Defragmentation measures and the increase of a local European badger (*Meles meles*) population at Eindegooi, the Netherlands

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Abstract: Twenty four years' data on European badger (*Meles meles*) and sett numbers have been collected by direct observation of a local population at Eindegooi, which straddles the Dutch provinces of Utrecht and Noord-Holland. The population has shown periods of both slow and exponential growth and spatial dynamics show colonization of the entire study area. Analysis of how population dynamics respond to defragmentation measures involving roads has been undertaken. This suggests that tunnels and other measures make a positive contribution. At low densities and during periods of slow growth these measures can increase the lifetime of reproducing individuals and help badgers to safely disperse and colonize new habitat patches. Their positive effect on the population is illustrated by the fact that an individual's mortality risk from traffic has remained more or less constant, despite the increasing number of cars on motorways and provincial roads that dissect the study area.

Keywords: badger, *Meles meles*, population growth, badger friendly measures, traffic, roads.

Introduction

The Dutch European badger (*Meles meles*) population is recovering after a strong decline in the second half of the last century (Wiertz & Vink 1986, Wiertz 1992, Moll 2002, Moll 2005). The decline of the species in the 1960s and 1970s seems to be strongly related to the growing density of roads at all spatial levels (motorways, provincial and local roads) and the more intensive use of the road network (van der Zee et al. 1992). In the 1970s this decrease in badger numbers was the main reason for carrying out the first badger friendly measures, which were spread across the entire country and mainly consisted of tunnels under roads and motorways and badger guiding fences. These measures focused mainly on reducing fatal traffic accidents, but also on defragmenting isolated badger populations. Initially organized at the local level, a national defragmentation policy was initiated, which is still ongoing (Ministerie van Landbouw, Natuurbeheer en Visserij 1990, Bekker & Canters 1997, Ministerie van Verkeer en Waterstaat et al. 2004). Since 1990 such measures have become an integrated part of motorway building and renovation projects. Special programmes have been formulated for existing roads that aim to mitigate the threat to local badger populations. Since these measures have been implemented, the Dutch badger population has shown an increase in numbers. The contribution of these measures to the population increase has never been analyzed, but can be hypothesized to be positive for a species that suffers from traffic, as illustrated by modelling work based on traffic casualty data (Seiler 2003) and on the survival of European badger meta-populations (Lankester et al. 1991).

Several studies in the Netherlands and other countries show that defragmentation measures such as tunnels and ecoducts are used by badgers and other mammal species (e.g. Nieuwenhuizen & van Apeldoorn 1995, Smit et al. 1996, Pfister et al. 1997, Clevenger & Waltho 1999). Furthermore, it has been shown that fences help to reduce the number of traffic victims but only if they are used in combination with passages that meet recommended standards for criteria such as size and accessibility (Clevenger et al. 2001, Iuell et al. 2003, Jaeger & Fahrig 2004). However, it is much more difficult to prove that these measures have caused the population increase in the Netherlands.

During a 24 year study of a local badger population in an area in the provinces of Noord-Holland and Utrecht, data was collected on the changes in badger numbers and their setts and their spatial distribution (Vink & van Apeldoorn 1995, Apeldoorn et al. 2006). A first analysis of data from 1983-2001 suggested the availability of good feeding areas as being the main cause for the increase of the local population and its spreading out over a larger area.

The study by Apeldoorn et al. (2006) does not analyze in detail the possible role of the badger friendly measures in the area and this study seeks to address this question, using the available badger population data up until 2006.

Material and methods

The study area

The area where badgers and badger activity have been studied lies near Eindegooi, between the cities of Hilversum and Baarn in the north, Soest and De Bilt in the east, Utrecht in the south and lake Loosdrechtse Plassen in

