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A review of negative impact factors threatening mammal populations in Germany

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A b s t r a c t . Factors which have a negative impact on mammal populations were reviewed for all 83 native species occurring in Germany today. Forest management affects most species of the mammal fauna as well as of the sub-groups of Red List species and of species for which a special responsibility for their conservation has been determined in Germany. This is because a high proportion of German mammals are forest-dwelling, which means they are exposed to current harmful forestry practices such as selective harvest of ancient trees. The review also highlights population reduction by direct take of individuals (legal, illegal or accidental) and habitat fragmentation as major conservation problems affecting many species. The analysis of negative impact factors underline the importance of ongoing „traditional" conservation measures. However, the result of climate change and invasive alien species being less important for conservation, as only few species are affected so far in Germany, is doubtful. The impacts of these two factors may be underestimated owing to a general lack of data. To ensure that conservation problems can be identified and appropriate measures are taken, the implementation of a mammal monitoring programme and specific research projects are needed. International cooperation might be helpful to overcome national shortcomings in mammal conservation in Germany and other European countries.

Key words: conservation, forest management, agriculture, direct take, habitat destruction and fragmentation, invasive alien species, climate change

Introduction

The 2010 target – to achieve by 2010 a significant reduction of the rate of biodiversity loss at the global, regional and national level (U n i t e d N a t i o n s 2002) – is a relevant goal of European Union policy, because member states agreed even to stop the loss of biodiversity by the year 2010 (C o m m i s s i o n o f t h e E u r o p e a n C o m m u n i t i e s 2006) and governments declared it during the G8 Summit in Potsdam 2007 as a main objective of world politics (G 8 E n v i r o n m e n t M i n i s t e r s M e e t i n g 2007). The 2010 target is also an obligation for biologists and conservationists, who analyse, observe or manage populations and habitats. It is their role to identify priorities for conservation, i.e. threatened populations, appropriate conservation measures or research needs.

Germany, which is an EU member and one of the wealthiest countries in the world, contains many species and habitats typical of Central Europe (S u n d s e t h & C r e e d 2008). But human population density is also very high in this country. Urban areas and a dense network of roads and railways cover 11.3 % of the country (B u n d e s a m t f ü r N a t u r s c h u t z 2004). Thus, nature conservation and especially the protection of species are in a competitive situation with many economic and social demands. In this situation a

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careful analysis of factors threatening species and habitats is needed to implement useful programmes and measures for the conservation of biodiversity and achieve the 2010 target. This paper presents such an analysis for the mammal species currently occurring in Germany. For our case study we asked three questions: Which threats affect most mammal species in Germany; is there a need to change current priorities in German mammal conservation in order to ensure the survival of populations until the year 2010 and beyond; and what are the priorities for research and monitoring?

Methods

A number of information resources about mammals and their conservation status in Germany are currently available. Taxa with conservation priority are species on Red Lists of threatened mammals (Schröpfer et al. 1984, on the regional level see Borkenhagen 1993, on national level see Boye et al. 1998, Braun & Dieterlen 2003, 2005 among many others) and those, for which a special responsibility for their conservation has been determined in Germany (Meinig 2004). Further species are focussed by the EC Habitats Directive. Their ecology and abundance was characterised by standard species accounts (Petersen et al. 2004) and adequate surveillance methods were outlined in a monitoring guideline (Schnitter et al. 2006). The current conservation status was recently summarised by the national report on the implementation of the Habitats Directive in Germany (Balzer et al. 2008, European Topic Centre on Biological Diversity 2008).

Factors threatening German mammal populations today were reviewed within an analysis of causes of threats for species of general importance in planning processes (Schulenburg 2005). The classification of negative impact factors of this publication was modified for mammals due to information from other literature and our own experience from the fields or after consultation with other mammalogists. The following threats (in alphabetical order) were taken as relevant for mammals: agriculture, climate change, direct take including hunting, pest control, accidental and illegal killing, fisheries, forest management, habitat destruction, habitat fragmentation, invasive alien species, and tourism and recreation. By this classification social groups who cause mammal population reductions are reflected as far as possible. However, it also distributes some negative impact factors such as contamination or disturbance among others, in these cases agriculture and forest management or habitat fragmentation and recreation.

