Decline of the number of occupied badger (*Meles meles*) setts in the Veluwe region (the Netherlands) and its possible causes

Hans Vink[1] & Jaap Schröder[2]

[1] Stichting Das en Boom, Rijksstraatweg 174, NL-6573 DG Beek-Ubbergen, the Netherlands, email: hansvink@kliksafe.nl

[2] Stichting Valouwe Natuur, Mecklenburglaan 9, NL-3843 BN Harderwijk, the Netherlands

Abstract: Comparison of surveys shows that the number of occupied badger (*Meles meles*) setts has declined by 42% in the past 25 years in the Central Veluwe (192 setts less) and by 15% in the Peripheral Veluwe (33 setts less). Probably this had a proportionally negative effect on the number of badgers. Concomitantly, the number of occupied 1 km² squares (km squares) has declined by 33% in the Central Veluwe (112 km squares less) and by 6% (11 km squares less) in the Peripheral Veluwe. The share of occupied km squares supporting more than one occupied sett dropped from, on average, 22 to 12%. These declines may result from diminishing supplies of food and accessibility of food for badgers. Some of the factors determining these supplies and their accessibility apply as much to the Central Veluwe as to the Peripheral Veluwe. However, long dry spells during summer, potential food competition with wild boar (*Sus scrofa*), the diminishing area of accessible manured grassland and local recreation pressure, probably have had a greater negative impact in the Central Veluwe than in the Peripheral Veluwe. The present paper proposes several measures to preserve and restore the badger population of the Veluwe.

Keywords: badger, *Meles meles*, sett, earthworms, grassland, drought, food accessibility, food competition.

Introduction

The population size of badgers (*Meles meles*) in the Netherlands hit an all-time low of around 1,500 animals in the beginning of the 1980s (Wiertz & Vink 1983). After that period their numbers started to increase as a result of re-introductions and better protection, including mitigation of traffic mortality (van Moll 2005, Dekker & Bekker 2010, La Haye & Vink 2016). The nationwide population in 2015 has been estimated at 5,000-6,000 animals, occupying around 2,000 setts (La Haye et al. 2015). Badgers have been present in the Province of Gelderland for many centuries, particularly in the Veluwe region (Vink 1985). This is confirmed by a listing of badger setts near Wageningen, Ede, Bennekom and Renkum (Ritzema Bos 1879). Moreover, there is a bounty administration In the Royal House Archives indicating the number of badgers killed in 1844 on the Royal Estate Kroondomeinen near Apeldoorn.[1]

Applicable legislation demands that the conservation status of animal species is seriously taken into account when deciding on changes in land use or land management. The Province of Gelderland recently assessed the conservation status of the badger from that

[1] Koninklijke Verzamelingen, Den Haag, Archief: Intendance van het Koninklijk Paleis en Domein Het Loo, inventarisnummer E09c-448.

perspective (Logemann 2018). His report qualifies the status of the species as 'favourable' and still considers the Veluwe a stronghold and a source from where badgers disperse. However, the report also expresses doubts about the future prospects of the badger population within the Veluwe region. This concern was also raised by badger specialists and pertains to the central part of the Veluwe in particular (Hollander & La Haye 2013, La Haye et al. 2015, van den Bosch 2015). The present paper intends to underpin this concern numerically by comparison of a recent survey of the number of occupied main setts and a similar survey that was executed 25 years ago. In this comparison a distinction was made between the central part (Central Veluwe) and the borders of the Veluwe (Peripheral Veluwe) as these two areas differ in land use and hydrology.

Materials and methods

Study area

The Veluwe region finds itself in the province of Gelderland, the Netherlands. The central part, from here on referred to as Central Veluwe, measures 1150 km^2 and is dominated by a mosaic of forests and heathlands (43%), locally larded by grassland and maize land (43%) on deeply drained dry sandy soils low in organic matter, and a relatively small amount of built-up areas (14%) (CBS Statline 2021a). Land use within the area devoted to agriculture has hardly changed between 2000 and 2015 (CBS Statline 2021b) and comprised 78% grassland, 16% silage maize and 6% arable crops. The Central Veluwe is known for its rich wildlife, among which red deer (*Cervus elaphus*) and wild boars (*Sus scrofa*), and appreciated by tourists. The Central Veluwe is defined as the area delineated by the motorways and roads A28 (Harderwijk-Hattemerbroek), A50 (Hattemerbroek-Hattem), N794 (Hattem-Apeldoorn), N786 (Apeldoorn-Dieren), A348 (Dieren-Arnhem), the northern bank of the Neder-Rijn river along the N225 (Arnhem-Wageningen), N781 (Wageningen-Ede), Ede-Lunteren-Otterlo, N310 (Otterlo-Stroe), Stroe-Veenhuizerveld and N303 (Veenhuizerveld-Harderwijk). Within the Central Veluwe two sub-regions are discerned (figure 1): the so-called Enclave westward from the village of Elspeet (denoted by a red line) which is almost entirely devoted to agriculture and the Southwest Veluwe (denoted by a brown line) finding itself between the motorway A12 (Ede-Arnhem) and the Neder-Rijn river. From both sub-regions wild boars are completely banned by fences and road grids. The Central Veluwe is adjoined by valleys in the west and east of which the total area amounts to 1040 km^2. These valleys are from here on referred to as Peripheral Veluwe. They are confined by the Veluwe Border Lakes in the northwest, the border with the Province of Utrecht in the southwest and the river IJssel in the east. Within the Peripheral Veluwe three sub-regions are discerned (figure 1): the Northwest Veluwe and the Gelderse Valley in the west and the IJssel Valley in the east. The soil type of the first two sub-regions is also mainly sandy but loamy here and there, more fertile and less prone to droughts. This applies also to the loamy and clay soils of the IJssel Valley. The Peripheral Veluwe is predominantly used for grassland and the production of silage maize amidst many villages and several cities. In our analysis we make a distinction between population trends in the (sub-regions of the) Central Veluwe and the (sub-regions of the) Peripheral Veluwe because of the differences in hydrology and land use.

