



DEER MANAGEMENT SOLUTIONS



REPORT SUBMITTED TO TRANSPORT INFRASTRUCTURE IRELAND AND LAOIS COUNTY COUNCIL

DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

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REPORT SUMMARY

1. Between July 27th and August 30th 2021, Deer Management Solutions commenced a comprehensive survey to establish the density, distribution and movement patterns of deer around the N77 and the wider landscape and to evaluate the potential impacts of deer ecology on spatial and temporal increases in the frequency of Deer Vehicle Collisions (DVCs) on the N77. Faecal Standing Crop counts were utilised to determine deer density and distribution, coupled with regular (direct and indirect) observations of deer movement patterns to assess the scale and extent of migratory behaviour within the project site and, using trail cameras to record the scale of deer movement in the vicinity of and across the N77.
2. The project site encompasses an area of approximately 912 hectares (9.12km²) and consists of a rich mosaic of agricultural, woodland and heathland habitats divided by the N77 carriageway. The project area was divided into three Zones, within which six broad habitat categories were identified. Deer density, distribution and movement patterns were assessed in the project area and also in each individual Zone. There was clear evidence of preference for woodland habitats, particularly by fallow deer and, given the high proportion of woodland (60%) in the project site and along the N77, is likely to lead to a significantly increased risk of DVCs occurring, particularly where woodland is the dominant habitat feature (For details see Section 5, p.5).
3. Three species of deer were identified in the project area, red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and sika deer (*Cervus nippon nippon*). However, two species (red and fallow deer) were more dominant, with red deer density estimated at 2.53 ± 0.87km² (14 – 29 red deer) while fallow deer density was almost twelve times higher and estimated at 24.35 ± 3.69km² (176 – 238 fallow deer). Sika deer were present but at extremely low density. Deer densities are generally variable, both between species and at different regional and spatial scales. To be sustainable, densities should normally be within the range of 6 – 8 km², but ideally should be maintained at, or below 6.0 km². High local deer density within the environs of the N77, is likely to significantly increase the probability of DVCs occurring (For details see Section 9, p.13).
4. Red deer were mostly confined to the north eastern and eastern part of Zone 1, preferring the lag woodland and the interface between Mixed Woodland and Heath habitats. Because of their distribution and low density, red deer are considered less likely to be involved in DVCs. Fallow deer were by far the dominant species, were more widespread and numerous, particularly in Zones 2 and 3. They were present at very high density in all woodland habitats, but at lower density in open Heath habitats (For details see Section 9.4, p.18,19).
5. There was evidence of a widespread network of trails and abundant faecal deposition throughout the project area. Evidence from the trail network, indicated extensive movement (mainly fallow deer) throughout the project area and some degree of migratory movement across the N77 at specific locations. There was little evidence of red deer moving westwards across the N77. Trail camera data thus far (cameras still operational), indicates that there is a seasonal element to movement patterns, with potential peaks in the autumn and spring. Fallow deer density was high on plots located adjacent to the N77 (W), but lower on plots adjacent to the N77 (E) while red deer density was negligible on the same plots (For details see Section 9.6, p.21).
6. The lack of consistent and verifiable historical data on the frequency of collisions on the N77, makes a thorough assessment of the scale of the problem almost impossible and therefore decisions on the extent of the mitigation measures required are more challenging. However, only a detailed evaluation of all the potential factors likely to impact on the frequency of collisions, will clarify precisely what factors, or combination of factors will need to be considered with regard to reducing collisions in future. A National database for the collection of DVC data is therefore considered an essential part of defining the scale of both overall DVC occurrence and mitigation response (For details see Section 10, p.24).
7. The findings in this report, in common with those of similar research in the UK and across Europe and the United States, propose that no one component alone can necessarily be attributed to the number and frequency of collisions that occur. In this regard, the solution to reducing deer vehicle collisions for this pilot project in the first instance, lies in a multi-faceted approach which includes traffic management, traffic speed, driver behaviour, improved signage, management of roadside vegetation and collaborative deer management, in situations where a prior assessment of local deer densities has been undertaken (For details see Sections 10, 11, 13).

This report has been prepared by DEER MANAGEMENT SOLUTIONS with all reasonable skill, care and due diligence within the terms of the contract.

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DRAFT

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

SECTION 1: INTRODUCTION

There has been relatively little recent research into the scale and cause of DVCs, both internationally and nationally and because official records are only maintained in relatively few countries (Langbein *et al.* 2011), the scale of the problem is likely to be greatly underestimated. What is evident, is that as road infrastructures proliferate, traffic volumes and speed increase. As ungulate densities throughout Europe are also increasing, (Gill, 1990; Appolonio *et al.* 2010), so also do the frequency of road traffic accidents involving ungulates escalate.

In Ireland, as in most of northern and central Europe, the UK and the United States, the abundance and distribution of the three main species of deer (red, sika and fallow) has increased significantly over the last two decades and is showing little sign of decline. For example, compound annual rates of expansion of 7% for red deer and 3% for fallow deer were found by Carden *et al.* (2011) while the total range increases were 565% for red deer and 174% for fallow (Carden *et al.* 2011). However, to date

there has never been any systematic attempts to quantify either deer density or distribution with the exception of some limited regional and local efforts. In general, these local and regional census efforts are often in response to either real or perceived levels of damage, or an increase in the frequency of DVCs or other negative effects of deer over-abundance. Unfortunately, in many parts of the country, DVCs are also on the increase, but actual real-time data on the number or frequency of these collisions is either limited or non-existent. Where evidence does exist, it is generally anecdotal rather than factual with the result that real numbers of collisions are either exaggerated or under-reported.

This project was commissioned by Transport Infrastructure Ireland (TII) and Laois County Council mainly because of concerns over the number of DVCs on the N77 south of the town of Abbeyleix, Co. Laois over the last number of years. Unfortunately, the majority of these have not been recorded and there is currently no central database onto which DVCs can be logged. Limited data from Laois County Council indicates that a minimum of up to a dozen DVCs have occurred on this 3.0km stretch of road between 2014 and 2018. Also, an Garda Síochána do not systematically record instances of collisions involving deer, although local Gardai have estimated that the number of collisions occurring annually is variable, but averages between 3-4 per year (pers.com.).

1.1 BACKGROUND

Traffic accidents involving deer have presented a major problem in the UK, the United States and many other European countries for decades. However, accidents involving deer (and other wildlife) have only recently become a serious problem in many parts of Ireland, mainly as a result of greatly improved road infrastructure and consequent increases in traffic volumes. A review by various authors of figures for European countries, where regular records of DVCs are kept, illustrates the scale of the problem. For example, the Deer Initiative in their National Deer-Vehicle Collisions project in the UK (2003-2005), showed that rates of DVCs in the UK in the late 1990s were estimated at around 30,000 but were more likely to be around 50,000. In Europe, collision rates were higher and have increased significantly with over 140,000 accidents involving deer in Germany, 55,000 in Sweden, 35,000 in Austria, 10,000 in Denmark and 9,000 in Switzerland. The authors estimated that in total, the number of deer killed on roads each year in Europe is in excess of 500,000 (Groot Bruinderink and Hazebroek, 1996). A similar picture is presented of the number of collisions occurring in the United States where the number of accidents involving deer also appears to be increasing (Romin and Bissonette 1996; Putman 1997; Staines *et al.* 2001; Hedlund 2003; State Farm Insurance 2009).

The economic costs associated with DVCs can be significant – serious human injury or fatality, damage to vehicles and costs to the insurance industry and additional burdens on health systems. Langbein (2007) estimated that the 'value of prevention' of human injury in the UK was likely to be in the region of £30 Million and that insurance claims arising from DVCs in England alone were estimated to be £13.5 Million (Langbein 2007). In Ireland, figures relating to vehicle damage and insurance claims are most likely logged by insurance companies, although they may not record these as specifically involving deer.

In most of Europe, the United States and the UK, DVC data are collected and maintained in a centralised system. In Ireland, data on the number, location, frequency and severity of deer vehicle collisions (DVC) do not appear to have been recorded centrally, but there are some exceptions. For example, limited data from An Garda Síochána in 2018, shows that just over 100 accidents involving deer have been recorded countrywide with some injuries but no identifiable fatalities. The lack of systematic quantitative data collection on DVCs clearly presents a significant problem for Local Authorities and Road infrastructure planners and makes planning and mitigation for both existing and new road projects extremely challenging. Furthermore, the lack of sufficient detailed information (i.e. time of year, time of day, species) on DVCs and a limited understanding of the factors which influence their frequency or risk, will likely pose a major handicap in the development of effective management in future.

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SECTION 2: DEER

2.1 SOURCE POPULATIONS

Two predominant species of deer have been identified in the project area – red (*Cervus elaphus*) and fallow deer (*Dama dama*). However, according to local sources, two other deer species, sika deer (*Cervus nippon nippon*) and red x sika hybrids are also reported, but their presence could not be verified. Hybrid deer species are currently only found in three locations in the country, Co. Wicklow, Co. Cork and Co. Fermanagh (Smith *et al.* 2014), although it is not known if red deer and sika deer have hybridised on site, or if the source population is Co. Wicklow, as the approximate linear distance between south Wicklow and Abbeyleix is less than 60km. It is considered locally that red deer (Fig. 1) have been in Abbeyleix for about 15 years and that they may have originated from a deer farm somewhere in the locality, while sika deer are relatively recent immigrants, either from nearby Jenkinstown Park (Kilkenny), or possibly from east Wicklow.

By contrast, fallow deer (Fig. 2) are the most widespread (and numerous) species occurring in Ireland and their distribution is mainly associated with fertile soils and mixed agricultural landscapes (National Biodiversity Data Centre) and it is considered locally that fallow deer have been present in the general area for about two decades. There are numerous large fallow deer populations in the wider landscape such as Emo Park (25km), Birr Castle (54km) and Clonaslee (37km) and there are also local fallow deer populations (within 5km) southwest of Abbeyleix on the Moyne and Dunmore estates, which are likely to be closely associated with the Abbeyleix population. However, some caution is required in interpreting data on deer distribution submitted to the National Biodiversity Data Centre, due to potential misidentification of deer species by the general public.