The negative impact factors were tested for all 83 native mammal species currently living in Germany, for the 38 species of the German Red List published in 1998, and for the 18 species with a special conservation responsibility of Germany. If a species suffers by a certain factor, this factor was ticked (Table 1). If a significant proportion or subpopulation was threatened by the factor the species was ticked as well (e.g. *Mus domesticus* for legal direct take), but not if the affected part of the species is of little conservation concern (e.g. *Myotis dasycneme* for tourism and recreation). The negative impact factors were ranked according to the number of species affected by each factor.

Results

The summary of the evaluation gives a common picture by comparison of the ranking of the ticked factors in all species, in the species of the Red List, and in the species for which

Table 1. Negative impact factors and the mammal species affected by them in Germany. For each impact factor species are listed, which occur in Germany with populations suffering significantly from the factor, even if species are not yet threatened in accordance to Red List criteria.
Underlined names – threatened species of the German Red List categories 0, 1, 2, 3, G and R (B o y e et al. 1998).
Names in bold – species for which a special German responsibility for their conservation has been determined (M e i n i g 2004).
Data sources: P e t e r s e n et al. (2004), S c h u l e n b u r g (2005), S c h n i t t e r et al. (2006), own data and expert consultations.

Impact factors	Affected mammal species in Germany
Forest management	***Sorex alpinus***, *Rhinolophus ferrumequinum*, ***Rhinolophus hipposideros***, ***Myotis myotis***, ***Myotis bechsteinii***, *Myotis nattereri*, *Myotis emarginatus*, *Myotis mystacinus*, *Myotis brandtii*, *Myotis alcathoe*, ***Myotis dasycneme***, *Myotis daubentonii*, *Plecotus austriacus*, ***Barbastella barbastellus***, *Eptesicus nilssonii*, *Pipistrellus pygmaeus*, *Pipistrellus nathusii*, *Nyctalus noctula*, *Nyctalus leisleri*, *Sciurus vulgaris*, *Glis glis*, *Muscardinus avellanarius*, *Arvicola scherman*, *Microtus oeconomus*, *Apodemus flavicollis*, ***Apodemus alpicola***, *Meles meles*, *Martes martes*, ***Felis silvestris***, *Lynx lynx*, *Sus scrofa*, *Cervus elaphus*, *Cervus dama*
Population reduction through direct take 1 = legal killing; 2 = illegal killing; 3 = kills by traffic; 4 = kills by windmills	*Erinaceus europaeus* (3), *Talpa europaea* (2), *Neomys fodiens* (2), ***Rhinolophus hipposideros*** (2), ***Myotis myotis*** (2), ***Barbastella barbastellus*** (3), *Eptesicus nilssonii* (3), *Vespertilio murinus* (4), *Pipistrellus pipistrellus* (2, 4), *Pipistrellus nathusii* (4), *Nyctalus noctula* (4), *Oryctolagus cuniculus* (1), *Lepus europaeus* (1, 3), ***Cricetus cricetus*** (2, 3), *Arvicola amphibius* (1), *Rattus rattus* (1), ***Mus domesticus*** (1), *Canis lupus* (2, 3), *Vulpes vulpes* (1), ***Lutra lutra*** (3), *Mustela erminea* (1), *Mustela nivalis* (1), *Mustela putorius* (1), *Martes martes* (1, 3), *Martes foina* (1, 2), ***Felis silvestris*** (3), *Lynx lynx* (2, 3), *Phocoena phocoena* (3)
Agriculture	*Talpa europaea*, ***Sorex coronatus***, ***Neomys anomalus***, *Crocidura leucodon*, *Crocidura suaveolens*, ***Rhinolophus hipposideros***, *Myotis nattereri*, *Myotis emarginatus*, *Myotis mystacinus*, *Myotis brandtii*, *Plecotus auritus*, *Plecotus austriacus*, *Eptesicus serotinus*, *Pipistrellus pipistrellus*, *Oryctolagus cuniculus*, *Lepus europaeus*, ***Cricetus cricetus***, *Arvicola amphibius*, *Microtus arvalis*, *Microtus agrestis*, *Microtus oeconomus*, *Microtus subterraneus*, *Micromys minutus*, *Apodemus agrarius*, *Mustela erminea*, *Mustela nivalis*
Habitat fragmentation	***Rhinolophus hipposideros***, ***Myotis bechsteinii***, *Myotis nattereri*, *Myotis emarginatus*, *Plecotus austriacus*, ***Barbastella barbastellus***, ***Castor fiber***, *Glis glis*, *Muscardinus avellanarius*, ***Cricetus cricetus***, *Microtus oeconomus*, *Apodemus flavicollis*, ***Lutra lutra***, *Martes martes*, *Meles meles*, ***Felis silvestris***, *Lynx lynx*
Habitat destruction	*Rhinolophus ferrumequinum*, ***Rhinolophus hipposideros***, ***Myotis myotis***, ***Myotis bechsteinii***, *Myotis alcathoe*, *Pipistrellus pygmaeus*, *Oryctolagus cuniculus*, *Lepus europaeus*, *Neomys fodiens*, ***Neomys anomalus***, *Crocidura suaveolens*, ***Cricetus cricetus***, *Microtus oeconomus*, *Micromys minutus*, ***Sicista betulina***
Tourism + Recreation	***Rhinolophus hipposideros***, ***Myotis myotis***, *Myotis nattereri*, *Myotis daubentonii*, *Plecotus auritus*, *Lepus europaeus*, ***Lutra lutra***, ***Phoca vitulina***, *Halichoerus grypus*, *Phocoena phocoena*
Climate change	***Sorex alpinus***, *Eptesicus nilssonii*, *Lepus timidus*, *Marmota marmota*, *Chionomys nivalis*, ***Sicista betulina***, *Capra ibex*
Fisheries	***Lutra lutra***, *Halichoerus grypus*, *Phocoena phocoena*
Invasive alien species	*Arvicola amphibius*, *Mustela putorius*