Surveying method

We took the badger sett survey of van Moll (1999) executed between 1995 and 1996 as a reference for the present survey of 2019-2020. The reference survey was based on the then available locations of main setts compiled by Das & Boom (Dutch society for the protection

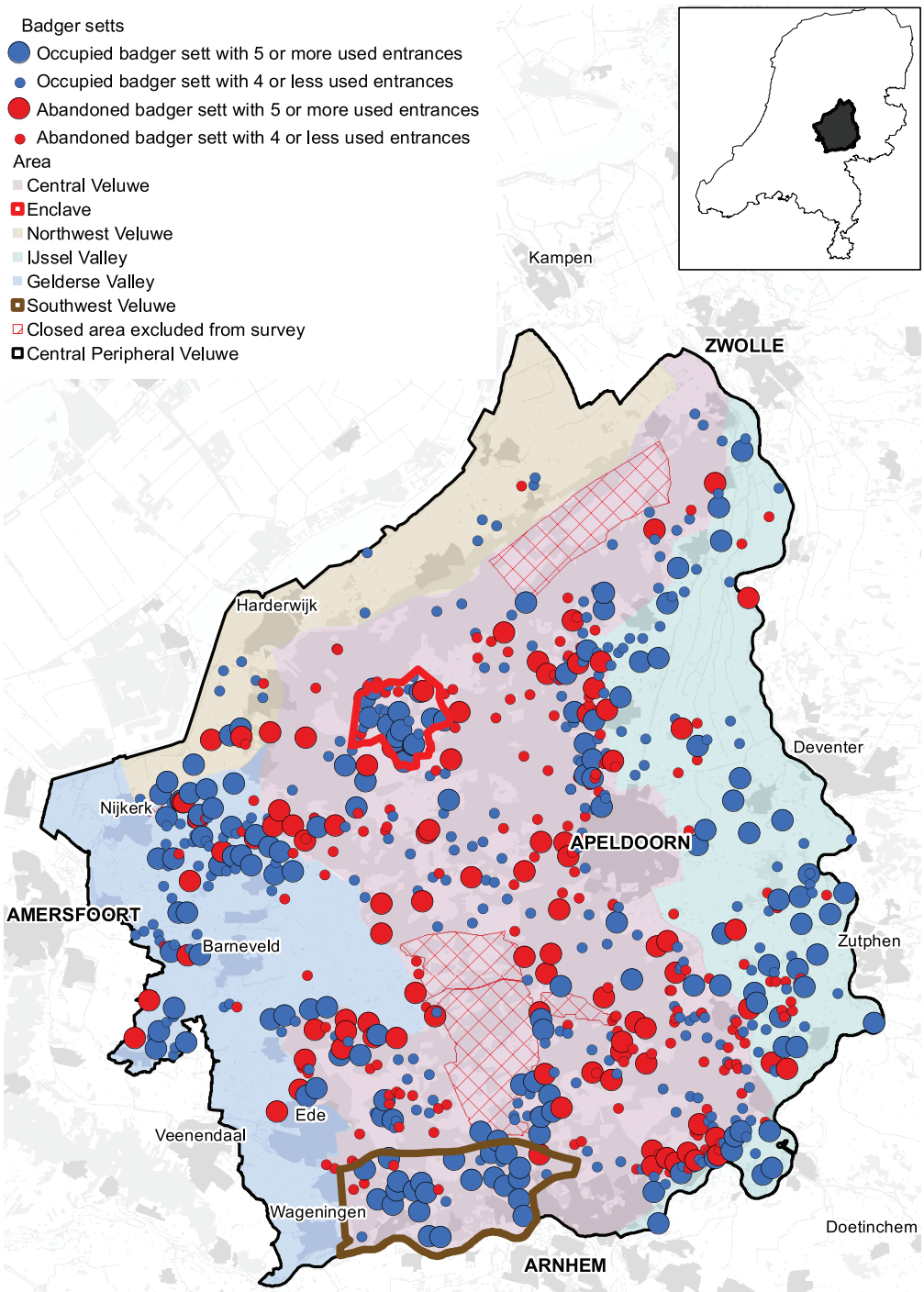

Figure 1. Occupation and abandonment of main setts of badgers (*Meles meles*), either once occupied in 1994-1996 or newly discovered between 1997 and 2020, as observed in 2019-2020 (Veluwe region, Province of Gelderland, the Netherlands.

of badgers) since 1981. Details of this survey were presented in van Moll (2005). His data set was supplemented with data based on a parallel survey of the Instituut voor Bos- en Natuuronderzoek (IBN) carried out between 1994 and 1996 (van Apeldoorn et al. 1997). For the purpose of this paper we took the number of occupied main setts as a proxy for the population size. An occupied main sett was defined as in Roper (2010), i.e. a regularly if not permanently inhabited multi-entrance sett with fresh signs of digging, traces of bedding material, foot prints, well-used tracks or latrines. Better ways to determine the exact size of a badger population are cumbersome, not in the least because of the nocturnal activity of the species. We excluded so-called subsidiary setts and outliers because of their notoriously variable state of occupation, as opposed to main setts including annexes (Roper 2010). The combined data sets of van Moll (1999) and van Apeldoorn et al. (1997) comprised 665 occupied main setts for the period 1994-1996 next to several abandoned main setts. Of these abandoned setts only three were found re-occupied in the 2019-2020 survey. Between 1997 and 2020, 46 new main setts were discovered, added to the database and included in the analysis. As opposed to the initial surveys, the present survey also recorded the size of a main sett by counting the number of open entrances, regardless whether they were in use or not. The relationship between the number of entrances and the number of inhabitants is quite weak (Roper 2010) but it may give at least an impression of possible differences between regions and be of use for future comparisons over time. We distinguished two classes of entrance numbers: main setts with at least five used entrances and main setts with at most four entrances. As in other surveys (e.g. van Moll 2005) we also expressed our findings in terms of the number and share of km squares (1 km^2) containing one or more occupied main setts. The significance of observed differences between the 1994-1996 and the 2019-2020 surveys was determined with chi-quadrat tests per region and for the Veluwe region as a whole. Significances were denoted with $_+$ and $_{***}$ for, respectively, $P<0.10$ and $P<0.01$.

