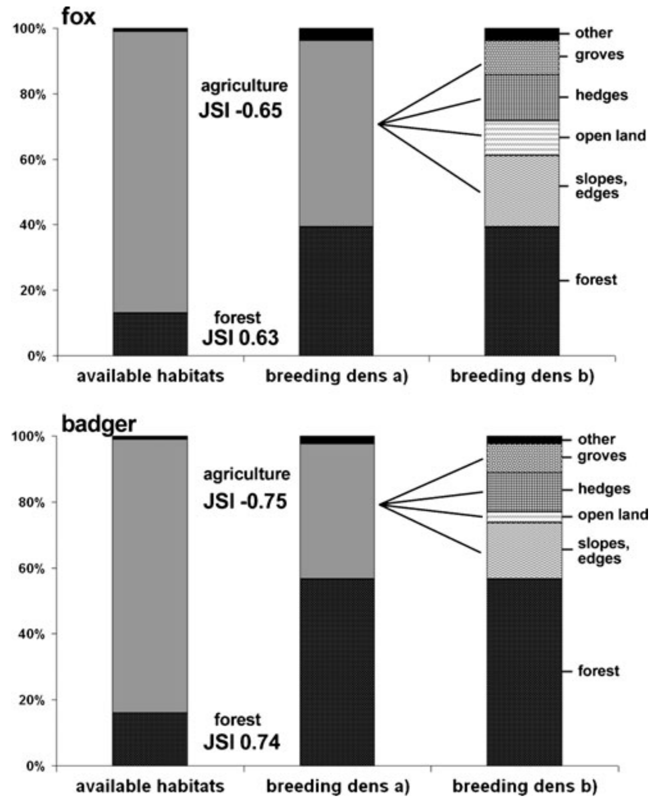

Fig. 4 Comparison of available habitats and location of breeding dens in 2006 for fox (N=220 reference areas, N=610 breeding dens) and badger (N=145 reference areas, N=297 breeding setts); JSI=Jacobs selection index, % give percentages of available area and of actual usage; in *b*, the locations of dens within agricultural habitats are defined more precisely

In 2006, 413 breeding setts were recorded with specification, 96.4% of which were natural setts, 1.9% artificial setts and 1.7% other setts of anthropogenic origin such as bunkers. The locations of 297 of the natural breeding setts out of 145 reference areas were analysed. A strong preference of forest and habitats offering shelter was clear (Fig. 4) for the natural breeding setts.

Discussion

Fox populations seem to be steady, since the litter densities were mainly stable within German WILD reference areas. However, the annual hunting bags varied much more than we would predict from our results for reproduction and fox density indices. Hence, hunting bags may depend more on hunting intensities, which are influenced by short-term