Germany has a special conservation responsibility (Table 2). The upper position of the ranking is commonly occupied by forest management, population reduction through direct take, and habitat fragmentation. In the middle there are agriculture, habitat destruction, and tourism and

Table 2. Summary of Table 1 notations and ranking of the impact factors by the number of species named per factor.

Impact factors	All German mammal species (n = 83)		Mammal species of the German Red List 1998 (n = 38)		Species that Germany carries a special conservation responsibility for (n = 18) [1]	
	Number of species affected	Factor ranking	Number of species affected	Factor ranking	Number of species affected	Factor ranking
Forest management	33	1	20	1	8	1
Direct take	28	2	15	2	7	2
Agriculture	26	3	12	3	4	5
Habitat fragmentation	17	4	12	3	7	2
Habitat destruction	15	5	11	5	6	4
Tourism and recreation	10	6	8	6	4	5
Climate change	7	7	7	7	2	7
Fisheries	3	8	3	8	1	8
Invasive alien species	2	9	0	9	0	9
any factor	71		37		17	

[1]) Species group without *Nyctalus noctula*.

recreation. At the lower end there are climate change, fisheries and invasive alien species. Thus, it is not necessary to consider sub-groups of threatened species and species with a special German responsibility in a different way to the whole mammal fauna of Germany.

Forest management

As woodland is the natural habitat of a great part of the German mammal fauna (i.e. most bats, carnivores and hoofed mammals), many species are affected by negative impacts of forest management (Table 2). Forests cover about 30 % of Germany, but strictly protected woodland with no human intervention is nearly non-existent. Sites with only minimum intervention are restricted to protected areas and make up only 0,8 % of all forests (Bundesamt für Naturschutz 2004, MCPFE Liaison Unit Warsaw, UNECE & FAO 2007). This is one of the main reasons why Bechstein's bat (*Myotis bechsteinii*) and the barbastelle (*Barbastella barbastellus*), which prefer primeval forests, are critically endangered in Germany (Boye et al. 1998) and vulnerable all over Europe (Temple & Terry 2007, 2009).

Forest management is one of the most important factors threatening mammal species. In particular it is by the selective harvest of ancient trees to supply global wood markets (e.g. Hermanns et al. 2005, Wesolowski 2005). During the 1990s, in some federal states special programmes for ecological forest management had been developed to contribute to nature conservation (Meschede & Heller 2000). But many of those programmes dropped their conservation goals when they were implemented. This was even the case in the national parks of Mecklenburg-Prepommerania, that lost their Forest

Stewardship Council (FSC) certificate repeatedly in 2006 and 2007, because among other reasons too many veteran trees were harvested (Auinger 2007). Today many bat species and the pine marten (*Martes martes*) suffer from such forestry practices (Schulenburg 2005) because their occurrence is linked to the abundance of habitat features like large tree-holes, crevices and loose bark which are rare among young trees (Birks et al. 2005, Dietz 2007).

