BAT ECOLOGY AND MITIGATION

Proof of Evidence of
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On behalf of the White Horse Alliance

Public Inquiry into
The A350 Westbury Bypass 2008
## Contents

1. Introduction ................................................................. P 2

2. Scope of Evidence ......................................................... P 2

3. Evidence ........................................................................ P 2

   3.1 Bats: ecology, conservation status and the effects of roads P 2

   3.2 Legislation ................................................................ P 8

   3.3 Bat surveys of the scheme ........................................ P 9

   3.4 National and International status of the site and adjacent SACs P 10

   3.5 The effects of the scheme on bats in the area and in adjacent SACs P 10

   3.6 Legal obligations as a consequence of 3.5 .................. P 11

   3.7 Mitigation and monitoring plans for the A350 Westbury Bypass P 12

   3.8 Case studies of mitigation in the UK and abroad ........ P 15

   3.9 The scientific case for the effectiveness of current mitigation practices P 26

4. Summary ......................................................................... P 31

5. Thoughts and suggestions on future practice .................. P 31

6. References ..................................................................... P 32
1. Introduction

1.1 My name is John Altringham. I hold a BSc in Biology (1978) and a PhD in Zoology (1981). I have been Professor of Biomechanics at the University of Leeds since 1999. I have conducted and published zoological and ecological research for over 25 years and was awarded the Scientific Medal of the Zoological Society of London in 1994.

1.2 I have been actively involved in bat research and conservation for over 20 years. Over the same period I have been a bat research and conservation trainer (licensed by Natural England and formerly English Nature and the Nature Conservancy Council). I am author of two major books on bat biology and conservation and numerous scientific papers and popular articles. I have extensive field experience with wild bats, applying a wide range of techniques to their survey and study. My research is funded by government research councils and conservation agencies and by national and international conservation charities. I regularly advise Natural England, the Countryside Council for Wales and the Bat Conservation Trust on bat ecology and conservation issues and am a past member of Bat Conservation International’s grants panel. I am a regular advisor and contributor to BBC Natural History Unit programmes on bats. I run and contribute to training courses in bat conservation.

2. Scope of evidence

In my evidence I will cover:

1. Bats: ecology, conservation status and the effects of roads.
2. Legislation in relation to bat conservation
3. Bat surveys conducted in the environs of the A350 Westbury Bypass scheme
4. National and international status of the site and adjacent SACs
5. The likely effects of the proposed road on bats in the area and in adjacent SACs
6. Legal obligations as a consequence of these effects
7. Proposed mitigation and monitoring plans
8. Case studies of mitigation in the UK and abroad
9. The scientific case for the effectiveness of proposed mitigation and monitoring
10. Can the proposed mitigation fulfil its objectives? Can the proposed monitoring demonstrate this to be the case?
11. Summary
12. Thoughts and suggestions for future practice

3. Evidence

3.1 Bats: ecology, conservation status and the effects of roads

3.1.1 There are over 1,100 species of bat in the world, comprising approximately 20% of all mammal species. They are arguably the most diverse group of
mammals and possess a unique combination of adaptations (flight, echolocation, hibernation) that give them an unparalleled place within mammalian diversity.

3.1.2 There are 16 species of bat resident in the UK, making up approximately one third of the country’s terrestrial mammal diversity (Altringham 2003). UK populations of most species are low and appear to have undergone substantial declines over the last 100 years. Five species number as few as 1,000 (grey long-eared bat) to 10,000 (Leisler’s bat) individuals. Only the two common pipistrelle species are likely to have populations exceeding 200,000 (Altringham 2003). For reasons summarised in the following paragraphs bats are highly vulnerable to anthropogenic changes in the environment.

3.1.3 Despite their small size, bats have life history strategies typical of much larger mammals and frequently live for 20 - 30 years or more. The larger species may take several years to reach full sexual maturity and females may not become experienced and successful mothers for several more years. A female produces only one pup each year. Recovery from population crashes is therefore slow and uncertain in the face of continued adverse conditions.

3.1.4 Bats lead complex life-histories that are lived out on a large landscape, utilising dispersed and seasonally varying resources. For example, in the summer they may commute large distances between roost sites and feeding sites (2-20 km is not unusual, Altringham 2003) and frequently rely on having access to several roosts and several major feeding areas in the same season (e.g. Senior et al. 2005). At the end of the summer they migrate considerable distances (60+ km and probably further) to autumn mating and winter hibernation sites (e.g. Parsons and Jones 2003; Rivers et al. 2006). Most species are highly faithful to their roosting and foraging sites, and the flightlines between them, over many generations (e.g. Bontadina et al. 2002, Senior et al. 2005, Glover and Altringham 2008). Nursery colonies and hibernacula may comprise tens, hundreds and in exceptional circumstances over one thousand bats (Altringham 2003). The destruction of roost sites or the severance of summer or migration flightlines can therefore have a profound effect on their livelihood. Destruction of woodland and the widespread intensification of agriculture over the last century have left a fragmented, structurally simpler and biologically impoverished landscape, depriving bats of suitable roost and foraging sites and reducing the number and diversity of insect prey available to them. Fragmentation of primary habitat can leave bat colonies on patches too small to sustain viable populations.

3.1.5 The loss of natural roosts has forced bats into close proximity with humans and many species are partly or entirely dependent upon built structures for roosting sites (Altringham 2003). Many of these roost sites have then been lost due to human intolerance or the destruction or redevelopment of older
3.1.6 **The effects of road development on bats.** Bickmore (2003) provides a broader and more detailed account of the effects of road development on bats than the following, brief summary. Whilst her emphasis is on anecdotal evidence concerning bats, I have given emphasis to scientific studies (largely published in peer-reviewed journals) on other animals, in the absence of such studies on bats.

3.1.7 **Collision mortality.** Although agile and manoeuvrable in flight, most species fly at low speeds (< 20 km/h) close to the ground or vegetation (0-4 m), particularly when crossing open ground and roads (Richarz 2000, Bickmore 2003). In contrast to the majority of birds, most bats also spend most of their time out of the roost in flight. They also make extensive use of linear landscape features, such as woodland edges and hedgerows along roads, as navigational aids (e.g. Limpens and Kapteyn 1991). In combination, these behavioural traits make bats highly vulnerable to traffic when either foraging along roads or when attempting to cross roads on commuting flights. Weighing only 4-30 g, they can be pulled easily into the slipstream of passing vehicles. Lesinski (2007) recorded bat casualties on an 8 km section of two-lane highway near Warsaw, Poland by weekly searches for corpses from May-October over a four year period. Casualties ranged from 0.3 bats/km/year in built-up areas to 6.8 bats/km/year where roads were bordered by trees. However, a study by Slater (2002) in mid-Wales suggests, based on the rate of removal of corpse by scavengers, that a census of this kind may underestimate wildlife road kills as much as 12-16 fold. Small corpses were, on average, removed by scavengers within 30 min in the hours just before and after dawn. The difficulty of spotting small bat corpses and the fact that many will be thrown clear of the road or carried some distance on the vehicle, suggests under-estimates will be even greater. Slater (2002) found that accident black spots were concentrated on A roads and a recently improved junction. Sections of surveyed road with no kills were always C roads. Bickmore (2003) summarises a number of earlier, less thorough studies which confirm that many European bat species are frequent road casualties.

There are no published, scientifically rigorous studies on the nature and consequences of traffic-caused mortality on bat populations. However, studies on terrestrial mammals and birds highlight some important considerations that will almost certainly apply to bats. In a review of studies going back over many decades, Forman et al (2003, pp 120-122) provided convincing evidence to show that wildlife collisions increase with increases in vehicle speed and traffic volume and with the proximity of wildlife habitat and wildlife movement corridors. Both theoretical (e.g. Lande 1987, With and King 1999, Carr and Fahrig 2001) and field studies (e.g. Bonnet et al. 1999) show that populations of animal species with low reproductive rates and high intrinsic mobility (such as bats) are more susceptible to decline and ultimately extinction by the additional mortality caused by roads.
3.1.8 **Roads as barriers.** Roads may act as barriers to flight between roosts and foraging sites, between different foraging sites and between their summer, mating and winter roosts. They thus prevent bats from accessing parts of their habitat or force them to make longer, energy- and time-consuming journeys. Roads act as barriers because they break existing flightlines along hedges or other linear features, because some bats are reluctant to cross open ground, because some species avoid lit areas (road and vehicle lights) and, at least initially, because they represent sudden change in the bats’ familiar landscape. Barriers therefore fragment the bats’ habitat, decreasing its area and quality. If habitat area and quality are major determinants of population size, which they usually are, then habitat fragmentation will lower the sustainable population size. Habitat fragmentation is widely recognised amongst scientists as one of the major causes of biodiversity loss across the world. The response of bats to roads and other disruptors of their normal flightlines is highly variable between and within species but there are numerous observations to suggest how detrimental the effects can be. Bickmore (2003) gives many examples and others will be described later in this report.

