Action plan
for the conservation of
the greater horseshoe bat in Europe
(*Rhinolophus ferrumequinum*)

Nature and environment, No. 109

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(*Rhinolophus ferrumequinum*)

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Foreword

At its 17th meeting, the Standing Committee of the Bern Convention decided to ask for the drawing-up of action plans for two bat species as a contribution to the EURO-SPECIES Programme (Action Theme 11 of the Pan-European Biological and Landscape Diversity Strategy).

The draft action plan for the conservation of the Greater Horseshoe bat *(Rhinolophus ferrumequinum)* in Europe has been circulated for comments (letter of the Secretariat of 22 February 1999) and presented at the 4th Advisory Committee to the Eurobats Agreement (Stockholm, 19-21 April 1999).

The final version takes into account the comments from the consultation process and the discussions of the Advisory Committee and of the Bern Convention Standing Committee.

The Standing Committee of the Bern Convention adopted Recommendation No. 72 on 3 December 1999 on the implementation of the action plan for conservation of the greater horseshoe bat *(Rhinolophus ferrumequinum)* in the territories covered by the Convention.

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Summary

The greater horseshoe bat (*Rhinolophus ferrumequinum*) is widespread in Europe, with major declines recorded this century, particularly in northern Europe. It is one of about 65 species of the genus *Rhinolophus*, which is found through much of the Old World, and the genus includes a high incidence of species of conservation concern. Five species occur in Europe and all are included in *The 1996 IUCN Red List of Threatened Animals*.

The species is included in Appendix II of the Bern Convention, Appendix II of the Bonn Convention (and its Agreement on the Conservation of Bats in Europe) and Annex II and Annex IV of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora. It also has protection through national legislation in most range states, although the nature of the legislation and its implementation varies.

Originally a cave-roosting bat, many summer (maternity) colonies in Europe are now found in buildings, particularly older larger houses and farm buildings. Most individuals still hibernate in underground habitats such as caves and artificial cavities. Species of this genus are believed to be particularly sensitive to disturbance to their roost sites and to changes to their foraging habitats.

Threats have been identified to both roosts and foraging habitats. Roosts in underground habitats are threatened by closure, change of use or increased disturbance. Roosts in buildings are threatened by unfavourable attitudes of owners or occupiers or by essential or required maintenance and renovation work. A particular problem associated with bats is their concentration in traditional communal roosts (principally for hibernation or in maternity colonies) where a high proportion of particular cohorts or of one sex of the population from a very large area can be eliminated in a single incident. Foraging habitats are affected by changes in land use (e.g. from favourable habitats such as pasture/woodland to unfavourable habitats such as extensive arable areas) and the landscape structure which provides protected flyways and foraging areas. The abundance of insect prey is affected by the same factors, as well as by pesticides and pollution.

There has been considerable effort in many range states for the conservation of this species and in some areas this has at least stabilised populations. Most of that effort has been for the conservation of roosts through designation of protected areas or negotiation over site management. In recent years, greater attention has been paid to the identification and maintenance of important foraging habitat and of prey availability, with the development of integrated management of key roosts and their associated key habitats. Conservation effort may differ between core areas (current centres of populations) and recovery zones (areas of depleted or extinct populations).

This Action Plan gives detailed background to the status and ecology of the greater horseshoe bat and how this relates to identified or perceived threats to the species, including at the national level through a series of tables. The plan proposes as objectives:

- to maintain and enhance greater horseshoe bat populations
- to assess more precisely the status, distribution and threats to populations in range states, especially those in southern Europe
- to co-ordinate land use policy that can influence the conservation of the species
- to promote awareness in those whose activities may affect its status and protection
- to co-ordinate the conservation of this species as far as possible with the conservation plans for other bat species (and other species and habitat plans).

The Contracting Parties to the Bern Convention are encouraged to adopt this plan with the following actions required to meet its goals at the European level. Numbers at the end of the action points refer to further discussion and possible mechanisms for implementation given in the body of the text.

Plan development and management

1. Greater horseshoe bat conservation status within each country should be registered according to IUCN criteria and based, as far as possible, on comparable estimation methods. (4.1.)
2. A system for the development and implementation of this action plan should be established, at national and Europe-wide levels, with power to modify its objectives and targets as implementation and the availability of research results progresses. Countries sharing populations should develop an effective mechanism for co-operation to secure transboundary conservation and management. The action plan should be reviewed and revised as appropriate every five years. (4.1.)

Species protection

3. Laws should provide for the protection of greater horseshoe bats, their roosts and foraging areas. Enforcement should be promoted and provide for appropriate penalties in regions where populations are known to be threatened by disturbance, pesticides, roost destruction or loss of foraging areas. (4.1.)
4. National criteria for sites needing protection for their greater horseshoe bat populations should be agreed internationally. These criteria should be reviewed periodically to ensure that they are set at an appropriate level. Protected areas should be established for sites meeting the criteria. (4.1.)

Species recovery

5. Identify, secure and enhance the survival of small populations through appropriate roost and/or foraging habitat improvements. (4.2.)

Habitat protection

6. Classify areas within present and past greater horseshoe bat range according to their suitability and likely importance to bats, in order to identify and implement management of core areas. (4.3.)
7. Identify, institute and maintain recovery zones to link up isolated populations within fragmented populations. (4.3.)
8. Prohibit or control activities carried out by any industries or agencies that are proven, or suspected, to be detrimental to either greater horseshoe bats, or to supplies of their insect prey, especially close to known roost sites, in core areas and recovery zones. (4.3.)

Human attitudes and advisory

9. Ensure that planning policies within areas inhabited by greater horseshoe bats identify the need for the species to be a material consideration in the demolition, restoration or conversion of buildings and underground structures used as roost or hibernation sites The same should apply to habitats used as foraging areas, and landscape elements used as flyways between roost sites and foraging areas of greater horseshoe bats. Promote the participation of bat conservation experts in planning development procedures. (4.4.)

10. Provide support and incentives for landowners to continue land management in approved ways that are beneficial to bats. Avoid changes in agricultural use of land from favourable habitats (such as pasture/woodland) to unfavourable habitats (such as large open arable areas) within the foraging range of maternity roosts. (4.4)
11. Ensure that spelaeologists, industrial archaeologists and bat conservation groups develop an agreed code of practice for the conservation of subterranean roosts used for hibernation and maternity. (4.4.)

Education

12. Initiate information campaigns designed for different target groups of people whose activities may affect bat populations. (4.5.)

Monitoring and research

13. Co-ordinate and prioritise scientific research on greater horseshoe bat through its European range. (4.6.)
14. Co-ordinate the regular gathering of all necessary data and material to monitor the status of greater horseshoe bats in Europe, and identify the causes of any status changes. (4.6.)

Cross-referencing

15. Ensure that in the development and implementation of this plan there is full cross-referencing to appropriate habitat and other species conservation and management plans and wider initiatives for the development of relevant policy, programmes and legislation. (4.7.)

1. Introduction

The conservation of the greater horseshoe bat is a feasible proposition, which can be achieved without high costs or significant human conflicts. Given enough secure suitable roosts, this insect predator benefits from the abundant insect prey generated by surrounding pasture/deciduous woodland habitat, managed sensitively under a favourable climate. Such habitat also favours a wide range of other threatened wildlife (both flora and fauna), including many other bat species, is visually attractive to the general public, can be used for human recreational activities, and generates income for landowners.

Much is already known about its ecological requirements and the influence of various factors upon survival rates and population levels. Hence it is possible to construct a detailed conservation plan for the species which has a high likelihood of success, if implemented.

This action plan presents the most recent assessments of the state of populations in various European countries within its range. It also considers the ecological and political aspects of greater horseshoe bat conservation in those countries.

Most of the data used for the preparation of this plan originates from northern (and particularly north-western) parts of the range in Europe. This is also where the most significant declines and losses have been recorded, and where conservation effort may be most needed. However, more data are needed on any differences in the conservation issues and ecology of the species elsewhere in its range.

2. Background information

2.1. Description of the species

The genus *Rhinolophus* (the single genus of the family Rhinolophidae) includes about 65 species and is found through most of the Old World, including temperate regions. The family is sometimes considered to include the Hipposideridae (73 species of tropical Old-World leaf-nosed bats). Rhinolophids are mainly cave-dwelling bats, believed to be particularly sensitive to disturbance. The family contains a high proportion of species of conservation concern. Five species of *Rhinolophus* occur in Europe and all are included in *The 1996 IUCN Red List of Threatened Animals.*

The greater horseshoe bat, *Rhinolophus ferrumequinum*, is one of the medium-sized species of the genus (but the largest in Europe with a mass from 14 to 34 grams). The subspecies *R.f.ferrumequinum* is distributed through Europe to about 52^{o}N in western Europe and 48 N in eastern Europe, south to parts of North Africa (Morocco, Algeria, Tunisia) and East to the Himalayas (Map 1). Further to the East it is replaced by *R.f. nippon* and it is closely related to *R. sinicus* of China, *R. clivosus* of the Arabian Peninsula and sub-Saharan Africa, and to *R. bocharicus* of Central Asia.

Rhinolophids are insectivorous bats distinguished by a complex nose-leaf. This is used to concentrate their very high frequency ultrasound pulses (which are long, almost pure notes) into a narrow beam. Their echolocation capabilities allow them to detect fine structural details, and judge both the speed and trajectories of their prey. Greater horseshoe bats recognise and select prey insect types, which they primarily hunt by either hawking or by perch-hunting like a flycatcher (Muscicapidae). Due to the rapid attenuation of high-frequency sounds in air, the effective sensory range for prey recognition is probably limited to less than a few metres. Like other temperate-zone bats they show typical insectivorous dentition.

They show the usual major adaptations of bats for flight, but are specialised for manoeuvrable flight in fairly confined situations by having broad wings, with a large hand-wing. Most prey are caught either close to the ground, or to lines of vegetation such as trees and substantial hedgerows.

Greater horseshoe bats grow to full skeletal size in two months, yet can live for over 30 years. Females show delayed sexual maturity, first breeding at age two years, three years or even older. They always have single births, usually annually, but some individuals have years without breeding.

Greater horseshoe bats are true hibernators, but seem incapable of the very prolonged periods of hibernation torpor shown by vespertilionid bats. They make use of mild winter spells to feed periodically throughout their hibernation period. When in hibernation torpor they hang freely from projections, like large black plums. Often they form large clusters, and these habits make them relatively easy to count or capture in winter, compared with vespertilionid bats.

Three aspects of the biology of temperate European bats make them particularly vulnerable to population pressures. Firstly, bats (mainly females) gather in maternity colonies in summer: more or less the whole of a breeding female population for a considerable area may be concentrated into one roost, which may be liable to destruction, disturbance or change of use. A colony can be very faithful to a particular roost, which may be occupied for long historical periods. Secondly, in winter bats hibernate and the greater part of the population may be concentrated into a few sites. These are also vulnerable to destruction, disturbance or change of use. The arousal of a bat from hibernation torpor is a very slow process, and as each arousal costs a great deal of energy, unscheduled arousals (which are far more costly than natural arousals) are potentially life-threatening. Thirdly they require a good supply and range of insects throughout their reproductive season, but especially in mid summer when females suckle their young. Insect food supplies available to foraging bats are not only influenced by the population densities of flying insects. They are also affected by habitat structure, including sheltered flyways linking up important foraging areas. Changes of land use, pesticide treatments, removal of linear landscape features and habitat fragmentation may all pose significant threats to bat populations.

