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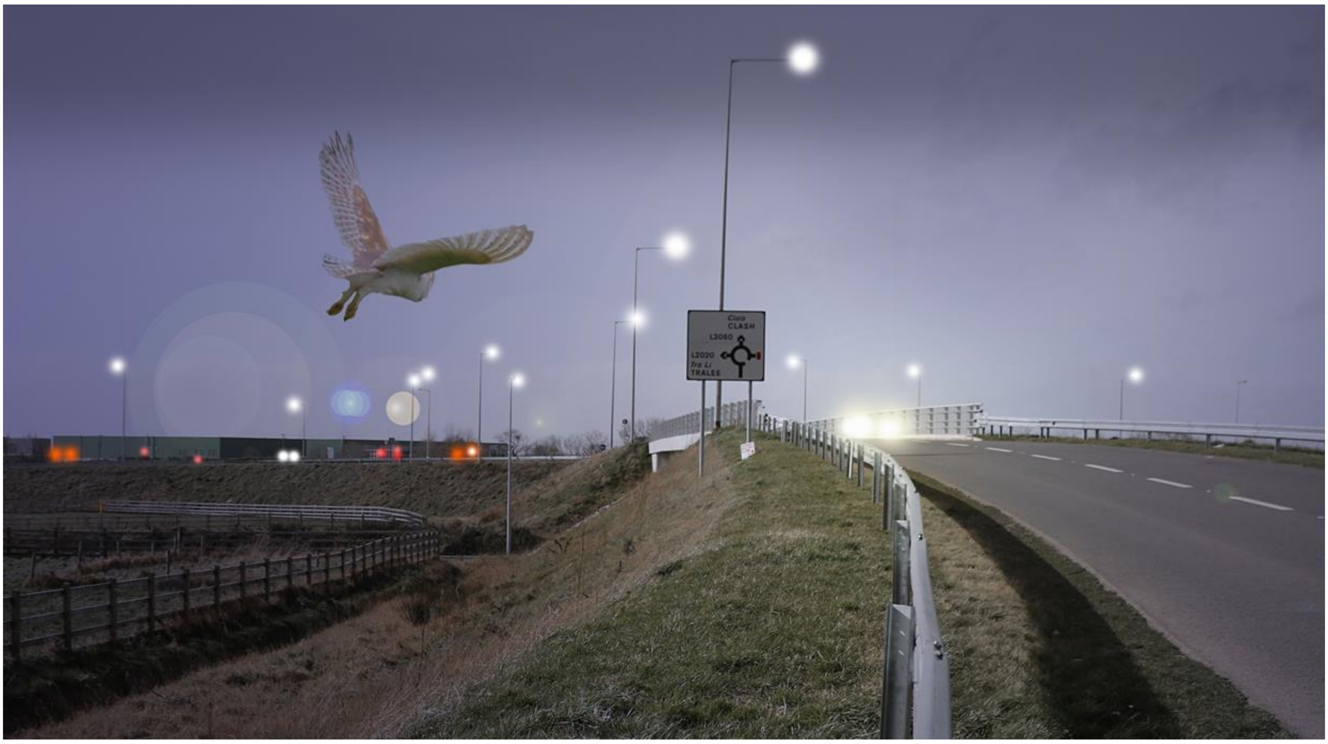
Barn Owl population status and the extent of road mortalities in relation to the Tralee Bypass



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EXECUTIVE SUMMARY

Barn Owls in Ireland and the potential impacts of major roads

- The Barn Owl population in Ireland has suffered extensive declines in distribution and abundance over the past 40 years (Balmer *et al.* 2013, Colhoun and Cummins, 2013).

- Due to their hunting behaviour, low flight and poor peripheral vision, Barn Owls are particularly susceptible to collision with vehicles (Illner 1992, De Bruin 1994, Massemin and Zorn 1998, Ramsden 2003, Boves and Belthoff, 2012). Several studies to assess avian mortalities on roads have recorded Barn Owls to be the most frequently affected raptor (Massemin and Zorn 1998, Shawyer and Dixon 1999), or the most frequently affected bird species (Baudvin 1997, Boves and Belthoff, 2012). It is estimated that new major road developments in the UK cause the loss of all Barn Owls within 0.5km, and severe depletion of populations within 0.5 to 2.5km of the route (Ramsden 2003). Mortality on major roads has been implicated as a contributing factor in the decline of Barn Owl populations in parts of Europe and North America (Illner 1992, De Bruin 1994, Massemin and Zorn 1998, Ramsden 2003, Boves and Belthoff, 2012).

- Barn Owls have been routinely recorded as road casualties throughout Ireland, which is the most frequent recorded cause of death (Lusby *et al.* 2013). The expansion of the road infrastructure has therefore caused concern that mortality on roads may be a contributing factor to the Barn Owl decline in Ireland. However there remain significant gaps in our understanding of the extent of road mortalities, the factors which influence risk of collision and the overall impacts of road mortalities on Barn Owl populations in Ireland which is necessary to inform the requirement for and direction of mitigation.

Proposed mitigation for Barn Owls on major roads

- To reduce wildlife mortality on roads, a range of mitigation measures have been proposed which focus on altering motorist behaviour or altering the behaviour of wildlife which encounter roads (Glista *et al.* 2009, Santos *et al.* 2015). Understanding the factors that influence mortality on roads is vital for developing effective mitigation for avian populations and for making appropriate management recommendations (Clevenger *et al.* 2003).

- A range of factors have been shown to influence risk of collision on major roads for Barn Owls which include the speed of road traffic, presence and width of roadside grass verges, adjacent habitat features and elevation of the route (Illner 1992 Baudvin 1997, Shawyer and Dixon 1999, Taylor 1994 Massemin and Zorn 1998). Proposed mitigation measures involve the use of natural or artificial screens to deflect the flight path of Barn Owls above the height of traffic, or management of the grass verges to reduce their suitability for foraging Barn Owls (Shawyer and Dixon 1998, Ramsden 2003). There are however potential health and safety and engineering considerations which may conflict with the application of these mitigation measures on a site specific basis, and the effectiveness of these measures have not been adequately assessed. It is clear that there remains the need for evidence-based mitigation measures which are proven to be effective in reducing Barn Owl mortality on major roads and which are also compatible with relevant environmental, engineering, road design and economic constraints.

The Tralee Bypass

- The N22 Tralee Bypass links the N69 Listowel Road with the N70 Killorglin Road via the N21 Limerick Road. It consists of a route length of 13.5km, of which 8km is a 'Type 2 Dual Carriageway', with a separate access route for the N22 Killarney Road which is a 'Standard two-lane single carriageway' of 5.5km. The Bypass was opened to vehicles in August 2013.

- Within a period of seven months (August 2013 to March 2014) from when the Bypass was opened to traffic, three Barn Owl road mortalities were recorded on the Bypass.

- County Kerry is a stronghold for the endangered Barn Owl population in Ireland, with the highest proportion of known active sites per county in 2014 (n=42), representing (30%) of known active sites nationally. In 2013, prior to the opening of the Bypass there were three Barn Owl nest sites and three roost sites known within 5km of the route, and a further seven nest sites and two roost sites within a distance of 5 to 8km of the Bypass. Based on the importance of County Kerry for Barn Owls, the apparently high Barn Owl densities within proximity to the Bypass and the recorded Barn Owl road mortalities on the Bypass an investigation into the extent of Barn Owl vehicle collisions and the potential implications for the local Barn Owl population was warranted.

Barn Owl status

- Within the study area for the Tralee Bypass (193.5 km^2) which encompasses a 5km radius either side of the route, there were 55 buildings across a range of site types classed as suitable for breeding Barn Owls. This represents a density of 28 suitable sites per 100 km^2 within the study area. The availability of sites in the Tralee Bypass study area is higher than the recorded density of suitable sites available to Barn Owls elsewhere in County Kerry, Cork, Limerick, Galway and Offaly which ranged from 10.8 to 17 suitable sites per 100km^2.

- The Barn Owl survey revealed signs of occupation in ten sites within the study area, representing 18% of sites which could be potentially used by Barn Owls. The proportion of sites used by Barn Owls to those available in the study area indicates that the local population is not limited by the availability of nesting sites, and that the development of the Tralee Bypass has not had an adverse impact on the local population in terms of nest site availability.

- In 2014 monitoring of all sites where signs of Barn Owl occupation were confirmed (n = 10) revealed that two sites held breeding pairs, five were roost sites and three were not active. Therefore, there were two nest sites and five roosts within the study area in 2014. In 2015 both nests which held breeding pairs in 2014 were once again used for nesting, two sites used for roosting in 2014 were used for nesting in 2015, one roost remained active and two roosts become inactive between years. Therefore, all nest sites (n =2) remained active over the study period (2014 – 2015) and there was an increase from two to four breeding pairs, indicating that the Tralee Bypass has not caused the loss of sites or displacement of the local population over the study period, as shown to be the case with major road developments in other parts of the Barn Owls range.

- The average distance of Barn Owl nest sites (n = 4) to the Tralee Bypass was 2.5km and ranged from 400m to 4.8km. In the UK it has been suggested that new major road developments caused the loss of all Barn Owls within 0.5km, and severe depletion of populations within 0.5 to 2.5km of the route (Ramsden 2003), however this was not the case within the study area, at least during the study period. There are a range of biotic and abiotic factors which can influence the impacts of a major road on Barn Owl populations and which vary on a site specific basis, including the vehicle volume, speed of traffic and road design and characteristics and therefore direct comparison between studies should be treated with caution.

- In 2014 there was a recorded density of one breeding pair per $100km^2$ within the study area. In 2015 there was a recorded density of 2.1 breeding pairs per $100km^2$ within the study area. These densities are higher than most Barn Owl density estimates for other regions of Ireland including elsewhere in County Kerry, Offaly, Limerick, Cork and Galway where recorded breeding densities ranged from 0.3 to one breeding pair per $100km^2$, but is lower than the breeding density of 2.6 pairs per $100km^2$ in an area of north Cork.

- Of two confirmed nest sites in 2014, one was successful (50%) which fledged two young and the other pair failed. There was an average productivity of one young per breeding attempt (n = 2) within the study area in 2014 (range 0 – 2). Of four confirmed nests in 2015, three (75%) were successful. An average productivity of 2.25 young per pair (range 0 – 3) was recorded within the study area in 2015. Although the breeding success rates and productivity of Barn Owls within the study area were lower than for Barn Owl pairs monitored throughout County Kerry in 2014 (breeding success of 74%; 1.8 young fledged per breeding attempt; n = 18) and 2015 (breeding success of 82%; 2.7 young fledged per breeding attempt; n = 26) the difference was not significant. However, the small sample size of pairs within the study area should be noted.

Barn Owl road mortalities on the Tralee Bypass

- Ten Barn Owl casualties were recorded on the Tralee Bypass between August 2014 and December 2015, which represents a minimum casualty rate of 52 Barn Owls per 100km per year on the Tralee Bypass. This casualty rate is within the mid-range of available estimates in Europe and North America which range from seven to 599 Barn Owl road mortalities per 100km per year.

- Barn Owl (n = 5) was the third most numerous of the 14 bird species recorded as road mortalities by the road casualty survey on the Tralee Bypass, representing 7% of all avian mortalities (n = 65), despite having a lower population density compared with other species for which there were two or more road mortality incidents recorded. Barn Owl was the only *Red-listed Bird of Conservation Concern* recorded as a road casualty on the Tralee Bypass.

- Of the ten Barn Owl road casualties recorded on the Tralee Bypass, one was recovered during the breeding season (March to July) with all other casualties (n = 9) recorded outside of the breeding season (January to February and August to December).

- It was possible to accurately age nine of the ten Barn Owl road casualties, of which eight (80%) were first calendar-year or second calendar-year pre-breeding season birds (i.e. recovered before March of their second calendar year) and one was an adult.

Seven of the ten casualties could be accurately sexed, of which six were male and one was female.

- Three (30%) of the ten Barn Owl road casualties recovered were ringed. Two were second calendar-year birds recovered in February 2015 and which had been ringed as young in the nest in 2014 at breeding sites in County Kerry located 16.7km and 13.3km from the Tralee Bypass. Mortality on the Tralee Bypass accounted for 9% of all Barn Owls ringed as young in the nest in County Kerry in 2014 (n = 22). An adult male associated with a breeding site located 2.6km from the Bypass which was ringed (as a breeding adult) in 2013 was recovered on the Tralee Bypass in late 2015. This was the only confirmed adult recovered on the Bypass and was one of eight (12.5%) breeding adults (from four confirmed nest sites) known to occur in the study area in the breeding season of 2015.

- Tralee Bypass affects pre-breeding season as well as adult Barn Owls, and affects birds which disperse into the area from natal sites outside the study area as well as adults which are resident within the study area. It has been suggested that the number of casualties on a major road reduces over time as the local population declines, however this may not be the case on the Tralee Bypass if the local population does not decline and particularly if the majority of birds affected are juveniles which disperse into this area from outside. Therefore, under current conditions Barn Owl mortality on the Tralee Bypass may continue at similar levels.

- Five Barn Owl road casualties (50%) were recovered from sections of the Bypass which were on an embankment (four where the embankment was 2 – 4m high and one where the embankment was >4m), four were recovered where the route was "at grade" and one was recovered where the road was in cut (0 – 2m). There was no significant difference between the elevation height of the route where Barn Owls were recovered (n = 10) to random control points (n = 50) on the route. Nine (90%) Barn Owls were recovered where grass verges were greater than 5m in width, however there was no significant difference between the grass verge width at Barn Owl recovery locations (n = 10) and random controls (n = 50). Nine (90%) Barn Owls were recovered where the adjacent habitats to the route were predominantly fields with hedgerows/tree lines. There was a significant difference between the adjacent habitats to the route at Barn Owl recovery locations to random control points (D = 0.5, p-value = 0.03101). It should be noted that the sample size of Barn Owl recovery locations was low (n = 10) which restricts more robust analysis.

- The average distance between locations where Barn Owl mortalities were recovered (n = 10) on the Tralee Bypass was 3.3km and ranged from 10m to 6.9km (se = 2.8km). Three Barn Owl road mortalities were recovered within 50m of each other. All other Barn Owl mortality locations (n = 7) were more than 50m from the next nearest recovery location.

- A total of 18 sightings of Barn Owls were recorded during the survey period within100m of the Bypass which demonstrate that Barn Owls exploit edge habitats along the roadside for foraging and also regularly cross the Bypass. Four sightings (22%) were within the breeding season (March to July), and 14 (78%) were in the non-breeding season. Nine of the Barn Owls observed (50%) were in flight over the Bypass, four were perched on roadside posts/signs, four were recorded in hunting flight actively foraging along the edge habitats at the roadside and one was observed in flight parallel to the

Bypass (<100m). However, the recorded road mortalities (n = 10) in addition to observations of Barn Owl interactions with the Bypass (n = 18), and the recorded flight height of four Barn Owl observations of birds crossing the Bypass (2-5m) highlights their susceptibility to vehicle collisions on the route.

