Research Report 10/1

Pilot study to assess the potential of selected existing structures on the A30 and A38 trunk roads to provide safer crossing places for deer.

J Langbein

July 2010

Pilot study to assess the potential of selected existing structures on the A30 and A38 trunk roads in Southwest England to provide safer crossing places for deer.

Prepared by Jochen Langbein
Langbein Wildlife Associates

Deer Initiative Research Report 10/1
July 2010

Further information can be obtained from:

The Deer Initiative
The Carriage House
Brynkinalt Business Centre
Chirk
Wrexham LL14 5NS

www.thedeerinitiative.co.uk

Or email: policy@thedeerinitiative.co.uk

This work was commissioned by the Deer Initiative for the Highways Agency.

Contents

Executive Summary

i. Collisions of motor vehicles with deer have escalated over the past five decades in most countries across Europe including Britain. Recent studies supported by the Highways Agency indicate that the annual toll of deer vehicle collisions (DVCs) in Britain is now very likely to exceed 42,500 and may be as high as 74,000, and lead to several hundred human injuries and a number of human fatalities each year. Although DVCs are also a serious problem in Scotland, within the UK close to 80% are recorded in England where traffic volumes are close to nine fold greater. The numbers of DVCs recorded on the strategic network of motorways and trunk roads in England managed by the Highways Agency (which make up only 2% of all roads in England) now commonly exceed 1100 per annum with many more likely to remain unreported. Such actual collisions, as well as the need to deal with many additional incidents with live or dead deer on trunk road carriageways, have serious implications for road safety and traffic delays.

ii. The only well proven method of reducing deer collisions on motorways and major trunk roads is the use of high roadside fencing, and it is most successful where it channels animals to safer crossing points. Wide "green bridges" or "landscape bridges" constructed primarily to reduce habitat fragmentation caused by infrastructure can help also to reduce animal collisions, but their high cost tends to rule them out from widespread use for DVC mitigation. To some extent the recent focus on high profile green bridge projects in continental Europe has led to a widespread misconception that much smaller or joint use structures have little potential as safer crossings for deer and other large mammals. Deer are, however, known to make (increasing) use of trunk road accommodation structures of relatively modest size not specifically built for wildlife.

iii. Few previous studies have specifically investigated the use by deer of existing accommodation structures on trunk roads in England. This pilot survey was initiated to:
- review past research into deer use of underpasses and overpasses and the dimensions and other features thought to influence their suitability as wildlife passages.
- survey a range of existing structures on trunk roads (the study used the A38 and A30 trunk roads in Devon and Cornwall) with the aim of assessing which were likely to be used by deer or offer good potential for adaptation to encourage use by deer.

iv. Several reviews from continental Europe have recommended minimum dimensions and other physical criteria of structures that increase the likelihood of use by deer. Common recommendations include that underpasses should be at least 4 m high (for roe deer, (higher for larger deer), over 7 m wide for overpasses, and have natural substrate for part of their width. Some consensus exists that how inviting a crossing structure will appear to a deer depends more on its relative openness (width x height / length) than any individual dimension. Structures that have been found to be used by deer vary widely in terms of substrate, location, joint use by motorised traffic and other disturbance, and the relative importance of such features remains difficult to define.

v. Several studies in continental Europe have concluded that regular use by deer of structures open to normal road traffic is unlikely, yet recent observations have shown that deer even use road bridges without any natural substrate in some parts of England (Langbein, 2008). These findings suggest that acceptance of man-made structures by deer may differ widely between countries and regions and is likely to alter over time depending on the degree to which local deer populations become accustomed to built up areas and human habitation. It is timely therefore to assess to what extent criteria for wildlife structures established elsewhere are likely to be transferrable to the current situation in England, and to explore the potential for differing types of existing structures to be adapted to enhance their use by deer and form a greater part of DVC mitigation strategies in future.

vi. The field survey for the present pilot study encompassed 47 existing structures (19 overpasses / 28 underpasses) across the A30 and A38 in Devon and Cornwall (Figure 2), with road sections along these routes selected to sample locations known to be frequented by red, fallow and roe deer. For most structures survey was limited to a one-off visit to record various physical features (dimensions / substrate / juxtaposition in relation to differing habitats) and searches for indirect recent signs of deer (dung / hoof prints / hair) nearby. For three structures where some clear signs of recent deer activity were noted CCTV video recording equipment was deployed for one to three nights, with the aim of obtaining some additional insights into the behaviour of deer at structures. Survey information was evaluated against criteria reported in the literature for structures known to be used by deer to help assess their potential as wildlife crossings.

vii. Evidence of some deer activity within 50 m was noted for 18 of the 47 structures surveyed, but evidence that deer had actually crossed recently was only found for two structures during the one-off site visits. None of the structures surveyed occurred in sections of road fitted with deer fencing. However, evaluation of other features recorded for each structure indicated that well over half of those visited meet or exceed the generally accepted minimum size and openness criteria taken from the literature on wildlife passages (e.g. minimum heights of 4 m for underpasses, and openness indices no less than 0.75 for roe deer; see Section 2). As such many existing structures would seem to have a reasonable basis for adaptation as safer crossings for use by deer.

viii. Many of the structures surveyed would not currently meet various other criteria commonly recommended for wildlife passages, in particular with respect to provision of a natural substrate or separation from joint usage by general public road traffic. However, recent observations of deer use of structures in other parts of England (e.g. Langbein, 2008) indicate that use of structures by light or intermittent public road traffic, and the presence of a hard substrate of tarmac or concrete, may be less of a hindrance for deer than previously thought. A negative feature noted for many underpasses surveyed was that side roads or tracks leading underneath trunk roads often have additional boundary fencing or thick hedges running along either side, which are not easily crossed by deer and may actually serve to divert them away unless some provision is made to improve direct accessibility.

ix. Several CCTV video clips recorded during the present study at one underpass on the A38, showed fallow deer, not moving through that structure itself, but walking across the top along the trunk road verge. The footage serves to demonstrate that deer often feed calmly within just 2 to 6 m of passing trunk road traffic, and that without any fencing to lead them into the structure deer may be more likely to cross the main trunk carriageways.

x. Overall, the study concluded that for a very high proportion of the existing structures inspected, appropriate low-cost adaptations are likely to encourage use by deer. To help demonstrate the feasibility and effectiveness of adaptation of existing structures as a means of DVC prevention, a number of practical demonstration projects are proposed at suitable structures identified during the present study.

xi. One of the demonstration proposals concerns adaptation of either one or two underpasses located within the longstanding fallow deer DVC hotspot at Haldon Hill (A38), while the second concerns two overpasses across the A30 at woodland near Ebsworthy frequented by red deer as well as roe deer. Adaptations of these structures to enhance use by deer are likely to be achievable at low cost, ranging from simple removal of obstacles that currently prevent or reduce access by deer (likely to be achievable at costs below 1K), to provision of more natural substrate for part of their width (also likely to be achievable at low cost), and provision of short lengths (from around 100 m) of lead-in fencing on one or more sides of each structure (with indicative project costs from around 5 K to 20 K). In addition, some parallel monitoring work to determine effectiveness of any physical adaptations undertaken is recommended, which ideally should include intermittent use of CCTV surveillance to maximise knowledge gained on the actual effects of differing adaptations on animal use.

1. Introduction

1.1. Over the past five decades collisions of motor vehicles with deer have escalated in most countries across Europe as well as North America (Ueckermann, 1964; 1987; Lehnert, Romin & Bissonette 1996, Groot-Bruinderink & Hazebroek 1996, Seiler, 2004). Most recent reviews on the subject concur that the toll of deer-vehicle collisions (DVCs) is now likely to be near 1.0 million per annum for Europe (Langbein et al. 2010a) and over 1.5 million in North America (State Farm Insurance, 2009; Mastro et al. 2008). The key factors that have contributed to that rapid growth, not only of DVC but of wildlife road casualties in general, are the expansion of road infrastructure and traffic volumes (Iuell et al. 2003). In Britain for example, traffic volumes have increased fourfold between 1960 and 2000 (Dft, 2006). Still further increases in traffic volume are now showing signs of slowing in some developed countries including Britain (Dft, 2009). In the case of deer, population numbers and distributions are also known to have increased very significantly over the last fifty years in many countries across Europe including Britain as well as in the US (Gill, 1990; Apollonio *et al.*, 2009), adding still further to escalation of DVCs.

1.2. Six species of deer live wild in Britain with a combined population estimated at around 1.5 million (POST, 2009). Following a short-term assessment commissioned by the Highway Agency in 1995 (SGS, 1997), which concluded that DVCs by that time were already very likely to have reached over 20,000 per annum and quite possibly 40,000, a more comprehensive Deer-Vehicle Collisions Project was set up in 2003 through The Deer Initiative. The main aims of that project for the first three years were to assess the true scale and distribution of the problem in England and Scotland, and build a database to help identify hot spots and priority areas for mitigation. Results from the first three years indicated that there are likely to be between 42,500 and 74,000 DVCs each year in Britain (Langbein & Putman, 2006; Langbein, 2007a; Deer Initiative, 2007).

1.3. This high toll of DVCs in Britain leads to extensive human costs (including a number of fatalities and several hundred people injured each year), damage to thousands of vehicles, and presents a major animal welfare issue (as over a quarter of deer are not killed instantly when hit by vehicles, but are left severely injured at the roadside until dispatch or treatment can be arranged). The number of DVCs leading to human injuries in Britain has been assessed to exceed 425 per year including 10 - 20 fatalities (Deer Initiative, 2007). The annual economic 'value of prevention'[1] of that level of personal injury road accidents alone amounts to GBP 30M (Deer Initiative, 2007), while additional economic losses in the region of GBP 17M result from the 11,000 or more private vehicles plus 2500 commercial vehicles estimated to sustain significant damage (above insurance excess) from DVCs each year. Further substantial economic consequences of DVCs, for which no national cost estimates are available at present, arise through traffic delays, attendance by suitably qualified personnel to treat or humanely dispatch deer at the roadside and clearance of animal carcasses from the carriageway.

1.4. Although the total numbers of deer in England and Scotland are estimated to be of comparable magnitude (~600,000 - 750,000 each), over 80% of DVCs recorded for Britain as a whole occur in England (Langbein, 2007a). This reflects foremost that English roads make up around 78% of the total road network in term of road length and carry over 85% of annual traffic (Annual traffic reports, DfT 2009), with the inevitable consequence that deer (as well as other species of wildlife) in England are exposed to much greater risk overall of being hit by motor vehicles. Within England DVCs are also not evenly distributed but occur mainly in "hotspots", often though not exclusively where roads run through woodland with high deer numbers, high traffic volumes and high traffic speed. The most prominent localised hotspots tend to involve fallow, although collisions with roe deer are the most widespread. Overall the species for which highest

[1] [Guidance for assessing economic impact of road accidents : Highways Economic Note 1, HMSO 2007]

numbers of DVC are recorded in England are fallow (40%), roe (32%) and muntjac (25%); and in Scotland, roe (69%) and red deer (25%).

1.5. Of over 10,000 DVC records accumulated during 2003-2005 for which road type is known, 63% occurred on major roads (A-road and motorways) and 37% on minor roads. Although major roads make up only 12% of the total road length in England they do carry 64% of total traffic volume. The Highways Agency are responsible only for the core strategic road network of motorways and major all-purpose trunk roads in England, which makes up just 1/6th of all major roads (or 2% of roads overall), but which carry close to 33% of all traffic. The precise number of actual collisions on the HA's trunk road network is not known. However, over 1100 such incidents have been reported in each of the last three years by trunk road managing agents and Highways Agency (HA) Traffic Officers, and actual numbers on the HA network are likely to be rather higher.

1.6. Estimates based on data accrued by the DI DVC project between 2000 and 2007 indicate that incidents with deer on trunk roads (which make up only around 2% of all road length) are likely to contribute to between 4 - 5% of all DVCs in England. Although the proportion of damage only DVCs tends to be somewhat lower on trunk roads, the percentage of all reported DVCs that lead to human injuries and fatalities is broadly similar for trunk and non-trunk roads in England. We may therefore reasonably estimate, in line with the national economic costs outlined in section 1.3 above, that DVCs on trunk roads alone are likely to incur costs of 2 Million GBP annually through human injuries and damage to vehicles alone. Significant additional impact is, however, likely to arise from DVCs and other encroachment of live deer onto the carriageway especially on trunk roads, because of the high potential here for such incidents to cause serious multiple accidents and traffic delays, as well as the need to deal safely with the humane dispatch of injured deer that are not killed outright in collisions.

1.7. The most successful mitigation measures will seek not to prevent crossings altogether, but to displace them so that deer cross the road in places where accident risk is reduced through lower traffic volume/speed, enhanced visibility and driver awareness, or by provision of relatively traffic free wildlife passages/bridges. Although numerous differing methods have been suggested and tried over the years, the only well proven method of reducing deer collisions on major roads remains the use of roadside fencing of specifications appropriate to the target deer species. However, fencing long lengths of roadway is likely to prove ineffective and result in animals forcing such barrier (with the added risk that they may then become trapped within the carriageway) unless some suitable alternative crossing places are available.

1.8. Wide landscape bridges and other structures constructed specifically for deer and other wildlife offer greatest potential to enable safer crossings and reduce animal collisions; that is, alongside provision of other biodiversity benefits which tend to be their primary purpose (Iuell et al. 2003). Specifications for such wide purpose-built structures are often very high (recommended designs often including width to length ratios above 1.0). The scale and cost of such structures also tends to make them more suitable for new-build roads with multispecies mitigation needs, rather than for widespread application across the existing trunk road network. Deer and other wild large mammals are also known to make use of some motorway and trunk road accommodation structures of much more modest dimensions, that were not built specifically or primarily for wildlife, ranging from footpath and farm accommodation overpasses and underpasses, to viaducts, as well as bridges carrying normal road traffic (e.g. Ballon, 1985; Olbrich, 1984, Langbein, 1996, 2008; SETRA, 1993; Halcrow, 2002). However, the extent and types of existing joint-use structures on the HA's trunk road network that may be used by deer in the UK, and the potential for adaptation (of the structure or surroundings) to increase such usage, has received only limited investigation to date.

1.9. This pilot study was initiated to begin to gather information on a range of existing structures on the A38 and A30 trunk roads in Devon and Cornwall, in order to assess whether any are already likely to be used by deer; or else, whether they offer real potential for adaptation in ways likely to bring significant benefits in terms of reducing risk of deer and other wildlife collisions on trunk roads.

Requirements for research and objectives of present study

1.10. The majority of recent research into use by large mammals of structures across major roads in Europe and elsewhere has focused on structures either specifically designed for wildlife, or to reduce habitat fragmentation due to road infrastructure (see reviews by Holzgang et al. 2000; Iuell et al. 2003; Georgii et al. 2007). By contrast, studies that have looked into use by wildlife of joint-use structures or ones not created with wildlife in mind, have concerned themselves almost exclusively with structures that also have deer-fencing on both sides of the carriageway, which helps to guide animals to the structures (e.g. Olbrich, 1984, Ballon, 1985m, Langbein, 2008). These and other previous studies addressing the latter issue will be reviewed in further detail in Section 2.