2.2. Distribution and population estimation methodologies

2.2.1. Definitions and population estimation

Greater horseshoe bats form their largest and most concentrated aggregations in July and August when related breeding females and their immature offspring congregate in a traditional maternity roost. At certain times of the summer, adult males which were originally born in the roost, may also be present. Such a collection of bats is termed a colony. Its size and constitution by sex, age and reproductive group varies continuously throughout the summer. Normally female young return to breed in their natal roost, but occasionally they emigrate to other maternity roosts.

In winter, bats from several summer colonies usually move to local caves, disused mines or other underground sites termed hibernacula, to form winter populations. In some instances a maternity colony occurs underground, and the same site may be used as a hibernaculum. Mature bats from different colonies seem to mate freely with each other and coexist in winter, often in sites used for mating. As hibernacula tend to be grouped into distinct geographical areas, genetic interchange is greater within a population than among populations separated either by ecological barriers or large distances. However, individuals which travel long distances provide genetic links among geographically isolated populations to form a metapopulation in a country or region.

Greater horseshoe bats do not distribute evenly at any time of year and their dispersion patterns vary seasonally. They are very difficult to count in the field whilst foraging for two reasons. First, because their echolocation pulses are so directional that they can only be detected from a limited angle in front of the bat. Second, they fly low alongside linear features, or within woodland where they are difficult to see. They are rarely silhouetted against the sky during flight. Hence the numbers foraging in an area are not easy to assess. Currently population estimates for a region tend to be based upon either dusk exit counts from all known maternity roosts, or counts of torpid bats in certain hibernacula. Such estimates should be regarded as minima, since they only tell us about known colonies or populations, and so are vulnerable to the discovery of further maternity roosts or hibernacula.

In regions where searching efforts for both maternity roosts and hibernacula have been intensive and prolonged over many decades, estimates are likely to be quite reliable. In regions where neither is true, estimates should be regarded as tentative minima, and a basis to build upon by further surveys.

Whatever the weakness of population estimates for a region, trends for specific colonies over years can be reliably followed by standardised annual summer counts. Three fairly simple population parameters for each maternity roost are useful for estimating total colony size. Dusk exit counts show two plateau periods, the first in late May and early June, and the second from late July to mid August. The second of these two plateau periods is the more reliable, and reaches the highest levels. Finally the maximum number of young counted within the maternity roost after the dusk exit of their mothers and older relations provides the third parameter. Appendix 1 provides details of the recommended method of estimating colony size from these parameters.

2.2.2. Status of the European populations

The greater horseshoe bat is found throughout the territory of Europe north to the UK (southern England and south-west Wales), Belgium, Luxembourg and the south of Germany, Poland, Ukraine and Russian Federation. In addition it occurs on many of the larger Mediterranean islands belonging to mainland European states and on Cyprus and Malta. It is extinct in the Netherlands (see Map 1 and Table 1).

The population levels of the greater horseshoe bat in the European countries for which data were made available to a 1995 conference ‘On the Situation of the Rhinolophidae’ showed no common pattern. Unfortunately no information from Spain or Portugal was presented at this conference, and it may be that these countries have more encouraging news on these rare bats.

Falling levels were recorded in Germany, Belgium, Bulgaria, parts of Hungary, parts of Italy around Milan, and France. Stable populations were recorded in parts of Hungary, Luxembourg and parts of the UK. Rising populations were recorded in parts of the UK. A more recent summary of the state of knowledge of the species in European range states is presented in Table 1.

The absolute level of populations in most of these various countries is difficult to assess. The trends listed above are based on surveys carried out over varying periods of time at the same sites. Such surveys may provide good data on trends, but unless the surveys cover all maternity roosts in a country, the total population level will be underestimated. Even in the UK, where surveys have been extensively carried out over many years, several new maternity roosts have only recently been discovered.

2.3. Life history

This account is based largely on studies in northern Europe (especially the UK) and behaviour may differ in southern Europe.

2.3.1. Food

Greater horseshoe bats are selective feeders, preferring larger insect prey. Extensive dietary studies in the UK show that beetles and moths are the preferred prey, with crane flies (Diptera, Tipulidae), caddis flies (Trichoptera) and ichneumonoid parasitic wasps (Hymenoptera, Ichneumonoidea) being taken in decreasing order of preference.

The beetles normally eaten are mainly from the family Scarabaeidae, and include the large cockchafer, *Melolontha melolontha*, the small dung beetle, *Aphodius sp.*, and various types of large dung beetle, *Geotrupes sp.*. The latter is particularly important in winter feeding from October to December, and again from February to April. Cockchafers seem to be the preferred prey to all others when abundant. It is eaten exclusively for several weeks in the spring in good years, and probably promotes rapid pregnancy by breeding females. Later in June until early August, females prefer various types of large noctuid moths, such as the yellow underwing moth, *Noctua pronuba*, and occasionally sphingid (hawk) moths. Moths are the preferred prey during lactation by mothers. Their young, however, prey almost exclusively upon *Aphodius* beetles when they begin to feed at 28-30 days of age, if available. In their absence, the young eat tipulids. Only when they are 45 days or older, can they feed upon moths, but *Aphodius* is still preferred.

Studies in continental European countries broadly support these findings. Two apparent differences occur, however. The small summer chafer, *Amphimallon solstitialis*, is commonly eaten in mid summer, and *Aphodius* beetles rarely feature in the diet. Tipulids may be the preferred prey of the young in continental colonies. Whether these differences reflect availability or preferences among metapopulations remains to be seen.

2.3.2. Foraging techniques, timing and ranges

The American term ‘foraging’ is used since it incorporates all activities involved in hunting or searching for prey items using flight and ultrasound, as well as capturing, dismembering and finally swallowing them after chewing. A foraging area is an area within which a bat may spend some time on these activities (about 30 minutes or longer), and a foraging bout is a period of time during which foraging occurs (usually from one to 2.5 hours). It is separated from other bouts by a period of resting during which rapid digestion and egestion of faeces occurs, permitting the consumption of more food. Inter-bout periods may be spent in daytime roosts, or in temporary night roosts.

Detailed radiotelemetry studies of bats from many colonies, some over several years, in three different European countries, show that these bats have a consistent specialised hunting technique, and use foraging areas with a similar structure. They travel quickly (commute) from the roost to a foraging area, flying about 1 to 2 metres above grassland, along the side of linear features such as tall hedgerows and woodland edge. Foraging areas can be adjacent to a maternity roost or as far as 14 km away. In the majority of studies, they were located within 3-4 km of maternity roosts, and the mean adult range in one extensive study was about 2.2 km. Whatever the commuting distance needed to reach foraging areas, bats fly about 21-25 km total distance in a night. Two individuals were shown to fly 51 and 35 km in a night respectively.

Within a foraging area, which averages 6-7 hectares, bats mainly use localised favoured spots or core areas of 0.35 hectares average size. They hunt within them, mainly by either hawking along the edges of linear habitat features (usually within 5 metres of woodland edge or hedgerows), or by perching on a twig some 2 metres from the ground and scanning for passing prey which they intercept, using their long echolocation pulses. Selected twigs are bare, and in the range 5-10mm diameter. Most prey are caught close to the ground, possibly because they fly slower as they take off or land. Many of their prey either emerge from the soil beneath short grassland, oviposit in it, or feed on the dung of domestic animals. Besides hawking and perch-feeding, some studies report regular gleaning of prey from vegetation, during which the bat may even hover.

The bare twigs used for perching may be selected for their safety from predators, as well as their size and position relative to good prey-capture opportunities. An overhead cover such as a leafy canopy, shaped like an umbrella, is preferred. Such a cover, besides protecting the bat from predator attacks, may also shelter it during rainfall. Tall hedgerows, or woodland edge delimiting pastures grazed by cattle, tend to be favoured core foraging areas. Cattle graze the lower hedge levels, creating an umbrella shape and bare twigs at about 2 metres height, which the bats find attractive for perching. They also generate high concentrations of dung close to hedges when they rest to ruminate in the shelter provided by a hedge. The dung attracts concentrations of nocturnal dung beetles as potential prey.

Tall, thick hedgerows, shaped as described above, may also be important as food sources, since they can generate many other insect prey species, including moths. Furthermore they provide shelter for foraging bats, and concentrations of insects during periods of high wind speed. Finally they may provide crucial linear features essential for bats to maintain their orientation whilst foraging or commuting. (A flying greater horseshoe bat is like a person in fog, with an effective sensory range of only 5 to 10 metres).

After a successful prey capture, the perch may also be used whilst a large prey item is dismembered, and the less digestible parts discarded. Occasionally groups of bats hunt together from perches within the same core area. Such behaviour may provide mutual benefits by warning of predator presence.

These bats may forage once, twice or three times a night according to season and reproductive class. Normally adults forage for about 3 hours each night, but the time may be lengthened or shortened by sex, reproductive condition and climatic factors. Foraging for most members of a colony concentrates soon after dusk when conditions are usually most favourable for the flight of their prey. Emergence timing relative to dusk, and hence to light levels at emergence, seems to reflect a conflict between the need to forage and the avoidance of predators. Birds of prey, such as sparrowhawks (*Accipiter nisus*)and some owls, are sometimes known to catch greater horseshoe bats.

Greater horseshoe bats do not spend the whole of a night's foraging in a single foraging area, but frequently switch to other areas. Adult bats normally use between 2 and 11 different foraging areas in a single night. There is currently no evidence for foraging areas being treated as territories belonging to a specific individual or group of bats. Foraging area switching behaviour may also be a predator-avoidance strategy, or just an attempt at finding more concentrated prey sources. Prey availability not only reflects the local current population level of a particular insect, but also the climatic temperature operating during a foraging bout. Above about 14 ^{o}C all of their insect prey can fly, but as the temperature falls, different insects become incapable of flight take-off and so become unavailable to foraging bats.. The lower the dusk temperature the poorer becomes the choice of prey. Most moths require at least 12 ^{o}C to fly; *Aphodius rufipes* and many tipulids need 9 ^{o}C and ichneumonoids need about 3 ^{o}C. Essentially it seems that, above 10 ^{o}C maximum climatic temperature on a particular day, these bats are able to forage profitably at dusk. If the minimum night temperature is above 7-8 ^{o}C they can forage at dawn as well, but on restricted prey.

These considerations mean that greater horseshoe bats can usually forage only at dusk, or not at all, in winter; dusk only in early spring; dusk and dawn in late spring and summer. In addition, lactating females usually also feed in the middle of the night in summer. These foraging patterns are often modified by the climatic conditions operating during a specific foraging period. Besides cold conditions, wet and windy weather can also prevent foraging, or reduce its success.

2.3.3. Energetics

Although the greater horseshoe bat is a large insectivorous bat, it is still a very small mammal. It has a very high metabolic rate even when resting, and this rate climbs dramatically at low ambient temperature (below about 15^{o}C), and when flight occurs. Active (thermoregulating) bats can minimize their energy costs by clustering closely together, and/or by selecting a warmer roost. Above about 25^{o}C the costs of thermoregulation fall to minimum levels, and above 40^{o}C they become heat stressed. Roosts rarely provide ideal thermal conditions for continuous activity by bats, and bats have the capability to switch off thermoregulation and become torpid. A torpid bat may use less than one hundredth of the energy costs of a resting thermoregulating bat.

To fuel the energetic demands of full activity over 24 hours, a bat must consume a high proportion of its body mass each day, even if it is merely carrying out body maintenance activities. Reproductive activity, or fat storage, may add considerably to energetic costs, and hence to the levels of food required. A lactating female may consume over 25 % of her body mass in a single dusk foraging bout, and a further 25 % in the two additional bouts before dawn without increasing her body mass. Hence over 50 % body mass level of food consumption may occur within a six-hour period of darkness. This is necessary to sustain sufficient milk production to provide for the growth demands of her offspring in the early stages of growth, as well as for her body maintenance.