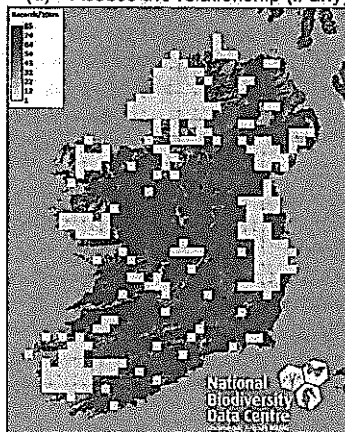
FIG. 1 Red deer distribution (Courtesy NBDC)

FIG. 2 Fallow deer distribution (Courtesy NBDC)

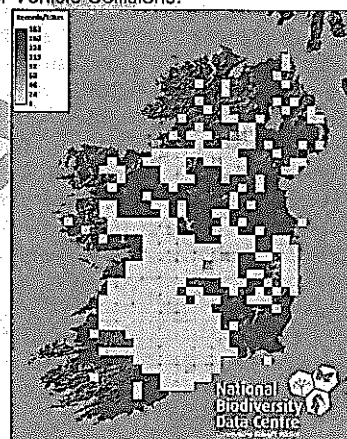
SECTION 3: OBJECTIVES

The main objectives and deliverables laid down at the commencement of this pilot project were to:

- (a) Establish the distribution, movement patterns and deer density (km²)* around the N77 south of the town of Abbeyleix. *(Number of Deer per square kilometre)
- (b) Characterise a broad habitat matrix in the project area and in each of the three Zones
- (c) Establish whether particular habitat variables or other factors may contribute to high deer densities
- (d) Assess the relationship (if any) between those factors and Deer Vehicle Collisions.



- (e) Investigate factors affect accident risk and effectiveness of current measures.
- (f) Make recommendations potential improvements for additional mitigation (design, installation and maintenance of deterrents) reducing the overall and frequency of Deer Collisions.



likely to assess the mitigation

regarding new or measures

aimed at numbers Vehicle

SECTION 4: APPROACH AND

METHODOLOGY

4.1 Sampling

There are a wide variety of methods and approaches for counting deer and many of these methods have been further developed and refined over a number of years (Buckland 1992; Mayle *et al.* 1999; Swanson *et al.* 2008; Luikart *et al.* 2010; Goode *et al.* 2019; Macaulay *et al.* 2019; Wingard *et al.* 2019; Peterson *et al.* 2020; Elenga *et al.* 2020). However, methods available can be broadly divided into direct (those that rely on seeing and counting animals) or indirect (relying on tracks, dung or other sign). Direct counts can often prove to be unreliable and errors caused by a number of factors are known to be difficult to quantify. Firstly, if deer are subject to regular disturbance (culling or human activity) they will always be wary of human presence. Secondly, deer are always difficult, if not impossible to see in dense cover present in woodland habitats and thirdly, during census work, deer frequently move into and out of counters view and can easily be missed or double counted. Furthermore, direct counts are only applicable to one single short visit and therefore can only provide a snapshot of deer abundance on the actual day that the census takes place. The most widely used indirect methods rely on sign left by deer (most frequently referred to as faecal pellet groups) and deer abundance can be indirectly estimated from the density of faecal pellet groups on the ground. The principal benefit of indirect counting over direct counting, is that bias due to counting errors can be assessed and reduced to acceptable levels. Although the methodology is based on sampling rather than on a complete count, the sampling errors are quantifiable (Swanson *et al.* 2008). In any event, most census methods will require data to be collected by sampling, principally due to time and resource constraints as the areas and site characteristics involved are usually too large to allow for a complete census.

There are a variety of different methods of indirect counting that utilise faecal pellet groups to estimate deer abundance. Faecal Pellet Counts exploit the fact that deer deposit a known number of faecal pellet groups at regular intervals over time and are one of the most obvious signs that deer are present in a particular area. Once a suitable indirect method has been chosen, it should aim to be as precise, accurate and unbiased as possible, allowing for the same methodology to be followed without deviation.

Faecal Pellet Counts assume a positive linear relationship between the number of animals and the number of pellet groups that are deposited. Deer abundance can then be estimated by counting the total number of pellet groups deposited, under the assumption that the number of pellet groups increases in line with the amount of time spent in a particular habitat. Pellet group count data can be thus be transformed into deer abundance, only if the following parameters are known:

- (i) The rate (per day) at which deer defecate faecal pellets and
- (ii) The rate (per day) at which these faecal pellet groups fully decompose in specific habitats.

4.2 Identification of Faecal Pellet Groups

Where more than one species is present in the area of study, this can lead to potential errors in the positive identification of faecal pellet groups. Swanson *et al.* (2008), suggest a guide (the 10mm 'cut-off rule') to assist in differentiating between species, particularly where there is overlap between juvenile red deer and fallow / sika deer. However, the actual proportion of mis-identified Faecal Pellet Groups in any survey usually depends on the relative abundance of each species present (Swanson *et al.* 2008).

4.3 Defaecation and Decomposition

In order to transform pellet group data into a measure of deer abundance, it is crucial to know the habitat specific decomposition rate and the average defecation rate of the species being surveyed. Faecal Standing Crop (FSC) is therefore an indication of the balance between the gains of recently defecated pellet groups and the losses (complete decomposition) of old pellet groups from the system. Over winter, decomposition rates slow down resulting in an increase in the standing crop biomass from October until late April. Conversely, during the summer months decomposition rates may be higher (due mainly to increased invertebrate activity) and the biomass of the standing crop decreases in size until the onset of winter.

Defecation rates are species specific and decomposition rates are habitat specific. Data on decomposition rates have been collected in 1994/1995, 1999/2000, 2016/2017 and 2020/2021, for a wide range of Irish habitat conditions for red, sika and fallow deer and decomposition rates have been recently updated during the over-winter period October 2020 to May 2021 (Burkitt, in prep.). Because of the availability of the most recent data on over-winter habitat specific decay rates and a hypothesis that deer density on this particular site was relatively high, Faecal Standing Crop counts were chosen as the preferred method for estimating deer abundance. Standard mean defaecation rates (Mayle *et al.* 1999) were used to transform both habitat specific and overall pellet group density into estimates of deer density.

Transformed pellet group count data actually quantifies 'average deer abundance' over the survey period as it is expected that deer are likely to move into and out of the study area during the survey period and as a result the number of deer present on any one day may not equal the average number of deer present during the study period. Transformed pellet group count data is therefore referred to as Effective Deer Utilisation or EDU (Swanson *et al.* 2008). This acknowledges the fact that the data represent the number of deer that were effectively present in the study area and not actually present. Variation in deer abundance due to migration in or out of the survey area usually causes estimates of EDU to differ from the actual number of deer present in the area at any one time. However, the degree to which the EDU estimates and the number of live deer on the ground in transient populations (such as fallow or red deer) agree, is likely to improve as the size of the sample area increases. Larger sample areas are more likely to

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encompass the total range of the deer population. Data are collected by counting all pellet groups (of all ages) that are present on one single visit to each survey area. Because deer density estimates are relatively crude, a comparatively low level of precision is acceptable and for this reason 90% confidence limits can be used. However, if greater precision (95%) is demanded the range of variability will increase.

4.4 Sample size

Sample size is usually a compromise between too small a sample that will be too imprecise to be of any use and too large a sample that will be too costly and inefficient. There is no absolute recommendation for sample sizes (m²) for indirect methods involving dung counting. However, Mayle *et al.* suggest 5% of the sample area as being sufficient while other authors use sample sizes from 0.5% (Swanson *et al.* 2008) to 1.7% (Marcon *et al.* 2019) of the survey area. However, this will depend on the area, habitat type and the required precision of deer density estimates and often fewer larger sampling units will normally give less accurate results than more smaller sampling units (Mayle *et al.* 1999). Sampling intensity and therefore the precision, bias and accuracy of the results will inevitably depend on budgetary and time constraints. Because this project was carried out during the summer, when vegetation growth was at a maximum, sampling intensity was deliberately increased to 800m² /100ha. (8%) to ensure a high level of precision and accuracy.

SECTION 5: STUDY SITE EXTENT AND LOCATION

The project site, located immediately south, east and west of the town of Abbeyleix, Co. Laois (Grid Reference (GR) S438 850) and straddles the N77 for approximately 2.5 to 3.0 kilometres, was identified from aerial photographs and original six inch maps (Fig.3).

