IMPACT OF ROADS ON BARN OWL *Tyto alba* POPULATIONS

DPU 9/51/2

Report to

The Highways Agency

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EXECUTIVE SUMMARY

Levels of Mortality

1. Between the months of September and March the Barn Owl *Tyto alba* was the species of owl killed most frequently on the A303, a 50 km stretch of major road randomly selected for this investigation from the trunk road network in England. In spite of its relative scarcity in south west England where this research took place, the number of Barn Owls killed exceeded by three-fold those of the ubiquitous Blackbird *Turdus merula* and nine-fold those of the most common bird of prey, the Kestrel *Falco tinnunculus*. Only one species, the Pheasant *Phasianus colchicus* (mainly from domestically reared stock), accounted for a greater number of bird casualties.

2. During the three September to March study periods between 1995 and 1998, 1233 animal casualties were recorded. These included 179 bird of prey casualties, represented by seven different species. Of these 155 (87%) were owls. They included 27 Tawny Owls, 16 Long-eared Owls and 10 Little Owls. The Barn Owl accounted for 102 (66%) of the owl specimens, representing a seasonal mortality figure of 68 road deaths per 100 km.

3. Extrapolation of this data to dual carriageway sections of all purpose trunk roads and motorways which fall within the Barn Owl's optimum geographical and altitudinal range in England, indicates that between September and March approximately 3065 individuals are killed annually. This investigation has shown that 90% of road mortality occurs between these autumn and winter months, supporting the findings of previous work. From this it can be estimated that 3375 Barn Owls are killed each year on England's trunk road and motorway network.

4. Barn Owls were shown to utilise roads in two different ways. Just over half (56%) of the live Barn Owls observed on the A303 during this study were crossing the road in direct flight. The remainder (44%) were actively flying along the road verge or hunting from roadside posts or bushes.

Influence on Population Dynamics

5. Barn Owl casualties in the A303 sample were made up of 67% immatures and 33% adults. An identical proportion was found in the larger sample collected as part of this study from 'other roads' in Britain. Based on well researched estimates of the current population and breeding productivity, 17% of adult Barn Owls and 24% immature owls are likely to be removed from their respective live populations each year as a result of road traffic accidents.

6. Immature Barn Owls comprised 83% of the birds killed in the autumn (September to November) and 58% in the winter (December to March). While the proportion of males and females killed in winter was similar, more females were found dead in the autumn period. This was especially noticeable in November when four times as many females (mainly immatures) were killed than immature males.

7. The high proportion (67%) of immature owls killed on roads between September and November may simply be a result of the high numbers of immature Barn Owls which exist in the population at this time of the year. Assuming a population of 3500 pairs in England producing on average of 2.5 fledged young per nest per year and that both age classes were equally vulnerable, the expectation might be for 58% immature and 42% adult mortality. Therefore the high proportion of immatures found dead in this study could only partly be explained by their increased numbers during late autumn and early winter.

Impact of Roads

8. Road verges and the small mammal communities that they support, offer attractive dispersal networks for young Barn Owls seeking independence from their natal areas and this is likely to be the main reason for the high proportion of immatures that are killed at this time of the year. The number of recoveries of ringed birds, mainly immatures, found dead on the road during this study was very low and indicated that they had originated from nest sites both within and outside the 50 km x 5 km corridor of the A303.

9. Adult Barn Owls, once established in a territory, are broadly sedentary throughout the year and throughout their lives. Most of the adults killed were believed to have originated from breeding territories near to the fringes of the study area, 2.5 km

from the A303. This is a likely consequence of range expansion which is known to occur in adults during winter, when defence of the nest and delivery of food to it, has ceased. Small mammals too, can become less abundant and have a more patchy distribution at this time of the year encouraging Barn Owls to move out of their traditional breeding territories.

10. In the A303 study area (50 km x 5 km) seven breeding territories were recorded. Six of these were more than 1 km from the A303. This was consistent with the findings of earlier research which concluded that Barn Owls were rarely able to maintain a viable breeding population close to major roads carrying fast moving traffic because the high level of mortality exceeds the breeding productivity and the successful recruitment of young birds into the area.

Sex and Condition

11. *Post mortem* examination of Barn Owls from the A303 which were recovered sufficiently intact from the road surface, showed that the sex ratio was close to unity with 19 males and 17 females making up the sample. In the specimens collected and examined from 'other roads' there was a trend towards more females in both the adult and immature classes, although this was not statistically significant.

12. 58% of the A303 sample and 45% of the specimens collected from 'other roads' in Britain failed to show any sign of fractured bones or bodily injury other than occasional bruising to the head. From this it was concluded that rather than being struck directly, a significant number of Barn Owls die from shock and hypothermia on the road surface having been caught in and stunned by the turbulence generated by high-sided vehicles.

13. The majority (94%) of Barn Owl specimens collected from the A303 and 77% of those collected from 'other roads', were in good body condition in terms of their subcutaneous fat deposits and in both samples less than 15% demonstrated lower than average weights. No evidence of disease was found in any birds following *post mortem* examinations of their organs or other body tissues and histopathology for *Hepatitis* and *Newcastle Disease* proved negative. 80% of the A303 and 60% of the larger sample of specimens from 'other roads', had one or more items in their gut and digestion levels suggested that they had been hunting successfully and were in the process of completing their meal prior to being killed. Findings from this investigation do not

support the idea that birds with inadequate hunting skills or those in poor condition are killed preferentially on roads.

Activity Patterns

14. Timing of hunting activity varied significantly between Barn Owls foraging on the roadside and on open farmland nearby. Activity peaks on farmland occurred between 16.00 and 20.00 hours and coincided with the hours around dusk. On the road however, hunting activities peaked much later between 22.00 and 3.00 hours coinciding with the time when traffic movements were at their lowest. It was concluded that at times of peak traffic flow the high level of background noise emitted by vehicles disrupted hearing and inhibited the Barn Owl's ability to locate and capture small mammals on road verges. When roadside hunting was at its peak around midnight, this also coincided with the time when the proportion of lorries to cars increased. High-sided commercial vehicles were believed to be responsible for the majority of Barn Owl road deaths in this study.

Road Characteristics and Predisposition to Mortality

15. In each of the three years, Barn Owl road casualties were not distributed evenly along the A303 but were concentrated at specific locations. These 'sink areas' or 'blackspots' matched those of more limited observations made on this road between 1992 and 1994. Of the 102 Barn Owl casualties found during this investigation the large majority (84%), could be traced to just five primary and two subsidiary 'blackspots'. All of these were associated with the lowest lying parts of the A303 and specifically at places where grassy corridors associated with river, stream and ditch banks intersected the road. It was concluded that Barn Owls concentrate much of their movement along the prey-rich banks of these watercourses (immatures for dispersal and adults when extending their breeding range in winter), with the result that they are funnelled onto the road where a watercourse and associated bank or other type of linear grassland intersects the road.

16. The number of Barn Owls killed per kilometre on sunken sections of the A303 was one-half those found on level sections and one-third those found on the elevated sections suggesting that the high banks of sunken roads afford more protection to those Barn Owls which are attempting to cross roads.

17. The majority (85%) of the 102 casualties occurred on the lowest lying sections of the A303, below 45 m asl and 74% were found where the width of the road verge was over 5 m.

18. Detailed habitat mapping of the eastbound and westbound verges of the A303 indicated that 58% of the linear length provided prime foraging habitat in the form of open grassland. In this study 70% of Barn Owl deaths occurred at the interface between favourable (open grassland) and unfavourable habitat types (tree or shrub belts) on verges. It was concluded that Barn Owls are able to forage and disperse along open stretches of grassland on road verges in comparative safety but when they arrive at barriers of unfavourable habitat, they divert from their line of flight onto the road itself where they become exposed to traffic.

Mitigation Measures and Surveys

19. This research indicates that it would be neither effective nor practical to recommend the elimination of continuous stretches of rough grassland from the verges of trunk roads and motorways by frequent mowing or the saturation planting of bushes and trees. To have any effect in discouraging Barn Owls these measures would need to be implemented over long stretches of road and are likely to act in a negative way on other animal and plant communities which depend on these semi-natural grasslands. Such measures would also reduce the visual amenity value to the travelling public, particularly in open landscapes which can fall within Areas of Outstanding Natural Beauty, Environmentally Sensitive Areas and/or SSSI's all of which are controlled by their own protective legislation aimed at maintaining and enhancing landscape quality.

20. Because Barn Owls remain relatively safe when confining their activities to road verges themselves it is recommended that these linear stretches of rough grassland should be continuous and not interrupted by the planting of long impenetrable blocks of dense trees or shrubs which extend the full width of the verge. On verges where shrubs or trees are to be planted or where they already exist, a swathe of grassland two or more metres wide should be left or cut through the centre of these 'barriers' to maintain continuous flightpaths of open grassland in order to discourage Barn Owls from diverting into the road itself.

21. Where it is considered practical on new or improved roads it is recommended that high hedges or tree screens are planted on raised banks (bunds) at locations where Barn Owls regularly cross roads and where potential or known 'blackspots' have been identified. These natural 'screens' can be of value by encouraging low-flying owls to rise above traffic, reducing their vulnerability to collision.

22. It is recommended that the grassy banks of rivers, streams and ditches (and other grass margins on farmland) which have been identified as important dispersal routes for Barn Owls and which intersect roads, are themselves intersected about 100 metres from the road by the provision of *diversion corridors* of rough grassland. These should be set at right-angles to the natural dispersal routes and parallel to the road in an attempt to encourage Barn Owls to utilise safe flightways on open farmland rather than the verge itself.

23. A comprehensive programme of nestbox provision should be undertaken on farmland at least 1.5 km either side of the A303. This should be targeted close to those linear grasslands which are identified as important dispersal corridors for Barn Owls which when intersecting the road were responsible for high levels of mortality. If successful these compensatory measures should also be encouraged adjacent to other newly proposed roads or those which are to be upgraded, to provide dispersing juvenile Barn Owls with the opportunity to settle and breed, thereby maintaining local populations.

24. These recommendations should be trialed during the next two years on the 50-km study stretch of A303. A repeat survey of the breeding population and mortality levels should be undertaken in order to determine the value of the mitigation measures which have been proposed in this report.

25. In more general terms Barn Owl field surveys which conform to an accepted scientific methodology (Toms *et al* 1998) should be undertaken for all newly proposed road construction schemes to identify potential/active nest sites and foraging habitats, including linear grasslands, on and within 1.5 km of the soft estate. Identification of known and potential hotspots of mortality ('Blackspots') should also form part of such a study in order to fully evaluate the level of impact and to inform appropriate action to mitigate any impact.

1 Introduction

1.1 Project Specification

This four-year research commission (DPU 9/51/2) was originally undertaken for the Department of Transport and since 1996, the Highways Agency. During the first year the study sought to select a suitable low-lying study area which included a major road, representative of a typical *all purpose trunk road* in England in terms of both construction, verge habitat and night movements of traffic.

1.2 Project Aims

Primary Aims - To determine:

- the level and seasonal occurrence of road mortality in Barn Owls and the significance of this mortality to the Barn Owl population in England
- if particular features of roads and their associated habitats predispose to high levels of mortality
- whether measures could be taken to help mitigate the impacts of mortality and advise how such measures might be implemented on new and existing roads.

Secondary Aims

- to establish a practical and repeatable methodology which could be used to assess the impact of future road upgrading and road verge management on Barn Owl mortality and on local populations and using repeat surveys, to determine the value of the mitigation measures which might be adopted.
- to record the details of other birds of prey found dead on the chosen road and the potential impact on other species of wildlife concern.

1.3 The Barn Owl - its Present Status

In England and Wales the breeding population of the Barn Owl declined by 70% between 1932 and 1985, from an estimated 12,000 pairs to 3,800 pairs (Blaker 1934, Shawyer 1987). Recent local surveys of Barn Owls in the UK have shown a

continuation of the decline (Trodd and Kramer 1991, Brucker *et al* 1992, Grant *et al* 1993, Day *et al* 1995). The Barn Owl is also in decline throughout Europe (Tucker and Heath 1994) and North America (Colvin 1985, Tate 1986). In the UK the most recent national survey of the Barn Owl conducted between 1995 and 1997 established an up to date population estimate of between 3000 and 4000 breeding pairs suggesting a stabilisation in numbers over the last ten years (Toms *et al* 1998) with some evidence of population increases in those areas where conservation effort has been concentrated, particularly eastern parts of England, south Wiltshire and parts of south west Scotland (Shawyer 1998).