Bats living in temperate countries, even under favourable habitat conditions, experience climatic conditions which do not permit such levels of food consumption to be maintained continuously, even in summer. Bats are frequently and erratically forced into the use of torpor in order to conserve energy reserves and survive. If torpor periods are brief, they cause no permanent growth damage to the young, but if prolonged for more than a few days continuously, permanent stunting of the young may occur.

2.3.4. Hibernation and hibernacula

Hibernation is a complex adaptation to long periods of food deprivation, which should not be confused with summer torpor. Summer torpor can only last for up to 24 hours, and leads to daily arousal at dusk. Hibernation torpor may last from 1 to 18 days according to the ambient temperature of the bat. It can only occur between October and May. As in summer torpor, arousal is normally at dusk when it occurs. After arousal, several hours of body temperature regulation occurs, during which some form of body maintenance occurs. If the bat experiences low body reserves, it may attempt to forage, and will do so successfully if temperature permits the flight of winter insects. Sometimes sufficient food is eaten to permit activity throughout the night, and a second dawn foraging bout may occur. Such behaviour is common, particularly in October, and often also in November in northern temperate latitudes. Most fat deposition for hibernation occurs rapidly in mild weather in mid to late October. At this time bats choose hibernation roosts (=hibernacula), which have good ventilation, so that they are relatively warm (about 9-11^{o}C), and fluctuate with local weather changes. Possibly the air-flow permits synchronisation of their arousals with dusk. Bats arouse every 1-2 days at this time. They are particularly sensitive to provoked arousals at this time of year, especially torchlight or unusual sounds.

Theoretically extra arousals should lead to lower body reserve levels and a greater risk of starvation later in the winter. There is no published data supporting this view, and the provoked arousals involved in my (RDR's) studies of up to four times in a winter are not associated with increased mortality. Greater horseshoe bats seem to be able to compensate for the additional arousals by adjusting their winter reserve losses, presumably at least partly by winter feeding in the temperate winters of the UK. However, in continental regions with severe winters, it is likely that additional provoked arousals would deplete reserves and increase mortality.

As the weather becomes colder from December to February in northern temperate latitudes, the autumn hibernacula often become too cold, and bats are forced into more stable cool hibernacula where temperatures lie between 6 and 8 ^{o}C. At these temperatures, in mid winter, bats normally arouse every 8-12 days. After arousal, they again spend several hours of maintenance activity. Foraging at this time of winter is much less frequent, but can occur at dusk during mild winter spells. Adult male bats are particularly likely to forage successfully at this time. All bats are less sensitive to provoked arousals at these lower temperatures, but are still aroused by lights, especially at dusk.

From February to May, as the weather warms again, bats return to well ventilated hibernacula, and arouse more often. At ambient temperatures of 8-9^{o}C they arouse each day, but can reduce their arousal frequency by moving to colder regions (5-7^{o}C) if cold weather persists. Foraging frequency at dusk normally gradually rises again, but is erratic due to sudden changes in the weather. During particularly warm spells, even in February, bats will return to the maternity roost and remain active for periods of 24 hours for several days. The return of cold weather forces them back to the hibernacula, where they can remain torpid for long periods again.

Eventually, in late May, the bats are unable to remain torpid for more than 24 hours, whatever the ambient hibernaculum temperature. This is the end of the hibernation period. Cold, or wet and windy weather after this time has a major effect on the survival of bats. If prolonged for more than a few days continuously, mortality will be high that year.

Within the hibernation period, which lasts for 7 months in the UK, many reproductive activities occur. Mating can occur from September until December, and possibly again in the spring. Sperm is stored within the female, and conception normally occurs early in April. The early stages of pregnancy take place well within the hibernation period.

Hibernacula are roosts used for hibernation by bats. Greater horseshoe bats may use a wide variety of underground sites. They may be natural caves, various types of mines, tunnels or large pipes, or extensive cellar systems beneath large buildings. Regardless of their origin, what matters to bats is their temperature and humidity regimes, their permanence as roosts, and because of winter feeding, the quality of the surrounding habitat close to the entrances.

There is evidence of a degree of segregation of greater horseshoe bats in winter, as well as in summer. Hibernacula can be classified into three types on the basis of the sex and age of the occupants. Type 1 hibernacula contain first-year bats and older immature bats of both sexes. Adult males may join them in mid-winter. In favourable habitat circumstances large clusters may develop. Type 2 hibernacula contain few first-year bats, but many second and third-year immature bats with surplus adult males. Clusters are also formed by these bats. Adult females, if present are usually solitary. Otherwise they are widely scattered in the deeper regions of larger hibernacula. Type 3 hibernacula are either smaller, often isolated sites, occupied by the same adult male bat over many years, or part of a larger cave system. He uses it as a breeding territory. The male does not always occupy the site, but is present in late summer to early winter, and again in the spring. He is joined by varying numbers of mature females for mating in the autumn, usually up to 7 may occur at any one time. Many of the same females return again in the spring. There is accumulating evidence that much of pregnancy occurs either in these territorial male sites, or satellite maternity roosts.

In a region where bats from several maternity colonies hibernate in the same group of hibernacula, only one or two type 1 and 2 hibernacula are required. However, possibly 20 or more male territorial sites may be needed to cope with the demands, during pregnancy, of all of the females in a large maternity roost. These may be scattered over a 40 or 50 km radius from the maternity roost, whereas the other hibernacula are usually less than 15 km away.

2.3.5. Movements between roosts

First-year bats normally occupy hibernacula which are within about 16 km of the maternity roost. They may even remain in hibernacula within or adjacent to their maternity roost building or underground site. Some travel up to 45 km to winter with bats from other colonies, and exceptionally they travel up to 96 km in their first winter.

During a single hibernation period, bats rarely move more than 15 km from one hibernaculum to another. However, from one winter to another, they may travel up to 80 km to occupy new hibernacula. The failure to catch a bat in its second winter is therefore not evidence of its death. The longest movement in the UK involved a bat, which moved 142 km over 8 years.

Mature male and female bats gradually tend to occupy the same hibernaculum, or group of hibernacula as they age. They remain in it, or them, for the remainder of their lives, so their disappearance is usually an indication of their death. Female bats may travel over 60 km from their hibernaculum to their natal maternity roost, and back again, annually over many years. Adult male bats have occupied mating territories up to 95 km from their natal roost, but such bats do not return to the natal roost.

2.3.6. Reproduction and growth

Males aged 2 or 3 years, or older, carry out spermatogenesis in June and July each summer. They may return to their natal maternity roost during this period. In August sperm pass into the epididymides where it may be stored until the following April or May. During August the males often leave the roost to occupy a territorial site, if one is available. Mating only occurs from September onwards, and the intense reproductive activity which peaks in the autumn results in adult males having the lowest body reserves of all sex and age groups at the start of hibernation. As a consequence they are the most likely bats to feed in winter, and suffer the greatest mortality at the end of a severe winter.

Females produce a single follicle which starts meiosis in October, rests over winter, and completes ovum production, usually in early April. After copulation the accessory gland secretions of both male and female combine to form a vaginal plug, and the spermatozoa attach themselves to the uterine lining where they are fed throughout the winter. The vaginal plug effectively prevents further winter copulations by blocking the vagina. Ovulation, and the ejection of the vaginal plug, normally occurs between early and mid-April, but probably varies with the severity of the weather, and is likely to be earlier in southern European countries. It is possible that spring matings occur, and conceptions involve sperm stored in the male, rather than in the female.

Pregnancy length is influenced by the frequency and success level of foraging bouts, which determine the length of torpor use. Weather conditions, especially during April and May, are crucial to birth timing. A rise of 2 ^{o}C in mean ambient April/May temperature accelerated mean birth timing by 18 days in the UK, where it varied between 3 and 27 July over a 9 year period. Individual females have given birth from 11 June to 17 August. Births generally occur over at least a 3-4 week period at any roost in a particular summer, hence the pregnancies of individual females are either longer or shorter relative to others under the influence of the same weather. This may reflect differing levels of food consumption, possibly as a result of differing foraging efficiencies, or variations in the quality of the habitat or the microclimate of the foraging sites used during pregnancy.

Lactating female bats forage for the longest periods of any age group each night, and show the highest food consumption levels early in lactation. The time spent foraging falls as the baby ages, as does her food consumption, and presumably her milk production. Hence milk levels are likely to match her baby's growth rate which peaks about the 4 days after birth. She starts lactation with some body reserves, but these are insufficient to sustain lactation for more than one or two missed foraging bouts due to bad weather. If poor weather persists, her young suffers growth retardation, which may be permanent.

Young are born weighing about 6.2 grams, with a forearm of about 26 mm. A baby grows rapidly to 13 g and 50 mm forearm in about 17 days, when it can just fly. Forearm growth rate slowly declines after its early peak, and ceases between 30 and 40 days. Between 20 and 28 days they become skilful flyers, and from 28 days they leave the roost and start to catch their food independent of their mothers. Normally they catch *Aphodius* beetles close to the roost (< 100 m) in the UK. They rapidly increase their foraging efficiency and range from day 28 to day 45, when their ultrasonic capabilities are completed, by the ability to Doppler-shift-compensate. This allows them to gauge the speed of their prey and intercept them. By 45 days they travel about 1.5 km from the roost, and reach adult distances (2.2 km) by about 60 days.

Normally weaning occurs about 45 days after birth. Early weaning may be advantageous to the mother, since it conserves calcium. Calcium occurs at very low levels in insect prey, and the mother progressively leaches it from her own skeleton to boost its concentration in her milk. During post-lactation she has to recover her skeletal levels before the onset of hibernation, since further losses occur in winter. Late birth-timing (parturition) is therefore believed to carry a mortality risk to the mother which may not occur until late in the following spring.

Although the growth of the young's forearm is complete by 40 days, and usually shows little change after 30 days, the length of the digits continues to increase until 60 days. Hence the young's foraging capabilities influence the final growth of its skeleton and other body tissues. A skilful juvenile forager probably relieves its mother of milk production in later lactation, and may even promote early weaning. Late-born babies show slower growth rates and often become stunted subadults, with small radius and digit 5 lengths. Stunted female young have poor survival prospects.

There is evidence that the lean body mass of first-year bats of both sexes increases significantly during their second summer, and that of females continues to rise slightly in the following two summers. The need for additional tissue growth, which is not reflected in skeletal lengths, may explain the long period of immaturity shown by this species.

2.3.7. Survival and longevity

Young bats rarely die at birth, but late embryos may be aborted in cold, or wet and windy weather. These are usually less than 1% of births at a roost. Mortality of the young up to day 28 is normally very low or absent in favourable weather. Mortality increases once the young begin to fly outside the roost and begin foraging. The highest mortality rates occur between the age of 45 and 55 days, just after weaning, when the young extend their foraging range considerably, spend longer out of the roost each night, and visit more foraging areas, night roosts and potential hibernacula for winter use. These activities may expose them to higher predation levels, and/or increase the risk of them becoming disorientated and unable to find their way back to the roost.

Mothers may leave the maternity roost and abandon their young soon after they are 55 days old, and usually before 65 days. Poor weather conditions in September may contribute to further juvenile mortality before hibernation starts. A variable proportion (10 to 80 %) reach the hibernacula in a given year. High mortality follows late births and poor September weather; low mortality follows early births and warm Septembers. Overall only about 53 % of those reaching the hibernacula survive to age 2 years. They represent from 5 to 42 % of those born the previous summer.