FIG. 3 Boundary of the project area - image courtesy of google maps (Map data © 2021Google)



As this pilot study was primarily focused on deer collisions, this inevitably meant that as part of the study, deer density, distribution and movement around the N77 was going to be a major component of the project. It is important to note that this site was chosen, primarily because of the high frequency of reported deer collisions on that particular stretch of road. Therefore, in the planning stage of the pilot project, it was essential that management and control of deer populations within the project site was going to form a crucial part of any future mitigation measures. It therefore followed, that the management and control of deer was going to be the sole responsibility of the major land-owners within the project site. During the planning stage and before survey work began, extensive scoping and personal communication (with the assistance of Laois County Council) was carried out to determine the extent and size of specific land ownership boundaries within the overall landscape. Thus, the approach was to use land ownership units as project Zones, whilst being acutely aware of the potential movement of deer across land ownership boundaries. Ultimately, these Zones will form the basis of deer management zones which will have operational deer management plans that will be active for the next four years. Also, from a practical point of view, it is often appropriate to divide the

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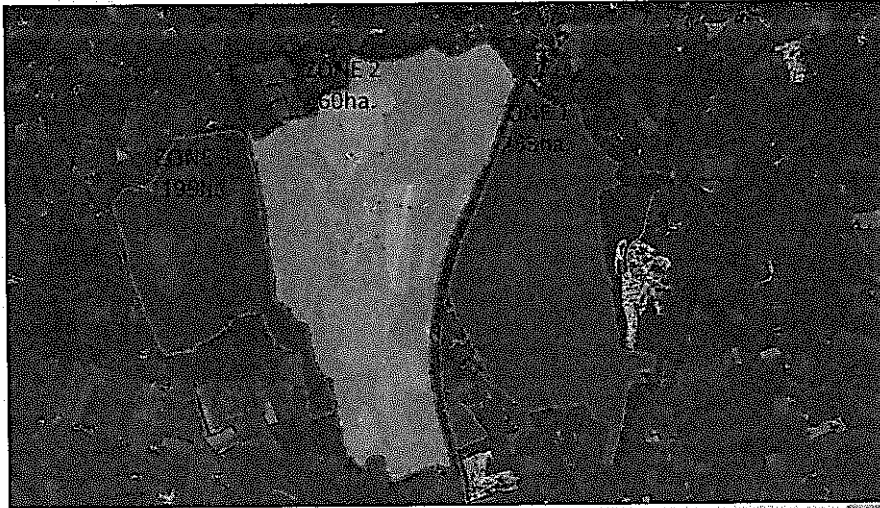
landscape into more manageable sub-sites with the advantage of providing deer density estimates at site scales, as well as for the overall landscape. In order to determine the extent of deer distribution, movement patterns and deer density specific to actual habitats and to accommodate local land ownership interests, the entire study site was then divided into three separate zones (Fig.4):

ZONE 1 – Approximately 2.53km² to the east of the N77.

ZONE 2 – Approximately 4.60km² west of the N77 between the main carriageway and the River Nore.

ZONE 3 – Approximately 1.99km² west of the River Nore to the R433.

FIG. 4. Zones 1, 2 and 3 - image courtesy of google maps (Map data © 2021Google)



5.1 Habitat assessment

Habitats within the site were assessed and categorised according to Fossitt's "Guide to habitats in Ireland" (Fossitt, 2000). Habitat survey work was carried out prior to deer survey work beginning and each Zone was walked in its entirety, to allow for a thorough assessment of the potential habitat categories present in each Zone. Habitat stratification for the purposes of deer density survey work is normally based on habitat structure and openness (i.e. vertical structure and vegetation density) rather than differences in actual habitat composition (species composition) because structure and vegetation density are often more important parameters for deer occupancy than species composition. Deer are unable to recognise habitat boundaries, or divisions between different habitat structural types, but tend to choose habitats according to the amount and location of forage, density of cover and vertical structure within specific habitats.

5.2 Habitat stratification

Habitat stratification is often carried out where there is likely to be large variation in the habitats across the survey area, but more importantly where there is some specific prior knowledge of the site and its deer population (Mayle *et al.* 1999). For the purposes of initial proportional plot allocation, habitats were first identified from aerial images of the study site and corroborated by subsequent habitat survey work. The following broad habitat types were identified:

WD2/4 - Mixed Conifer / Broadleaved Woodland

HH - Heath

WN - Native broadleaved woodland

WS5 - Recently clear-felled woodland

WS - Scrub woodland

GA1 - Intensive Agriculture

Areas of intensive agriculture (GA1), were deliberately omitted from sampling, but have been included in the overall estimate of site size and composition.

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SECTION 6: SITE EXTENT AND COMPOSITION

The estimate of the approximate extent of the entire site is 9.12km² or 912.0 hectares. Of this 42% is WD2/4 (382.0ha.), 6% is WN (52.0ha.), 15% is HH (135.0ha.), 1% is WS5 (12.0ha.), 12% is WS (114.0ha.) and 24% is GA1 (217.0ha.) (Fig. 5). Thus, the entire site is made up of 60% woodland (all types) compared to 40% open non-woodland (Fig. 6).

FIG. 5 Habitats and Zone boundaries - Project area

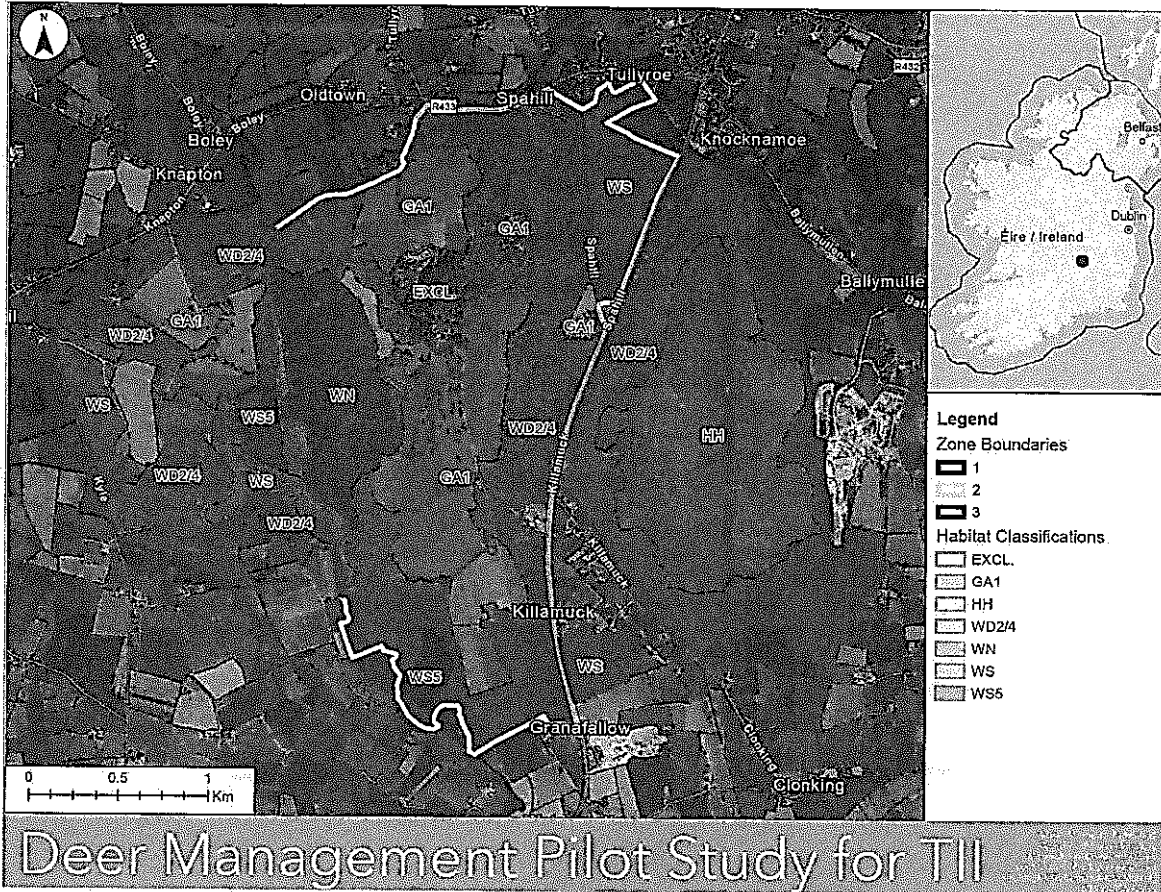
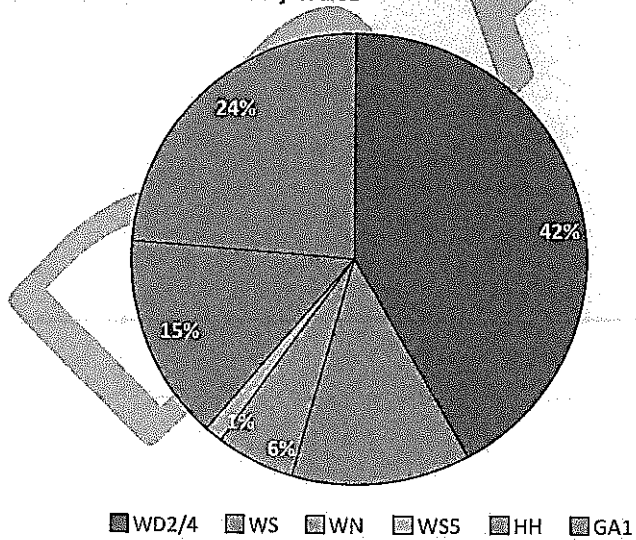
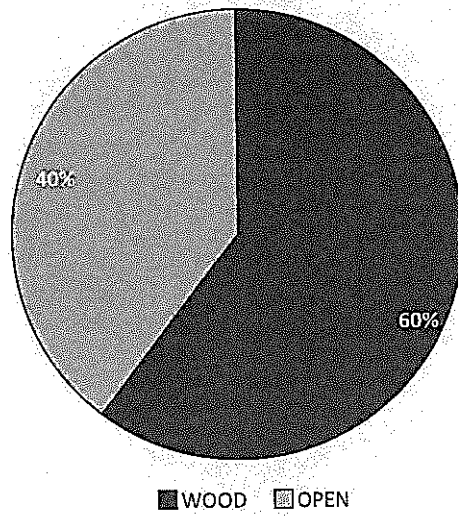


