Dynamics of a local badger (Meles meles) population in the Netherlands over the years 1983–2001

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Abstract

Long-term data on badger population dynamics are scarce. For 19 years data on badger and sett numbers were collected by direct observation of a local population in the province of Utrecht, the Netherlands. Analysis of these data show two different patterns of population growth. The first shows a slow growth in numbers and setts and the second an exponential growth. Spatial dynamics were also analysed in combination with habitat use. The first increase showed colonisation of the entire study area by social groups. Subsequently, new groups settled at the border of the area and inbetween established group territories. Population dynamics are discussed given the many badger-friendly measures that were taken.

Key words: Meles meles, population growth, spatial expansion

Introduction

The European badger (Meles meles) is a protected species in the Netherlands. Its protection was first based on the Hunting Law (1946–1994) but later on the Nature Conservation Law and recently (2002) on the Flora–Fauna Law regulating species protection in the Netherlands. The protected status of the badger is based on nation-wide counting of setts. The first counting was carried out in the period 1957–1959 (Wijngaarden and van de Peppel 1964), further on an irregular basis till 1980 when a new census of all badger setts had been organised (Wiertz and Vink 1986). The period 1959–1980 showed a steady decline in the number of occupied badger setts, together with a decline in the total amount of suitable habitat. From 1990 a badger census based on the number of square kilometres where badger-activity was detected started every 5 years financed by the Ministry of Agriculture, Nature Management and Fisheries. The period 1990–2000 now showed a constant increase in the species distribution and the occupied square kilometres, respectively, of 635 (1990), 736 (1995) and 948 (2000) (Wiertz 1992; Moll 2002).

The main cause of the decline of the species prior to 1990 in the Netherlands seems to be the increase of roads and traffic (Zee et al. 1992). From 1988 many measures have been taken to reduce traffic mortality. Generally the increase in the species during the last
decades of the last century is believed to have resulted from these measures. However, no studies have been published in the Netherlands to underpin this believe. To be sure these measures and no other factors cause the recovery of the species, long-term data are needed on the dynamics of badger populations. Long-lasting studies on badger populations are very scarce (but see Hofmann 2000; Rogers et al. 1997, 2000; da Silva et al. 1993; Macdonald and Newman 2002) in the Netherlands with the exception of a single local population (Vink and van Apeldoorn 1995). Also at the border of the provinces of North Holland and Utrecht in the area between the towns of Hilversum and Utrecht (Fig. 1) a small and nearly totally isolated badger population is situated which increased its distribution by 50% (square kilometres grids) from 1995 onwards (Moll 2002). In this area many badger-friendly measures have been taken such as badger tunnels (18 in total), badger-proof fences and artificial setts between 1988 and 2002. In this area detailed data on mortality and reproduction have been collected by the second author and many volunteers starting in 1983. In this study the data until 2001 are used to describe and analyse the dynamics of this isolated population.

Material and methods

Study area

The study area lies between the city of Utrecht and the town of Hilversum (Fig. 1) and is situated on a soil gradient with a sandy wooded bank in the east called Utrechtse Heuvelrug and a peaty area (pastures, marshland and open water) to the west with the villages of Westbroek, Loosdrecht and Maartensdijk. The groundwater level varies from 80 cm under the field surface in the (sandy) east to 40 cm in the (peaty) west. The acidity of the soil in the area is pH 4–5 and rather low and illustrates the occurrence of acid soils. Agricultural use in the study area especially in the west is mainly of pastures and an increasing number of hectares used for growing maize-crops for cattle feeding. Grasslands are mainly used for dairy cattle and mowed usually twice a year. The study area is dissected from south to north by a railway, a motorway and a secondary road that are very close to each other and form a barrier for badgers moving from east to west.