Late-born cohorts of young rapidly die out in a few years, leaving no surviving offspring, whereas early-born ones may continue for over 20 years, and so provide the bulk of the colonies offspring. This happens because female survival long-term is linked to successful growth as juveniles as described above. Early-born female young grow into larger females than late-born ones, and have better survival rates, especially in the first few years of life. Late-born stunted females may be stressed bats which cannot cope with the demands of pregnancy and lactation. They frequently die in the year following their first birth.

If they reach the age of 2 years, female survival is about 72 % annually until the age of 5 years, after which it remains at 80 to 90 % until the age of about 18 years. It then seems to fall to 60 % up to 25 years. Exceptionally individuals reach 30 years and are still capable of breeding. In their final years, although their pregnancies and births seem normal, the young of such old female bats become progressively smaller with lower survival rates. This poor juvenile growth may be due to a reducing competence of the mother’s mammary tissue to supply sufficient milk, even though she forages successfully. The same appears to be true of first-time breeders. They give birth much later than experienced mothers, and the early growth of their young is often very poor, possibly as the mammary tissue achieves competence. Later in development juvenile growth may recover, if the weather and foraging circumstances are good. If severe weather dominates the summer when a female first gives birth, she is much more likely to die than in one with favourable weather.

2.3.8. Roost requirements

There are at least three major types of roosts necessary to maintain a viable population in a region. They are nursery roosts, night roosts and hibernacula. Their uses have already been outlined above, so here we will only consider their structure and microclimates.

Nursery roosts may be underground or above ground, often in various types of buildings. If underground, only large colonies seem to be capable of rearing young successfully. Such colonies usually occupy vertical blind domes near entrances which permit the accumulation of body heat losses, and warming from external circulation. Such positions, although they do not reach high temperatures, do not cool down rapidly at night. Nursery roosts in buildings, usually in dark or semi-dark roof spaces with a large entrance hole for free flight, may reach high temperatures (in excess of 40°C) during the daytime, especially if sunshine occurs. However, at night temperatures may drop below 10°C, especially in spring. Such roosts have to be regularly abandoned in poor weather, and so a nearby underground roost is essential to allow survival by using torpor.

Night roosts can be any building or system providing shelter, such as the chimneys of derelict buildings, garages, stables, porches, caves and even the branches of large trees. Since they are only used at night, they can be open structures which are brightly lit in daytime. Studies of their microclimates do not exist, but the most suitable ones are probably those which are waterproof, and allow the retention of body heat whilst digestion occurs.

Hibernacula can be any underground structure, of almost any size. Short tunnels only 10 m long may be used as territories for mating and early pregnancy, and extensive multi-entranced systems may be used as type 1 or 2 hibernacula. The more variable the air-flow pattern present, and hence the ambient temperature regime provided, the greater the potential use of the site for hibernation by bats of all species.

A summary of roost site types is given in Table 2.

2.3.9. Social organisation and dispersal

Studies of social organisation among bats are at an early stage at present. Preliminary investigations suggest that maternal care may continue over the immature years of a bat’s life, especially in females. Since females almost always breed in the natal maternity roost, they consist of matrilines which may be closely related. This situation favours the development of complex behaviours by kin-selection.

Almost all immature males return to the natal maternity roost at Woodchester Mansion (UK) in their second summer, but the frequency of their presence falls after that. About 60% return in their third summer, and their presence is increasingly erratic after that. Mostly they return in early summer only, whilst spermatogenesis takes place.

Immigration of mature females into the Woodchester maternity roost is a rare event, and such females may take many years to become successful breeders (those whose young survive long enough to breed themselves). Often they have several years without breeding. Immature females on the other hand immigrate regularly for short periods, usually after the post-lactating females leave the roost, or before many pregnant females return in the spring. Many of these immigrating females do not eventually give birth in the Woodchester roost however. Overall it appears that the older mature females may influence the stay of immigrants by methods which are not yet apparent. Infra-red video surveillance has not shown serious aggressive interactions within the roost, despite several year’s studies.

Gene-flow among colonies almost certainly occurs during copulations within the territorial male sites. Mature females which arrive in a particular territorial site during autumn may derive from two or more maternity roosts over 60 km away. Conversely males have been shown to move up to 95 km from their natal roost to take up territories occupied by non-related mature females. Such movements probably allow genetic interchange to occur across the whole of England’s metapopulation of greater horseshoe bats, spread over 400 km maximum distance (NE to SW), since a chain of colonies exist, separated by less than 150 km.

2.3.10. Summary of habitat requirements

Greater horseshoe bat populations are promoted by a foraging habitat which consists primarily of permanently-grazed pastures interspersed with blocks or strips of deciduous woodland, or substantial hedgerows. Such pasture/woodland habitats generate large levels of their preferred prey, especially dung beetles and moths, but also tipulids and ichneumonids. The pastures should be cattle-grazed by preference, as their dung sustains the life-cycles of the most important beetles, but sheep and horse-grazing may also be beneficial in a rotation to reduce parasite problems. Sheep-grazing, which results in a short sward, may also benefit the life-cycles of tipulids and cockchafers.

Deciduous woodland blocks or strips should be linked by suitable hedgerows as flight-lines. Substantial broad hedgerows with frequent emergent trees can provide suitable foraging conditions, both in their structure and prey supplies if woodland is scarce. Mature grazed parkland, or orchards are also suitable. Cattle are preferred to smaller grazers, since they create the ideal structural conditions for perch-hunting bats in hedgerows and woodland edge.

In addition to the grazed pasture/woodland ecosystem, lakes and rivers close to the roost are beneficial, especially if they are tree-lined. Such habitats generate the maximum populations of insect prey types required by the bats throughout the year. Bats will benefit from insecticides being used to control insect pest species only where strictly necessary using improved targeted application of more selective pesticides. Alternatives to insecticides, such as Integrated Crop Management, may benefit bats. Some endectocides used for parasite control within grazers affect their insect prey.

Habitats which are avoided by greater horseshoe bats include urban areas, arable land, amenity areas such as playing fields, and many types of coniferous forest. Lights, such as street lights or security lamps, are strong deterrents to greater horseshoe bats, both when they emerge from roosts, and when they forage.

Within suitable habitat, a range of three roosts types must be present for a colony to exist. A single maternity roost, with many surrounding night roosts nearby (usually up to 4 km, but exceptionally up to 14 km) for resting between foraging bouts and a range of suitable hibernacula within a 60 km radius. The type 1 hibernaculum should be as close as possible, but within 15 km of the maternity roost.

A summary of habitat preferences is given in Table 3.

2.4. Greater horseshoe bats and humans

Greater horseshoe bats have received enormous benefits from humans throughout Europe in past historical times. Human activities have inadvertently created a much wider spread of suitable habitats from previously limited ecosystems, in which natural cave systems are likely to have been an essential feature. Three aspects have been particularly beneficial. First the extraction of stone and other minerals from mines, which were later abandoned. Second the construction of substantial buildings, especially those with complex and voluminous roof spaces, dungeons, extensive cellars, ice-houses and storage tunnels. Third the widespread development of extensive grazed pasture/woodland and grazed pasture/hedgerow ecosystems in agriculture.

2.4.1. Public attitudes

Until recent decades public attitudes to all bat species were negative in many European countries, largely due to historical prejudices, partly fostered by the literature. Bats were regarded as pests, and were treated as such by many house owners. With persistent publicity and education, a reversal in attitudes has been achieved in certain countries, so that only a minority of people are now averse to them. Some of these are genuinely bat-phobic, and panic-stricken at the thought of sharing their homes with bats. Most can have their fears allayed by visits from bat workers who can explain about the many fascinating aspects of their long lives, show them how small they are and may be able to demonstrate a bat's amazing ultrasonic powers with a bat detector.

2.4.2. Conflicts with humans

Serious conflicts with humans rarely occur. Usually interactions involve the nuisance caused by excrements (faeces and urine) in occupied buildings which may stain or cover property. Maternity roosts may occur in parts of occupied buildings, and bats may hibernate in cellars which are beneath them. In many cases the bats and owners happily co-exist for many years. Problems can occur when ownership changes, and the new owners are less tolerant of the bats, or wish to utilise the roost spaces for other purposes.

In some caves the interests of hibernating bats conflict with the desire of cavers (spelaeologists) to carry out their sport without restrictions. Alternatively, an owner may wish to open up the cave for commercial visits which involve disturbance due either to lighting regimes or noise.

2.5. Threats, limiting factors, and obstacles to conservation

2.5.1. Intrinsic or natural factors

2.5.1.1. Severe climate

Greater horseshoe bat populations show a significant fall after a series of severe winters and cold springs. Their recovery after such a climate-induced population crash is very slow. It can take in excess of 12 years for a maternity colony to regain its former size, if this happens at all. Recovery is slow, partly due to the small litter size of one birth per female per year, and the long period of immaturity of sub-adults. They may be two, three, or more years old before they first give birth. Mortality is normally high in two-year old, first-time breeders, which give birth very late in the summer. Also about 8-10% of mature females do not breed every year. These are generally the inferior mothers.

The mature females which survived one climate-induced population crash in the UK were the older ones. These are more likely to produce male births, and within a few years of the crash, will become senescent breeders whose young have a poor survival record. The future reproductive success of the colony after a crash may depend upon the immature and non-breeding females which survive the crash, and any female young generated by the older females before they become too old to be successful breeders.

If a large colony occupies a cool roost, before the crash it can successfully rear many large female offspring by mutual heat loss, which keeps ambient temperatures high. After a crash, the numbers may be insufficient to generate suitable ambient temperatures, and the female young grow poorly, showing low survival rates and a tendency towards male births. Without artificial heaters installed in the roost, the colony may never recover its former size, even in favourable habitat circumstances.

2.5.1.2. Demographic viability

Small population size is generally a threat to population viability because random events can cause serious sex and age-distribution anomalies to arise. This is particularly true of animals which are long lived, and in which reproductive performance varies with age. Both have been shown to occur in this bat. However, many current greater horseshoe bat colonies in Europe number between 80 and 200 animals, with only 25 to 50 young born each year.

The most likely widespread random factor which may suddenly influence bat populations adversely is severe climate. Its geographical distribution is clearly influenced not only by latitude, but also by winter severity. This increases with altitude, and distance from the warming influence of the Gulf stream and westerly prevailing winds. In the northern end of the range, high summer temperatures may not be entirely beneficial to successful reproduction: night-time levels regularly rising above 12 ^{o}C throughout the night permit the flight of large moths, but if they rise too high, in the absence of sufficient rainfall, the productivity of *Aphodius* beetles will be reduced to the detriment of the young's growth. Hence frequent arid climatic conditions may be just as undesirable as cold wet ones, and may set the southern limits to distribution. Studies at maternity roosts near its southern limits in Europe and North Africa are needed to investigate this possibility.

Two severe periods of general bat population crashes have been documented in the UK since the 1950s. The first was between 1962 and 1965, and the second was between 1984 and 1986. On each occasion the populations fell to less than 50% of their original levels. At two sites in the UK the number of young born annually fell from about 45 to 20 after 1986. Both crashes followed a series of severe winters with abnormally prolonged cold periods which continued well into spring. This delayed mean birth dates until late in July, and led to poor growth of the young. There was high mortality of both mothers, who had little time to recover from lactation stress, and the young which were stunted. Both were also faced with cold September and October conditions which affected fat storage for hibernation. The mortality of first-time breeders was especially high during these periods, so that an ageing population remained after the populations crashed. Recovery from such crashes can take 10 to 15 years.