1.4 Population Decline

The long-term decline of the Barn Owl is attributed to decreases in the populations of small mammals, particularly the Short-tailed Vole *Microtus agrestis* as a consequence of agricultural intensification and increased urbanisation since the 1930's, which have resulted in the loss and fragmentation of rough grassland habitat. Since 1940, 97% of lowland meadows and 80% of calcareous grassland has been lost in Britain (Wildlife Link 1989). In addition more sophisticated methods of grain harvesting and storage have resulted in further reductions in small mammal prey in farmyards during winter (Shawyer 1987). Severe winters between 1940 and the mid 1970's, the disappearance of nest sites in mature trees and farm buildings, the effects of organochlorine pesticides (Newton *et al* 1991), anticoagulant rodenticides (Shawyer 1985) and increasing levels of road mortality (Bunn *et al* 1982, Shawyer 1987) have also been implicated in the decline of the Barn Owl population.

1.5 Protection

Under UK and European law the species is specially protected under Sections 1 and 9 of *The Wildlife and Countryside Act 1981, Appendix II of the EU Birds Directive, 1979 and on Appendix II of the Bern Convention.* It appears in *Red Data Birds* (Batten *et al* 1990) which include species that are rare or in danger of extinction and is *Amber Listed* in *Birds of Conservation Concern in the UK, Channel Islands and Isle of Man* (Anon 1996).

1.6 UK Action Plans

Concern about the fragile status of the Barn Owl prompted the establishment of a UK Action Plan for the species which formed part of a wider document, *Biodiversity*

Challenge: an agenda for conservation in the UK (Wynne *et al* 1995) which took account of the *RSPB/JNCC Species Action Plan 0735* (Williams 1992).
Specific targets have been set by this *Action Plan* with two main policy objectives:

- To maintain the present range and numbers of the Barn Owl throughout the UK over the short-term.

- To achieve a substantial increase in the breeding population by at least one half over the period 1995-2020.

Recommendations are also made in the Species Action Plan to reduce the level of road mortality in Barn Owls.

The *UK Biodiversity Action Plan* (UK BAP), (HM Government 1994) drew on the Biodiversity Challenge document. The Barn Owl is included on the Long List (Species of Conservation Concern) in the UK Action Plans contained in *Biodiversity: the UK Steering Group Report* (HM Government 1995) where the Barn Owl is classified as *having declined by between 25-49% in numbers over the last 25 years* with *unfavourable conservation status in Europe*

The Highways Agency has a remit to encourage biodiversity on their estates. Over the last decade habitat enhancement of verge habitats for wildlife and for aesthetic reasons has become an increasingly important consideration in the design and maintenance of roads. Transport policies now take account of other Government initiatives and targets especially where these involve the environment. A current objective of the Highways Agency is '*to manage its network in a practical way which promotes the maintenance and enhancement of biodiversity*' and *'in particular to seek to manage its own estate so as to add to its existing value as a refuge and a linking feature for wildlife'* with actions which include *'developing a biodiversity action plan for the management of its soft estate - the land surrounding its network - founded on the Government's action plans to protect species and habitat'*. This includes a *'programme of research to develop a better understanding of biodiversity in the context of highways management* and *implementing a programme of engineering measures to protect wildlife from road traffic where highways cross their habitats'* (Highways Agency 1999). These are also referred to in other Agency publications (Highways Agency 1996, 1998, 2000) and in a non-Government publication (RSPB 1994) where it states that *'consideration of biodiversity should be an integral part of Government programmes, policy and action and must be*

based on the best scientific knowledge'.

Government planning guidance on nature conservation also recognises the importance of the planning system in ensuring that protected species are not unduly affected by development. Paragraph 47 of *Planning Policy Guidance note 9 on Nature Conservation (PPG9)* establishes that the presence of a protected species, such as the Barn Owl *'is a material consideration when a local planning authority is considering a planning proposal which ... would be likely to result in harm to the species or its habitat'.*

1.7 Roads and their Significance to Wildlife Communities

Road construction and improvement not only consumes significant areas of land but often results in the fragmentation of landscapes and the habitats that they support. In particular roads bisect many important habitat features such as rivers, streams, ditches and disused railway lines, the grassy banks of which provide important foraging habitat and dispersal networks for a wide range of wildlife. For the larger and more mobile species of mammal like Badger, Otter and Fox and certain birds like the Barn Owl which use these corridors for foraging and to move from one area of their home range to another, bisection by roads can expose these animals to hazardous ‘barriers’ of traffic.

1.8 Road Network Expansion and Verge Management

The period 1980-1990 was responsible for the greatest increase in the road network this century, when it expanded by 5%.

In the mid 1970's a combination of factors contributed to a reduction in the management of road verges (de Hanel 1975). These factors included an increasing awareness of thriving and sometimes rare animal and plant communities, the escalating costs of maintenance resulting in a reduction in chemical treatment and less intensive cutting regimes. Today, with the exception of the metre strip next to the carriageway itself there is infrequent management and minimal trampling resulting in a tussocky grass structure on most verges (Way 1977). Indeed more than 30,000 hectares of 'soft estate' are looked after by the Highways Agency which is actively developing these areas as a safe refuge for wildlife (Highways Agency 1998).

As a result road verges have become more characteristic of hay meadows than of

grazing pasture with their continuous recycling of nutrients. Because of the favourable management changes that have occurred over the last 20 years, roadsides have the capacity to attract high densities of voles and other small mammal and insect communities. It has also been reported that roads in themselves may considerably enhance the dispersal of these animals (Jonkers and Van Wijngaarden 1975). Such a rich and dependable food supply entices predators like the Barn Owl to forage and disperse along road verges the total length of which is currently estimated at 155,334 km (Alexander undated), in preference to adjacent farmland which is usually more intensively managed. The attraction of these foraging and dispersal habitats, may in part be more an indication of the poor quality of the surrounding habitats than the real value of the verges themselves.

1.9 Impact of Roads on Barn Owls

Increased mortality due to collision with road traffic has been considered a threat to the viability of local Barn Owl populations and prompted several detailed studies in Europe (Bourquin 1983, Illner 1992, Baudvin 1993, Panks 1996, 1997 and Massemin *et al* 1998). In the UK the impact of motorways on Barn Owl populations has also been reported. Of almost 3000 breeding Barn Owls reported to the national survey between 1982 and 1985, it was shown that under 0.5% of the breeding population nested within 1 km of a motorway and less than 2% within 3 km. (Shawyer 1987). Re-analysis of the national survey data during the current study indicated that less than 1% (37 Barn Owl pairs) nested within 1 km of a trunk road in England and Wales. This is something in the order of five times lower than would be predicted by chance based on the average population density found during the national survey of 2-3 pairs per occupied 10 km^2. Where this disparity becomes most significant is in clusters of squares which support some of the highest populations of between 10-30 pairs. In these areas the lack of breeding pairs within 1 to 2 km of a major trunk road or motorway is especially marked.

1.10 Dispersal and Settling

Once Barn Owls have selected a place to breed usually at about 7 to 9 months of age, they remain very site faithful rarely moving out of their home range even when their traditional nesting places have been lost or their foraging habitats destroyed. It is believed that once young Barn Owls become independent (usually in September or October) they move out of their natal areas and follow prey-rich habitats to disperse. Rough grassland is now a rare habitat on open farmland as a consequence of

agricultural intensification mainly because of high stocking rates of sheep in western districts and the maximisation of land for cereals and root crops in the east. The grassy banks of watercourses and roadsides often provide some of the only opportunities for uninterrupted dispersal within intensively farmed areas today. The importance of road verges as an aid to the dispersal of immature Eastern Screech Owls in America, has also been recognised (Loos & Kerlinger 1993). Habitat enhancement of river banks in the UK*, 'Operation Riverside Link* and part of the *UK Protection Plan for the Barn Owl* (Shawyer 1987), has been instrumental in delivering the increasing conservation status of this bird during the last decade (Shawyer 1998).

2 Methods

2.1 Selection of the Study Area

A sample stretch of road needed to be selected for this research which was relevant to the topographical characteristics of Barn Owl distribution in England (Map 2) and representative of English trunk road design, in terms of construction, verge vegetation and management.

In addition a number of essential and practical factors had to be taken into account in the selection of the road to provide the following:

- a region where previous conservation and research work would enable good and ready access to farms within 2.5 km of the road

- the presence of a Barn Owl population within 2.5 km of the road which was accessible for marking with leg rings and whose numbers and breeding/roosting locations could be firmly established

- a level of Barn Owl road mortality which would provide a sufficient number of carcasses to enable relevant analyses to be performed

- a sufficient length of continuous road which was not scheduled for upgrading during the three-year period of this investigation

- a stretch of road and verge which would demonstrate varied constructional characteristics and habitat features which would provide opportunities of evaluating these against any observed differences in the spatial and temporal levels of mortality.

2.2 Size of the Study Area

One of the requirements of this investigation was to establish the number of Barn Owls whose home range during the breeding season was likely to bring them into contact with the road. Foraging ranges rarely exceed 2 km from the nest at this time of the year (Shawyer 1989, Cayford 1992, Taylor 1994.). A land corridor 2.5 km either side of the chosen road would be required. The road also needed to be of sufficient length in order to embrace a sufficient variety of road characteristics, topography and verge habitat and also be capable of providing an adequate sample size of Barn Owls in terms of both breeding pairs and road casualties. A 50 km stretch was considered the minimum necessary to provide these needs, at the same time offering a manageable area for intensive field surveys to identify breeding pairs and in which regular road surveys could be undertaken to record and collect carcasses.

2.3 Period of Research

Number of years

Barn Owl breeding success in the UK is known to cycle at an average frequency of 3.6 years in synchrony with the abundance of the Short-tailed Vole, the main prey of this owl (Shawyer 1987). In habitats which comprise largely rough grassland these fluctuations are usually more pronounced than in areas of mixed habitat which offer a wider variety of small mammal prey (Shawyer 1994, 1998). In order to embrace the peaks and troughs in breeding success the investigation was designed to take place over a period of three years.

Time of the year

Previous work (Glue 1973, Shawyer 1987, Newton *et al* 1997, Percival 1990 and de Bruijn 1994) has established that over 85% of Barn Owls are killed on roads during autumn and winter. In order to maximise resources for this investigation, fieldwork involving the recording and collection of carcasses was timed to coincide with the seven-month period of peak mortality between the months of September and March.

2.4 Identification of Breeding Sites

Local Barn Owl surveys in Britain have shown that a combination of methods need to be employed to achieve reliable population estimates for a given study area (Cayford 1992). These surveys involve a combination of media requests, interviews with local farmers and landowners and systematic field searches during the breeding season between April and August.

To provide some idea of the potential number and potential locations of Barn Owl breeding sites which might fall within the 10-km squares traversed by the A303, records were initially scrutinised from the national database of the 1982-1985 Barn Owl Survey of Britain and Ireland where sites were mapped to an accuracy of 1 km.

During the spring months of 1995 and 1996, 110 farms and estates within the 5 km x 50 km study corridor were subsequently visited to establish the presence or absence of breeding Barn Owls. Interviews with farmers and countrymen were individually recorded. Positive sightings were followed up by specific fieldwork searches under English Nature Licence DBE 1532 to confirm occupancy and in the case of successful nest sites, to ring the young.

2.5 Gathering of Additional Information

Gathering of additional live sighting and road mortality data was achieved at two levels within the study area. *Level I* involved the Field Researcher and *Level II* involved the general public. Two further levels, *Level III* involved the Specimens Surveyor who recorded and collected Barn Owl carcasses from trunk roads and motorways in central and southern England (subsequently referred to as *'other roads'* in this report) and *Level IV*, experienced laboratory staff who undertook gross *post mortem* examinations.

Level I
Surveying A303
(Field Researcher and Assistant)

Road-surface surveys
Collection, inspection and storage of Barn Owl carcasses
Habitat mapping of road verges
Farm surveys to confirm Barn Owl breeding/roosting sites
Visits to breeding sites to ring Barn Owls

Validation research

(Field Researcher)	Random road verge surveys
	Potential impact of scavenging on carcass retrieval

Level II

Supply of Additional Data

(Public Participants)	Reporting owl casualties on A303
	Reporting live Barn Owl sightings in the study area
	Media appeals
	Collation of local weather reports

Level III

Surveying 'Other roads'

(Specimens Surveyor)	Recording and collection of intact carcasses from trunk roads and motorways elsewhere in England for post mortem examination.