Before 1940, the badger was assumed to be common on the sandy soils in the east part of the study area, but the species was thought to be almost totally extinct since the sixties in the whole area (Wijnegarden and van de Peppel 1964). Nevertheless in 1983 one permanently occupied badger sett was discovered in a small private woodlot just south of the country estate Einde Gooi (No. 1 in Fig. 1). Local enquiries reveal the possibility that this only sett had been occupied by badgers at least since 1975. The population in the study area has to be considered to be more or less isolated because of the long distance (about 30 km) through open landscape to the nearest area permanently inhabited by badgers. This is the most western local badger population in the Netherlands. Badger habitat does not exist to the west as the landscape is below sea level and consists mainly of wet grasslands that are unsuitable for digging setts. The core area of the studied population consists mainly of mixed and deciduous woodland. The main tree species are Oak (Quercus pubescens), Birch (Betula pendula), Rowan tree (Sorbus aucuparia) and Scotch pine (Pinus sylvestris) mixed with some pastureland. Einde Gooi is owned and managed mainly by the private nature conservation organisation “Natuurmonumenten”.

Counting badgers and setts

From 1983 badgers were counted several times each year (with a minimum of three times a year) during the period May–July. Setts were searched in the whole area suitable for digging setts and were visited at least five times a year. Other signs of badger activity (latrines, hairs, prints and tracks) and traffic victims were also collected in the field. All data were collected with the help of many volunteers (naturalists, wardens, other fieldworkers, policemen and animal-ambulance people).

Only data between 1983 and 2001 are analysed and presented. The mean number of badgers counted during the period May–July was taken as an estimation of the number of badgers present in the study area (the minimum number of badgers alive). The number of all cubs observed above ground at different setts was taken as an estimation of the reproduction.

Traffic victims registered by the dense network of volunteers were assumed to represent a high proportion of all traffic casualties in this dense human populated area. Therefore, animals killed before and during the counting period were included to the minimum number of badgers that live in the study area (Table 1).
Two types of setts (main setts and outliers) were recognised. Permanently inhabited setts (main setts) in which cubs are born or regularly observed during a year were discerned as main “breeding setts” (BR) compared to permanently used setts without reproduction (main “not breeding setts”: NBR).

Fig. 1. The study area. Dark grey=open water, wetlands and marshes. Medium grey=forested landscape sparsely occupied by houses and farms. Light grey=towns and villages. White=wet (peaty) grassland and sandy arable landscape. Circles indicate main setts with numbers giving the sequence in time they were found for the first time. Also the year is given a sett started to be permanently inhabited for the first time (main sett) and showed reproduction (M) or not (B). The dark line indicates where a railway, a motorway and a secondary road are very close to each other and cross the study area.;*=badger tunnels.
Setts only used by badgers during a short-time period were identified as “outliers”. Sett positions were taken by global position system (GPS) with a mean accuracy of 7 m.

The number of social badger groups each year was estimated according to the number of main setts and using qualitative field data (latrines). Mean group size each year was calculated as the mean number of adults per group. Mean number of cubs per litter (number of main setts) was calculated each year using the number of juveniles.

**Territories**

All spatial data was analysed using ArcView software with the Animal Movement extension. Group territories were calculated in two ways and the results were compared. First data of the position of setts and other signs (especially latrines) were used to calculate territories by the minimum convex polygon method (MCP) (Southwood 1966). This data was not available for all groups in all years, so the area used by badgers in terms of group territories was also calculated as buffers around setts. Buffer area was calculated as a core area around permanently inhabited main setts (BR and NBR) with a 500 m radius. This 500 m distance is based on the smallest distance between main setts and 87% of all outliers that are situated in these core areas. Some space is still used around outliers with high badger activity during a part of the year. For this reason an area with 200 m radius around all outliers was added to the core areas. Group territories calculated in this way did not differ significantly from group territories calculated by MCP (96 ha versus 100.26 ha, t-test, n = 11, P = 0.44). Also the (mean) annual area used per social group and area used by all groups together in a year were calculated.