1.11. To date, no systematic assessments have been undertaken for trunk roads in England to assess which types of structures are used or have most potential for use by deer, nor of the factors (including dimensions, locations and surrounding habitats) that influence such use by deer. In particular investigations into the use by deer or by other large mammals of structures without deer fencing are rare, as is knowledge on the extent to which use of such structures in unfenced areas can be increased through provision of deer fencing, habitat manipulation or other adaptations.

Objectives for this pilot study

1.12. The main objectives set for the pilot study were as follows:

- review past published and unpublished literature (esp. from within UK) on use by deer of structures not specifically designed for wildlife.
- to survey and record the characteristics (dimensions / substrate / juxtaposition in relation to differing habitats / deer species) of a large sample of up to 50 existing overpasses, underpasses or viaducts beneath along one or more trunk roads.
- to identify if possible any structures with clear evidence of deer use, and / or others with nearby deer activity but no apparent current crossing activity.
- assess the potential for further enhancement of use by deer of structures that already appear to be used to some extent, and/or adaptations that might encourage the use of structures which are not currently known to be crossed by deer.
- make recommendations for further research, and practical works to enhance use of existing structures by deer on the HA trunk road network.

2. Previous research into use by deer of wildlife specific crossing structures and of structures primarily designed for road traffic or other purposes.

2.1. Expanding road networks during the 20th century, and in particular of wide motorways and other major strategic traffic routes, have led to natural habitats and animal populations becoming increasingly fragmented across much of Europe, including Britain. Increased rates of animal mortality through collisions with traffic are another inevitable consequence of that expansion. To help redress the impact of fragmentation through infrastructure on wildlife, in many countries increasing use is being made of green bridges and other means to reconnect habitats and aid animals crossing major roads. Green bridges purpose built for wildlife can also provide optimal solutions for creating safer passage of large mammals across major roads, but the generally high cost of such large structures (commonly upward of 1 to 3 million EU; Georgii et al, 2007) tends to restrict their use to a fraction of the most important conservation sites. The literature and research on green bridges and other means of reducing fragmentation due to infrastructure has been extensively reviewed by others and will not be repeated in detail here, but can be found in the various outputs of the transeuropean collaborative COST341 Action: *Habitat fragmentation due to transport infrastructure*; in particular see Iuell et. al. (2003), Trocmé et al. (2003) and others available at the IENE web-site).

2.2. The above and other recent reviews of the effectiveness of green bridges (Iuell et al. 2003, Georgii et al. 2007) recommend that to maximise their use by deer, green bridges should ideally be over 40 m wide or else no less than 20 m at their narrowest points, though ideally still with wider entrances. While such demanding criteria would rule out use by deer of the vast majority of existing structures on the trunk road network in Britain, it must be borne in mind that the aims for green bridges tend to be much broader than only to reduce animal mortality and related traffic collisions; among multiple objectives their primary aim tends to be to reduce fragmentation by providing a degree of habitat continuity to encourage use by a high proportion of species and individuals within a given wildlife population.

2.3. The majority of previous research and reviews about the use by deer of smaller crossing structures has also been focussed mostly on assessment of structures specifically designed as wildlife overpasses or underpasses. Several authors have attempted to define minimum criteria for wildlife specific structures, but the minimum dimensions set tend to vary widely (CTGREF, 1978; SETRA, 1993; Ballon, 1985; and see review by Holzgang et al., 2000). CTGREF (1978) analysed the use by large mammals of a range 17 existing overpasses and underpasses that had been built specifically for wildlife on motorways in France, of which only 3 could be positively shown to be used by ungulates. A wider questionnaire study by CTGREF of game managers with regard to 152 different structures, however, did indicate likely use by deer or other ungulates (e.g. wild boar) of 30 wildlife overpasses and 23 underpasses. They concluded, as did Ueckermann (1964) in Germany, that wildlife fencing of appropriate size generally needs to be provided to deter animals from crossing motorway carriageways, and to lead animals instead to suitable crossing structures.

2.4. CTGREF provided some of the first recommendations regarding dimensions for wildlife specific rather than joint-use passages. They suggest a width of 6 m as minimum for overpasses for ungulates, and a height of at least 1/10 of the length or else no less than 3 m for underpasses. Ballon (1985) came to similar conclusions for overpasses, but suggested that width of underpasses should be no less than 8 m for deer. These as well as other early experiences from assessments in France are reviewed by SETRA (1993), to provide various design guidelines for building wildlife specific structures, including that the minimum width of overpasses should be 12 m for red deer, and 7 m for roe deer. Minimum heights for wildlife underpasses are given as 4 m for red deer and 3 m for roe deer, and 2.5 m for wild boar. Berthoud et al. (2000), for wildlife underpasses beneath motorways in Switzerland to be suitable for ungulates, also still recommend a width of 8 m and a minimum height of 3 m provided the passage is no longer than 16 m long, but rising to 4 x 9 m if 25 m long and 5 x 12 m if 32 to 40 m long.

2.5. For 'narrow' wildlife overpasses on Swiss motorways suitable for all deer Berthoud et al. suggest these need to be at least 25 m wide, thus in effect almost as large as many purpose-built green bridges. However, as discussed above, use by roe deer of much narrower overpasses from around 6 m wide has been reported in some instances, and more recently Langbein (2007c) recorded use also by fallow deer of two farm accommodation overpasses only 4 m and 7 m wide crossing over the M25 in London.

2.6. During research again restricted to assessments of wildlife passages free of any public road traffic, Georgii et al. (2007) by means of video recording and track analysis found roe deer to make fairly regular use (between 0.3 to 5 crossings per day) of six underpasses beneath German motorways ranging in height from just 2.4 to 8.0 m; no larger species of deer were recorded in these underpasses. These authors nevertheless recommended that the height of underpasses designed for wildlife should not be less than 8 m, illustrating that while design criteria will generally err on the side of caution, smaller structures may still suffice as mitigation to aid crossings by individuals of some if not all species of deer present locally. A number of wildlife underpasses 3 to 4 m high have also been confirmed as being used at least by small deer in England, including an underpass beneath the M40 used by muntjac and roe deer (Halcrow, 2002), and ones observed to be used by muntjac, but quite possibly also by fallow, beneath the M25 near Epping and A120 near Stansted (Langbein, 1996; 2008). Georgii et al. (2007) also included 20 purpose built green bridges in their study ranging from 20 m to 200 m wide, finding that intensity of use by wildlife including by deer increased with the width of such bridges. As nearly all, including the narrowest green bridge included in their sample, were used to at least some extent by roe deer, no minimum or threshold widths could be defined for deer.

2.7. Far fewer studies have investigated the use by deer of structures not designed for wildlife but built for joint use for farm or forestry accommodation, footpath diversions or indeed general road traffic. One exception here is a seminal work by Olbrich (1984) who reviewed the use and suitability of near 800 structures of various types on the German Autobahn (motorway) network. All of the structures included in that study occurred in deer-fenced sections of road, and before considering his results, it is interesting to trace briefly the history of the quite extensive use of such deer fencing in Germany and consequent development of ideas for wildlife passages. With as much as 30% of the land area of Germany being covered by woodland, high numbers of collisions with deer were already a longstanding issue even during the early 1960s, leading Ueckermann (1964) to first propose the more widespread use of high fencing to protect traffic against collisions with deer. At the same time Ueckermann mentioned that one underpass in a fenced section had been observed to be used by roe deer as well as foxes and hares. Encouraged by those positive reports the German Transport Minister in 1967 set up a major trial of wildlife fencing across 22 sections of motorway with a total length of 125 km (Busch & Kaemer, 1973), which resulted in a significant reduction in accidents with deer and other game animals within those protected sections. The use of deer fencing in on German motorways expanded rapidly.

2.8. In 1979 Olbrich (1984) for his assessment of overpasses and underpasses selected 49 sections of major trunk routes all of which had been fitted some year earlier with deer fencing. In total 824 crossing structures were identified along these routes, for which site visits and local assessments were made for 788. In each case surveys recorded details of the dimensions of the structures, their location, fencing, and evidence of use by deer and other large mammals. Use by deer was determined by searches for tracks (slots) and dung pellets, or else consultation of each local hunter or forester responsible for deer management in the district where each structure was located. To validate results obtained through views of local deer managers, those structures for which use by large mammals had been reported were visited again after first snowfall in winter to obtain confirmation from assessment of tracks leading across each structure. For roe deer use of structures was confirmed for 45% of underpasses and 22.5% of overpasses located in areas with roe deer present (n=788); a surprisingly high number considering that roe deer have relatively small home ranges and hence possibly rather lesser need to move between sites. Fallow deer were present in the vicinity of 162 structures, of which they were noted to utilize 26.3% of overpasses and 21.7% of underpasses; whereas for red deer among 162 structures within their range, 8.1% of underpasses and 4.8% of overpasses were used.

2.9. Based on analysis of the dimensions, substrate and usage of the structures investigated Olbrich made a number of key recommendations: minimum measurements for height and width of underpasses for deer and other ungulates should be 4 m, with as a matter of principle the shortest possible structures being preferable. The openness index (or relative narrowness) taken for underpasses as width x height divided by length, is highlighted as of particular importance, with suggestions that this should not be less than 1.5 for red deer and also fallow deer. Olbrich found roe deer to prefer underpasses rather than overpasses, and recommends that underpasses should have an openness index of at least 0.75, He suggests that in favourable positions (e.g. quiet farm roads) roe as well as fallow may also use overpasses, but does not provide guidance on their relative openness or maximum length. Olbrich (1984) however concludes that reinforcement of the base (substrate) of the construction with concrete or tarmac makes them more difficult for ungulate use, while proximity to woodland encourages use by large mammals. However, although it is unclear how many of the structures included in his study were open to general road traffic, Olbrich suggests that all structures that are frequented by public traffic are generally unsuitable as wildlife passages.

2.10. Only very few studies to date have looked more closely into the use by large mammals of crossing structures designed primarily to lead public road traffic over or under trunk roads. Pfister (1997) used infrared video cameras along Swiss motorways to study the extent to which crossing structures built for traffic are used as by wildlife. His findings indicated that here such engineering structures may mitigate the barrier effect for burrowing species such as foxes, weasels and martens, but concluded that other more ‘timid’ species such as roe deer or hares were seldom or never observed on structures not specifically built for wildlife, even if found in the immediate vicinity of the structure. These findings in Switzerland, however stand in stark contrast to a number of recent studies in England (Langbein, 2007c, 2008) that have confirmed use not just by small deer such as muntjac, but also by fallow deer of a number of structures built primarily for road traffic, and other smaller structures.

2.11. Langbein (2008) assessed the effectiveness of new deer fencing and use of various engineering structures by deer one to three years post-construction of the new A120 Stansted to Braintree dual carriageway. Numerous joint-use over and underbridges were constructed as part of that A120 scheme to accommodate side road traffic, river courses, and/or farm access and footpath diversions. None of the structures, aside from a number of badger tunnels, were specifically designed for wildlife. Deer fencing was provided on either side for 12 km of the new route between Stansted to Dunmow where high densities of fallow were known to occur, and had resulted in nearly 40 DVC per annum locally on the old A120. Investigations of deer use post-construction used a combination of searches for indirect signs of deer (including use of sand track-beds on or near entrance to these structures) and intermittent periods of CCTV surveillance. Results demonstrated that both fallow and muntjac deer did make at least some occasional if not yet regular use of several of the structures within two years of construction. The structures where most conclusive evidence including video of deer crossings were found included public road overbridges at Frogs Hall and Warish Hall (see Photos 1 and 2) used by muntjac and fallow, as well as a high underpass bridging the River Chelmer. For a number of other smaller farm and footpath accommodation structures use by deer was reported as having been seen by local landholders but could not be confirmed by video or other signs during the study.

Photos 1 and 2: Examples of structures accommodating public road traffic leading over A120 Essex, known to be frequented by fallow and muntjac deer. Both structures cross over deer fenced sections of trunk road; base substrate for both is of concrete or tarmac throughout the main span. (Langbein, 2008)

2.12. It is interesting to note further that the A120 road bridges used by fallow (above) both had concrete or tarmac substrate without any strip of natural surface, although a natural substrate is widely reported as critical to achieve use by deer by many past studies. Another example of a concrete-only overpass used by fallow occurs over the M25 London orbital motorway at Copthall, Epping Forest. Fallow deer have been filmed crossing this 4 m wide and 85 m long concrete-only bridge (see Section 5: Photos 5 and 6), as well as regular deer movement across a slightly wider 7 m overpass which does have a part soil covered base (Langbein, 2007c). Further examples of joint use structures of modest size in England used by deer, include a roadbridge over the M40 near Oxford (Halcrow, 2002) which was provided with a grass and gravel verge to enoucourage wildlife, and use by red deer of an underpass and a narrow overbridge over the M6 Toll motorway (Cresswell pers. comm). In common with all the above examples these structures on the M40 and M6 also occur within sections of trunk roads provided with deer fencing.

2.13. Several of the literature resources discussed above have recommended minimum criteria or conditions for structures that will increase the likelihood of use by deer, and which should be aimed for when planning new-build wildlife passages. However, the exact conditions that lead to some but not other existing structures to be used by deer remain difficult to define. Some consensus does exist that in deciding how inviting or off-putting any man-made structure may appear to a deer, a factor probably more important than any individual dimension is its relative 'openness' (see 2.9). In simplistic terms shorter wider structures tend to become more readily used by deer than long narrow structures, given other influencing factors remain equal. However, findings from past studies with regard to other factors such as the substrate, location, amount of disturbance, and lead-in fencing and their relative importance remain very variable. The latter is likely to be influenced also by differences between countries and regions in how deer populations are managed and how accustomed deer are to living close to built up areas and human habitation.

2.14. The above review, and in particular the recent observations of structures used by deer in Britain (2.11 and 2.12) illustrate that structures not specifically designed for use by wildlife, including ones of comparatively modest size, given the right conditions may nevertheless become adopted as passages by deer. Furthermore, there may be significant potential to adapt a small proportion of the many hundreds of existing engineering structures over or under the UK trunk road network, to provide safer passage for deer and other large mammals and help minimise risk to traffic.

2.15. Although the examples given where deer use existing joint-use structures are encouraging, the relatively small number and short-term nature of studies that have looked at this issue in Britain suggests this remains a field worthy of much more widespread and detailed research across the UK trunk road network.

Table 1: Example dimensions of selected road crossing structures for which deer use has been confirmed during past studies, and recommendations arising from past reviews for design of overpasses or underpasses suitable for wildlife (for more details see text section 2).

	Existing structures for which deer use reported	**Recommended design characteristics to encourage regular use by deer**
Underpasses (UP)		
Internal height (m)	2.4 – 8.0 (Georgii et. al, 2007) 3.0 - 4.0 (Halcrow, 2002) 4.0 - 7.0 (Langbein, 2008)	>4.0 (Olbrich, 1984) >3.0 for roe deer (SETRA, 1993) >4.0 red deer (SETRA, 1993) >8.0 (Georgii et al. 2007)
Width (m)	4.0 (Olbrich, 1984, Halcrow, 2002, Langbein,2008) 8.0 (Ballon,1985)	>4.0 (Olbrich, 1984) >12.0 for red deer (SETRA, 1993) >7.0 roe deer (SETRA, 1993)
Length (m)	up to 48 (Langbein 2007b, 2008)	Variable depending on height / width
Openness index (*width times height divided by length)*	0.5 (Langbein, 2008)	for roe deer ratio >0.75 for red deer >1.5 (Olbrich, 1984)
Overpasses (OP)		
Accessible width (m)	6.0 (CTGREF, 1978) 3.5 – 7.0 (Langbein, 2007b, 2008)	>6.0 (CTGREF, 1978) >7.0 (Olbrich, 1984) >25m (Berthoud et al. 2000)
Length (span) (m)	85 -106 (Langbein, 2007b, 2008)	
Openness (*width divided by length)*	0.05 - 0.06 (Langbein, 2007b)	ratio >0.1 (CTGREF, 1978)
Purpose-built Green Bridges / Wildlife Overpasses		>40 m or at least 20 m at narrowest point with wider entrances (see reviews Iuell et al. 2003; Georgii et al. 2007).