Level IV

Post Mortem Investigations

(Laboratory Staff and Veterinarians)	Examination of carcasses

2.6 Level I - Surveying the A303

Road-surface surveys

Both carriageways of the entire road-surface (total 100 km) were surveyed every 48 hours, recording all road casualties larger than a small passerine such as a Blue Tit or small mammal such as a vole. Surveys were conducted between 1995 and 1998 during the months September to November and January to March.

Road surveys were undertaken from a vehicle equipped with appropriate safety equipment specified by the Highways Agency for this project and carried out in accordance with the Agency's recommended safety guidelines. This included the mounting and operation of an orange flashing beacon on the vehicle when stationary on the road verge (Dorman trafibeacon-m, conforming to BS 3143: part 2: 1990) and a *Motorway Maintenance* sign mounted on the rear of the vehicle. During road surveys a High Visibility Waistcoat was worn conforming to EN 471 Class 2.

Because of the high speed of traffic on the A303, safety was given high priority throughout the study. Trial runs in different types of vehicle indicated that a motorcycle had the advantage of offering greater peripheral vision of the highway, associated verges and central reservations and could be manoeuvred easily onto the verge at the site of a road casualty. It also offered a greater degree of safety for the Field Researcher because it could be parked easily without hindrance to other road users.

Road surveys were conducted at a constant speed of 40 miles per hour, during the early morning, commencing at about 08.00 h.

Recording of road casualties

The following details were recorded on to pre-prepared survey forms (Appendix 1) at the time of finding:

Species type:
Presumed sex and age:
Date of finding:
Presumed time of death:
Weather conditions at time of death:
Precise position - on open highway, road edge or verge:
Map reference:
Lane direction:
Verge habitat:
Condition of carcass:
Finder:

To accurately and conveniently record the findings at the roadside, often in wet weather, Ordinance Survey Pathfinder maps 1:25,000 (4 cm to 1 km) of the study stretch were colour photocopied and laminated onto eight separate sheets. The species and number of each carcass were then marked on these maps with permanent-ink marker pens.

Maps used:
Pathfinder 1260 (ST 62/72) Wincanton & Sparkford
Pathfinder 1259 (ST42/52) Langport, Somerton & Ilchester
Pathfinder 1279 (ST 41/51) Yeovil & Merriott
Pathfinder 1278 (ST 21/31) Ilminster

Two sets of maps were used. One set was laminated and used to record the current

month's casualties at the time of finding and the other set to record the three months' overall total of casualties for each study period. On finding an owl or other raptor, photographs were taken of the casualty *in situ* and of the road and the immediate verge area (Appendix 2). A habitat assessment was also made of the verge itself, the surrounding agricultural land and the grassland quality associated with any major grassland feature such as a river, stream or ditch, or other habitat corridor which was adjacent to or intersected the road at or near the place the casualty was found.

Collection of carcasses

Owls and diurnal raptors

Specimens found on the A303 were recorded in the following way: *intact, severely damaged* or *squashed flat***.** All intact and severely damaged specimens were weighed, photographed and labeled with the date, time and place of finding. Specimens were then deep-frozen for future *post mortem* examination. In those specimens which were very severely damaged or squashed, the wings and tail were removed and labeled at the place they were found to enable them to be aged and sexed in the laboratory.

Other species

All other species found during the road surveys were recorded in the same way as the birds of prey. These were not collected but removed from the highway or verge to avoid any future duplication of recording. Some specimens, which could not be removed safely when they were first located, were recorded and removed at a later date.

Habitat mapping

A number of different methods were investigated in an attempt to compile accurate maps of road verge habitat throughout the 50 km stretch of road. Aerial photographs (taken in June 1994) belonging to the Somerset Environmental Records Centre were scrutinised using a stereoscopic viewfinder which provided a three dimensional image from pairs of photographs. Habitat and verge maintenance maps of different stretches of the road, held by the Highways Agency and originally compiled for them by an environmental organisation, were also inspected.

Neither of these map sets provided sufficient fine detail to meet the current needs of this research. A habitat mapping programme was thus undertaken during the three-year study period on both sides of the A303 for the purpose of recording fine details of the type of road verge vegetation together with its extent and frequency. These micro-habitat features were then compared with the precise locations of the Barn Owl casualties which had been found (for an example - see last in Chart Sequence).

Habitat assessments were carried out using methods similar to those recommended by English Nature for Phase 1 habitat surveys (JNCC 1990). These were modified for use in habitat corridor surveys and were accomplished on foot along both sides of the A303, recording road topography (single carriageway or dual carriageway, elevated road, level road or sunken road) together with vegetation types and widths of the road verges. These characteristics were then recorded on OS Pathfinder maps, specifically enlarged for this purpose (see last map in Chart Sequence).

Habitat types were divided into the following 11 categories:

Grassland. Close mown (amenity type)
Grassland. Semi- natural (Graded 1, 2 or 3)
Sparsely planted shrubs < 2 m high & >2 m high
Closely planted shrubs < 2 m high & >2 m high
Densely planted shrubs < 2 m high & >2 m high
Sparsely planted trees
Densely planted trees
Mature tree belt

The frequencies in terms of the lengths and widths of the different verge habitat types were then analysed.

Grassland

All open areas of semi-natural grassland on the verges of the A303 were carefully graded, 1 to 3 according to the level of Short-tailed Vole activity, and hence their likely suitability for Barn Owls. Ten random 1 m quadrats were selected in each of the continuous grassland stretches. Within these quadrats grassland was graded on the basis of the number of vole nests, runs, droppings and food stores which were found. The presence of tussocks and a dead 'surface mat' or 'thatch' were the primary indicators of whether or not voles were present in these semi-natural grasslands.

Rankings were as follows:

Grade 1 - Poor quality. Evidence of one or more indicators for vole activity in 0% - 19% of quadrats. No tussock or thatch layer present, short grass and/or bare earth visible on ground surface.

Grade 2 - Medium quality. Evidence of one or more indicators for vole activity in 20%-65% of quadrats. Tussocks small and thinly distributed and shallow layer of

thatch, less than 50 mm deep, present in parts of quadrat.

Grade 3 - High quality. Evidence of one or more indicators for vole activity in 66%-100% of quadrats. Large tussocks closely spaced and a deep thatch layer, 50-150 mm deep, and present throughout quadrat.

Particular attention was paid to the recording of both natural and man-made features adjacent to the road such as rivers, streams, hedgerows, rail and road embankments, the grassy banks of which are all known to provide prey-rich foraging corridors and dispersal routes for Barn Owls (Shawyer 1987). The banks of rivers, streams, ditches and any other significant grass corridor which were bisected by the A303 were also more finely graded according to their grassland structure (ie. quality to small mammals). Broad habitat and farm type classifications were also recorded for the adjacent farmland as a means of evaluating the suitability of the wider habitat to the different owl species.

Identification of breeding/ roosting sites

One in three farms was randomly selected from the OS maps within the 50 km x 5 km corridor of the A303. Farmers and landowners were interviewed at these sites and the presence or absence of Barn Owls recorded onto standard logs (Appendix 5). All potential nest and roost sites within 500 m of the road were surveyed. Barns, sheds and hollow trees were inspected for any evidence of Barn Owls, following authorisation from the owners. To minimise disturbance, visits were undertaken late in the afternoon at the time Barn Owls are preparing to leave their nests/roosts to begin hunting. All buildings and trees which were surveyed as potential roost sites were mapped and photographed and any occupied sites recorded.

Pellet analysis

The diet of the road casualty specimens on the A303 (determined from analysis of their gut contents) was compared with live Barn Owls (determined from pellet analysis) occupying winter roost sites on adjacent farmland. Intact pellets (n=462) were collected during the three-year study period, from 10 sites within barns and beneath hollow trees.

Validation research

Random road verge surveys

In order to provide an estimate of the numbers of carcasses which might have gone undetected in roadside vegetation, 20 random sample surveys, 1 km long were selected

during each of the six survey periods (total 120 surveys). The study corridor was divided into four sectors (equivalent to two study stretch maps each). The 'eastings' were divided into 0.5 km lengths and random numbers generated from the 'westings' grid over the 50 km stretch. Surveys were then carried out on foot at these random locations. In each of the four sectors, five road-verge surveys were undertaken during each study period.

A width of between 2-5 m from the curb (dependent on overall verge width at the randomly selected location) was chosen for these searches. These were undertaken on foot, 500 metres in front of and behind the parked vehicle which was being used for the road surveys. Consistency in methodology for these road verge surveys was maintained throughout the course of the study.

Scavenging assessments

Scavenging by corvids during the daytime and by mammals such as cats, foxes or badgers at night, could potentially lead to an underestimate of the number of Barn Owl carcasses which were found and recorded (Slater 1994). Previous studies of road mortality found that scavenging of carcasses, was not uncommon (Korhonen and Nurminen 1987, Johnson 1989). A validation trial was thus undertaken on the A303. This involved laying out four fresh owl carcasses on prominent stretches of the road which were freely accessible to avian and mammalian scavengers. Carcasses were positioned adjacent to four overhead road bridges, the high vantage points enabling daily observations to be made by the Project Researcher. The carcasses were inspected over the ensuing four days, during morning and evening. This trial revealed that although two of the carcasses were partly scavenged they remained at or very close to the place they had originally been positioned. This provided the necessary confidence that owls which were being killed on the road were unlikely to have been seriously under-recorded during the road surface surveys which were being undertaken every 2nd or 3rd day during the course of the three-year study.

Rainfall and consequent wetting of the road surface was found however, to cause rapid deterioration of specimens making their recognition and location more difficult.

2.7 Level II - Supply of Additional Data

Reporting

Throughout the course of the three-year study the police, road and verge maintenance crews, local wildlife groups, rehabilitation centres (RSPCA, West Hatch), veterinary

practices, taxidermists and other relevant individuals and groups, were contacted by the Project Researcher. They were asked to notify him of any owl casualty as well as any live owls which they had observed within the study area. Recording cards, specifically colour coded for each of the three main public interest groups, were produced to enable data to be recorded in a standardised way (Appendix 1). All respondents were contacted by telephone and where their observations involved live owl sightings, specific details about the activities of the owl (foraging along the road, post hunting or flying directly across the road) were carefully recorded and analysed.

Contact was made with numerous organisations and individuals during the project. The Royal Mail delivery service was contacted to determine whether their drivers used the road during the night (a possible source of live sightings). Other lorry drivers were approached by the Project Researcher at the main service stations on the A303 to try and gain further live sightings and to record the circumstances of any Barn Owl collisions which they may have experienced.

Collection of carcasses by members of the public was discouraged because of the danger of stopping on the road. Maintenance crews and the police who had authority to do so were asked to record and where possible collect any Barn Owl carcasses which might have occurred in the 48 hour period after the Project Researcher had undertaken the road survey and during the month of December when the 48 hour surveys were not being undertaken routinely. Regular road users were also asked to provide information about any owl casualties they had observed during the month of December.

Media appeals

A poster campaign, was initiated at the start of each autumn and winter study period to draw attention to the project and encourage the public to participate with information. This involved placing prominent posters in garages and service stations along the study stretch. Within the study area posters were also placed in local village shops, post offices, cafes, on community boards and in retail farm supply outlets. The poster displayed the Project Researcher's telephone number and appealed for help from the public for sightings of Barn Owls, seen alive or dead, on or near the road.

Regular and frequent articles were also prepared and submitted to local newspapers and regional monthly magazines and contact with journalists was encouraged. As a result, the Project Researcher appeared on two local regional television programmes publicising the project and details of the study were featured regularly on local radio stations, Orchard FM and BBC Somerset Sound.

Lectures on Barn Owls and the project were given by the Project Researcher to local wildlife groups in the area. By also attending other talks at local wildlife group meetings and asking officials of the relevant group to alert members to the study, the Project Researcher was able to further increase local awareness of the project and encourage the submission of information.

Weather Reports

The Meteorological Office at Yeovilton Air Base and a nearby amateur weather station were both used as the source of daily weather reports in an attempt to determine any relationship between Barn Owl mortality and climatic conditions. Details about the weather were recorded for each Barn Owl on the night when death occurred and for the 24-hour period prior to death.

After each of the six seasonal (autumn/winter) periods of fieldwork on the A303, Study Reports were prepared summarising the methods and detailing the findings. These reports were sent to the project managers at the Highways Agency, London as a means of reporting progress of the project (Dixon 1995, 1996a, 1996b, 1997a, 1997b and 1998).