**Habitat composition analysis**

Habitat composition was analysed by discerning important biotopes for badgers using topographical maps 1:10,000. Biotopes could be defined as important food biotopes (good habitat) such as leaf forest, arable fields and grasslands, less important biotopes (mixed and coniferous forest) (Kruuk and Parish 1982; Neal 1986) and others (roads, water, etc.) (Fig. 3).

The relation between badgers and good food biotopes was analysed by using the number of badgers and these biotopes expressed as their percentages (hectares) of the whole area used by all badgers.

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**Table 1.** Numbers of social groups, badgers; setts (main setts with (BR) and without cubs (NBR) and outliers) and traffic mortality in the study area during 1983–2001. Between brackets badgers killed of other reasons than traffic (p = poached; ac = accidentally killed; u = unknown; dr = drowned).

<table>
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<th>Total</th>
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Results

Numbers of badgers and setts

During 19 years the badger population increased from four animals in 1983 up to 41 in 2001. There was reproduction in nearly all the years except 1989, 1990 and 1994 (Table 1). Table 1 also shows that the number of badgers increased in the first 5 years then fluctuated over a few years but grew exponential from 1996 onwards.

The table shows the minimum number of adult badgers living in the study area at the beginning of an observation period (May–July) and juvenile badgers seen after reproduction. The minimum number of all badgers (adults and juveniles) each year minus the traffic victims reported between observation periods can be compared with the number of adult badgers 1 year later to indicate the reliability of the countings. In 3 out of 19 years the difference is more than two animals.

Reproduction in most years was very low (yearly 1–4 juveniles till 1992) but from 1993 onwards total reproduction increased steadily up to 9–13 juveniles during the last 4 years (Table 1). Although this increase the mean litter size (cubs/litter) did not increase significantly during the whole period (Fig. 2b; mean 2.3, std. dev. = 1.3, N = 19 and $R^2 = 0.01$, P < 0.39). The number of badger groups did not exceed 5 groups till 1997 but increased rapidly during the following 4 years till 12 groups in 2000.

Yearly mortality (mainly caused by traffic) is more or less constant (up to five) between 1983 and 2001. The mean group size increased significantly over time (Fig. 2a; mean = 2.34, std. dev. = 0.54, N = 19 and $R^2 = 0.43$, P < 0.001) mainly due to a strong increase starting in 1992.

Together with the number of badgers also the number of badger setts increased during the study period from 5 to 78 of which the growth in outlier setts was the strongest (Table 1). The number of permanently used setts (main BR and NBR) is more or less constant over a long time but increases strongly after 1997 just like the number of badgers, the reproduction and social groups. Fig. 1 shows the location of the only (main) sett found in 1983 near the country estate Einde Gooi that is permanently inhabited and where badgers reproduced in that year (sett No. 1). Further, the number of the setts (1–9) gives their sequence of founding illustrating the spread of the species in the area. Close to the first sett new setts were found in 1984 and 1985 but also north of Loosdrecht (Nos. 2 and 3). All these setts showed reproduction in later years. South and far south of sett No. 1 new setts were observed in 1988 and 1990 (Nos. 4 and 5 close to Utrecht and De Bilt). Both setts also showed reproduction in later years. In the years 1991–1997 no new setts were found and both new setts found in 1998 and 1999 (sett Nos. 6 and 7) are close to or in between existing setts and...
showed already reproduction, respectively, 3 and 2 years later (in 2001). In 2000, five new permanently inhabited main setts (NBR) were found in the neighbourhood of existing and inhabited setts of which only two showed reproduction in 2001 and 2003. Two of these five setts were in open landscape. In 2001, a new sett (No. 9) was found east of the old sett No. 4 in the forested area and juveniles were already seen in the same year. Over the study period the oldest sett No. 1 functioned as main sett (BR) during 9 years. The same is for sett No. 3 close to No. 1. Sett No. 2 showed cubs (main BR sett) during 5 years. Sett No. 3 close to Loosdrecht and No. 5 close to Utrecht functioned as main (BR) sett during 3 years and the setts Nos. 6, 7 and 9 only in 1 year.