In addition natural forest diversity was significantly reduced by common management practices like the exclusion of clear cutting, natural fires and cattle grazing. Cattle grazing in forests has been prohibited in Germany for more than 120 years. The order was a good measure once to support reforestation of large degraded areas, but now it is a disadvantage for species conservation. For example common dormouse (*Muscardinus avellanarius*) and lesser noctule (*Nyctalus leisleri)*, which prefer habitats with edge effects, would find much more sites appropriate for their nests or roosts respectively if forest vegetation is opened to sunlight by browsing mammals. However, with the exception of a few experimental projects (e.g. Höltigbaum, Solling, see Oheimb et al. 2006 and Gerken et al. 2008) large herbivores other than deer and wild boar (*Sus scrofa*) are strictly excluded from forests and even the red deer (*Cervus elaphus*) is restricted to certain areas by law (e.g. for Rhineland-Palatinate see Simon 2003).

Another point of reason is the exploitation of forests for the production of paper or renewable energy. In some areas fast growing trees are planted and any dead wood is taken away. Planted tree species (e.g. poplar and conifers) often replace beech or oak forest types, which would naturally grow on 88 % of the land surface (Bundesamt für Naturschutz 2004) and offer best habitats to most woodland mammals (e.g. Dietz & Simon 2008 for bats), but are limited today to about 24 % of forest land (Reif et al. 2005). Furthermore professional forest management staff was stepwise reduced because of the costs. As a result most foresters are forced to focus on the economy of forests and have no or very limited resources for conservation measures, even on public properties. Mammal populations are only cared about if they can grow to a pest, like field voles (*Microtus agrestis*) and water voles (*Arvicola scherman*) may do, or if they are profitable game species, like the red deer.

For the exploitation of forests a dense forest road network, often with paved roads, is maintained. This causes barrier effects for species like the common dormouse (Bright & Morris 1989). Other species need areas with little or no disturbance. As roads are also used by hikers, who are frequently accompanied by free ranging dogs, along such recreational routes habitat quality is low for species like the wildcat, *Felis silvestris* (Hötzel et al. 2007) or lynx (*Lynx lynx*) (Haller & Breitenmoser 1986) that are sensitive to disturbance. The dense network of forest roads also gives reason to cut down many old trees, especially those with dead branches and holes, because in Germany the owner of a forest is liable for any damage to persons caused by falling trees or branches (see Agena 2007).

Population reduction through direct take

Direct take of individuals from a population is relevant for a number of mammal species in Germany. The reduction of the population is either intended, legally or illegally, or it occurs by accident (Table 1). The latter affects mammals which are frequently hit by cars or vessels, e.g. hedgehog (*Erinaceus europaeus*), barbastelle bat, otter (*Lutra lutra*), roe deer (*Capreolus*

capreolus) and harbour porpoise (*Phocoena phocoena*). Some bat species suffer from being struck by windmills quite often, e.g. common pipistrelle (*Pipistrellus pipistrellus*) and noctule (*Nyctalus noctula*) (R o d r i g u e s et al. 2008).

Legal take of mammals is part of hunting. But in some game species local populations were overexploited or reduced to unnatural low abundances, like brown hare (*Lepus europaeus*; B o y e 1996) and pine marten (*Martes martes*; S c h r ö p f e r 1997). Water voles (*Arvicola amphibius*), black rats (*Rattus rattus*) and house mice (*Mus domesticus* and *M. musculus*) are taken as pest species in houses or gardens and may be killed legally which is relevant for species conservation as far as native black rat populations and the endemic subspecies of the house mouse on the Island of Heligoland are concerned (B o y e et al. 1998, M e i n i g 2004).

Each year an average amount of 75 tons of rodenticid is sold in Germany. The major part of these poisons is applied in private homes and gardens. Only a small fraction is used in agriculture and forestry (J a c o b & P e l z 2005). There is no indication for conservation problems with current pest control practices in Germany.