2.8 Level III - Surveying 'Other Roads' in England.

A taxidermist whose professional work involved testing new motorcycles made his extensive records of raptor road mortality for the period 1994-1998 available, and as part of this investigation, collected intact Barn Owl carcasses for *post mortem* examination. (The Department of Transport and the Regions (DETR), as part of UK licensing, required that records were kept of any species listed on Schedule I of the Wildlife and Countryside Act 1981, which are collected for taxidermy). Motorcycle testing involved about 850 miles a month on trunk roads and motorways, averaging 100,000 miles a year mainly in central and southern England (Map 1). The finding date and place of each carcass, its weight and sex, was carefully recorded.

2.9 Level IV - Post Mortem Examinations

Post mortem examination coupled with other laboratory tests were carried out on two distinct Barn Owl samples. The first comprised those specimens collected during the three-year study on the A303 and the second from trunk roads and motorways elsewhere in Britain.

Of the 102 carcasses found on the A303, 36 were sufficiently intact to allow gross *post mortem* examination. Because only intact carcasses were collected for the supplementary 'other roads' sample this provided a further 100 specimens for autopsy.

Carcasses were defrosted for 12 hours prior to being dissected and a log sheet designed for recording the finding details of each specimen (Appendix 2). The findings were compiled into specific databases (Appendix 3) to enable rapid sorting and analysis (Appendix 4).

The following examinations were conducted:

External
Each specimen was weighed and its plumage characteristics graded on a scale of 1-5 (diagram - Appendix 2) depending on the degree of spotting or flecking displayed by the bird. A close external examination was made of the eyes, ears, nares and beak and the mouth was inspected for any obvious sign of disease or haemorrhaging.

Skeleton
The wings, legs and backbone of each specimen were checked for any signs of breakage or dislocation and the skull for fractures or haemorrhage. When broken bones were revealed, evidence was sought for any associated haemorrhaging in an attempt to confirm if this was a likely consequence of the initial impact or the result of the carcass being crushed after death. Likewise evidence of haemorrhage (bruising), particularly on the head, was sought and used to confirm that impact had occurred just prior to death, and not *post mortem.*

Body condition
Body weight was recorded for each of the intact specimens both at the time of finding and after the specimens had been thawed immediately prior to *post mortem* examination. No significant differences were found between the two weights but the fresh weights were used in all calculations. General body condition, taking into account the weight of subcutaneous fat deposit around the pectoral muscles and abdomen, was graded - *high, good, average, poor* or *very poor.*

Body organs
The main body organs were examined for any obvious parasites, lesions or other abnormalities. After autopsy a section of liver was removed and tests performed for

Hepatitis and *Newcastle Disease*.

Gonads sexing and ageing

Particular attention was paid to the gonads to determine sex and their degree of maturation. The size of the Bursa of Fabricius which is situated ventrally to the cloaca was graded, *large* (10-15 mm), *medium* (5-10 mm), *small* (2-4 mm) or *not present* (zero). The bursa decreases in size and finally disappears by the time Barn Owls are about one year old (Grasse 1950). Owls which showed no sign of a bursa were recorded as adults (ie. in their first or subsequent breeding seasons). Although some birds less than twelve months old may have lost their bursa by May any error in categorising these owls as either juvenile or adult is likely to be very low since none of the road casualties in this study were collected from roads after the first week in April when surveys had already ceased.

Gut contents

The alimentary tract was removed, the contents weighed and the numbers and species of prey individually recorded. The extent of digestion was assessed visually and categorised as *early* (whole intact prey), *mid* (some obvious breakdown of prey tissues) or *complete* (prey tissues the consistency of disgorged pellets).

Plumage evaluation

In spite of some owl specimens being unsuitable for autopsy because of their severely damaged state, intact wings were removed from a further 50 of these carcasses. This increased the sample size within which ageing and sexing could be undertaken (wings were also removed and preserved from the intact specimens). Comparison of the plumage with the gonads and associated organs at *post mortem* enabled firm conclusions to be drawn about the age and sex of each bird.

3 Results

3.1 Choice of Study Area

A36 Trunk Road

The A36 trunk road which bisects a 50 km stretch of the Wylie valley near Salisbury in Wiltshire was considered a likely candidate area for this research. Past knowledge of the Barn Owl population adjacent to this road was good and its mixed design and

habitat characteristics met the main criteria for the proposed study. An evaluation of the road and general area was undertaken in 1994. This revealed that the breeding population in the valley had fallen dramatically since 1985 from an estimated 10-15 pairs to about 2 pairs. An experienced local Barn Owl specialist ascribed this loss to the recent road improvements on the A36. This mainly involved road straightening and upgrading to dual carriageway status and the consequent increase in traffic speed and the greater number of road kills were believed to have been the primary cause of the decline in the breeding population within 2.5 km of the road (Lewis pers com). The low Barn Owl population in this area thus rendered the A36 unsuitable for the proposed research.

A17 Trunk Road

A 50 km stretch of the A17 between Kings Lynn, Norfolk and Sutterton, Lincolnshire was also investigated. The road itself appeared to meet most of the criteria for the proposed research and the area adjacent to the road was particularly well-researched in terms of the Barn Owl population. Mortality was commonly reported and the road possessed many of the mixed structural characteristics required for this study. A reconnaissance in 1995 however, revealed that large sections of this road were undergoing comprehensive restructuring and upgrading which would have made surveying for wildlife casualties, difficult and inconsistent. Difficulties were also anticipated in the interpretation of the eventual results, particularly where these attempted to assess mortality levels in relation to verge habitats which were to undergo much disruption and change during the three-year study period as a result of the road re-alignments which were being undertaken.

A303 Trunk Road

A 50 km stretch of the A303 between Broadway close to the Devon border, and Wincanton, near to the Wiltshire and Dorset border, was eventually selected for this research. It met the full criteria for this investigation. From 1992 to 1994, eight Barn Owl casualties, located between Ilminster and Wincanton, had been notified to the authors by members of the public. This indicated that Barn Owls were probably being killed annually in significant numbers on this road to make the proposed investigation viable. Contact with farmers in the area as part of a recent conservation programme also offered good access to farms and estates to accomplish the fieldwork necessary to identify breeding sites, record breeding productivity and to ring Barn Owls.

The 50 km section of the A303 between Broadway, near Ilminster (ST 3215) and Wincanton (ST 7227) comprised both single and dual carriageway sections. The road

bisected low-lying farmland in largely non-urban areas which in most regions in Britain provide the optimum habitat for Barn Owls. This study area embraced a 5 km corridor of land, 2.5 km either side of the road. The road traversed a varied mix of agricultural land-use ranging from arable, grazing pasture and small blocks of woodland. It also bisected numerous river, stream and ditch systems which provide essential micro-habitats for Barn Owl foraging (Shawyer 1987).

3.2 Road Topography and Constructional Characteristics

The A303 road study stretch emerges out of the Blackdown Hills in the west on the Somerset/Devon border. It then extends eastwards and with few exceptions, lies for most of its length at between 20-50 m asl terminating at Wincanton where the land rises to its maximum of 135 m asl. Most significantly, 85% of all casualties occurred on stretches of road which were lowest lying, between 20 m asl. and 45 m asl. where the majority of the rivers, streams and ditches intersected the road.

The 50 km stretch (ie. a total of 100 km of road surface and associated verge) comprised the following constructional types: level road (26.2 km), sunken road (27.5 km) and elevated road (38.4 km) (Table 7). The number of Barn Owls killed on these different types of road were 1.07/km, 0.55/km and 1.54/km respectively, confirming that three times as many Barn Owls are killed on elevated stretches of the A303 than on sunken stretches (Table 9a).

Most of the road (84%) comprised dual carriageway and the remainder single carriageway with between 4-6 km of single carriageway present for each of the above constructional types. No significant difference was found in the proportions of Barn Owls killed on dual carriageway or single carriageway sections however, since average traffic speeds generally exceed 80 km/hr on all sections of the study stretch (speed at which significant levels of mortality are reported to occur in Barn Owls), similar mortality rates might in any case be anticipated for both classes of road.

Sunken and elevated sections of the road were both associated with the greatest widths, usually between 18-25 m whilst level sections generally ranged from 2-10 m (Table 7). Verge widths are shown in their ranges of abundance and the numbers of Barn Owl casualties recorded within each range (Table 9b). Most (74%) of Barn Owl casualties were found on or alongside verges over 5 m wide within the range, 6 m to 20 m.

The composition and proportions of the different types of verge habitat on the A303 are

shown in Figure 1 and Table 8.

Road verges also varied considerably, in their aspect (north and south facing), water run-off, depth of top soil, shrub and tree density, vegetation maturity and in their maintenance regimes. These factors were all believed to contribute to varied types of ground vegetation in terms of species and structure, which had the potential to influence relative densities of small mammals. The ranking of Short-tailed Vole activity and grassland structure was undertaken as part of the quadrat surveys.

3.3 Barn Owl Population in the Study Area

Breeding sites

Results of The Barn Owl Survey of Britain and Ireland revealed six confirmed breeding pairs within the 5-km corridor of the A303 study stretch, between 1982 and 1985. Farm surveys (n=118) were conducted during the current study. Barn Owls were recorded at 37 sites. Twenty-six of these sighting records applied to the breeding season.

Following subsequent field surveys within the study corridor, seven breeding sites were confirmed together with an additional two breeding sites just outside the boundary of the study corridor. Seven clusters of breeding season sightings which were unassociated with the nine confirmed breeding sites, suggested the possible presence of a further seven active Barn Owl territories in the study corridor.

It was concluded that an estimated 9-16 active Barn Owl breeding territories were present within the 50 km x 5 km study corridor of the A303. However, occupancy of the confirmed breeding sites appeared unexpectedly erratic between years and it was estimated that the actual breeding population in any one year was unlikely to exceed 5-8 pairs within the study corridor. Of the seven confirmed breeding pairs which were found within the 5-km corridor only one was within 1 km of the road, two were within 1-2 km and the remaining four fell between 2-2.5 km.

Winter locations

In addition to the records from the farm survey, 92 live Barn Owl sightings were reported to this investigation by members of the public on the A303 itself or within the 5 km study corridor. The majority were winter sightings on or close to the A303, most of which were not associated with the breeding territories identified during the farm visit surveys. These were assumed to comprise dispersing immature owls or adults

which can extend their home range during winter months (Cayford 1992).

Roost sites

Seven occupied roost sites in barns and hollow trees were located close to the A303. Pellets accumulated at these sites between October and February and declined thereafter indicating that these were primarily winter roosts. The build-up of pellets at these sites soon after the breeding season suggested that they were being tenanted either by adult birds from outlying breeding sites or immature birds which were in the process of dispersing from their natal areas within or outside the study corridor.

Locations of the road victims, breeding sites, roost sites and live sightings 2.5 km either side of the A303, are recorded in this report on the four sequential maps from Buckland St Mary in the west to Wincanton in the east (Chart Sequence).

3.4 Numbers Killed

The precise locations of all bird and mammalian casualties found on the A303 were systematically recorded during the three-year study period. Table 2 and Table 3 list the full range and numbers of species found dead each week during the autumn and winter periods. Table 4 provides a summary of the totals for all three years.

Animals

Between autumn 1995 and winter 1998, 1233 animal carcasses were recorded (Table 4). Birds accounted for 463 individuals from 28 different species. Mammals were represented by 777 individuals from 13 species. (Only mammals larger than voles and birds larger than tits were recorded). Of these, predatory mammals accounted for seven species. By far the most numerous were Badger (131) and Fox (104).

Birds of Prey

179 bird of prey casualties comprised the bird sample. These were represented by seven different species, of which 155 (87%) were owls. The owls included, 102 Barn Owls, 27 Tawny Owls, 16 Long-eared Owls, 10 Little Owls. Diurnal birds of prey accounted for 24 (13%) of the bird of prey casualties and comprised 13 Kestrels, 6 Buzzards and 5 Sparrowhawks (Table 1, Table 4, Map 3).

Barn Owl

The Barn Owl (102 specimens) accounted for 67% of the bird of prey victims found on the A303. This represented a seasonal mortality figure for Barn Owls of 34 road deaths

per year for every 50 km of road (0.68/km/year) or about one death per week for every 50 km of road. The only other road casualty study undertaken in England which set out to investigate owl mortality, was conducted in the autumn and winter of 1992/1993 on the Shrewsbury by-pass in Shropshire. During this period and in the first nine months after the by-pass opened to traffic, 21 Barn Owls were found dead on a 22 km stretch of this road (Law 'pers comm'), equivalent to a similar death rate of almost 1/km/year.