Habitat use

The minimum area of habitat in the study area that is used by badgers was calculated by using a distance of 2 km around each sett in the year with the highest number of setts (2001, \( n = 78 \)). The distance of 2 km was based on the mean distance of 2028.36 m \( (n = 3240; \text{std. dev.} = 386.32 \text{m}) \) between all setts over the whole time period. In this way an amount of 9008.96 ha was calculated as potential available from the start of the study. Fig. 3 shows the total area used by all social groups in each year (left y-axis) increases when the number of badgers and setts increases. This illustrates the expansion of the area used by badgers around Einde Gooi during the population growth. The area used by all badgers increased slowly during the period 1983–1993 then dropped in the years 1994 and 1995 to show a strong growth in hectares after 1996. The strong positive relation between the number of badgers and the area they use is also illustrated by the \( R^2 \) of 0.9 of this relation.

Badgers can theoretically use the calculated area for searching food and digging setts. But the position and distribution of main setts in this area show that they are not equally distributed suggesting that badgers select locations to build their setts. The unequal distribution of setts is illustrated by the mean distance between the permanently inhabited main setts (with and without cubs) that correspond to the most important place of a social group. This mean distance of 3304.02 m \( (n = 105; \text{std. dev.} = 2348 \text{m}) \) indicates that some of the permanently inhabited setts are very close and others far situated from each other indicating that distances between groups.

\[ \text{Fig. 3. Used area per social group (right y-axis) and for all groups (left y-axis) per year.} \]
vary and that badgers do not equally use the whole potential available area. 

Fig. 3 shows that group territories (right y-axis) increase from 1983 to 1995. In this time period the total area used by all groups increased but less strongly while the number of groups were nearly constant (Table 1), but especially from 1991 to 1997 the area used per social group strongly increased. After 1997 this (social group) area decreased although both the number of badgers and the area they use still increase. This indicates that from 1997 on relatively less space was used per social group.

**Habitat composition**

The minimum area of about 9000 ha that was available for badgers from the start of the study, is composed of several types of habitat (Fig. 4) of which each area was more or less constant during the whole period. Some types are more preferred by badgers than others as is illustrated by the distribution of main setts (BR and NBR). The distribution of these permanently inhabited setts over 3 important types of forest shows that 57% is located in broadleaf forest, 36% and 7% are located, respectively, in mixed forest and coniferous forest.
forest suggesting habitat preference by digging setts and searching for food. The habitat composition of the area used by all badgers per year (Fig. 4) shows that the total percentage of broadleaf forest, arable fields and pastures outnumber each year that of mixed and coniferous forest and other biotopes together. Further, the percentages of the biotopes arable fields and pastures used by badgers dropped a little after 1997. The percentages of mixed and coniferous forest that are used increased after 1997. Up to 1989 the area of broad leaf forest used was more or less stable, afterwards it decreased a little to 1998 and increased to 2001.

The relation between the number of badgers (adults, juveniles and total numbers) per year and the biotopes that provide good food opportunities (percentages of pasture, arable field and leaf forest of the yearly used area) were calculated and is shown in Fig. 5. The figure illustrates a negative relation between both variables (especially for adults, $R^2 = 0.41$) indicating that if the number of badgers increases the percentage of good food habitat types decreases. This indicates that less good types are available per individual badger.

**Discussion**

Wilson et al. (2003) studied the relation between trapping, direct observation and several signs of sett activity on predicted badger numbers and found a significant correlation between badgers trapped with the number estimated from direct observation ($r = 0.93$, $P < 0.001$, $n = 12$ setts). They also observed that the number counted was either the same or higher (up to two individuals) than the number trapped. They conclude that direct observation is a good method to measure badger abundance (see also da Silva et al. 1993; Schley et al. 2004).