Table 1. Precipitation and average daily temperature (meteorological station De Bilt) during the autumn-winter season (September-February) and the spring-summer season (March-August) during years in which the surveys were conducted.

Winter, summer	Precipitation (mm)		Temperature (°C)	
	Winter	Summer	Winter	Summer
1993-1994, 1994	n.a.[a]	447	n.a.	13.7
1994-1995, 1995	650	337	8.2	13.7
1995-1996, 1996	252	207	5.6	12.1
2018-2019, 2019	n.a.	423	n.a.	14.3
2019-2020, 2020	585	308	8.6	14.3
Normal winter, normal summer[b]	445	391	7.0	13.3

[a]not applicable

[b]1981-2010

Unfortunately we did not get permission to visit and check setts in the National Park Hoge Veluwe (Central Veluwe, 55 km squares), the military training grounds of 't Harde (Central Veluwe, 20 km squares) and De Harskamp (Central Veluwe, 14 km squares), the private Deelerwoud (Repelaer) Estate (Central Veluwe, 6 km squares) and the Salentein Estate (Peripheral Veluwe, 2 km squares). These omitted km squares represented 8% of the Central Veluwe and less than 0.2% of the Peripheral Veluwe.

Due to their laboriousness, region-wide surveys can only be carried out periodically. Therefore, collected data are based on snap shots and can be affected by weather-induced factors, bearing in mind that even a main sett might be temporarily left during dry and hot summers. For this reason the checking of badger setts has been carried out entirely outside the summer-season. Therefore, the combination of high temperatures and droughts as, for instance, in the summer of 2020 (table

Table 2. Number of main setts of badgers in the Veluwe region occupied in 1994-1996 (van Apeldoorn et al. 1997, van Moll 1999), newly discovered and re-occupied in 1997-2020, occupied in 2019-2020 and abandoned between 1994-1996 and 2019-2020.

Region	Sub-region[a]		Old surveys 1994-1996	Newly discovered and re-occupied 1997-2020	Present survey 2019-2020	
	Name	Total km²	Occupied setts	Occupied setts	Occupied setts	Abandoned setts
Central Veluwe	Enclave	39	31	0	24	7
	Southwest Veluwe	104	24	6	27	3
	Remainder Central Veluwe	1003	397	5	209	193
	Sub-total	1146	452	11	260 ***	203
Peripheral Veluwe	Gelderse Valley	351	107	13	83	37
	Northwest Veluwe	238	22	2	22	2
	IJssel Valley	449	84	23	75	32
	Sub-total	1038	213	38	180 *	71
TOTAL		2184	665	49	440 ***	274

[a]see figure 1 for exact locations

1) will not have affected our findings.

We had access to a subset of nine main setts situated around the village of Buurlo in the Central Veluwe, that has been surveyed annually between 1980 and 2020 in a similar way. This subset was used to test whether the observed changes could have been coincidental or reflecting a consistent trend. Regression analysis was used to assess the significance of observed changes around Buurlo.

Results

A map showing the checked setts (figure 1) indicates that the occupation status has changed considerably. Particularly in the Central Veluwe many of the once occupied main setts were abandoned in 2019-2020, but less so in the subregions Enclave and Southwest Veluwe. The decline of occupied setts also occurred in the Peripheral Veluwe, however. Of the 665 setts that qualified as occupied main setts in 1994-1996 a total of 274 appeared to be abandoned in 2019-2020. This loss was compensated by in total 49 main setts that were either re-occupied (3) or discovered (46). The latter occurred particularly in the IJssel Valley (table 2). The relative net loss amounted to 42% in the Central Veluwe and 15% in the Peripheral Veluwe. An annual survey of 9 setts around Buurlo (Central Veluwe) shows a consistent downward trend ($P<0.05$) over time (figure 2) and suggests that the observed decline in the Veluwe region as a whole is not just determined by two arbitrary points in time as implied by figure 1. The reduction of the number of setts was accompanied by a reduction of the number of occupied km squares, absolute losses being greatest and significant ($P<0.01$) in the Central Veluwe (table 3). Relative losses amounted to 33% in the Central Veluwe and 6% in the Peripheral Veluwe. Nevertheless, the share of occupied km squares remained slightly higher in the Central Veluwe than

Table 3. Number of km squares with main setts of badgers in the Veluwe region occupied in 1994-1996 (van Apeldoorn et al. 1997, van Moll 1999), newly occupied and re-occupied in 1997-2020, occupied in 2019-2020 and abandoned between 1994-1996 and 2019-2020.

Region	Sub-region[a]		Old surveys 1994-1996	Newly discovered and re-occupied 1997-2020	Present survey 2019-2020	
	Name	Total km²	Occupied km squares	Occupied km squares	Occupied km squares	Abandoned km squares
Central Veluwe	Enclave	39	22	0	18	4
	Southwest Veluwe	104	23	6	26	3
	Remainder Central Veluwe	1003	296	3	185	114
	Sub-total	1146	341	9	229 ***	121
Peripheral Veluwe	Gelderse Valley	351	82	11	72	21
	Northwest Veluwe	238	18	2	16	4
	IJssel Valley	449	70	22	71	21
	Sub-total	1038	170	35	159 *	46
TOTAL		2184	511	44	388 ***	167

[a]see Figure 1 for exact locations

in the Peripheral Veluwe. Within the Central Veluwe region the Enclave and Southwest Veluwe were least affected (table 4). The share of occupied km squares containing just one main sett increased from 78% to 88% (table 5). Most setts had four used entrances or less. Small setts seemed, on average, as often abandoned as the larger setts (table 6).