Barriers such as roads may also limit the flow of individuals between populations. This has two consequences: (a) it reduces gene flow and increases inbreeding, leading to a greater risk of local extinction (b) it slows recovery from local population crashes because recruitment from neighbouring populations is slowed, further increasing the likelihood of local extinction. These factors are only likely to be relevant to rare species that already have small and fragmented populations, such as horseshoe bats, Bechstein’s bats and barbastelle bats. Indeed, their rarity is likely to be due in large measure to their susceptibility to these and other anthropogenic pressures. The combined effects of barriers is to lower local population sizes (Forman et al. 2003, p 129), increasing the probability of local extinction.

In the absence of studies on bats, I looked at studies of other animals. Many of these are summarised by Forman et al. (2003) who show that roads act as significant barriers to a variety of mammals from voles to grizzly bears. Primary roads are significantly more effective barriers than secondary roads and the barrier effect increases with increasing traffic volume. The effects in some cases are severe. Gerlach and Musolf (2000) have shown that populations of bank vole are genetically different either side of a four-lane highway (50 m wide, ~30,000 vehicles/day), but not either side of a two-lane country road (10 m, ~5,000 vehicles/day) or a railway. Genetic isolation such as this can only occur with very low levels of migration. Highways have been shown to be major genetic barriers even to large and mobile animals such as coyotes and lynx (Riley et al. 2006). Studies of birds are likely to be particularly relevant to bats. Develey and Stouffer (2001) and Laurance et al. (2004) have shown that narrow, unpaved forest roads can act as a barrier to forest birds, supporting the view that woodland bats are likely to be affected by more substantial roads.
3.1.9 **Loss of habitat: roosts and foraging sites.** Road development frequently involves the removal of trees and old buildings that hold potential or actual bat roosts. The removal of trees, hedges, scrub, water bodies and unimproved grassland also reduces available foraging habitat. The metalled surface alone removes significant habitat: 10 km of 7 m wide, two-lane highway covers 7 ha. Associated verges and structures remove yet more habitat. Several studies (e.g. Rydell 1992, Blake et al. 1994) have shown that road lighting deters many bat species from approaching not just the road, but the habitat for some distance on either side of it. However, light can also attract some species. This may be a mixed blessing: certain types of lighting attract insect prey, increasing foraging efficiency, but bats will be at greater risk of collision with traffic.

Again, in the absence of studies on bats, it is necessary to look at applicable studies on other animals. A detailed series of studies on birds shows that traffic disturbance reduces both the number of species and the population density of individual species on either side of a major highway, in both grassland and woodland (Foppen and Reijnen 1994, Reijnen and Foppen 1994, 1995, Reijnen et al. 1995, 1996). The distance over which these effects were observed varied with species and traffic volume, e.g. 0.02 – 1.7 km from roads with 5,000 vehicles per day to 1.5 - 2.8 km for roads with over 10,000 vehicles per day. The magnitude of the effects is also substantial: 26 of 43 species showed reduced densities. Within 100m of the road, this reduction was as high as 98%. Traffic noise was the most important factor in these studies. Other studies in Europe and North America, showing similar effects, are summarised by Forman et al. (2003, pp 124-126). We cannot quantitatively extrapolate these results to bats, but it is likely that the effects of light and noise (and possibly other factors) will contribute to a similar effect.

Roads can provide roosts for bats. For example, bats will roost in road bridges (Keeley and Tuttle 1999), but not over busy roads. Bats roosting and foraging close to roads, perhaps attracted by new planting, may do so at the expense of a greater risk of collision.

3.1.10 **Disruption during construction.** The noise, lights and sudden, dramatic landscape changes associated with construction may have both short- and long-term effect on bats due to many of the factors discussed in the preceding paragraphs.

3.1.11 **Time lag and cumulative effects.** Most of the factors discussed above will be cumulative. The effects of each need not therefore be great to have a profound effect on a bat population. Furthermore, there will be a lag (extinction debt) between cause and effect (Tilman et al. 1994, Loehle and Li 1996). This is illustrated in Fig. 1 (based on Forman et al. 2003, Fig. 5.7).
The effects of habitat loss and reduced habitat quality will usually be seen quickly, but collision mortality, unless very high, will not have a significant effect for several generations and the barrier effect may take several more generations to show itself. Although no data exist for bats, a study of the effects of roads on wetland biodiversity (birds, mammals, reptiles, amphibian and plants) suggests that the full effects may not be seen for several decades (Findlay and Bourdages 2000).

Figure 1. The cumulative and delayed effects of roads on wildlife populations.

### 3.2 Legislation

3.2.1 The Wildlife and Countryside Act 1981 (WCA 1981) is the principal legislation for the protection of all bats and their habitats. Under Schedule 5 it is an offence to intentionally kill, injure or take bats, or to damage, destroy or obstruct access to any structure or place used by bats for shelter or protection.

3.2.2 The Countryside and Rights of Way Act 2000 (CROW 2000) requires government departments to have regard for biodiversity in carrying out their functions, and requires the Secretary of State for Environment, Food and Rural Affairs to take positive steps to further the conservation of listed species and habitats. Under CROW, further protection is provided to species protected under the WCA so that it is an offence to intentionally or recklessly disturb them, or to damage or destroy their habitat.

3.2.3 The Conservation (Natural Habitats, &c.) Regulations 1994, ‘The Habitats Regulations’ (C(NH). 1994) provide for the protection of European wildlife sites and European species of animals and plants. European protected species (EPS) listed in Schedule 2 of the Habitats Directive include all bat species. Under regulation 44, a licence must be obtained from Natural England in order to, amongst other things, disturb, capture or kill EPS, or to damage or deliberately destroy a breeding site or resting place of such a protected animal. A licence can only be granted where there are imperative reasons of overriding public interest, if there is no satisfactory alternative, and where the action taken would not be detrimental to the maintenance of
the population of the species concerned at a favourable conservation status in their natural range.

3.2.4 The Conservation (Natural Habitats, &c.) (Amendment) Regulations 2007 (C(NH Amend). 2007). There has been a change to the favourable conservation status test as a result of changes to regulation 39. An offence would only be committed where the deliberate disturbance is likely to significantly affect the ability of a significant population of a given species to survive, breed, or rear or nurture their young or significantly affect the local distribution or abundance of that species.

3.3 Bat surveys of the scheme

Summary of Chapter 9 of Wiltshire County Council 2007 Planning Application (WCC 2007a), including Appendices 9.14 and 9.15. Bat surveys were carried out 2002-2006. At least 12 of the 16 resident UK species were recorded, including all four ‘Annex II’ species (bold):

**Rhinolophus ferrumequinum**, Greater horseshoe bat

**R. hipposideros**, Lesser horseshoe bat

**Myotis bechsteinii**, Bechstein’s bat

*M. nattereri*, Natterer’s bat

*M. daubentonii*, Daubenton’s bat

*M. mystacinus*, Whiskered bat (and possibly *M. brandtii*, Brandt’s bat)

**Eptesicus serotinus**, Serotine

**Nyctalus noctula**, Noctule

**Pipistrellus pipistrellus**, Common pipistrelle

**P. pygmaeus**, Soprano pipistrelle

**Barbastella barbastellus**, Barbastelle

**Plecotus auritus**, Brown long-eared bat

Successive surveys, using a range of techniques, revealed progressively more species at more locations along or close to the proposed route. The pattern of discovery suggests that further work could reveal higher levels of activity and perhaps greater diversity. Bats (including all four Annex II species) were present on both sides of the proposed scheme and used flightlines that will be severed by the scheme. Table 9.7 and the associated text in WCC (2007a) highlight the key flightlines to be severed.

A number of important roosts were discovered in the vicinity of the scheme. Two Bechstein’s bat roosts are located ~1 km (Clanger Wood) and 100 m (Wellhead Springs) from the scheme. The former is home to a minimum of 53 bats, a large colony. A third Bechstein’s bat colony had previously been found 2 km north of the Clanger Wood roost (Biss Wood). A small greater horseshoe bat roost was found within several hundred metres of the scheme (Westbury Cemetery) and a soprano pipistrelle roost 25 m from the scheme. Although the roosts will not be directly affected by construction, bats from some (if not all) use flightlines severed by the scheme. The following roosts are more distant
from the scheme, but close enough that bats from them may use flightlines that will be severed by it: Bratton Church (lesser horseshoe bats, few individuals, <3 km), Dilton Court (lesser horseshoe bat nursery of 25+ bats, 3 km), Rood Ashton Manor (lesser horseshoe bat nursery of 60+ bats, 5 km), Westbury Leigh (greater horseshoe bat nursery of 40+ bats, 1 km) and Fairwood House Stables (Greater horseshoe bats, number unknown, 3 km). A number of other substantial Annex II species roosts are within 10 km of the scheme, e.g. Ilford Manor, 10 km NW has a nursery of about 300 greater horseshoe bats.