3. Approach and methods

Study site selection

3.1. Fulfilment of the study objectives (1.11), within the limited resources available and a time frame of less than 10 man-days of field work, required selection of study areas that offer a sizeable sample of existing structures (up to 50) within reasonable proximity of one another. To ensure that results would be widely relevant for other parts of the Highways Agency (HA) trunk road network, sites surveyed also ideally needed to include a mix of areas with both small deer species (roe or muntjac) and larger deer (fallow / red / sika). Availability of good background information on DVCs over several past years was also considered important for site selection, to confirm not only the common presence of deer, but also local potential for reducing such accidents in future should the study indicate that adaptation of specific structures could bring significant benefit.

3.2. Alternative sites considered during planning of the pilot study included:

i. A38 Exeter to Bodmin plus A30 Exeter to Bodmin (HA Area 1);
ii. Possible extension of above to include M5 Exeter to Cullompton (HA Area 2).
iii. A303 Andover to Sutton Scotney ; plus A34 Sutton Scotney to Newbury (HA Area 3).
iv. A31-M27 Ringwood to Southampton (HA Area 3).

3.3. Each of the above offered potential to satisfy most requirements for the study. The first option (HA Area 1) was selected foremost on the basis of the particularly wide range of structures available, ranging from small livestock accommodation underpasses to much larger bridges and viaducts spanning river valleys, and secondly availability of comprehensive background information on deer and other animal casualties via the managing agents and through other previous work by the Deer Initiative.

3.4. Review of route plans provided to us by Enterprise Mouchel (HA Managing Agents Area 1) showed the presence of well over 200 existing structures along the A38 between Exeter to Bodmin (including overbridges, underpasses, and culverts) with a similar additional number along the A30 Exeter to Bodmin. As survey of every structure along each route would not be feasible within the time available, the pilot study was focused on structures within six main sub-sections of road chosen to encompass parts of the A30 & A38 with relatively high numbers of reported DVCs, and to ensure representation of some areas with significant presence of roe, fallow and red deer among the sample. Collection of DVC data for the A38 & A30 did not form a specific objective of the present project, but past records available from the DI's National DVC project were updated with most recent records available from HA Area 1 managing agents and other sources [to end 2009] and mapped to help with identification of high priority sites. An overview of the relative distribution of reported DVCs along both trunk roads (2003-2009) is provided in Figure 1.

3.5. National deer distribution data indicates at least some occurrence of roe, red, and fallow in almost all of the 20 differing 10 km grid squares overlapping the A30/A38 between Exeter to Bodmin; muntjac have also been recorded as widely present but so far in only about half the area [Figure 3]. While this information suggests any of these species might be encountered almost anywhere along both routes, information on deer presence from local deer managers and from the (small proportion of) DVC reports for which deer species information is available, indicated that fallow would be the most common species contributing to the DVC hotspots (see Figures 1 and 2) along A38 near Haldon, red deer along the A30 west of Okehampton, with roe deer the predominant (but not only) deer species in most other parts. In addition significant numbers of (feral) wild boar are known to be established within less than 1 km of the A30 near Whitstones east of Tedburn St Mary. Muntjac are also likely to be present in small numbers along the route, but no information or direct evidence of their presence was noted during this study. (For the predominant deer species present near different parts of the routes see also Section 4 -Table 3).

3.6 Six main road sections were selected on which to focus the survey of existing structures (see Table 3). These were chosen so as to sample some of the main known DVC hotspots along each route, and to encompass some areas where either fallow or red, as well as roe deer are present in significant numbers (see Figure 1 - 3). Along each of these sections the majority of existing underpasses and overpasses were included for survey provided ready access could be gained. Small stream culverts less than 1.5 m high (and least likely to be used by deer) were however excluded. In addition a number of other individual underpasses and viaducts along other parts of the route were also surveyed, either opportunistically if passing through en route to other field work, or selected to help extent the range of different types of structures visited.

Field survey of structures

3.7 In line with Health & Safety regulations for working along HA trunk roads, induction training provided by Enterprise Mouchel (HA MAC agents for Area 1) was undertaken by the author prior to commencement of any survey work. As part of requirements for this, Area 1 Command & Control Centre were informed at start and regularly during each fieldwork day if working alone on the network; although for many structures access from or inside trunk road boundary fencing was not required.

3.8 For the purpose of the present pilot study only a one-off survey visit during late March or April 2010 was possible in the case of most structures. Each site inspection covered the following main aspects:

- assessment of the main dimensions of each structure (length, width of carriageway and in the case of underpasses, internal height).
- search for indirect evidence of recent deer activity (slots / dung / other signs) within or close to structure entrances, and up to 50 m (in some cases 100 m) along the verge of the passage leading over/under the trunk road and on the outside of any highway boundary fencing present.
- type of substrate within structure (i.e. hard: man-made concrete / tarmac ; or natural: mud / grass / river-bed)
- type and juxtaposition of habitats abutting either side of the structure (e.g. whether scrub / hedgerow or trees present, and approx distance to nearest wooded area).
- digital photographs of structures / structure entrances.

Dimensions were in all cases measured as the minimum distance for which a deer would need to remain on or within a structure in order to get across. In case of underpasses this was taken as the length under cover excluding any lead-in open to the sky. For further details of information recorded at each structure see survey form – Appendix I.

3.9 Systematic assessments of actual extent of animal usage for every structure (through for example CCTV or track-bed counts to records footprints over extended periods) was beyond scope of the present study. However, for three of those structures where some clear signs of recent deer activity were noted close-by to structure entrances during initial survey, CCTV video recording equipment was deployed for short periods of from 1 to 3 nights. The aim of this opportunistic filming was to obtain some additional insights as to the behaviour of deer crossing through structures or else their behaviour when near them. Two different video set-ups were trialled for this work: a) a set-up available from a previous project developed for surveillance of deer behaviour when crossing main roads and traffic, with a capability for filming and recording at relatively high quality for periods of 24h or more, but also relatively labour intensive in terms of installation and review of extensive amounts of continuous footage recorded; and b) a small pocket-size trail-cam (Scoutguard SGC550) with a video recording function triggered by passive infra-red sensors, and set to start filming for a period of a few minutes when a moving object passes within 10 m in front of the camera. Digital footage obtained was reviewed on computer, to assess presence and behaviour of any deer or other large mammals.

Analysis and interpretation of findings

3.10 Data recorded on survey forms and other field notes were catalogued by structure in a spreadsheet format with cross references to photographic images taken on site. In addition placemark references were created using GoogleEarth to enable ready review of aerial views of land surrounding each structure.

3.11 Dimensions recorded during structure surveys were used in the first instance to compare against minimum values for height and width recommended in the literature and to calculate an 'openness factor' associated with each structure (for underpasses taken as internal height x width divided by length; for overpasses, width divided by length. The openness values obtained were compared with recommendations in the literature (e.g. Olbrich, 1994; Iuell, 2003) of 0.75 for roe deer and 1.5 for larger deer such as red, fallow or sika (Table 1), so as to help assess which structures might have greatest potential to be utilized by deer based on dimension criteria alone.

3.12 However, because visits were "one-off" it was possible to obtain positive evidence of deer use for only a small minority of sites (possibly partly as the great majority of structures had a hard substrate of either concrete or tarmac on which deer tracks do not show up). As a result, no statistical assessment of an association of dimensions or other features with actual deer use could be undertaken on the basis of the findings from this pilot study. Nevertheless, to allow as objective an assessment as possible of the potential of each structure as a safer passage for deer, the main physical features recorded at each site (e.g. openness factor / substrate within passage / presence and level of road traffic / habitats abutting either side, and accessibility for deer of structure entrance) were allocated qualitative scores dependent on whether each feature at a given site was judged to exert a positive, neutral, or negative effect in terms of encouraging deer to make use of that structure.

3.13 In the case of the openness factor for underpasses the criteria suggested by Olbrich (1984) were used to define cut-off points: to allocate single or double positive scores to those structures with openness values exceeding those recommended for roe and for large deer respectively. A negative score was allocated where openness was less than half (=<0.375) of the recommended minimum values for roe, while intermediate values were taken as neutral with regard to the openness factor. For overpasses, for which Olbrich did not set similar specific openness criteria, the range of openness values (0.05 to 0.20) recorded among the sample of structures surveyed was divided equally to allocate either a –ve, neutral or +ve score; as such those scored as –ve fell below the minimum level of 0.1 put forward by CTGREF (1978) (see Section 2). For other characteristics such as substrate and access by motorised vehicles, qualitative scores were allocated as further outlined in Table 2.

Table 2: Criteria used for allocation of qualitiative scores to differing features that are likely to influence the potential use by deer of existing structures.(see text for further details)

Feature	Score	Criteria used for allocation of subjective scores
Openness factor		
Underpasses: (width x height) / length	-ve N +ve ++ve	*x<0.375 (i.e. less than half recommended)* *x= 0.375-0.75* *x>0.75<1.5 (exceeds min. recommended criteria for roe)* *x>1.5 (exceeds min. recommended criteria for large deer)*
Overpasses: (width / length)	-ve N +ve	*x<0.05 (width <10% of length)* *x>0.1<0.15* *x>0.15*
Substrate	-ve n +ve	*Hard surface only (concrete / tarmac)* *Some (small) part natural cover* *Significant proportion natural (soil / veg. / riverbed)*
Vehicle traffic	-ve n +ve	*Main (usually A or B class) road with high traffic at times* *Minor road with moderate to light traffic* *Quiet lane with very low or no traffic or farm vehicles only.*
Adjoining habitat	-ve n +ve	Open land or built up with limited nearby cover Some scrub / hedgerow cover but no sig. woodland nearby Woodland and scrub cover abutting closeby (<50m)
Accessibility	--ve -ve N +ve ++ve	Entrance blocked or sig. restricted by fencing, high water etc.. Stock fencing / hedgerows partly restrict or extent lead-in. Access not significantly restricted not particularly favourable. Good access without hindrance (though not necessarily as helpful to channel animals in as could be) Good access with good fence lay-out to channel animals in.

Figure 1: Relative distribution of deer road casualties and related vehicle collisions reported via the Highways Agency's Area 1 Control Centre for the A30 and A38 trunk roads between Exeter and Bodmin during 2003 to 2009 (346 incidents mapped)

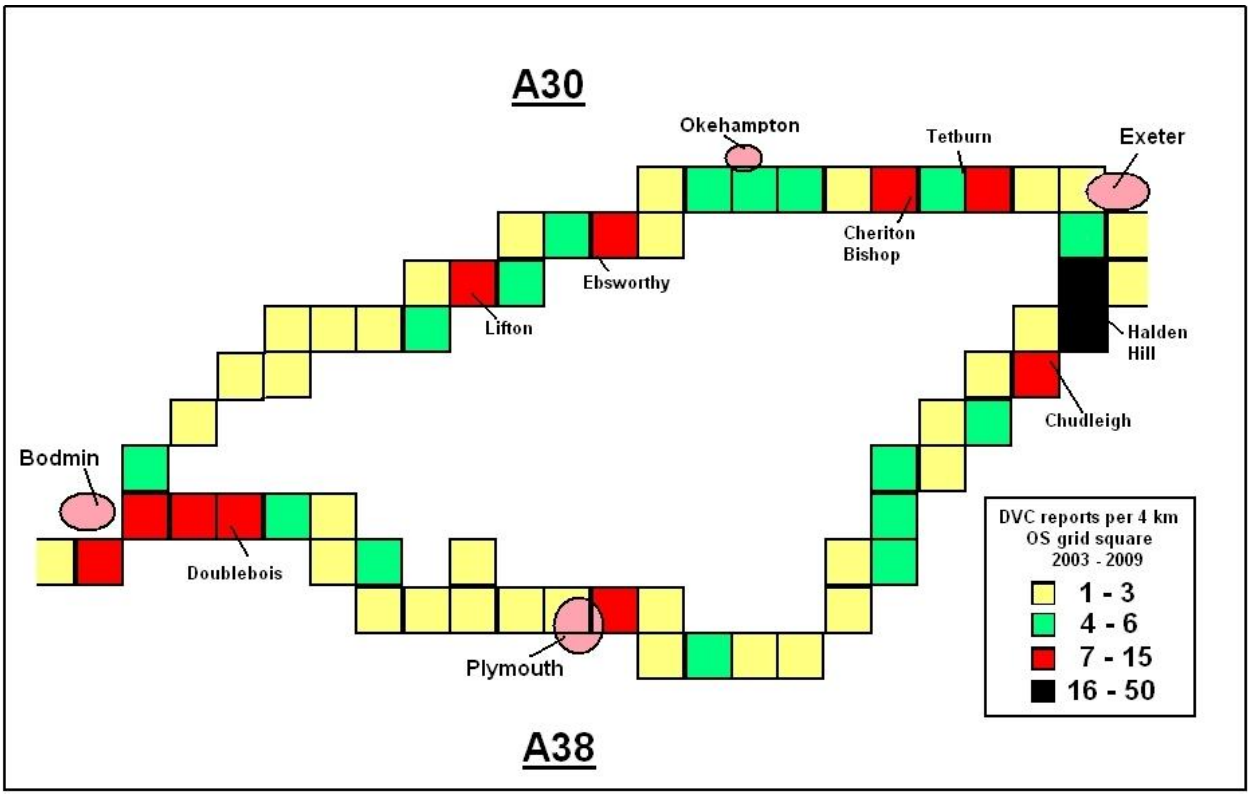


Figure 2: Map showing the main sections of A30 and A38 included for surveys of existing structures (blue highlights). Also mapped are DVC records (red dots) collated by the DI DVC project 2003-2009 for trunk roads as well as other roads in the study region.