- Kestrel was the most frequently observed bird of prey when conducting the road casualty survey, observed on 30 (44%) of the 68 survey visits with a total of 37 sightings. Of the 37 sightings, 31 (84%) were of birds actively hunting the edge habitats alongside the route indicating the conservation value of this habitat for the species.

Other avian and mammalian road casualties

- A total of 65 avian road casualties of 14 species (including Barn Owl) were recorded on the Tralee Bypass between August 2014 and December 2015 which equates to 340 avian mortalities per 100km per year. The most common bird species killed on the route were Rook *Corvus frugilevus* (n = 24), Jackdaw (n = 9) and Barn Owl (n = 5). Other raptors recorded as road mortalities included Kestrel (n = 1) and Sparrowhawk (n = 1).

- The number of avian casualties on the Tralee Bypass ranged from two to nine per month, with the lowest numbers in November and January (n = 2) and peaks in June (n = 9) and August (n = 7). It was possible to age 53 (81.5%) of the avian road mortalities, of which 28 (53%) were adults and 25 (47%) were immature/juvenile.

- A total of 21 mammalian road casualties of seven species were recorded on the Tralee Bypass of which Rabbit (n = 8) and Hedgehog (n = 8) were the most numerous. This equates to 110 casualties per year per 100km.

Recommendations - research

- These results show that the Tralee Bypass did not result in the loss of sites or displacement of the local Barn Owl population over the two breeding seasons (2014 and 2015) since it was opened to traffic**.** Individual sites may however remain active over time even if associated breeding birds are killed on the road, provided there is sufficient recruitment to these sites, such that they can act as a population 'sinks'. Research to identify survival of individual birds and turn-over at specific sites would facilitate a greater understanding of the potential impacts of the Bypass on breeding birds and sites within the study area.

- Although the sample size of observations of Barn Owls which were interacting with the Bypass was low (n = 18), this information nevertheless served to indicate that birds regularly encounter the route, and both utilise the edge habitats for foraging as well as cross over the Bypass. The use of GPS tags to monitor in detail the movements of individual birds within the study area to determine the frequency, behaviour and locations of Barn Owl interactions with the route would significantly add to our understanding of collision risk and how it can be appropriately mitigated for.

- In the UK it has been shown that Barn Owl mortality levels on a new motorway dropped over time, which was attributed to declines in the local population. It would be beneficial to extend the monitoring period of the road casualty survey on the Tralee Bypass to determine changes in casualty rates over time which may not have been detected over the current study period.

- With the exception of one 'cluster' where three Barn Owls were recovered within 50m of each other, there were no obvious 'high risk' areas for Barn Owl vehicle collisions recorded on the Tralee Bypass. However, the sample size of mortality records collated during the study period is small, which is in part related to the route length. It is recommended to continue the road casualty survey on the Tralee Bypass and to supplement with data available from major roads elsewhere in the country to facilitate more robust analysis to determine if specific variables influence risk of collision on major roads for Barn Owls in Ireland.

- The Barn Owl sites identified through this study should be prioritised within routine annual monitoring conducted by BWI to determine occupancy, breeding status and breeding performance over time in order to identify any changes in status of the local Barn Owl population that may not have been detected during the current study period.

- For future major road developments in Ireland it is recommended that a comprehensive survey and monitoring protocol following the same methods as outlined in this study is conducted prior to development to inform pre-construction mitigation requirements and to facilitate the adequate assessment of the potential impacts on the local Barn Owl population before and after the development of a route.

1. INTRODUCTION

1.1 The potential impacts of road networks on Barn Owls

The Barn Owl *Tyto alba* population in Ireland has suffered extensive declines in distribution and abundance in recent decades. The *Breeding Birds Atlas (2007–2011)* highlighted a decline of 39% in the breeding range of Barn Owls in Ireland over the 40-year period since the original *Breeding Birds Atlas of Britain and Ireland (1968–1972)* (Sharrock 1976, Balmer *et al.* 2013). Barn Owl is categorised as a Red-listed *Bird of Conservation Concern in Ireland* as the population is considered to have suffered losses of over 50% in the last 25 years (Colhoun and Cummins, 2013). The specific factors which influence the status and trends of Barn Owls in Ireland, and which have brought about these widespread declines are not fully understood. The population in Ireland is not limited by the availability of suitable nest sites as has been previously recorded in Britain and in other parts of its range (De Bruin 1994, Petty *et al.* 1994, Taylor 1994, Newton, 2004, Lusby *et al.,* 2009, 2010, 2010a & 2011, O'Clery 2013, 2013a & 2015). The intensification of agriculture, particularly the reduction of prey rich foraging habitat has been implicated as a primary driver of long-term Barn Owl population declines (De Bruin 1994, Shawyer 1998). Vehicle collisions can be an important cause of mortality and several studies have also linked the increase in major road networks to Barn Owl population declines (Illner 1992, De Bruin 1994, Ramsden 2003, Boves and Belthoff 2012). Barn Owls have been routinely recorded as road casualty victims in Ireland, which is the most frequent recorded cause of death (Lusby *et al.* 2013). The significant expansion of the road infrastructure has therefore caused concern in relation to major roads as a potentially contributing factor to the Barn Owl decline in Ireland. In addition to direct mortality the development of road networks can also affect the quality and quantity of available habitat for Barn Owls (Glista *et al.* 2009), and may cause local displacement of birds through loss of nest sites. However, to date the impact of road networks on the Barn Owl population in Ireland has not been determined.

A wide range of wildlife can be killed on roads, with significant implications for specific populations (Trombulak and Frissell 2000). The increases in traffic and expansions to road infrastructures which have occurred throughout the world have coincided with the continued increase in the extent of road casualties of wildlife (Newton *et al.* 1997, Seiler et *al.* 2004). Due to their hunting behaviour, low flight and poor peripheral vision, Barn Owls are particularly susceptible to collision with vehicles (Illner 1992, De Bruin 1994, Massemin and Zorn 1998, Ramsden 2003, Boves and Belthoff, 2012). Several studies to assess avian mortality on roads have recorded Barn Owls as the most frequently affected of the raptors and owls (Massemin and Zorn 1998, Shawyer and Dixon 1999), or the most frequently affected bird species (Baudvin 1997, Boves and Belthoff 2012, Loss *et al.* 2014). Newton *et al.* (1997) showed that recorded Barn Owl road fatalities have increased dramatically in the UK since the early part of the last century, from 6% in 1910 – 54, to 15% in 1955 – 69, to 35% in 1963 – 70 and 50% in 1991- 96. Road mortalities accounted for approximately 10 – 15% of adult Barn Owl deaths in central Westphalia in Germany, which was considered to have a significant impact on the population (Illner 1992). An intensive study over an eighteen-year period in Liemers in the Netherlands linked long term Barn Owl population declines in the region to increases in major road networks (De Bruin 1994). Ramsden (2003) estimated that 72% of Barn Owls which encounter a major road are likely to be killed and showed that the risk of mortality to Barn Owls from motorways increased dramatically with proximity to nest and roost sites.

This study indicated that new major road developments caused the loss of all Barn Owls within 0.5km, and severe depletion of populations within 0.5 to 2.5km of the route. An examination of body weights of carcasses and the time of year casualties were recovered also showed that there was no indication that owls killed by traffic were predominantly weak or underweight individuals. Based on the findings from a 15-year study in Devon in the UK, it was estimated that the presence of major roads in rural England has removed Barn Owls from an area of between 8,100 and 16,200km^2 and depleted the population over an area of roughly 48,600km^2 which corresponds to 40% of the total area of rural England (Ramsden 2003). The findings of the Barn Owl Survey of Britain and Ireland indicated that only 20 breeding pairs of an estimated 5,000 pairs were located within 1km of any major road and fewer than 100 pairs were within 3km (Shawyer 1987). Shawyer (1998) also ascertained that new major road schemes caused the local displacement of Barn Owls, predicting the rapid depletion of all Barn Owl sites within 2km of new major road developments.

Many studies have employed systematic searches of motorways for avian road casualties to determine the extent of road casualties for Barn Owls. In Switzerland, seven Barn Owl casualties per 100km were estimated on an annual basis along a 36.9km stretch of motorway (Bourquin 1983). Two studies in north-eastern France, estimated an annual casualty rate of 65 Barn Owls per 100km along a 259km stretch of motorway (Baudvin 1997) and 25 Barn Owl casualties per 100km per year on a 150km stretch of motorway (Massemin and Zorn 1998). In Britain, a 50km stretch of major road, with single and dual carriageway sections, was searched intensively over two years, and the casualty rate for Barn Owls calculated at 68 per 100km per year (Shawyer and Dixon 1999). There are however numerous constraints to be considered when assessing the relative importance of road traffic accidents as a cause of mortality for Barn Owls and in determining the population level impact of road networks. The potential to overestimate vehicle collisions as a cause of death due to methodological bias is one factor which must be taken into account in order to accurately determine the potential impacts of road mortalities on a population (Illner 1992). The probability of finding a road casualty victim is likely to be greater than a bird which died of other causes, and therefore the ratios of recorded causes of death may not be representative (Newton 1979). Sampling bias related to locating and recording wildlife road casualties can be influenced by search effort, removal of carcasses by scavengers, habitat conditions and other site specific factors (Santos *et al.* 2015). Boves and Belthoff (2012) showed that Barn Owl road casualties were under-recorded by standard search methods, and when the numbers of Barn Owl casualties were adjusted for search and removal bias this significantly increased estimates of casualty rates on a road which was regularly surveyed in Idaho.

Although several studies highlight the importance of road deaths as a cause of mortality for Barn Owls and the potential population level implications, the impact of road mortalities will vary between populations according to a range of biotic and abiotic factors including population densities, breeding success, recruitment, survival and other forms of mortality and therefore requires detailed assessment for individual populations. A long-term study through BirdWatch Ireland (BWI) provides the only data on the extent of road mortalities relative to other recorded causes of death in the Irish context. Over a nine year period (2006–2014) a total of 279 Barn Owl mortality incidents were recorded, of which the majority (64%) were vehicle collision victims. The majority of road casualties were recovered from Motorways or National routes (76%), which is similar to findings from other studies which suggest that motorways and dual carriageways, due to their design and high vehicle speeds, present a greater threat to Barn Owls than other road types (Ilner 1992, Ramsden 2003). A total of 61 Barn Owl collision victims were recorded on the M8 motorway in north Cork and south Tipperary over a seven-year period, indicating that certain routes or sections of a route may present a higher risk of collision, which has also been shown to be the case elsewhere in the Barn Owls range (Massemin and Zorn 1998, Shawyer and Dixon, 1999). Similar to other studies, peaks in the number of road casualties were observed outside of the breeding season, with highest numbers recovered in February, October and November (Masssemin and Zorn 1998, Shawyer and Dixon 1999). Of 34 Barn Owl carcasses which were retrieved and reliably aged, the majority were first calendar year or second calendar pre-breeding season birds and therefore were unlikely to have been recruited to the breeding population prior to being killed on the road. The weight at death of 23 Barn Owl road casualties assessed was also significantly lower than the weight of a representative sample of twenty-five live adult males trapped over the same period, which indicates that while adults and breeding birds are killed on the roads, it is predominantly birds which have not yet reached breeding age or which are in poor condition that are affected. This study also analysed thirty-three Barn Owl ringing recoveries between 2006 and 2013, to determine the relative importance of vehicle collisions as a cause of death from ringed birds alone, which showed that one third of Barn Owl recoveries were attributed to road traffic accidents (BWI, unpublished). However there remain significant gaps in our understanding of the impacts of road networks on Barn Owl populations in Ireland and the requirement for mitigation.

1.2 Proposed mitigation measures for Barn Owls on major roads

Understanding the factors that influence roadway mortality is vital for mitigating the impact of roads on wildlife populations and for making appropriate management recommendations (Clevenger *et al.* 2003). To reduce wildlife mortality on roads a range of mitigation measures have been developed, which primarily focus on altering motorist behaviour or altering the behaviour of wildlife which encounter roads which includes animal crossing signs, construction of wildlife crossings, and the use of fences to prevent wildlife from encountering the road (Glista *et al.* 2009, Santos *et al.* 2015). Since mitigation measures are generally expensive, economic factors often dictate the choice of road mortality mitigation measures (Glista *et al.* 2009). In addition, evaluations of the effectiveness of mitigation measures for wildlife have been limited (Forman *et al.* 2003). This is particularly the case for birds, which present significant challenges in terms of the development of effective mitigation on roads compared with mammals (Glista *et al.* 2009).

For Barn Owls the speed of road traffic has been shown to be an important factor which influences mortality on major roads (Illner 1992). Road types also have a significant influence on the risk and level of Barn Owl road casualties (Baudvin 1997, Shawyer and Dixon 1998). In Devon in the UK, Barn Owls were often recorded crossing minor roads, however were rarely observed hunting along them, most likely because of the lack of suitable wide verges of grassland habitat over which to hunt (Ramsden 2003). Several studies have linked high Barn Owl road casualties to sections of dual-carriageway and motorway where wide verges of open grassland habitat occur, potentially encouraging owls to hunt along the road verges (Baudvin 1997, Shawyer and Dixon 1999, Taylor

1994). Baudvin (1997) showed that predators of small mammals represented the highest recorded fatalities on motorways in France and concluded that Barn Owls were attracted to the road side verges to forage for small mammals. In a study on a 50km section of the A303 in southern England, it was found that Barn Owl road casualties were more likely to occur where the road traversed linear habitat features along which the birds might hunt (Shawyer and Dixon 1999). However, in contrast, more owls were killed along sections of a major road in France which lacked roadside hedges and/or which crossed open fields (Massemin and Zorn 1998). There is also evidence to suggest that many owls are struck while crossing major roads and not hunting along them. Shawyer and Dixon (1999) showed that Barn Owl road casualties were not evenly distributed on a major road and identified a number of 'high risk' areas which corresponded with sections of the route which were embanked or level with fewer casualties along excavated sections. Several other studies have also identified the elevation of the route as a factor which accentuates risk of collision for Barn Owls as it is thought that where the route is excavated Barn Owls will be more likely to fly above the height of passing vehicles, whereas on level or embanked sections, due to their low flight Barn Owls would be more at risk of encountering vehicles.

One of the main mitigation recommendations to reduce Barn Owl mortality on major roads involves the use of natural or artificial screens to deflect the flight path of Barn Owls above the height of traffic (Shawyer and Dixon 1998, Ramsden 2003). To achieve this Ramsden (2003) proposed planting the verges with scrub, hedges or trees, or by installing high screens that force birds to rise above passing traffic when traversing the road. It has been suggested that this mitigation is likely to be particularly effective on embanked sections of motorway where Barn Owls may be most susceptible to collision (Massemin and Zorn, 1999). There is conflicting opinion as to whether natural vegetation or artificial barriers to flight are the most appropriate, as it has been suggested that planting natural vegetation at the edge of the roadside may have an adverse effect on other avian populations. Even if natural or artificial screens proved to be effective, it would be likely that they would only reduce fatalities where birds are crossing the route as opposed to where birds are hunting the edge habitats, and for the majority of studies there is no comprehensive data available on the behaviour and associated risk of birds which encounter major roads. There are also health and safety, engineering and other environmental considerations which may conflict with the practical application of this mitigation on a site specific basis, and the effectiveness of this measure has not been adequately assessed.