Some of the ringed or radio-tracked greater horseshoe bats were shown to belong to populations in the Bath and Bradford on Avon Bats SAC (15 km, 15% of UK greater horseshoe bats). The Mells Valley SAC is 11 km west of the scheme (12% of the UK greater horseshoe bat population).

A significant proportion of the serotines and common pipistrelles caught were reproductively active females, indicating the presence of undiscovered nursery colonies.

3.4 National and international status of the site and adjacent SACs

The conservation status of the site in relation to bats was judged to be very high/high (WCC 2007a, Chapter 9, Table 9.8), a conclusion I would support.

3.5 The effects of the scheme on bats in the area and in adjacent SACs

“The proposed route will sever flight lines used by nationally and internationally important species of bat. This would result in the isolation of important feeding areas and some day and night roost sites. Construction and use of the proposed bypass may also disturb bats using known roost sites close to the preferred alignment” (WCC 2007a, Appendix 9.15). I would add that in addition, it could lead to significant mortality due to road casualties. The effects of construction itself could have long-term deleterious effects unless managed properly.

Under Regulation 48 of the Conservation (Natural Habitats, &c.) Regulations 1994, if a proposed scheme is considered likely to have a significant impact upon a SAC, an Appropriate Assessment is required to assess whether the scheme will have an adverse impact on the integrity of this European site. Two nearby SACs hold an estimated 27% of the UK greater horseshoe bat population. Greater horseshoe bats from one were captured during the surveys and it is likely that bats from the second are also be present in the vicinity of the scheme. Although the number of bats positively linked to the SAC is small (two in 2004 and three in 2006), they represent a significant proportion of the bats caught. There is therefore a strong possibility that many more bats from the SACs use the habitat around the proposed bypass. An Appropriate Assessment would therefore seem desirable unless it can be confidently shown that the bypass will have no effect on local bats. The argument that there will be no
significant effect on the SACs therefore rests largely on the success of mitigation.

3.6 Legal obligations as a consequence of 3.5

It is accepted that the foraging and commuting habitats of bats will be disturbed by the scheme and that without effective mitigation the effects would be sufficient to recommend refusal of the scheme (WCC 2007b). However, despite the presence of all four Annex II species, since no roosts are to be destroyed NE has ruled that licences are not required to carry out the work. However, Garland and Markham (2007) argue “that there is an existing legal basis for the protection of these features [bat commuting and foraging habitat] in accordance with The Conservation (Natural Habitats, &c.) (Amendment) Regulations 2007 (Habitat Regulations (HR), The Natural Environment and Rural Communities Act 2006 (NERC 2006) planning policy and international treaties.” They go on to make a detailed case in support of this assertion.

Paragraph R.39(1)(b) of the HR states that: ‘A person commits an offence if he .... deliberately disturbs animals of any such species [Annex IV of the Habitats Directive 92/43/EEC (HD) which includes all UK bat species] in such a way as to be likely significantly to affect (i) the ability of any significant group of animals of that species to survive, breed, or rear or nurture their young, or (ii) the local distribution or abundance of that species’. Markham and Garland argue that there is no reference in the HR to the location of this disturbance, so it can apply to foraging and commuting sites as well as roosts.

Furthermore, the Habitats Committee (established by the Environment Directorate-General of the European Commission (EDGEC) to consider interpretation and implementation of the HD) advise that Article 12.1(d) of the HD should be understood as ‘aiming to safeguard the ecological functionality of breeding sites and resting places’ (EDGEC 2007), which can be sensibly interpreted as giving protection to foraging and commuting routes, since these are critical to the functionality of habitat. If it is accepted that a roost or roosts is of little or no functional value without its associated foraging habitat, then no other interpretation makes sense.

Natural England issue licences under R.44 of the HR, to permit activities that are otherwise unlawful with respect to Annex IV species protected under R.39 of the same legislation. Natural England’s European Protected Species Guidance Note (2007) states that: “a licence is needed if .... the proposed activity is reasonably likely to result in an offence under regulation 39.....If an activity is likely to result in disturbance or killing of a European protected species, damage to its habitat or any of the above activities [those listed in R.39], then a licence will usually be required.” Thus, it can be interpreted that where development causes disturbance to bats while foraging or commuting, a licence is required.
Planning Policy Statement 9: Biodiversity and Geological Conservation (PPS9; ODPM 2005), concerns the duty required under the CROW Act. According to PPS9, developers must demonstrate that they have considered alternative options to prevent “significant harm” to “biodiversity interests” (including all bat species). It also recommends that where “significant harm cannot be prevented, adequately mitigated against, or compensated for, then planning permission should be refused.”

Garland and Markham (2007) discuss interpretations of several more legal structures. Although their arguments are ecologically sound and logical and could, in principle, be applied to give protection to bat habitat, interpretation in support of bats is less convincing.

Finally, Garland and Markham (2007) make the point that I (Altringham 2003) and others have made frequently: that conservation will only be effective if carried out on a landscape scale. Protection of roosts alone will not work: foraging sites and the commuting routes must also be protected. Protecting habitat, the whole habitat, is what protects species.

The proximity of the proposed road to two SACs raises the issue of whether or not an Appropriate Assessment is required under Regulation 48 of the Conservation (Natural Habitats, &c.) Regulations 1994. There is evidence to show that bats from at least one SAC, probably in significant numbers, spend part of their annual cycle in the area to be affected by the scheme. An Appropriate Assessment would be a sensible precaution.

All parties agree that without mitigation the scheme will have a severe adverse effect on an important bat assemblage. It is therefore critical that the proposed mitigation measures are effective. I will therefore summarise the proposed mitigation plans, review published mitigation case studies and assess their effectiveness. I will then assess the likely effectiveness of the measures proposed for the A350.

3.7 Mitigation and monitoring plans for the A350 Westbury Bypass

3.7.1 Introduction. The aims of mitigation fall into three broad, overlapping functional categories:

- To minimise the loss of habitat that is, or could be, used by bats for roosting, commuting or foraging and/or to provide (in equal or greater measure) resources to replace those lost.
- To minimise enforced changes in the behaviour of the bats as they move about the landscape, either by avoiding the severance of flightlines between roosting and foraging sites or by providing structures that maintain flightlines or at least divert them along acceptable, alternative routes.
- To avoid unsustainable increases in mortality as a result of bats crossing a
wider road that may carry more and faster vehicles.

This report is concerned primarily with the second two of these, where the proposed road will sever known flightlines. Detailed discussion of the mitigation measures proposed and their likely efficacy are discussed below. First, I will give a brief description of the basic approaches that have been adopted.

3.7.2 **Underpasses: bridges, tunnels and culverts to carry bats safely under new roads.** Where a new road is carried on a raised embankment, or the local natural topography allows, existing flightlines can, in principle, be retained by building a bridge over a hedge, stream or other feature. In most circumstances the feature will in fact be modified, e.g. a section of hedge is removed but a tunnel links directly the two severed ends that meet the road. These may be no more than modifications of structures already planned to carry minor roads, tracks or waterways, or to bridge several such features across a small valley. If such structures are not planned, or are incompatible with use by bats, purpose-built structures may be used. The principal critical considerations are the dimensions of the tunnel and the links to severed flightlines.

3.7.3 **Overpasses: bridges, green bridges and gantries to carry the bats safely over new roads.** Where natural topography allows, existing flightlines can, in principle, be retained by building a structure over a new road, linking the severed ends of known flightlines. These too may be structures already planned to carry minor roads and tracks or purpose-built. A green bridge is one that carries hedges and/or other vegetation to recreate a semi-natural flightline for bats. A gantry is an overhead framework designed as a navigational aid to echolocating bats aimed at guiding them over a road at a height safely above traffic. The principal critical considerations of an overpass are the dimensions of the bridge and the links to severed flightlines.

3.7.4 **Structures and techniques to guide bats to and from underpasses and overpasses, or to alternative crossing points.** Ideally existing flightline structures such as hedges, streams and woodland edges would continue right to the road and the new crossing structure. However, in the majority of circumstances construction itself (e.g. for access by machinery), or the building of embankments, cuttings, roundabouts, slip roads, etc. will lead to severance of these features. Temporary measures may be necessary during construction to retain continuity and permanent measures will be needed on completion of the work. In addition to guiding bats along the ‘correct’ paths, measures may need to be taken to prevent bats attempting to cross the now dangerous new road. Temporary guiding structures have included solid and mesh fencing and camouflage netting. Fencing has also been used as a ‘permanent’ measure, but trees and hedges are seen as more appropriate. Fencing has also been used in attempts to deter bats from crossing roads. Lighting can be used as a
deterrent for many bat species, but those species that habitually feed in open spaces are attracted to lights by the insects that gather around them.