3.5 Seasonal and Annual Peaks in Mortality

In the supplementary study which involved the collection of Barn Owl road casualties throughout the year from other roads in Britain, 600 Barn Owl carcasses were recorded during 350,000 miles of travelling of which 350 were collected because they were considered sufficiently intact for taxidermy (Map 1). A random sample of 100 was examined by *post mortem*. Only 9% of the 600 specimens were found between April and August. This concurred with previous studies which found that about 90% of Barn Owl mortality occurs between September and March (Glue 1973, Shawyer 1987, Newton *et al* 1997, Percival 1990 and de Bruijn 1994).

Two dark-breasted Barn Owls found in Oxfordshire and possibly of the sub-species *guttata* or *affinis* (probable captive-released birds), formed part of this sample.

On the A303 the numbers of Barn Owls found dead peaked between the months of October and November.

Intact Barn Owl specimens from the combined A303 and 'other roads' samples, were subjected for *post mortem* examination and used to examine the incidence of mortality by month and the proportion of adults and immatures found dead (Figures 2a and 2b).

3.6 Age Structure

Previous workers have been able to distinguish at autopsy between immature Barn Owls and birds aged one year or more from the activity of the gonads and in the case of females the appearance of the oviducts (Newton *et al* 1990). Others have distinguished between immature and adult owls from the size of the Bursa of Fabricius which is prominent in immatures but contracts and has usually disappeared by breeding age. For the purposes of this study Barn Owls were categorised as immatures up to the end of March following the year they fledged. By April most of these owls, including first year birds, are likely to be in the process of mating when they were defined as adults.

For this study ageing was also determined by careful observation of differences in the hue and shape of the bars and speckling displayed on the primary and secondary wing feathers. Detailed explanations of ageing by this method, which takes advantage of the Barn Owl's prolonged and complex wing moult sequence, are described elsewhere (Shawyer 1998). We were able to compare the ageing results from examination of the bursa and gonad activity, with those deduced from the wing plumage. In 12% of specimens the results were in disagreement. This was ascribed to the combined difficulties of deducing the presence or absence of a bursa in those carcasses which were partly autolysed, and of accurately interpreting the often subtle variations on the wing feathers in a small number of birds

The A303 casualties (comprising 30 specimens which were sufficiently intact for examination of the bursa), were made up of 67% immatures and 33% adults. An identical proportion was found in the larger 'other roads sample'. In the combined sample, adults comprised 17% of the birds killed in the autumn, (September to November) and 42% in winter, (December to March), (Table 5).

Mortality of immature owls began in September and peaked in November, when it represented 85% of the combined age classes. By March mortality of immatures had largely ceased.

Adult mortality began in November and peaked in January/February when it represented 45% of the combined age classes, and like the mortality levels in immature owls, had declined to very low levels by March (Figures 2a and 2b).

Barn Owl mortality was twice as high in the 1996/1997 season than in the previous or subsequent season. When these birds were aged from wing plumage characteristics (severely damaged specimens) or at *post mortem* examination (intact specimens), it was shown that the increased number of owls found dead during this season comprised mainly immature birds, probably representing a high vole year and hence better than average fledging success for Barn Owls.

From these results and assuming a population of about 3350 breeding pairs in England producing on average 2.5 fledged young per pair (Shawyer 1987), it was calculated that 17% of adult Barn Owls and 24% immatures are likely to be lost from their respective populations per annum.

3.7 Mortality 'blackspots'

During each year of this investigation the precise finding location of each wildlife casualty was recorded on the A303 road map and habitat map. It became clear from these records that in each of the three year study periods Barn Owl mortality was occurring at similar locations and in distinct clusters.

For the purpose of this investigation these clusters or 'blackspots' were defined as short stretches of road, not exceeding 4.5 km in length, where exceptionally large concentrations, averaging 1.4 Barn Owls/km/year (range 1.1-1.7), were occurring during this investigation. Outside of these 'blackspots', mortality on the remaining 30 km of the A303 study stretch averaged less than 0.2 Barn Owls/km/year, almost a magnitude lower. (The cluster of 6 records at West Camel was not defined as a 'blackspot' because these casualties were found to have originated from captive-bred owls which were being released into the wild from a nearby farm during the final year of this study). This was the only site on the A303 corridor where captive-released owls were involved.

Five primary and two subsidiary Barn Owl 'blackspots' were identified on the A303. The primary ‘blackspots’ were centred on Ilminster/Whitelackington (4.5 km); Ilchester (3.5 km); Podimore (4.0 km); Sparkford (4.3 km) and Wincanton (2.0 km). The two subsidiary spots were at South Petherton (0.8 km) and Stoke Sub Hamdon (1.3 km). These seven 'blackspots' with a collective length of 20 km accounted for 84% of the total mortality during the three-year investigation. They were centred on the places where the six main rivers of the region, and their tributaries, including smaller drains and ditches; bisected the A303 (Table 6). The rivers were the Isle, Parrett, Yeo, Cary, Cam (part of the River Brue catchment) and Cale (part of the River Stour catchment).

3.8 Origins of the Barn Owl Mortality

The origin of about 75% of the Barn Owls found dead on the road was thought to be 5-10 km north in the southern parts of the Somerset Levels at West Sedge Moor, Mulceney Level, Wet Moor, King's Moor and Somerton Moor. Another potential but subsidiary feeder route was the dismantled railway line (now a grassy track) which crosses the A303 at Cartgate again originating in Wet Moor. Pudd Moor and the Blackmoor Vale, a few kilometres to the south of the road and a source of breeding population in the low-lying lands bounded by Blandford Forum, Sturminster and Shaftesbury, were the likely origins for many of the remaining casualties on the eastern stretch of the A303 near Wincanton.

In addition to these main river systems the rivers Otter, Axe and its tributary the Yarty, provided opportunities for the northward funnelling of Barn Owls from south Devon onto the A303 near Buckland St Mary where the study stretch began. This was partly confirmed by the ringing recoveries of the owl casualties on the A303 which were found to have originated in Devon.

3.9 Ringing and Ring Recoveries

Because of the difficulties of accessing young Barn Owls from some of the breeding sites (eg. in a house chimney and in a deep hollow of a tall tree), a total of only four young from two sites were ringed in 1996 and a further four young from two sites in 1997. From these only one ringed immature was recovered on the A303 during the study period, 6 km from the place it had bred.

Ringing was also undertaken on the Somerset Levels (situated 6 -15 km north of the A303) where it was believed that many of the A303 road casualties originate. From a total of 62 Barn Owls ringed on the Levels in 1996 and 1997, three were recovered as immatures on the A303 having travelled 13-14 km south of their place of ringing (see Appendix 5 for the details of ringing and circumstances of each recovery).

Barn Owls were also being ringed to the west of the study stretch in Devon from which six Barn Owls were recovered dead, four as immatures and two adults, one almost four years old and the other just over two years of age. The distance from their place of ringing in Devon to recovery on the A303 ranged between 13 and 14 km in three of the birds, 28 km in one, and 55 km and 113 km in the remaining two. Researchers have suggested that records of long distance movements which are unusual in Barn Owls, can be ascribed to birds which had been killed earlier and accidentally transported on the superstructure of vehicles before being displaced (Taylor 1994). This could not be discounted as a possible explanation for the two long distance recoveries in this investigation.

3.10 Influences of Weather

The weather conditions which were prevailing at the time each Barn Owl carcass was found on the A303 showed no obvious trend towards any particular type or extreme (Figure 3). However, in 60% of cases particularly inclement conditions, notably prolonged periods of wet or very cold weather, prevailed in the 24 hour period prior to death (Figure 4). These conditions commonly inhibit foraging at the time but encourage sustained activity thereafter, perhaps explaining this trend.

3.11 Types of Activity

Figure 5 shows the activities of Barn Owls recorded by observers on the A303 during the course of this investigation. Of the 59 observations made of live Barn Owl movements, 56% involved Barn Owls flying directly across the road. A further 42% of Barn Owls were seen on the verges engaged in deliberate and active foraging (flight or post hunting from posts or bushes). A further 2% were being mobbed by other birds

The position of the carcase in the road at the time of finding and the condition of each carcase was recorded and the results are shown in Figure 6 and 7.

3.12 Timing of Activity

During the three-year investigation the timing of hunting was recorded for 200 sightings of live Barn Owls on or within 2.5 km of the A303. Of these records 56 were on the A303 itself and 24 from adjacent farmland. The remainder was recorded from other minor roads within the study area.

A clear distinction was found in the timing of hunting on open farmland in the study area and on the A303 itself. On farmland the peak of activity confirmed the findings of previous research, peaking soon after sunset, between 16.00 and 19.00 h and declining towards midnight with a small increase of activity before sunrise (Bunn et al 1982). On the A303 however, an entirely different pattern occurred. On the roadside itself hunting activity was very rarely observed in the period around sunrise and sunset and commonly began at 21.00 h with the most activity occurring between 22.00 h and 3.00 h (Figure 8).

3.13 Feeding

In Barn Owls, three vole-sized prey items are on average consumed within a single meal. Prey is usually swallowed whole and then digested at the bird's roost. Barn Owls do not possess a crop and the food is digested and the resulting pellet formed, in the muscular part of the gizzard, the proventriculus. As in many other birds of prey, pellets containing the indigestible components of their prey such as bone, fur and feather, are ejected through the mouth. These normally contain the entire remains of the previous meal. Studies have shown that between 6-8 hours are required for complete digestion to occur (Shawyer 1998). Barn Owls rarely attempt to consume food on top of a previously digested meal (presumably this would hinder pellet ejection) such that a single pellet is usually ejected before setting forth to hunt.

Prey composition

Analysis from gut contents

The Short-tailed Vole was the most common item of prey found in the gut by both number (66%) and weight in the Barn Owl carcasses collected from the A303, Common Shrews constituted the second most common prey item (16%), Wood Mice (11%), Pygmy Shrews (5%), and House Mice (2%) (Table 10 and Figure 10). A single beetle was recorded in one bird with an otherwise empty gut.

In the Barn Owls examined from the 'other roads' sample, prey constituted: 41% Wood Mouse, 21% Short-tailed Vole, 12% Pygmy Shrew, 12% Common Shrew, 9% Harvest Mouse, 4% House Mouse, 1% Bank Vole and 1% Water Vole (Figure 11).

Analysis from pellets

Analysis of pellets collected from farmland roost sites alongside the A303 revealed a similar prey composition to that found in the guts of the road carcasses collected from the A303, with the Short-tailed Vole predominant (51%). The larger size of the pellet sample probably resulted in the detection of a wider range of species than that found in the gut sample (Table 11 and Figure 9).

Foraging success

Barn Owls collected from the A303 for *post mortem* examination revealed that 85% had one or more prey items in their gut with an average gut content of 2.0 prey items. The number of items consumed, ranged between 1 and 6 with 26% having consumed a full, or near full meal of three or more prey items (Figure 12).

57% of the Barn Owls from the 'other roads' sample had one or more items in their gut with an average gut content of 2.1 prey items each. The number of items consumed ranged between 1 and 7 prey items with 29% having eaten a full or near full meal, of three or more prey items (Figure 13).

Digestion levels

The total weight of the prey items in the gut divided by the live weights for the species concerned, less their residual weight values provided an index of digestion. Live weights were taken based on Yalden (1993) and the calculations took account of the residual weights of fully digested prey. These were determined from the weights of eight freshly cast pellets of two captive owls which had been fed on nine voles and eight mice respectively.

Digestion levels in the wild Barn Owl casualties were low, (5%-40%) in 50% of the owls; intermediate, (41%-60%) in 25%; and high, (61%-100%) in 25% (Figure 14).

3.14 Barn Owl Body Weights

In the A303 specimens, Barn Owl body weights averaged 327 g (range 286-361 g) in female Barn Owls and 300 g (range 256-366 g) in males. In the larger 'other roads' sample it averaged 322 g (range 234-388 g) in females and 305 g (range 237-352 g) in males (Figure 15). A histogram was constructed from the combined sample of 121 Barn Owls which were found between the months of September and March and from which weights were recorded to provide the average body weights from the end of one breeding season to the beginning of the next. This showed a progressive increase in both male and female weights from September to February which had levelled off by March. Weight gain in females and males over this six month period was 10% and 14% respectively (Figure 16).

3.15 Fat Levels

A combination of subcutaneous and pectoral muscle fat levels was judged to be average or above average in 81% of the combined A303 and 'other roads' specimens. The remainder, 19%, was considered below average.

3.16 Sex Ratio

From *post mortem* examination of the 36 intact specimens collected from the A303, 19 were male and 17 were female. In the sample of specimens from the 'other roads' in which the carcasses were fresh enough to distinguish the sexual organs (n=90), 41 were male and 49 were female.