Other recommended mitigation measures are aimed at discouraging Barn Owls from encountering major roads and in particular from hunting along road side verges. Proposed measures focus on limiting the quality and quantity of suitable foraging habitat in the form of rough grassy verges. This can be achieved by intensive mowing or by allowing dense vegetation such as bramble or gorse to cover the verge habitats (Ramsden, 2003). There is however conflicting opinion as to the validity of this measure in terms of its effectiveness for reducing Barn Owl mortality and its benefits for wildlife in general (Shawyer and Dixon 1998). In the UK roadside verges have been increasingly recognised for their importance as wildlife habitats, particularly for small mammal populations (Spellerberg and Gaywood 1993). It has been suggested that the presence of small mammals on road verges may be more beneficial to some predator populations than the consequences of road mortality (Garland 2002). Planting roadside verges with dense shrubs would serve to conceal small mammals from foraging Barn Owls (Baudvin 1997), and therefore birds may be less likely to be attracted to the road-side. However, such vegetation at the road-side may increase mortality of other bird species, and also could present a fire hazard in certain situations. An alternative, which could benefit Barn Owls, small mammals and biodiversity in general, is to allow rough grassland habitat to flourish along the road side verges but provide continuous screens adjacent to the road surface so that Barn Owls can forage these areas without high risk of collision (Ramsden 2003). However, the installation of continuous screens adjacent to the road surface may be incompatible with health and safety and road design requirements in many situations, and would therefore render this measure impractical. Shawyer and Dixon (1999) also proposed that the grassy banks of rivers, streams and ditches which traverse major roads, should be intersected by diversion corridors of rough grassland about 100 metres and at right angles to the road in an attempt to encourage Barn Owls to utilise safe flight ways on open farmland rather than the verge habitats, however the effectiveness of this measure is not known.

Based on available evidence of the factors which influence Barn Owl mortality on roads as well as current best practice mitigation recommendations, it would seem logical that in order to inform appropriate mitigation requirements for Barn Owls on major roads it is first necessary to understand; the behaviour of birds killed on the road – whether these were attracted to and actively hunting road-side habitats, or whether they were in transit over the route; whether there are specific areas on the route which present a higher risk of collision, and the specific physical or geographic variables which influence risk of collision. The absence of this information in combination has been a constraint to the development of evidence-based mitigation for Barn Owls. In addition, if mitigation is to be successful then it must also be practical to implement and compatible with health and safety, economic, environmental and engineering considerations. A significant limitation of the current mitigation recommendations is also that their effectiveness has not been proven or otherwise. This presents a dilemma in that the effectiveness of these mitigation measures can only be adequately assessed through their practical application, preferably through monitoring casualty rates before and after mitigation is applied. However due to the lack of evidence of their effectiveness and also potentially due to the cost and constraints regarding other road design requirements, the proposed Barn Owl mitigation measures as outlined above are not routinely incorporated to major road schemes. Therefore, the development of evidence based and effective mitigation measures to reduce Barn Owl mortality on major roads, which are compatible with relevant environmental, engineering, road design and economic constraints are still outstanding.

1.3 The Tralee Bypass and Barn Owls

The N22 Tralee Bypass links the N69 Listowel Road with the N70 Killorglin Road via the N21 Limerick Road. It consists of a route length of 13.5km, of which 8km is a 'Type 2 Dual Carriageway', with a separate access route for the N22 Killarney Road which is a 'Standard two-lane single carriageway' of 5.5km.

The Bypass was opened to vehicles in August 2013. Within a period of seven months (August 2013 to March 2014), three Barn Owl casualties on the Bypass were reported to BWI by independent observers. These were recorded in October 2013, February and March 2014, all of which were located on the southern section of the Bypass. All incidents were confirmed by BWI and the carcasses were retrieved. Over this seven-month period five sightings of Barn Owls in flight over the Bypass were also received from the northern section of the route, two in December 2013 and three in March 2014.

Although no systematic survey to assess Barn Owl density and distribution has been previously undertaken within the area surrounding the Tralee Bypass, BWI documented three Barn Owl nest sites and three roost sites within 5km of the Bypass, and a further seven nest sites and two roost sites within a distance of 5 to 8km of the Bypass in the two years prior to the opening of the Bypass. County Kerry is a stronghold for the endangered Barn Owl population which held the highest number of known active nest sites per county in 2014 (n=42) (Fig. 2.1, below), representing (30%) of known active sites nationally. The importance of County Kerry for Barn Owls, in addition to the apparently high Barn Owl density within proximity to the Tralee Bypass and the recorded Barn Owl road mortality incidents (August 2013 to March 2014), lead to concerns regarding the extent of Barn Owl vehicle collisions and the potential implications for the local Barn Owl population.

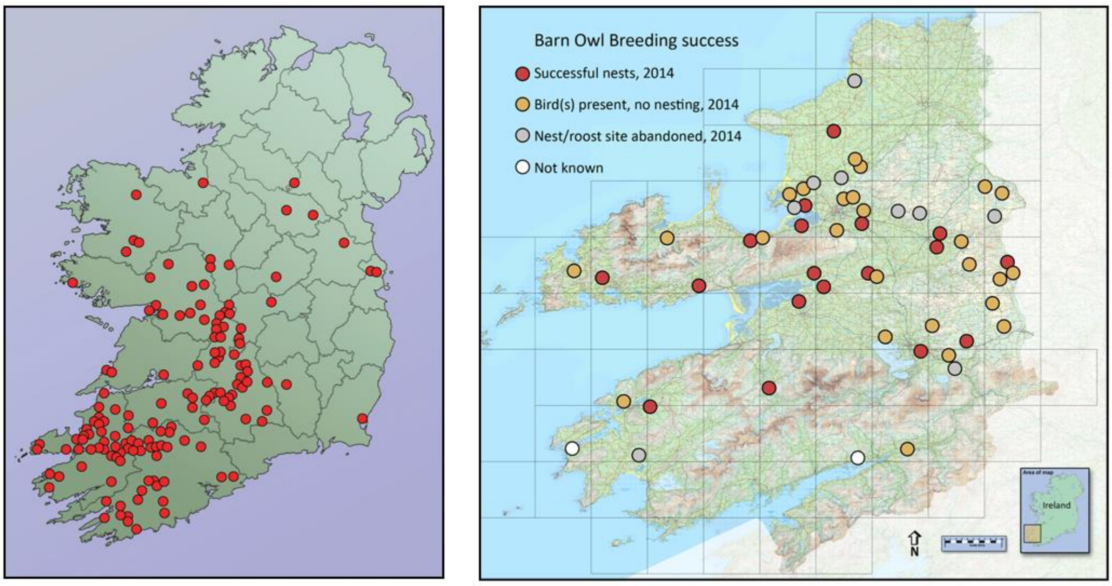

Figure 2.1 *The distribution of registered Barn Owl sites in the Republic of Ireland (left) and the status and distribution of registered Barn Owl sites in Co. Kerry (right) in 2014*

1.4 Objectives

The objective of this study is to determine Barn Owl distribution and abundance within the selected study area encompassing the Tralee Bypass to include all Barn Owl sites which may be affected by the Bypass; to assess occupancy and breeding status of the local population over a two-year period and to identify potential impacts of the route on Barn Owl densities, distribution and breeding performance. We will also determine the extent of Barn Owl road mortalities on the Tralee Bypass and investigate the factors that may influence risk of collision.

The specific objectives of this study are to:

- To determine Barn Owl status, distribution and abundance within the defined study area.
- To monitor Barn Owl population densities, occupancy and breeding success throughout the study period.
- To compare breeding densities and breeding performance within the study area to representative Barn Owl populations over the same period.
- To determine the extent of Barn Owl road mortalities on the Tralee Bypass.
- To identify the sex, age and breeding status of birds recovered as road casualties as well as the timing of incidents.
- To identify the relationship between the physical characteristics of the route and the risk of mortality for Barn Owls on the Tralee Bypass.
- To identify, if relevant, potential high risk areas for Barn Owl vehicle collisions on the Tralee Bypass.
- To outline relevant recommendations based on the findings of this study.

3. METHODS

3.1 Barn Owl status

3.1.1 Study Area

The study area for the Barn Owl survey was defined by drawing a buffer of 5km radius either side of the route. This area was selected to include all Barn Owl sites that may be affected by the Tralee Bypass based on best evidence of Barn Owl home range size. Assessment of aerial images in combination with a ground-truth exercise was conducted on the 18th of June 2014 to determine the extent of the study area suitable for Barn Owls based on habitat suitability and availability of nest and roost sites. This initial assessment identified an urban area of 6.5 km^2 encompassing Tralee town as unsuitable for breeding Barn Owls. Barn Owl nesting within built up areas is uncommon (Copland and Lusby 2012), and due to difficulties in accessing buildings within urban areas to comprehensively assess the suitability and occupancy of Barn Owls this area was excluded from the Barn Owl survey. The study area for the Barn Owl survey therefore comprised 193.5 km^2 (Fig. 3.1).

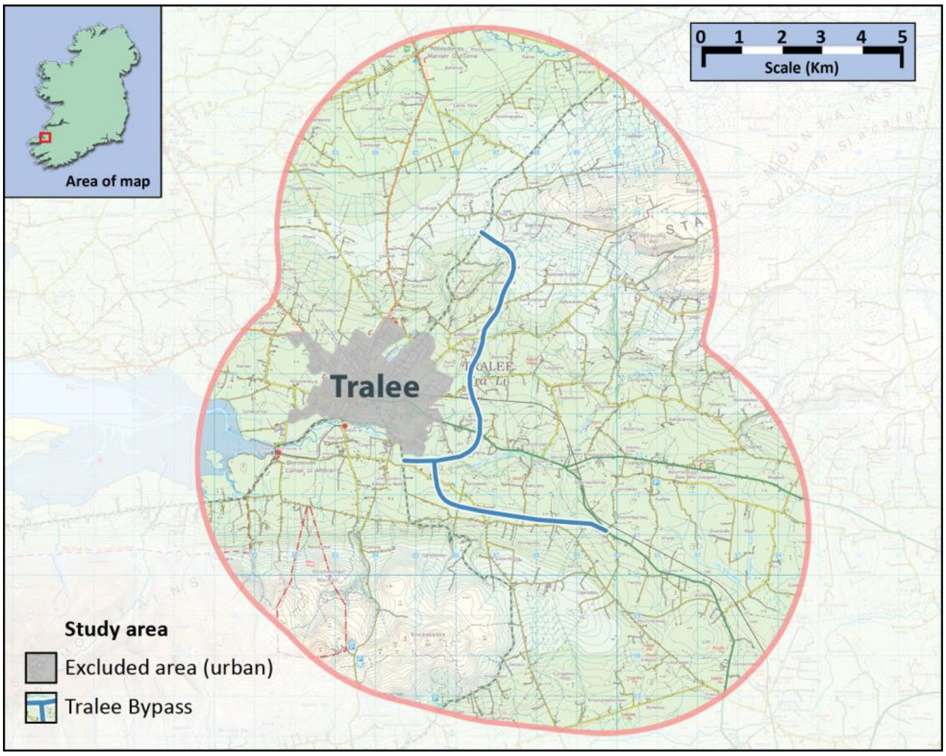

Figure 3.1 *The study area for the Barn Owl survey*

Prior to initiating fieldwork all relevant information on existing and previously active Barn Owl sites, sightings and mortality records from within the study area over the period of January 2012 to May 2014 were extracted from relevant the BWI Barn Owl databases and the *Bird Atlas (2007–2011)* database. All data on Barn Owl sites, sightings and mortality records were plotted on large-scale Ordnance Survey maps to inform survey fieldwork.

3.1.2 Distribution and abundance

The Barn Owl survey was undertaken between the 18th of June 2014 and the 30th of July 2014. Field surveyors were equipped with official BWI identification, a copy of the BWI insurance policy, and appropriate Personal Protective Equipment including a torch, hard hat, first-aid kit, whistle and mobile phone.

A specific data sheet was used to record the following aspects for each site assessed; date of survey visit, grid reference of site assessed, site type, site name (or townland name), suitability of the site for Barn Owls based on a scale of 0 – 3, activity status of the site based on signs or sightings indicating the presence of Barn Owls, and whether a roost watch was required to confirm activity. Additional information was recorded relating to the suitability and presence of Kestrel *Falco tinnunculus*, Peregrine Falcon *Falco peregrinus*, Raven *Corvus corax* and Jackdaw *Corvus monedula* and the presence of other species of conservation interest were recorded where relevant.

All roads within the survey area were systematically travelled and the suitability of all buildings and quarries assessed. Sites that were considered to be potentially suitable were comprehensively searched for signs indicating the presence of Barn Owls. All sites were categorised on a scale of 0 – 3 based on potential nesting and roosting opportunities for Barn Owls, with category 0 sites those which were not suitable for Barn Owls; category 1 sites represented potentially suitable sites for roosting but where there were no nesting opportunities; category 2 sites were considered suitable for roosting and where nesting was possible, and category 3 representing sites considered to be very suitable for nesting.

At each site, a thorough search was conducted inside and outside of the building or within quarries in order to locate signs indicating the presence of Barn Owls, particularly pellets, evidence of whitewash splashings and moulted feathers. Adjacent buildings and potential perches in the immediate vicinity of the site were also assessed. At certain active Barn Owl sites, due to the concealed nature of nest and/or roost site (i.e. blocked chimneys, deep cavities, etc.), signs are not always obvious or accessible. Therefore, at sites where this was judged to be a possibility it was recorded that a roost watch was necessary to confirm activity. Roost watches were subsequently conducted at dusk on the same night or night thereafter. The site was watched from a suitable vantage point from approximately one hour before sun set to record the presence of Barn Owls using the site either visually or by confirming vocalisations. Sites were recorded as active if calls from an adult or owlets were heard, or if a Barn Owl was observed either within the site or entering or exiting the site. These methods were designed to locate all Barn Owl sites in buildings and quarries within the study area.

Tree sites were not assessed as part of this survey. Information on Barn Owl activity and sightings was sought from landowners when requesting permission to access lands and buildings. This method was used to identify any areas of potential activity where trees might be used and which would not be recorded through searches of buildings. Interviews with landowners have been successfully used to assess Barn Owl occupation in Barn Owl surveys in the UK (Toms *et al.* 2001). Landowners were asked a series of standardised questions, shown images and played vocalisations of Barn Owls to determine whether they had encountered Barn Owl activity. An assessment was made as to the reliability of each individual report based on the account and the observer's description. Reports that were considered to be potentially unreliable were discarded. Reliable reports were divided into two categories based on the timing of the sighting as either within the "breeding season" consisting of the period March to July or the "non-breeding season" which comprises the remainder of the year. This categorisation was used to differentiate between sightings that were likely to be resident breeding birds (breeding season sightings) or sightings which could be either a resident adult bird or a dispersing juvenile (non-breeding season). The location and behavior of the sighting was recorded where this information was available.