Discussion

General

Comparison of the 2019-2020 survey and the 1994-1996 survey indicates that the number of occupied main setts, the number of occupied setts per occupied km square, and the number of occupied km squares has declined drastically during the last 25 years, particularly in the Central Veluwe. The risk of becoming abandoned appeared as great for setts with many open entrances as for setts with fewer entrances, considering the comparable shares of large setts among both occupied and abandoned setts in the 2019-2020 survey. However, entrances of abandoned setts may partly have collapsed in the course of years and the number of entrances can thus initially have been greater. That could mean that the true share of large setts has been greater among abandoned setts than among setts that are still occupied, implying that it is not the marginal sett that is particularly at risk of becoming lost. The fraction of km squares with at least one occupied main sett in the Veluwe region as a whole dropped from, on average, 0.23 in 1994-1996 to 0.18 in 2019-2020. Note that this is much lower than the 0.40 reported by van Moll (1999) for 1995-1996. However, van Moll expressed the occupation of km squares as a fraction of the cells with habitat that he considered suitable, whereas we expressed it as a fraction of the total area. Our analysis shows that the number of occupied main setts has decreased slightly more than the number of km squares with an occupied main sett. The vast majority of occupied km squares con-

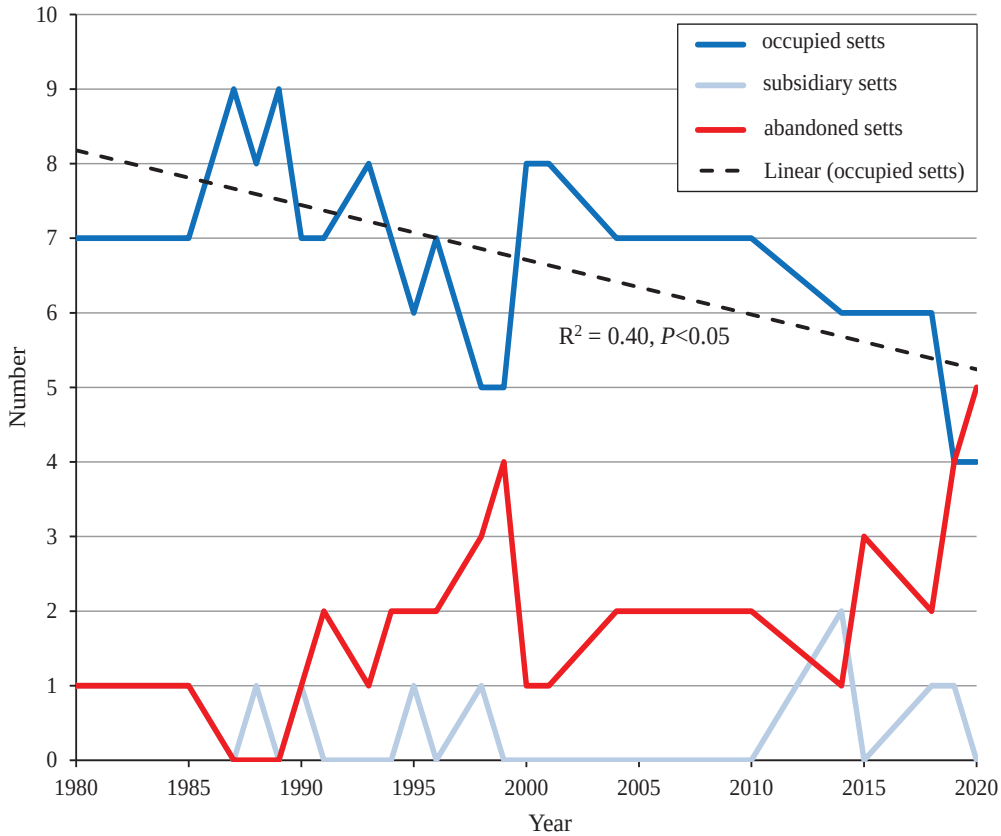

Figure 2. Long-term monitoring of the typology of nine setts around Buurlo, Central Veluwe.

tained only one occupied main sett nowadays as was the case 25 years ago, suggesting that the size of a badger territory in the Veluwe region was and still is generally at least 100 hectares and often more. That confirms what Mulder et al. (2015) consider typical for drier environments. Abandonment of initially occupied setts was slightly compensated by the discovery of setts that were not known before. Theoretically, these newly discovered setts might have been already existing 25 years ago. In that case the relative declines are even greater. Surely there must have been some main setts in 1994-1996 that have not been discovered until the present day, implying that the true relative declines are smaller rather than greater. However, this error is probably very small, bearing in mind the dense network of dedicated observers in the Veluwe region who all submit their findings to the database of Das & Boom.

The observed changes call for a closer look at possible explanations and measures to stop the decline. As for explanations, the availability of food, the accessibility of food sources, disturbance and non-natural mortality seem potential factors. The following sections explain why some of these factors may have had a greater negative impact in the Central Veluwe than in the Peripheral Veluwe. As for the measures, it must be emphasised that interventions favouring one aspect, in this case the wellbeing of badgers, are not necessarily in favour of other biota or welcomed by other land users (e.g. Schröder et al. 2020). Decisions on measures are, as such, nothing but a matter of political preferences.

Table 4. Fraction of km squares containing one or more occupied badger setts in 1994-1996 (van Apeldoorn et al. 1997, van Moll 1999) and in 2019-2020, and the relative change (%) over time.