Between September 1996 (the end of the breeding season) and March 1997, 29 carcasses were recovered from 'other roads' of which 22 were female (16 immature) and only seven male (three immature). Previous observations have suggested that in certain years there appears to be a disproportionate number of one sex occurring in fledglings (Shawyer 1998). These results suggest this may indeed have been the case during the 1996 breeding season.

From the 139 intact specimens of the combined A303 and 'other roads' samples, the sex of each bird was deduced from the extent of spotting or flecking on the underwing and body. When these specimens were then sexed at *post mortem*, from their gonads we

were able to show that sexing by plumage was 87% accurate.

3.17 Breeding Condition

This was determined from the combined A303 and 'other roads' specimens. This sample was of sufficient size to deduce the level of gonad activity month by month. Enlargement of the testis or ovaries did not become apparent in either sex until the month of January by which time 36% of the Barn Owls displayed active gonads. Twice as many females as males showed activity during this month. By February 57% of specimens, equally split between males and females, showed activity. Although only a few road casualties were found during March and April and sample sizes were small, almost all exhibited active gonads.

3.18 Nature of Injuries

59% of the A303 sample and 45% of specimens collected from roads elsewhere in Britain, failed to show any signs of fractured bones or other serious bodily injury although mild bruising to the head was apparent in half of these. In the A303 sample, 17 injuries (including those to the head) were recorded on the right side of the body and 17 on the left. In the larger 'other roads' sample numbers were split 33 and 39 respectively. There was no suggestion in this study that injuries were biased towards the right hand side of birds. Cooper (pers comm) had concluded in his studies that a predominance of right wing fractures in his sample was a consequence of owls having insufficient time to gain height and rise above the traffic when they emerged onto the road from the nearside verge.

4 Conclusions and Discussion

4.1 Increasing Levels of Road Mortality

An increase in the number of new roads and the upgrading of old ones (usually to dual carriageway) over the last two decades has resulted in an increase in traffic speed. This coupled with the development of faster vehicles in the late 1980's, are considered to be the main causes of the high incidence of Barn Owl road kills experienced in Britain today (Shawyer 1987). On roads where vehicles are regularly able to achieve speeds in

excess of 80 km/h over twenty times more owls are reportedly killed than on roads whose design characteristics do not permit these speeds (Ilner 1992). Traffic density itself is not necessarily associated with the increasing road death toll because this can actually lead to congestion and a reduction in the speed of vehicles.

Barn Owl road deaths appear to have tripled in Britain since the mid 1950's and since the early part of century have increased as a proportion of total mortality from 6% in 1910-1954; 15% in 1955-1969 (Glue 1971); 42% in 1963-1989 (Newton *et al* 1990) and 52% in 1982-1986 (Shawyer 1987). Even though the proportion of road deaths is likely to be biased towards those forms of mortality most readily detected by people (Ilner 1992) the upward trend is convincing and not unexpected given the major development in Britain's road network. The high number of road casualties is now believed to be responsible for decline in those Barn Owl populations which are within foraging range of trunk roads and motorways. (Shawyer 1987).

4.2 The Attraction of Roads to Barn Owls

Habitat quality

The linear grasslands associated with road verges which are largely unmanaged and characterised by thick sward and deep litter layer, are capable of supporting high densities of small mammals particularly the Short-tailed Vole. This species provides an important proportion of the diet of some predatory mammals and at least seven British raptors, including the Barn Owl. It has been reported previously that the warmth emitted by vehicles may result in an extended growing season for road verge vegetation thereby offering a hospitable micro-habitat and good over-wintering opportunities for small mammals. Verges which are often salt-loaded in winter may also retain exposed strips of grassland during periods of heavy frost or snow, increasing hunting opportunities for predators (Shawyer 1987).

During road construction the obligatory installation of fences which separate the verge from adjacent farmland also provides Barn Owls with good post hunting opportunities. Posts are known to be important to other species of raptor, such as Kestrels which use roadsides for foraging, and commonly post hunt, during winter (Shawyer 1994).

Interruption of flightpaths

Unlike the situation with some small mammals, birds and insects there is no evidence that roads constitute a physical barrier to Barn Owls. Threats from traffic are not necessarily wholly associated with roadside foraging and dispersal but because roads

can bisect home ranges of adult owls they have the potential to interrupt traditional flight paths. Death can therefore occur because the road constitutes a hazardous part of a Barn Owl's home range or because it bisects a river, stream or ditch, the banks of which offer prey-rich foraging corridors for adult Barn Owls, particularly in winter, and prey-rich dispersal routes for immature birds leaving their natal areas in late autumn.

Other factors

Owl mortality has also been attributed to carrion feeding on the road surface itself or being attracted to and dazzled by vehicle headlights when in flight (Hodson 1962, Sutton 1927, Labisky 1960). There is however little evidence in this investigation for either of these factors being implicated in any significant way for the death of Barn Owls. Wild owls for example, are very reluctant to feed on carrion preferring to go out and seek live prey even when carrion is offered artificially.

There is no real indication that Barn Owls are actively drawn to roads by the light emitted by moving vehicles. Indeed they are commonly seen hunting on verges alongside moving vehicles at night with little signs of distraction although in most cases they fly with the direction of traffic perhaps to avoid being dazzled or to 'light their way' as an aid to hunting. Being dazzled is more likely to become a factor once an owl has been struck and is attempting to recover whilst on the road surface itself, but the prey-richness of road verges is likely to be the primary reason Barn Owls are attracted to these areas.

There is currently little scientific evidence of any traffic awareness in Barn Owls. A few observers have noted that some Barn Owls appear to be flying at great height within their home range where major roads are sometimes present. However, this is probably less to do with any learned response to avoid traffic but to avoid being mobbed or to reduce acts of territorial aggression which can occasionally occur when Barn Owls are competing for a limited habitat resource (Shawyer 1994).

4.3 Population Dynamics

Numbers killed

One of the objectives of this research was to attempt to understand more about the relevance of road deaths in terms of Barn Owl population dynamics. Assuming a stable breeding population in the UK (Toms *et al* 1998) it has been estimated from the number of breeding Barn Owls in Britain and Ireland and the average number of owls which fledge from each nest, that about 15,000 die annually (Shawyer 1998).

The number of road deaths in the UK has previously been estimated at between 3000-5000 per annum, equivalent to 20%-30% of total mortality (Shawyer 1987). It has not however, been possible to establish if the Barn Owl population is being depressed by the high and increasing levels of road mortality since all or a proportion of these birds may succumb to some other form of natural death before reaching breeding age. If roads were shown however, to be responsible for a significant number of adult deaths, then it might be concluded that road mortality was likely to be a contributory factor for the species' decline in recent decades.

This investigation revealed a mortality figure of 68 Barn Owl road deaths per 100 km per year. A similar study of Barn Owl road mortality in France involving 259 km of motorway, recorded 517 Barn Owl casualties between 1993 to 1995, equivalent to 67 Barn Owl deaths per 100 km per annum (Baudvin 1993 and Baudvin *et al* 1997). On a newly opened motorway stretch in central England during 1992/1993, 95 road deaths were recorded per 100 km, equivalent to almost one victim per kilometre per year. All of these figures are higher than those reported elsewhere in Europe in the 1970's and 1980's. For example in Switzerland between 1964 and 1981, ten deaths were recorded per 100 km per year (Bourquin 1983) and in Germany from 1972-1988 it accounted for almost five deaths per 100 km on trunk roads where traffic speeds exceeded 80 km per hour (Illner 1992).

Extrapolation of the information from this investigation to dual carriageway sections of 'all purpose trunk roads' and motorways which fall within the Barn Owl's geographical and altitudinal range in England (Table 12), indicate that between September and March (when 90% of all Barn Owl mortality has been shown to occur in this and other studies), about 3065 individuals are killed every year in England. Total levels of annual mortality on England's trunk roads and motorways can therefore, be estimated at approximately 3375 individuals per annum. Based on current population estimates and breeding productivity, 17% of adult Barn Owls and 24% of juvenile owls are likely to be removed from their respective live populations each year as a result of road traffic accidents.

Seasonal mortality

Most other bird deaths from traffic occur in the spring and summer months when breeding activities increase and populations are swelled by immatures (Dunthorn and Errington 1963, Govett 1960, Johnson 1989). In Britain it was found that of the eleven most numerous bird species (all passerines), 80% of road casualties occurred between

the months of April and August (Hodson 1965). It has also been reported that the greatest number of deaths occurred on roads bordered by shrubs particularly when they are between four and eight metres high (Hill *et al* 1992). For mammals such as the Badger, and for many birds, peak mortality occurs in the spring and late summer as a consequence of increased activity associated with mating and breeding (Davis *et al* 1987). For Barn Owls the reverse is the case.

4.4 Exposure to Roads and Age Structure

Mortality of adult owls

The home range of adult Barn Owls during the breeding season (April to August) is relatively small and normally confined to 1 to 2 kilometres radius (3 km^2) of the nest within most habitat types (Shawyer 1987). Female Barn Owls remain at the nest or rarely venture far from it for a large part of this time. Barn Owls are therefore minimally exposed to roads and their associated hazard at this time of the year and is the most likely reason why only 9% of the annual mortality in Barn Owls occurs between April and August.

The home range of Barn Owls although small in summer often extends up to 3 - 5 km in winter. This increase in range size which is often coupled with the occupation of new outlying roost sites, is thought to reflect the decline and more patchy distribution in the food supply as vegetation dies back (Cayford 1992) and the reduced need to deliver prey, defend the nest and guard mates.

Although the food requirements in winter are not nearly as high as they are during the breeding season, the energy demands needed to support the associated increase in metabolic rate, can be significant. These extra food needs during winter are likely to bring many adult Barn Owls into closer contact with roads which were previously outside the limits of their home range in summer, thus increasing their exposure to traffic. In years when winter conditions are particularly harsh (low vole years, cold/snowy winters) adult Barn Owls may need to forage harder and may be tempted even further afield. Even those owls with nesting territories some distance from a major road may become increasingly exposed to road accidents in harsh winters. The accumulations of pellets, many of which were only found in barns alongside the A303 during winter, are undoubtedly a partial consequence of the range extension of adult owls at this time. Indeed it is possible that these roosting sites near roads are actively sought by owls to enable them to maintain station in winter near these prey-rich verges. With only a single pair of Barn Owls breeding within 1 km of the A303, (the distance

in which most summer foraging occurs), the high proportion of adults killed during this study was initially of some surprise. However it is likely that these adults are those which bred outside the 1 km band and have succumbed as a result of their need to extend their foraging ranges during the winter. Since only seven nest sites were confirmed within the 2.5 km of the A303 during this study, indications are that the adult birds killed on this road were those which were associated with the breeding territories situated at the outer edges of the study corridor.

Trunk roads and motorways in Britain which traverse potential Barn Owl habitats are unlikely to sustain Barn Owls which attempt to breed within 1 km. A proportion of owls which breed up to 5 km away are also likely to be at additional risk by virtue of range extension in winter.

Mortality of immature owls

In September when the majority of young Barn Owls have fledged, an average of three per successful nest (Shawyer 1987) the population in the UK increases about 2.5 times. These immatures begin to move away from their natal areas in August and September and have usually established their own breeding territories by January/February where most remain for the rest of their lives (Shawyer 1998). Recent analysis of ringing data has shown that the median distance for natal dispersal in Barn Owls is 12 km. When these data are analysed further, dispersal distances are 3 km, 10-40 days post fledging from mid August to mid September, rising to 7.5 km 40-70 days post fledging from mid September to mid October and 12 km, 70-100 days post fledging from mid October to mid November. Ringing recoveries also suggest that the dispersal of young Barn Owls is largely completed within the first four to five months after fledging (usually by the end of January) and that movement largely ceases after January and thereafter during the birds' lifetime (Wernham in prep).

Since 1988, dispersal patterns in Barn Owls have been investigated by the principal author of this report. This has involved about 220 hours of observation and is coupled with a programme which began in 1998 aimed at re-capturing breeding adults which were previously ringed as young in the nest. This has confirmed that rough grassland corridors particularly those associated with the banks of rivers, streams and ditches, are a critical habitat feature for dispersal in this species, especially in areas where agricultural intensification or urbanisation has resulted in the disappearance or fragmentation of larger expanses of grassland (Shawyer 1987). Linear rough grasslands are being used as part of a habitat restoration plan for the Barn Owl in the UK. Since 1988 this programme, *The Farmland, Riverside and Forestry Link Initiative*, has been responsible for the widespread re-establishment of habitat continuity on riparian banks,

has aided dispersal and resulted in significant increases in the breeding numbers of this bird. In the UK road verges offer a network of prey-rich linear grassland similar to banksides (although hazardous) for the dispersal of young Barn Owls (Shawyer 1987).