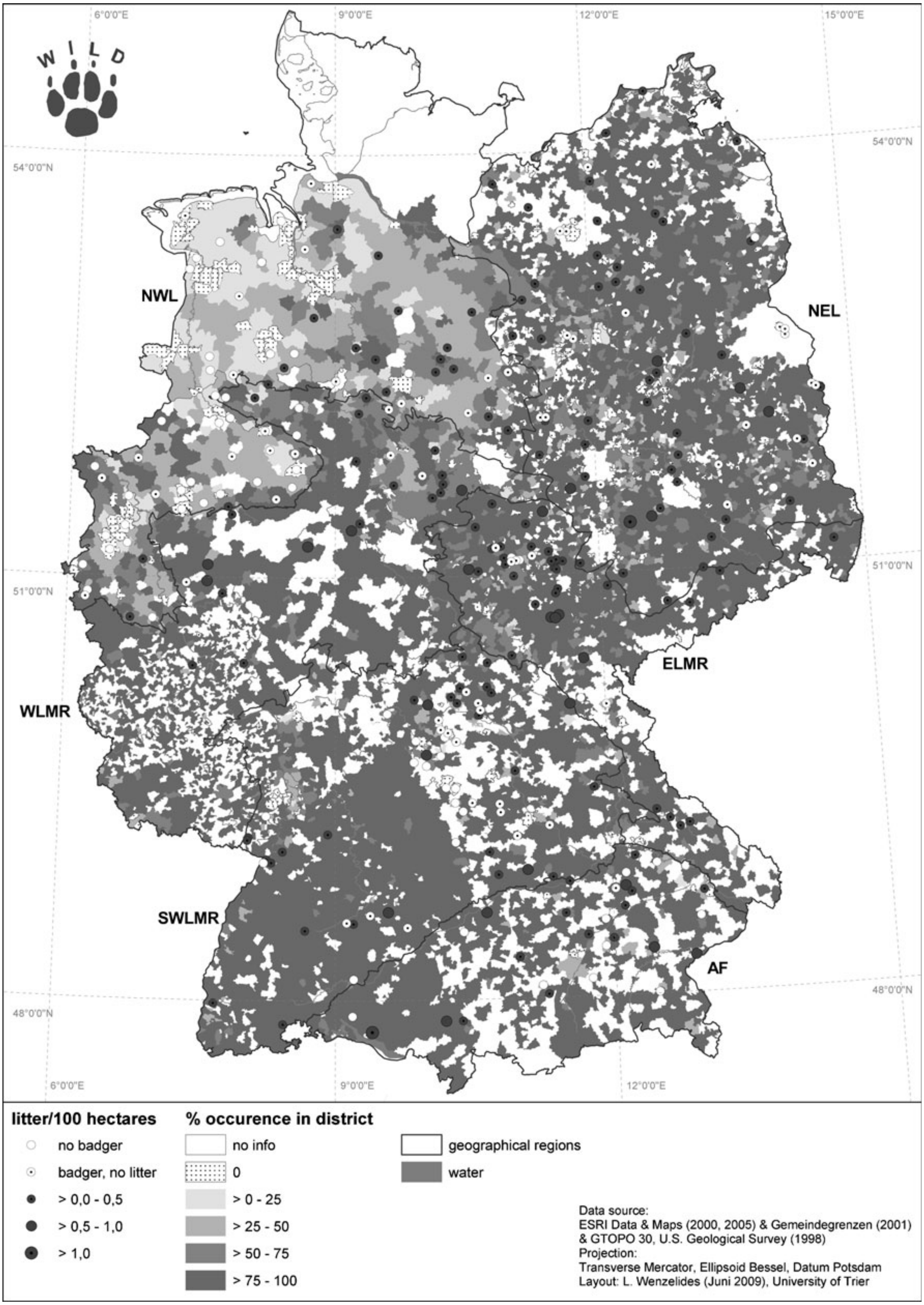

Fig. 5 Occurrence and distribution of badgers within German municipal districts (*shaded areas*) and badger litter densities within the reference areas (*circles*) for 2006. The occurrence is given in percent of hunting grounds within a municipal district. For description of geographical regions, see Fig. 2 and text

weather and other local conditions as well as individual hunter activity and fashion than is the reproductive rate (see also Cavallini and Santini 1996; Heydon and Reynolds 2000b; Selås and Vik 2006; Tryjanowski et al. 2009).

Litter size and density are supposed to belong on habitat quality (Funk 1994; Cavallini and Santini 1996; Heydon and Reynolds 2000a). The differences in fox litter density indices between geographical regions presumably reflect the biological needs of the species. The most important resource limiting the fox population in Germany seems to be the availability of suitable territories containing convenient breeding dens (Stiebling 1997; Dekker et al. 2001) and food availability (Jankowiak et al. 2008). The red fox shows a clear preference for forest and sheltering structures for breeding dens (compare also Behrendt 1955; Weber and Meia 1996). As the fox is also able to use artificial dens for parturition (in our study, about 12% of breeding dens existed of anthropogenic structures), especially in urban areas where food and den sites are much more plentiful than in forested or agricultural regions, very high densities can occur (Baker et al. 2000; Gloor et al. 2001).

The results of the nationwide badger survey are coincident with those of regional studies (e.g. Pegel 2001). Some authors have assumed that lack of forest, inappropriate soil properties and shallow groundwater are the main causes of local absence of badgers (Noack and Goretzki 1999; Sleeman et al. 2009). This hypothesis is supported by the observation of lower densities and gaps in the distribution of badgers within NWL, where these three factors, often simultaneously, occur frequently. Analysis of the locations of breeding setts confirms previous evidence of a close bond between badgers and forest or forest-like habitat (Walliser and Roth 1997). In our study, the badgers strongly preferred natural habitats and natural setts for breeding and very seldom used anthropogenic structures. The minimum habitat requirements of badgers are for grassland and shelter (Good et al. 2001; Delahay et al. 2006; Palphramand et al. 2007), plus adequate food (da Silva et al. 1993). If those key habitats and resources are sparse, fewer territories may be occupied, leading to lower population density (Doncaster 2001; Rosalino et al. 2005; Delahay et al. 2007) in continental Europe.

The badgers litter densities and indices of abundance have remained steady since 2003, corresponding to the stable hunting bags (DJV 2009) during this period. The annual hunting bag within our reference areas equals the annual German hunting bag (about 0.16 badgers per 100 ha) and, thus, amounts to only one third of the calculated reproduction. As hunting bags, as well as calculated density indices and reproduction, have been stable since 2003, we assume a high natural mortality and a high proportion of unreported traffic mortality (compare Broekhuizen and Derckx 1996).