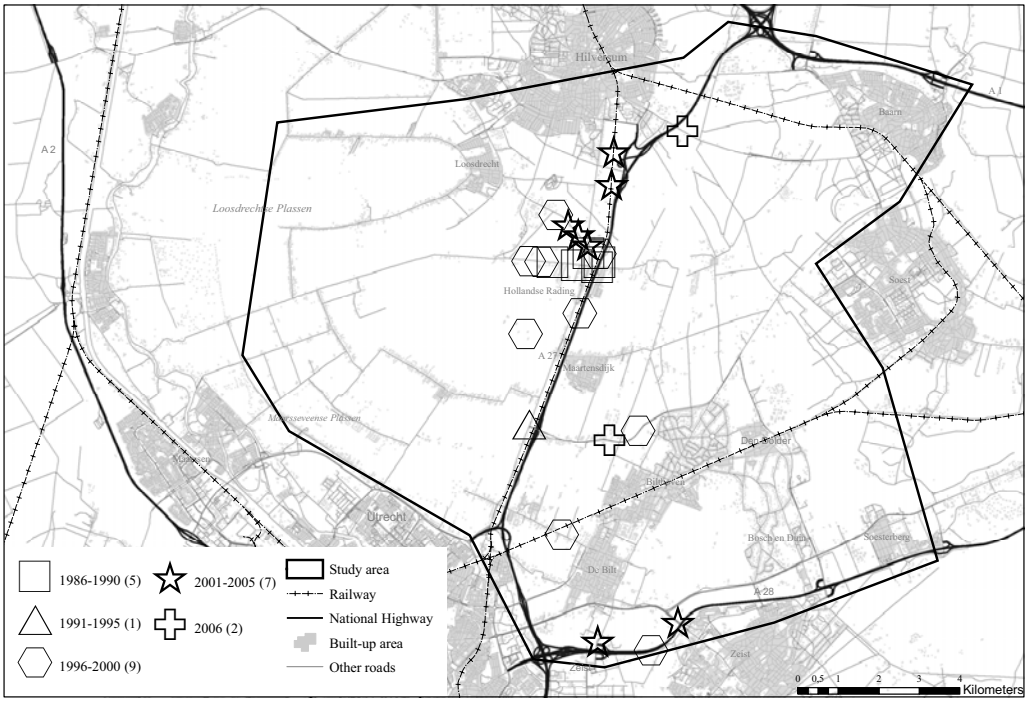

Figure 1. Badger tunnels in the study area and their use over five periods.

the west. The area is dissected by railways and motorways (A27, A1 and A28) and several provincial and local roads. Between Utrecht and Hilversum the A27 motorway, a secondary road and the railway line all run very close to each other (figure 1). Other secondary roads (provincial and local) cross the area, connecting small villages such as Bilthoven, Maartensdijk, and Nieuw Loosdrecht. The A28 motorway is situated to the south of this area and the A1 motorway to the north. These motorways constitute strong dispersal barriers in the north, south and east of the study area and contribute to the isolation of the population. The area is situated on a soil gradient, with a sandy wooded bank above sea level in the east (the Utrechtse Heuvelrug) and a peaty area that lies below sea level around lake Loosdrechtse Plassen in the west, where a mixture of pastures, marshland and open water can be found. Urban areas, pastures and woodland are the most important habitat types. An increasing amount of farmland is used for growing maize for cattle feed. More detailed information on the habitat types in the area and how they are used by badgers can be found in Apeldoorn et al. (2006).

The badgers in the study area are considered to be more or less isolated because of the long distance (about 30 km) across open landscape to the nearest other area permanently inhabited by badgers. However a few badger setts have been found in the southern part of the wooded Utrechtse Heuvelrug, about 15 km from the edge of this study area. This area is densely populated, contains many small villages and is crossed by crowded secondary roads and separated from the study area by the A28 motorway. To date, no dead badgers have been found on this motorway.

Counting badgers and setts

Apeldoorn et al. (2006**)** give a detailed description of the methods they used for counting badgers (adults and juveniles) and setts. Badgers were counted several times each year between May and July. A yearly an area-wide search for setts was carried out. Setts were searched for in the whole area and were visited at least five times a year. Victims of traffic accidents were also counted. All the data collection involved the help of many volunteers.
The mean number of badgers counted in the period May-July was taken as an estimate of the number of badgers present in the study area (minimum numbers alive). The number of all cubs observed above ground at different setts was taken as an estimate of the reproduction.

Permanently inhabited setts (main setts) in which cubs were born or regularly observed were classified as main 'breeding' setts. Setts only used by badgers during a short period were identified as 'outliers'. The number of social groups was estimated according to the number of main setts and by using qualitative field data (latrines). The use of tunnels was observed using barbed wire and footprint beds. Data on traffic victims were collected monthly and the search area was enlarged following the badger expansion.

Results

Use of roads

Traffic data for motorways and other types of roads was collected in 1995, 2000 and 2005 by the Rijkswaterstaat (Centre for Transport and Navigation) and by Utrecht Province (Verkeersinformatie Systeem Puvis). These figures show a clear increase in the number of cars on most motorways and provincial roads during the study period (table 1). The traffic levels in 1985 and 1990 are assumed to be lower than the numbers mentioned here (Rijkswaterstaat Adviesdienst Verkeer en Vervoer 2003). Along the motorways traffic flow occurs at all hours of the day and night. Traffic flows are lowest during the night and the early hours of the morning, when badgers are most active. Traffic volumes at weekends are lower and fluctuate more during the day than on weekdays.