3.1.3 Breeding Status

At all sites where Barn Owl activity was confirmed (either via presence of signs or via roost watches) nocturnal visits were carried out to confirm activity and breeding status between June and August in 2014 and 2015. A total of 49 nocturnal visits were carried out across 32 sites to determine activity and breeding status. Active sites were classed as either a 'nest site' where a pair was present during the breeding season or a 'roost site' where no breeding activity was not recorded during the breeding season but where signs of occupation or birds were confirmed during the study period. A breeding pair may use several roost sites in addition to the nest site and roost sites may also be used on a sporadic basis (Shawyer 1998), therefore the occupancy of nest sites provides a more accurate indication of the status and trends of the local population and is used in generating density data and occupancy trends across years.

3.1.4 Breeding Performance

Nocturnal visits were carried out to determine breeding success and performance of nesting pairs. At accessible breeding sites, nest visits during the day (under licence from the National Parks and Wildlife Service) were also conducted to determine the number of young (brood size) and to ring the owlets. A special metal ring was fitted to each owlet (under license from the National Parks and Wildlife Service and British Trust of Ornithology), and their sex, weight, maximum wing chord, and the length of the seventh primary was recorded.

Three measures were used to quantify the breeding performance of confirmed Barn Owl pairs: (i) breeding success was defined as the success or failure of a breeding attempt to fledge one or more young in a single year; (ii) number of fledged young from successful nests describes the number of young raised to, or close to, the stage of fledging for successful pairs, and (iii) productivity describes the number of fledged young for all breeding attempts for which the outcome was known (where a failed pair = 0 fledged young).

3.2 Avian and mammalian road mortalities on the Tralee Bypass

A road casualty survey to record avian and mammal mortalities on the Tralee Bypass was undertaken once per week on 68 of 70 weeks from August 2014 to December 2015. The survey was undertaken each Thursday morning between 09:00 and 12:00hrs commencing on the 29th of August 2014 (week 1) and ending on the 30th of December 2015 (week 70).

A fixed route was driven at a speed of 20–35 km per hour on each visit. The survey route started at the Curraghleha Roundabout, north to the Lissatanvally Roundabout, south and west to the Castlemaine Road Roundabout, south to the southern end of the Bypass (at the junction with the Flemby turn-off, and back to the start point, such that all sections and both sides of the route were surveyed (Fig. 3.2).

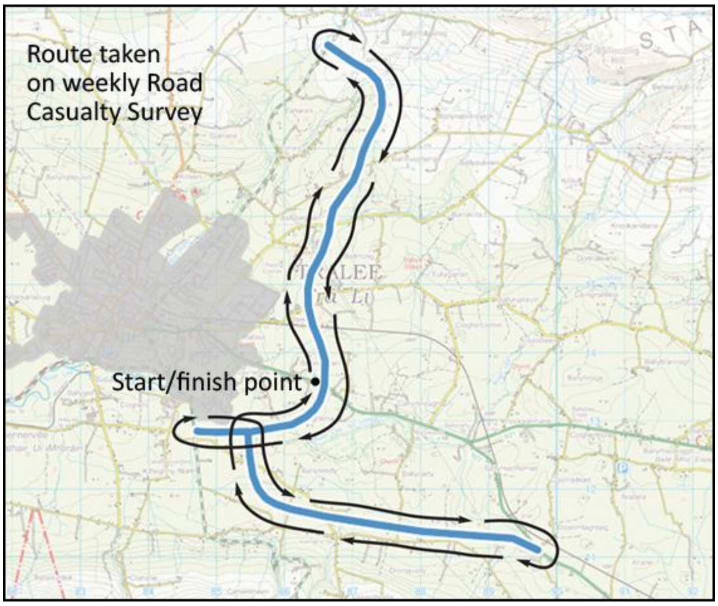

Figure 3.2 *The route of the road casualty survey*

3.3.1 Barn Owl road mortalities

All Barn Owl road mortalities observed along the route were recorded on specific data sheets. The date and month in which the road casualty was recovered was recorded and assigned to either the 'breeding' season (March to July) or 'non-breeding' season (January to February and August to December). The location of the road casualty which included the grid reference (ten-figure), position of the casualty on the route (central median, hard shoulder, or verge) and orientation (southbound, northbound, eastbound or westbound) were recorded. The age class of the bird was determined by plumage characteristics and the development of the talon flange (Johnson 1991, Baker 1993, Taylor 1993, Shawyer 1998) and classed as either 'pre-breeding' if the individual was first or second calendar year recovered before March, or 'adult' if the individual was second calendar year recovered later than March or older. Sex (M/F) was determined based on plumage characteristics (Taylor 1993, Baker 1993, Shawyer 1998). It was also noted if the bird was ringed (Y/N) and the ring details were recorded where relevant.

For each Barn Owl road mortality incident the following road characteristic and habitat variables were recorded at the location of recovery; the elevation and embankment characteristics of the route was estimated for both sides of the route and assigned to one of the following six categories; >4m cut, 2 – 4m cut, 0m, 0 – 2m embanked, 2 – 4m embanked, >4m embanked. The width of the grass verge on the side of the route where the casualty was recovered was assigned to one of three categories; 0m, 0 – 5m, >5m. The adjacent habitat features on the side of route where the casualty was recovered was assigned to one of five categories; open fields, fields with hedgerows/tree lines, woodland, dense vegetation, urban. The presence of fencing, wooden screens and barriers were also noted.

In addition to the data collated through the road casualty survey, requests were made to relevant organisations to report information on potential Barn Owl road mortalities and Barn Owl sightings within 100m of the Bypass. Circular email requests were sent to the Ecology Department of Tralee Institute of Technology, the Irish Wildlife Trust Kerry Branch, BirdWatch Ireland Kerry branch, in addition to frequent posts on social media including the Kerry Birding Blog www.kerrybirdingblog.ie and the West Kerry BirdWatch Ireland Facebook page. All reports received were investigated and the relevant details recorded as per the criteria outlined above.

An annual casualty rate of Barn Owls per 100km of route was generated by extrapolating the number of all casualties recorded across the length of the Bypass (13.5km) to 100km per year, then calculating the annual figure based on the length of the survey period (70 weeks). To investigate the difference between road characteristics at the recovery location of Barn Owl mortalities to the road characteristics throughout the route, random control points (n = 50) along the route were generated using the QGIS Random Point Generator (Fig. 3.3). The elevation of the route and the presence and width of the grass verge and adjacent habitat features were estimated for all random control points (n = 50) using the same methods as described above. The route characteristics at the point of Barn Owl recovery locations were compared with those for the random control points to investigate any potential relationship between risk of collision and the route characteristics. The minimum, maximum and average distance between Barn Owl mortality locations was determined using QGIS. We created buffers of 50, 100 and 200m around each Barn Owl mortality location to identify overlap and thus determine Barn Owl mortality locations which were within the defined same distance band as other mortality locations.

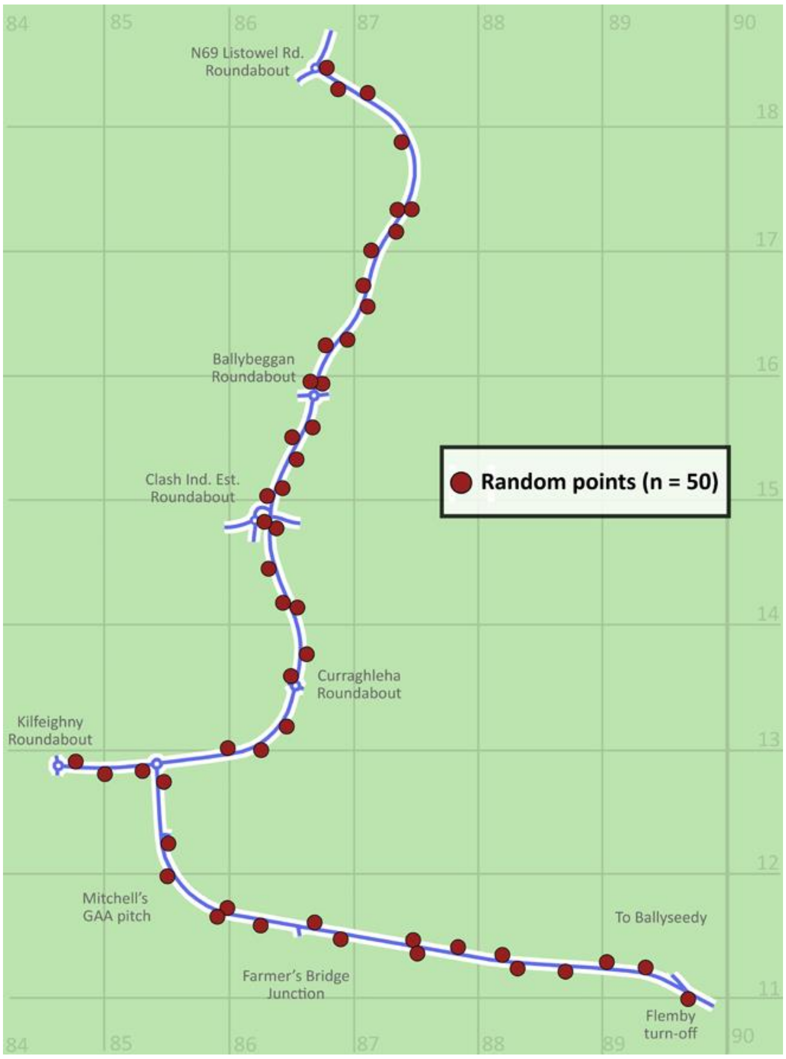

Figure 3.3 *The distribution of random control points (n = 50) on the Tralee Bypass*

3.3.2 Barn Owl sightings

Sightings of Barn Owls within 100m of the Bypass were collated over the survey period. The behaviour of the bird was recorded using the following criteria; in transit flight, hunting flight, perch hunting or perched. For birds in flight the height was estimated using the following three categories; 0 – 2m, 2 – 5m and >5m. Using QGIS we used buffers of 50, 100 and 200m around the location of all Barn Owl sightings to determine overlap and thus to identify any clusters of sightings within these specified distance bands.

3.3.3 Other avian and mammalian road casualties

All other avian and mammalian road casualties observed along the route were recorded on specific data sheets using the following criteria where relevant to each incident: the date, species, grid reference (ten figure), age and sex.

3.3.4 Raptor sightings

Observations of Kestrels, Peregrine and Sparrowhawk *Accipiter nisus* within 100m the Bypass were recorded as part of the road casualty survey. The date, grid reference, distance to Bypass (0-50m of Bypass or 50-100m of Bypass) and flight height (0-5m, 5-10m, or >10m) were recorded. The sex and age of the individuals were also recorded for all observations. For Kestrel observations the behaviour was also recorded using the following criteria; in transit flight, hunting flight, hovering, perch hunting or perched.

3.3 Data analysis

Analyses were carried out using R 3.1.2 (R Development Core Team, 2015). We used Poisson regression analysis to assess variation in the productivity of breeding pairs in the study area to breeding pairs elsewhere in County Kerry. We performed a two-sample Kolmogorov-Smirnov test to compare the road and adjacent habitat characteristics of Barn Owl mortality locations to random control points. We used QGIS to assess the spatial relationship between Barn Owl mortality locations and between Barn Owl sightings locations.

4. RESULTS

4.1 Barn Owl Status

4.1.1 Study area

Collation of information on Barn Owl sites and sightings within the study area between 2012 and May 2014, revealed three Barn Owl nest sites, and four roost sites. One additional site, a derelict cottage at Lack Beg (IQ 849 209), was known to be a nest site in 2013, though access to monitor this site was denied during the study period, it was not possible to determine the status of this site and therefore it is excluded from density and occupancy estimates. There were nine sightings of Barn Owls within the study area between 2012 and May 2014, of which five were within 1km of known sites and four of were more than 1km away from known sites. There were three Barn Owl mortality records in the study area between 2012 and May 2014 all of which were road casualties on the Tralee Bypass.

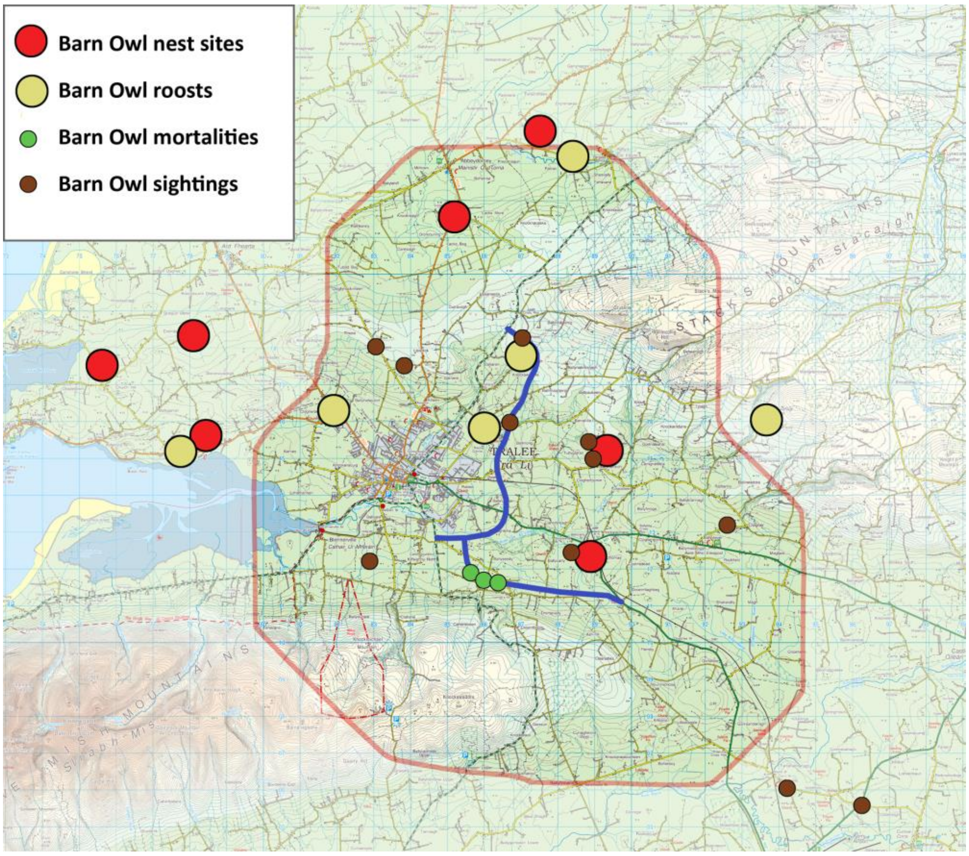

Figure 4.1 *The distribution of recorded Barn Owl sites, sightings and mortality records in the study area (January 2012 – May 2014); to keep Barn Owl site locations discrete the centre point for the nest/roost is plotted at random within the 1km square in which the actual site occurs*

4.1.2 Distribution and abundance

The Barn Owl survey was carried out between the 18th of July and the 30th of August 2014. A total of 147 sites were assessed to determine suitability and occupancy of Barn Owls. Of these, the most common site type assessed were derelict cottages (n = 92), followed by derelict two-story farmhouses (n = 26), stone barns (n = 11), metal-roofed barns (n = 6), castles (n = 3), derelict mansions (n = 2), derelict churches (n = 2), and a single tree (previously used by breeding Barn Owls), derelict warehouse, quarry, outdoor tree nest box, and a derelict school. The site types are shown below (Fig 4.2.).