To fit the needs of a monitoring programme, the most practicable method has to be selected, as different methods have different levels of cost–benefit ratios, i.e. accuracy and precision versus cost efficiency (Gaidet-Drapier et al. 2006; Elphick 2008; Lyra-Jorge et al. 2008; Vine et al. 2009).

Hunting bag statistics in total might be correlated with population data (Grauer and König 2009) and show relative population trends, especially when verified or exemplarily proved. However, hunting bags depend a lot on ability (weather conditions, changing hunting restrictions etc.) and willingness of hunters (Gaillard et al. 2003; Kalchreuter 2003; Keuling 2007). Additionally, hunting bags might show completely opposite or wrong trends or dimensions, especially for migratory birds (Frederiksen et al. 2004) or due to insufficient harvest rates (Grauer and König 2009). Therefore, live monitoring seems to be necessary to develop strategies for conservation and sustainable use of game populations (compare also Strauß et al. 2008).

Indirect counts by searching for field signs are more practicable at a large scale. However, pure field signs might not deliver accurate data for density estimates as often the correlations between number of signs, activity and number of individuals are not clear (Sadlier et al. 2004). Thus, indirect counts by field signs are only useful for the detection of the presence of one species but not for density estimates or reliable indices (Sadlier et al. 2004; Vine et al. 2009).

Direct census methods such as capture–mark–recapture, spotlight counts, camera trapping and radio tracking are predominantly of high quality and deliver the most accurate results, nevertheless are also very expensive and costly (Delahay et al. 2009; Grilo et al. 2009). Additionally, direct counts usually deliver insufficient data for rare or cryptic species (Heydon et al. 2000; Sadlier et al. 2004; Vine et al. 2009). Direct methods might be very useful in special cases (Delahay et al. 2009; Grilo et al. 2009) like local management programmes for cryptic, rare or endangered species even with low densities (e.g. genotyping, Frantz et al. 2004) as well as for populations causing economic problems at a regional scale. The live monitoring programme used in this study was carried out with comparably low effort and cost, while achieving its aim of providing indices of abundance (or "estimates of density") for cryptic species. Furthermore, this method is independent from factors which influence hunting bags (Gaillard et al. 2003; Kalchreuter 2003; Grauer and König 2009) and supplies minimum density numbers instead of detecting presence or absence of a cryptic species solely.

Of course, there are some disadvantages of a survey performed with local volunteers in sampling areas exclusively, e.g. there is the problem of missing data (Elphick 2008): the hunters might miss dens (Stiebling 1998). Nevertheless, the hunters, well trained in using standardised methods, deliver most reliable data as they have the knowledge of the area (compare Gaidet-Drapier et al. 2006). Although the reference areas represent only small sampling plots, the number of reference areas and the consistency of the results with other specific small scale studies (e.g. fox: Goretzki and Paustian 1982; Heydon et al. 2000; Bartón and Zalewski 2007, badger: Walliser and Roth 1997; Kowalczyk et al. 2000; Do Linh San et al. 2007) strengthen the use of litter and animal densities giving reliable trends for Germany's badger and fox populations.

As the hunters collect data voluntarily, this method is indeed restricted to countries with area-based hunting systems, where hunters hold (owned or rented) private hunting grounds. This method would not deliver reliable data without a high effort of non-local assistants in a system based on hunting licences on public game management units. The high level of variation between years within the GR might also be influenced by differing participation of reference areas (see "Materials and methods") which did not deliver data continuously every year.

The assumptions on which spring and summer densities were based contain a high degree of uncertainty (Elphick 2008), as the relationships between field signs, litter densities and individual densities are not clear. For these reasons, spring and summer densities have to be used as relative indices. To achieve more reliable individual density estimates, such large-scale indices would have to be calibrated with more accurate and precise methods. However, this is a common issue for many survey methods, such as hunting bags and field signs (compare also Palomares and Ruiz-Martinez 1994; Heydon et al. 2000; Grauer et al. 2009), and it would be worthwhile validating survey methods.

Concurrent to the hunting bag statistics (DJV 2009), the populations of badgers and foxes stayed stable at a high level. Two main key resources seem to be necessary for both species: suitable setts or dens for breeding and adequate nutrition (e.g. Baker et al. 2000; Revilla and Palomares 2001; Rosalino et al. 2005).

To summarise, den mapping and observation of litters by local hunters is an appropriate method for surveying fox and badger populations in Germany. At a large scale, this method has less effort and costs than direct counts; however, it provides live population estimates of more accuracy than hunting bags do. Additionally, direct mappings might deliver additional data on the species biology like habitat utilisation.

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