Table 1. Use of different types of roads by number of cars; (1) average of three working days in February, May and October; (2) average use per day.

	1995	2000	2005
Motorways (1)			
A27 S=>N	33620	42812	46310
A27 N=>S	32779	42012	44478
A28 W=>E	43044	50156	52641
A28 E=>W	44179	51958	55468
Provincial roads (2)			
234	12400	14700	15000
237	18400	17600	18100
238	8900	10300	11700
413	9200	8600	12500
415	8900	9500	9500
417	11400	12200	12500

Badger friendly measures on and around roads

Since the mid 1980s, a range of badger friendly measures has been undertaken across the area. This was partly stimulated by estimates that, in 1987, two-thirds of the local badger population were dying in traffic accidents (Vink, personal communication). Badgers almost immediately started to use these facilities. In each study period, badgers used more than 50% of the tunnels (figure 1). By 2006, more than 14.2 km of fences and 27 tunnels had been constructed, alongside and under motorways, provincial and local roads. Six existing civil engineering structures, bridges, viaducts and tunnels for crossing local and provincial roads, were adapted so they could also be used by animals, including badgers. Sound walls along the motorways were also found to function as badger fences, guiding individuals during their daily movements.

Numbers of badgers, setts and social groups

Regular observations and counting of badgers and setts started in 1984, under the lead of the first author, with the help of many volunteers. Over 22 years the population increased from six animals (1984) to 91 in 2006 (figure 2). During the first five years the increase was very slow. Between 1988 and 1997 the numbers of badgers fluctuated and then began to increase again. Overall the population shows an exponential growth ($y=4.3\exp^{(0.13x)}$, $R^2=0.92$; figure 2), while the regression curve shows a yearly growth of 13%. We have indications that in 2007 and 2008, the population continues to grow (J. Vink, unpublished data).

Until 1996 reproduction was low in most years (fewer than six juveniles) but between 1996 and 2006 the number of juveniles increased, with the most (twenty-four) cubs being born in 2003 (figure 2). Probably no cubs were born in 1989, 1990 and 1994. The occurrence of more than one litter at main breeding setts was only observed in a few years. In 1999 two litters were found at an old main sett at the Eindegooi estate, with a third

litter found at a former main sett 30 m away (J. Vink, unpublished data). In 2003 three cubs were born at an artificial sett very close to an existing main sett in the north of the area near Loosdrecht. The numbers of cubs per main breeding sett (BR; see figure 2) was usually between two to three, although in five years (1991, 1998, 1999, 2002 and 2003) more than three cubs per main breeding sett were born.

In addition to the increases in the numbers of adults and juveniles (figure 2), there was also an increase in the number of social groups and setts (breeding and non-breeding) over time. Before 1998 the number of social groups never increased by more than one per year. Since 1998 the annual increase has generally been by more than one group. The increase in number of social groups coincides with an increase in the number of permanently inhabited setts (figure 3; main BR and NBR setts) and their distribution (figure 4), and illustrates the growth of the local population and its expansion all over the area.

The occupation of the area

Badgers have shown a strong expansion across the study area, starting from the Eindegooi estate in Hollandsche Rading, where badgers were present when observations began (figure 4). After an initial increase of the population at this location, the first new main sett was built to the north in the vicinity of Loosdrecht. This was followed by new inhabited setts on the eastern side of the A27 motorway and to the southeast of the Eindegooi estate between 1986 and 1995. Between 1996 and 2000 there was a further expansion, mostly to the eastern side of the motorway in a small-scale landscape with good grasslands. From 2001 onwards, inhabited setts could be found spread across the area enclosed by the mires in the west and the cities of Utrecht and Zeist in the south, Soest and Baarn in the east and Hilversum in the north (figure 4). Between 2001 and 2005 setts were also built in the western part of