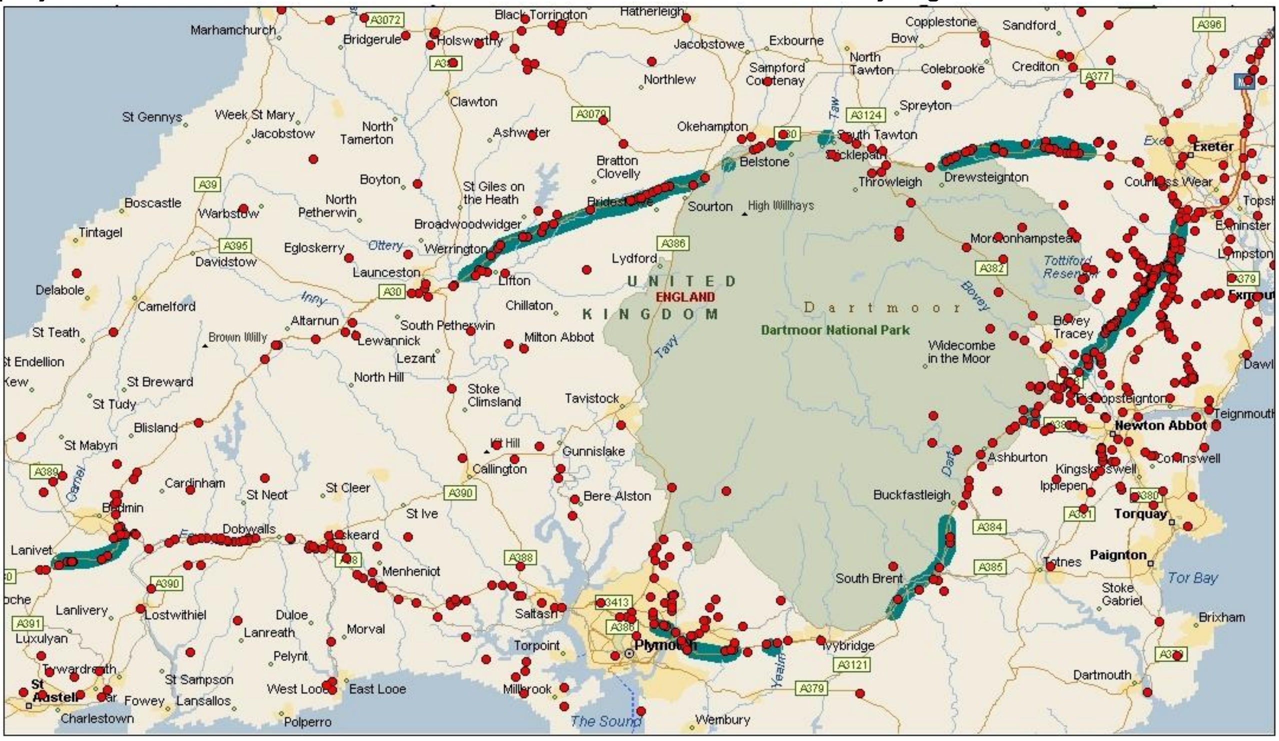
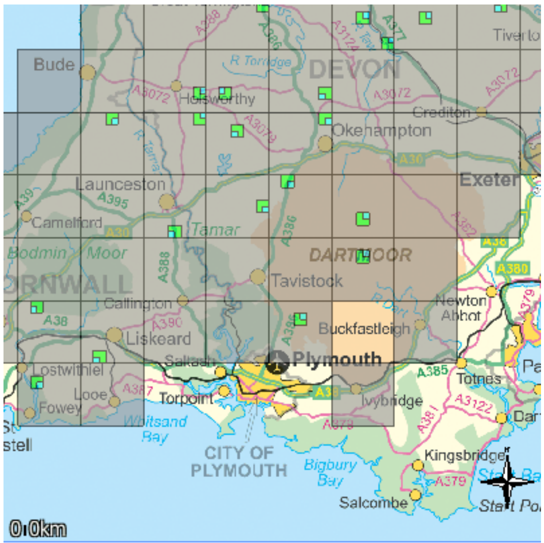


Figure 3 : Recorded presence (grey squares) of roe, red, fallow and muntjac deer in different 10 km by 10 km OS grid squares overlapping or in the vicinity of the A30 & A38 study roads between Exeter and Bodmin.

[Distribution data as provided by various contributors to the National Biodiversity Gateway (including from British Deer Society's '*Great British Deer Survey*', Biological Records Centre, and Devon Wildlife Trust). NBN web-site http://data.nbn.org.uk/ consulted May 2010. The data providers and NBN Trust bear no responsibility for the further analysis or interpretation of this material, data and/or information. Maps copyright © Crown Copyright. All rights reserved NERC 100017897 2004.]

a) Roe

b) Red



c) Fallow

d) Muntjac

4. Results and interpretation

4.1 Site surveys for the present pilot study encompassed a total of 47 separate existing structures, including 19 overpasses (8 over the A30 & 11 over the A38) and 28 underpasses (16 under the A30 and 12 under the A38). The different road sections selected for survey and numbers of structures included for survey are shown in Table 3 below. Details recorded for each of the separate structures included for survey are presented in full in Table 5 (Appendix II), including tabulation of dimensions, surrounding habitat, substrate and any signs of deer activity noted within or nearby, as well as cross reference to photographic images taken on site. To aid visualisation of the local conditions and alignment of each structure, a *GoogleEarth* placemark aerial imagery file was prepared and is provided in Appendix VI (on CD).

Table 3: Road sections and number of structures selected for field survey (figures in brackets show number of Overpasses / Underpasses included).

A38	Approx. Length (km)	Structures included	Main Deer species
i. Kenn to Heathfield Cross	14	10 (2/8)	Fallow; roe
ii. Marley Head to Bittaford	7	8 (3/5)	Roe
iii. Plympton to Deep Lane	5	4 (3/1)	Roe, fallow
(plus individual structures at Bickington, and Lee Mill)	-	2 (0/2)	Roe, fallow
A30			
v. Lanivet to Lanhydrock (Bodmin bypass south)	5	6 (3/3)	Roe, fallow
vi. Liftondown to Sourton	18	8 (4/4)	Red, roe
viii. Crockernwell to Whitstones	10	6 (4/2)	Roe; fallow, (+wild boar)
(plus selected structures at West Okement, East Okement and Taw rivers)	-	3 (0/3)	Roe, red
Total	**59**	**47 (19/28)**	Roe,fallow,red

Deer presence

4.2 Evidence of some deer activity within less than 50 m (based on presence of dung pellets or slots marks) was noted during the survey for 18 of the 47 structures. In the case of a further six sites possible deer signs were noted, but could less confidently be identified due to presence also of extensive slots made by sheep within or near the structure. Deer signs on or within the structures, providing direct evidence of recent entry by deer, were only found for two structures (River Thrushel UP; West Okement UP).

4.3 The lack of evidence found during these one-off site inspections of deer signs within structures does not necessarily indicate that most are not used by deer at any time; not least as, with the exception of just 11 of the structures surveyed, the remainder all had a hard non-natural substrate (tarmac or concrete) for their entire width, on which slots (hoof prints) will not show up even after wet weather. Careful attention was therefore paid to inspect also grass or soil verges leading into structures for any deer slots or dung. Some deer signs were noted within 15 m of structure entrances for 14 sites, but as these were found outside of structures this cannot be taken as conclusive evidence of use of the actual structure by deer. Some short trials of CCTV recording (see section 4.33 below) undertaken for one to three nights at three different structures did succeed in recording several deer close to the entrance of one of them - a road underpass at Belvedere Cross on the A38. This shows them moving along the grassy highway verge directly above that structure within less than 5 to 10 m of busy trunk road traffic, but did not provide firm evidence of recent use by deer actually moving through the structure itself.

4.4 The fact that during the one-off site inspections evidence of recent deer use was only found within two of the existing structures does not preclude the possibility that deer may well also use some of the other structures. However, for the present assessment it does preclude statistical exploration of any correlation between actual recorded deer use and individual features or combination of features for each structure. Nevertheless, to make as objective as possible an assessment of the potential of each of the structures to serve as a crossing for deer, the main features measured or recorded for each were allocated qualitative (+ve , neutral , –ve) scores based on whether or not they were judged to exert a positive influence on use of the structure by deer (as outlined in Table 2).

4.5 Findings are summarised below for each survey criterion. Thereafter different features are considered in combination to help identify firstly those structures in the study sites that appear to have highest potential for acceptance by deer, and secondly to help identify structures that might become utilised by deer as safer crossing locations given certain adaptations.

Individual Dimensions (length / width / height)

4.6 As discussed in Section 2, previous experience suggest that below certain minimum critical dimensions even structures designed as wildlife passages over or under major roads have only a low probability of being utilised by deer or other wild ungulates. <u>Minimum</u> internal height of underpasses to have a reasonable probability of use by any deer are widely recommended >3 m for use by roe and >4 m for fallow, red and other large deer, although <u>recommended</u> dimensions for purpose built structures are generally much greater (for references see section 2). However, while wider structures may offer the ideal solution where the main aim is to reduce fragmentation of animal populations, the minimum dimensions of particular interest during this study are those likely still to enable use of an existing structure by at least that proportion of local deer that are most determined to cross the line of the trunk route, and may thus still offer some potential as mitigation to reduce deer collisions. The dimensions (height, width and length) recorded for all underpasses and overpasses inspected during the present study are presented in Table 5 (Appendix II).

4.7 The A30 and A38 both form dual-carriageways with at least two traffic lanes in either direction throughout the length of all the sections included for this scoping study. As such the minimum length for any structure crossing the road is at very least 23m throughout, but rather longer in many places depending on variable additional width of the central reservation, hard shoulder and embankments.

4.8 In the case of underpasses the *covered* length (beneath trunk roads) recorded among the sample of 28 such structures inspected ranged from just 25 m (e.g. Stidson Lane and Pipehouse Lane) to a maximum of 58 m (Belvedere Cross), with an average of 34.6 metres. The width of the underpasses varied several fold depending on the primary purpose: from just 3 to 4.5 m for accommodation structures without road traffic intended for farm access or footpath diversion only, to between 4.6 and 18.5 for all underpasses open to public traffic and including some for bridging relatively narrow rivers (mean 10.3m, n=20), and was much larger still for three large river bridges / viaducts included in the sample with approximate widths of 50, 54 and 83 m. The minimum available internal heights measured ranged from just 3 to 6.3 m for all underpasses measured, with exception of just one higher structure (East Okement viaduct) at approximately 11.5 – 13m. The widely agreed minimum height threshold of around 4 m (see Table 2) was thus exceeded by all except three of the structures inspected, while the latter (culverts at Dogs and Jews, and a farm accommodation underpass at St Inunger) still measured just over 3 m in height.

4.9 The length of overpasses will commonly be substantially greater than the width of the road being spanned due to engineering considerations and requirement for embankments for bridge construction. For overpasses surveyed during the present study minimum distances that a deer travelling across would need to cover ranged from 44m to 106m, with a mean of 70.3 m (n=19). Although the average length of overpasses was greater even than the longest underpass included among our sample, as discussed further in Section 2 above, examples of frequent use by fallow deer of overpasses up to 106 m long has been recorded in some previous studies on trunk roads in England also fitted with high deer-fencing (Langbein, 2007c, 2008).

4.10 The width of overpasses recorded ranged from just 3.5 m and 4.0 m for a narrow farm accommodation bridge and one cycle route over-bridge, and from 4.5 m up to 13.5 m for the remaining overpasses inspected, all of which carry at least some public road traffic (mean 8.7 m, =17). Although five of the above overpasses visited were narrower than the minimum of around 7m advocated by past studies (see 2.4 above), only two accommodation structures were narrower than a number of 4.0 m wide bridges for which deer use in England has been found to occur more recently by Langbein (2007b, 2008). The height and degree of shielding provided by bridge parapets may be another factor with potential influence on likelihood of use by deer of overpasses. This factor was not investigated specifically during the present study. However, parapets of those structures included for surveys were mostly of closely similar construction, most being 1.1 to 1.40 m metres high, composed of weld mesh panels supported on a framework of 3 to 4 horizontal as well as regular vertical steel railings (e.g. see Images 3480; 4042; 4100; 4129) .

Openness

4.11 For underpasses, Olbrich (1984) concluded that to have a good chance of becoming used by roe deer their openness factor (*w x h / l*) should not be less than 0.75, while for larger deer such as fallow or red deer a higher factor of 1.5 or greater would be recommended; with similar recommendations by others (for detail see Section 2.9). Among the 28 underpasses assessed during the present study, 24 readily exceeded the above recommended minimum openness factor (width x height divided by length) of 0.75 for roe deer, while 14 also exceeded the higher 1.5 level recommended for large deer. Among the four structures with the lowest openness factors, three nevertheless still exceeded 0.5, equivalent to openness values of two structures in Essex recently confirmed by the author to be used by muntjac deer (Langbein, 2008). The lowest scoring underpass inspected (openness factor 0.27) is St Inunger farm accommodation underpass (see Photo 4546). For this quite narrow and relatively dark structure, however, the restrictive presence of stock gates close to the structure entrances and regular livestock movement through the structure may well play as crucial if not a more important role in determining whether deer are likely to enter that structure. For comparison, an example of a road traffic underpass with a comparatively high openness factor of 3.0 is shown in Photo 3465 (Harcombe Cross) and one with more intermediate score of 0.95 in Photo 3452 (Belverdere Cross). No positive evidence that deer use any of these three structures was found during the inspection survey, but signs of deer activity were found within less than 50m of the latter two but not near St Inunger underpass.

4.12 For overpasses no specific openness criteria were provided by Olbrich (1994), though guidance by CTGREF (1978) and others suggests structures with a width of less than 1/10th of their length are unlikely to be used by deer (see section 2.4). Overpass openness factors (calculated simply as w / l) for the 19 overpasses inspected during this pilot study ranged from around 0.06 (e.g. Horsebrook Lane road bridge (Photo 4228) and Halgavor cycle bridge [Photo 4582]), up to 0.21 (Brewer's road bridge (Photo 4078)). Overall five of the structures fell short of the minimum openness factor of 0.1 suggested above, for 11 structures it lay between 0.1 – 0.15, while factors higher than 0.15 were recorded for the three remaining structures (e.g. see Photo 4096, Ebsworthy Farm).

4.13 Although it is widely accepted that overpasses with greater openness indices are generally more likely to be used by deer, examples of overpasses with openness indices as low as 0.05 to 0.06 used commonly by fallow deer include two farm access accomodation bridges over the M25 near Epping (Langbein, 2007c).

Substrate

4.14 The presence of a natural grass or soil substrate for at least part of the width of a joint-use structure is another feature likely to have a bearing on the probability of up-take as a passage by wildlife including deer, with several authors suggesting that structures with hard substrate of tarmac or concrete throughout will rarely be used by deer (refs. see section 2).

4.15 Among the 47 existing structures inspected, only 11 have some form of natural substrate for part or all of their width, while 36 had a hard substrate of concrete or tarmac (Table 5 – Appendix II). All those with at least part natural substrate were underpasses or culverts, while the only overpass structure included with a 'softer' (playground type) surface was the Halgavor Cycle network bridge (see Photo 4582).

4.16 Two of the three locations where potential deer signs were actually found within the structures were underpasses with at least part natural substrates, on which deer slots show up more easily during such one-off inspections; the third (Wartham) was a road underpass with hard surface where many dung pellets were noted on the ground (the majority were believed to be of sheep origin but possibly included some from roe deer). In addition, however, roe deer have been seen by local residents to cross the hard-surface road bridge over the A30 located close to residential housing at Venn Bridge Hill nr Cheriton Bishop (Photo 4061).

4.17 Recent investigations in other parts of the UK have also demonstrated, supported by video recording, the use by fallow deer of several overpasses across the M25 and A120 that do have concrete substrates throughout their width (Langbein, 2008). Iuell et al. 2003 also conclude that for large mammals including deer width and length considerations are likely to be of greater importance than the substrate.

Vehicle traffic

4.18 Among the 47 structures included, 36 are open to at least some level of public road traffic. The remaining 11 structures not open to general road traffic included 3 with some low level vehicle access by farm vehicles only, 1 foot bridge / cycle bridge, 1 disused railway line, 3 river culverts with public footways, and 3 culverts without footpaths (see Table 5 – Appendix II).