4.5 Viability of Barn Owl Populations

This investigation has indicated that 33% of the Barn Owls killed annually on roads are adult birds whilst 67% are juveniles. Based on the current breeding population of 3800 pairs in England and Wales producing about three young per pair with levels of road mortality of 3375 individuals this would represent an estimated 17% loss of the live adult population and 24% of the immature population each year.

The loss of immature birds from vehicle collisions may not be considered sufficiently large to contribute to any long term decline in the Barn Owl population in the UK since a proportion of these birds is likely to have succumbed later in the year to other natural and unnatural causes.

The 17% loss of the adult breeding population each year to road mortality may be more significant however but estimating the overall impact of roads on the Barn Owl population in Britain is however, both difficult and complex since any losses to mortality may be offset by the extensive dispersal and foraging habitat provided by the Highways Agency's soft estate and hence the positive contribution this makes to the overall carrying capacity for Barn Owls in Britain.

Given the distribution and amount of suitable habitat on farmland (whole fields/field boundaries and potential nesting sites) it was estimated that in the absence of any road hazard, a breeding population of at least 25 pairs could be supported in the 5 km x 50 km corridor adjacent to the A303. In the event only 5-8 breeding pairs were present. The great scarcity of Barn Owl breeding sites within 2.5 km of the A303 suggests that in spite of the high level of potential recruitment of young Barn Owls into the area, evidenced by the high numbers found dead on the road, the breeding population remains low because the high levels of mortality exceed the breeding productivity.

Even for those breeding adults whose home ranges in summer are outside the 2.5 km band, mortality increases significantly in winter as foraging ranges are extended to take in the road. In local terms therefore, this may result in a lowered life expectancy of adults and the failure of communities breeding within 5 km of the road to attain their real potential in terms of population size.

This supports the previous findings of the Barn Owl Survey of Britain and Ireland. The research demonstrated that of the total of 2700 breeding records logged between 1982 and 1987 only 38 were located within 1 km of a major trunk road or motorway (Shawyer 1987). This survey concluded that populations had been permanently depleted on farmland close to major roads in Britain because their breeding productivity was insufficient to match the levels of road mortality.

Because of the widespread and complex road network it is likely that there are many places in low lying districts of Britain where the carrying capacity for Barn Owls has been reduced by roads and where Barn Owl populations are now unable to achieve their full breeding potential.

4.6 Sex Structure

Although the proportions of male and female deaths found in this study were close to unity the high proportion of female (82%) deaths which occurred in the autumn, especially during November (in both the A303 and 'other roads' samples) may be because immature females are believed to disperse greater distances than immature males (Taylor 1994). This may place female Barn Owls at greater risk because they are potentially exposed to traffic for longer periods than immature males at this time. The high incidence of females in autumn mortality figures has been observed elsewhere in Europe for Barn Owls (Massemin 1998) and in Tengmalm's Owl *Agolius funereus* (Soncrud *et al* 1998).

4.7 Road Design Characteristics, Predisposition to Mortality and 'Blackspots'

A major difference was found in the proportions of Barn Owls found dead on the different types of road. Proportionally three times as many owls were found on the elevated sections of the A303 (and twice as many on the level sections), than on the sunken stretches. This suggests that sunken roads which are located in cuttings, encourage Barn Owls which are crossing the road to maintain height above the road thereby protecting them from collision. Elevated road sections on the other hand predispose to much higher levels of mortality because the owls maintain their existing low level of flight as they cross (1-3 m above ground level represents their typical flight pattern).

For Barn Owls which are using the verge for dispersal and foraging however, all three road types are likely to result in similar levels of mortality and this too appears to be

supported by the findings of this investigation.

Previous studies have shown that birds in general and Barn Owls in particular, are commonly killed at particular places on roads which may reflect habitat preferences or crossing points because of some particular feature of the terrain (Finnis 1960, Dunthorne and Errington 1963, Shawyer 1987).

Barn Owl carcasses appear each year on the A303 (and on other low-lying trunk roads and motorways throughout England), with great regularity between the months of September and March. The distribution of casualties along roads is rarely random usually occurring in most years at specific locations over relatively short stretches. The 'blackspots' found in this investigation were similar to those on the A303 in 1993/4 when mortality was intermittently recorded by the Hawk and Owl Trust as part of a regional conservation programme in south west England (Sperring pers comm).

These 'blackspots' coincide with the places where the road is at its lowest altitude, between 20 -50 metres asl. Here roads in general are more likely to be intersected by ditches, dykes and streams, the grassy banks of which offer both rich and continuous foraging habitat for Barn Owls. In the absence of suitable grassland elsewhere on farmland these habitat corridors can provide an abundance of small mammal prey. These constitute the catchments of major rivers and tributaries and have the potential to funnel birds from outlying districts, onto roads at set places. Farm tracks and disused railway lines, when these are associated with rough-grassland edges, can also act in a similar way although they are often less continuous and less numerous than riparian features. Intersecting smaller roads when these too possess rough grassland verges, can also contribute to the funnelling of Barn Owls onto larger roads, and the numerous live sightings recorded as part of this study on the A37, A358, A359, A371, B3151 suggest that these roads may also contribute to the movement of birds towards the A303 itself.

It was concluded therefore, that immature Barn Owls dispersing from their natal areas and adults attempting to increase their foraging ranges in winter, appear to be routed on to the A303 mainly via the major rivers in north Somerset which are sourced by the often complex network of ditches and streams which bisect the A303 itself. On arrival at the A303 Barn Owls appear to divert from the grassy banks of these natural feeder corridors to hunt and disperse along the prey-rich verges of the road itself. The association of Barn Owl 'blackspots' with rivers and the prime prey-rich foraging habitats associated with their rough grassland banks was not unexpected and was supported by the results of the Barn Owl Survey of Britain and Ireland which identified

that 82% of the breeding sites recorded during this survey were located within 1 km of a river, stream or main drain (Shawyer 1987).

4.8 Barn Owl Movements

Although the movements of immature Barn Owls in Britain (Wernham *et al* in prep.) and elsewhere in Europe (de Bruijn 1994), demonstrate no noticeable directional pattern, the presence of certain topographical features such as large areas of water and high ground can limit the movement of Barn Owls and the places they finally settle and breed (Barlein 1985, Frylestan 1972). In the UK for example, 92% of the breeding population nest below 150 m with 81% below 100 m (Shawyer 1987) (Map 2). In particular topographic features such as high ground inhibit movement and influence the dispersal routes of young birds with Barn Owls funnelling through valleys and gaps between hills where these exist (Shawyer 1998).

The A303 traverses a low-lying region of land in south west England with its limits defined by the Blackdown and Brendan Hills in the west, the Mendips in the north, and the elevated chalk downlands of Salisbury Plain in the east. The main concentration of breeding Barn Owls in this part of south west England lies in the Somerset Levels to the north. The offspring of the Barn Owls which breed here are largely restricted from dispersing northwards (except through a narrow valley through the Mendip Hills through which traverses the M5) and westwards because of the high ground which surrounds them on these two sides. The rivers and streams which feed the Somerset Levels have their source close to the A303 and flow into the Rivers Yeo, Cary, Parrett and Brue with their confluence 20 km to the north between Langport and Bridgewater eventually flowing into the sea at Burnham. The greatest opportunity for dispersal is southwards along the banks of these rivers which emerge out of the Levels. These rivers and their associated tributaries and ditches eventually bisect the A303 at numerous places thereby providing important entry routes for Barn Owls onto the road itself.

Concentrations of Barn Owl casualties found on the eastern edge of the study stretch around Wincanton, probably have their source via the River Cale which flows into the Blackmoor Vale to the south of the road via the River Stour where an enclave of Barn Owls exists in an area of low-lying land bordered by Blandford Forum, Shaftesbury and Sturminster.

4.9 Verge Habitat Features and Mortality

The frequencies in terms of the length of each of the 11 different verge habitats on the A303 were mapped and analysed to an accuracy of +-5 m (see example - last of Chart Sequence). Although Barn Owl mortality was concentrated along particular stretches of the A303, the specific points where the vast majority of victims were found could be linked to places on the road verge where continuous lengths of open rough grassland are abruptly interrupted by an unfavourable habitat type. This commonly involved a belt of bushes or trees or at a spot on the verge where a road or bridge intersected a stretch of grassland. It is at these points that Barn Owls in an attempt to skirt these interfaces which are likely to be seen as an obstacle to hunting, are believed to be at their most vulnerable, straying onto the road itself and into the path of vehicles.

4.10 Food and Activity

Prey

The prey spectrum of both the road casualty Barn Owls and of the live birds (from pellets collected within 2.5 km of the A303) was very similar to that found in previous pellet studies in Britain conducted on low-lying farmland during winter. This suggested that the A303 provided no special opportunities in terms of prey type although the quality of these edge habitats probably offered higher than average densities of small mammals.

The prey spectrum in the 'other roads' sample was different with Wood Mice assuming a much higher proportion of the diet than that seen in the A303 birds. This could not be explained by any temporal variation and was most likely to be a reflection of the different finding pattern of the 'other roads' specimens, most of which came from midland and central southern England where Wood Mice have previously been recorded as a more common component of the diet in Barn Owls (Burman unpub, Shawyer 1998).

Hunting times

Barn Owls normally leave their daytime roosts and begin foraging at about sunset (Bunn *et al* 1982). The duration of hunting is then largely dependent on the abundance of potential prey and the ease with which it can be captured. Capture rates can be influenced by many factors, particularly the state of the vole cycle and the condition of the weather, frosts and snowcover can for example, inhibit the activity of small mammals whilst strong winds and prolonged rainfall can disrupt hunting.

In winter the numbers of many small mammals decline and this coupled with the more

patchy distribution of suitable habitat as a result of vegetation die-off, often means that hunting can be prolonged and extend well into the night and early morning. In situations where prey is very scarce daytime hunting can occur and this is not only confined to the winter period but to the summer period too when large and hungry broods of young demand more food than can often be gathered during the hours of darkness.

In previous research the very high incidence of mortality in Barn Owls during winter has been attributed to the fact that optimum foraging for Barn Owls (around sunset and sunrise), coincide at this time of the year with the peak in commuter traffic, normally about 17.00 h and 7.00 h. (Massemin *et al* 1998).

In winter the highest traffic densities on the A303, and on trunk roads in Britain generally, occur at or around sunset and sunrise when people are commuting to their workplaces. The high density of fast-moving traffic at these times creates a constant high level of background road and engine noise which is likely to seriously disrupt the ability of Barn Owls to detect the movements of small mammals within road verge vegetation.

This research has indicated that Barn Owls largely avoided foraging on the A303 during the first and last few hours of darkness (16.00-20.00 h and 7.00-9.00 h) which, during late autumn and winter, coincides with the period when commuter traffic is at its peak. The low number of live sightings recorded on the road at these times, which is in direct contrast to those recorded on open farmland, is likely to be a consequence of the Barn Owl's inability to distinguish between the high background noise level emitted by traffic and the sounds of small mammal movements in road verge vegetation. Southern (1954) concluded that hunting in Tawny Owls can be similarly disrupted in woodland when the sound clues normally emitted by small mammals are drowned out by the background noise of heavy rain falling on the woodland floor.

Foraging activity on the A303 peaked around the hours of midnight, between 22.00 h and 3.00 h at a time when traffic movements are relatively low and road noise intermittent. However the increased proportion of high-sided vehicles such as lorries travelling at this time of night and at high speed in the absence of congestion, is likely to be the ultimate cause of the high level of Barn Owl mortality on British roads.

Excessive road noise is considered a serious human nuisance and the development of quieter road surfaces is considered a high priority by the Highways Agency and are being specified in future maintenance contracts as a matter of course (Highways

Agency 1998, in press 2000). A stretch of motorway on the M65 has recently been resurfaced with specially formulated tarmac designed to reduce noise levels and surface spray (The Guardian 1999). It was claimed by the Agency that this noise reduction trial was being undertaken to encourage owls to hunt road verges more successfully. Although the seriousness of the Guardian report is difficult to assess, the findings in this report would draw quite the opposite conclusion, since during times of peak traffic flow and in the absence of high road noise larger numbers of owls are likely to be drawn to hunt road verges with a consequent increase in owl mortality.