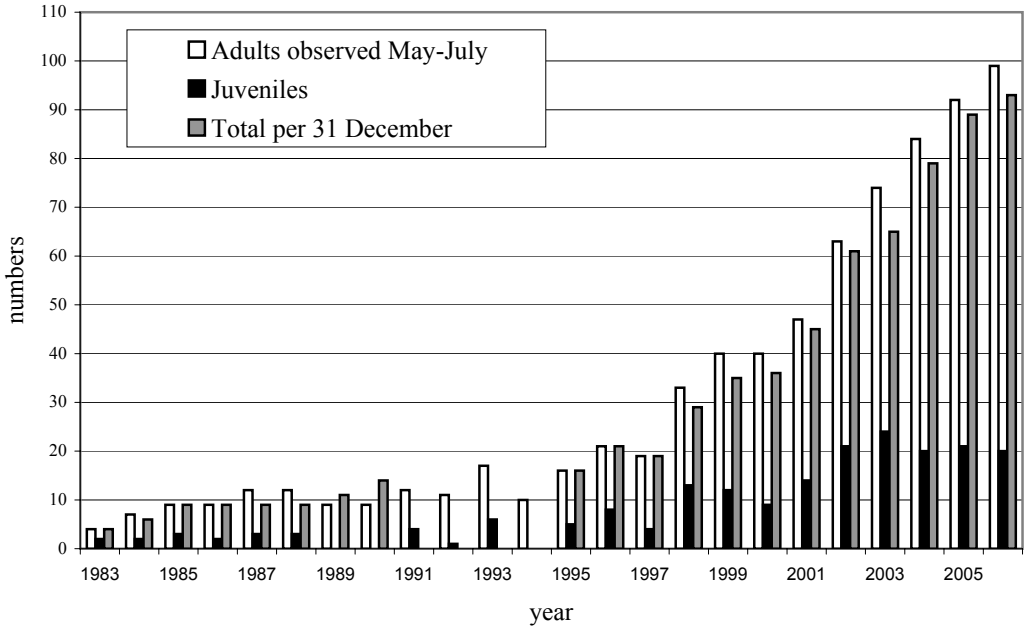

Figure 2. Number of badgers (adults and juveniles) observed during the period 1984-2006 and assumed end-of-year survival rate

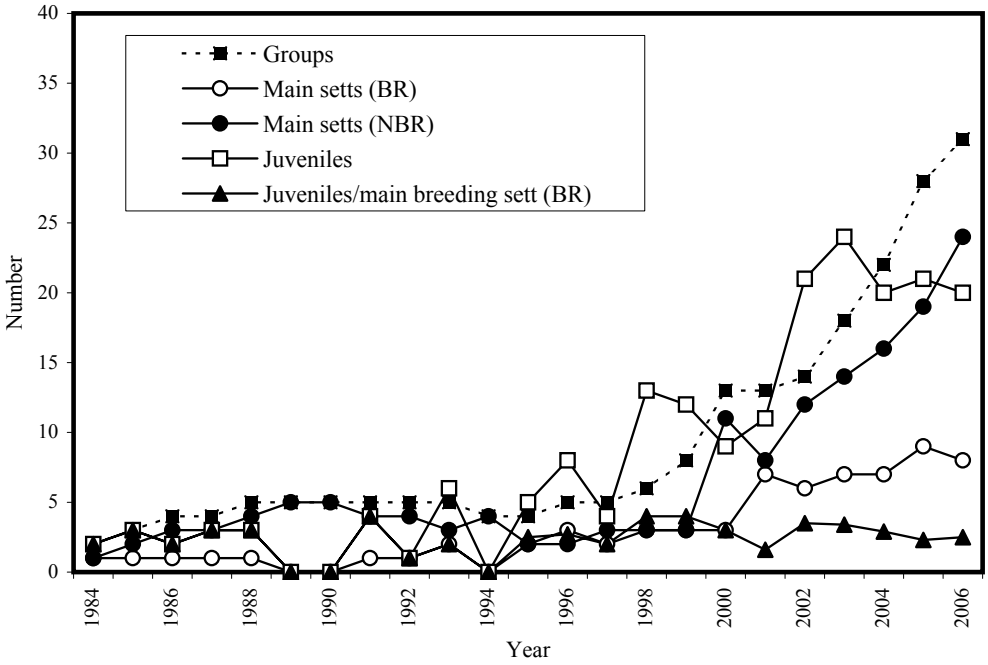

Figure 3. Number of social groups, main setts with and without breeding (BR, NBR), juveniles and juveniles per main breeding sett (as an index of reproduction).