4.19 Although the majority of existing structures included for assessment do carry some road traffic, the actual size of road and amount of traffic flow varies widely between them, ranging from some quiet and remote country lanes with minimal vehicle traffic to others with moderate to occasionally heavy traffic. Figures for actual levels of traffic flow or division of flows between day and night were not available to the study. All 36 road bridges or underpasses were therefore categorised as falling into one of three broad categories as outlined in Section 3 (Table 2) based on level of estimated traffic flow: 10 of the structures (6 overpasses / 4 underpasses) carry main A or B class roads with moderate to high levels of traffic at times, 15 (10 / 5) have minor roads with light to moderate traffic, and 11 carry only quiet lanes with very low infrequent motorised traffic; and as discussed above a further 11 are not open to any public vehicular traffic.

4.20 Several previous studies in Switzerland and Germany have asserted that any structures open to public road traffic will only very rarely be used by deer (Pfister, 1997; Olbrich, 1984). This however, runs counter to findings so far in England, where both fallow and muntjac deer are known to make regular use of two newly constructed public road bridges over the A120 dual carriageway (Langbein, 2008). Furthermore crossings by fallow deer of these bridges (see Frogs Hall & Warish Hall – GoogleEarth placemark file (CD - Appendix IV) ; and see Photos 1 and 2 in Section 2 above) were first reported within just six months of opening the new road, even though neither bridge had any particular design features to encourage wildlife (although there was deer fencing on both sides of the carriageway to prevent direct access over the carriageways and guide animals towards the available crossing structures). Thus, although presence of vehicle traffic may deter use by deer to some extent, the characteristics of such traffic (e.g. level and type of traffic, and whether largely confined to just part of the day or night) are likely to be of greater importance than any clear distinction between presence / absence of vehicular traffic.

Habitat

4.21 The habitat adjacent and leading to structure entrances can play an important role in providing cover for deer approaching structures, or indeed increase the likelihood that deer will use areas close to the structure as part of their regular home range. A full vegetation survey and mapping for areas around all the structures visited was beyond the scope of this short project. Instead, descriptive records of the main habitat within 50 m of structure entrances on both sides of the road (made during field visits) were reviewed, alongside aerial views (see GoogleEarth file – Appendix IV) and maps to assess approximate distances to nearest woodland or scrub cover if none was recorded on site within 50m. As outlined in Section 3 (and Table 2), the habitats surrounding each structures were categorised as favourable (+*ve*) if some woodland or scrub with at least some high trees was present within 50 m; *neutral* if scrub or hedgerow but no significant tree cover were close by, and unfavourable (-*ve*) if adjacent habitats were largely open farmland or built-up residential or industrial areas and with little or no nearby scrub cover.

4.22 Nearly half of all the structures (23 incl. 14 underpasses and 9 overpasses) had at least some tree or woodland cover adjoining within approximately 50m on one or both sides. All of the remaining 24 structures inspected also had at least some linear scrub cover running on the trunk road verges leading up to the structures, even where other land either side was fairly open (see e.g. Photos 3476, 4220, 4230 and Google Earth aerial views file – Appendix IV). As such all the latter were considered as 'neutral' with respect to habitat characteristics, with none among the overall sample given an 'unfavourable' habitat score.

4.23 Woodland or other concealing cover is indeed likely to have a positive influence on deer use of a structure, with several of the structures that have been shown to be well-used by deer being located close to tree cover (e.g. see Section 5 - Photos 5 and 6 at M25 Epping Forest). However, examples of deer use have also been found for structures located in fairly open areas (e.g. see Photos 1 and 2 , Langbein, 2008) devoid of any nearby cover. Thus, as with many individual characteristics discussed above, whilst certain features may help to make some structures more favourable than others, they are not necessarily critical provided other local conditions (such as lead-in fencing / high deer density) are favourable.

Accessibility

4.24 The accessibility of structure entrances (i.e. how readily deer are able to gain direct access into underpasses or onto overpasses without diversion or significant obstacles), was one of the most variable factors noted during the pilot survey. Information on this factor was also more difficult than others to summarise or allocate objectively to distinct categories, as some particular features that appear to hinder access or, conversely, may actually help channel deer into a structure, were themselves highly variable. For example, dense and difficult to penetrate hedgerows or some types of stock fencing that joined up with structure entrances running in line with the direction of the passage may significantly extend the actual length of path an animal needs to follow in order to cross over the structure; whereas similar barriers running parallel to the trunk road or at a slight angle may positively channel animals into the structure. Other examples of obstacles which reduce accessibility included gates across farm accommodation bridges, lorries or horseboxes parked long-term on / within a number of structures (e.g. see Photos 4110, 4183), sileage bales blocking exits, areas of hard standing wider than the structure or road leading through it abutting the entrance).

4.25 To aid in overall assessment of their potential, each structure was categorised (see Table 2) according to whether: i. either entrance was blocked or significantly restricted by fencing, gates, high water or other obstruction (double -ve); or ii. stock fencing or dense hedgerows not readily crossed by deer extendsr the length of the crossing (-ve); iii. access is neither significantly restricted nor particularly favourable (neutral); iv. good direct access without any hindrance, even if not necessarily well designed to help channel animals (+ve), or very good access with fence lay-out likely to encourage access by large mammals.

4.26 Among the samples of structures surveyed accessibility was considered favourable more often for overpasses (12 of 19 sites) than underpasses (14 of 28 sites). In part this difference is explained by fencing up to overpasses more commonly being roughly parallel to the trunk road in line with highway boundary fencing. Roads or tracks leading into underpasses however often have additional fencing or thick hedges running on either side, which in some cases will not be readily crossed by deer and may divert them away rather than into the passage.

4.27 For a further seven underpasses and five overpasses accessibility was classified as being 'neutral'; including for example locations where presence of stock fencing hindered direct access to an extent, but where at least some gaps were noted (in some cases through fencing having fallen into disrepair) that would allow passage of deer. Other cases included obstacles that reduced the available width of entrance or exit from the structure without preventing access altogether.

4.28 Based on the above criteria, the remaining seven underpasses and two overpasses were judged as having features that at present significantly hinder or reduce accessibility of the structure by deer. However, it should be noted that in many of these cases, mitigation to improve accessibility is likely to need only minor modifications; for example, through removal of physical obstructions on or near structure entrances (e.g. Photos 4111, 4116, 4279, 4546), or by creation of suitable gaps or deer leaps in stock fencing or hedgerows in a manner enabling passage by deer but not livestock. How this is best achieved will be site specific. In some cases increased access by deer may be facilitated simply through creation of a small gap in hedgerow vegetation where such hedging is covering low stock fencing near structure entrances. In other situations a reduction of the specification of stock fencing for a short length (i.e. to reduce its height, or by use of horizontal line wires only rather than mesh fencing), or raising the ground to form a ramp either side of the fence, may be designed in such a way as to enable deer but not sheep to cross the adapted section of fencing.

Evaluation of overall potential based on combination of features

4.29 It will be clear from the findings outlined above, and examples of structures for which deer use has been recorded by previous studies, that the extent to which any particular structure will be used by deer is unlikely to be determined by any one single feature on its own. All of the different features discussed above (minimum dimensions, openness, substrate, traffic and other disturbance, surrounding habitats, and accessibility) are likely to exert some influence on whether a structure will be used by deer, as well as other factors such as the local deer density (for the latter, good information to assess difference between sites is not currently available).

4.30 To obtain some overview of the likely overall suitability of each structure as passages for deer (as they are, without any modifications), the positive, neutral or negative values allocated to them for different influencing features are summarised in Table 4a and 4b below. The tables are arranged in descending order starting with those structures with the highest number of positive scores and the fewest negative scores. Actual numerical scores have not been allocated, as that would imply that, for example, a negative value with regard to, for example, 'openness' could be directly compensated for by having a positive score for another characteristic such as 'substrate' or 'surrounding habitat'. In reality an objective judgment is not possible at this stage to say to what extent one feature may be more important than another; i.e. this would need another longer term study to establish actual levels of use per structure to enable statistical analysis. The ranking in the tables should therefore be interpreted cautiously, and taken as no more than a general guide to the potential of each structure.

4.31 Unsurprisingly four of the five structures with greatest number of positive scores and no negative scores are large bridges or viaducts (in one case a bridge over a disused railway line) without any access by public road traffic or else a substantial traffic free section within the passage with a natural substrate. Such large structures will tend to provide least hindrance to the free and safe movement of deer even without any special provisions made for widlife. One other structure which was also judged as relatively positive for all the features features considered was Portland Underpass, mainly as it is one of very few road underpasses in the sample without a hard concrete or tarmac surface but also good accessibility. Its high rank within the table relative to a number of similar road underpasses may however be unjustified as, for example, the underpasses at Torpeek and Little Bittaford both had far higher openness factors (which may well be of greater importance, than the fact that the latter each have a hard man-made substrate rather than muddy / loose stone surface). This underlines that as the relative importance of different features has not been assessed systematically, the table only serves as a general guide to those structures with most positive or negative features rather overall assessment of their suitability for use by deer. For a further seven underpasses, a hard substrate was again the only key feature scored as negative, rather than neutral or positive. Similarly for five overpasses, a hard substrate was the only 'key' feature allocated a negative score (Table 4b); and as (fallow) deer have been shown to use hard substrate overpasses by some previous studies (e.g. Langbein, 2007b; 2008) this may not necessarily greatly reduce the potential of those structure being used by deer.

4.32 The overview of findings shown in Table 4a and 4b is probably of greatest value as a guide to the potential of individual structures, and how readily each might be made more suitable as a passage for deer and other wildlife, through adaptation to make improvements to one or more features. Equally Table 4 also serves to highlight which structures appear, at least on paper, to have the lowest potential as wildlife passages. These will include, for example those with negative scores allocated for high levels of use by vehicles, and which are hence less likely to be suitable for increased use by deer, as structures with high levels of traffic might not in fact provide a significantly safer route for deer than crossing the trunk road itself. A further aim of the tabulation, is to serve as a basis for informing future research trials to assess a) the validity of current perceptions as to which features are of greatest importance for encouraging or deterring use by deer, and b) to test whether for structures judged as having relatively low potential and with little or no evidence of past use by deer, increased deer use can be achieved in practice through quite limited and cost-effective adaptations (for example, removal of obvious obstacles that reduce accessibility). Suggestions for possible sites to test the viability of such modification will be discussed further in Section 5.

Table 4a : Overview of Underpasses surveyed and qualitative scores (see Table 2) allocated according to each for openness, traffic, habitat, access and substrate characteristics. (Structures are arranged in descending order starting with those with highest number of positive and fewest negative scores)

Site Name	Road / StrNumber	Openness factor		Openness	Veh. Traffic	Habitat	Access	Substrate
Underpasses								
Portford Lane	A38/74.30	**0.842**		+ve	+ve	+ve	+ve	+ve
East Okement River	A30/299.90	**22.778**		++ve	+ve	+ve	n	+ve
River Teign	A38/98.00	**8.100**		++ve	+ve	+ve	n	+ve
Heathfield Rly	A38/96.20	**1.350**		+ve	+ve	n	+ve	+ve
River Thrushel Via	A30/315.50	**16.907**		++ve	+ve	n	n	+ve
Torpeek	A38/68.20	**2.322**		++ve	+ve	+ve	+ve	-ve
West Okement River	A30/304.30	**2.133**		++ve	+ve	+ve	-ve	+ve
Little Bittaford	A38/68.80	**1.800**		++ve	+ve	+ve	+ve	-ve
Jews	A38/96.70	**1.594**		++ve	+ve	n	n	+ve
Harcombe Cross	A38/103.6	**3.190**		++ve	n	+ve	+ve	-ve
Stidston Lane	A38/74.90	**1.456**		+ve	+ve	n	+ve	-ve
Belvedere Cross	A38/106.4	**0.950**		+ve	n	+ve	+ve	-ve
Dogs	A38/96.60	**0.817**		+ve	+ve	n	-ve	+ve
Higher Tredenham	A30/371.10	**0.789**		+ve	+ve	n	+ve	-ve
Pipehouse Lane	A38/97.80	**0.773**		+ve	n	+ve	+ve	-ve
Fingle Glen	A30/274.3	0.529		n	+ve	+ve	-ve	+ve
Beech Farm	A38/61.50	**2.298**		++ve	-ve	+ve	+ve	-ve
The Mills	A38/90.90	**2.217**		++ve	n	n	+ve	-ve
Beazle OvSpill	A30/317.40	**1.919**		++ve	+ve	n	n	-ve
A38 Woodpecker	A38/72.30	**1.616**		++ve	-ve	+ve	+ve	-ve
Reperry	A30/372.10	**1.414**		+ve	-ve	+ve	+ve	-ve
Wartham	A30/325.50	**1.391**		+ve	+ve	+ve	-ve	-ve
Dilly Bridge	A30/278.10	**0.910**		+ve	+ve	n	n	-ve
Taw River	A30/294.70	0.630		n	+ve	n	--ve	+ve
Plympton Hill	A38/55.90	**3.532**		++ve	-ve	n	+ve	-ve
Liftondown A388	A30/326.40	**2.019**		++ve	n	n	n	-ve
St Ingunger	A30/370.40	0.269		-ve	+ve	n	--ve	+ve
Dark Lane	A38/100.50	0.579		n	+ve	n	-ve	-ve

Table 4b : Overview of Overpasses surveyed and qualitative scores (see Table 2) allocated according to each for openness, traffic, habitat, access and substrate characteristics. (Structures are arranged in descending order starting with those with highest number of positive and fewest negative scores)

Site Name	Road / StrNumber	Openness factor		Openness	Veh. Traffic	Habitat	Access	Substrate
Overpasses								
Cowsen lane	A30/308.30	0.157		+ve	n	+ve	+ve	-ve
Ebsworth farm	A30/312.20	0.152		+ve	n	+ve	+ve	-ve
A30 Halgavor NCN	A30/367a	0.059		-ve	+ve	+ve	n	+ve
Brewers	A30/320.80	0.207		+ve	n	n	+ve	-ve
BartonHeadRoad	A30/273.3	0.148		n	n	+ve	+ve	-ve
Holewell Lane	A30/282.30	0.110		n	n	+ve	+ve	-ve
Saltram House	A38/53.30	0.107		n	n	+ve	+ve	-ve
Bible Christian	A30/369.40	0.138		n	-ve	n	+ve	n
Marely Head	A38/75.50	0.132		n	-ve	+ve	+ve	-ve
Lanhydrock	A30/367.70	0.130		n	-ve	n	+ve	n
Merafield Road	A38/54.20	0.124		n	-ve	+ve	+ve	-ve
Deep Lane Jnc	A38/57.50	0.123		n	-ve	+ve	+ve	-ve
Ellacott (Ebsworthy)	A30/314.10	0.091		-ve	+ve	n	--ve	-ve
Forder Lane	A38/69.50	0.079		-ve	+ve	n	+ve	-ve
Hackworthy Lane	A30/276.5	0.133		n	n	n	n	-ve
Milestone Lane	A38/103.2	0.100		n	n	n	n	-ve
VennBridgeHill	A30/280.60	0.133		n	-ve	n	n	-ve
Old Exeter Road	A38/102.7	0.094		-ve	n	n	n	-ve
Horsebrook Lane	A38/73.40	0.064		-ve	n	n	-ve	-ve

Results of trial video recording at structures

4.33 Short trials of between 1 to 3 nights of CCTV video surveillance were completed at three separate structures. The sites chosen for this trial filming were ones where several clear signs of deer (slots or dung) had been found in the vicinity of structures during early parts of the site visits, and which offered reasonable cover for setting up video equipment covertly (i.e. normally mounted within a nearby tree or shrub). A small trail camera [Scoutguard SGC550 – provided by LWA] was used in turn at each of the sites to attempt filming of deer or other wildlife movement actually through two underpasses (at Belvedere Cross - 2 nights; Harcombe Cross 2 - nights) and one overpass (Ebsworthy Farm 1 night). In addition, a larger video set-up available to the DI from a previous project, with capability to film during darkness over a wider field of view and greater distances (up to 40m) using stronger infra-red lighting was used to attempt filming of deer moving around or above the Belvedere Cross structure on three separate nights. All filming took place during April if and when this could be fitted around other field surveys days.