3.7.5 Summary, Chapter 9 of WCC Feb. 2007 Planning Application (WCC 2007a).

3.7.6 Long-term mitigation plans

Madbrook Roundabout. The area is used by three of the four Annex II species and flightlines cross the area proposed for the new roundabout. Proposed mitigation involves the use of minimal permanent lighting, leaving the roundabout itself unlit, so as not to disturb commuting and foraging bats. This will include the use of solar powered road studs, unlit reflective signs and vehicle activated ‘slow down’ signs. A planting schedule prior to hedge removal and construction aims to minimise disruption to flightlines. The centre of the roundabout will be planted in an attempt to maintain connectivity across the roundabout, although only the centre of the island will have trees, to avoid restricted views for cars entering the roundabout. This approach, if successful will bring bats close to the road, but traffic will in principle be going round the roundabout slowly.

Chalford Accommodation Bridge. This is a flightline used by at least 11 species, including all four Annex II species. Proposed mitigation is a 25 m span (~13 m wide) green bridge with a double hedge across the middle, linked to existing hedging. Additional planting will be carried out on the flightline. On either side of the bridge 2m high solid fencing will be topped by 2m mesh fencing to dissuade bats from dropping onto the road. This may also shade the bridge from vehicle lights to some extent. Low level bollard lighting will aim to deter bats from going under the bridge where they would be in danger from traffic. Significant effort has gone into appropriate spacing and direction of lighting.

Wellhead Underpass. This is also used by at least 11 species, including all four Annex II species. Proposed mitigation is a culvert under the road (4 m x 4 m approx.), connected to existing hedgerow flightlines by additional planting. Fencing (3m not 4 m) and bollard lighting will again be used to discourage bats from using the road. A bat gantry will be built for the use of high flying bats.

Bere’s Mere Farm. The hedgerow south of the farm is used by at least six species including one Annex II species. Proposed mitigation is a 4 m tunnel to be built alongside the hedge with additional planting, fencing and lighting to encourage bats to use it and not cross the new road. A bat gantry is also proposed.

Bratton Road Bridge and Underpass. At least four species use the area, with greater horseshoe bats using a flightline across the scheme. A roughly semicircular 3.7 x 4 m underpass is proposed, together with additional planting, 4 m fencing and bollard lights as above. A bat gantry is also proposed.

Bitham Bridges. The three branches of the Bitham Brook are used by at least nine species, including two Annex II species. Mitigation will be in the form of fencing, bollard lighting and bat gantries, since the crossings are too
low (~1.5 m) for the preferred option of underpasses. **Shallow Waggon Lane.** This is used by at least five species, including one Annex II species. Proposed mitigation will include 4 m fencing, bollard lighting and a bat gantry. **General.** Additional planting, including new hedgerows along the new road, will aim to enhance the quality of the habitat for bats as well as encourage them to continue using existing flightlines.

3.7.7  **Mitigation during construction**

This will involve:

- Minimal lighting at all times, particularly near known commuting and foraging sites.
- Clearance of hedges, trees and woodland between September and April.
- The use of temporary linear features (typically some form of fencing) along severed commuting lines.
- Advance planting prior to hedge removal, wherever possible, at key locations.

3.7.8  **Monitoring**

Bi-monthly, static, manned, bat detector monitoring would be carried out (dusk and dawn) from April to August (i.e. three surveys) during construction. In the “unlikely” event that temporary fencing is unsuccessful, NE/WCC will be consulted regarding alternative solutions.

A similar survey approach (April – August) would be used each year for five years, with alternative solutions to existing mitigation implemented as necessary.

It is acknowledged that success rates for mitigation vary. Details of how success will be measured are not given and contingencies in the event of failure are not specified. There is very little considered appraisal of the success or otherwise of past mitigation efforts. Nevertheless, “The magnitude of the potential impact is considered to be Minor Negative once all of the environmental design measures have been taken into consideration. Overall, the significance of the residual impact on the bat assemblage is assessed as being **Slight Adverse.**”

3.8  **Case studies of mitigation in the UK and abroad**

It is first necessary to define some terms and ecologically desirable objectives. Mitigation features may be used by bats, but this does not mean that they are necessarily effective. To take a hypothetical example, 50% of bats crossing a new road may do so via a safe ‘green bridge’, showing that it is used. However, if the remaining 50% cross the new road itself and mortality increases to levels
that lead to population decline, then the feature is clearly not effective. It is therefore important to distinguish between use and effectiveness. This is linked with the distinction between assessing mitigation at the individual and population levels. Conservation is the protection of species and ecosystems at the population level: maintaining favourable conservation status means maintaining stable populations. Assessment at the individual level is not a guide to what is happening at the population level. Studies that examine the effectiveness of mitigation at maintaining bat populations are the ideal, but are difficult. Studies of use by individuals are easier to carry out, but less valuable. However, if well-planned and quantitative they can be of considerable value. I will return to this subject later in the proof.

My assessment of the likely efficacy of the above mitigation measure is based on case studies of past attempts to mitigate for road developments, informed by knowledge of the behaviour of bats. What follows is a summary of all the published and unpublished case studies I could find. The information presented in the various documents is almost exclusively anecdotal and qualitative. In the absence of quantitative, statistically robust analysis, I have found it necessary to describe the most relevant studies in some detail in order to support any conclusions that can be drawn.


2001. “All hedgerows and other potential linear features crossing the route had been removed prior to the 2001 surveys”. Mitigation measures were put in place after limited survey in the autumn. Thus, no pre-construction surveys were carried out.

Summer (April-Sept) 2002. The road was opened at the end of August 2002. The survey protocol selected the 12 most likely crossing points (for greater horseshoe bats, criteria not stated), each was monitored at least twice, three hours post-sunset. A maximum of one greater horseshoe bat was recorded at each of seven of the new crossings on seven of 14 visits. Other species crossed the road at all but one crossing-point. The most relevant part of the study concerned two new culverts and one existing, extended culvert, aimed at diverting bats under the road. Appropriate planting was carried out to funnel bats into the culverts. 50% of the observed bats did not fly through the new culverts, but crossed the road. They were said to do so at different heights. No summary statistics are given, but examination of summaries showed that most bats crossed 2-4 m above the road surface, i.e. in the collision zone.

- The three culverts (Milton, 6B, 6C) were monitored by single automated loggers placed outside each culvert. It was assumed by the surveyors that all bats detected by the loggers flew through the culverts. These loggers may have recorded bats approaching the entrance without flying through, since bat detectors are only weakly directional, particularly in confined spaces which enhance the reflection of sound. Although they
have lower sensitivity to bats approaching from the rear, they can record such bats. I was unable to determine from the reports whether these loggers faced into the culverts or away from them. Furthermore, bats approaching obstacles may make several attempts before passing, and can thus be counted more than once. It is not clear how often reliance was placed on the loggers alone. I believe that unless an observer was present there is some doubt about how many bats actually flew through the culverts.

- **Culverts 6B and 6C** (these were newly constructed). There was a “significant” reduction in greater horseshoe bat activity in 2002 relative to 2001 (no data are presented for 2001). Each culvert was only seen to be used by a single greater horseshoe bat on one occasion. 6B was used by lesser horseshoe bats on two occasions. Both were used “extensively” by *Myotis* and *Pipistrellus* species.

- **Milton culvert** (this was not new, but had been lengthened). On two nights a greater horseshoe bat was seen flying over the culvert headwall to cross the road, 2-4 greater horseshoe bats flew through the culvert on each survey night. *Myotis* and *Pipistrellus* species also ‘used’ the culvert. I attempted, from the individual site reports, to compare the numbers of bats that flew through the culverts with those that flew over the road above. This proved impossible since numbers were not given with any consistency. The only conclusion I could draw was that the two numbers were low and appeared similar.

**Summer (May-Oct) 2003.** Eight surveys were carried out, four of them focused on the Milton culvert. Across the whole scheme greater horseshoe bats were recorded on four of eight surveys and crossed the road above the culverts on two of these. Other species also crossed the road, but numbers were not given. The surveyors state that the intensity and design of monitoring preclude detailed comparison with 2002 data.

It can be said that the Milton culvert was used by greater horseshoe bats on four of eight occasions in 2003, compared to 13 of 14 in 2002. The intensity of bat activity was also lower: 33 bat passes were recorded in 2002 compared to six in 2003.