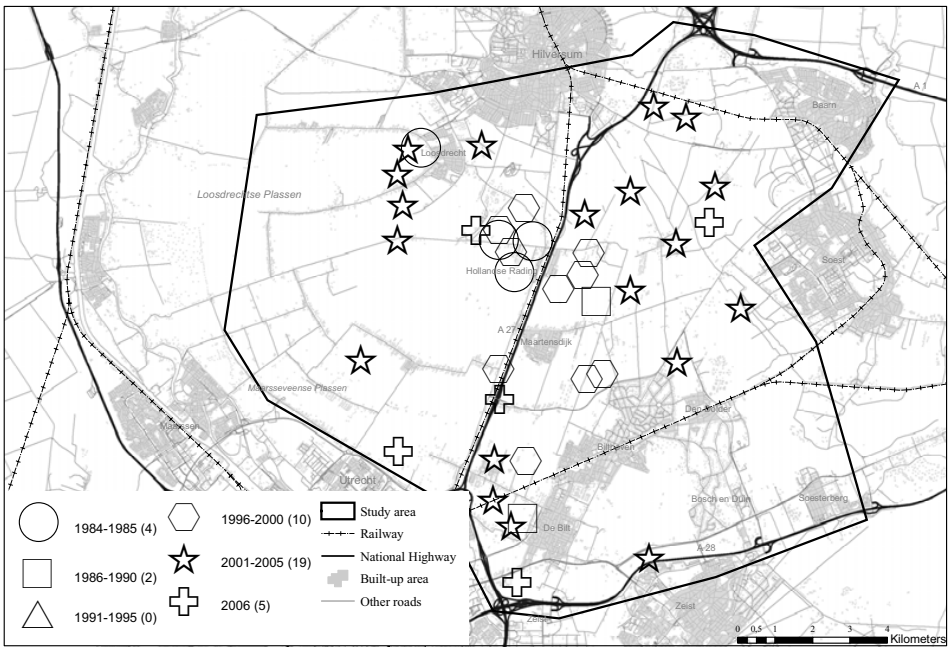

Figure 4. Inhabited badger setts during six periods.

the area, where the predominant habitat is wet peaty grasslands, and in the east, with relatively monoculture coniferous forest (Apeldoorn et al. 2006). Although all the good habitat patches seemed to be already in use, five new setts were discovered in 2006. A more detailed description of the occupation process can be found in Apeldoorn et al. (2006).

Mortality

Of the 98 badgers found dead in the area between 1984 and 2006, 28 were found along motorways, 3 on the railway, 19 on provincial roads and 48 on local roads (figure 5). The number of traffic victims remained quite low till 1998 (six or fewer) but, following the rapid population increase since then, the number of traffic victims increased, although it has not exceeded 14 (in 2000) and 11 (in 2006).

By comparing the number of traffic victims with the total number alive each year, one can calculate the risk to individual badgers of being killed by a car. While this has varied over time, it has not increased significantly (figure 6; P=0.557).

Until 1995, most traffic victims were concentrated around the Eindegooi estate, although a few dead badgers were found further away (figure 7). Since 1995 the distribution of road kills, which are now found all over the area, illustrates the expansion of the population (figure 2). Several victims were found alongside the A28 and A1 motorways, although all were within the area that these motorways enclose.

It is noticeable that dead badgers are no longer (or less frequently) found at several locations where measures have been taken to reduce badger/traffic conflicts. One of the roads crossing the area (Graaf Florisweg) yielded six victims before four badger tunnels and badger-proof fences were built, but only two since this time, despite badger numbers in this area increasing strongly. At another road (Noodweg) there were nine traffic victims before one km of badger-proof fences were installed, but only two since then. On a third road (Groenekanse weg) two badgers were killed before a badger tunnel was built, but none since.

Until 1988 all except one of the victims along the A27 were found close to Eindegooi. After fences were built there in 1988, the victims were found further to the south (between 1988–1995). After the fence was extended in this direction in 1995, the victims were again found further to the south. Over recent years the victims are found along the unfenced sections of the motorway. A similar shift in the location of fatal accidents has been found along the Noodweg and the Graaf Florisweg.

In 1999 twelve tattooed badgers were translocated from elsewhere into the study area. Due to concerns about the genetic background of these animals, three of them were recaptured and replaced by four new ones. In the same year a high number of traffic victims (eleven) was registered; five of which were identified as introduced badgers. For a combination of reasons, the other dead badgers can also be assumed to be released badgers (Apeldoorn et al. 2006).