Illegal population reduction takes place in species commonly living in houses and garden areas. Bats which form large maternity colonies (in particular greater mouse-eared bat *Myotis myotis*) can suffer from extermination campaigns as well as the mole (*Talpa europaea*). Poaching is relevant for the two large carnivores wolf (*Canis lupus*) and lynx (*Lynx lynx*) occurring only in very low numbers in Germany.

Currently unknown is the role of free-ranging domestic cats as predators which are independent from the abundance of their prey by receiving supplementary food from pet keepers. They could have a negative impact on small mammal populations by killing significant numbers (B a k e r et al. 2005) or by changing species assemblage structures similar to what was observed in birds (S i m s et al. 2007). In Germany, however, there has been no systematic investigation of this issue so far.

A g r i c u l t u r e

As in most European countries agriculture has a strong negative impact on wildlife in Germany. Today's farming is characterised by high speed harvest practices with heavy machines on huge acres and large-scale application of fertilisers and pesticides. A significant reduction of outdoor cattle keeping took place the last decades parallel to a general decline of pasture land and a concomitant increase in intensive arable farming. Species specialised on grassland habitats or feeding on cattle dung beetles become rare in some regions (e.g. brown hare and serotine *Eptesicus serotinus*). On many farms a former variety of crops is replaced by only one product, which leads to monotonous vegetation cover on large areas or even regions. Small habitat patches within farmland, which were formerly abundant and important habitats for mammals (e.g. Miller's Water shrew *Neomys anomalus*, northern root vole *Microtus oeconomus*, harvest mouse *Micromys minutus* and weasel *Mustela nivalis*), vanished from many regions. In addition farmland mammals may have reduced survival rate and reproduction success because of agrochemicals, but there is little evidence for that in Germany.

Nowadays another shift is going on, as farms change their production from food to so called bio fuels. Fields with little or no economic value, which were set aside under former EC programmes and that were of high value for mammals and other species (e.g. S p i t t l e r 2000), are put under intensive exploitation regimes again.

Not a new problem but becoming more and more important is the segregation of conservation areas from used farmland. This leads to a concentration of wildlife in protected sites or habitats under incentive schemes while very few mammals can survive in the remaining areas.

Habitat fragmentation

The negative impact factor of habitat fragmentation is most relevant for mammals which are endangered by isolation, because of either a loss of genetic diversity and inbreeding effects of small populations in restricted habitats or the suppression of migration as an essential behaviour in the species. Interstate motorways in Germany and other federal roads are effective barriers for wildlife, as observed in Bechstein's bat (Haensel & Rackow 1996), hamster (*Cricetus cricetus*; own data), otter (*Lutra lutra*, Stubbe et al. 1993) and badger (*Meles meles*, Herrmann 1998). To reduce road mortality of animals many motorways are accompanied by fences, which may even strengthen the barrier effect of the road for badger, deer species and wild boar as passages suitable for these species are still very rare (Table 3). To protect wildcats in the Eifel mountains a special fence was constructed to prevent medium-sized mammals from crossing motorways and force them to use fauna passages nearby (Jungelen 2000).

Table 3. Length of motorways and federal roads and number of fauna passages (except amphibian tunnels) in Germany.

Type of road	Total lengh	Number of wildlife bridges		Number of wildlife subways (waterways which support fauna passages are included)	
		present	planned or under construction	present	planned or under construction
Motorways	12.400 km	16	26	100	45
Federal roads	41.000 km	20	10	60	2

The isolation of woodlands can also be increased by the reduction of connecting hedgerows or other linear features in arable land. As a result, populations of woodland species like the yellow-necked mouse (*Apodemus flavicollis*) (Alf et al. 1997) and the pine marten became isolated and lesser horseshoe bats (*Rhinolophus hipposideros*) cannot find a flyway along linear features between their roosts and feeding sites (Biedermann 1998).

Habitat destruction

German nature conservation legislation ensures that most habitats important for the survival of wildlife must not be destroyed. However, mammals living on sites with special features are still vulnerable to lose their habitats. This is the case in horseshoe bats (*Rhinolophus* spp.) and the greater mouse-eared bat. They prefer large attics for their maternity roosts, but colonies are easily detected by house owners and highly vulnerable to be driven away by closing all entrances. Other mammal species suffer from changes in water quality or the water regime on used land, e.g. the water shrews (*Neomys fodiens* and *N. anomalus*) and the root vole. A general reduction of unused grassland habitat patches limits the occurrence of lesser white-toothed shrew (*Crocidura suaveolens*) and harvest mouse in many regions.