In our study in 12 out of 15 cases the number that should be present after the reproduction season and winter compared to the number in spring–early summer also differs between one or two individuals. Differences of counted animals between years especially of small numbers (one or two) can be caused by individuals being not observed as cubs but counted as adults for the first time or by animals that dispersed or died (e.g. juvenile mortality) and are not seen anymore. Although, immigration of animals from outside the study area cannot be excluded this seems not to happen on a regular basis. Therefore, we conclude that our data also estimate well the number of badgers of this more or less closed population in the study area.

The number of badgers, groups and setts and the dispersion of the species in the study area illustrate the increase of the population in time and space. An important external factor that can explain this increase is habitat quality. Important quality variables for badgers are the total amount of food that determines badger numbers and badger group size and the area and distribution of food patches but also suited locations for sett building that determine shape and size of territories (Kruuk and Parish 1982; Macdonald 1983; Hofer 1988; Woodroffe and Macdonald 1993; Doncaster and Woodroffe 1993). Further, da Silva et al. (1993) related the increase in both abundance and number of social groups to an increase in pasture habitat rich in earthworms.

The area of pasture and other types of habitat in the study area showed no major changes during the years data was collected. Further it was shown from faecal analyses and an earthworm inventory (present in 97% of the faeces; volume percentage 54%; Wansink et al. 1996) that the earthworm *Lumbricus rubellus* constitutes the main food item during the whole year. But for this species the acidity of the grassy peatlands and forested sandy soils constitutes suboptimal conditions resulting in low earthworm densities (Edwards and Lofty 1977; Marinissen 1992; Kowalczyk et al. 2003). Despite these unfavourable earthworm conditions grasslands and the broadleaved forest (that is also preferred for digging setts) in the area offer relatively good food conditions. Furthermore arable fields offer maize which is good food in autumn and winter. The mixed and coniferous forest offer less favourable food conditions. This habitat suitability is confirmed by the location of main setts near the edge of the forest close to grasslands and
Fig. 5. Relation between food habitat types and the number of badgers.
arable fields (see also Hofer 1988; Cresswell et al. 1990).

Although habitat composition did not show big changes at the landscape scale at a smaller spatial scale the grasslands at the estate Einde Gooi were managed in a different way starting in 1995. The estate of 136 ha is composed of mainly broadleaved and mixed forest, circa 1 hectare is yearly used for growing maize and 17 ha of grassland at the east and 23 ha at the west side are used for grazing cattle and mowing. In 1995 and 1997 all grasslands at the east side were chalked as was done the same in 1996 and 1997 with the grasslands at the west side.

Before 1995 the population slowly increased. It expanded first into the northern part of the area and it lasted till 1988 and 1990 before across the traffic barriers (roads and railway) new setts were found in the east and south of the study area situated in an artificial sett and an old fox earthwork. During this first population growth no old setts indicating a former occupation of the area by the species were found. Most main (BR and NBR) setts have been dug by badgers after 1995.

During the spatial expansion before 1995 the area used by all groups increased too in the first years but stabilised more or less around 450 ha. In the same period the mean group size varied and the mean size of the group territories increased from circa 80 to 105 ha. The most important habitat types that badgers used in this period are broadleaved forest, arable (maize) field and pasture.

The population growth from one to five groups and two to 11 animals illustrates very low densities (0.4–2.2 badger/km²) and suggests very small groups (male, female and young of the year) living in large territories. This seems to be the normal case for badgers living in areas with poor-to-medium habitat quality (Feore and Montgomery 1999; Kowalczyk et al. 2003). Under these conditions the population growth rate seems to be very slowly as is illustrated by the 10–12 years of colonisation of the study area. This time period fits remarkably well with the 9–10 years badgers needed to recolonise two cleared areas in England because of bovine tuberculosis (Cheeseman et al. 1993).