Conservation action in regions close to the bat's northern limits, which are prone to such climate-induced serious population crashes, should therefore include steps to minimise climatic impacts.

2.5.1.3. Genetic viability

Current genetic studies of several species of bats show that most maternity colonies have originated from very small numbers of females, in some cases only one or two. The colony may then grow to several hundred individuals over time. The gene pool provided by the founder females may be very unrepresentative of the parent population or metapopulation. As female bats, including greater horseshoes, appear to be resistant to large-scale immigration of other females into maternity roosts, gene flow among maternity roosts must be primarily via the males. This has been demonstrated by DNA studies of brown long-eared bats (*Plecotus auritus*). From the known mating behaviour of a range of species, it seems likely to happen generally in bats, including greater horseshoe bats.

Small populations of mammals may suffer from genetic drift. Its effect would be aggravated by any factor(s) which restricted the size and numbers of maternity colonies in a metapopulation, or which increased the isolation of colonies from genetic interchange with each other. This may result from the loss of colonies within a metapopulation, where previously distances between colonies were small enough to allow inter-colony matings within territorial male sites. If the distance between two maternity colony roosts exceeds about 150 km, it is unlikely that adult males from one colony would be able to meet females from the other, so gene-flow between them would cease.

Whatever the theoretical possibilities of extinction in small populations due to genetic factors, a number of small populations, with less than 30 births annually, have managed to exist for several decades without evidence of any reduction in reproductive capacity or significant genetic defects.

2.5.2. Extrinsic or artificial factors

2.5.2.1. Habitat changes

A summary of habitat changes which threaten populations is given in Table 4.

2.5.2.1.1. Loss of roosts

Many former greater horseshoe bat roosts have been effectively lost to them for a variety of reasons. Former natural roosts in caves have been lost when caves were opened to the public as show caves, or because they were heavily used by caverns for their sporting activities. As a result of these pressures, many populations came to depend upon various kinds of disused mines and other subterranean structures. In recent decades many of these have been sealed off for safety reasons, or used as dumps for different kinds of waste material, some of which have been toxic.

Maternity roosts in old buildings have been lost by exclusion when building have been restored. Some entire buildings have been demolished to provide stone for other constructions. Also parts used as roosts or night-roosts, such as cellars, attics, out-houses and old barns, have been converted for regular human use. The practice of externally illuminating imposing old buildings, such as churches and cathedrals at night, is also likely to have driven out any greater horseshoe bats which formerly occupied them. These pressures are likely to intensify with time.

A special consideration affecting maternity roosts is the use of remedial timber treatments in restoring old buildings. Solvent-based treatments involving certain organochlorine pesticides have been especially damaging to bats, and their high long-term persistence has meant that any treated roost may be lost to bat use for many decades.

The public perception of bats still needs to be greatly improved. In particular the bats may be unwelcome visitors in the view of many roost owners or occupiers, who may make efforts to remove or kill ‘their’ bats.

2.5.2.1.2.Degradation of habitat

There are powerful arguments supporting the view that a major cause of serious population declines recorded in western Europe since the 1950s has been habitat degradation, primarily due to changes in forestry and agriculture. Since several years, forestry policy has been encouraging the planting and natural regeneration of deciduous and mixed forests; however, the preference of faster-growing conifers in past decades has led to a lack of deciduous trees in middle-aged stands. Along with a growing awareness of environmental issues a broad array of environmentally safer forms of agriculture has been developed within the last decades. These includes for example programmes for the promotion of the conservation of arable land into extensive grassland, or the promotion of wetlands and field margins which support the creation of habitats for endangered species and encourage the development of biotope networks. However, there have also been agricultural practices in the past which have encouraged the conversion of small pastures delineated by substantial hedgerows, into extensive arable fields, either without hedgerows or with small ones, unsuitable for bat foraging. A repeat of these processes in eastern European countries may lead to a similar deterioration in greater horseshoe bat populations.

Pesticides are thought to have aggravated the problems of foraging habitat loss and degradation. Cockchafers, tipulids and cutworms (the larvae of many noctuid moths) are all regarded as pests by agriculture since they feed on the roots or stems of important commercial plants, including grasses. In the past cockchafer populations have reached epidemic proportions in parts of southern Europe. These outbreaks also caused extensive damage to the leaves of deciduous trees in some years, but provided a welcome spring feast for the bats. Their regular annual control by pesticides, which still continues, must reduce the biomass of prey available to greater horseshoe bats, and hence their populations. In addition, sub-lethal levels of persistent pesticides in prey have built up in the bodies of bats and either caused their deaths, or been transferred to the young via milk supplies.

Changes in stock management, especially for cattle, have interrupted the life-cycles of the *Geotrupes* beetles which form an important part of the bat's diet in autumn, winter and spring. These beetles take quantities of fresh dung into brood chambers which they excavate some 0.5 metres into the soil below cattle dung, and lay their eggs inside them. They are dependent upon free-ranging cattle to supply the dung in field conditions. The trend towards housing cattle within enormous slatted barns, fed on concentrates, and kept on deep litter straw beds must inevitably reduce the populations of these beetles. The old dung in deep-litter beds is normally dumped in large piles outside in late spring after grass growth accelerates. It is both too old and too late for the beetles to use.

Parasite control in many farm animals has become heavily dependent upon endectocides, synthetic chemicals related to fungal secretions. They are capable of treating or preventing the damage to livestock caused by many groups of parasitic worms. Pour-on, injection and bolus formulations exist. Some, such as avermectins, may not only kill their intended targets, but pass out in the animal's dung, where it also kills many of the dung fauna upon which a wide variety of wildlife depend. This includes the *Aphodius* and *Geotrupes* beetles. Pour-on and injection formulations of avermectins are less damaging than the bolus form. This is because the bolus stays in the stomach of the animal and affects its dung over many months, whereas the other methods only affect the dung for a week of two after administration. Avermectin bolus use in sheep and cattle near greater horseshoe maternity roosts is therefore potentially very harmful.

2.5.2.1.3. Fragmentation and isolation of habitat

The greater horseshoe bats occupying a roost, either maternity or a hibernaculum, need to be able to commute to their foraging areas. They do so using well-defined, sheltered flight lines, which can run for many kilometres, and persist over many years. Alterations to the habitat which seriously interfere with these flight-lines, such as urban developments including well-lit roads or bridges, are likely to reduce or prevent access to certain foraging areas and so restrict their food supplies. The large scale removal of hedgerows, some of which must have been along their flight-lines, may have been a significant factor influencing population reductions in the past.

2.6. Conservation status and recent conservation measures

2.6.1 International

The greater horseshoe bat is included in Appendix II (strictly protected fauna species) of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979) and is specified in its recommendation 43 (1995) on the conservation of threatened mammals in Europe and in its Emerald Network for species requiring specific habitat conservation measures. Conservation of bat species would also be influenced by Recommendation No. 36 (1992) on the conservation of underground habitats.

The species is included in Annex II of the Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979) and its Agreement on the Conservation of Bats in Europe. This action plan takes account of the Agreement's Conservation and Management Plan and other Resolutions adopted by parties to the Agreement.

The species is included in Annex II and Annex IV of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC). Special Areas for Conservation are required to be established for Annex II species, and these are being developed as Natura 2000 sites.

The Convention on Biological Diversity was an important product of the Earth Summit held in Rio de Janeiro (1992). Signed in Rio by 153 States and with others that have acceded since, it requires each contracting party to 'develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity, or adapt for this purpose existing strategies, plans or programmes which shall reflect, inter alia, the measures set out in the convention relevant to the contracting party concerned'. It seeks sustainable development, with one of the key tests of sustainability being the conservation of biodiversity; development cannot be regarded as sustainable unless biodiversity is conserved. A range of actions are identified to meet this aim.

The species is included in *The 1996 IUCN Red List of Threatened Animals* as Lower Risk: Conservation Dependent. Its conservation is discussed in a *Global Action Plan for Microchiropteran Bats* in preparation by IUCN/SSC's Chiroptera Specialist Group, where it is highlighted in a sample summary Species Action Plan. The Co-ordinating Panel for the Conservation of Bats in Europe (a regional subgroup of the Chiroptera Specialist Group) comprises a Europe-wide network of bat conservation specialists, established to develop and implement collaboration on bat conservation activities in Europe under relevant intergovernmental treaties and non-governmental concerns.

2.6.2. National

The greater horseshoe bat is protected in all range states except Channel Islands, and some countries of the former Yugoslavia and former USSR, although the level of protection provided by the legislation and its implementation varies (Table 5). It is the subject of national species action plans in some range states or included in a general bat action plan in some others (Table 5). Its protected status outside Europe and the former USSR is not known to the authors.

2.6.3 Recent measures for conservation

Apart from the measures identified above, conservation has generally been directed to site protection. This particularly relates to the protection of underground sites used by maternity colonies and/or for hibernation, and of buildings used by maternity colonies. Efforts have been particularly strenuous in the north of the range to stop the evident declines there. There can be little doubt that many further colonies throughout Europe would have been lost without such efforts, and it is for this reason that the species was afforded the category of Conservation Dependent in the 1996 IUCN List.

Co-operation in building renovation and the maintenance of interest and concern by government and non-government organisations and individuals has retained or improved many maternity colonies in buildings. The conservation of underground sites has been complicated by concerns for the legitimate leisure use of caves, and the safety aspects of access to underground disused mines. These have been resolved in many cases by the installation of grilles at the entrances of many sites, and the operation of close seasons at certain times. The grilles are designed to allow free access to bats, but limit unauthorised human access. Protection of underground sites by grilles is not without its problems. Grilles may be difficult to install and maintain from vandalism and deterioration. More importantly, grilles that are suitable for the protection of a site used for hibernation may deter some species, including horseshoe bats, from using it in summer. This not only includes occupation of the site by maternity colonies, but also its use for autumn swarming behaviour, when bats congregate at night and mating may occur.

Alternatives to grilles, such as fences, are being developed. The European Bats Agreement has adopted a project that will identify key sites in Europe that need protection and devise guidelines for measures to protect important underground habitats.

A model for international collaboration in the identification and protection of underground sites for bats with special reference to the greater horseshoe bat can be seen in the EC-LIFE project 'Transboundary Protection of Bat Winter Roosts in Western-Central Europe', organised between adjacent areas of Belgium, France, Germany and Luxembourg. The collaborators in the Transboundary Association for the Protection of Bats, which includes The Netherlands, have worked to develop a network of safe hibernation sites as 'stepping stones' for migratory species and as centres of re-immigration. The project has also involved carrying out educational programmes and detailed scientific research on the bats of the region.

A recent (1995) meeting in Nebra, Germany, brought together many of Europe's experts on rhinolophid bats to present reports on their national status, distribution and population trends, as well as current research. The proceedings of this meeting were compiled by Ohlendorf.