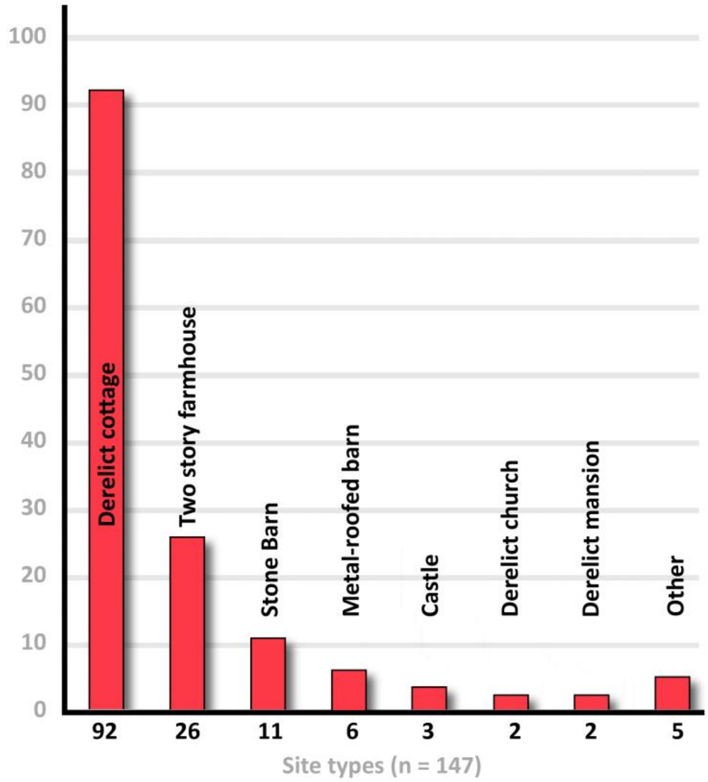

Figure 4.2 *Variation in all site types surveyed (n=147)*

A total of 50 sites (34%) were considered to be unsuitable for Barn Owls (category 0), 42 sites (28%) were deemed to offer potential roosting opportunities but were not suitable for nesting (category 1). A total of 23 (16%) sites were considered to be suitable for roosting and potentially suitable for nesting (category 2). The remaining 32 sites (22%) were assigned to category 3, considered to be suitable for nesting. Therefore, there were a total of 55 sites (category 2 and 3) in the 195 km^2 study area that could be used by breeding Barn Owls, representing a density of 28 suitable sites per 100 km^2. These consisted of derelict cottages (n = 28), two story farmhouses (n = 22), stone barns (n = 3) and a single derelict mansion and derelict warehouse. The number of buildings assigned to each category (Fig. 4.3) and a map of the sites surveyed (Fig. 4.4) are shown below.

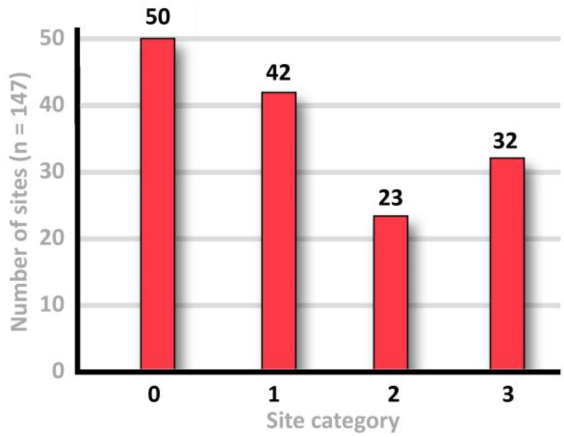

Figure 4.3 *The variation in suitability (categories 0 – 3) across all buildings surveyed (n = 147)*

Signs of Barn Owl occupation were recorded at ten sites in the survey area in 2014, representing 18% of sites which could be potentially used by Barn Owls (n = 55). Of these ten sites, seven were previously documented by BWI, of which two were confirmed as nest sites and five were used for roosting between 2012 and May 2014. In addition Barn Owl activity was confirmed at three previously undocumented sites within the study area. The ten sites consisted of six category 3 and four category 2 sites. The site types were derelict two story houses (n = 4), derelict cottages (n = 3), and a single derelict mansion, tree and ruined house.

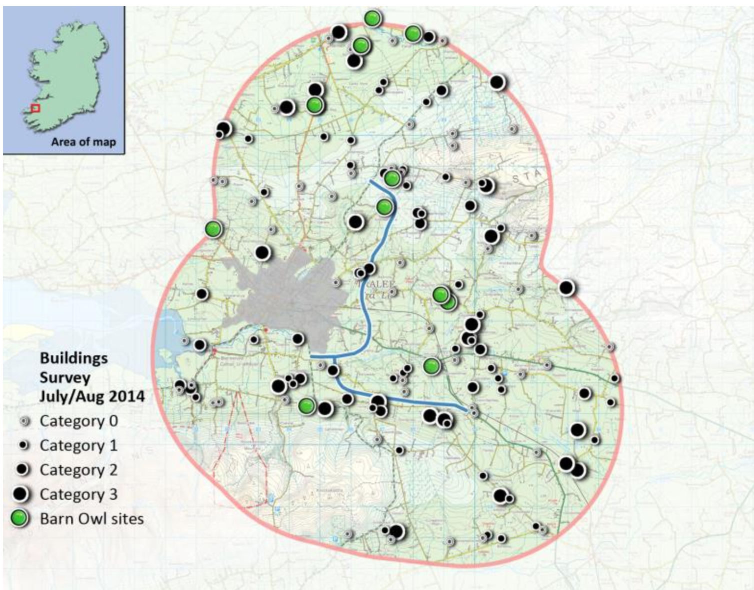

Figure 4.4 *The distribution, suitability and occupancy status of all sites surveyed (n = 147); to keep Barn Owl site locations discrete the centre point for the nest/roost is plotted at random within the 1km square in which the actual site occurs*

4.1.3 Activity and breeding Status

Monitoring of all sites where evidence of Barn Owls was recorded revealed that in 2014 two were used for nesting and five were roost sites. The other three sites where signs of occupation were confirmed were deemed to be inactive in 2014. Therefore in 2014 there were seven active sites within the study area, of which two were nest sites and five were roosts.

Both active nest sites in 2014 were once again used for nesting in 2015. In addition two sites used for roosting in 2014 held breeding pairs in 2015. One roost site used in 2014 remained active in 2015. There was no activity recorded in 2015 at two roost sites which were confirmed as active in 2014. Therefore in 2015 there were five active sites within the study area, of which four were nest sites and one was a roost.

In 2014 there was a recorded density of one breeding pair per 100km^2 within the study area. There was a density of 2.1 breeding pairs per 100km^2 in the study area in 2015.

The four confirmed nest sites in 2014 and 2015 consisted of a derelict two-storey farmhouse, a derelict cottage, a nest box in a stone barn and a nest box in a tree. Of five roost sites confirmed within the study area in 2014 and 2015 three were in derelict two story houses, two were in derelict cottages and one was in a derelict mansion. Fig. 4.5 below shows the distribution and status of all Barn Owl sites recorded within the study area in 2014 and 2015.

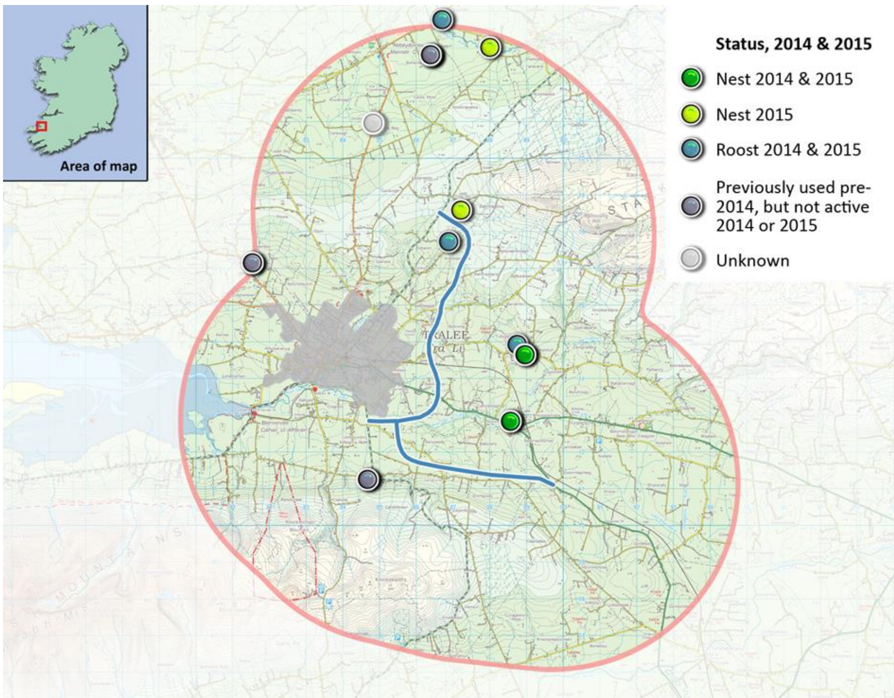

Figure 4.5 *The location and status of all active Barn Owl sites within the study area in 2014 and 2015; to keep Barn Owl site locations discrete the centre point for the nest/roost is plotted at random within the 1km square in which the actual site occurs*

4.1.4 Breeding performance

Of two confirmed nests in 2014, one was successful (50%) which fledged two young and the other pair failed. There was an average productivity of one young per breeding attempt (n = 2) within the study area in 2014 (range 0 – 2). Of four confirmed nests in 2015 three were successful (75%). An average productivity of 2.25 young per pair (range 0 – 3) was recorded within the study area in 2015. Table 4.1 below shows the status, location, site type, and proximity of sites to the Bypass in 2014 and 2015.

Table 4.1 *The location, distance from Bypass and breeding status of all Barn Owl sites within the study area in 2014 and 2015*

Site name	Site type	Distance from Bypass	Status 2014	Successful 2014	Fledged young 2014	Status 2015	Successful 2015	Fledged young 2015
Ballycarty	Tree	2.2km	Nest	Yes	2	Nest	Yes	0
Ballynahinch	Derelict house	2.6km	Nest	Failed	0	Nest	Yes	3
Ballyconnell	Derelict cottage	4.8km	Roost	n/a	n/a	Nest	Yes	3
Ballintobeenig	Derelict house	400m	Roost	n/a	n/a	Nest	Yes	3
Lismore	Derelict mansion	250m	Roost	n/a	n/a	Not active	n/a	n/a
Bawnboy	Derelict house	5km	Previously used not active 2014/15	n/a	n/a	Not active	n/a	n/a
Ballynahinch 2	Ruined house	2.6km	Roost	n/a	n/a	Roost	n/a	n/a
Shannow Bridge	Derelict cottage	5.0km	Roost	n/a	n/a	Not active	n/a	n/a
Clahane	Derelict house	1.2km	Previously used not active 2014/15	n/a	n/a	Not active	n/a	n/a
Boherroe	Derelict cottage	4.8km	Previously used not active 2014/15	n/a	n/a	Not active	n/a	n/a

4.2 Avian and mammalian road mortalities on the Tralee Bypass

4.2.1 Barn Owl road mortalities

A total of ten Barn Owl casualties were recorded on the Tralee Bypass between August 2014 and December 2015. Five road casualties were recorded through the weekly road casualty survey and five were reported to BWI by independent observers. There was a minimum casualty rate of 52 Barn Owls per 100km per year on the Tralee Bypass during the study period.

Of the ten Barn Owl road casualties recorded, one was recovered during the breeding season (March to July) with all other casualties recorded outside of the breeding season (January to February and August to December). The week of occurrence of all ten Barn Owl casualties recorded between August 2014 and December 2015 are shown below (Fig. 4.6).

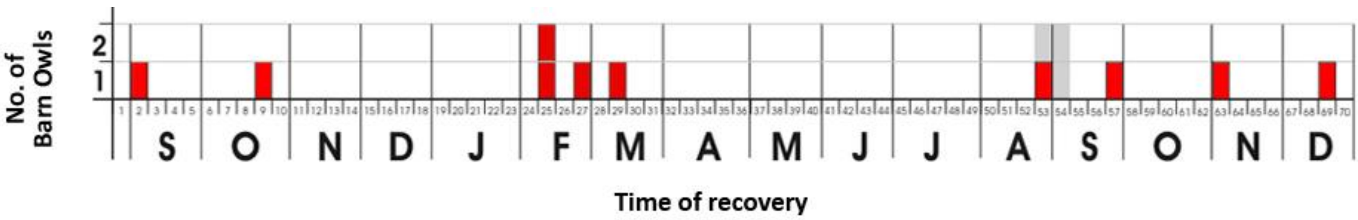

***Figure 4.6** Period of occurrence of Barn Owl casualties (n=10) on the Tralee Bypass*

It was possible to accurately age nine of the ten Barn Owl road casualties, of which eight (80%) were first calendar-year or second calendar-year pre-breeding season birds (i.e. recovered before March of their second calendar year) and one was an adult. Seven of the ten casualties could be accurately sexed, of which six were male and one was female.

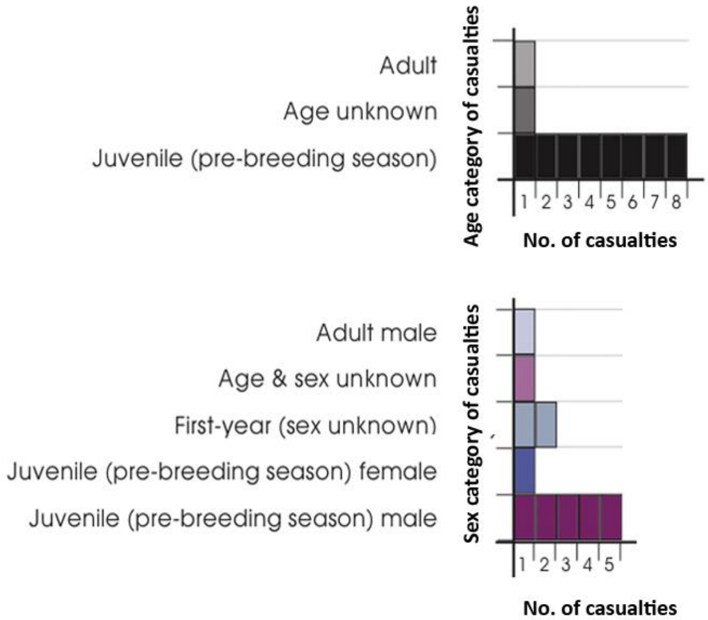

***Figure 4.7.** The age and sex of Barn Owl road casualties on the Tralee Bypass*

Three (30%) of the ten Barn Owl road casualties recovered were ringed. Two of these were ringed as young in the nest during the breeding season of 2014 at nest sites near Castleisland and Milltown in County Kerry which are located 16.7km and 13.3km from the Tralee Bypass respectively. Both birds were recovered on the 15th of February 2015 as part of the road casualty survey. An adult male which was ringed as a breeding bird at Ballynahinch nest site in June 2013 which is 2.6 km from the Bypass was recovered on the 1st of September 2015 as part of the road casualty survey. This male was of the pair which successfully fledged three young in 2015. The natal or breeding sites of the ringed birds and the location of their recovery on the Tralee Bypass is shown in Fig. 4.8.