Activity patterns

Although large birds such as the Barn Owl are likely to be found dead on the road surface near to where they were hit (and are often squashed flat near to the point of collision), the finding details of corpses ie. in the gutter, middle of the road or central reservation, are beset with difficulties when trying to interpret what the owl was doing just prior to death. It might be concluded that those found in the centre of the road or near the central reservation might have been flying across the road rather than hunting the verges but equally those found near the gutter may also have been in the process of crossing. Behavioural observations recorded showed that almost 50% of Barn Owls were actively hunting on the verge, parallel to the road itself or on posts where the verge adjoined the farmland, the remainder were crossing the road in direct flight.

From the significantly large number of Barn Owls which were found without any sign of fractures or other major injury, except in some cases light bruising to the head, it was concluded that the majority of these birds were probably flying alongside the road and were caught in the turbulence created by high-sided vehicles and rather than being struck, were catapulted onto the road surface when they eventually succumbed to the effects of shock and hypothermia. For the remainder with fractured bones, there was a greater likelihood that they were hit as they flew across the road. Only four observations were made of owls being injured by high-sided vehicles during this study. In all cases they were diagnosed as having mild concussion and were all successfully rescued and rehabilitated.

Significant proportions of Barn Owl casualties which are found annually on roads and are taken into wildlife rehabilitation centres in Britain, exhibit no obvious signs of injury. After basic veterinary care which generally involves administration of fluids and warmth, many of these owls recover and are rehabilitated successfully (Dewar pers comm.) and veterinarians conclude that most were suffering from the effects of shock and reduced body temperature, rather than any major physical injury. These observations lend further support to the idea that many Barn Owls do not collide directly with vehicles but become disrupted in their slipstream, eventually dying from

the effects of shock which in winter is likely to be accompanied by hypothermia.

The public commonly report to organisations involved in the research and conservation of wildlife that they have observed owls sitting on the road surface. The reason for this unusual behaviour has previously been difficult to comprehend but may support the idea that this behaviour is the result of temporary debilitation following the effects of turbulence, disorientation and shock.

Foraging success

The gut contents of the Barn Owls recovered from the A303 indicated that the majority (75%) had caught one or more prey items and been hunting successfully, probably along the verge itself up to the time of their death. Those with full or near full guts were probably flying back to their night-time roosts when they were killed. The remainder with empty guts were probably in the early stages of hunting the verge or were in the act of crossing the road, en route to their feeding grounds when they were struck.

The 'other roads' sample showed a different pattern with only 57% of the birds with one or more prey items in their gut. The higher proportion of Barn Owls with empty guts in this sample was mainly inflated by the carcasses collected during the 1994/1995 winter. This was much harsher than any of those experienced during the following three winters when carcasses on the A303 were collected. The higher incidence of empty guts may have been the consequence of the greater difficulties in finding prey during this particularly harsh winter. When the1994/1995 birds were removed from the 'other roads' analysis, 69% had one or more prey items in their gut, not dissimilar to the A303 findings.

4.11 Quality of Barn Owls Killed

Debate has previously centred around whether or not road casualty Barn Owls represented a true cross section of the healthy live population or were 'poor quality' birds which had been drawn to roads and were destined to die anyway because they were either sub-standard or were young birds which were not yet part of the breeding population. This has important repercussions on the likely impact that road deaths may have on the breeding population in Britain and for the declining numbers which have been observed since the 1950's.

Poor body condition may predispose Barn Owls to accidents if it leads them to spend

more time having to hunt, hunting in places where accidents are more likely such as road verges, or renders them less able to avoid collision. It has been suggested that poor quality birds are in the main the ones which succumb to collision and that road accidents are a secondary cause of death. If this were the case they are less likely to represent any real loss from the breeding population since they were likely to have died from other causes before reaching breeding age (Taylor 1989, 1994). Other workers who have researched this subject dispute this finding because, following autopsy of significant numbers of road casualty Barn Owls, they were able to conclude that most were within the normal weight range with no obvious signs of disease (de Bruijn 1994, Poprach 1996, Newton *et al* 1997).

Body mass

Weight is generally considered a good indicator of body condition in birds and in Barn Owls can vary during the year. Female weights are believed to increase as the breeding season approaches while in males weight is thought to be more constant throughout the year. In this investigation body weights for both male and female birds were within the normal range for the month that they were killed (Shawyer 1997) and perhaps surprisingly, none of the specimens fell below the starvation level of 227 g reported for Barn Owls by Shawyer (1987) for the combined sexes, or by Newton *et al* (1991), who differentiated between male (240 g) and female (250 g) starvation weights and found in his sample that 4% of male and 7% of female trauma victims were below these weights.

Weight change in both males and females showed a similar level of increase as the months progressed from September to March but the more dramatic increases found by Taylor (1989) in live Barn Owls in late winter and early spring were not apparent from the findings of this research.

Fat levels

Abdominal and subcutaneous fat deposits are a particularly good and perhaps even better indicator of quality although in healthy Barn Owls these are never high. For the majority of the road casualty specimens fat deposits were graded *good* or *very good*. Even in those Barn Owls which displayed relatively low body weights, fat deposits were usually graded *good*, suggesting that they were probably healthy birds at the lower end of their weight range.

Gonad activity

Ovarian activity which became apparent in January in almost half of the female specimens collected indicated that a significant proportion of Barn Owls come into

breeding condition 16-20 weeks prior to egg laying. By March almost all were in condition. Males showed a similar pattern, with testes in about 20% of birds showing activity in January, 50% active by February and the majority active by March. In males testicular activity was apparent in all of the Barn Owls found during July, August and September, suggesting that some males may remain in breeding condition throughout the breeding season in readiness for the fertilisation of any females which remained in sufficient condition to attempt a second brood.

4.12 Weather Conditions

The majority of Barn Owls (70%) were found dead on those nights preceded 24 hours earlier by heavy rainfall or periods of low temperature rather than when conditions were mild and dry. The foraging success of Barn Owls is known to be negatively influenced during wet conditions probably because wet plumage hinders flight hunting, small mammals tend to go to ground and the sound clues they normally emit become drowned out in saturated grassland. During cold periods too, Barn Owls tend to conserve energy by reducing their flight hunting in order to maintain their increased metabolic rate and small mammals may reduce their output for similar reasons. The higher levels of mortality which appeared to occur following those nights when conditions were particularly harsh were possibly a consequence of the need to extend their hunting periods (thus increasing their exposure to traffic) to make up for the low capture rates the previous night.

4.13 Winter Severity and Small Mammal Numbers

During the three-year study, winters were all comparatively mild so that there was little chance of establishing if the annual levels of road mortality were positively correlated with the winter severity. A doubling of the numbers of dead Barn Owls was apparent however, in the 1996/1997 autumn/winter. This could most easily be ascribed to 1996 being a year of high vole numbers. This resulted in a high level of nest site occupancy and breeding productivity throughout much of England and the consequent recruitment of high numbers of immature Barn Owls into the population later that year (Shawyer 1998). Since vole populations tend to cycle every three years it is likely that road deaths on the A303 and probably in England as a whole, will assume their next peaks during the autumn/winter of 1999/2000 and 2002/2003.

4.14 Other Birds of Prey

The numbers of the other six species of bird of prey found dead on the A303 during this investigation have already been documented in this report. The frequency of road casualties was nine times greater in the Barn Owl than in any other bird of prey in spite of the fact that it is the least common of the seven species found. This is undoubtedly reflected in the Barn Owl's need for specialised habitat requirements for feeding and dispersal coupled with its low-level method of foraging.

The Tawny Owl whose population in England outnumbers the Barn Owl about twenty-fold, was only an occasional victim on the A303. This was undoubtedly a consequence of its preference for woodland habitat which was uncharacteristic of the land adjacent to this road. Tawny Owl carcasses were found on discrete stretches of the A303 where trees were situated close to the road edge and probably offered good opportunities for still-hunting from branches. The highly sedentary nature of this owl in both summer and winter also means that only pairs with woodland territories very close to the road would be at risk. In other places where trees border roads, Tawny Owls can be a much more common casualty.

The Long-eared Owl was also a relatively frequent and surprising victim but like the Barn Owl has a high preference for hunting open grassland. The high levels of Long-eared Owl mortality during the winter of 1997 (December to March) coincided with a year of winter immigration from Scandinavia and other parts of Europe and rather than involving resident birds, were possibly those which were in the process of returning from their wintering areas in south west England to their breeding grounds abroad.

For all species of owl (except Little Owl) deaths occurred year upon year on particular stretches of the A303, where habitats on adjacent farmland presumably favoured their particular foraging and nesting needs (Map 3).

The Kestrel is the most common bird of prey in south west England and in Britain as a whole. This raptor which commonly feeds on small mammals and insects on road verges was a relatively uncommon casualty. Specimens were randomly distributed throughout the 50 km stretch of the A303 and showed no noticeable concentrations or 'blackspots'. The specialised hunting methods of the Kestrel which often involves hovering above the height of traffic rather than adopting the quartering low-level flight of Barn Owls, makes them much less vulnerable.

Buzzard deaths may be partly ascribed to scavenging from the road surface but

observations made during this study suggested that most were killed when alighting from roadside posts (sometimes in the process of being mobbed), into the path of vehicles.

Sparrowhawks, which chase smaller birds in low level flight over farmland (and across roads), were an uncommon casualty and once again showed no particular concentrations on the 50 km study stretch of the A303.

5 Recommendations

5.1 Specific

Reducing the attractiveness of road verges as foraging places

In the past recommendations have been made in the UK and abroad, that rough grassland on road verges should be removed in an attempt to reduce its attraction to Barn Owls.

The findings of this investigation suggest that it is neither favourable nor practical to eliminate rough grassland on the verges of trunk roads and motorways through frequent mowing or the saturation planting of bushes and trees. To discourage Barn Owls from feeding on road verges these measures would have to occur over long distances. This is likely to reduce the conservation value of road verges to those other animal and plant communities which are dependent on semi-natural grassland, and have a negative impact on the visual amenity value they provide to the travelling public in open landscapes and be contrary to protected landscapes and the legislation concerning them.

Likewise it would be impractical to plant high tree screens along extensive stretches of road to encourage owls to fly over the tops of vehicles when crossing. However the establishment of short but continuous lengths of high bushes or tree screens specifically at those places where Barn Owls are known to cross regularly or at those locations where 'blackspots' have been identified can be valuable in mitigating the impact of mortality (Design Diagram 2).

Establishment of uninterrupted flightpaths on verges

Because Barn Owls face minimal danger from traffic when confining their hunting activities to wide grass verges it is recommended that these grasslands should be

continuous and not interrupted by the planting of impenetrable blocks of dense trees or shrubs which can encourage foraging owls to move out into the road in an attempt to skirt these habitat barriers (Design Diagram 1). Where dense plantings of trees or shrubs already exist on lengths of otherwise uninterrupted grassland on verges, a swathe of grassland 2 m or more wide should be cut through the centre of these existing 'barriers' to maintain safe flightpaths in an attempt to discourage Barn Owls from moving off of the verge and into the road.

Establishment of diversion corridors

It is recommended that the grassy banks of rivers, streams and ditches (and grass-lined tracks) identified in this study as important dispersal routes for Barn Owls onto the A303, are managed within 50-100 metres of the road in such a way as to reduce small mammal densities (close mowing etc). Diversion corridors of rough grassland on farmland parallel to the road should then be created from the ends of these existing linear habitats at least 100 m from the road, to encourage more Barn Owls to utilise these new pathways rather than becoming attracted to the road verge itself.

Provision of artificial nest sites

A comprehensive programme of nestbox provision should take place on these diversion corridors, in an attempt to halt the dispersal of immature Barn Owls from outlying areas and provide greater opportunities for these birds to settle and nest before reaching the road and its associated hazard. A trial scheme involving nest boxes on trees or poles should be undertaken adjacent to the five main mortality 'blackspots' which have been identified in this investigation. This trial should be scientifically monitored to establish the potential of these measures for mitigating the impact of Barn Owl mortality on the A303 with the aim of introducing them elsewhere alongside Britain's major roads, if success is proven.

5.2 General

The targeted programme of major road scheme improvements in Part III of *A New Deal for Trunk Roads in England* (1998) and *An Introduction to The Highways Agency* (1999) indicates a number of roads where significant road upgrading is proposed over the next few years. Many of these are within areas which already hold breeding Barn Owls or where significant conservation effort has already taken place or is taking place for this species (part of the *Species Action Plan*). It is recommended that when impact assessments are conducted on these proposed schemes that Barn Owl surveys are given high priority and that the authors of this report are consulted to provide advice.