**Summary:** It is implicit in the report summaries that evidence for use of culverts equates with successful mitigation. This is an inadequate criterion for success for reasons given at the beginning of this section. Furthermore, the following statements can be made that weaken the case for successful mitigation:

1. In the absence of preconstruction monitoring, the effects of the road on local bat populations are unknown.
2. From 2001-2003 bats flew over the road near culverts in significant numbers relative to those flying through the culverts, thus placing themselves in danger.
3. At all culverts there was a decline in overall greater horseshoe bat
activity from 2001 to 2002/3.

4. The use of automated loggers makes it uncertain whether all of the bats recorded actually flew through the culverts or around the entrances.

I conclude that the case for successful mitigation is unproven. There is weak evidence to suggest the road has led to a reduction in local bat activity. Some bats may have been displaced from the area or have been dissuaded from crossing the scheme as part of their normal flight activity, both of which may have a longer term effect on population levels.

Further mitigation measures were recommended and it was suggested that monitoring should continue, perhaps until 2007. Neither appears to have been done.

3.8.2 A465 Abergavenny to Gilwern (2005 – 2006) (TACP 2006a,b)

The aim was to monitor lesser horseshoe bat flights from a nearby nursery roost through culverts before, during and after road construction. Clearance and construction work began during the 2005 surveys and continued during the 2006 surveys. The Hopyard Farm Underpass, the route taken by a large majority of the commuting bats, was extended in August 2006.

2004. Surveys were carried out by Jacobs Babtie using Anabat (Frequency Division) automated echolocation call recorders.  
2005. Surveys were carried out by TACP using hand-held Bat Box Duet and Pettersson D230 (Heterodyne) detectors.  
2006. Surveys were carried out by TACP using hand-held Bat Box Duet and Pettersson D230 (Heterodyne) detectors and Anabat (Frequency Division) automated echolocation call recorders.

There was a several-fold difference in the number of bat passes recorded by the automated detectors in 2004 and 2006, relative to the hand-held detectors in 2005. This is seen in Fig. 6.1 of TACP (2006b), after a crude correction for differences in survey intensity. This is due to the known differences in sensitivity of the equipment. Furthermore, Tables 1.0 and 2.0 of the same report (TACP 2006b) show data recorded at the main crossing point of the road (Hopyard Farm Underpass, which accounted for over 90% of all bat passes recorded) from both hand-held and automated detectors over the six months of survey in 2006. I found no statistically significant correlation between the results obtained from the two systems. (Automated equipment used by Billington (2001-2006) is more sensitive and yielded a weak but statistically significant correlation, but data were again sparse). It is therefore impossible to compare the results from different years, or indeed draw any quantitative conclusions. The problems are exacerbated by the different design and intensity of surveys in all three years and by changes in protocols and the positioning of the numerous recorders within some years.
Despite the flaws in the surveys, it is clear that throughout construction, lesser horseshoe bats continued to use the Hopyard Farm underpass in significant numbers. However, it is not possible to say whether numbers increased or decreased post-construction. Data are too sparse from other crossing points to draw meaningful conclusions.

It should be noted that at Hopyard Farm the new culvert was placed inside an existing, high, wide and short underpass that was already being used by the bats. This would have significantly increased the likelihood of adoption by the bats.

**Summary.** Bats continued to use a flight corridor under the new road during the insertion of a new, longer culvert within the old underpass. Continued, improved monitoring is needed before the success of the scheme can be properly evaluated. The continued use of an existing but modified structure is encouraging, but gives no assurance that bats would respond to a completely new structure in a similar way.


Construction started in January 2000 and the road was opened in September 2000.

Summary of early surveys (capital letters in brackets refer to locations on Map 1, Appendix 1, Billington 2006)

1997. Two lesser horseshoe bats recorded at Dafarn Dudur (H)
1999. Two lesser horseshoe bats recorded at Glynllifon (E)
2000. Flight corridors confirmed at Dafarn Dudur (H) and Glynllifon (E) (a minimum of 7 & 14 bats respectively.)
2001. 576 lesser horseshoe bats counted at Glynllifon nursery colony, the largest in Europe and present for 40+ years

These surveys revealed two flight corridors but did not adequately quantify their use. They do not provide useful pre-construction baseline data. Roost emergence counts had been made at the large Glynllifon lesser horseshoe bat roost for several years before the road was built. No surveys of the other six or more bat species were carried out pre-construction.

**2001.** Mitigation was put in place in May–November 2001, i.e. commencing six months after the road was opened. This included the construction of a culvert at Glynllifon (E) (to which 2/4 m high fencing was later added).

- May 2001. Bats were now crossing the road at four new points (B, J, K & L), but few lesser horseshoe bats were recorded at each. There appears to either have been fragmentation of the lesser horseshoe bat flight corridors, or the discovery of previously undetected crossing points.
- August 2001. Up to 84 lesser horseshoe bats crossed the road at Groeslon (S), a previously unused site. Bats crossed the road at vehicle
collision height. Five lesser horseshoe bats flew through the Glynllifon culvert (E) and two flew over the road above it. Five lesser horseshoe bats crossed the road at Dafarn Dudur (H) one of the two known pre-construction crossing points.

- September 2001. Five lesser horseshoe bats and five *Myotis* bats crossed the road at (B) and two brown long-eared bats at a previously unused site (A). One lesser horseshoe bat and several *Myotis* bats flew over the road at Glynllifon (E) and two lesser horseshoe bats used the culvert. 13 lesser horseshoe bats and 6 *Myotis* bats crossed the road at Groeslon (S). Seven lesser horseshoe bats and six *Myotis* bats crossed the road north of Bethesda Bach Bridge (T), another new crossing point.

- Similar patterns with reduced activity were observed in October.

- Road casualties in 2001: Eight lesser horseshoe bats and two whiskered bats, at S, B and J.

- Mitigation measures were modified during the surveys. Lighting at Groeslon (S) (3/4 and 22/23 October), the major LHB crossing point, was said to be deflecting bats from crossing the road. This supplemented existing 2 m high fencing. However, the number of bats crossing had already declined steadily, almost to zero, for other reasons (most likely a natural, seasonal trend) and there is no evidence from these data to support the use of lighting as effective mitigation.

**2001 summary.** Bats were making use of more crossing points than before road construction, with very limited use of the new culvert at their traditional crossing point at Glynllifon (E). Behaviour appeared to be in flux throughout the season. There were significant casualties on the new road. There is little evidence to suggest any of the mitigation features were effective at this stage.

**2002.** Festoon lighting was erected at Groeslon(S) on 15/16 April and on 13-15 May this was extended north of Bethesda Bach Bridge to (T). The lighting was in place until the end of November. Other mitigation measures were adopted at other sites.

- The Glynllifon culvert (E) was used by a maximum of two lesser horseshoe bats per night over seven survey nights (April-October). Six lesser horseshoe bats in total used the culvert in this period. Over the same period 20 lesser horseshoe bats flew over the road above the culvert, with a maximum of eight on any one night. On the same night two used the culvert. We do not know with any certainty how many lesser horseshoe bats used this crossing before construction, since the surveys were limited (but suggest a minimum of 14), but it was now used by fewer bats and most did not use the culvert provided, despite further modification of the fencing to funnel bats into the culvert and prevent them crossing the road.

- At Groeslon (S) small numbers of lesser horseshoe bats continued to cross the road: 25 over five nights. Of these, 16 did so away from lit areas. The numbers of bats using lit and unlit areas were not significantly different to those expected by chance. It cannot be assumed from these
data that the lights reduced the number of bats crossing the road. However, 193 lesser horseshoe bats crossed the road over a 500 m section north of the Groeslon crossing (S) over 10 nights of survey. 105 of these crossed at two locations not previously used. Either the lights were dissuading bats from crossing at Groeslon, or this change in behaviour was due to some unknown cause. If the lights at Groeslon (S) were altering the bats’ behaviour, they were merely moving the problem to another stretch of road: six dead bats (incl. four lesser horseshoe bats) were found in this area.

- A strong recommendation was made for a culvert at Groeslon (S) as the most likely solution to the problem of bats crossing the road at the north end of the scheme.

2003. The suggested culvert at Groeslon (S) was not built, but low-level bollard lighting was installed on both sides of the road between Groeslon (S) and a point several hundred metres north along the road, near Bethesda Bach Bridge (T). Over seven survey nights (April-Sept) 131 bats flew under Bethesda Bach bridge, a safe route previously unused. However, 63 lesser horseshoe bats crossed the road north of Bethesda Bach Bridge and a further 27 crossed the road 1 km south of the bridge between the Groeslon crossing(S) and the cycleway bridge at (B), an area previously used by few bats. These bats may have been displaced by the lighting. Only two bats were recorded using the Glynllifon culvert (E) despite further planting to improve flight corridors. Over the same period 10 dead bats were found along the road (incl. seven lesser horseshoe bats).