We cannot fully explain the first growth of the population. The increase in groups and numbers does not seem to result from an increase in mean litter size. Together with the assumption of no immigration the growth can be explained by a reduction in mortality and so in a higher individual survival (compare Cheeseman et al. 1993). More badgers living in suboptimal habitats force individuals to stay or to disperse looking for new territories to establish new groups. They can do so until all food resources in an area are consumed. Especially older sows can be expected to show longer movement distances as compared to females living in optimal food situations were the species act as “a contractor species” and where territories are more obvious and fixed (Kruuk and Macdonald 1985). Long-distance movements were shown by a few females in the cleared areas in the study of Cheeseman et al. (1993). The low density and founding of new groups at far distances from the place of the oldest sett in our study area suggest large territories and no or weak territoriality and are comparable with the results of studies showing low sett and badger densities, small group size and large territories in areas with poor-to-medium habitat quality (Feore and Montgomery 1999; Kowalczyk et al. 2003).

Our results fit well with all these findings and illustrate the slow growth of a population under suboptimal habitat conditions with food supply as the main constraining factor. The construction of tunnels together with badger-proof fences starting in 1988 caused a lower adult mortality and indirectly influenced the growth of the population in a positive way.

After 1995 the situation changed because of the start of a relatively fast increase in numbers of badgers and groups (up to 12 in 2000) suggesting an exponential growth in contrast to a more linear one before. Also the mean number of adults per group increases significantly (up to more than three adults) as does the adult density. Nevertheless, this increase from 0.8 to 2.5 adult badger/km² is small compared to other data from the Netherlands and other parts of Europe (Vink and van Apeldoorn 1995; Griffiths and Thomas 1993; Kowalczyk et al. 2003).
Further, a larger area is used by all badgers (up to 1200 ha) and smaller distances between main setts suggest smaller group territories (from around 115 to 90 ha).

At the same time the percentage of good food habitat types (meadows, arable fields and broadleaved forest) that are used by all badgers decreases while more mixed and coniferous forest representing less good habitat types are used more indicating that less good food habitat is used per individual badger. Also new setts but relatively less than before appear in open landscape and further into the wooded area. They are situated in the neighbourhood of border setts or in between existing ones.

Growing badger densities, number of social groups and setts combined with smaller group territories have been reported from Wytham Woods in England by da Silva et al. (1993) and Macdonald and Newman (2002) (see also Ostler and Roper 1998). A first increase in badger abundance in their area was caused by a reduction in food-patch dispersion brought about by the conversion of earthworm-poor arable land to earthworm-rich pasture and was accompanied by territory fission facilitated by the excavation of new setts. A further increase of badger abundance was compared to the steady increase in national number of badgers and both were related to changing weather patterns as due to climate change that should influence habitat quality (abundance of earthworms) and winter mortality and so favour cub and adult survival (Macdonald and Newman 2002).

Also the increased badger abundance in our study area has been accompanied with an increase of the species in the Netherlands in the time period 1990–2000 (Moll 2002). If the local and national increase in Holland can be explained in the same way as for Wytham Woods has still to be analysed but seems plausible. Also in our study area the chalking of grasslands of a high acidity between 1995 and 1997 at the estate Einde Gooi will have influenced earthworm abundance in a positive way resulting in locally better food conditions but also changing food distribution. In this way food availability (habitat quality) and the carrying capacity of the area increased in general and locally for some group territories leading to an increase of the local population density and a change in badger territoriality. The climatic factors mentioned by Macdonald and Newman (2002) may have played the same role as in England influencing cub and adult survival in a positive way and so increasing population density.