Region	Sub-region[a]		Fraction of occupied km squares in:		Relative change over time (%)
	Name	Total km^2	1994-1996	2019-2020	
Central Veluwe	Enclave	39	0.56	0.46	-18
	Southwest Veluwe	104	0.22	0.25	-14
	Remainder Central Veluwe	1003	0.30	0.18	-40
	Sub-total	1146	0.30	0.20	-33
Peripheral Veluwe	Gelderse Valley	351	0.23	0.21	-9
	Northwest Veluwe	238	0.08	0.07	-13
	IJssel Valley	449	0.16	0.16	0
	Sub-total	1038	0.16	0.15	-6
TOTAL		2184	0.23	0.18	-22

[a]see Figure 1 for exact locations

Availability of food

Analysis of the content of stomachs and excrements reveals that the diet of badgers in the Netherlands consists for at least one third of earthworms, surface dwelling *Lumbricus* spp. in particular (Wansink et al. 1995, Mos et al. 2014, van Bommel et al. 2015). Because of this preference for earthworms, badgers tend to live close to agricultural land (Kruuk 1989). One hectare of grassland may contain around 700 kilograms of earthworms. The supply in arable land is often 80% less (Mos et al. 2014, van Eekeren et al. 2014). In forests the relative presence may even be 90% less, whereas earthworms are virtually absent under heather. The dependence on earthworms puts the forested Central Veluwe hence *a priori* in a disadvantaged position. Awaiting the results of an ongoing survey in various kinds of habitats across the Netherlands (Rutgers et al. 2009), it is yet unclear whether and where earthworm densities have declined over the past few decades. Such a decline cannot be fully ruled out as earthworms are sensitive for drought, heavy metals, organic micro-pollutants, veterinary medicine residues, acidification and a low base saturation of the soil adsorption complex (Butter 1990, Ma 1990, Kerkhofs et al. 1993, Klok et al. 1998, Klok 2004, Rutgers et al. 2008, van Eekeren et al. 2008, Usmani & Kumar 2015, Lahr et al. 2017, De Vries et al. 2019). As for the incidence of droughts it must be noted that the precipitation deficit between April and September has increased by, on average, 86 mm from 2000 to 2019 but not yet statistically significant due to considerable differences between separate years (KNMI 2020). In dry soils earthworms withdraw to deeper layers and may thus have become less available for badgers, particularly where soils tend to dry out easily as when soils are sandy.

Table 5. Distribution (%) of the number of occupied setts per occupied km square in 1994-1996 (van Apeldoorn et al. 1997, van Moll 1999) and in 2019-2020.

	Number of occupied setts	Old surveys 1994-1996	Present survey 2019-2020
Km squares with	1	78	88
	2	17	11
	3	3	1
	4	2	0

Table 6. Share (%) of setts with five or more open entrances in the 2019-2020 survey.

Region	Sub-region[a]	Share (%) of setts with 5 or more entrances used	
		Occupied setts	Abandoned setts
Central Veluwe	Enclave	54	29
	Southwest Veluwe	78	50
	Remainder Central Veluwe	22	32
	Sub-total	30	32
Peripheral Veluwe	Gelderse Valley	43	47
	Northwest Veluwe	28	50
	IJssel Valley	47	19
	Sub-total	43	35
TOTAL		35	33

[a]see Figure 1 for exact locations

The acidification of soils in the Netherlands still goes on, be it slowly, despite the drop in acidifying atmospheric deposition (Compendium voor de Leefomgeving 2020).

The presence of earthworms is not only determined by the above factors but as much by the provision of organic matter through crop residues and manures (Blakemore 2018, Onrust & Piersma 2019, Ros et al. 2020). Earthworms need something to eat, after all. The application of manure on sandy soils in the Netherlands has dropped by 15% between 2000 and 2015 (CBS Statline 2020a, Schröder & Neeteson 2008, CDM 2017). The lower input of organic matter might have had a negative effect on the presence of earthworms in arable land in particular. The provision of organic matter is less of a limiting factor in grassland due to the inherently extensive turn-over of grass roots, but even there inputs of organic matter through manuring stimulate the presence of earthworms (Onrust et al. 2019). Other management factors of grassland may have an impact on the availability of earthworms for badgers as well. It is much easier for badgers to acquire surface dwelling earthworms in short swards, as is the case when grasslands are regularly grazed. The extent to which grasslands are grazed instead of cut, has decreased. Consequently, the amount of dung pats per hectare in Gelderland has also dropped by circa 60% in between 2000 and 2015 (CBS Statline 2020b). Dung pats are appreciated by badgers as a source of earthworms and insects (Roper 2010).

Less grazing means that a greater share of the excrements is collected indoors and mechanically applied as slurry. From the late 1990s this slurry must be applied by injection into the grassland sods or top soil. Research has indicated that injection is not more harmful to earthworms than the former surface application of slurry (Huijsmans et al. 2008, Thissen 2018, Ros et al. 2020). The type of manure, however, is quite decisive as the input of organic matter per unit plant nutrient is much greater in farmyard manures than in slurries (den Boer et al. 2012, Onrust & Piersma 2019, Ros et al. 2020). The almost full transition from farmyard manure-based systems to slurry-based systems was already completed in the 1970s, however, and this disqualifies the abandonment of farmyard manure as an explanation for the recent decline of the number of occupied badger setts in the Veluwe region.

Until the beginning of this century badgers will undoubtedly have benefited from feeding practices of gamekeepers in the Central Veluwe in support of red deer and wild boar. This complementary feeding has been legally banned now. The summer population

of wild boar has nevertheless almost doubled between 1995 and 2019 and amounts to almost four times more than the official management target (Spek 2019). It cannot be ruled out that badgers living in forested areas such as the Central Veluwe have to compete with wild boars for the same sources of food (Massei et al. 1996, Payne et al. 2013, Groot Bruinderink 2016, La Haye & Vink 2016). It is noteworthy that the Southwest Veluwe, a region just as forested as the remainder of the Central Veluwe but where wild boars are banned, shows no decline in the number of badger setts. This observation may serve as circumstantial evidence for the negative impact that wild boars may have.

From the above observations several interventions can be inferred to improve the food supply for badgers. Liming of soils may improve the living conditions for earthworms and soil fauna in general (Springett & Syers 1984). Similar results were recently obtained with high dose applications of ground stone meal (de Vries et al. 2019). More attention is also needed for the addition of organic matter to arable land. This can increase the presence of earthworms as well, particularly in combination with reduced tillage (Briones & Schmidt 2017). The availability of food for badgers is also enhanced by substituting grazing for cutting and farmyard manure for slurry. Halting the conversion of manured grassland to completely unfertilised 'natural' grassland, a conversion advocated in favour of the botanical diversity, can understandably also have a positive effect on the food supply for badgers. Last but not least, it seems plausible that a more stringent control of the numbers of wild boar might also improve the carrying capacity of the Central Veluwe for badgers.