Fig. 6 Proportion of different habitats - Project area



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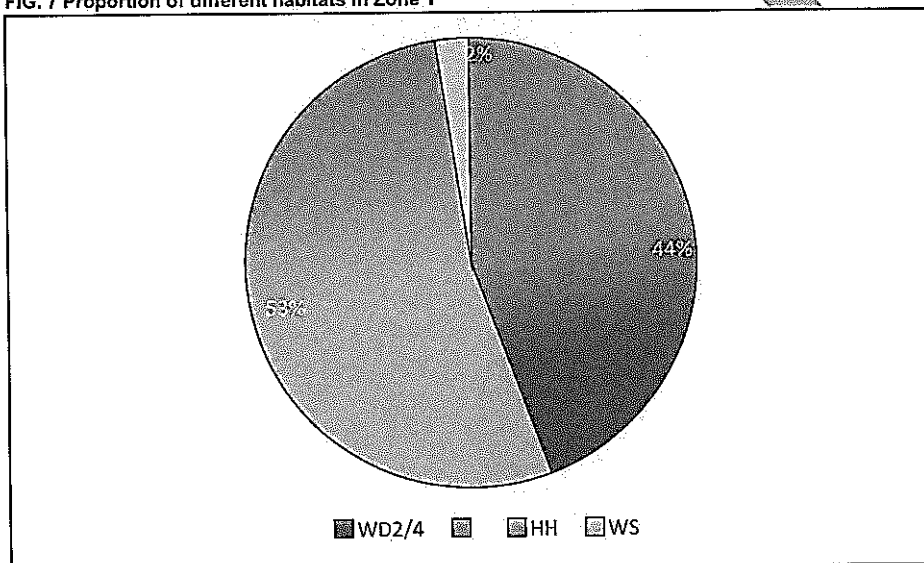
FIG. 6 Proportion of Woodland : Open Habitats – Project area



6.1 ZONE 1.

Habitat categories identified were: WD2/4 (112.0ha.), WS (6.0ha.) and HH (135.0ha.) (Fig. 7)

FIG. 7 Proportion of different habitats in Zone 1

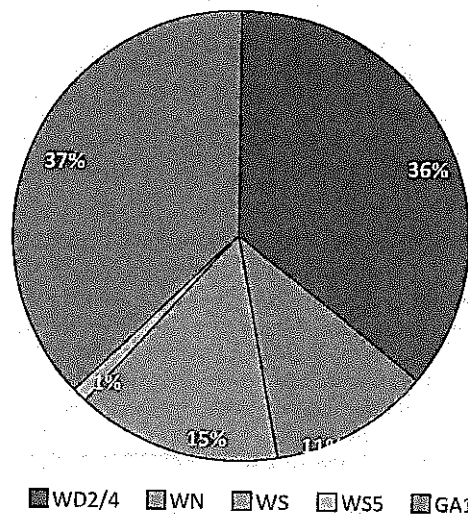


6.2 ZONE 2.

Habitat categories identified were: WD2/4 (165.0ha.), WN (52.0ha.), WS (67.0ha.), WS5 (5.0ha.), GA1(171.0ha.) (Fig. 8)

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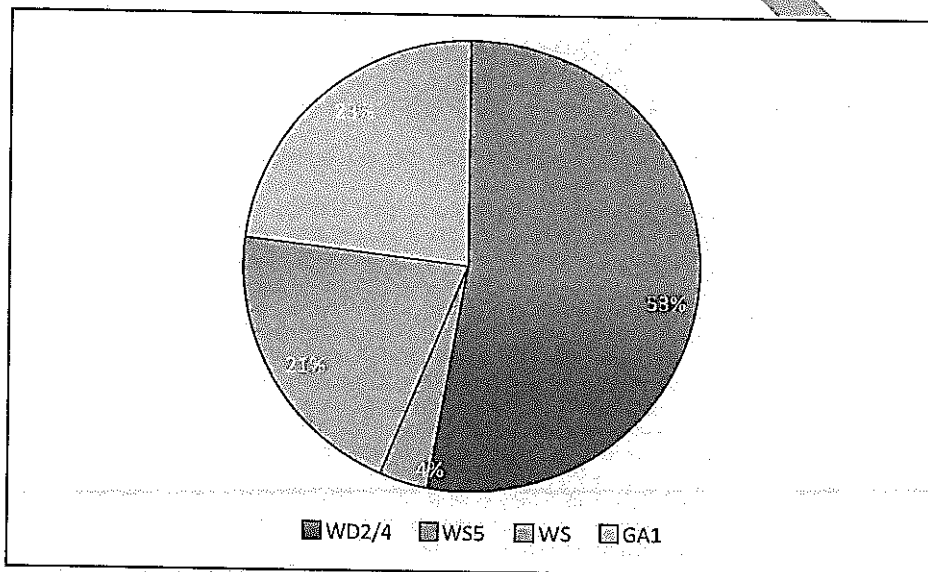
FIG. 8 Proportion of different habitats in Zone 2



6.3 ZONE 3.

Habitat categories identified were : WD2/4 (105.0ha.), WS (41.0ha.), GA1 (46.0ha.) and WS5 (7.0ha.) (Fig. 9).

FIG. 9 Proportion of different habitats in Zone 3



6.4 STUDY SITE DESCRIPTION

ZONE 1 (Abbeyleix bog)

Abbeyleix bog is an extensive area of old, cut-over bog that is in the process of gradual restoration. Old drains established to dry out the bog for peat extraction have now been blocked allowing water retention and gradual restoration of natural peatland habitats. The area of heathland extends to approximately 135 hectares and this is surrounded by a mosaic of growth stages of both hardwoods (mostly *Betula* spp.), scots pine (*Pinus sylvestris*), oak (*Quercus petraea*), ash (*Fraxinus excelsior*) and transition woodland. On the heath, scots pine that had re-generated

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is now beginning to fail, as water levels within the bog begin to rise. Around the periphery of the site are mixtures of mature sitka spruce (*Picea sitchensis*), beech (*Fagus sylvatica*) and scots pine (*Pinus sylvestris*) and there is lag woodland at the northeast corner consisting mainly of alder (*Alnus glutinosa*) and willow (*Salix* spp.). There is a dense understorey of bracken (*Pteridium aquilinum*) and rhododendron (*Rhododendron ponticum*) throughout much of the woodland. There is abundant evidence of re-generation, which suggests that deer may only have been present in the area for around 10 – 15 years and

given the moderate fallow deer density (9.22km²) and low red deer density (5.44km²), the woodlands are in a favourable conservation status.

The agricultural area to the southwest of Zone 1 was omitted because of high density of housing and pasture used mainly for horses that were present all year round. There was no evidence (tracks or dung) found that deer used this area, likely due to openness and continuous livestock presence. However, the southern part of the areas was used by deer to transit between Zone 1 and 2 via the small area of woodland adjacent to the N77. The entire 3.5km length of the N77 on both sides was walked to determine where deer were crossing and the frequency of use of crossing points where these were identified. There was no evidence of deer use or indeed any crossing points in the agricultural area north of this piece of woodland.

Zone 2 (Abbeyleix Estate)

Abbeyleix estate is a substantial tract of land, situated between the N77 and the River Nore Special Protection Area (Site code SPA 4233) and the River Barrow / Nore Special Area of Conservation (Site code SAC 2162). It is heavily wooded with approximately 62% of the land area under timber. The woodland contains mixtures of conifer woodland, mixed conifer / broadleaved woodland, mixed scrub woodland and old oak woodland interspersed with intensive agriculture and grazing land (mainly cattle and horses). Much of the woodland has a dense understorey of bracken, nettle (*Urtica dioica*) and briar (*Rubus fruticosus*). There is also abundant evidence throughout the woodlands of past re-generation events, with a plentiful array of saplings of beech, oak, birch, ash, sycamore (*Acer pseudoplatanus*), and alder, which would suggest that deer density is likely to have been at relatively low levels to allow regeneration to take place. However, fallow deer (the predominant species) are now at particularly high density (37.99km²) and the evidence of more recent re-generation occurring is almost negligible.

ZONE 3 (Knapton)

Knapton (once part of the Abbeyleix estate) is located west of the River Nore and is a sizeable tract of mixed woodland and agricultural land. Approximately 74% of Knapton is under timber, which is managed by thinning, clear-felling or a combination of replanting and allowing natural regeneration to occur. The remaining 26% is a mixture of arable (barley) and grazing land. There is a mosaic of woodland growth stages from mature to re-generating scrub, consisting of coniferous and broadleaved woodland dominated by spruce, beech and oak. Scrub woodland is a mixture of spruce, pine and an array of hardwood species such as birch, alder, beech, whitethorn (*Crataegus monogyna*), sycamore and willow (*Salix* spp.). Also, understory vegetation is dominated by bracken and large thickets of briar. Both red and fallow deer are present, but fallow deer are the dominant species at current densities of 25.14km². However, damage to newly established woodland and arable crops is substantial and according to the owner, deer had been absent or at least in very low numbers in the area and only first appeared in the early to mid 1970s (T.de Vescei pers. comm.).

SECTION 7: PROJECT DATA COLLECTION

7.1 Deer density

Data collection for deer field survey work began on the week beginning 26th July 2021 and continued until the week ending 27th August 2021.

For this project, a decision was made to use linear strip transects (ST) or plots. Fifty three 80m x 1.25m (100m² plots) Faecal Standing Crop plots were set up, nineteen in Zone 1, twenty-two in Zone 2 and twelve in Zone 3. In all, a total sample area of 5,300m² (0.53km²) was surveyed in all three Zones, 1,900m² in Zone 1, 2,200m² in Zone 2 and 1,200m² in Zone 3. There are no set criteria for determining the size and shape of plots – it's a personal choice, which is based on time and resource budgets, practicality and achieving maximum accuracy and precision of data collection from a given sample area. However, from a practical perspective, the use of linear strip transects is more effective because of reduced time spent laying out and searching long narrow plots compared to large square plots, particularly in dense difficult vegetation, such as thicket-stage spruce. Large square plots (for example 7m x 7m) need to be divided internally, which is time-consuming and inefficient in terms of time, which also increases the potential for missed or double counted FPGs. Also, large plots take much longer to search and can be mentally demanding, particularly if search times exceed 1 or 1½ hours as they often do. Small plots of the size used in this study (80m x 1.25m) could be searched thoroughly in about forty five minutes in most habitats. Furthermore, multiple small plots allow for greater spatial coverage of the survey area, allowing for a more precise estimate of deer density within specific habitats being sampled. The downside of multiple small plots, particularly in large sites, is the increased edge: area ratio (increasing error due to edge effect) and time taken to travel between plot locations. Edge effect can be offset by intensive searching and strict criteria for inclusion / exclusion of FPGs along plot boundaries.