Roost site conservation is not enough to secure populations. Increasingly attention has been paid to integrating roost conservation with the important features of habitats for foraging bats. Radio-telemetry studies in the UK, Luxembourg, Germany and Switzerland have helped to define the essential structural habitat requirements for foraging, and access to foraging areas, so that sympathetic management of those features can be retained or developed. Together with extensive dietary studies which related insect types to specific habitat and land-use regimes, radio-telemetry has contributed to a sound understanding of the habitat features which are needed to sustain high population levels of these bats. They flourish in a deciduous woodland/permanently-grazed pasture ecosystem with maximum edge lines, linked by substantial hedgerows. Dietary studies have also highlighted the potential problems posed by pesticide use, including the use of antiparasitic drugs for the treatment of cattle. At its 5th meeting in 1998, the Group of Experts on the Conservation of Invertebrates of the Convention on the Conservation of European Wildlife (Bern Convention) have issued a draft recommendation on the consequences of the use of endectocides (internally administered toxic drugs such as avermectins and milbemycins) in a variety of grazing mammals on non-targeted invertebrates. It recommends Contracting Parties to promote studies to measure the toxicity of intestinal boluses on the functioning of natural and modified pasture ecosystems. In the event of a major risk to non-targeted organisms present in pastureland being discovered (and this would presumably include greater horseshoe bats), it recommended restrictions or even a ban on the use of intestinal boluses.

Most recently attention has been focused on the quality of maternity roost structures, especially their thermal regimes, and its effect upon reproductive performance and the survival of young. Relatively minor changes at a roost may achieve significant improvements in colony numbers, and at least partly insure again population crashes after prolonged poor climate.

3. Goals and objectives

3.1 Goals

The overall goal is to maintain all maternity colonies, and hibernating populations of greater horseshoe bats in regions where they are currently at a favourable status, and enhance those that have shown declines. This goal will be achieved by taking appropriate measures for the conservation of roosts and the foraging opportunities in areas around them. These measures should be compatible, as far as possible, with the legitimate activities of landowners. A viable colony is one which is capable of resisting a future climate-induced population crash, after which only 50% of the bats may be alive. A colony of about 200 bats, producing 45 to 60 births per year seems to be viable long-term, and should be the target level.

This action plan has been developed using data from Europe, but it is hoped that the principles can be applicable to North Africa (Morocco, Algeria and Tunisia), the Middle East and other areas of the range of the species

3.2 Objectives

Objective 1

To maintain all currently known maternity colonies and their associated hibernating populations. To enhance populations which are known to have recently declined, or are vulnerable to extinction. To prevent the decline of populations in countries where large populations exist, but which are threatened by environmental degradation.

Objective 2

To assess more precisely the status, distribution and threats to greater horseshoe bat populations in European range states, especially those in southern Europe.

Objective 3

To co-ordinate policies of agricultural, forestry and environmental government ministries that can influence bat conservation.

Objective 4

To promote awareness of greater horseshoe bats and their conservation needs, in the general public, professional and special interest groups whose activities may affect their status and protection.

Objective 5

To co-ordinate greater horseshoe bat conservation plans with those for other bat species.

4. Actions required to meet the goals at the European level

4.1. Species protection

Greater horseshoe bat management should focus at the population level on the area including maternity roosts and their associated hibernacula. Some populations exist within national borders, and the responsibility for their management rests primarily upon the country concerned. However, the conservation of many populations and metapopulations, within which genetic interchange occurs, requires cross-border co-operation and formal agreements between countries sharing them.

The Bern Convention should adopt this Action Plan, and thereby make greater horseshoe bat recovery/conservation a political goal for all member countries in collaboration with non-party range states in Europe.

To implement any European management policy at a national level, it is essential for each range state to develop a national greater horseshoe bat Management Plan, designed and approved within the guidelines of the present Action Plan. Each national authority should co-ordinate strategies with adjacent countries sharing (meta)populations.

In devising a strategy for the Management Plan, it is important to include all the authorities and organisations interested in, or affected by greater horseshoe bats, from the start. Potentially affected groups include agriculture and forestry industries, water agencies, other land managers including hunters, spelaeologists, wildlife conservation organisations, and regional authorities. No single group should be permitted to dominate the strategy devised.

A national Management Plan should include detailed regulation on relevant legal and policy matters, the educating and training of specialised staff, public awareness, implementation of a monitoring programme, and promoting scientific research. The national Management Plan should identify and suggest any changes to the national and/or sub-national legislation necessary to implement the plan. The national authorities in each country should develop a system, which can take the form of a "greater horseshoe management group", to initiate, co-ordinate, enhance and supervise all this work. Each national Management Plan should be based on scientific data concerning greater horseshoe bat ecology and population status.

In order to set up a realistic, feasible, and effective greater horseshoe bat Management Plan, a government should first identify priorities. A working group, including individuals from several interested groups (administrators, scientists, agriculture, forestry, speleologists, conservation bodies, etc.), may be necessary to help a government to identify priorities.

Greater horseshoe bats are rarely killed intentionally. Most serious impacts upon their populations are concerned with roost destruction, pesticide contamination from certain wood preservative or habitat loss. To secure viable populations, and to allow their appropriate management, protection of individuals, of all maternity and hibernation roosts, and of foraging habitats are all required. Once in place, legislation should be followed by effective law enforcement. In exceptional circumstances of over-riding national interest, populations should be safeguarded by mitigating measures taken before changes affecting their populations are carried out.

Actions

4.1.1. Adoption of this Action Plan by the Standing Committee of the Bern Convention.

4.1.2. Greater horseshoe bat conservation status within each country should be registered according to IUCN criteria and based, as far as possible, on comparable estimation methods.

4.1.3. A system for the development and implementation of this action plan should be established, at national and Europe-wide levels, with power to modify its objectives and targets as implementation and the availability of research results progresses. Countries sharing populations should develop an effective mechanism for co-operation to secure transboundary conservation and management. The action plan should be reviewed and revised as appropriate every five years.

4.1.4. Laws should provide for the protection of greater horseshoe bats, their roosts and if appropriate foraging areas. Enforcement should be promoted and provide for appropriate penalties in regions where populations are known to be threatened by disturbance, pesticides, roost destruction or loss of foraging areas.

4.1.5. National criteria for sites needing protection for their greater horseshoe bat populations should be agreed internationally. These criteria should be reviewed periodically to ensure that they are set at an appropriate level. Protected areas should be established for sites meeting the criteria.

4.2. Recovery of endangered populations

Populations which have been reduced to very low levels should be assisted by roost and habitat improvements to increase their levels. In cooler climates, the installation of incubators into maternity roosts may promote recovery rates.

Translocations to augment populations should not be attempted, as our current knowledge of their behaviour suggests that new animals would be rejected at maternity roosts.

Actions

4.2.1. Identify, secure and enhance the survival of small populations through appropriate roost and/or foraging habitat improvements.

4.3. Habitat protection and recovery zones

A considerable habitat threat to existing populations of greater horseshoe bats is the conversion of favourable ecosystems (e.g. numerous small cattle-grazed fields separated by substantial hedgerows, with woods and copses), into large-scale arable prairies. Such conversions within the foraging ranges of roosts of bat populations, should be prevented. If they are not, the previously documented decline in populations throughout Europe will continue, and spread.

Greater horseshoe bats will never occupy all ecologically suitable areas, primarily due to the influence of climatic factors. The aim is to ensure that sufficient suitable habitat occurs in areas within and across their range, which are close enough to permit bat movements to occur and ensure genetic linkage of the existing populations. Alternatively, if populations have become extinct in key intermediate areas, they should be designated recovery zones and attempts made to encourage recolonisation by bats through special management. This may be achieved by:

a. strongly protecting areas of natural ecological suitability, containing large bat populations, in situations of low conflict potential, as core areas from which bats may spread into recovery zones ;

b. the restitution of suitable roost types in recovery zones, including, where appropriate, an incubator within the potential new nursery roost ;

c. the re-creation of favourable habitat, with sympathetic land management practices, around the roosts created in recovery zones ;

d. restriction in the use of pesticide applications and other potentially damaging practices which may seriously reduce prey abundance or quality in both core and recovery zones.

Actions:

4.3.1. Classify areas within present and potential greater horseshoe bat range according to their suitability and likely importance to bats, in order to identify and implement management of core areas.

4.3.2. Identify, institute and maintain recovery zones to link isolated populations with other populations.

4.3.3. Prohibit or control activities carried out by any industries or agencies that are proven, or suspected, to be detrimental to either greater horseshoe bats, or to supplies of their insect prey, especially close to known roost sites, in core areas and recovery zones.

4.4. Conflicts with humans and public attitudes

Conflicts with most humans are most likely to arise in occupied buildings, during the, restoration or conversion of old buildings, or when extensive land management changes are proposed.

Conflicts may also arise when speleologists or industrial archaeologists wish to visit caves and disused mines which are used by bats as hibernacula or for the early stages of pregnancy. A ‘Conservation Code’ between interested parties can be agreed, as in the UK.

Conflicts should be minimised to avoid illegal acts against either the bats or their roosts, and to create a positive attitude towards them. Several complementary activities are needed to help ensure that important populations are safe. First are regular visits to survey and monitor a roost, after gaining access permission from the landowner, and the supply of information back to the landowner. This can build up confidence between the roost owner and the bat worker. Second, safeguards to roosts in buildings and underground sites can only be achieved by an agreed consultation procedure which should involve local planning authorities, since they have the power to regulate what is done. If their officers are sympathetic to bats, and efficient in their duties, many potentially damaging events will be avoided. Third, the existence of an important bat roost in the building, or on the land, can be registered on title deeds to the property. This means that any future sale of the property will be made in the knowledge that a bat roost is present, and needs to be considered in any plans a purchaser may have for the property.

Planning permission can be made a requirement before old buildings are demolished, restored or converted. Planning consent can depend upon the results of a bat survey carried out by a competent person or agency. The same procedure can apply to the closure of any underground structure, including mines, tunnels and ice-houses. If, discovered, the needs of bats should be considered, and mitigation plans incorporated into the planning consent. The presence of a bat roost, or roosts, could be recorded on title deeds to properties, and be a part of land search procedures by legal advisers.

Actions:

4.4.1. Ensure that planning policies within areas inhabited by greater horseshoe bats identify the need for the species to be a material consideration in the demolition, restoration or conversion of buildings and underground structures used as roost or hibernation sites. The same should apply to habitats used as foraging areas, and landscape elements used as flyways between roost sites and foraging areas of greater horseshoe bats. Promote the participation of bat conservation experts in planning development procedures.

4.4.2. Provide support and incentives for landowners to continue land management in approved ways that are beneficial to bats. Avoid changes in agricultural use of land from favourable habitats (such as pasture/woodland) to unfavourable habitats (such as large open arable areas) within the foraging range of maternity roosts.

4.4.3. Ensure that spelaeologists, industrial archaeologists and bat conservation groups develop an agreed code of practice for the conservation of subterranean roosts used for hibernation and maternity.

4.5. Public awareness, education and information

Agencies promoting bat conservation needs and awareness should be initiated and supported by governments, so that the measures they take to implement this Action Plan receive sympathetic responses from the public. Public funding may best be spent by promoting the image of greater horseshoe bats, and bats generally. When people are shown the true nature of bats they are usually fascinated by them. However, bats are both nocturnal and highly secretive; features which make them largely unknown to most people. CCTV using infra-red cameras and time-lapse recorders can show the public interesting bat activities at selected maternity roosts, without disturbance. The more the public knows about bats, the more likely it is to accept the conservation measures taken to safeguard them. At present the media are keen to promote all kinds of bat events, since they provide original material.

A suitable educational campaign should be prepared and conducted by following these stages:

a. find a lead agency that raises funds for all stages ;

b. identify target groups, their present knowledge levels and attitudes, and assess the current educational information available ;

c. design efforts and messages appropriate to each group ;

d. identify individuals within each target group to deliver the messages, to increase the chances of successful implementation ;

e. implement the educational campaign ;

f. conduct an evaluation of each educational effort made;- what success/failures resulted; what modifications are needed for further improvements; which aspects were most effective?

g. monitor annual achievements to gauge progress being made.