4.34 Good footage of deer (readily recognisable as such) was obtained at one of the structures (Belvedere Cross). Here no fewer than at least seven different fallow deer were filmed, not seen moving through the structure itself, but recorded walking across the top of the underpass along the verge of the A38 trunk road. Several sequences filmed here show deer feeding calmly within just 2m to 6m of the main (eastbound) carriageway. Despite the close proximity of busy trunk road traffic, which on video footage can be seen passing in the background, groups of fallow deer filmed at night appeared to take little notice of the nearby traffic (see Video clip 1 – Appendix IV), and freeze frame Photo 3 below). Several further fallow deer were recorded above the same underpass during daylight soon after dawn. Video Clip 1 shows deer grazing or slowly walking along the trunk road verge above the underpass for nearly 15 minutes, with heavy traffic passing alongside; Clip 2 shows deer walking up the embankment in daylight, within just one metre of the edge of the structure and the road below. The video recordings and presence of very extensive deer slots and dung found along the verges (Photos 4148 - 4151) indicate that fallow use this areas very commonly as a normal part of their home range. That is, approaches by the deer onto the trunk road verges at this location appear to occur mostly not with intention to actually cross the main road, but to feed on the verge or move across the side road. The regular exposure to the flow of road traffic closeby is likely to lead the local deer to become increasingly habituated to the noise of approaching vehicles, and possibility less cautious of crossing into the traffic at other times.

Photo 3: Freeze frame from video filming across top of Belvedere underpass with A38 trunk road on right.
(for video clips see Appendix IV)

4.35 Belvedere underpass was also filmed on two nights using the additional small trail camera (see above) set up within 10m of the entrance (also on the eastbound carriageway). Reasonable quality footage was obtained on one night including of a pedestrian walking through the underpass during darkness, as well as of occasional passage of motor vehicles during the night. Whilst confirming that the camera was readily triggered at this location by any large animal or object moving in or out of the structure within less than 10m in front of the camera, no footage of deer actually entering or moving through the structure was obtained on either film night.

4.36 During similar test filming for a single night each at Harcombe Cross underpass and Ebsworthy Farm overpass using the small trail camera no deer or other large mammals were recorded. At both these locations finding suitable covert vantage points for the equipment within 15m of the structure entrance was more difficult, so that not all movement across the passage would necessarily have been noted. However, neither would positive results be expected from a single attempt, as even if deer do use the structure they might only cross occasionally or seasonally; and video recording would need to be repeated several times at regular intervals at these structures to obtain more conclusive results on whether and how frequently they are used by deer.

4.37 In terms of trialling the suitability of the small, relatively low-cost trail camera set-up, this appeared to perform reasonably well for the purpose of filming structure entrances, but with two main limitations that would need to be considered for any more comprehensive video monitoring: i. the distance at which moving objects successfully triggered the video recording was generally < 11 m, whereas good locations (e.g. within nearby trees) in which to set up the equipment covertly are often not available that close to structure entrances; ii. Infra-red lighting also was rather dim at distances over 8m. For more systematic filming on / within structures using similar trail-cam video equipment, development of some method of securely fixing the equipment on the structure itself (to internal walls of underpasses, or bridge railings in case of overpasses) should help overcome those issues.

4.38 Results from video recordings at Belvedere Cross (Haldon Hill) show that aside from the main purpose of that filming to study deer behaviour around structures, such recordings can be extremely informative more generally to illustrate the type of risks posed by deer on trunk roads and their actual behaviour and extent of habituation to heavy road traffic.

5. Discussion and further work

5.1 Over recent years discussion of mitigation to reduce the impact of roads on large mammal populations in many European countries has been dominated by increasing numbers of high profile projects to construct ‘green’ or habitat bridges’ (e.g. see COST341, Iuell et al. 2003; Pfister et al, 1997; Georgi et al. 2007). For large species of deer the COST341 European wide review (Iuell, 2003) suggests for example, that to maximise their use by deer, green bridges should ideally be over 40m wide or else no less than 20m at their narrowest points but with wider entrances and natural habitats established on the structure. Such large habitat bridges have an important role, but their application tends to be restricted - not least by their high cost - to a minority of areas where there is a primary need to reduce fragmentation by road infrastructure of natural or semi-natural habitat with wildlife populations of high conservation importance. To some extent focus on large green bridges (e.g. Photo 4) has led to the widespread misconception that much smaller or joint use structures (e.g. Photo 5) across major roads have little potential to provide safer crossing places for deer and other large mammals.

Photos 4, 5 and 6: A large green habitat bridge in Switzerland (left) and a narrow joint use bridge with concrete substrate across M25 nr London (centre & right): each structure was designed for a quite different set of aims but both *are regularly used by deer.*

5.2 The published literature on the design of joint use structures for use by deer (mostly based on studies of deer population in Europe rather than in England) tends to dismiss narrow structures, or ones without natural substrate, or ones used by public road traffic, as unsuitable (review see Holzgang et al. 2000). For new-build structures purpose built for joint use by wildlife this may often be entirely appropriate, as higher-spec structures may in some cases be more able to guarantee that cost-benefit criteria are met.

5.3 However, as emphasised also by the Europe-wide COST341 reviews (e.g. Iuell et al. 2003, Torcome et. al 2003), at locations where the primary aim is to reduce animal road mortality and improve traffic safety, smaller structures suitable for wildlife can play an important role in providing safe passage for those animals most determined to cross major roads and maintain some connectivity of populations. In particular along major roads where high safety fencing is provided to deter animals from crossing the carriageway itself, the effectiveness of fencing will also be enhanced and its barrier effect reduced where deer can access alternative routes over or under the road.

5.4 It seems likely that evidence of deer use of relatively small existing structures not designed for wildlife is lacking partly because of comparatively little investigation. By contrast, findings by the author (described in Section 2 above), during a number of recent short term studies along the M25 and A120 trunk roads in Essex (Langbein, 1996, 2007c, 2008) have demonstrated that even large deer, such as fallow, for which generally more stringent criteria for structure size and openness are recommended in the literature, do make use of some structures of quite modest size; some of which fall well short even of the size and openness indices recommended in the literature for smaller deer species such as roe, and some that are also used by normal road traffic.

5.5 In each of the above cases of use of road bridges and small overpasses, deer do occur at quite high density on either side of deer-fenced trunk roads, and in areas where they are relatively accustomed to people and road traffic. In view of the increasing occurrence, not just in England but also in parts of North America and continental Europe, of rather higher local deer densities than in the past and their colonisation of some increasingly populated and built up environments, it is timely to re-assess to what extent criteria for wildlife structures established elsewhere in the past are in fact transferrable to these situations. Furthermore, as deer become increasingly accustomed to living in areas with abundant road infrastructure and high traffic flows (e.g. see video clips recorded during present study (Appendix IV), it seems likely that they will also become less wary of man-made structures, including those used by humans and road traffic.

Potential of existing structures

5.6 Findings of this pilot survey with regard to the potential of a range of 47 existing structures along the A30 & A38 dual-carriageway trunk roads in Southwest England to act as passages for wildlife, suggest that well over half of those visited (excluding small stream culverts) do meet or exceed the generally accepted minimum size and openness criteria taken from the continental literature on wildlife passages (e.g. minimum heights of 4m for underpasses, and openness indices no less than 0.75 for roe deer; see Section 2). As such many existing structures would seem to have a reasonable basis for adaptation as safer passages for use by deer and other mammals. Many of the structures surveyed would at present not meet some other recommendations in the literature, in particular with respect to provision of a natural substrate (for all or part of their width) or separation from joint usage by general public road traffic. However, recent observations of deer use of structures in England (see 5.2 above; & Section 2), indicate that use of structures by light or intermittent public road traffic and the presence of a hard substrate of tarmac or concrete may be less of a hindrance for deer than commonly thought. The features of relevance are reviewed briefly in turn below in relation to the findings of the present pilot survey, before outlining suggestions for future demonstration trials to show whether in practice a) deer can in fact be encouraged to use existing structures through modest cost-effective adaptations, with tangible reductions also in DVC risk, and b) whether structures below currently accepted minimum criteria of size and openness can nevertheless be adapted to encourage deer use provided other features are made more favourable for deer.

How critical are recommended criteria for use of structures by deer?

Underpass openness index

5.7 Previous reviews (discussed more fully in Section 2) have concluded that below certain minimum critical dimensions and openness index even structures designed for use as wildlife passages over or under major roads have only a low probability of being utilised by deer or other wild ungulates. As minimum height and width for designs of underpasses, 3 to 4 m is widely considered as critical for roe, while for larger deer species wider structures >8 m are generally recommended. Most studies conclude that one of the most important feature of underpasses is how open they appear to an approaching deer, with a recommended openness index (width x height divided by length) of >0.75 for small deer species and >1.5 for large deer (red / fallow).

5.8 Such openness criteria remain a useful guide and are met by a very high proportion of the existing underpasses surveyed on trunks roads in the Southwest (24 of 28 underpasses assessed readily exceeded the minimum openness factor for roe deer, while 14 exceeded the higher 1.5 level recommended for large deer), and very likely throughout the UK trunk route network. However, as with all guidance regarding any individual feature, this needs to be interpreted in the local context, as falling short on any one criterion may not be critical provided other conditions are favourable. For example, Georgii et al. (2007) report regular crossings of roe deer of some underpasses as low as 2.4 m with relative openness of just 0.25 to 0.45, while recent findings in England (e.g. see Langbein 2008) indicate that larger deer such as fallow in some situations may also accept structures with an openness well below the 1.5 level recommended for larger deer.

Overpass dimensions

5.9 For joint-use overpasses to be suitable for deer minimum width is recommended by most past studies at around 7 m (for detail see Section 2), though ideally wider for red deer. As discussed above, there are however again examples of some structures as narrow as 4.5 m being well used by fallow in some areas. Among 19 overpasses surveyed in the present study all but five in fact exceeded 7m width while only two farm accommodation structures were narrower than 4.5 m. The length of overpasses surveyed during the present study ranged from just 44 to 106 m, with again examples from elsewhere in England of fallow as well as smaller deer using structures at the upper end of that range. As a matter of principle shorter overpasses are generally more likely to be accepted by deer than longer ones, although location and aspect may be even more important.

Substrate and traffic

5.10 The presence of a natural base of grass or soil for at least part of the width is another feature likely to improve the probability of up-take as a passage by a wide range of animals including deer (e.g. Georgi et al, 2007; Olbrich, 1994; review Iuell, 2003). Among existing structures included in the present study only 11 out of 47 had a natural substrate for all or part of their width, and in some cases this maybe one of the feature viable for adaptation. However, several overpasses with concrete and tarmac surfaces throughout their span on the trunk roads in England are known to be well used by fallow deer (Langbein, 2008). This is well illustrated by the sample Video Clip (Appendix IV) showing a fallow buck crossing over the six-lane M25 while traffic is passing beneath. Perhaps not least as deer of several species increasingly inhabit such suburban areas in the UK their timidity towards bases reinforced with concrete or tarmac does appear to be reducing. In another example from the present study, fallow deer dung pellets were regularly noted within the tarmac car park of a service area restaurant at Haldon Hill barely 15 m from the A38 trunk road (see Photo 4274). Whist addition of a grass or soil substrate is nevertheless likely to improve uptake of structures by wildlife, Iuell et al. (2003) also conclude that for large mammals including deer width, length and openness considerations are likely to be of greater importance than the substrate.

One drawback of the present study was that in view of the very high numbers of structures (36 of 47) with entirely hard substrates this significantly reduced the chances of being able to obtain evidence of use by deer during the one-off inspection visits. To obtain more conclusive results at hard substrate structures repeat visits using sand-traps, video recording or visits after snow cover would be required to enable tracks to be recorded, though more generally where deer do use such structures it is more likely to be under-recorded by comparison to substrates where tracks show up more readily.

Traffic / disturbance

5.11 The majority of existing structures surveyed during the present study do carry some road traffic, but the actual size of road and amount of traffic flow varied very widely between them, ranging from some quiet and remote country lanes with minimal vehicle traffic to others with moderate to occasionally heavy traffic. Several previous studies (see section 2) have asserted that structures open to public road traffic will very rarely be used by deer. This however, runs counter to recent findings in England (Langbein, 2008), where both fallow and muntjac deer are known to make regular use of a number of recently constructed public road bridges subject to low to moderate traffic flows (e.g. see Photos 1 and 2, Section 2).

5.12 It is likely that the presence of vehicle traffic will deter use by deer to some extent, but that the actual characteristics of such traffic (e.g. level and type of traffic, and whether largely confined to just part of the day with only occasional use at night) are of greater importance than any clear distinction between presence or complete absence of vehicular access. In the present study, of 36 structures surveyed that are open to some public traffic, 11 were small lanes with only very low levels of traffic even during the day, which would be highly unlikely to deter deer from using them as a crossing. A number of others among those 15 carrying minor roads with light to moderate traffic, by comparison with structures open to motorised traffic used by deer elsewhere in England, would also seem to have some potential for use by deer. On the other hand some structures which carry medium to occasionally high levels would seem less likely to have high potential to be used by deer, and adaptations to encourage such use might in any case not produce significantly 'safer' crossings in such cases.

Habitat

5.13 The habitat adjacent and leading to structure entrances plays an important role in providing cover for deer approaching structures, and indeed increases the likelihood that deer will use areas close to the structure as part of their regular home range. For structures assessed during the present pilot study, nearly half of all the structures had at least some tree or woodland cover adjoining within 50 m on one or both sides, while most of the remainder also had at least some linear scrub cover running along the trunk road verges leading up to the structures. Therefore habitat conditions were not felt to be particularly limiting with regard to possible use by deer, although in many cases improvements would be possible through increasing cover near structure entrance to try and enhance probability of use by wildlife. As with many of the features discussed above, while having woodland cover as close to the entrance as possible would increase probability of use by deer, its presence is not necessarily critical provided location and other local conditions (such as lead-in boundary fencing / high deer density) are favourable.