Individual pellet groups are rarely distributed evenly on the ground and are frequently grouped together, which usually results in wide variations in the number of groups detected per plot sampled. From a statistical perspective, if

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the aggregated groups occur on a scale that is greater than the proposed sampling plots, then a more precise estimate of the between plot variance can be achieved. This can be accomplished by using multiple small plots rather than a small number of large plots of equivalent sample size.

Plots were set up in each identified habitat category according to the proportion of each habitat present within the overall Zone. Plots were surveyed according to habitat category and each plot thoroughly searched for deer faecal pellet groups (both fresh and aged). A group was only counted if >18 pellets were present and clearly identifiable (Swanson *et al.* 2008). Strip transects or plots have a large edge to area ratio and therefore are sometimes prone to problems of edge-effects that occur when dung groups lie across plot boundaries.

Therefore, decisions on inclusion must be made in advance to reduce the potential for error prior to sampling beginning. Those groups on the transect boundary were counted only if more than 50% of the group was located within the plot boundary. Ideally plots must not therefore be greater than 1.25m wide, as there is a risk that dung groups are likely to be missed if plots are too wide. Plots must also be sufficiently long to optimise the ratio of time spent counting and to increase the proportion of positive counts in areas of low animal density (thus avoiding as far as possible, skewed distributions with many zero values). Because

of the time of year (peak vegetation growth), search times for each plot averaged between forty five minutes and an hour and fifteen minutes, depending on the habitat type. The numbers of pellet groups were recorded by species in each 12.5m² plot sector and the total number of pellet groups (for each species) were then summed for each plot within each habitat category.

7.2 Plot dimensions

In statistical terms, where a component of the aggregation occurs on a much larger scale than the size of the potential sampling plots, a more precise estimate of variance is generally obtained by using many small plots rather than a smaller number of large plots of equivalent total sample area. Also, it has been consistently found that individual pellet groups are rarely distributed evenly across the ground and can often be aggregated or clumped, which sometimes results in a wide variation in the number of pellet groups found per plot.

7.3 Plot allocation and start points

Plots were initially allocated according to the approximate percentage of each habitat and the overall size (In ha.) of each Zone, based on major identifiable habitat types determined from aerial photographs of the study area. All transects were orientated on a North to South axis and start-points described by co-ordinates located on 1km grid squares in each Zone based on 1:50,000 OS maps. A SATMAP (Active 20) GPS was used in the field to locate plot start points. Where possible, identifiable features were noted to assist in relocation if necessary. Plots located in open areas were covered in a zigzag fashion to improve spatial coverage. Plots were numbered sequentially according to the Zone in which they were in, for example Z1/01 (Plot number one in Zone 1).

7.4 Data Analysis

Deer density was estimated using PELLET, a semi-automatic based procedure in Microsoft Excel®. The density calculation includes a range of variations in selected decay time, while also incorporating spatial variation and defaecation rates. This eliminates the practice of subjectively selecting one single defined value for all of these parameters (Mandujano 2014).

7.5 Trail Cameras

Trail cameras were set up at three locations along the N77 from early August, to gain supplementary information on the frequency of crossings at known crossing points and seasonal movement patterns of deer. Two 4G camera traps (Vosker V100) operated from Monday 9th August and were initially set to record photo / video footage from 21.00 hrs until 6.00hrs each day, whilst a third (LTL Acorn) was set to record round the clock photo and video footage. Alerts from each 4G camera were received daily at 9.00hrs. Trail cameras were set at three points Killamuck, Colemans and Collins' Bog and were ranked according to the estimated frequency of crossings. Ranking was C = Irregular crossing (Collins' Bog), B = Intermittent crossing (Colemans) and A = Recurrent crossing (Killamuck). Cameras are referred to according to their ranked locations i.e. A, B or C (Fig. 10).

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FIG. 10 Location of Trail Cameras -image courtesy of google maps (Map data © 2021Google)



SECTION 8: CURRENT DEER POPULATION CONTROL

Currently, the situation with regard to the control of deer populations is mixed, mainly because of different land-ownership priorities and additional complicating factors such as high recreational and scientific use of some parts of the site. For example, some owners prioritise agriculture and forestry over conservation, whereas others see conservation and biodiversity as being of primary importance over agricultural interests. Therefore, the future management of the deer population must balance all of these interests, while at the same time making significant and sustained efforts to drastically reduce deer densities in the general area.

Zone 1 is an area of high amenity and recreational use, in addition to being a site regularly used for a wide variety of ongoing scientific research projects. The approach to the control of deer populations at present is not regarded as a priority, nor is it considered feasible because of high-level of recreational / scientific research use. Also, deer at their current densities are regarded as having both a neutral and a positive (rather than negative) impact on the ecology of the restored bog and associated woodland habitats (C.Uys, pers. com). There is a limited amount of recreational hunting activity around the north-eastern periphery of the bog and this is considered unlikely to have any real local impact on overall deer numbers, although it may have the unintended consequence of contributing to increased dispersal into adjacent areas.

In Zone 2, a syndicate of deer hunters has operated for a number of years and there has been a deer management plan in place since 2018. Estimates of deer numbers were 150 – 180 in 2018/19, 130 in 2019/20 and over 180 for 2020/21, while reported culls of fallow deer were 60 in 2018/19, 31 in 2019/20 and 51 in 2020/21 (Abbeyleix Deer Management Plan 2018-2020). The estate has recently changed hands and the new owners are keen to see a significant reduction in deer density to reduce impacts on conservation and agriculture while also being cognisant of DVCs on the N77.

In Zone 3, there has been a regime of annual control of the local fallow deer population in place for the last twenty years or so. The owner has recognised that deer in this area are creating unnecessary difficulties in establishing new woodlands in addition to negatively impacting on normal agricultural activities. Deer are culled both during the statutory open season (September – February) and also out of season under license from the National Parks and Wildlife Service in response to damage. Out of season licenses are issued where a protected species is causing damage to crops or habitats. However, even with regular culling (both in and out of season) it is considered likely that at the current level of offtake, although reducing local population density, may not have the desired effect of reducing population density at the landscape level, because of population flux across invisible boundaries between Zone 2 and Zone 3. Thus, general localised culling may in all probability maintain the status quo, but is unlikely to have an appreciable effect in reducing the levels of damage. An annual average of around thirty deer (J. Smith pers. com.) are removed from Zone 3, which includes animals removed under Section 42 of the Wildlife Acts.

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SECTION 9: RESULTS

9.1 DEER DENSITY(km²) IN THE PROJECT AREA

9.1.1 Red deer – Project area

Red deer were not widely distributed throughout the Project area and there were more red deer in Zone 1 than in either Zone 2 or Zone 3, the majority of which were found along the north-eastern and eastern fringes of Abbeyleix bog. The estimated

density of Red deer in the project area (912.0ha.) was (95% CI) $2.53 \pm 0.85\text{km}^2$ ($\pm 1.67 \times \text{SE}$, $N = 53$), or an equivalent population size of between 14 and 29 deer.

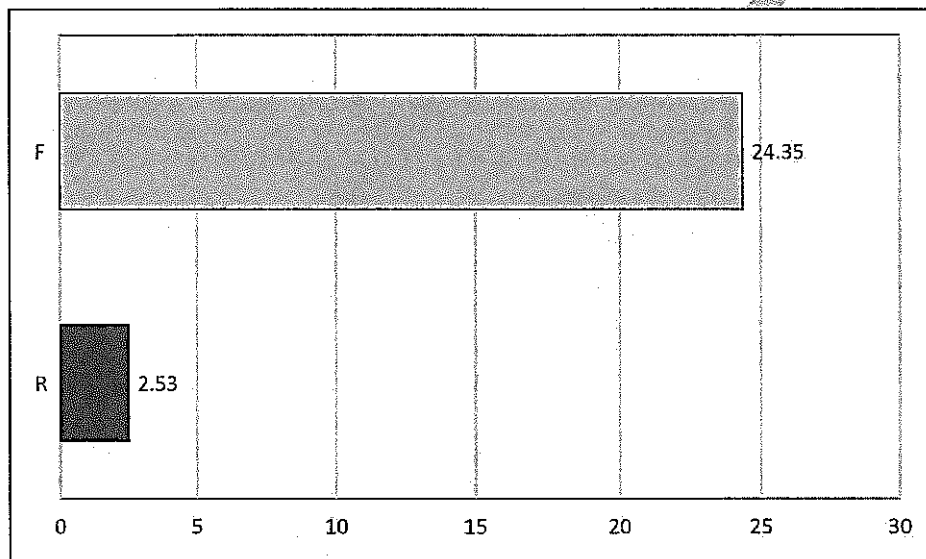
RED DEER DENSITY (km^2) – PROJECT AREA									
PROJEC T	SP	HABITA T	AREA (ha.)	SAMPLE (m^2)	Σ PG	Σ DEE R	Av. Km^2	95% CI	Σ DEER
TOTALS	R	ALL	912.0	5,300	78	23	2.53	1.67 – 3.38	14 - 29

9.1.2 Fallow deer - Project area

In contrast to red deer, fallow deer were widely distributed throughout the Project area. Fallow deer abundance was greatest in Zone 2 and 3 with lower densities in Zone 1. The estimated density of fallow deer in the project area (912.0ha.) was (95% CI) $24.35 \pm 3.69\text{km}^2$ ($1.67 \times \text{SE}$, $N = 53$), or an equivalent population size of between 176 and 238 deer.