- Expressed as bats/survey night, there was a decrease in the number of bats crossing the road north of Bethesda Bach Bridge between 2002 and 2003 (19.3 and 9.0 resp.), but an additional 3.9/night crossed the road further south in 2003.

- Again, a strong recommendation was made for a culvert at Groeslon (S). Further mitigation recommendations were made at other locations.

2004. Over eight survey nights 166 lesser horseshoe bats used the Bethesda Bach Bridge (T), or 20.8/night, very similar to the 18.7/night recorded in 2003). 89 lesser horseshoe bats, or 11.1/night, crossed the road north of it, a small increase on the 2003 levels. A planted earth bank had been built on the west side of the road prior to the surveys. Eight dead bats (three lesser horseshoe bats) were found during the surveys.

2005. The number of bats using Bethesda Bach Bridge (T) had increased to 30.7/night (215 over 7 nights), but 16/night (96 over 6 nights) were still crossing the road north of the bridge. Ten dead bats (four lesser horseshoe bats) were found.

2006. The number of bats using Bethesda Bach Bridge (T) remained at 31/night (186 over 6 nights), and 8.3/night (50 over 6 nights) were still crossing the road north of the bridge. Road casualty surveys were not carried out.
Summary to 2006. Road construction led to the disruption of two known lesser horseshoe bat flightlines over the route of the road. Bats attempted to cross at numerous points in subsequent years. Mitigation was carried out one year after the road opened. A culvert on one of these flightlines, Glynllifon (E), designed to guide the bats safely under the road has been unsuccessful: few bats use it and a small number continue to fly over the road at this point. Large numbers of lesser horseshoe bats attempted to cross the road at a new location near Groeslon (S). Repeated recommendations were made for a culvert at this point, but were not acted upon. Fencing did not deter bats from crossing the road but lighting appears to have displaced them both north and south along the road. Many bats used a safe route under the road at Bethesda Bach Bridge between 2003 and 2006, a previously unused crossing, which was not a designed mitigation structure. However, significant numbers of bats continued to cross the road north and south of the bridge, despite additional mitigation measures. These measures may be responsible for a moderate decline in the number of bats crossing the open road in this area. Small numbers of bats continued to cross the road at several other locations. Bat casualties were reported each year. Mitigation cannot yet be said to have been successful, since a substantial minority of the bats recorded continue to cross a dangerous road six years after completion of the scheme.

The 47 casualties (29 lesser horseshoe bats) recorded over five years will be an unknown but small fraction of the real total, given the low probability of recovering corpses (Slater 2002) and the survey frequency. We can estimate the casualties over the two most intensively surveyed months, August and September, and from this we can estimate annual mortality at least to a first approximation.

41 dead bats (25 lesser horseshoe bats) were recovered in the months of August and September between 2001 and 2005. One bat was found in May and five (four lesser horseshoe bats) in October. The low counts in October are presumably due to low bat activity, since many surveys were carried out. The single bat in May reflects very low survey effort April-July. Over the five years, surveys were carried out on 214 of the available 305 days in August and September. Pro rata, this raises the death toll to 58 bats (36 lesser horseshoe bats). Bats will certainly be as active May-July inclusive as in August and September. Lesinski (2007) reported a bias towards juveniles, but this was not evident in the data from Billington (2001-6). However, if we nevertheless assume that inexperienced juveniles are most at risk, road kills will be fewer prior to their first flights in July. We could therefore increase the August - September death toll by a conservative 50% to cover the main active season of the bats (May-September incl.), i.e. 87 bats (54 lesser horseshoe bats). These figures do not take into account bats not found or bats scavenged prior to the survey, both of which will be significant. Slater (2002) suggests the effects of scavengers can lead to a 12-16 fold underestimate. I doubt the underestimate is so great in this case, since surveys were done on most nights and quite early in the day, but it would certainly be safe to double the reported figures. We arrive at a conservative estimate of 100 lesser horseshoe bats or 20 per annum.
Road casualties of 20 p.a. represent 5% or more of the probable annual recruitment to the Glynllifon colony of lesser horseshoe through births. On top of other, existing causes of death, this may be unsustainable in the long term (NACHTaktiv and SWILD 2006).

The number of lesser horseshoe bats in the roost at Glynllifon has fluctuated between 1998 and 2006 (Billington 2006), and in 2006 was 443, 28% lower than its 2001-4 maximum of 614 and the lowest number since counts began in 1998. It would be unwise to draw any conclusions from trends over this short period, but it would be a concern if numbers continued to decline.

3.8.4 A66 Stainburn and Great Clifton bypass, Cumbria 2001-2003 (Highways Agency 2006, based on Billington 2001a, b, c, 2003). The Highways Agency has not released a detailed report, so an assessment of this scheme is based on a joint summary published with the Bat Conservation Trust. This unfortunately leaves some significant omissions and ambiguities in the data.

**July 2001.** A temporary ‘ribbon’ bridge was erected after clear-felling a narrow strip of woodland crossed by the new road. The bridge consisted of three pairs of posts each supporting four nylon ribbons. 33 of 35 bats recorded on the one survey night followed the ribbon bridge across the clear-felled area, at an average height of 3.4 m above ground level, but “some” flew as low as 2 m. Although seven species were recorded, activity (number of bat passes) was 77% lower than in September 2000, prior to clear-felling.

**September 2001.** The two lower ribbons had been removed and 2 m high mesh fencing had been erected in an attempt to raise the height at which bats crossed the road. Only three species were recorded and activity was just 1% of that recorded in September 2000 and only two bats (of an undeclared total) used the ribbon bridge.

**October 2001.** Activity was “slightly” higher than in September 2001 and three of eight bats used the ribbon bridge, flying at a height of 3.8 m.

**July 2002.** The two lower ribbons had been reinstated and the fencing was still in place. Five species were recorded and 22 of 25 bats (88%) used the ribbons (flight height not given). It is not stated how activity compared to that in 2000.

**December 2002.** The road was opened. A wire bridge had replaced the ribbon bridge, with only two pairs of posts instead of three.

**July 2003.** 28 of 89 bats (31%) used the wire bridge relative to the 88% that used the ribbons at the last survey. Average flight height was 4.2 m, i.e. still within the collision zone. Again, activity levels are not compared to
pre-construction levels.

**May 2004.** Audit by Capita. The fencing had been vandalized and none of the specified tree retention or planting had been done. Plans to improve the wire bridge had not yet been implemented.

Further surveys have been conducted, but reports have not been released by the HA.

**Summary:** There was a very large decline in activity post-construction and a minority of the remaining bats used the bridge, most within the collision zone. The mitigation cannot be judged successful.

3.8.5 **Sirhowy Enterprise Way, Abergavenny (Highways Agency 2006).** A bat gantry was built, but no useful data are available on bat use from the brief and qualitative final 2008 report (Stebbings 2008).

3.8.6 **Bickmore (2003) reviewed past work in the UK and continental Europe.** Anecdotal observations are collated to show that bats of several species have been observed to fly through tunnels as small as 1.5 m X 2 m section and in rare instances as small as 1 m X 1 m. It is not known how common this behaviour is.

3.8.7 **European studies**

A large number of publications discuss the use of green bridges and tunnels as mitigation features, but very few provide any data to support their use or measure the potential effects of roads on bats: I will discuss only those that do. There appear to be no published case studies that have investigated bat activity from the inception of a road scheme through to completion or beyond, nor any documenting long- or short-term monitoring.

**Bach et al. 2004.** Bat activity was monitored in a large number of tunnels and bridges in Germany. The tunnels were built for the use of forestry and agricultural vehicles. Three tunnels were studied in Würzburg and eight in Hessen (4-4.5 m X 4 m X 31-45 m long). Due to inconsistencies and omissions in the text and figures, protocols are unclear, but the maximum number of bats (of all species) flying through a tunnel was approximately 16/night. Nine other tunnels, as small as 1.5 m X 2 m, were investigated briefly and all appeared to be used by bats, although the criteria defining use are unclear. Based on a sample of five bridges, it was concluded that very small numbers of bats used them, relative to those using tunnels. No information is given about the age or structure of the tunnels and their connection with the landscape, nor details of local bat populations. The study can conclude no more than that bats will fly through tunnels. How long bats take to adapt to such structures, what proportion of bats use them and the effects of road construction on local bats remain unknown. More species used tunnels than bridges, but data are too sparse to draw firm
conclusions about inter-specific differences.

Anecdotal evidence from past studies is cited, stating that bats will make use of tunnels rather than take a more direct line across a motorway. Most of the examples relate to *Myotis dausymene* and *M. daubentonii*, which habitually fly low over waterways, along which they feed, but other species are reported to use tunnels.