Accessibility

5.14 The accessibility of structure entrances (i.e. how readily deer are able to gain direct access into underpasses or onto overpasses without diversion or significant obstacles), was one of the most variable factors noted during this pilot survey of existing structures. Most common were unfavourable fencing lay-outs (including often lengths of mesh stock-fencing overgrown with hedgerows making them difficult for deer to penetrate) that artificially extend the length of crossing for the passage. Other obstructions noted ranged from gates across entrances of farm accommodation bridges, lorries or horseboxes parked long-term on or within a number of structures, silage bales blocking exits, and areas of hard standing to either side of the structures. Among the samples of structures surveyed accessibility was considered favourable more often for overpasses (12 of 19 sites) than underpasses (14 of 28 sites). In part this difference is explained by fencing for overpasses more commonly being laid out roughly parallel to the trunk road in line with highway boundary fencing. By contrast, roads or tracks leading into underpasses often have additional fencing or thick hedges running on either side, which unless readily crossed by deer may divert them away from the structure entrance. However, in many such cases it is likely that improved accessibility to deer could be achieved through small, site-specific adaptations of the boundary fencing, hedgerow or by provision of small deer leaps [see 4.

5.15 Deer fencing is not currently provided along the trunk road boundary in any of the sections of A38 and A30 encompassed during this pilot study. However, almost all experiences and recommendations arising with regard to wildlife crossing structures in Europe, and also the small numbers of previous assessments in England, are derived from studies of deer fenced roads. It is widely accepted that deer fencing combined with suitable crossing structures can substantially reduce numbers of deer road casualties. Whether or not long lengths of full height deer fencing (which themselves can have negative as well as positive effects) are in fact essential in order to guide deer to use underpasses or overpasses remains a topic for future research. For example no good information is currently available on whether deer can successfully be guided to use existing structures and reduce crossings across the main road by use of only relatively short length of fencing either side of the structures; or whether using lower than full height deer fencing (< 1.8 m) which may not be fully effective at excluding deer, may nevertheless suffice to lead them to easier crossing places. Where wildlife and in particular deer fencing is considered, involvement in the design of the lay-out and installation in the field of an ecologist familiar with deer behaviour is often as important, as the fence specification in terms of height and mesh size. Fencing is often one of the mostly costly parts of a mitigation scheme, but nevertheless poorly installed and inadequately maintained fencing penetrable by deer (often due to underestimation of the gaps that deer can and will exploit) can cause more problems than it solves.

Combined potential

5.16 It will be clear from the findings outlined above, and examples of structures for which deer use has been recorded by previous studies, that whether and extent to which any particular structure will be used by deer is unlikely to be determined by any one single feature on its own. All of the different features discussed above (minimum dimensions, openness, substrate, traffic and other disturbance, surrounding habitats, and accessibility) are likely to exert some influence on whether a structure will be used by deer, as well as other factors such as the local deer density.

5.17 The summary Table 4 (Section 4) showing which features of each of the structures visited were judged as being favourable or unfavourable from view of potential use by deer, unsurprisingly shows those found to have the greatest numbers of positive features were mostly high river valley bridges or viaducts, that generally preserve much of the natural land beneath them allowing wildlife to continue to pass relatively freely beneath. Most such viaducts along the two roads studied are already likely be used to some extent by deer, though in some instances adaptation or removal of stock fencing and other possible obstacles could help enhance these further as wildlife passages.

5.18 Table 4 also serves to highlight which structures appear to have the lowest potential as wildlife passages. These will include, for example those with negative scores allocated for high levels of use by vehicles and lowest openness indices. Overall, however, while many existing structures surveyed had some features that would not be considered ideal or be at the lower end of criteria that would be recommended if designing a wildlife passage, it is likely that a quite high proportion (probably more than half) could be adapted in ways to attain some utilisation by deer; not least if resources for some highways fencing were available to help channel animals to specific structures near accident hot spots and deter them from crossing the main trunk road nearby.

5.19 Not all deer may adopt crossing structures as part of their normal daily range that are at the lower end of the generally accepted dimensions (Table 1) and other criteria for wildlife passages. The minimum criteria of greatest importance from view of assessing potential for adaptation of existing structures for purpose of reducing traffic risks through deer collisions, should be those that will enable use of the structures by that proportion of the local deer population most determined to cross the major roads. Deer vehicle collisions, for trunk roads in particular, tend to be highly seasonal (Langbein, 2007a; Deer Initiative, 2007), associated with breeding seasons and annual dispersal phases. Therefore structures that may facilitate only occasional use by deer, or use only at certain times of the year, are still likely to offer high potential to reduce deer collisions.

Recommendations for follow-up work

5.20 With the above in mind, Table 4 and other results from the present study also serve as a basis for informing and designing future research trials or demonstration projects. To help assess the practicability and effectiveness of modifications to existing structures in terms of increased deer use and reduced DVC risk, it is suggested that follow up work should include:

- One or more practical trials to show whether targeted limited adaptations to structures near deer vehicle collision hot spots can be shown to reduce deer accident risk through free passage under or over the road.
- Practical trials should be designed in such a way as to help also with re-evaluation of the validity and relative importance of minimum criteria that need to be met in order to attain use by large as well as small species of deer (dimensions / joint-use by motorised traffic / substrate / fencing and accessibility).
- Assessment of whether structures currently judged as having relatively low potential and with little current evidence of use by deer, increased deer use can be achieved in practice through quite limited and cost-effective adaptations (such as removal of physical obstacles hindering present access by wildlife).

Two specific initial trial sites are suggested for consideration for some practical adaptation covering four existing structures (two underpasses, and two overpasses) within HA Area 1, which should include some pre and post works monitoring in each case. Both sites are located in major DVC hotspots, involving in one case fallow deer and roe deer (Haldon Hill), and red deer and roe deer in the other (Ebsworthy Woods). Brief descriptions and what works might be involved in each are provided below. More detailed design of practical adaptations and other work required can be prepared on request. All the recommended adaptations to achieve increased deer use at each of the structures are estimated to be of relatively low cost. In some cases, for example, removal of obstacles or modification of existing fencing to improve accessibility by deer is likely to be achievable at costs below £1,000. In other cases adaptations including provision of short lengths (from around 100 m) of lead-in deer fencing on one or more sides of each structure (@ approx. £30/m) would be estimated to have associated project costs of between 5K and 20K. These broad indicative costs exclude any supplementary follow-up research to assess effectiveness of the measures taken.

A) Belvedere Cross and Harcombe Cross underpasses beneath A38 Haldon Hill

5.21 The A38 across Haldon Hill between Kennford and Harcombe has been a deer collision accident hot spot for many years. Haldon Forest holds a fallow deer population well in excess of 500 head, as well as large numbers of roe deer and occasionally some red deer. Between 10 to 20 deer casualties are recorded by the managing agents each year within a distance of around 5 km, while many others are likely to go unreported. Two road underpasses beneath the A38 included in the present study occur within the Forest at Belvedere Cross (Photo 3452]) in the northern part of the forest, and another at Harcombe Cross [Photo 3465] south of the Forest. Signs of deer were found within less than 10 to 50 m of entrance to both underpasses, but not clear evidence of current crossing through these structures. However, extensive frequent fallow deer activity (as shown by video recordings made – see Video Clips 1 – 3, Appendix IV) was noted directly on top of the overpass within 2 m of the main trunk carriageways. Deer activity was also noted within woodland adjacent to Harcombe Cross underpass.

Photos 3452 and 3465 – Underpasses beneath A38 at Belverdere Cross (left) and Harcombe Cross (right)

5.22 In case of Belvedere Cross underpass it seems very likely that movements of fallow deer through this underpass could be attained (or increased if already occurring to a limited extent) through installation of a number of short length of fencing. The latter would require careful design lay-out to ensure minimal risk of deer entering the inside of the fenced section through end-runs and maximise its use to deter deer from crossing the trunk road. The opportunity may also exist in this area for possible use of less than full-height deer fencing or fencing erected on the slope of existing embankments that would enable deer to cross in one direction but not another. If such adaptation is found practical after closer investigation and resources are available, some systematic pre and after monitoring of deer use and behaviour around the underpass should be included as part of the scheme, ideally using CCTV equipment or else alternative methods alongside continued monitoring also of deer collisions, in order to assess the actual effectiveness and cost effectiveness of adaptations undertaken.

5.23 Harcombe Cross underpass (Photo 3465) is one of the widest and highest road underpasses surveyed, benefitting also from wide footpath / sideways either side of the carriageway carrying intermittent low levels of one-way traffic leading onto the A38. The main adaptations to consider here might be to provide a more natural surface along one of the wide sideways to assess whether possibly increased use by deer can be created through that means alone. Again short length of deer fencing (c.200m) along either side of the wood traversed by the A38 in this area could also be considered to help channel deer towards the underpass. As above (5.18) monitoring of deer use before and after such works should be part of the scheme.

B) Ebsworthy Wood (Ebsworthy Farm and Ellacott Farm Overpasses over A30)

5.24 Ebsworthy Woods lies 2 miles from the northwestern boundary of Dartmoor National Park. Deer road casualties are not only a recent problem here but have been recorded in this area for a long time, in particular along a 1 km stretch where the A30 bisects the woodland and where wildlife warning reflectors and signs have been installed for several years in attempt to mitigate the problem. The fact that in recent years red deer (which at around average >100 kg for adult females and > 150 to over 200 kg for adult males, are around twice as heavy as fallow and four times as heavy as roe deer) are crossing the road in this area is of particular concern, as seriousness and likelihood of injury in DVCs is known to increase with size of the species involved. Information on the species of deer involved has mostly been unavailable from past records provided by the managing agent and other sources, and the proportion of DVCs involving red deer in this area is not currently known. (A request to keep species details and/or take a digital image of all animal casualties collected has been made by the EM ecologist to obtain more detailed information in future). The presence of red deer in the area is well known, and was also confirmed during the present survey (e.g. see image Photo 4592). Two overpasses occur 2 km apart to either side of Ebsworthy Wood. Ellacott Farm Overpass and Ebsworthy Farm overpass.

5.25 Ellacott farm overpass (Photos 4111; 4119) is a narrow farm accommodation bridge free of any road traffic and only occasional farm vehicle access. At the time of survey a lorry had been parked continuously on the structure for several months, blocking much of the path (Photo 4111) , whilst a metal gate and piles of silage bales block much entrance onto the structure from the south. Signs of deer were found within less than 50 m on the northern side, though no signs noted directly on the (hard substrate) bridge itself. Although this overpass is only 4m wide, it is very favourably located to serve as a deer crossing in a very quiet area where Ebsworthy wood and a new tree plantation abut closely to its northern side and pasture fields to the south. The main adaptation suggested in this instance would centre around removal of current obstacles to deer use of the structure; i.e. by ensuring no farm vehicles or other machinery are parked long-term on the structure in future, and other obstacles such as silage bales and gates are removed to enable freer passage for deer and other wildlife. Stock fencing adjoining the structure especially on the southern side should also be adapted in a way that enables ready access by deer. In addition, consideration should be given to improvement of the woodland / trunk road boundary fencing for the c. 2 km section located between the two overpasses, to help channel deer to the safer crossing places and prevent them crossing over the trunk carriageways in this area.

Photos 4110 and 4096 – Overpasses over A30 at Ellacott Farm (left) and Ebsworthy Farm (right)

5.26 Ebsworthy Farm overbridge is a somewhat wider (7 m) overpass carrying a minor road / lane (e.g.Photo 4096, 4102) with very light local traffic flow. Woodland abuts within 75m on the southern side, with pasture and moorland to the north. Signs of red deer activity were found within 75m of the entrances, and although no direct evidence of deer crossing activity was noted during the short pilot survey, it seems likely that deer may already use the bridge to some extent. The main adaptations that might be considered to enhance this passage for use by deer would include minor adaptations to the stock fencing surrounding woodland on the south side to enable more direct access by deer from the wood near the overpass entrance. Creation of a soil, grass other natural substrate along one or both existing concrete verges, and some improvements to existing lay-out of lead-in fencing would also be considered beneficial here. In addition (as outlined in 5.24) improvements to existing trunk road boundary fencing between this structure and the second overpass at Ellacott Farm should be considered to maximise use of both structures by the deer. Some repairs to that stretch of fencing (believed to the responsibility of the landowner abutting the HA estate) are required at present in any case as that fencing has been damaged by errant vehicles involved in accidents over the past year.

5.27 If any adaptations of the overpasses to enhance their joint use by wildlife are initiated, then as suggested also for A above (5.21) some systematic pre and after monitoring of deer use and their behaviour on and around the structures (ideally using CCTV) should form part of the scheme.

5.28 The two areas for local adaptation trials outlined under A & B above have been chosen for their potential to serve as demonstration sites of what may be achievable through similar adaptations also in other areas of the network, and in order to test past assumptions regarding the characteristics of suitable structures for use by deer and other large mammals. Many of the other structures surveyed along the A30 & A30 could similarly benefit from various similar though site-specific adaptations should resources be available for trials at a wider selection of sites.

5.29 Consideration should also be given to a desk-top study of other areas of the HA trunk road network throughout England to help identify a selection of those structures in each HA region likely to offer greatest potential for adaptation to mitigate DVC risks (possibly initially based on use of existing on-line aerial mapping resources and information on animal collision hotspots).

Acknowledgements

This study was enabled by a grant from Highways Agency to The Deer Initiative. Majority of fieldwork was undertaken by the author, who would like to acknowledge the input and local information provided by John Stowers and Brian Johnson who each accompanied him for one field survey day, and to Leo Gubert, Ed Dyson, David Hinde and Richard Bernhardt for helpful discussion during site visits and comments on a draft version of this report.

References

Apollonio, M., Andersen, R., and Putman, R.J. (eds.) (2010a) European Ungulates and their Management in the 21st century. Cambridge University Press.

Ballon, P. (1985) Bilan technique des aménagements réalisés en France pour réduire les impacts des grandes infrastructures linéaires sur les ongulés gibiers. In: XVIIth Congress of the International Union of Game Biologists, Brussels. 679-689.

Berthoud, G. et al. (2000) (15+ authors ; see IENE web-site for fuller detail): COST341 Habitat fragmentation due to Tranport Infrastructure. Swiss State of the Art National Report. European Commission, Brussels.

Busch, F. and Kraemer, E. (1973) Wildschutz an Bundesstrassen. Strasse und Autobahn 24, 172-173.

Cresswell, W. , Dean, M., Jones, R., Langbein, J. and S. Wray (2008) Use of underpasses, culverts and tunnels under roads by mammals. Presentation to The Mammal Society's Autumn Symposium,Nov.2008. Institute of Zoology, London.

CTGREF (1978): Autoroute et grand gibier, 41 S. (Note technique No. 42). Groupement technique forestier, Nogent-sur-Vernisson, Paris.

Deer Initiative (2007) Deer on our Roads – Counting the Costs. Deer Initiative, Wrexham.

DfT (2006) Transport Statistics Great Britain (TSGB) 2006 Edition.

DfT (2009) Transport Statistics Great Britain (TSGB) 2006 Edition. Department for Transport web-site http://www.dft.gov.uk/

Georgii, B., Peters-Ostenberg, E., Henneberg, M., Herrmann, M., Müller-Stieß H. and Bach, L. (2007) Nutzung von Grünbrücken und anderen Querungsbauwerken durch Säugetiere. Gesamtbericht zum Forschungs-und Entwicklungsvorhabe. [In German] Forschung Strassenbau und Strassenverkehrstechnik Heft 971. Bonn.

Gill, R.M.A. (1990) Monitoring the Status of European and North American Cervids. GEMS Information Series, 8; Global Environment Monitoring Systems, United Nations Environment Programme, Nairobi. 277 pages.

Groot Bruinderink, G.W.T.A. and Hazebroek, E. (1996). Ungulate Traffic Collisions in Europe. Conservation Biology 10, 1059-67.