FALLOW DEER DENSITY (km^2) – PROJECT AREA									
PROJEC T	SP	HABITA T	AREA (ha.)	SAMPLE (m^2)	Σ PG	Σ DEER	Av. Km^2	95% CI	Σ DEER
TOTALS	F	ALL	912.0	5,300	731	222	24.35	20.66 – 28.04	176 - 238

FIG. 11 Red and Fallow deer density (km^2) In the Project area.



Σ PG	TOTAL NUMBER OF FAECAL PELLETS DETECTED
Av. Km^2	AVERAGE DEER DENSITY PER SQUARE KILOMETRE
95% CI	95% CONFIDENCE LIMITS
SE	STANDARD ERROR OF THE MEAN
Σ DEER	APPROXIMATE TOTAL NUMBER OF DEER
	AVERAGE / MEAN

WP3.30 - DEER DENSITY(km^2), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

9.2 DEER DENSITY IN EACH ZONE

9.2.1 Red deer Zone 1

Red deer were at low density in Zone 1, but densities in Heath habitats (HH) were not dissimilar to Mixed Woodland (WD2/4) (5.94km^2 compared to 4.90km^2). However, red deer were found mainly along the eastern fringe of Abbeyleix bog from north to south, with higher concentrations in the north-eastern corner than in the remainder of the Zone. The estimated density of red deer (in all habitats) in Zone 1 was (95% CI) $5.44 \pm 1.49\text{km}^2$ ($1.73 \times \text{SE}$, $N = 19$).

RED DEER DENSITY (km^2) – ZONE 1									
ZONE 1	SP	HABITA T	AREA (ha.)	SAMPLE (m^2)	Σ PG	Σ DEER	Av. Km^2	95% CI	Σ DEER

TOTALS	R	ALL	253.0	1,900	55	13	5.44	3.5 – 7.38	9 - 18
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9.2.2 Fallow deer Zone 1

Fallow deer were found at higher density (9.52km²) than red deer although their distribution was similar. The estimated density of fallow deer (in all habitats) in Zone 1 was (95% CI) 9.52 ± 2.23km² (1.73 X SE, N = 19).

FALLOW DEER DENSITY (km ²) – ZONE 1									
ZONE 1	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	ΣDEER	Av. Km ²	95% CI	ΣDEER
TOTALS	F	ALL	253.0	1,900	75	24	9.52	6.62 – 12.42	16 - 31

9.2.3 Red deer Zone 2

Red deer were not resident in Zone 2, but used the area in transit to other parts of the project area. The estimated density of red deer (in all habitats) in Zone 2 was (95% CI) 0.267 ± 0.207km² (1.72 X SE, N = 22).

RED DEER DENSITY (km ²) – ZONE 2									
ZONE 2	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	ΣDEER	Av. Km ²	95% CI	ΣDEER
TOTALS	R	ALL	460.0	2,200	4	1	0.267	0 – 1.53	0 - 2

9.2.4 Fallow deer Zone 2

Fallow deer were widespread and abundant in Zone 2 and were found at very high densities overall (37.99km²). Within the Zone, fallow deer were found at particularly high densities in Oak (WN) woodland (64.04km²), although this particular habitat only represented 13% of the total area. Densities in Scrub woodland (WS) and Mixed Woodland (WD2/4) were also high (28.69 – 36.63km²). The estimated density of fallow deer (in all habitats) in Zone 2 was (95% CI) 3.99 ± 3.56km² (1.72 X SE, N = 22).

FALLOW DEER DENSITY (km ²) – ZONE 2									
ZONE 2	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	ΣDEER	Av. Km ²	95% CI	ΣDEER
TOTALS	F	ALL	460.0	2,200	477	175	37.99	33.35 – 42.63	135 - 172

9.2.5 Red deer Zone 3

Red deer

In Zone 3, red deer were present but at low density (2.09km²) and were found only in two of the habitats at similarly low densities. The estimated density of red deer (in all habitats) in Zone 3 was (95% CI) 2.09 ± 0.66km² (1.79 X SE, N = 12).

RED DEER DENSITY (km ²) – ZONE 3									
ZONE 3	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	ΣDEER	Av. Km ²	95% CI	ΣDEER
TOTALS	R	ALL	199.0	1,200	16	4	2.09	1.39 – 2.79	3 - 6

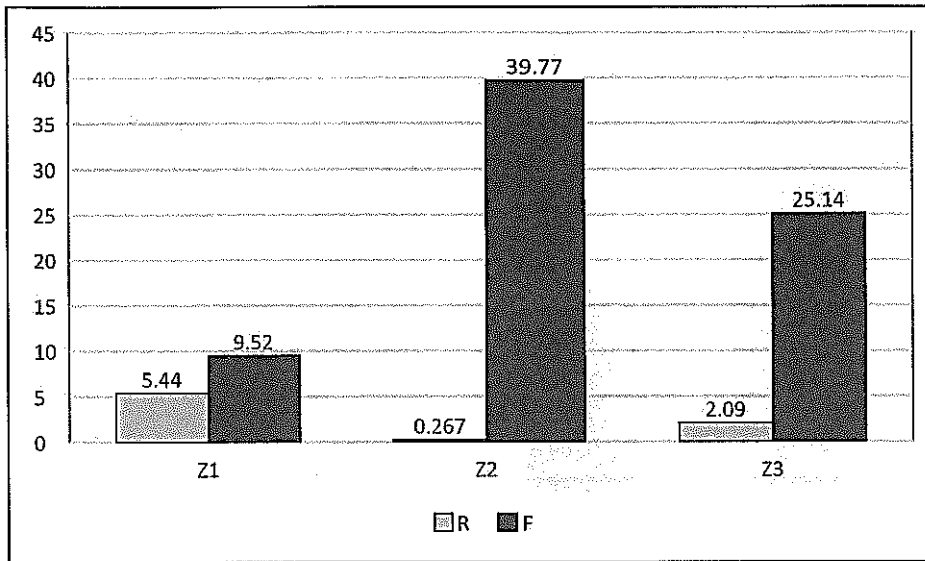
WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

9.2.6 Fallow deer Zone 3

In contrast to red deer, fallow deer were found to be widespread and abundant in Zone 3 and at high density. Fallow deer were present in Mixed Woodland (WD2/4) and in Scrub woodland (WS), but densities were particularly high in Scrub woodland (WS) habitats (34.89km²), even though these habitats only represented 21% of the total area. The estimated density of fallow deer in Zone 3 was (95% CI) 25.14 ± 2.76km² (1.79 X SE, N = 12).

FALLOW DEER DENSITY (km ²) – ZONE 3									
ZONE 3	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	ΣDEER	Av. Km ²	95% CI	ΣDEER
TOTALS	F	ALL	199.0	1,200	174	50	25.14	21.51 – 28.77	43 - 57

FIG. 12 Red and Fallow deer density (km²) in each Zone



9.3 DEER DENSITY IN EACH HABITAT TYPE

9.3.1 ZONE 1

Estimates of red deer density in Heath habitats (HH) were (95% CI) $5.94 \pm 2.59\text{km}^2$ ($1.83 \times \text{SE}$, $N = 10$) while in Mixed Woodland habitats (WD2/4), estimates of red deer density were (95% CI) $4.90 \pm 3.34\text{km}^2$ ($1.86 \times \text{SE}$, $N = 9$).

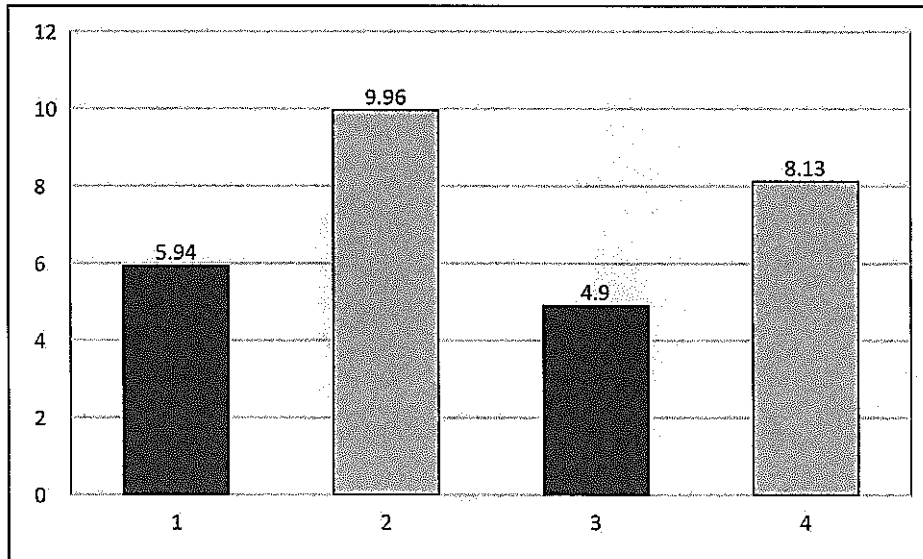
RED DEER DENSITY (km ²) IN EACH HABITAT – ZONE 1								
ZONE 1	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	Av. Km ²	95% CI	ΣDEER
	R	HH	135.0	1,000	25	5.94	3.35 – 8.53	5 – 12
	R	WD2/4	112.0	900	30	4.90	1.56 – 8.24	2 – 9

Fallow deer densities were comparable in both Heath (HH) and Mixed Woodland (WD2/4) although they were also found to use the eastern fringe of the bog. However, fallow deer were also found in the Mixed Woodland (WD2/4) along the southern and western fringe of the Bog. For fallow deer, density in Heath habitats (HH) was (95% CI) $9.96 \pm 5.11\text{km}^2$ ($1.83 \times \text{SE}$, $N = 10$) compared to densities in Mixed Woodland habitats (WD2/4) of (95% CI) $8.13 \pm 3.77\text{km}^2$ ($1.86 \times \text{SE}$, $N = 9$).