Discussion

Growth

Before 1940, the European badger was assumed to be commonly found on the wooded sandy soils in the eastern part of the study area, but was thought to have become extinct there during the 1960s (van Wijngaarden et al. 1971). In 1983, four badgers and a permanently occupied sett were observed in a woodlot close to the Eindegooi estate (figure 2). The population grew slowly in the first years of observation, but in more recent years numbers have grown exponentially. The initial increase in groups and numbers does not seem to result from an increase in mean litter size. Given an assumption of no immigration, the population growth can be explained by a reduction in mortality resulting in a higher individual survival that will increase the reproduction rate. The

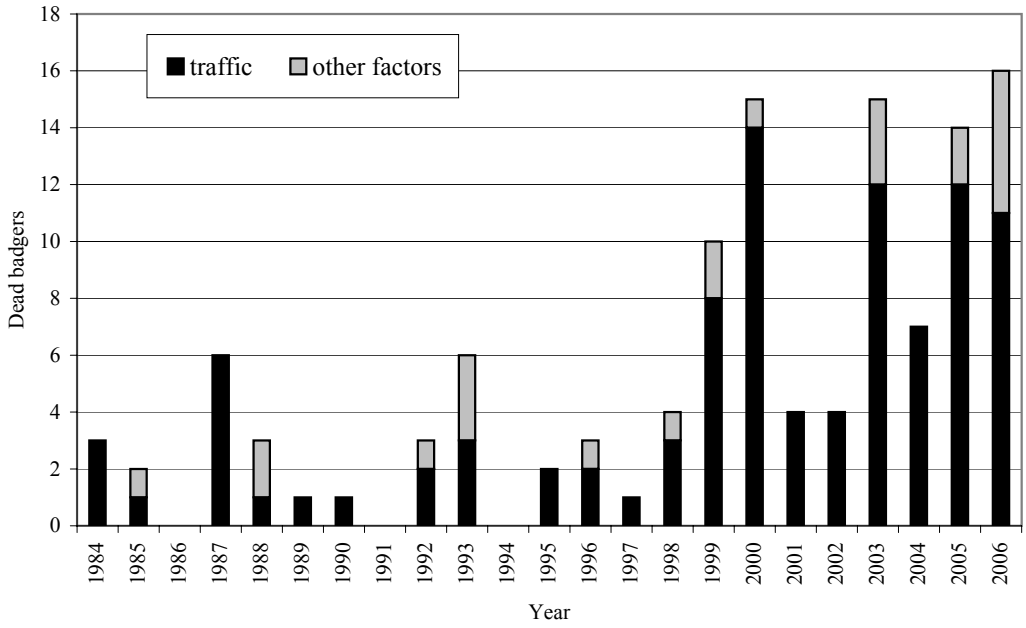

Figure 5. Mortality due to traffic and other factors.

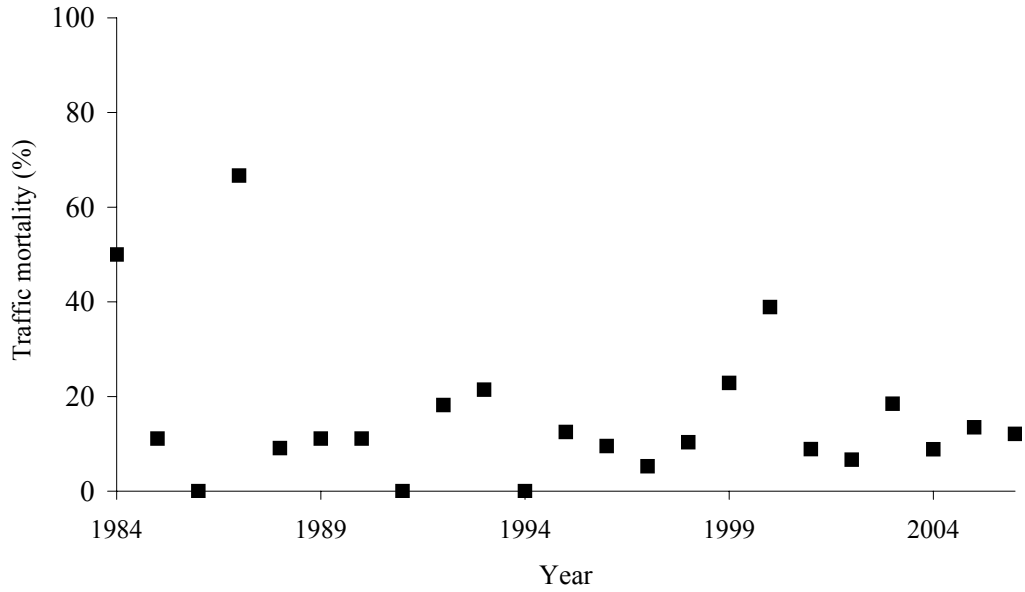

Figure 6. Traffic mortality (% of badgers killed by cars annually).