Attitudes and beliefs of the target groups, as well as the campaign goals, have to be reassessed in a continual process by returning to stage ‘b)’. Target groups may include managers of sites or land occupied by the species, or sectors involved in maintenance and restoration of such sites.

A campaign to inform the public is an integral part of any conservation programme. Its action must be both continuous and far-reaching. It can be promoted by the same lead agency, which would follow a plan previously agreed upon in terms of content, instruments and personnel with the concerned ministries and regional administrators. The information provided should be tailored to its target audience to be effective.

An information campaign will cover several aspects including:

Greater horseshoe bat ecology: To understand the reasons behind the strong roost and habitat protective measures taken, people should be informed about the ecology of bats. The need to protect large land areas for a single maternity roost, and their vulnerability to human activities, especially farming regimes, should also be stressed.

Potential conflicts involving greater horseshoe bats and people in their homes: Case examples of situations where conflicts have arisen and been solved should be discussed. These should reduce any unfounded anxieties people may have over the consequences of having bat roosts in their homes.

Actions:

4.5.1. Initiate information campaigns designed for different target groups of people whose activities may affect bat populations.

4.6. Monitoring and research

Our current level of knowledge of greater horseshoe bat ecology is high compared with other European bats. However, a large proportion of the long-term studies has been carried out in one region of the UK, which enjoys an oceanic climate, rather than the continental climate experienced by most of the European populations. Furthermore much of the UK data originates from a single maternity colony at Woodchester Mansion, so it is clearly desirable to carry out at least some parallel studies at other sites.

Even the studies at Woodchester Mansion are not complete, since we have no clear understanding of the social behaviour of these bats. Since colony members are closely related to each other, and live for many years, complex behaviours are predicted to occur. Some of them are likely to have important impacts upon demography and populations.

For the some European countries, the main initial requirement is to develop sound baseline data about the current status of their populations. This should include the identification, cataloguing and registering of maternity and hibernation sites; the relationships between the two types of sites, and their geographic distribution.

Once suitable study sites have been identified in each country, scientific studies on specific aspects (such as dietary variation) should be co-ordinated at the European level. An advisory body which can supply training in appropriate methods should be established.

The species should be included in its list of priority species for autecological studies, particularly in southern Europe, by the Agreement on the Conservation of Bats in Europe (Bonn Convention).

4.6.1. Population dynamics

The mechanisms which operate within bat populations, influencing both the sex ratios at birth and the age-structure of females in maternity roosts, are poorly understood. Climate seems to exert effects upon both population parameters, and severe conditions over several years seems to prepare populations for a precipitous crash. Such crashes are synchronised over large geographical regions, suggesting that common mechanisms are at work simultaneously. Recovery from such crashes can take many years, and so conservation efforts should concentrate on catering for such events, if the species is to be safeguarded. Ultimately the cause of such crashes are likely to be influenced by factors affecting global climatic changes. Although some good data exists, there is a need to support more long-term studies. This will necessitate additional ringing studies at selected maternity roosts across their range. If properly introduced and implemented, following appropriate training, such ringing studies will not harm the colonies concerned. Once the mechanisms are understood, we may be able to implement management procedures to minimise the impact of poor climate.

4.6.2. Dispersal

The re-establishment of greater horseshoe bats into former regions, by providing suitable roosts and habitat regimes, depends upon the species' ability to disperse from successful colonies. The factors promoting dispersal, and the distances over which it can feasibly occur, are not currently understood. It is likely to be influenced by intervening habitat conditions, and Geographical Information Systems (GIS) may assist in the selection of suitable regions for any recolonisation attempts, where historical records are sparse or absent.

4.6.3. Diet variability and its impact on populations

Current data from a limited number of European countries suggests that greater horseshoe bat diets are similar over wide areas, but all studies have taken place in the cooler, north-western parts of their range. The diets may differ in the hotter, more arid regions of southern Europe. Further studies are required to assess the potential for variability among insect prey types, and the impact of dietary quality on population performance. Such information can then be related to the bat's specific habitat and land management requirements by country or geographic region.

The storage of small amounts of dried faecal samples, collected at intervals from beneath each maternity site under an agreed protocol, will provide valuable material which can be used to assist in interpreting any dramatic population changes occurring at specific sites. In the absence of any significant changes the samples need not be analysed, but kept for later analysis in case problems arise later on.

Over significant time periods, dried faecal samples can be used to monitor changes in environmental pollution, such as persistent pesticides, or heavy metals such as lead, mercury and cadmium. As insect predators, bats are expected to concentrate any pollutants in their prey, and excrete them in their urine which contaminates the faeces. As predators which consume over half of their body mass per day in summer, their capacity to concentrate pollutants rises even more. Since they sample insects from a known foraging range, the source of any pollution should be able to be located if the insects derive from local food chains. In this way the costs of dietary and pollution analysis of faecal samples can be justified in terms of environmental monitoring to safeguard human health, as well as for bat conservation.

4.6.4. Climatic effects on populations

Climate exerts major effects on bats at all times of the year, but is especially crucial during two periods annually. Severe winter weather prevents or restricts winter foraging, and cold springs prolong pregnancy, delaying births. Currently it is believed that this delay results from reduced food consumption, and possibly also from poorer quality food, as colder conditions prevent the flight of preferred insect prey. Ultimately climate seems to determine the northern limits to the distribution of the species, but little is known about the factors limiting its southern distribution. Studies across its entire range are needed to test the mechanism outlined above, and expand it to cover both northern and southern ranges.

Thermostatically-controlled electrical tubular heaters (incubators) have been installed in some UK maternity roosts. Preliminary results show an encouraging improvement in the growth of the female young, compared with unheated roosts. Incubators may protect populations against climate-induced population crashes following cold springs in northern countries. Trials in other European countries are needed as controls.

4.6.5. Habitat use

The impact of specific habitat changes upon population performance should be studied. The interaction needs to be clearly understood, as it is essential information in planning considerations. The collection of basic information about the state of the habitat (topography, habitat types and land use) around all maternity sites should be part of baseline data collected, alongside population counts. If all data for European roosts is compiled into a single database, it may be possible to pin-point more precisely the habitat features which favour large populations, and those which may lead to extinction.

Currently, although it is known that these bats need to feed in winter, the distances involved in winter foraging flights are poorly understood. Studies supplying such information are needed to be able to protect habitats for a suitable range around hibernacula. It may be particularly crucial to do this around male territorial roosts, since females occupy them in spring, and much of pregnancy may occur within them.

4.6.6. Surveying and Monitoring

Surveys to discover the status of greater horseshoe bat populations should be conducted in all European countries. The results of these surveys should be compiled in an agreed form, and an acceptable monitoring programme devised. This should be capable not only of assessing population trends by region and country, but also the underlying causes of any trends, which emerge. To do this, records of climatic variables and the habitat state of relevant foraging areas over time will need to be maintained. Monitoring methodology should be in line with the recommendations of the Agreement on the Conservation of Bats in Europe (Eurobats Agreement).

The collection of faecal samples from maternity sites under an agreed protocol should be a part of any monitoring programme (see 4.6.3).

4.6.7. Genetic studies

Whilst there is no current evidence that greater horseshoe bats suffer from the effects of inbreeding, or genetic bottle-necks after population crashes at small maternity colonies, it is possible that problems may be identified over time, or with further studies. Nuclear DNA based studies are needed to discover the genetic variability present across the European range, and the effects of isolation, as well as mating and dispersal strategies.

4.6.8. Inter-bat species interactions

There is evidence that the range of the serotine (*Eptesicus serotinus*) is increasing in some European countries. Serotine bats have a considerable dietary overlap with greater horseshoe bats, and also utilise buildings for their maternity roosts. Hence the two species may be in ecological competition. Whether serotine expansion is linked to the decline in greater horseshoe bat populations is a matter for conjecture at present. Studies in regions where the two species co-exist should be carried out to assess the extent of any competition, or to identify differences in ecology and behaviour that favour one species more than the other.

Actions:

4.6.1. Co-ordinate and prioritise scientific research on greater horseshoe bats throughout its European range.

4.6.2. Co-ordinate the regular gathering of all necessary data and material to monitor the status of greater horseshoe bats in Europe, and identify the causes of any status changes.

4.7. Cross-referencing with other action plans

4.7.1. With action plans for other bats

Activities for the conservation of greater horseshoe bats will also help other bat species, e.g. in the educational aspects of bat roosts in buildings, in the development of land-use policies that also favour other bats species, and in the protection of underground habitats used by a wide range of bat species.

As far as possible the implementation of the Action Plan for the conservation of the greater horseshoe bat should take account of other bat conservation initiatives, including those being developed under the various international treaties, especially the Agreement on the Conservation of Bats in Europe (Eurobats Agreement), Bern Convention (and its relevant Recommendations), and Council Directive 92/43/EEC, Conservation of Natural Habitats and of Wild Fauna and Flora (ABL L 206, 22.07.1992) of the European Union. Europe-wide the IUCN SSC Chiroptera Specialist Group's Co-ordinating Panel for the Conservation of Bats in Europe can assist with liaison on bat conservation action internationally and nationally.

Geoffroy's bat (*Myotis emarginatus*) frequently forms mixed colonies with greater horseshoe bats. The two species are given the same status in international treaties, and Geoffrey's bat is included in the 1996 IUCN Red List as VU:A2c.

4.7.2. Wider cross-referencing

The implementation of the greater horseshoe bat action plan should relate to wider activities for conservation.

With reference to the Pan-European Biological and Landscape Diversity Strategy (PEBLDS), the implementation of this action plan will assist in the delivery of, and can be assisted by, many of the general objectives and other Action Themes of PEBLDS; in particular to Action Themes 2, 3, 4 and 9. It can contribute to the Bern Convention's Emerald Network of Areas of Special Conservation Interest (ASCI).

The plan can also assist with cross-cutting policies for habitat and other species conservation, and management plans at a national level. Also it will benefit various international initiatives, such as those of the EC, the Council of Europe (including its proposed Vertebrate Red Data Book), European Bats Agreement and other interest groups.

Action:

4.7.1. Ensure that in the development and implementation of this plan there is full cross-referencing to appropriate habitat and other species conservation and management plans and wider initiatives for the development of relevant policy, programmes and legislation.

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Supplementary references

Appendix II of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979): also Recommendations Nos. 36 (1992) & 43 (1995). Emerald Network.

Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979): Agreement on the Conservation of Bats in Europe.

Annex II & Annex IV of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC).

The Convention on Biological Diversity (Nairobi, 1992).

The Pan-European Biological and Landscape Diversity Strategy (Sofia, 1995).