Tourism and recreation

There are few human recreational activities which have negative impacts on mammal conservation. Unauthorised visits to caves especially during the winter may disturb bats and lead to a reduction of the hibernating population (Mitchell-Jones et al. 2007). Species that are sensitive to disturbance are affected by hikers and their dogs as mentioned before in the cases of wildcat and lynx. It is presumed that this is also a negative effect for the brown hare which avoids open fields close to pathways after having the experience of being hunted by humans and dogs (Boye 1996). In some coastal areas summer activities on the beach drive seals away and jet-skis are a threat to harbour porpoises.

Fisheries

The negative impact of fisheries on mammal populations is restricted to two effects. One is the accidental killing of mammals as by-catch, which is relevant in otter and harbour porpoise. Another one is the reduction of prey fish, which affects grey seal (*Halichoerus grypus*) in the Baltic Sea. This population also cannot recover by reintroduction because Baltic fishermen resist (Schneider 2001).

Climate change and invasive alien species

The assessment of a low relevance of the two impact factors „climate change“ and „alien species“ is based on the fact that there are no current problems identified for particular mammal populations. The species named in Table 1 as being negatively affected by climate change and invasive alien species are more or less presumed to be affected by these factors, but detailed investigations are not present. Data on population trends and current occurrence are not available for any of the named species except the Alpine ibex (*Capra ibex*).

However, climate change may reduce populations of mammals, in particular species living at higher altitudes, like northern bat (*Eptesicus nilssonii*) and Alpine shrew (*Sorex alpinus*). Their habitats may become smaller or even vanish when temperature goes up, rainfall pattern changes to dry summers and wet winters, and the tree-line moves uphill. Climate change will also alter habitats and species assemblages in the lowlands, but the consequences for mammal populations are not yet evaluated.

The same is the case with invasions of alien species, which may expose native species to unforeseen threats directly or indirectly. The example of the American mink (*Neovison vison*) driving the native water vole near to extinction in Britain (Macdonald & Strachan 1999) is well known. In Germany American mink, which is introduced to many regions of the country, is expected to lower the presence of water vole and polecat, but data are not available. This is alarming, as the water vole may additionally suffer from a number of other threats like water pollution, channelization and loss of bank-side vegetation. A growing problem is the spreading of the alien plant Himalayan balsam (*Impatiens glandulifera*), which already covers large areas along rivers and streams and changes structures and microclimate of the bank habitats where water voles live.

Availability of data

A further result of our data analysis is that in a number of mammal species relevant negative impacts on populations and specific conservation problems are still insufficiently known.

This is the case with Miller's water shrew, Geoffroy's bat (*Myotis emarginatus*), Alpine hare (*Lepus timidus*) and weasel (*Mustela nivalis*).

Another example is the garden dormouse (*Eliomys quercinus*), which is listed as "Near Threatened" by the IUCN, because it has declined more than any other rodent in Europe and possibly disappeared from as much as 50 % of its former range during the last 30 years (T e m p l e & T e r r y 2007, 2009). In Germany two populations with different ecology can be recognized, one in gardens and orchards of the western lowlands and the other dispersed in boulder fields in mountainous areas of the eastern country. Although Germany has a special conservation responsibility for the species (M e i n i g 2004) nothing is known about populations' conservation status and possible threats. This example illustrates existing gaps of information, which may give a significant bias to our results.

Discussion

Our analysis identified forest management, agriculture and habitat fragmentation as the factors with a strong negative impact on the mammal fauna in Germany. Currently there is no indication that these threats might decrease in the near future. For this reason the designation of protected areas, habitat conservation measures as part of landscape planning processes and projects, and the implementation of conservation and management plans for particular species will continue to be appropriate elements of mammal conservation programmes in Germany.