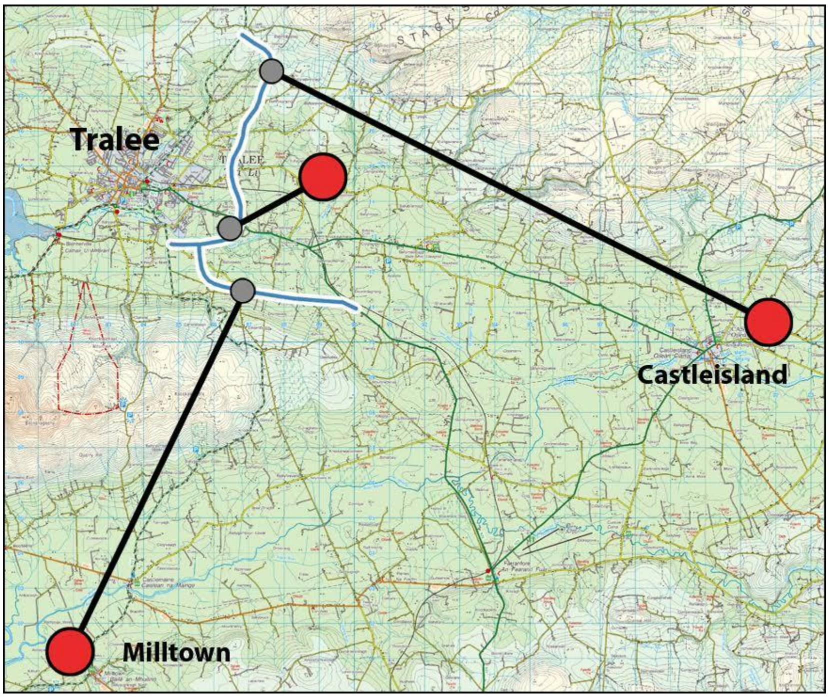

Figure 4.8. *The location of Barn Owls were ringed (red dot) and subsequently recovered (grey dot) on the Tralee Bypass; to keep Barn Owl site locations discrete the centre point for the nest/roost is plotted at random within the 1km square in which the actual site occurs.*

Five Barn Owl road casualties (50%) were recovered from sections of the Bypass which are embanked, of which four were where the route has an embankment height of 2 – 4m, and one was where the route was embanked by >4m. Four Barn Owl road casualties were recovered from sections of the route which were level and one was recorded on a section of the route which was lower than the surrounding landscape (0 – 2m cut). There was no significant difference between the elevation height of the route where Barn Owls were recovered (n = 10) compared to random control points (n = 50) on the route. Nine of the ten Barn Owls were recovered where grass verges were greater than 5m in width with one location having a grass verge between 0 – 5m. There was no significant difference between the grass verge width at Barn Owl recovery locations (n = 10) and random controls (n = 50). Nine of the Barn Owl recovery locations had adjacent habitats which were predominantly fields with hedgerows/tree lines with one dominated by woodland. There was a significant difference between the adjacent habitats to the route at Barn Owl recovery locations to random control points (D = 0.5, p-value = 0.03101). The details recorded for all Barn Owl road mortalities are shown below in Table 4.2. The location of the Barn Owl casualties (n = 10) on the Tralee Bypass between August 2014 and December 2015 and the elevation of the route is shown below (Fig. 4.9).

***Table 4.2** The date, location, road and habitat characteristics of Barn Owl road mortalities on the Tralee Bypass*

Date	Grid Reference	Recorder	Embankment height	Position of casualty on road	Grass verge	Adjacent landscapefeatures
23.10.2014	IQ 86215 13113	Road Survey	0m	Grass verge	>5m	Fields with hedgerow/tree lines
12.12.2014	IQ 87517 17617	Road Survey	0–2m cutting	Grass verge	>5m	Open fields
12.12.2014	IQ 86672 11638	Road Survey	0m	Grass verge	0–5m	Fields with hedgerow/tree lines
05.11.2015	IQ 86209 13100	Road Survey	0m	Path by road	>5m	Fields with hedgerow/tree lines
17.12.2015	IQ 87070 16592	Road Survey	0m	Central median	>5m	Fields with hedgerow/tree lines
11.09.2014	IQ 87212 18282	Member of public	2–4m embankment	Centre of 2 SB lanes	>5m	Fields with hedgerow/tree lines
02.03.2015	IQ 86225 13117	Member of public	0–2m embankment	Central median	>5m	Fields with hedgerow/tree lines
18.03.2015	IQ 87494 17896	Member of public	2–4m embankment	Central median	>5m	Woodland
01.09.2015	IQ 86606 13979	Member of public	0–2m embankment	Grass verge	>5m	Fields with hedgerow/tree lines
30.09.2015	IQ 87694 11471	Member of public	>4m embankment	Centre of EB lane	>5m	Fields with hedgerow/tree lines

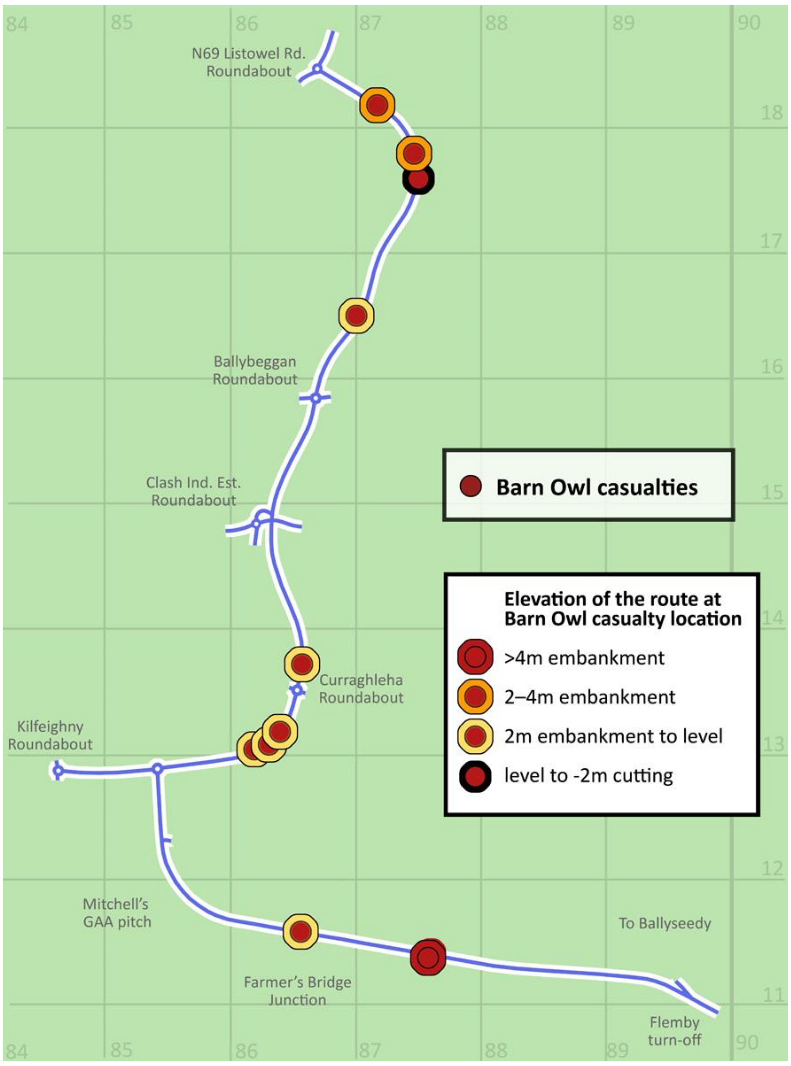

***Figure 4.9** The location of Barn Owl casualties on the Tralee Bypass in relation to the elevation of the route*

The average distance between Barn Owl mortality locations (n = 10) was 3.3km and ranged from 10m to 6.9km (se = 2.8km). Three Barn Owl road mortalities (IQ 86125 13113, IQ 86209 13100 & IQ 876225 13117) were recovered within 50m of each other that were close to the western edge of Ballyseedy Woods. A further two Barn Owl mortalities (IQ 87517 17617 & IQ 87212 18282) were located between 50 to100m of each other on the northern section of the Bypass, and two (IQ 87517 17617 & IQ 87494 17896) were within 200m of each other also on the northern section of the route.

4.2.2 Barn Owl sightings

A total of 18 sightings of Barn Owls were recorded during the survey period within100m of the Bypass, all of which were reported by independent observers. Twelve sightings were mapped to within 5m accuracy; five were mapped to within 50m, and one to within 200m. Of the 18 sightings, four were within the breeding season (March to July), and 14 were in the non-breeding season.

A description of the behaviour of the birds when observed was recorded for all sightings (n = 18). Nine (50%) were observed in flight over the Bypass. The flight height was recorded for four of these observations, all of which were between 2–5m. Four sightings were of birds perched on roadside posts/signs within 10m of the road verge, four were recorded actively hunting in flight, hovering or flying parallel to or near to the Bypass, and one was observed in transit flight within 100m of the Bypass. All Barn Owl sightings recorded within 100m of the Bypass between August 2014 and December 2015 (Fig. 4.10), and month of sighting (Fig. 4.11) are shown below.

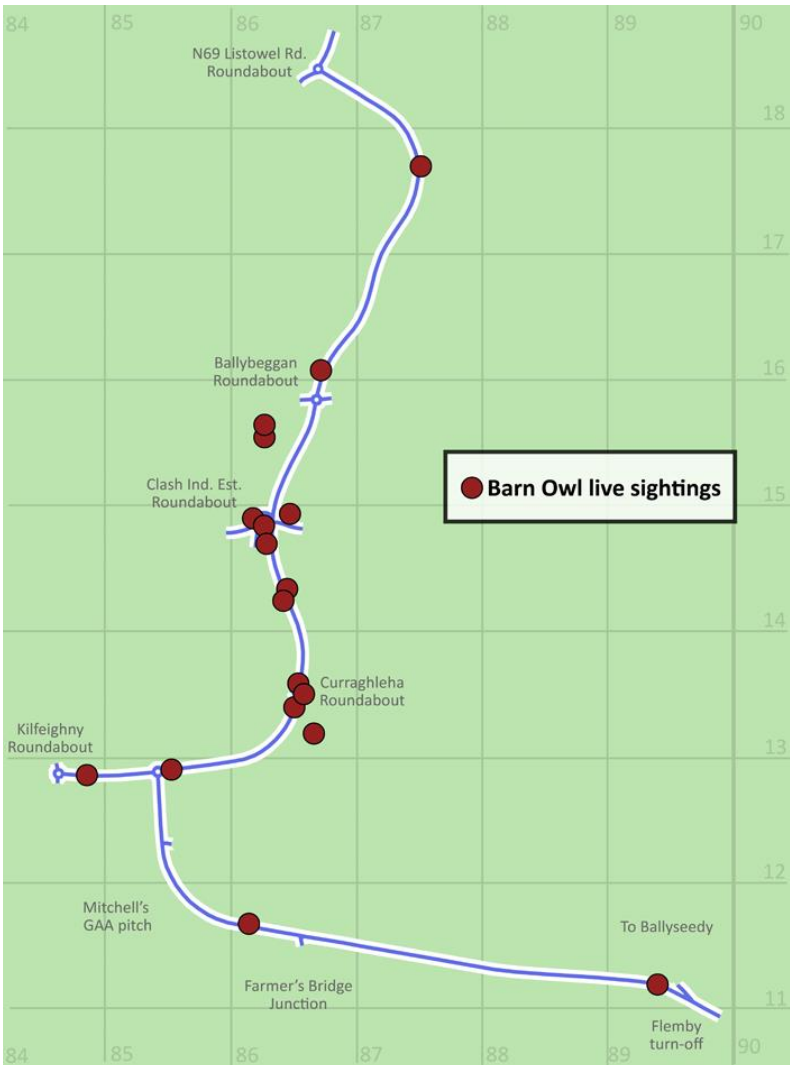

Figure 4.10. *The distribution of Barn Owl sighting within 100m of the Tralee Bypass (August 2014 – 2015)*

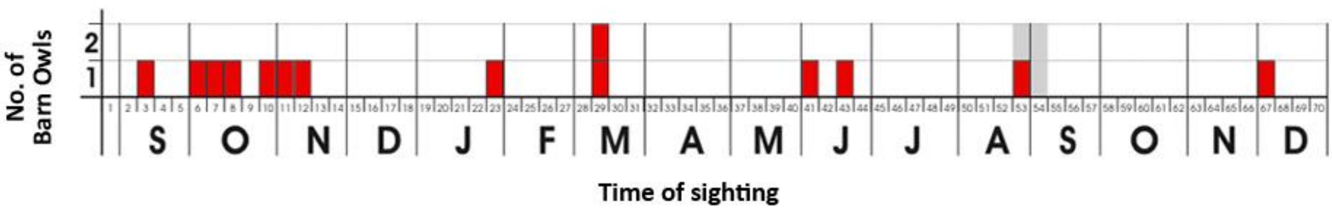

Figure 4.11. *The period of occurrence of Barn Owl sightings within 100m of the Tralee Bypass (August 2014 – 2015)*

4.3.3 Other avian and mammalian road casualties

A total of 65 avian road casualties of 14 species (including Barn Owl) were recorded on the Tralee Bypass between August 2014 and December 2015. It was possible to identify to species level all casualties except one. Of the 65 incidents the most common was Rook *Corvus frugilevus* (n = 24), followed by Jackdaw (n = 9), Barn Owl (n = 5), Woodpigeon *Columba palumbus* (n = 4), Blackbird *Turdus merula* (n = 4), Magpie *Pica pica* (n = 3), Hooded Crow *Corvus cornix* (n = 3), Pheasant *Phasianus colchicus s*(n = 3), Starling *Sturnus vulgaris* (n = 3), Sparrowhawk (n = 2), Pied Wagtail *Motacilla alba* (n = 2), and one each of Kestrel, Pigeon Spp. (Rock *Columba livia* or Stock Dove *Columba oenas*), and Lesser Black-backed Gull *Larus fuscus*.