Accessible hectares

Total food supplies are not just determined by the food supply per hectare but also by the total number of hectares and, obviously, their accessibility. The area under agriculture in the Veluwe region decreased by 5% (42 km^2) between 1996 and 2015, mainly in favour of the area devoted to roads, buildings and recreation (CBS Statline 2021a). The return of the wolf (*Canis lupus*) to the Veluwe from 2018 (Lelieveld et al. 2021) and the official designation of most of the Central Veluwe as a wolf area may further limit the accessibility of the remaining grassland for badgers now that farmers install wolf-averting fences in addition to wild boar-averting fences. These measures are unnecessarily denying badgers access to feeding grounds unless fences near setts would from now on be perforated with 0.3 m wide tubes (figure 3) allowing only badgers to pass. Accessibility of additional food sources can of course also be improved by the provision and maintenance of sufficient cover by hedgerows and re-wilded field edges.

Figure 3. PVC tube, 0.3 m diameter, across a fence enabling badgers to visit their feeding grounds. *Photo: Hans Vink*.

The accessibility of food might also have been deteriorated by a greater human disturbance. Recreation pressure in the Central Veluwe has increased considerably during the last 25 years (e.g. Bijlsma 2006, Provincie Gelderland 2017). This may have had a negative effect on the required peace and quietness near some of the setts and the routes of the badgers to their feeding grounds, especially at the borders of the Central Veluwe where recreational activities tend to concentrate and during summer when the time window for

Badger cubs. *Photo: Michiel Schaap*.

feeding in the dark is short. Awareness about it has recently lead to the intended decision to divert recreation from particular areas in the Veluwe region (Provincie Gelderland 2020b).

Disturbance and non-natural mortality

Traffic is still the major cause of mortality among badgers in the Netherlands (Dekker & Bekker 2010, Mulder et al. 2015). Traffic intensity increased by 13% in the province of Gelderland between 2000 and 2019 (Provincie Gelderland 2020a). Construction of new fauna passages and the maintenance of existing ones is therefore needed more than ever, as well as a decision to limit the permitted speed during nightly hours wherever relevant. Note that such measures become more urgent once food supplies diminish. Badgers have to increase their home range then and may have to cross more roads than before to take-in sufficient food.

The survival rate of badgers is of course also served by adequate control of illegal prosecution. There is a growing resentment among farmers that they have to adjust their management for the sake of nature conservation. Unfortunately, badgers and the damage they inflict to crops have become one of the symbols of this societal pressure in some regions (Thissen et al. 2020). This may particularly pertain to regions where farming and nature conservation are competing for space, such as in the Veluwe region.

Conclusion

The number of occupied badger setts in the Veluwe region has declined by 42% in the Central Veluwe during the last 25 years and by 15% in the Peripheral Veluwe. This development may result from a decrease of food supplies and accessibility of these supplies.

Acknowledgements: The present analysis would not have been possible without the meticulously administered database of badger setts by the staff and vol-

unteers of Das & Boom (www.dasenboom.nl). The authors also wish to thank all land-owners who gave us permission to check badger setts on their properties, among which Vereniging Natuurmonumenten, Staatsbosbeheer, Geldersch Landschap & Kasteelen, Koninklijke Houtvesterijen Het Loo and Landgoed Leuvenum. We are grateful to Andries Huibers (Staatsbosbeheer) for his assistance with the preparation of the map and Marc Moonen (Das & Boom) and two anonymous reviewers for their helpful comments and suggestions on drafts of this paper.

References

Blakemore, R.J. 2018. Critical decline of earthworms from organic origins under intensive, humic COM depleting agriculture. MDPI Soil Systems: 2-33.

Briones, M.J.I. & O. Schmidt 2017. Conventional tillage decreases the abundance and biomass of earthworms and alters their community structure in a global meta-analysis. Global Change Biology 23: 4396–4419.

Butter, M. 1990. Dassen, verzuring en regenwormen. Rapport 28. Biologiewinkel Rijksuniversiteit Groningen, Groningen, the Netherlands.

Bijlsma, R.G. 2006. Effecten van menselijke verstoring op grondbroedende vogels van Planken Wambuis. De Levende Natuur 107 (5): 191-198.

CBS Statline 2020a. Dierlijke mest en mineralen; productie, transport en gebruik. Https://opendata.cbs.nl/statline/#/CBS/nl/dataset/7311SLMI/table?ts=1612770266368

CBS Statline 2020b. Dierlijke mest; productie, mineralenuitscheiding; bedrijfstype regio. Https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83983NED/table?ts=1612770467083

CBS Statline 2021a. Regionale Kerncijfers; Veluwe. Https://opendata.cbs.nl/#/CBS/nl/dataset/70072ned/table?searchKeywords=bebouwd%20terrein

CBS Statline 2021b. Landbouw, gewassen, grondgebruik; Veluwe. Https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80783ned/table?ts=1617787123965

CDM 2017. Advies 'Stijging gewasopbrengsten en stikstofgebruiksnormen'. Https://www.wur.nl/upload_mm/3/5/4/7d4005bd-d85c-4533-9709-f8f1e307f59f_1716206_Oene%20Oenema%20bijlage%201.pdf

Compendium voor de Leefomgeving 2020. Geschiktheid zuurgraad bodem verzuringsgevoelige landnatuur, 2018. Https://www.clo.nl/indicatoren/nl1593-kwaliteit-verzuringsgevoelige-ecosystemen?ond=20899

Dekker, J.J.A. & G.A. Bekker 2010. Badger (*Meles meles*) road mortality in the Netherlands: the characteristic of victims and the effects of mitigation measures. Lutra 53 (2): 81-92.

den Boer, D.J., J.A. Reijneveld, J.J. Schröder & J.C. van Middelkoop 2012. Mestsamenstelling in Adviesbasis Bemesting Grasland en Voedergewassen. Rapport 1. CBGV, Wageningen, the Netherlands.

de Vries, W., M.J. Weijters, J.J. de Jong, S.P.J. van Delft, J. Bloem, A. van den Burg, G.A. van Duinen, E. Verbaarschot & R. Bobbink 2019. Verzuring van loofbossen op droge zandgronden en herstelmogelijkheden door steenmeeltoediening. Rapport OBN229-DZ. Vereniging van Bos- en Natuurtereineigenaren, Driebergen, the Netherlands.