FALLOW DEER DENSITY (km ²) IN EACH HABITAT – ZONE 1								
ZONE 1	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	Av. Km ²	95% CI	ΣDEER
	F	HH	135.0	1,000	35	9.96	4.85 – 15.07	7 – 20
	F	WD2/4	112.0	900	40	8.13	4.36 – 11.90	5 – 13

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FIG. 13 Average deer density (km²) in different habitats – Zone 1



9.3.2 - ZONE 2

In individual habitats identified in Zone 2, red deer were only found in Mixed Woodland habitats (WD2/4) and were absent in both Oak woodland (WN) and Scrub woodland (WS) habitats. Estimated density of red deer in Mixed Woodland habitats (WD2/4) was (95% CI) $0.452 \pm 0.45 \text{ km}^2$ ($1.78 \times \text{SE}$, N = 13).

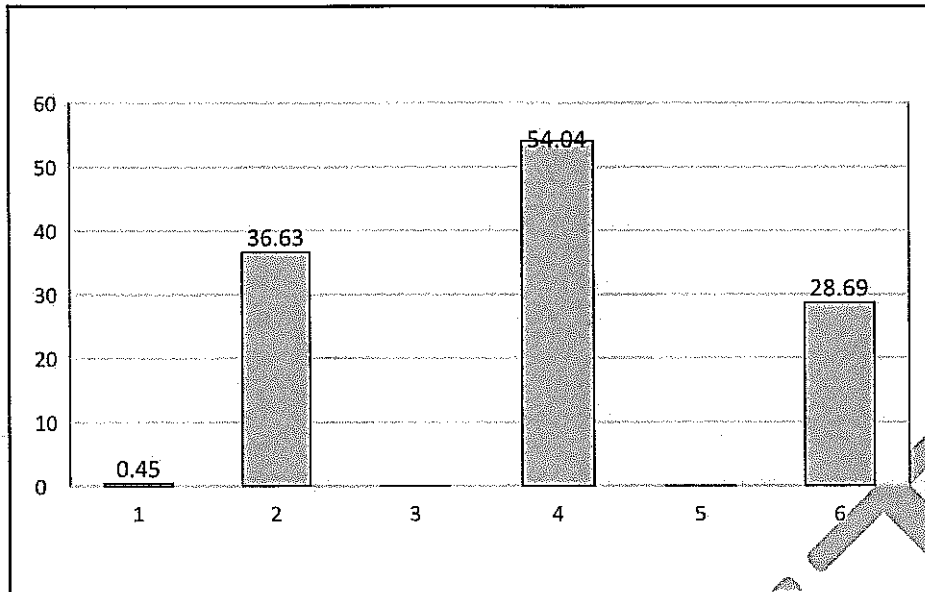
RED DEER DENSITY (km²) IN EACH HABITAT – ZONE 2								
	SP	HABITAT	AREA (ha.)	SAMPLE (m²)	ΣPG	Av. Km²	95% CI	ΣDEER
ZONE 2	R	WD2/4	170.0	1,300	4	0.452	0.05 – 0.90	0 – 2
	R	WN	52.0	400	0	0	Na	Na
	R	WS	67.0	500	0	0	Na	Na

Estimates of fallow deer density however, were extremely high and varied between (95% CI) $54.04 \pm 6.67 \text{ km}^2$ ($2.35 \times \text{SE}$, N = 4) in Oak Woodland habitats (WN), (95% CI) $28.96 \pm 8.37 \text{ km}^2$ ($2.13 \times \text{SE}$, N = 5) in Scrub woodland (WS) and (95% CI) $36.63 \pm 5.59 \text{ km}^2$ ($1.78 \times \text{SE}$, N = 13) in Mixed Woodland habitats (WD2/4).

FALLOW DEER DENSITY (km²) IN EACH HABITAT TYPE – ZONE 2								
	SP	HABITAT	AREA (ha.)	SAMPLE (m²)	ΣPG	Av. Km²	95% CI	ΣDEER
ZONE 2	F	WD2/4	170.0	1,300	263	36.63	31.04 – 42.22	53 – 72
	F	WN	52.0	400	118	54.04	47.37 – 60.71	25 – 32
	F	WS	67.0	500	96	28.69	20.59 – 37.33	14 – 25

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

FIG. 14 Average deer density (km²) in different habitats – Zone 2



9.3.3 ZONE 3

In individual habitats in Zone 3, estimates of red deer density were less variable but considerably lower in both habitats than fallow deer. For example, in Mixed Woodland habitats (WD2/4) estimated density was (95% CI) $2.20 \pm 0.10\text{km}^2$ ($1.89 \times \text{SE}$, $N = 8$) compared to (95% CI) $2.0 \pm 1.76\text{km}^2$ ($2.92 \times \text{SE}$, $N = 3$) in Scrub woodland habitats (WS).

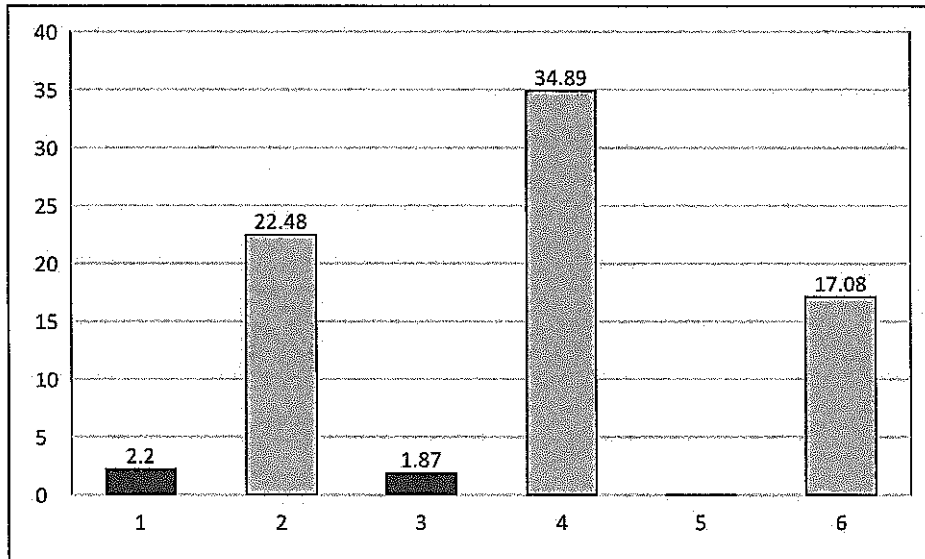
RED DEER DENSITY (km ²) IN EACH HABITAT – ZONE 3								
	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	Av. Km ²	95% CI	ΣDEER
ZONE 3	R	WD2/4	105.0	800	13	2.20	2.11 – 2.29	2 – 3
	R	WS	41.0	300	2	1.9	0.11 – 3.63	0 – 1
	R	WS5	7.0	100	0	1.5	Na	Na

Estimates of fallow deer density also varied from (95% CI) $34.89 \pm 3.85\text{km}^2$ ($2.92 \times \text{SE}$, $N = 3$) in Scrub Woodland habitats (WS) compared to (95% CI) $22.48 \pm 2.82\text{km}^2$ ($1.89 \times \text{SE}$, $N = 8$) in Mixed Woodland habitats (WD2/4).

FALLOW DEER DENSITY (km ²) IN EACH HABITAT – ZONE 3								
	SP	HABITAT	AREA (ha.)	SAMPLE (m ²)	ΣPG	Av. Km ²	95% CI	ΣDEER
ZONE 3	F	WD2/4	105.0	800	98	22.48	19.66 – 25.30	21 – 27
	F	WS	41.0	300	70	34.89	31.04 – 38.74	12 – 15
	F	WS5	7.0	100	6	17.08	Na	Na

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FIG. 15 Average deer density (km²) in different habitats – Zone 3



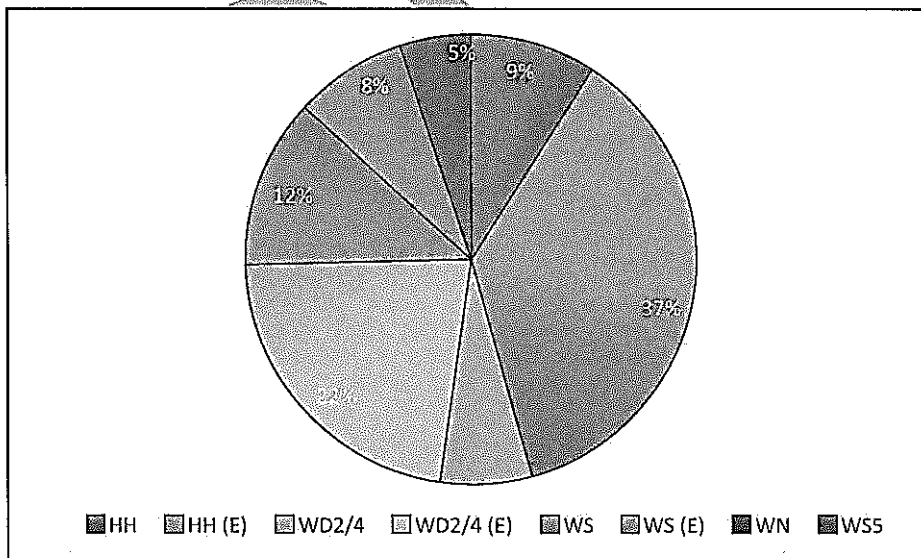
9.4 DEER DISTRIBUTION

To get a better perspective on how deer were using habitats within the project area, a number of plots within each habitat category (12 in total) were assigned to edge habitats (i.e. along the interface between woodland and open) as edge habitats are used extensively by all deer species.