It is stated that tunnels “can minimise the fragmentation effect of large roads such as motorways, when they are situated at the right places.” There is no discussion anywhere in the paper of the concept of the “right place” and the use of a tunnel by an unknown proportion of local bats an unspecified time after construction does not allow firm conclusions to be drawn about their benefits in a fragmented landscape.

**Bach and Müller-Steiss 2005.** An average of 5.9 bat contacts/hour (~three survey nights) was recorded over eight green bridges in Germany. The bridges were not specifically designed for bats and varied considerably in dimensions and cover. Ten species were recorded in all. Bridges varied in width from 9 to 64 m. Although the data presented did not allow me to carry out a statistical analysis, activity was typically greater over the wider bridges. However, this is difficult to interpret given the low sample size and the absence of data about adjacent habitat, bat populations, the disposition of recorders on the bridges and whether or not the bats were commuting or foraging. More activity was recorded on green bridges (mean 3.9 contacts/hour: it is not clear why this figure differs from the 5.9 stated in the first sentence) than on road bridges (mean 1.4 contacts/hour). Three underpasses studied also had relatively high activity (mean 6.9 contacts/hour). However, the data are subject to several uncertainties and are too few to allow meaningful statistical analysis. As in the previous study, activity in the surrounding habitat is unknown, as are the ages of the structures. However, as with the previous study, it shows that bats will use green bridges and suggests that tunnels may be more effective.

**NACHTaktiv and SWILD 2006.** This is a study based around a lesser horseshoe bat roost in Ottendorf Castle, Germany, 300 m from a proposed road development. The study was based on monitoring activity across three sections of the proposed road (260m in length, 130 m wide) for 19 nights over the season. At the same time continuous automated monitoring of bats leaving and entering the roost was carried out, using a directional light barrier. From this they calculated there would be 1400 crossings of the proposed road section per annum, 4.3% of the total flight activity of the colony. 67% of the crossings would occur in the collision zone (based on monitoring with thermal imaging cameras). The colony numbered an average of 96 adult bats and population dynamics modelling indicated that an additional mortality of 5 bats p.a. could lead to extinction of the colony. This equates to one mortality for every 300 flights over the proposed road.
Anti-collision fencing had been proposed as suitable mitigation. Based on the authors’ interpretation of the studies in Wales described above, it is stated that “it is, however, doubtful that this anti-collision fencing envisaged for both sides of the proposed road line would provide adequate protection.”

They go on to review the same schemes I have reviewed above and conclude that none of the mitigation measures have yet been shown to be satisfactorily effective, although underpasses are promising. They note that lights were effective in redirecting bats but suggest they should be used only in exceptional circumstances due to unknown side-effects.

**Furhmann and Kiefer 1996.** This paper describes the use of netting to simulate an underpass and a bridge over the line of a planned road, within 20 m of a roost of greater mouse-eared bats, *Myotis myotis*, in an old railway station building. The bats were initially presented with an 8 m wide by 5 m high gap in a wall. The percentage of bats using the gap increased from 3% to 48% between 4 April and 27 July (5 study nights, max 431 bats). The top and then the bottom half of this gap were then closed, to simulate entry to an underpass and an over the road bridge respectively. ~65% used the 8 m wide underpass configuration, ~85% a 16 m wide bridge configuration. No data are provided for other configurations that appear to have been studied. Recommendations were the lowering of the road by 2 m, construction of a bridge at least 1.5 m wide (this probably means high and no information is given in support of this dimension) with sound-proofing walls 50-100 m either side of the building and a 60 kph speed restriction.

**Lambrechts et al. 2006.** Monitoring over two nights recorded small numbers of three species of bat over a green bridge in the Netherlands (linking two areas of deciduous woodland) approximately one year after construction.

**Bontadina et al. 2005.** In this study, artificial hedges (shrubs in pots or camouflage netting) were used in an attempt to guide lesser horseshoe bats emerging from their roost along a new 200 m route into forest. Over a six week period the proportion of bats using the line of the new ‘hedge’ increased from 2.8/5.7% in the absence of the hedge to a maximum of 11.8±2% (mean ± standard deviation, maximum on a given night = 20%). This small increase was statistically significant.

### 3.9 The scientific case for the effectiveness of current mitigation practices

I was asked to answer the following general questions using the evidence available.

Q. Does the literature show that mitigation 'works' - i.e. has it been demonstrated to prevent an adverse impact on the favourable conservation status of the species of concern or enhance connectivity between habitats?
There is no evidence to show that mitigation prevents the potential adverse impacts of road development on bats. This is due to inadequate research and in particular to an absence of studies designed in such a way that they could answer this question. Conversely, there is as yet no concrete evidence linking road developments with a decline in a local bat population. However, data on the persistent use of dangerous flightlines across roads and studies of road kills show that new, faster roads will have a negative impact on bats.

Evidence to show that mitigation enhances connectivity between habitats is almost non-existent. The single new structure to be clearly adopted as a safe flightline by significant numbers of bats is the Bethesda Bach Bridge on the A487 in north Wales. This is a broad, high structure (much bigger than most structures designed for bats) taking a track a minor road and a stream under the new road. It was not intended for use by bats and was not adopted until several years after the new road was opened. Furthermore, a significant proportion of the bats continued to cross the road in the vicinity of the bridge. The bats appeared to have been fortuitously diverted to the bridge by lights erected to prevent them crossing at another location. It is worth noting here that lights do appear to be effective in diverting bats away from roads, although more systematic research is needed to confirm this. Fencing, however high, does not appear to be effective.

Q. Can levels of impact before and after mitigation be predicted with any precision or scientific confidence, in principle, and in this particular case? What do predicted post-mitigation impacts of 'slight' or 'moderate' mean in practice for the conservation of bats in this case?

A. Until more structured and well-planned research is done, we lack the basic knowledge needed for making accurate predictions about levels of impact. In principle, and after appropriate research, prediction accuracy of some value is achievable. At present I believe prediction is little more than guesswork and terms such as slight and moderate have little meaning. For example, is the loss of say 5% of a bat colony to road deaths slight or moderate? Without an understanding of the long term consequences of elevated mortality on population dynamics it is not possible to say. As yet, no study has taken the first step of estimating before or after mortality, let alone look at population dynamics. Most other measures of impact are even more difficult to interpret. If we wish mitigation to be founded on objective evidence then better research is essential. We should be using measureable effects of past schemes, to predict the consequences of future schemes. Whilst accepting the constraints of time and money, there are useful steps that can be taken that would facilitate more objective appraisal. These need not necessarily increase costs or delay work if carefully planned.

- Monitoring before, during and for some time after construction at a frequency/intensity sufficient to detect trends in often inherently ‘noisy’ ecological data. No study has yet achieved this satisfactorily.
• Systematic and standardised measurement (in terms of effort, location, protocols and equipment) of bat activity in key habitats and/or across an unbiased grid, before, during and after construction, on both sides of the development.
• Systematic and standardised measurement of bat activity on flightlines severed by the road and on their associated mitigation features. Again, before, during and after construction.
• Systematic and standardised measurement of bat activity on safe and unsafe routes at mitigation features.
• Systematic road kill searches. Billington (2001-5) has shown that this can be done and that the data produced can be informative.
• Quantitative and statistical analysis of the data generated rather than descriptive and/or anecdotal presentation with subjective interpretation.
• Collaboration between consultancies and practicing scientists to develop the most effective monitoring protocols and analysis methods.
• Systematic long-term monitoring of large and/or vulnerable bat roosts in the vicinity of the scheme.
• Monitoring of agreed mitigation measures. In past studies there are examples of uncompleted work, unscheduled changes in design and unrepaired vandalism that make data interpretation difficult.

The results will always be subject to different interpretations and ambiguities, but analysis will at least be more objective, quantitative and based on known assumptions.

The current, largely implicit, criterion for the success of a mitigation feature is that it is used by bats. This is far too simplistic. At the very least, it must be demonstrated that the majority of bats are still using old flightlines to reach traditional feeding and roosting sites and in crossing new roads do so by safe routes. If this is not the case then a more detailed study is required to see if altered behaviour may be increasing road kills or is related to the loss of traditional foraging and roosting sites that might compromise the viability of local populations.

Will the proposed mitigation deliver as claimed? Can the proposed monitoring demonstrate this to be the case?

I was asked to address the following questions specific to the Westbury Bypass. I will first make a general comment about the most recent mitigation plans I have seen (November 2007 – April 2008). I believe them to have been drawn up with considerable thought and attention to detail, due in large measure (I understand) to the experience and effort of G. Billington. Given our current, very poor level of understanding, I can see little room for changes that would lead to an assured improvement in effectiveness.

Q. Are the mitigation methods proposed at Westbury appropriate to the species most vulnerable to disturbance by habitat severance and other adverse impacts of roads and traffic? In particular are they appropriate to the rarest and
most endangered (Annex II species) recorded in habitats that would be crossed by the proposed bypass?