Groot Bruinderink, G.W.T.A. 2016. Wild zwijn. In: S. Broekhuizen, K . Spoelstra, J.B.M. Thissen, K.J. Canters & J.C. Buys (eds). Atlas van de Nederlandse Zoogdieren: 288-290. Zoogdiervereniging / Naturalis, Nijmegen / Leiden, the Netherlands.

Hollander, H. & M. La Haye 2013. Dassenschade en -preventie. Rapport 2013.001. Zoogdiervereniging, Nijmegen, the Netherlands.

Huijsmans, J.F.M., J.J. Schröder, G.D. Vermeulen, R.G.M. de Goede, D. Kleijn & W.A. Teunissen 2008. Emissiearme toediening: ammoniakemissie, mestbenutting, nevenaspecten. Rapport 195. Wageningen UR, Wageningen, the Netherlands.

Kerkhofs, M.J.J., W. Silva & W. Ma 1993. Zware metalen en organische microverontreinigingen in bodem, regenwormen en dassen in het winterbed van de Maas bij Grave. RIZA, Arnhem, The Netherlands.

Klok, T.C. 2004. Effecten van zware metalen op de das. Informatieblad 384/396.01. Wageningen UR, Wageningen, the Netherlands.

Klok, C., A.M. de Roos, S. Broekhuizen & R.C. van Apeldoorn 1998. Effecten van zware metalen op de das: interactie tussen versnippering en vergiftiging. Landschap 15 (2): 77-86.

KNMI 2020. Daggegevens van het weer in Neder-

land. Http://projects.knmi.nl/klimatologie/daggegevens/selectie.cgi

Kruuk, H. 1989. The social badger: ecology and behaviour of a group-living carnivore (*Meles meles*). Oxford University Press, Oxford, UK.

La Haye, M., F. van Bommel & S. Vreugdenhil 2015. Verspreiding en aantallen. In: F. van Bommel, S. Vreugdenhil & M. La Haye (eds). De Das: 34-43. KNNV, Zeist, the Netherlands.

La Haye, M. & J. Vink 2016. Das *Meles meles*. In: S. Broekhuizen, K. Spoelstra, J.B.M. Thissen, K.J. Canters & J.C. Buys (eds). Atlas van de Nederlandse Zoogdieren: 244-246, Zoogdiervereniging / Naturalis, Nijmegen / Leiden, the Netherlands.

Lahr, J., E.L. Wipfler, N. Bondt, T. de Koeijer, B. Berendsen, P. Hoeksma, L. van Overbeek & D.J. Mevius 2017. Aanzet tot milieuprioritering van diergeneesmiddelen uit dierlijke mest. Water Matters*: Knowledge Journal for Water Professionals 7* (11): 8-11.

Lelieveld, G., J. Gouwy & K. van den Berge 2021. De terugkeer van de wolf in een volgende fase. De wolvenwelpen van de Lage Landen. Zoogdier 32 (1): 13-15.

Logemann, D. 2018. De Staat van Instandhouding: fact sheets voor 25 soorten in Gelderland. Arcadis, Arnhem, the Netherlands.

Ma, W. 1990. Bioaccumulatie en effecten van schadelijke stoffen in het terrestrisch milieu, biomonitoring met regenwormen. De Levende Natuur 91 (4): 168-172.

Massei, G., P.V. Genov & B.W. Staines 1996. Diet, food availability and reproduction of wild boar in a Mediterranean coastal area. Acta Theriologica 41 (3): 307-320.

Mos, J., I.M.A. Heitkönig & S.E. van Wieren 2014. The spring diet of badgers in two contrasting habitats in the Netherlands. Lutra 57 (1): 17-24.

Mulder, J., F. van Bommel & H. Hollander 2015. Ecologie. In: F. van Bommel, S. Vreugdenhil & M. La Haye (eds). De Das: 14-33. KNNV, Zeist, the Netherlands.

Onrust, J. & T. Piersma 2019. How dairy farmers manage the interactions between organic fertilizers and earthworm ecotypes and their predators. Agriculture, ecosystems and environment 273: 80-85.

Onrust, J., E. Wymenga & T. Piersma 2019. Rode regenwormen: sleutelspelers voor boerenlandbiodiversiteit. De Levende Natuur 120 (4): 145-148.

Payne, A., L. Millet, J. Hars & B. Dufour 2013. Interactions between wild boar, badgers and cattle in Cote d'Or: which opportunity for the transmission of Mycobacterium bovis? Epidemiologie et santé animale 63: 77-92.

Provincie Gelderland 2017. Beheerplan Natura 2000 Veluwe (057). Provincie Gelderland, Arnhem.

Provincie Gelderland 2020a. Verkeer. Https://www.gelderland.nl/GeldersVerkeer

Provincie Gelderland 2020b. Plan van Aanpak Recreatiezonering Veluwe. Provincie Gelderland, Arnhem, the Netherlands.

Ritzema Bos, J. 1879. Landbouwdierkunde. Nuttige en schadelijke dieren van Nederland. Eerste deel. Wolters, Groningen, the Netherlands.

Roper, T.J. 2010. Badger. Collins, London, UK.

Ros, M.B.H., A.G.M. Schotman & T. Visser 2020. Effecten van mesttoediening op regenwormen als voedsel voor weidevogels. Commissie Deskundigen Meststoffenwet, Wageningen, the Netherlands.