Harris, S., Morris, P., Wray, S. and Yalden, D., (1995) A review of British mammals:population estimates and conservation status of British mammals other than cetaceans. JNCC, Peterborough.

Holzgang, O. , Sieber, U., Heynen, D. , von Lerber, F., Keller, V. and H-P Pfister (2000) Wildtiere und Verkehr: Eine kommentierte Bibliographie. Schweizerische Vogelwarte, Sempach.

IENE web-site. www.cbm.slu.se/iene/cost341.php

Iuell,B., Bekker, G.J., Cuperus, R. Dufek,J., Fry, G., Hicks,C.,Hlavac, V., Keller, V.B., Rosell, C., Sangwine, T., Torslov, N, Wandall, B. le M, (2003) Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions. European Commission Action 341 on "Habitat Fragmentation due to Transportation Infrastructure", Brussels.

Halcrow (2002) Managing Integration : Highways Agency -Minimising Fragmentation. Efficacy of Existing Green Bridges M40 between Junctions 8 and 9. Research Report. Halcrow Group Ltd. Swindon.

Langbein, J. (1996) Conservation and management of deer in Epping Forest and its Buffer Land Estate. Corporation of London.

Langbein, J. and Putman, R. J. (2006). National Deer-Vehicle Collisions Project : Scotland 2003-2005. Final report to Scottish Executive. The Deer Initiative, Wrexham.

Langbein, J. (2001) A120 Stansted to Braintree Bypass: Pre-construction Deer Studies. OverArup, Solihull.

Langbein, J. (2007a) National Deer-Vehicle Collisions Project : England 2003-2005. Report to The Highway Agency. The Deer Initiative, Wrexham.

Langbein J. (2007b) Use of remote video surveillance to investigate deer behaviour in relation to wildlife deterrents, roads and vehicles. Presentation at 'Deer on our Roads Seminar', Ashridge, UK, October 2007. [http://www.deercollisions.co.uk/pages/workshop2.html]

Langbein J. (2007c) Epping Forest Deer Management Review. Report to Open Spaces Department, City of London.

Langbein, J. (2008) A120 Stansted to Braintree post-construction deer studies. Balfour Beatty. London.

Langbein, J., Putman. R.J., and B. Pokorny (2010b) in press. Road Traffic Collisions involving deer and other ungulates in Europe and available measures for mitigation. In: Ungulate Management in Europe: Problems and Practices (eds. R.J. Putman, M. Apollonio and R. Andersen), Cambridge University Press, in press.

Lehnert, M.E. and Bissonette, J.A. (1997). Effectiveness of highways crosswalk structures in reducing deer-vehicle collisions. Wildlife Society Bulletin 25, 809-818.

Mastro,L.L., Conover, M.R. and Frey, S.N. (2008) Deer-vehicle collision prevention techniques. Human-Wildlife Conflicts 2, 80-92.
Olbrich, P. (1984). Untersuchung der Wirksamkeit von Wildwarnreflektoren und der Eignung von Wilddurchlässen. Zeitschrift für Jagdwissenschaft 30, 101-116.
OveArup (1995) A120 Stansted to Braintree Bypass, Environmental Statement.
PFISTER, H.P. (1997): Wildtierpassagen an Strassen. Vorprojekt zur Abklärung der Nutzung von für den Verkehr erstellten Unter- und Überführungen durch Wildtiere. Forschungsauftrag 30/92. Bundesamt für Strassenbau und Vereinigung Schweizerischer Strassenfachleute (VSS), Zürich. 29 S.
Pfister, H.P., D. Heynen, B. Georgii, V. Keller, and F. von Lerber. (1999). Häufigkeit und Verhalten ausgewählter Wildsäuger auf unterschiedlich breiten Wildtierbrücken (Grünbrücken). Schweizerische Vogelwarte, Sempach, Switzerland.
POST (2009) Note number 325 Wild Deer in the UK: Impacts of rising deer populations. The Parliamentary Office of Science and Technology, London.
Putman, R.J., Langbein, J. and Staines, B.W. (2004) Deer and Road Traffic Accidents; A Review of Mitigation Measures: Costs and Cost-Effectiveness. Report to the Deer Commission for Scotland.
Seiler, A. (2004). Trends and spatial pattern in ungulate-vehicle collisions in Sweden. Wildlife Biology 10, 301-313.
SETRA (1993) Passages pour la grande faune, Guide technique. Service d'Etudes Techniques des Routes et Autoroutes, Bagneux. pp. 121.
Smith, G. and Langbein, J. (1998) (eds). The Prevention of Wildlife Casualties on roads through deterrents: Prevention of casualties amongst deer populations. Final Report SW335/V3/11-98 to Highways Agency. SGS Environment Ltd.
Trocmé, M.; Cahill, S.; de Vries, J.G.; Farrall, H.; Folkeson, L.G.; Hicks, C. and Peymen, J. (eds), 2003. COST 341 - Habitat Fragmentation due to Transportation Infrastructure: The European Review. Office for official publications of the European Communities, Luxembourg.
Ückermann, E. (1964) Wildverluste durch den Strassenverkehr und die Verkekrsunfaelle durch Wild. Z. Jagdwiss. 10: 142-168.
Ückermann, E. (1983). Die Auswirkung der Wildverluste durch den Stassen Verkehr auf die Nutzungsfähigkeit der Reviere. Zeitschrift für Jagdwissenschaft, 29, 264-265.

Appendix I : *Field Survey Form*

Existing Structures Survey Sheet **March/April 2010**		**1: Recorder**	**2. Date of initial survey:**
3. Site Name:	**4.Road:**		**5. Structure Type:**
6: General description:			
Dimensions (m):			
7. Length:	**8 Width:**		**9. Height**
10.Substrate:			
Vegetation			
11a: Carriagway A		**11b: Carriagway B**	
12. Deer use signs: (position / distance / frequency)			
12a Slots			
12b Pellets			
12c Trackways			
13. Other Comments (incl. other animal signs):			
14: Photographs taken:	**Yes / NO**	**Images nos:**	
15. Overall Potential of structure:			**15a Score:**

Appendix II : *Tables 5a & (overleaf) 5b*

Table 5a: Summary of main features recorded during field survey of Overpasses

Structure Name	Road / Str number	Type	Length m	Width m	Substrate - Hard (H) or Natural (N)	Openness Factor	Poss. Deer signs	Nearest sign	Photographs taken
Brewers	A30/320.80	O/B	46	9.5	H: concrete / tarmac	0.207	Yes/inc.	<10m	IMG:4077-78
Cowsen lane	A30/308.30	O/B	51	8	H: concrete / tarmac	0.157	Yes	<10m	IMG:4126-9
Ebsworthy Farm	A30/312.20	O/B	46	7	H: concrete / tarmac	0.152	Yes	<75m	IMG:4093-102;4592-5
Barton Head	A30/273.3	O/B	64	9.5	H: concrete / tarmac	0.148	Yes	<15m	IMG:4040,1,2,3
Bible Christian	A30/369.40	O/B	65	9	H: concrete / weedy	0.138	Nf		IMG: 4564-67
Venn Bridge Hill	A30/280.60	O/B	60	8	H: concrete / tarmac	0.133	Nf		IMG: 4060-62
Hackworthy Lane	A30/276.5	O/B	64	8.5	H: concrete / tarmac	0.133	yes	<50m	IMG:4047-51
Marely Head	A38/75.50	O/B	77	10.2	H: concrete / tarmac	0.132	Nf		IMG: 4219-21
Lanhydrock	A30/367.70	O/B	73	9.5	H: concrete / weedy	0.130	Nf		IMG: 4568-75
Merafield Road	A38/54.20	O/B	101	12.5	H: concrete / tarmac	0.124	Nf		IMG: 4255-58
Deep Lane Jnc	A38/57.50	O/B	106	13	H: concrete / tarmac	0.123	Yes	<50m	IMG:4243-49
Holewell Lane	A30/282.30	O/B	73	8	H: concrete / tarmac	0.110	yes	<15m	IMG: 4058,59
Saltram House	A38/53.30	O/B	58	6.2	H: concrete / tarmac	0.107	Yes/inc.	<30m	IMG: 4259-63
Milestone Lane	A38/103.2	O/B	80	8	H: concrete / tarmac	0.100	Nf		IMG:3475; & 3476
Old Exeter Road	A38/102.7	O/B	90	8.5	H: concrete / tarmac	0.094	Nf		IMG:3479-84
Ellacott (Ebsworthy)	A30/314.10	O/B	44	4	H: concrete / tarmac	0.091	Yes	<50m	IMG: 4110-4125
Forder Lane	A38/69.50	O/B	76	6	H: concrete / tarmac	0.079	Nf		IMG: 4233-35
Horsebrook Lane	A38/73.40	O/B	102	6.5	H: concrete / tarmac	0.064	Yes/inc.	<30m	IMG: 4227-30
A30 Halgavor NCN	A30/367a	O/B	59	3.5	H: Playground type	0.059	Yes	<20m	IMG: 4576-86

Key : UP=Underpass; OP=Overpass; Nf=not found; inc.=inconclusive (e.g. whether deer or sheep or other animal signs)

Table 5b: Summary of main features recorded during field survey of Underpasses

Structure Name	Road / Str number	Type	Length m	Width m	Height m	Substrate - Hard (H) or Natural (N)	Openness Factor	Poss. Deer signs	Nearest sign	Photographs taken
East Okement River	A30/299.90	U/P	27	50	12.3	N: soil / stones / veg.	**22.778**	Yes	<10m	IMG:4063-71
River Thrushel Via	A30/315.50	U/P	27	83	5.5	N: mainly /some hard	**16.907**	Yes/inc.	0m	IMG:4082-92
River Teign	A38/98.00	U/P	30	54	4.5	N: mainly /some hard	**8.100**	Yes	<30m	IMG:4204-15
Plympton Hill	A38/55.90	U/P	33	18.5	6.3	H: concrete / tarmac	**3.532**	Nf		IMG: 4253-54
Harcombe Cross	A38/103.6	U/P	31	17.5	5.65	H: concrete / tarmac	**3.190**	Yes	<25m	IMG:3465-71
Torpeek	A38/68.20	U/P	27	11	5.7	H: concrete / tarmac	**2.322**	Nf		IMG: 4241-42
Beech Farm (Lee Mill)	A38/61.50	U/P	34	12.5	6.25	H: concrete / tarmac	**2.298**	Yes	<45m	IMG: 4218
The Mills UP	A38/90.90	U/P	27	9.5	6.3	H: concrete / tarmac	**2.217**	Yes/inc.	<25m	IMG:4183-89
West Okement Viaduct	A30/304.30	U/P	36	16	4.8	N: firm muddy track	**2.133**	Yes	0m	IMG:4072-76
Liftondown A388	A30/326.40	U/P	39	12.5	6.3	H: concrete / tarmac	**2.019**	Yes	<10m	IMG:4106
Beazle Over Spill	A30/317.40	U/P	29	10.5	5.3	H: concrete / tarmac	**1.919**	Nf		IMG:4079-81
Little Bittaford	A38/68.80	U/P	27	9	5.4	H: concrete / tarmac	**1.800**	Nf		IMG: 4236-40
A38 Woodpecker Jnc	A38/72.30	U/P	41	12.5	5.3	H: concrete / tarmac	**1.616**	Nf		IMG: 4231-32
Jews Culvert (R Bovey)	A38/96.70	U/P	32	17	3	N: mainly water	**1.594**	NF		IMG:4190,91,92
Stidston Lane	A38/74.90	U/P	25	7	5.2	H: concrete / tarmac	**1.456**	Nf		IMG: 4222-24
Reperry	A30/372.10	U/P	41	10.5	5.52	H: concrete / tarmac	**1.414**	Yes/inc.	<5m	IMG: 4524-34
Wartham	A30/325.50	U/P	29	7.4	5.45	H: concrete / tarmac	**1.391**	Yes/inc.	0m	IMG: 4107-8
Heathfield Rly	A38/96.20	U/P	35	9	5.25	N: part , Rly grit/wood	**1.350**	Yes	<5m	IMG:4196-4203
Belvedere Cross	A38/106.4	U/P	58	10.5	5.25	H: concrete / tarmac	**0.950**	Yes	<4m	3452-63,4146-51
Dilly Bridge	A30/278.10	U/P	38	6.5	5.32	H: concrete / tarmac	**0.910**	Yes	<20m	IMG: 4052-57
Portford Lane	A38/74.30	U/P	39	6	5.47	N: firm muddy track	**0.842**	Nf		IMG: 4225-26
Dogs	A38/96.60	U/P	30	7	3.5	N: mainly water	**0.817**	Yes/inc.	<15m	IMG:4194,5
Higher Tredenham	A30/371.10	U/P	56	8.5	5.2	H: concrete / tarmac	**0.789**	Yes	<20m	IMG: 4535-44
Pipehouse Lane	A38/97.80	U/P	25	4.6	4.2	H: concrete / tarmac	**0.773**	Yes/inc.	<15m	IMG:4216,17
Taw River	A30/294.70	U/P	54	8.5	4	N: rocky / water	0.630	Nf		No
Dark Lane	A38/100.50	U/P	35	4.5	4.5	H: plus hard entrance	0.579	Nf		IMG:4276-79
Fingle Glen	A30/274.3	U/P	34	4	4.5	N: gravelly / mud	0.529	Yes/inc.	<25m	IMG: 4044,5,6
St Ingunger Accom. UP	A30/370.40	U/P	39	3	3.5	N:muddy track	0.269	NF		IMG: 4546-63

Key : UP=Underpass; OP=Overpass; Nf=not found; inc.=inconclusive (e.g. whether deer or sheep or other animal signs)

Appendix III: Thumbnail images of existing structures surveyed. See CD (Appendix IV) for larger and additional images for each structure)


Barton Head_IMG_4040


Beale OS _ IMG_4079


Beech Farm IMG_4218


Belvedere_IMG_3452


Bible Christian _ IMG_4566


Brewers IMG_4078


Cowsen Lane IMG_4127


DarK Lane _ IMG_4278


Deep Lane - IMG_4243


Dilly bridge IMG_4054


Dogs _ IMG_4195


East Okement _ IMG_4063


Ebsworthy Farm IMG_4096


Ellacott Farm IMG_4110


Fingle Glen IMG_4044


Forder Lane IMG_4235


Hackworthy Lane IMG_4050


Halgavor Cyc IMG_4582


Harcombe_IMG_3465


Heathfield RLY _ IMG_4196


Higher Tredenham IMG_4537


Holewell Lane IMG_4059


Horsebrook Lane IMG_4228


Jews UP _ IMG_4190


Lanhydrock - IMG_4571


Liftondown _ IMG_4106


Little Bittaford _ IMG_4236


Marley Head IMG_4221


Merafield - IMG_4257


Milestone Lane IMG_3475

(continued page 2)

Appendix III *(page 2)*


Old Exeter Road IMG_3484


Pipehouse Lane _ IMG_4216


Plympton Hill _ IMG_4253


Portford Lane _ IMG_4225


Reperry _ IMG_4532


River Teign -IMG_4205


River Thrushel _ IMG_4082


Saltram House IMG_4260


St Inunger IMG_4546


Stidson Lane _ IMG_4222


The Mills _ IMG_4183


Torpeek IMG_4241


Venn Bridge Hill IMG_4061


Wartham _ IMG_4108


West Okement R _ IMG_4072