There were no avian casualties recorded on 26 (38%) of the 68 survey visits, with a maximum of five avian casualties recorded on a single visit. The number of avian casualties recorded ranged from two to nine per month, with the lowest number per month in November and January (n = 2), and peaks in June (n = 9) and August (n = 7). The occurrence and species of all avian road casualties is shown below (Fig. 4.12, and 4.13).

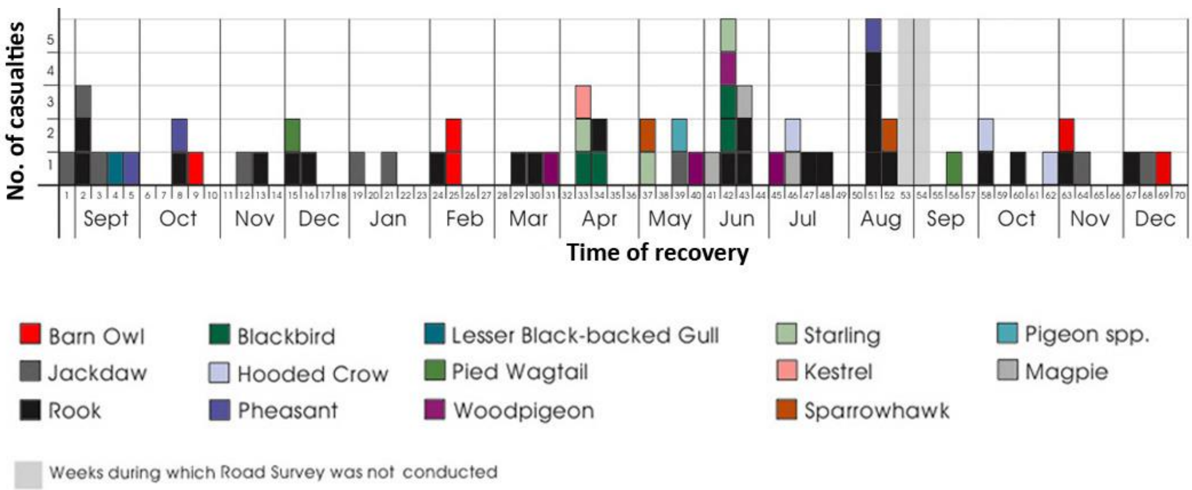

Figure 4.12 *The number and period of occurrence of all avian casualties (n = 65) recorded on the Tralee Bypass (August 2014 – 2015)*

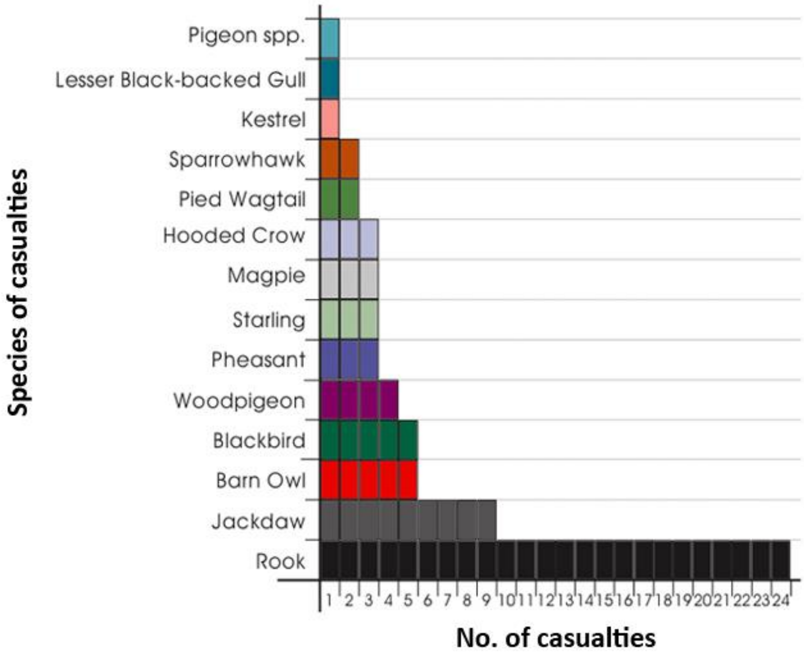

Figure 4.13 *The number per species of all avian casualties (n=65) recorded on the Tralee Bypass (August 2014 – 2015)*

Of the 65 avian road casualties, it was possible to age 53 of the road casualties. Of these, 28 (53%) individuals of nine species were adults and 25 individuals (47%) of ten species were immature/juvenile.

There was a total of 21 mammalian road casualties of seven species recorded, of which the most common was Rabbit *Orycholagus cuniculus* (n = 8) and Hedgehog *Erinaceus europaeus* (n = 8), with one each of Mink *Mustela vison*, Fox *Vulpes vulpes*, Brown Rat *Rattus norvegicus*, Badger *Meles meles*, and a Domestic Cat *Felis cattus*.

There were no mammalian casualties recorded in six months of the survey (October, December, January, February, May and July), with three incidents recorded in each of five months (November, March, April June and October).

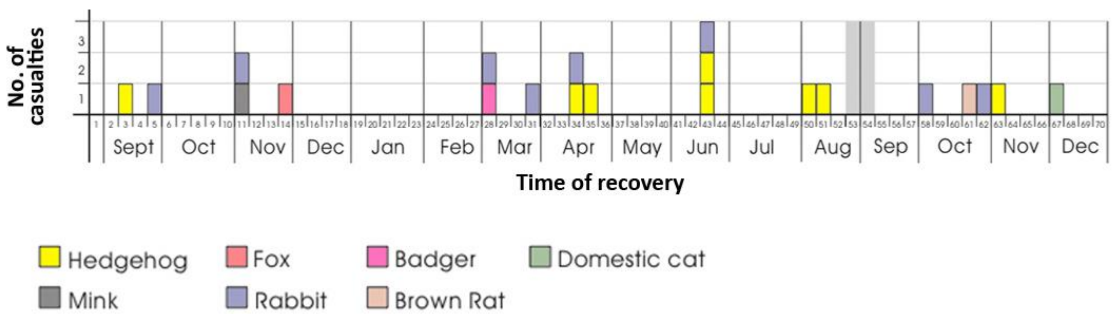

Figure 4.14 *The number and period of occurrence of all mammalian casualties (n = 21) recorded on the Tralee Bypass (August 2014 – 2015)*

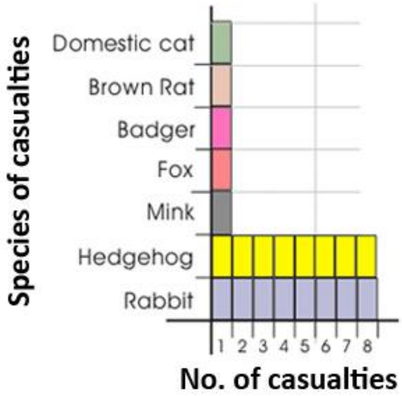

Figure 4.15 *The number per species of all avian casualties (n=65) recorded on the Tralee Bypass (August 2014 – 2015)*

4.2.4 Raptor sightings

A total of 41 sightings of three species of raptor were recorded during the road casualty survey. Kestrel was the most frequently recorded bird of prey, with 37 sightings on 30 of the 68 survey visits. Kestrels were recorded most often in October (n = 9) with no sightings in September or November 2015. A Sparrowhawk was recorded on three survey visits and Peregrine Falcon on one occasion.

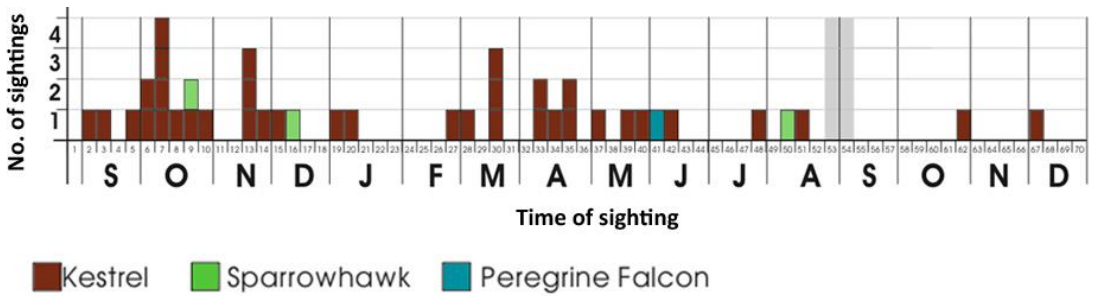

Figure 4.16 *The number and period of occurrence of all raptor observations (n = 41) on the Tralee Bypass (August 2014 – 2015)*

Of the Kestrel sightings where it was possible to determine sex (95%), the majority were adult males (n = 27), followed by female/immature (n = 5) and adult females (n = 3), while two individuals were not possible to sex. Of the three Sparrowhawk sightings two were adult females, and one was female/immature. The Peregrine Falcon was an adult, and the sex was not determined.

Of the 37 Kestrel sightings, 31 (84%) were actively hunting, either perched on posts, trees or pylons directly over grass verges (n = 8), or actively hovering directly over grass verges (n = 23). Where the height of flight was recorded (n = 13) ten were at 0–5m and three were at 5–10m in height. In only six cases were Kestrels seen flying over or along the Bypass without apparent hunting behaviour. In two instances Kestrels were seen to dive onto the grass verges, unsuccessfully on one occasion, on the other, emerging from the long grass with a Bank Vole *Myodes glareolus* (Image 4.6, Appendix). The three Sparrowhawks recorded during the survey were crossing the Bypass laterally, two at a height of 0 – 5m and one at a height >10m. One Peregrine Falcon sighting was of a bird flying across the Bypass at >10m height.

5. DISCUSSION

5.1 Barn Owl status

Survey work revealed a high availability of suitable sites within the study area for Barn Owls, with a recorded density of 28 suitable sites per 100km^2 across a range of site types. This site availability is higher than findings from similar studies which recorded an availability of 17 suitable sites (category 2 and 3) per 100km^2 in North and East Kerry (O'Clery *et al.* 2013). A site availability of 12 suitable buildings per 100km^2 was estimated in County Offaly in 2012 (Lusby *et al.* 2012). In Counties Limerick and Cork in 2010 a density of 10.8 suitable sites per 100km^2 was recorded (Lusby *et al.* 2010), and in Duhallow (north Cork and east Kerry) in 2013 a density of 14.6 suitable sites per 100km^2 was recorded (O'Clery *et al.* 2013a). The fact that there is a high proportion of suitable sites which are not used by Barn Owls (82%) within the study area indicates that the availability of nest sites is not a limiting factor for the local population and that any direct loss of sites or reduced suitability of sites resulting from the development of the Bypass is not likely to have had a adverse effect on the local population in terms of availability of nest sites.

There was a greater number of sites used for roosting (n = 5) compared to sites used for nesting (n = 4) recorded within the study area across both years of the study combined. Roost sites can be used on a sporadic basis, as some may be used for a short period by dispersing birds and others may be used by a bird/s associated with a nest site. Therefore, the number of roost sites in an area does not reflect the number of breeding pairs, or indeed the occupancy of roost sites over time does not accurately reflect the occupancy of a resident pair in an area. For this reason greater emphasis is placed on breeding sites when assessing occupancy and density within the study area and to allow for comparisons with other studies as the density and trends of breeding pairs provides a more accurate indication of the health and status of the population. It is nevertheless important to record and monitor roost sites, as shown by the fact that two sites classed as roosts in 2014 were subsequently used for nesting in 2015. However, cessation of activity at roost sites, as recorded at two roosts during the study period does not reflect changes in Barn Owl status. There was a density of one breeding pair per 100km^2 in the study area in 2014 and 2.1 breeding pairs within the study area in 2015. These densities are similar or higher than most Barn Owl density estimates available for elsewhere in Ireland where the same survey methods have been applied. A study in north and east Kerry in 2013 confirmed three breeding pairs within 300km^2, which equates to one pair per 100km^2 (O'Clery *et al.* 2013). In County Offaly density survey work in 2012 produced an estimate of 0.3 pairs per 100km^2 (Lusby *et al.* 2012), while in Counties Limerick and Cork 0.35 nesting pairs per 100km^2 were estimated in 2010 (Lusby *et al.* 2010). A survey of 225km^2 surrounding Galway city in 2015 produced 0.8 pairs per

100km^2 (O'Clery and Lusby 2015). In Duhallow in north Cork and east Kerry a higher density estimate compared with the current survey was generated at 2.6 pairs per 100km^2 (O'Clery *et al.* 2013a).

There was a high occupancy rate of nest sites in the study area prior to and during the study period. Both sites which were known to hold breeding pairs in 2012 and 2013 prior to the opening of the Tralee Bypass remained active during the study period (2014 – 2015). In addition, there was an increase in breeding sites from two breeding pairs in 2014 to four breeding pairs (100%) in 2015 indicating that the Bypass is not having a negative effect on the occupancy of local Barn Owl sites. Shawyer (1998) suggested that soon after major road schemes are complete Barn Owl mortality increases with the result that local populations are rapidly depleted within 2km over a few years, however this does not seem to be the case in the area surrounding the Tralee Bypass, at least during the current study period. The proximity of nest sites to the Bypass also further indicates that the route has not affected the occupancy of sites within the study area. Both known nest sites which have held breeding pairs before and after the Bypass has been in operation are located 2.2km and 2.6km from the route. The closest confirmed nest site to the Bypass was 400m which was a site used for roosting in 2014 and subsequently used for nesting in 2015. These findings differ from those of a UK study which indicated that new major road development caused the loss of all Barn Owls within 0.5km, and severe depletion of populations within 0.5 to 2.5km of the route (Ramsden 2003). The findings of a Barn Owl survey of Britain and Ireland suggested that only 20 of the 5,000 estimated pairs were located within 1km of a motorway and fewer than 100 pairs were within 3km (Shawyer 1998). It must be noted however that a range of biotic and abiotic factors which vary between sites can influence the extent of road mortalities and impacts on a particular population, which include characteristics relating to the route such as the traffic volumes, speed of vehicles and physical characteristics of the road, as well as ecological factors such as population density, survival, mortality and recruitment. Also, individual sites may remain active over a period of time, but this may be due to a high turn-over and recruitment at these sites, such that they act as a population 'sink' if resident birds are killed on the road and then replaced. However, based on the age demographics and breeding status of Barn Owl road mortality incidents recovered on the Tralee Bypass it would seem that only one adult was killed on the Bypass over the study period. A greater understanding of recruitment and turn-over at individual sites, as well as other mortality causes and survival in the study area would facilitate a more complete understanding of the overall impacts or otherwise of the Bypass on the local population.