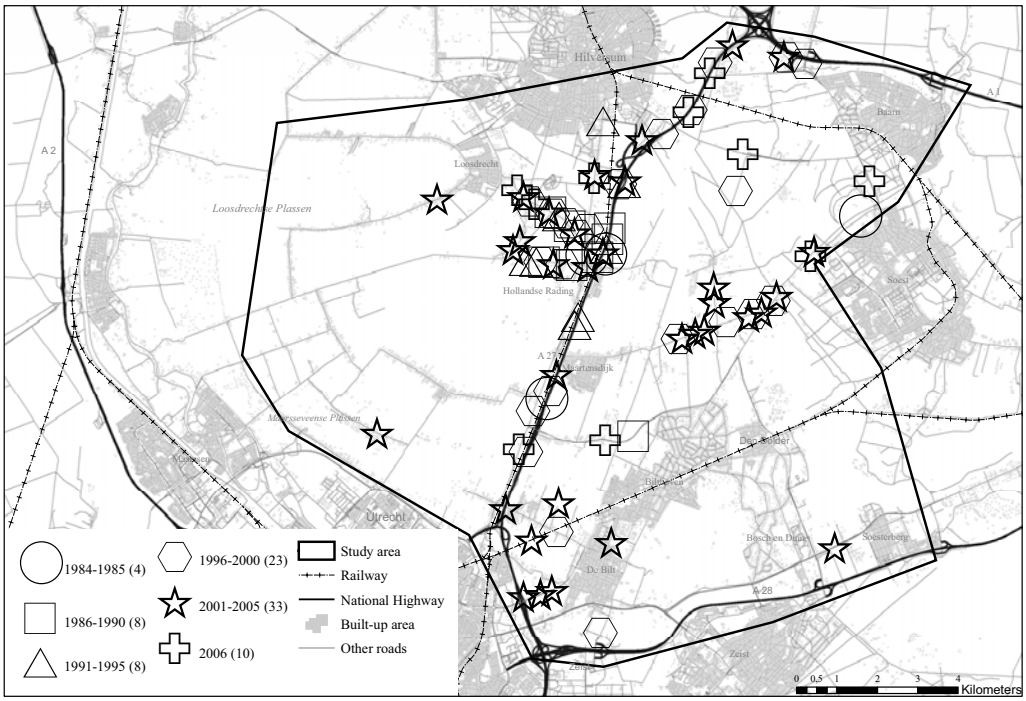

Figure 7. Locations of traffic victims in four periods.

initial slow population growth occurred before tunnels were constructed and fences were erected. Although tunnels were put in place and were being used between 1988 and 1995, there was little increase in badger numbers, suggesting the tunnels did not directly affect population growth. However, these measures may have indirectly stimulated population growth, by making it easier for badgers to safely cross their home ranges in their search for food, causing individuals to live longer and to take part in reproduction longer. This is especially important in populations with low densities. At the same time, the measures have also helped badgers to disperse safely over the busy motorways and secondary roads and thereby enabled a rapid colonization of parts of the study area that provide good habitat. The exponential growth of the population is described by Apeldoorn et al. (2006) who also discuss the possible causes. They analyzed the population growth up till 2001 and concluded that better habitat quality is the main cause of the exponential population growth. This exponential growth suggests that badger numbers are not regulated by internal population factors (Begon et al. 2006). This interpretation of density independence is supported by the increased productivity of younger sows, which correlates with the observations of more than one litter at main setts and with breeding at an artificial sett that can be interpreted as breeding at an annex sett (Cresswell et al. 1992). The authors also concluded that the population still had not reached its population ceiling; this was confirmed by the subsequent increase in badger numbers since 2001.

Mortality

Our data clearly shows that traffic is the most important cause of badger mortality in the study

area (figure 5). With three motorways and a number of very crowded secondary roads in the study area, one would expect traffic mortality to increase because of increases both in traffic volumes and in the number and density of badgers. Since 1999, levels of fatalities were higher in two years, but this is most likely due to the high number of badgers that were introduced into the area in 1999. Introduced animals can influence the social structure of badgers and can cause dispersal of resident badgers, thereby influencing mortality rates (Rogers et al. 2000).

Throughout the period there was no increase in an individual badger's risk of dying in a traffic accident (figure 4). This can be explained by the expansion of the species throughout the area during the period of growth which offset an increase in population density. At the same time the number of cars on all types of roads in the area also increased, but this did not result in higher traffic mortality, indirectly showing the positive effect of the protection measures that were taken. This is also illustrated by the fact that dead badgers were no longer found at locations where measures had been taken.