Referring to our second highest ranking of direct take of specimens legal and illegal deliberate killing should be restricted and avoided as far as possible because it currently is a relevant factor for many mammal populations. In this context hunting restrictions, improvement of the implementation of legal protection, public awareness campaigns and the construction of more fauna passages across roads and railways have to be mentioned as appropriate conservation measures. As roadkills are also a consequence of habitat fragmentation this problem deserves higher attention than before. Landscape planners, constriction companies, nature conservation authorities and mammalogists should improve their communication and common knowledge to reduce the loss of local mammal populations along roads and railways.

However, in general there is no reason to ask for a radical change in mammal conservation paradigms in Germany, one may just ask for more consistency in the application of existing conservation regulations and programmes.

As a consequence of the stated lack of data about threats in a number of mammal species we have to self-confirm some doubts on the results of our analysis. In particular, the assessment of climate change and invasive alien species as factors with low relevance for mammals may be an error because it is based on too little information. Effects might be hidden by other negative impact factors, which are mentioned above and got higher positions in our rankings (Table 2), or they will be detectable only in the future after major changes in behaviour, abundance or occurrence of mammal species took place. Nevertheless, we can also expect positive impacts of climate change on a number of species which can increase their future distribution and abundance in Germany (e.g. *Crocidura* species, bats, brown hare, fat dormouse *Glis glis*).

To get a more detailed picture of the situation and trend of Germany's mammal fauna as well as specific conservation needs a monitoring programme is needed, which provides data on the occurrence and abundance of all mammal populations in the country. An assessment of the situation of a number of species should be a target of priority in the frame of such a German mammal monitoring programme (Table 4). Among these are Alpine hare, forest

Table 4. Mammal species which deserve priority in a future German mammal monitoring programme.

Name of species	Reason for priority
Miller's water shrew *Neomys anmalus*	Decline and even extinction of small populations can be expected in the species because of agricultural intensification and road constructions.
Alpine hare *Lepus timidus*	No data on distribution or abundance are available for this species which falls under the German hunting law.
forest dormouse *Dryomys nitedula*	The fate of the German populations of the species is unknown since the beginning of the 1980s. In Austria and Switzerland (T e s t e r & M ü l l e r 2000) there have been strong declines and it seems possible that the species is already extinct in Germany.
garden dormouse *Eliomys quercinus*	No actual data on the species range and abundance in Germany exist. As a strong decline of the species was observed all over its range (T e m p l e & T e r r y 2007, 2009) this also has to be apprehended for Germany.
northern birch mouse *Sicista betulina*	Only accidental data exist on this species which is only known by about 20 records from 3 distant regions of Germany (M e i n i g 2004).
northern root vole *Microtus oeconomus*	A significant decline of populations can be assumed because of the intensification of agriculture in north-eastern Germany

dormouse (*Dryomys nitedula*) and northern birch mouse (*Sicista betulina*), which are species of Annex IV of the Habitats Directive.

In addition to the introduction of a mammal monitoring programme more research has to be done to evaluate the conservation status of species. For example, the interspecific relationship of the common pipistrelle and Kuhl's pipistrelle (*Pipistrellus kuhlii*) should be investigated as the latter one is extending its distribution area to southern Germany due to rising summer temperatures. As well, specific research is needed in the case of large scale application of *Bacillus thuringiensis* (*Bt*) and its effects on bat populations. This bacterium is sprayed from planes every year to reduce mosquitoes in the southwest of Germany. But there is no surveillance scheme in place to detect the effects either for species like bats, which feed on small insects, or for the whole ecosystem. From the United States there are first studies documenting a negative impact on the activity of bats because of the heavy disruption of food webs over fields treated with *Bt* (K e n n a r d et al. 2007).

To monitor mammal populations, to implement research projects with conservation concern, and to investigate synergistic effects of negative impact factors relevant for mammals, for example climate change plus landscape transformation, it is essential to rely on enthusiastic mammalogists who know the species, have experience with appropriate field methods and are able to use modern communication techniques. For this reason the unsatisfying situation of mammal conservation in Germany is not only caused be the impact factors outlined above, but also by financial shortcomings, academic apathy towards applied field biology and a lack of educated volunteers. As the situation is probably similar in other European countries mammalogists should intensify their international cooperation to overcome existing shortcomings by improving the exchange of information and personnel and developing a common framework of monitoring and conservation programmes for mammals in Europe.

A c k n o w l e d g e m e n t s

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