**A.** Mitigation measures in this scheme are primarily concerned with guiding bats safely over or under the new road. Additional planting is part of this aim and is therefore limited, although small areas of new woodland will be created around some of the new crossing points. All four of the Annex II species have been seen to use underpass structures. There is little evidence to suggest that any other species, with the exception of the larger noctule and serotine, are any less (or more) likely to use underpasses. It is probably safe to assume that the higher and wider the structure the more likely it will be used and the proposed underpasses are probably large enough to accommodate all but the two large species named. The sparse data available suggest that only a small proportion of bats may adapt quickly to the underpasses and long-term, extensive use is by no means certain. In the absence of adequate data, a similar, conservative summary could be applied to the green bridge. The likelihood that a significant proportion (if any) of the Annex II species will use the bat gantries is probably small. Use by a significant proportion of other species is also uncertain: past studies suggest that a high proportion of bats will fly dangerously close to a road, ignoring gantries.

**Q.** Would construction work planned for the site, including clearance of vegetation and trees, cause unacceptable disturbance? Does the Construction Environment Management Plan provide adequate protection and mitigation of impacts during construction?

**A.** The principle of keeping lighting to a minimum is sound, but more details would be useful, such as the light levels necessary for safe work and how much work is expected to be done that necessitates lighting at times when bats are flying. Much rests on the application of the term minimal lighting. Tree, hedge and woodland clearance would be carried out September to April. This avoids the peak activity period, but bats will still be very active in April and September, so some disturbance is inevitable. Temporary navigation features will be erected every night to minimise this disturbance and may be effective if the work is carried out diligently, using the specified materials, and if they faithfully restore old flightlines. Advance planting is to be carried out at key locations. Again, this is a sound proposal but the effectiveness will depend on timing and the size and extent of planting.

**Q.** Does the 5-year post-construction monitoring plan make adequate and appropriate provision for survey work, enabling adverse effects to be detected and corrected in time to prevent population decline? Is the budget adequate for the work required? What measures are proposed in the event of adverse effects on bat populations being detected?

**A.** The monitoring plan is brief, vague and lacks critical detail. Clear objectives and methodology that will demonstrably deliver results that can be tested statistically are needed. Given the generally poor design of monitoring
programmes in past studies, which have made results difficult or impossible to interpret, it is imperative that this is addressed. If the Westbury Bypass scheme is to go ahead it should strive to be a much needed exemplary study of bat mitigation practice, setting standards for the future.

**During construction monitoring** is described in a single paragraph. "Monitoring during construction would involve surveyors assessing the success rate of temporary fencing set up to maintain flight routes (see above). This would involve bi-monthly static surveys between April and August at each of the temporary flight routes by experienced bat ecologists using appropriate bat detectors. In the unlikely event that the temporary fencing is found to be unsuccessful, Natural England and relevant sections of WCC would be consulted with regards to applying other methods to maintain the flight paths."

To have any confidence in this monitoring much more detail is required. The “experienced bat ecologists with appropriate bat detectors” need to carry out well-designed and consistent work that has clearly defined and achievable goals. There is no mention of pre-construction monitoring, so how will success be monitored in the absence of control data? Past surveys have not been systematic and have not therefore generated suitable baseline data. Does the term bi-monthly mean only three surveys, in April, June and August? This is insufficient to reveal a true picture of how the bats respond. It is also not frequent enough to detect problems quickly and implement essential remedial action. How many survey nights will there be on each occasion? Replicate surveys are needed if reliable data are to be generated. How many surveyors will there be at each site, how will they be disposed and what will they measure? How *specifically* will they measure “success”? Where does the confidence come from to suggest that failure of the temporary fencing is unlikely? In the only quantitative experiments conducted on temporary fencing, Bontadina et al. (2005) showed that only 12% of bats were using it after six weeks. What other methods will (or indeed could) be applied to maintain flight paths if the proposed methods fail? Are those proposed not the best available? How quickly can/will such methods be implemented to limit adverse effects?

A **five-year monitoring plan** is proposed. This is equally vague, and raises many of the same questions, including the fundamental question of how “success” will be measured. How will a single surveyor at a crossing “measure the inter-relationship of bats and the new road, and the success of the crossings”? What does “measure the inter-relationships” mean?

“....success rates for mitigation do vary, and as such, if the mitigation is found not to be working and there is a significant impact relating to bats, then there should be provision for enabling emergency mitigation measures to be employed.” How will impact be assessed? Again, what options are there for emergency mitigation measures?

**Budget.** No budget has been set.
4. Summary

The proposed mitigation measures are perhaps the best that can be sensibly employed given the current state of knowledge. However, that knowledge is very poor. Confidence in their success is based more on a desire for success than on objective appraisal of the available evidence. Monitoring plans are wholly inadequate. There is insufficient detail to assess their effectiveness.

5. Thoughts and suggestions on future practice

Although my brief was to discuss bats and the following was written with specific reference to bats, much of it can be applied to wildlife conservation and mitigation studies in general.

If mitigation is to be effective and cost-effective it must be subject to thorough testing and refinement. Some innovative and potentially useful methodologies are being developed. However, monitoring has rarely been adequate in either quality or quantity and we still have a very poor understanding of how effective mitigation is. It is imperative that sufficient resources are made available for monitoring and that a more rigorous and quantitative approach is taken. I am far from alone in holding this view and will cite a number of important supporters in expanding on this subject below.

The lag (extinction debt) that will invariably occur between environmental degradation and the appearance of its ecological consequences (see section 3.1) assures that short-term monitoring will be wholly inadequate if the aim is to assess the consequences of road schemes and mitigation measures to bat populations. Yet it is at the population level that legislation works – it aims to maintain viable populations. It will in fact be difficult indeed to assess the effects of roads at the population level even with long-term monitoring. It is therefore all the more important to carry out meaningful monitoring at the individual level, as the second best option, if resources are limited.

However, in addition to the ‘individual level’ monitoring typically carried out by environmental consultants in relation to specific road schemes, there is a pressing need for strategic, rigorous research that addresses questions at both the population and individual level to inform conservation/mitigation policy and practice. This need is now recognised by scientists and governments in many parts of the world.

Forman and 13 other scientists and transportation professionals, (Forman et al. 2003) wrote the 481 page Road ecology: science and solutions, sponsored by the US Federal Highway Administration, California Department of Transportation and The Nature Conservancy. In their chapter on mitigation, they highlight the subjective nature of current practice, the “urgent need for rigorous evaluations” (p 141), the fact that “few rigorous studies have been carried out to date” (p 157) and the inadequacy of experimental design in many
studies (pp 157-161). They also suggest ways in which mitigation science can be improved (pp 161-165).

A workshop in Germany led to a paper by several European and North American scientists (Roedenbeck et al. 2007) which draws similar conclusions. The key problem they focus on is poor experimental design, stressing the need for improvement and particularly for rigorous before versus after and control versus impact designs.

Van der Ree et al. (2007) were contracted by the Department of the Environment and Water Resources of Australia to review mitigation measures used to deal with the issue of habitat fragmentation. They pointed to similar problems in the literature reviewed to those already discussed: e.g. poorly defined, designed and described methodology and reporting, and inadequate replication. They stress that “mitigation works and evaluation must have a clearly defined and measureable goal” and also point to the cost-effectiveness of getting things right the first time, reducing the need for expensive re-survey and costly retro-fitting of mitigation features.

The need for improved standards has long been recognised in the UK. Byron et al. (2000) reviewed 40 Environmental Impact Statements published between 1993 and 1997. They concluded: “New approaches to ecological assessment will need to be found if biodiversity impacts are to be addressed with any confidence at a more strategic level. To date, EISs for proposed road developments in the UK have failed to address biodiversity issues explicitly or adequately”. This follows similar reviews they published in 1993 and 1997 in which similar failings were reported. The situation had improved, but was still far from satisfactory. They go on to say: “Many of the shortcoming which this review identified arise from the lack of time and resources generally allocated to the ecological assessment within the EIA process and because of failure to consult ecologists early in the design and planning of road developments. This results in the provision of ecological information which is of limited predictive value, or of limited relevance.” Whilst consultation is now frequently earlier, issues surrounding the resourcing and design of survey and monitoring have not been resolved.

Even with appropriate time and resources, many consultants may still lack the expertise to design the effective survey and monitoring protocols required to assess the success or failure of mitigation features. Despite the problems highlighted by Byron et al. (2000) and the guidelines on good scientific practice suggested by Forman et al. (2003), recent work is seriously flawed. The suggestions of Forman et al. (2003), Roedenbeck et al. (2007) and van der Ree et al. (2007) need to be adopted and developers, consultants and research ecologists need to work together to make mitigation a science rather than an expensive and contentious art.
6. References


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