So far, no new setts or signs of badger activity have been found outside the area enclosed by the A28 and A1 motorways, the cities and villages. These features seem to function as absolute barriers. However, the colonization of parts of the study area by badgers after measures were taken on the A27 motorway and smaller roads indicate that measures are effective in decreasing this barrier effect.

The increased badger abundance in the study area has coincided with an increase of the species in the Netherlands from 1990-2000 (Moll 2002). It is not known whether the local and national increase have the same causes, although factors relating to improvements in habitat quality seem to play a dominant role at both the local and national scale (Apeldoorn et al. 2006).

Conclusions and recommendations

Based on the existing data it is hard to prove that badger friendly measures caused the increase of the local badger population. Habitat quality alone may be more important (Apeldoorn et al. 2006). However, it can be concluded that measures have made a positive contribution to the increase, as demonstrated by the reduction in mortality at places where fences and badger tunnels are installed. The colonization of the study area by badgers that followed the weakening of the barrier effect of roads illustrates the effectiveness of such measures in creating ecological corridors that enhance the movement and dispersal of badgers into unoccupied habitats.

The five new setts found in 2006 and the increase in numbers and occupied setts in 2007 indicate that the carrying capacity of the area still has not been reached and higher densities of badgers and setts might be expected. At present the badger population is still expanding and dispersing badgers may potentially colonize adjacent (uninhabited) areas.

This leads us to recommend the construction of more fences and badger tunnels (following the technical descriptions of Kruidering et al. 2005). According to the Long Term De-Fragmentation Programme, the Ministry for Transport, Public Works and Water Management is currently planning to install several more badger friendly measures along the A27 and A28 motorways between 2009 and 2011 (Ministerie van Verkeer & Waterstaat et al. 2004). An ecoduct will be built over the A27 motorway and the adjacent provincial road and railway line. Another ecoduct will be built over the A28 motorway, between Zeist and Soesterberg, and a third will be constructed over the A1 motorway, just outside our study area to the west of the junction of the A1 and A27 motorways. In addition the Province of Utrecht is planning to build some ecoducts and other badger friendly measures inside the study area.

In addition to these measures we also recommend the building of fences and tunnels at several other specific locations. These are:

- local roads that produce relatively high numbers of traffic victims (the road between Maartensdijk and Pijnenburg, the remaining part of the Noodweg, the Biltse Rading, the

provincial road between Bilthoven and Soest and the road linking Hilversum with Baarn);
- Across the A1 motorway, between km 30 and km 40 as there is good feeding habitat to the north of this motorway;
- Across the A27 motorway (north of km 82), where many victims are found;
- Across the A28 motorway, because there is good badger habitat south of this motorway.

Such measures are likely to continue to support the continued growth in badger numbers in this area and their dispersal to adjoining attractive habitats, although with an expanding badger population in this crowded part of the Netherlands, traffic victims are inevitable.

Acknowledgements: We would like to thank J. Pohlmann and P. Brous for drawing the maps, P. Patchett for correcting the English, and all volunteers which helped to collect the data. We would like to thank two anonymous reviewers for their critical and constructive reading.

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Samenvatting

Ontsnipperingsmaatregelen en de groei van de lokale dassenpopulatie (*Meles meles*) op Eindegooi

Vanaf 1984 zijn gegevens verzameld over aantallen dassen (*Meles meles*) en burchten op het landgoed Eindegooi en omgeving. De gegevens tot 2006 laten zien dat de populatie eerst langzaam en vanaf midden jaren ’90 exponentieel groeide. Daarbij koloniseerde de das nieuwe terreinen. In dezelfde periode zijn vele ontsnipperende maatregelen bij wegen getroffen, waaronder een groot aantal tunnels en rasters. Deze maatregelen lijken een positieve bijdrage aan de groei van de populatie te leveren. Dit zou blijken uit de kans dat individuele dassen slachtoffer worden van het verkeer. Deze kans bleef min of meer constant gedurende de waarnemingsperiode, ondanks het toegenomen autoverkeer op de snelwegen en provinciale wegen die het gebied omgeven en doorkruisen. Bij lage dichtheden en een langzame populatiegroei kunnen de maatregelen de gemiddelde leeftijd van dieren verhogen waarbij ze indirect de overlevingskans van de populatie positief beïnvloeden. Daarnaast kunnen ze de (lokale) sterfte van dassen verlagen gedurende bewegingen binnen hun leefgebied en tijdens dispersie.

Received: 16 Oktober 2007
Accepted: 20 August 2008