Furthermore, in 1999 the old main sett on the estate Einde Gooi showed two litters and another one on a main sett 30 m further (observations J. Vink and T. Roper) that could be seen as an annexe (Cresswell et al. 1990). The presence of annexe setts is correlated with increased productivity in younger sows (Cresswell et al. 1992). This mechanism implies social constraints for females on reproduction. This can be reduced by dispersal (Woodroffe et al. 1993) as illustrated in our study area during the first population growth under suboptimal habitat conditions. But also by the fission of existing territories as maybe occurred in our population after 1995 when habitat quality increased in combination with the development of nine (out of 11) main setts from outliers and artificial setts suggesting that sett availability did not restrict group formation and reproduction.

Besides habitat quality other external factors in the study area can be mentioned and have to be discussed such as the fences along roads and tunnels underneath. Between 1988 and 2001, 18 tunnels and more than 10 km of badger-proof fences have been build. Fourteen tunnels are concentrated around the oldest sett No. 1 (within 1.5 km) and situated under secondary roads, the motor way and the railway (only one). Four are distributed over the area. Fifteen are used nowadays by badgers of which 13 were used within 2 years of construction. Although, tunnels are used between 1988 and 1995 there is no increase in badger numbers suggesting the tunnels did not affect population growth. This conclusion seems to be confirmed given the growth of the population before 1988 when tunnels were totally absent.

Despite this conclusion on tunnels and population growth these badger-friendly
measures can be important. We know from model exercises that the survival of small badger populations consisting of only a few social groups depends strongly on adult numbers (Lankester et al. 1991) that can move freely within and between their groups. This seems to be confirmed in our study area starting with one group. In spite of the population growth before the first tunnels were constructed they made it safer for badgers to move in and between their territories. Further, the low constant number of traffic victims in the growing population means that the effect of road mortality relatively decreases and causes that animals live longer. So tunnels are still important because they reduce adult mortality that is important to enhance the survival of small populations and the dispersion of growing populations.

Construction of artificial setts is also an external factor in the study area. Thirteen of these setts were constructed between 1989 and 2000. Most of them are only used by badgers for a short time (days to less than a few months). Several are used in spring by foxes to breed. Only five artificial setts became inhabited up to 6 months (main sett NBR). In the period 1983–2001 only in one cubs were born in 2001. Also in 2003 a sixth artificial sett became used in the north near Loosdrecht close to the existing main sett and presumably three cubs were born that year. So we conclude that the artificial setts in the study area are not important for reproduction but they play a role for badgers to use the area in a more optimal way.

A third external factor was the release of 12 badgers in the study area by the organisation Das and Boom in late 1999. After comments on the genetic origins of three of them (Mulder 1999) these three animals were recaptured but again four new ones were released and so in the beginning of 2000, 13 (tattooed) introduced badgers stayed in the study area. In the same year 11 badgers were killed by cars in the study area and surrounding areas. Five of them were collected and shown to be introduced (tattooed) badgers. Because of the distances between the study area and the places where these traffic victims were found we assume they all are introduced badgers. The assumption is also based on experiences with two other reintroduction experiments in the Netherlands. In these experiments of a total of 22 introduced badgers six were still alive after 1 or 3 years. Most badgers did not stay in the reintroduction area but sometimes moved over very long distances and usually died as traffic victims. If our assumption is wrong the other six traffic victims can only be resident animals that left their home ranges or dispersing badgers coming from outside the study area. In both cases the reintroduction probably caused the dispersal of badgers and also changed the composition of the local population of which the consequences are unknown. But the increasing numbers in 2000 and 2001 suggest there are no clear effects of the reintroduction on the growth of the local population.

It can be wondered when food and site conditions will limit the population growth in our study area. The mentioned occurrence of two litters in one social group should indicate that the founding of new groups has reached its ceiling. However, the occurrence of more breeding females in a group and more than one litter on two other existing main setts in 2002 and 2003 suggest that food is still not limiting. If this analysis is right we assume that the local population still has not reached its population ceiling.

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Zusammenfassung

Dynamik einer lokalen Dachspopulation (Meles meles) in den Niederlanden von 1983 bis 2001


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References


during two years with different weather patterns. Soil Biol. Chem. 12, 1647–1654.

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