Rutgers, M., C. Mulder, A.J. Schouten, J. Bloem, J.J. Bogte, L. Brussaard, R.G.M. de Goede, J.H. Faber, G.A.J.M. Jagers op Akkerhuis, H. Keidel, G.W. Korthals, F.W. Smeding, C. ter Berg & N. van Eekeren 2008. Soil ecosystems profiling in the Netherlands with ten references for biological soil quality. Report 6076040009/2008. RIVM, Bilthoven, the Netherlands.

Rutgers, M., T. Schouten, J. Bloem, E. Buis, W. Dimmers, N. van Eekeren, R.G.M. de Goede, G.A.J.M. Jagers op Akkerhuis, H. Keidel, G. Korthals, C. Mulder & E.J.W. Wattel Koekoek 2009. Een indicatorsysteem voor ecosysteemdiensten van de bodem. RIVM Report 2014-0145. RIVM, Bilthoven, the Netherlands.

Schröder, J.J. & J.J. Neeteson 2008. Nutrient management regulations in The Netherlands. Geoderma 144 (3-4): 418 – 425.

Schröder, J.J., H.F.M. ten Berge, F. Bampa, R.E. Creamer, J.V. Giraldez-Cervera, C.B. Henriksen, J.E. Olesen, M. Rutgers, T. Sandén & H. Spiegel 2020. Multi-functional land use is not self-evident for European farmers: a critical review. Frontiers in Environmental Science, 18 September 2020. Https://doi.org/10.3389/fenvs.2020.575466

Spek, G.J. 2019. Jaarrapportage Grofwild 2018-2019. Vereniging Wildbeheer Veluwe, Vaassen, the Netherlands.

Springett, J.A. & J.K. Syers 1984. Effect of pH and calcium content of soil on earthworm cast production in the laboratory. Soil Biology and Biochemistry 16 (2): 185-189.

Thissen, J. & F. van Bommel 2018. Dassen en bemesten. Van Bommel Faunawerk, Wageningen, the Netherlands.

Thissen, J., H. Blanken, F. van Bommel & H. ten Holt 2020. Evaluatie dassenovereenkomsten. Rapport project 036-19. Van Bommel Faunawerk, Wageningen, the Netherlands.

Usmani, Z. & V. Kumar 2015. Role of earthworms against metal contamination: a review. Journal of Biodiversity and Environmental Sciences 6 (1): 414-427.

van Apeldoorn, R.C., J. Verboom & W. Nieuwenhuizen 1997. DASSIM, een simulatiemodel voor de evaluatie van verkeersscenario's: calibratie en validatie. Rapport W-DWW-97-027. DLO Instituut voor Bos- en Natuuronderzoek, Wageningen / Rijkswaterstaat Dienst Weg- en Waterbouwkunde, Delft, the Netherlands.

van Bommel, F., S. Vreugdenhil & M. La Haye 2015 (eds). De Das. KNNV, Zeist, the Netherlands.

van den Bosch, H. 2016. Op zoek naar de das. Nieuwe Veluwe 2015 (3/4): 42-44.

van Eekeren, N., L. Bommelé, J. Bloem, T. Schouten, M. Rutgers, R.G.M. de Goede, D. Reheul, D. & L. Brussaard 2008. Soil biological quality after 36 years of ley-arable cropping, permanent grassland and permanent arable cropping. Applied Soil Ecology 40: 432-446.

van Eekeren, N., J. Bokhorst, J. Deru & J. de Wit 2014. Regenwormen op het melkveebedrijf. Louis Bolk Instituut, Driebergen, the Netherlands.

van Moll, G.C.M. 1999. Nederland als woongebied van de das van 1900 t/m 1995. Werkdocument IKC Natuurbeheer nr W-109. IKC, Wageningen, the Netherlands.

van Moll, G.C.M. 2005. Distribution of the badger (*Meles meles* L.) in the Netherlands, changes between 1995 and 2001. Lutra 48 (1): 3-34.

Vink, J. 1985. De Veluwe, één van de laatste bolwerken van de Das in Nederland. Het Edelhert 2: 10-13.

Wansink, D., H. Lubbers & J. Vink 1995. Het voedsel van de Gooise dassen. Zoogdier 6 (4): 3-10.

Wiertz, J. & J. Vink 1983. Inventarisatierapport over de das in Nederland 1960-1980, deel 1 Methode en resultaten, deel 2 Basisgegevens, kaartbijlagen. Rijksinstituut voor Natuurbeheer, Leersum, the Netherlands.

Samenvatting

Afname van de dassenpopulatie op de Veluwe en de mogelijke oorzaken

Uit inventarisaties blijkt dat het aantal belopen dassenburchten op de Veluwe in de afgelopen 25 jaar met 42% is gedaald in de Centrale Veluwe (192 burchten minder) en met 15% aan de randen van de Veluwe (33 burchten minder). Dit gaat zo goed als zeker gepaard met een proportionele afname van het aantal dassen. Tegelijkertijd daalde het aantal bezette kilometerhokken met 33% (112 minder bezette hokken) in de Centrale Veluwe en met 6% (11 minder bezette hokken) aan de randen van de Veluwe. Deze afnames houden mogelijk verband met een afname van het voedselaanbod en de toegankelijkheid van voedselbronnen. Een aantal factoren die dit beïnvloeden, zijn zowel in de Centrale Veluwe als in de randen van de Veluwe aan de orde. Echter, periodieke droogte, mogelijke voedselcompetitie tussen dassen en zwijnen, de omvang en toegankelijkheid van bemeste graslanden en plaatselijke recreatiedruk, hebben waarschijnlijk een sterker negatief effect gehad in de Centrale Veluwe dan in de randen. Het artikel stelt maatregelen voor waarmee de daling van het aantal belopen burchten en hun bewoners kan worden gestopt.

Received: 10 February 2021
Accepted: 24 April 2021