In addition to the trends of the local Barn Owl population as measured by occupancy rates of breeding sites, breeding performance is also an important indicator in assessing the health of a population. Barn Owl breeding performance can vary on an annual basis and therefore breeding output between populations is best compared in the same breeding seasons. In 2014 the breeding success of Barn Owls in County Kerry was 74% (n = 23) with a productivity of 1.8 young per breeding attempt (se = 0.3, n = 18, range = 0 – 4). This was higher than the breeding success of 50% and productivity of one young fledged per breeding attempt (n = 2) recorded in the study area in 2014. In 2015 the breeding success of Barn Owls in County Kerry was 82% (n = 34) with a productivity of 2.7 young per breeding attempt (se = 0.3, n = 26, range = 0 -6). This compares with a breeding success rate of 75% and productivity of 2.25 young per breeding attempt (n =

4) in the study area in 2015. Although the breeding output was lower within the study area compared to other breeding pairs monitored in the county this difference was not significant. Therefore, the findings indicate that the Bypass is not having a significant effect on breeding performance of the local population compared with the wider population in County Kerry. However, it should be noted that the low sample size of sites within the study area in both years restricts more robust analysis.

5.2 Avian and mammalian road mortalities on the Tralee Bypass

5.2.1 Barn Owl road mortalities

The estimated annual road casualty rate of 52 Barn Owls per 100km on the Tralee Bypass is within the mid-range of available estimates for Barn Owl mortality rates on major roads in other parts of their range. The estimates for the current study are higher than those of seven Barn Owl casualties per 100km on a motorway in Switzerland (Bourquin, 1983), and 25 Barn Owl casualties per 100km per year on a motorway in north-eastern France (Massemin & Zorn, 1998). The current estimates are however lower than 65 casualties per 100km on a motorway in north-eastern France (Baudvin, 1997), 68 Barn Owls per 100km per year on a major road with single and dual carriageway sections in the UK (Shawyer and Dixon, 1999) and 599 Barn Owls per 100km per year on an Interstate in Idaho (Boves and Belthoff, 2012). Direct comparisons of road casualty rates between studies should be treated with caution. Boves and Belthoff (2012) showed that Barn Owl road casualties were significantly under-recorded by standard search methods alone. Survey methods and potential for bias arising in search methods varies across different methods. Santos et al. (2011) showed that birds of prey and other large bird road casualties had a persistence time of between three to six days on the road during which time they could be recorded. Shawyer and Dixon (1999) showed that four Barn Owl carcasses placed on a major road remained intact and visible for a minimum of four days. The timing and frequency of survey visits varies significantly between studies and may affect the results and comparisons between studies. Shawyer and Dixon (1999) conducted road casualty surveys every 48 hrs, whereas Baudvin (1997) carried out three surveys daily of the section of route assessed. Boves and Belthoff (2012) carried out standardised surveys every two weeks. In addition to the one visit per week we employed the use of reports from members of the public and relevant organisations to facilitate recording of Barn Owl road casualties outside of survey visits, which has also been employed successfully by other studies (Shawyer and Dixon 1999). Nonetheless the number of Barn Owl road mortalities recorded should be considered a minimum estimate as there is the potential for carcasses to be removed by scavengers or to be in position where they not possible to detect. In addition to variation in search methods there are a range of factors which may influence the extent of road mortalities for a particular species, such as the characteristics of the route and surrounding landscape such as the traffic volumes, speed of traffic and physical attributes of the route (elevation of the road, presence of grass verges etc.), as well as ecological factors including population densities for the species in proximity to the route. The estimated casualty rate for the Tralee Bypass nevertheless seems to be high relative to other studies given the apparently low traffic volume on the route coupled with the relatively low population density of Barn Owls in the study area compared to other parts of its range (Shawyer 1998).

The fact that Barn Owl was the third most frequently recorded avian road mortality by the road casualty survey, representing 8% of all avian mortalities highlights the susceptibility of the species to vehicle collisions, as the population density of Barn Owls in Ireland is considered to be lower than that of all other species for which there was two or more road mortality incidents recorded. Two other studies which assessed avian road casualties in Ireland recorded proportionally fewer Barn Owls relative to other species. A survey of avian road casualties in Counties Cork and Waterford between July 1984 and June 1985 recorded 492 bird road casualties of which two were Barn Owls (<0.1%) (Smiddy 2002). A survey of a minor road in County Tipperary over a thirteen-month period in 1986 and 1987 recorded 70 birds of 17 species with no records of Barn Owl (Butler 1992).

The timing of Barn Owl road mortality incidents (Masssemin and Zorn 1998, Shawyer and Dixon 1999) and the age demography of birds recovered on the Tralee Bypass is broadly similar to findings from other studies, with the majority of road mortalities occurring outside the breeding season and involving non-breeding birds. Barn Owl numbers typically peak in the post breeding season period (Shawyer 1998). The proportion of juveniles to adults is generally higher at this time of year which also coincides with the dispersal period for juveniles and therefore it is more likely that this age group comprise a greater proportion of road casualties. The loss of juvenile birds may have less of a population level impact population as these birds have not been recruited to the breeding population, and there is typically a high mortality rate for juvenile Barn Owls due to a range of factors in addition to road mortalities (Shawyer 1998). In 2015 a total of 30 owlets from nine broods were ringed in County Kerry, of which 7% (2) were killed on the Tralee Bypass. A single adult Barn Owl was recovered on the Tralee Bypass which was also ringed. This bird was a male associated with a nest site located 2.6km from the Bypass which failed to breed in 2014 but which fledged young in 2015. This male was recovered on the Tralee Bypass in late 2015 which indicates that adult birds which are resident within the study area are also susceptible to vehicle collisions. This was the only confirmed adult recovered on the Bypass which equates to one of eight (12.5%) adult breeding birds known to occur in the study area in 2015.

The average distance between locations where Barn Owl mortalities were recovered (n = 10) on the Tralee Bypass was 3.3km and ranged from 10m to 6.9km (se = 2.8km). Three Barn Owl road mortalities were recovered within 50m of each other close to the western edge of Ballyseedy Woods. All other Barn Owl mortality locations (n = 7) were more than 50m from the next nearest recovery location. The area where three Barn Owl road mortalities were clustered is considered to be a potentially 'high risk' area and is the only such area identified by this study. The embankment characteristics of the route at the three Barn Owl recovery locations were recorded as level (2) and 0-2m embanked. In contrast to other studies, based on the Barn Owls mortality data (n = 10), the height of the route relative to the surrounding landscape and the presence and width of grass verges did not seem to influence risk of collision on the Tralee Bypass. Apart from the single cluster of three Barn Owl mortalities on the Bypass close to Ballyseedy Woods, Barn Owl mortalities were otherwise widely distributed across the route and were not significantly associated with specific route characteristics. This makes identification of sections or characteristics of the route for mitigation difficult. The presence of hedgerows and tree lines in proximity to the route was the only variable tested which significantly influenced risk of collision. This seems to concur with findings from a study in England, which found that Barn Owl road casualties were more likely to occur where the road traversed linear habitat features along which the birds might hunt (Shawyer and Dixon 1999). In interpreting the findings in relation to the significance of adjacent habitat features on risk of Barn Owl collision, the caveat of small sample size of Barn Owl mortality records collated by the current study needs to be taken into account.

The observations of Barn Owls in proximity to the Bypass show that birds routinely come into contact with the route and highlights their susceptibility to being hit by vehicles, as birds were recorded directly foraging along the verge habitats of the route (n = 8), and in flight over the route (n = 8). The recorded flight height of birds crossing the route which was less than 5m (n = 4) is within the height range of certain vehicle types. Ramsden (2003) estimated that 72% of Barn Owls which encounter a major road are likely to be killed, whereas our findings show that the number of Barn Owl encounters with the Tralee Bypass recorded by this study is greater than the number of recorded road mortalities over the same period. It must also be assumed that the sightings recorded are a fraction of the actual number of Barn Owl encounters with the Bypass which occurred over the study period. The observations of birds foraging alongside the verge habitats (n = 8) confirms the suitability of these edge habitats for Barn Owls which may be potentially important as foraging areas for the local population. However, the balance between the benefits of these habitats and the risk association with foraging in close proximity to the route is not known. Of the Barn Owl road mortalities it is not known whether birds were killed when in flight across the route or while foraging the margin habitats. Although outside the scope of the current study, GPS tagging to monitor movements and encounters with the Bypass of resident adult birds within the study area would be valuable in understanding Barn Owl interactions with the route which would help inform the possibility and direction of mitigation.

6. RECCOMENDATIONS – RESEARCH

- The findings of this study indicate that the Tralee Bypass has not caused the loss of sites or displacement of the local Barn Owl population over the two breeding seasons (2014 and 2015) since it was opened to traffic. Individual sites may however remain active over time even if associated breeding birds are killed on the road, provided there is sufficient recruitment to these sites, such that they can act as a population 'sinks'. Research to identify survival of individual birds and turn-over at specific sites would facilitate a greater understanding of the potential impacts of the Bypass on breeding birds and sites within the study area.

- Although the sample size of observations of Barn Owls which were interacting with the Bypass was low (n = 18), this information nevertheless served to indicate that birds regularly encounter the route, and both utilise the edge habitats for foraging as well as cross over the Bypass. The use of GPS tags to monitor in detail the movements of individual birds within the study area to determine the frequency, behaviour and locations of Barn Owl interactions with the route would significantly add to our understanding of risk the collision and if and how they can be appropriately mitigated.

- In the UK it has been shown that Barn Owl mortality levels on a new motorway dropped over time, which was attributed to declines in the local population. It would be beneficial to extend the monitoring period of the road casualty survey on the Tralee Bypass to determine changes in casualty rates over time which may not have been detected over the current study period.

- With the exception of one 'cluster' where three Barn Owls were recovered within 50m of each other, there were no obvious 'high risk' areas for Barn Owl vehicle collisions recorded on the Tralee Bypass. However, the sample size of mortality records collated during the study period is small, which is in part related to the route length. It is recommended to continue the road casualty survey on the Tralee Bypass and to supplement with data available from major roads elsewhere in the country to facilitate more robust analysis to determine if specific variables influence risk of collision on major roads for Barn Owls in Ireland.

- The Barn Owl sites identified through this study should be prioritised within routine annual monitoring conducted by BWI to determine occupancy, breeding status and breeding performance over time in order to identify any changes in status of the local Barn Owl population which may not have been detected during the current study period.

- For future major road developments in Ireland it is recommended that a comprehensive survey and monitoring protocol following the same methods as outlined in this study is conducted prior to development to inform pre-construction mitigation requirements and to facilitate the adequate assessment of the potential impacts on the local Barn Owl population before and after the development of a route.

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APPENDIX



(Left), a derelict mansion located 250m from the Tralee Bypass which was used for roosting in 2014, but not active in 2015. A derelict two-storey house (centre), located 400m from the route, used for roosting in 2014 and nesting in 2015. A derelict cottage (right), located 4.8km from the Bypass where a single Barn Owl roosted in 2014, and which held a successful pair in 2015.

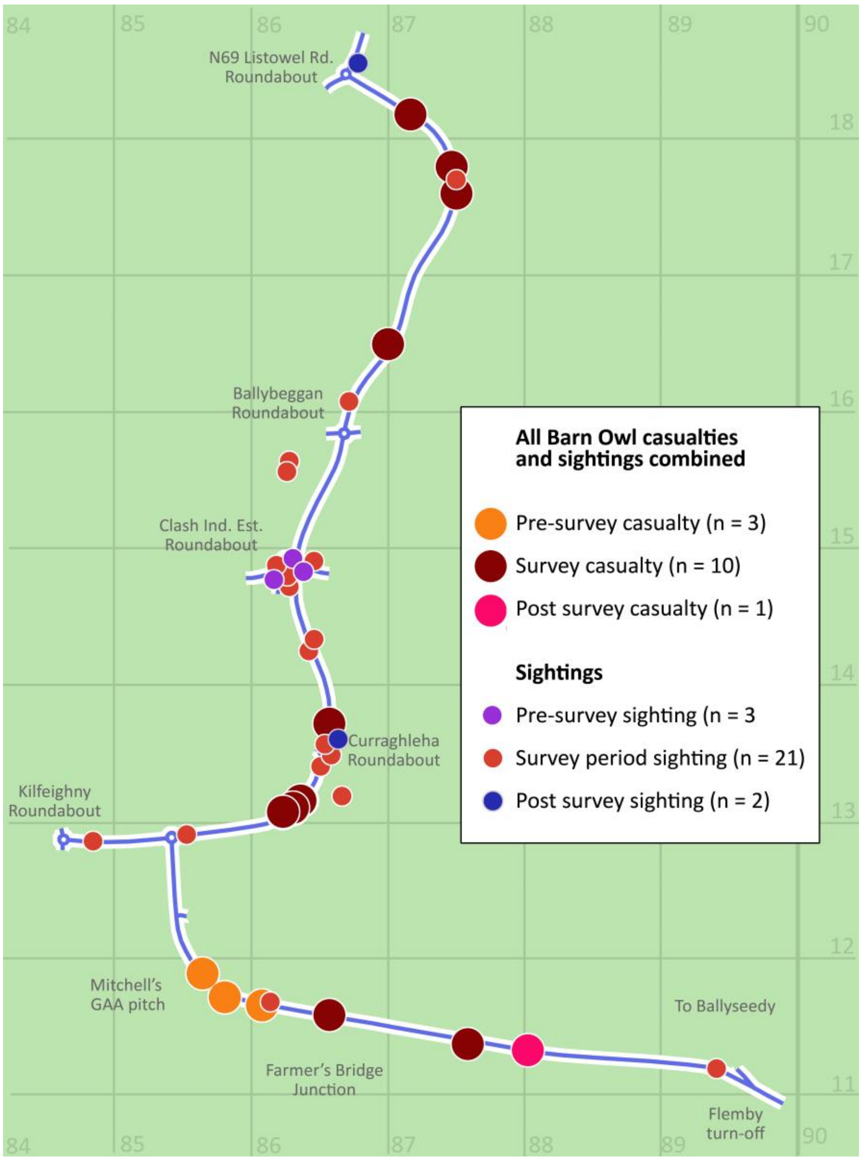

Barn Owl road mortality (left) found in the central median on the 2nd of March 2015, near the western edge of Ballyseedy Wood. A Barn Owl casualty (right), one of two found on the 12th of February 2015, at the Farmer's Bridge junction on the south side of the Bypass


A first-year female Barn Ow Barn Owl road mortality on the broad grass verge towards the northern end of the Bypass, on the 12th of February 2015. A young male Barn Owl (right) found just on the edge of the grass verge near Ballyseedy Wood on the 23rd of October 2014.

Male adult Blackbird road mortality (left) on the 11th of June 2015. Juvenile Magpie(centre) on the hard shoulder, 4th June 2015. Adult Rook (right), 20th August 2015

A Fox road casualty on the grass verge of the Bypass on the 27th of November 2014. Hedgehog (centre), near the Clash slip road on 24th April. The only Badger casualty (right) on the Bypass during the survey, on 5th March 2015, close to the western edge of Ballyseedy Woods

Adult male Kestrel (left) hover-hunting along grass verges on the Tralee Bypass, 16th October 2014. (Centre) Adult male Kestrel having caught a Bank Vole Myodes glareolus along the south section of the Tralee Bypass, 16th October 2014. (Right) Adult female Kestrel perch-hunting from overhead wire along the Bypass on 2nd October 2014



The distribution of all Barn Owl casualties and sightings combined, from October 2013 to April 2016.