Map 1. *Rhinolophus ferrumequinum*: Northern limits of distribution in Europe

Table 1. Current general status and state of knowledge of *Rhinolophus ferrumequinum* in European range states

	Present	Hibernation roosts	Completeness of winter survey (high, medium, low)	Maternity roosts now	Female roosts	Male roosts	Mating roosts	Foraging habitat	Flight paths	Completeness of summer survey (high, medium, low)	Evidence of migration	Population estimate	Basis of estimate (e.g. summer / winter counts)	Population trend (+++ to ---)
Albania														
Andorra														
Armenia														
Austria	❼	❼	H	❼	?	❼	?	x	x	H		>200	s/w	---
Azerbaijan	❼	❼	L	❼	❼	❼	x	❼	x	L	x	[<30,000][1]	s/w	-
Belgium	❼	x	H	❼	❼	❼	❼	❼	❼	M	❼	200-500	s/w	---
Bosnia and Herzegovina														
Bulgaria	❼	❼	L	❼	❼	❼	❼			M	❼	13-15,000	summer	-
Croatia														
Cyprus														
Czech Republic	❼	❼	H	x	x	x	x	x	x	M	❼	<10	winter	?
France	❼	❼	H	❼	❼	❼	❼	❼	❼	H	❼	c.26,000	s/w	= to ---
Georgia														
Germany	❼	❼	H	x	❼	❼	x	❼	x	H	x	<200	s/w	= to ---
Greece														
Hungary	❼	❼	H	❼	❼	❼	❼	❼	❼	H	❼	3-10,000	s/w	= / +
Italy	❼	❼	L	❼	❼	❼	❼	❼	❼	L	❼	?		= to --
Luxembourg	❼	❼	H	❼	❼	❼	❼	❼	❼	H	❼	200-250	s/w	+
"the former Yugosl. Rep. of Macedonia"														
Malta	❼	x	M	x	x	x	x	x	x	M	x	<10	s/w	?
Moldova														
Netherlands	Ex													
Poland	❼	❼	H	x	x	x	x	x	x	M	x	<10	w	?
Portugal	❼	❼	H	❼	❼	❼	❼	❼	❼	M		[3-5,000][1]	w	--
Romania														
Russian Federation	❼	❼	M	❼	❼	❼	x	❼	❼	L	x	[150-200,000][2]	Density estimate	= to +
San Marino														
Slovakia	❼	❼	M	❼	x	x	x	❼	x	M	❼	1-2,000	s/w	+
Slovenia	❼	❼	L	❼				❼		L		2000	w	=

	Present	Hibernation roosts	Completeness of winter survey (high, medium, low)	Maternity roosts now	Female roosts	Male roosts	Mating roosts	Foraging habitat	Flight paths	Completeness of summer survey (high, medium, low)	Evidence of migration	Population estimate	Basis of estimate (e.g. summer / winter counts)	Population trend (+++ to ---)
Spain	❼	❼	M	❼	❼	❼	❼	❼	❼		x	<25,000	s/w	
Switzerland	❼	❼	H	❼	❼	❼	x	❼	❼	H	x	<500	s/w	= to --
Turkey	❼	❼		❼	❼	❼					x			-
Ukraine	❼	❼		❼	❼	❼					x			
UK	❼	❼	H	❼	❼	❼	❼	❼	❼	H	x	4-6,000	s/w	to = -+
Yugoslavia, Federal Republic	❼	❼	M	❼	❼			❼	❼	M	❼	13-15,000	s/w	=

1. Author's estimate based on extrapolation of sample provided; *2.* Estimate for whole of Russian Federation

❼=positive; x= negative

Table 2. *Rhinolophus ferrumequinum*: preferred roost sites in Europe. S = summer use; W = winter use.

	Attic / loft	Natural cave	Mines	Basement/cellar	Bunker	Fortification	Ruined castle	Other disused artificial structure	Other
Albania									
Andorra									
Armenia									
Austria	s	s/w	s/w	s/w	w				
Azerbaijan	s	s/w	s/w	s/w	s	s		s/w	Ganat (water conduit), animal shelters, e.g. stables
Belgium	s	w	w	s/w	?	w		w	
Bosnia and Herzegovina									
Bulgaria	s	s/w	w		s	s			Rocky crevices
Croatia		w	w	w					
Cyprus									
Czech Republic									
France	s	s/w	s/w	w	s/w	s/w	w		
Georgia									
Germany	s	s/w	s/w		s/w				
Greece									
Hungary	s	s/w	s/w	s/w					
Italy	s	w	s/w			w			
Luxembourg									
"the former Yugoslav Republic of Macedonia"									
Malta									
Moldova									
Netherlands									
Poland		w							
Portugal	s	s/w	s/w	s		s			
Romania									
Russian Federation	s	s/w	s/w						
San Marino									
Slovakia	s	w	w		w				
Slovenia	s	s/w				w			
Spain	s/w	s/w	s/w	s	s			s	
Switzerland									
Turkey	s	s		s		s			
Ukraine	s	s	w		w				
UK	s	w	w		s/w		s/w	s/w	
Yugoslavia, Federal Republic	s	s/w	s/w	s/w		s/w	s/w	s/w	

Table 3. *Rhinolophus ferrumequinum*: preferred foraging habitats in Europe

	No Data	Water	Wetland	Woodland	Pasture	Hedgerow	Scrub	Arable	Other
Albania									
Andorra									
Armenia									
Austria	❼								
Azerbaijan				❼	❼	❼	❼	❼	Plantations of tea, vines or other subtropical cultures and rocky habitats.
Belgium			(❼)	❼	❼	❼	(❼)		
Bosnia and Herzegovina									
Bulgaria	❼								
Croatia									
Cyprus									
Czech Republic	❼								
France		(❼)		❼	❼	❼			
Georgia									
Germany					❼	❼	❼		Semi-open valleys
Greece									
Hungary			❼	❼	❼				Gardens
Italy			❼	❼	❼				
Luxembourg				❼	❼	❼	❼		Urban, orchards
"the former Yugoslav Republic of Macedonia"									
Malta	❼								
Moldova									
Netherlands									
Poland	❼								
Portugal	❼								
Romania									
Russian Federation				❼	❼		❼		Woodland, karstic river valleys
San Marino									
Slovakia	❼								
Slovenia	❼								
Spain				❼	❼				River valleys
Switzerland			❼	❼	❼		❼		
Turkey									
Ukraine				❼	❼		❼		
UK				❼	❼	❼			
Yugoslavia, Federal Republic		❼		❼	❼	❼	❼		Karstic river valleys

❼=positive

Table 4. *Rhinolophus ferrumequinum*: threatened habitats in Europe

	No Data	Renovation of buildings	Closure or Destruction of roosts	Disturbance of roosts	Disturbance of underground habitat	Food availability	Pesticides and pollutants affecting food/habitats	Loss of foraging habitat	Landscape features esp. habitat fragmentation	Other
Albania										
Andorra										
Armenia										
Austria		❼		❼			❼		❼	Climate
Azerbaijan			❼	❼			❼	❼		Destruction of ancient buildings
Belgium		❼	❼	❼	❼	❼	❼	❼	❼	
Bosnia and Herzegovina										
Bulgaria				❼	❼		❼	❼	❼	
Croatia										
Cyprus										
Czech Republic	❼									
France		❼	❼	❼	❼		❼		❼	Barn owl, climate

Georgia										
Germany		❼	❼	❼		❼		❼	❼	Barn owl,
Greece										
Hungary			❼	❼	❼			❼	❼	
Italy		❼	❼	❼			❼			Unsuitable cave protection
Luxembourg		❼	❼			❼			❼	Loss of wetlands
“the former Yugoslav Republic of Macedonia”										
Malta	❼									
Moldova										
Netherlands										
Poland	❼									Changes in populations in Slovakia
Portugal		❼	❼		❼			❼		
Romania										
Russian Federation		❼		❼			❼	❼	❼	Habitat
San Marino										
Slovakia		❼								
Slovenia	❼									
Spain		❼	❼	❼	❼			❼		
Switzerland						❼		❼	❼ ❼	
Turkey							❼	❼	❼	
Ukraine			❼		❼		❼		❼	
UK		❼		❼				❼	❼	
Yugoslavia, Federal Republic		❼	❼	❼	❼				❼	Unsuitable cave protection

❼=positive

Table 5. *Rhinolophus ferrumequinum*: protected status in Europe

	National Red List	All bats protected	Roosts protected	Foraging habitats protected	Legislation adequate	Legislation needs better enforcement	Legislation incorporates foraging habitat protection	Species included in Natura 2000 sites	Species included in Conric sites	Species has national action plan
Albania										
Andorra										
Armenia										
Austria	EN	❼			❼	❼	❼	X		X
Azerbaijan	X	❼						N/A		
Belgium		❼	❼		❼	❼		❼		X
Bosnia and Herzegovina										
Bulgaria	VU	❼	❼				❼	N/A	❼	(❼)
Croatia										
Cyprus										
Czech Republic		❼								
France	VU	❼	❼	X			❼	❼		❼
Georgia										
Germany	CR	❼	❼		❼	❼	❼	❼		X
Greece										
Hungary	EN	❼	(❼)		❼	❼		N/A		X
Italy	VU	❼	X		X			(❼)		X
Luxembourg	CR/EN	❼	❼				(❼)			❼
“the former Yugoslav Republic of Macedonia”										
Malta										
Moldova										
Netherlands										

Poland	X	❼								
Portugal	EN	❼	❼			❼		❼		(❼)
Romania										
Russian Federation	VU	❼	❼			❼	❼	N/A		X
San Marino										
Slovakia		❼	❼							
Slovenia	VU	❼								
Spain	VU	❼	❼			❼		❼		
Switzerland	CR	❼	❼				❼	N/A		❼
Turkey	EN	❼	(❼)	(❼)	X	❼		N/A		
Ukraine	EN	❼								
UK	EN	❼	❼		❼	❼	❼	❼		❼
Yugoslavia, Federal Republic	LR:nt	❼	❼	❼	❼	❼				

❼=positive; x= negative; N/A = not applicable

Appendix 1

Suggested method of estimating the total number of bats involved in a maternity colony

The number of bats occupying a maternity roost at any one time during the summer months is less than the total number using it. Exit counts of flying bats, whenever they are made, therefore underestimate the total number of bats in the colony.

Hence it is necessary to base colony size estimates upon standard parameters which can be easily obtained. They involve a minimum of disturbance.

In one major UK study of 6 maternity roosts, two periods of relative stability of numbers occurred in 1996, and this pattern existed at one roost over many years. They were called 'plateau periods' (Ransome 1997a). The first plateau period was from late May to early June, and the second was from mid July to early August. A third parameter collected was the total number of young born that year. At some sites the total number of young born was known since all were ringed. At each of the others, the maximum number of young left in the roost site after the exit of adults at dusk during the second plateau period was multiplied by 1.23 to obtain an estimated number of young born.

At four of the UK maternity sites the first plateau period numbers were very close to the total number of young born. At the other two there was no relationship.

During the second plateau period the ratio of flying bats leaving to forage: number of young born varied from 1.64 to 3.31. This large variation was caused by differences in the occupation of the roost by immature bats of both sexes, and by adult males, at the different roosts. The causes of this variation are currently unknown.

To correct for these differences a formula was devised as follows:

Total colony size = (n young born x July/Aug max. ratio*) + n young born

NB if the July/August ratio* fell below 2.2, it was corrected by adding 1.0. If it was above 2.5 it was left uncorrected. The assumption was made that the major differences between the roosts lay in its level of occupation by non-breeding bats (immature and adult males).

Summary:

1. Carry out four dusk exit counts of foraging bats at intervals of one week from mid July to obtain the second plateau period data.
2. On each occasion enter the roost after the dusk emergence of the older bats, and count the number of young. Include and record any dead young or aborted foetuses in the counts. (A red filter placed in a torch minimises the impact of light on the young.)
3. If possible, also carry out three dusk exit counts at intervals of one week from the end of May.

NB If suitable clean trays are put in place below the colony and collected on each subsequent visit, samples of faeces suitable for dietary analyses will be obtained with little further effort. Samples should be air-dried and stored in labelled photographic canisters. If all seven visits are made, five faecal samples will be obtained.

4th cover page

Conservation policies have not given enough priority to bats. This report presents an action plan on one of the most threatened species of Europe, the greater horseshoe bat.