Red deer were not particularly widespread within the project area and they showed a preference the edges of Heath and Mixed Woodland and Heath (59%) habitats along the fringes of Abbeyleix Bog more than either Scrub woodland (12%) or Mixed Woodland (7%) on their own (Fig. 16).

Fallow deer however, were much more widespread throughout the project area, with most fallow found at the edges of woodland habitats (34%) and oak woodland habitats (27%), while a lower proportion were found in Mixed Woodland (11%). However, in contrast to red deer, only a very small proportion of fallow deer (2%) were found in Heath habitats and most of these were at the edges of Heath and Mixed Woodland (9%) (Fig.17).

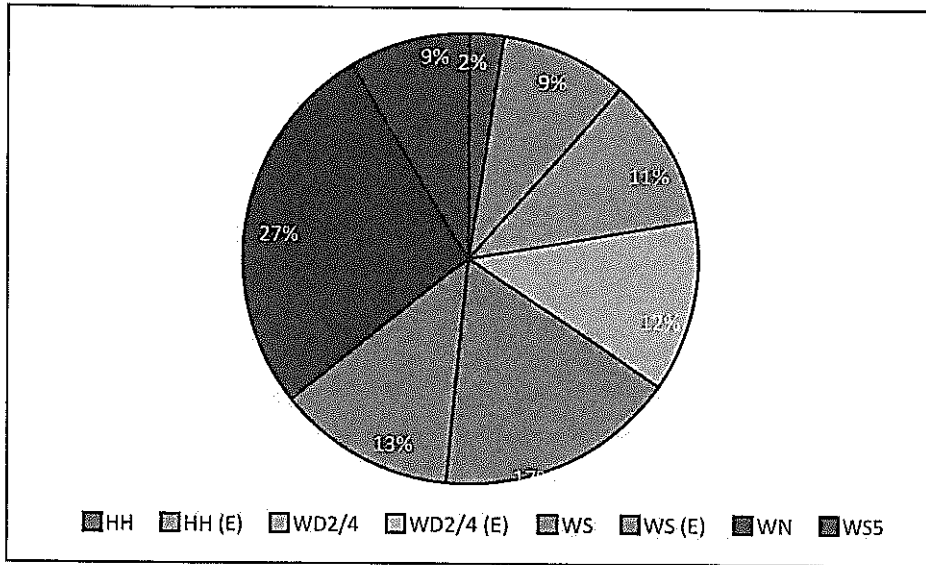
FIG. 16 Red deer distribution in different habitats in the Project area.



WP3.3a - DEER DENSITY(km⁻²); DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -

RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

FIG. 17 Fallow deer distribution in different habitats in the Project area.



9.5 DEER DENSITIES (km²) ADJACENT TO THE N77

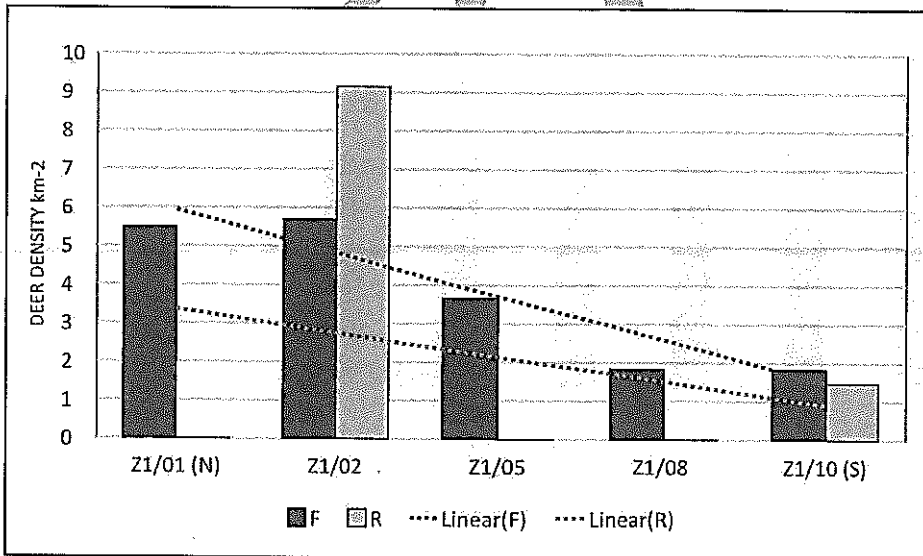
9.5.1 Red deer – ZONE 1 (East of N77)

Red deer faecal pellet groups were found on only two plots adjacent to the N77. One (Z1/02), close to the northern western edge of Zone 1 and the other (Z1/10), at the southern end of Zone 1. Red deer faecal pellet groups were absent in the intermediate plots. Average red deer density on the eastern side of the N77 carriageway in Zone 1 was low (2.12km²) and varied from 9.1km² in the North to 1.5km² in the South (Fig 18-19).

9.5.2 Fallow deer – ZONE 1 – (East of N77)

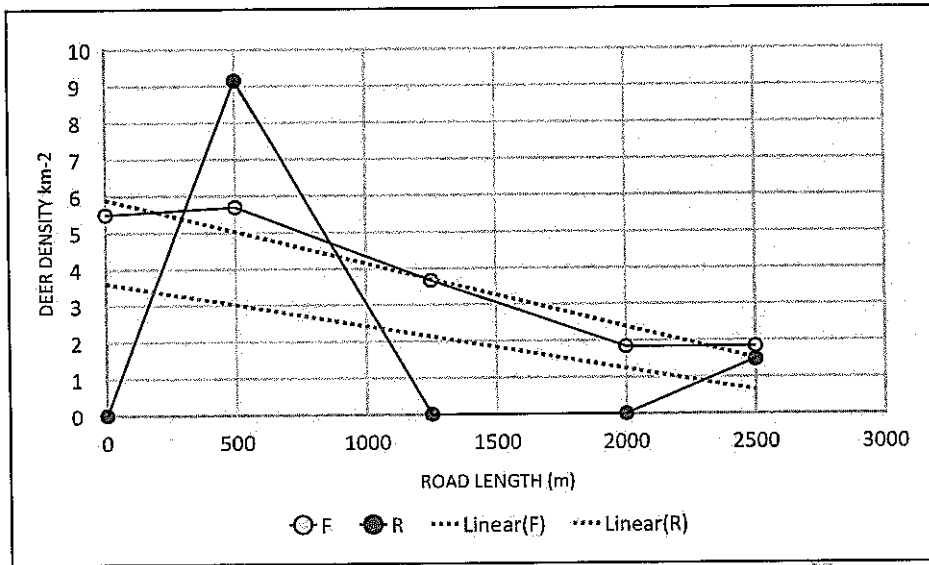
Fallow deer faecal pellet groups were found in all plots sampled adjacent to the N77 in Zone 1. However, density declined (5.49km² to 1.83km²) in plots located towards the southern end of Zone 1. Average fallow deer densities along the 3.0km stretch of the N77 were only slightly higher (3.70km²) than red deer (Fig 19, 20).

FIG. 18 Red and Fallow deer density (km²) on plots – North to South – Zone 1 - (East of N77)



WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

FIG. 19 Red and Fallow deer distribution on Plots along the N77 (east) – North to South



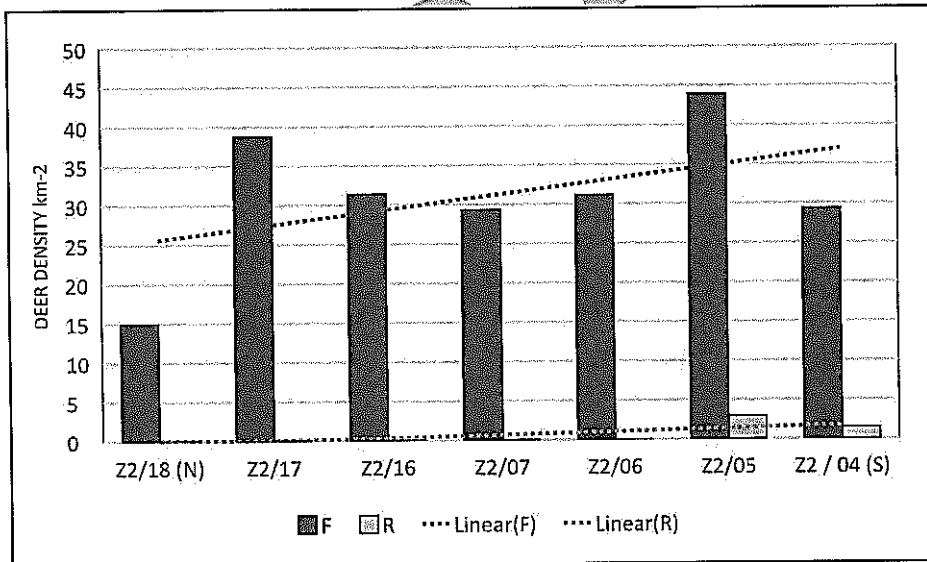
9.5.3 Red deer – ZONE 2 (West of N77)

Only two plots (out of seven) yielded red deer faecal pellet groups that were located along the western side of the N77, with an average density of groups per plot of 0.004m². Average red deer density in the Mixed Woodland along the western edge of the N77 in Zone 2, were much lower (0.62km²) than in Zone 1 (Fig 20, 21).

9.5.4 Fallow deer – ZONE 2 (West of N77)

In contrast to red deer, fallow deer faecal pellet groups were found on all plots located along the western edge of the N77 with an average density of groups per plot of 0.18m². Average fallow deer densities were over thirty times higher (31.26km²) than red deer and densities in excess of 15.0km² were found on all plots sampled (Fig 21-22).

FIG. 20 Red and Fallow deer density (km²) on plots – North to South – Zone 2 – (West of N77)



WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

FIG. 21 Red and Fallow deer distribution on Plots along the N77 (west) – North to South

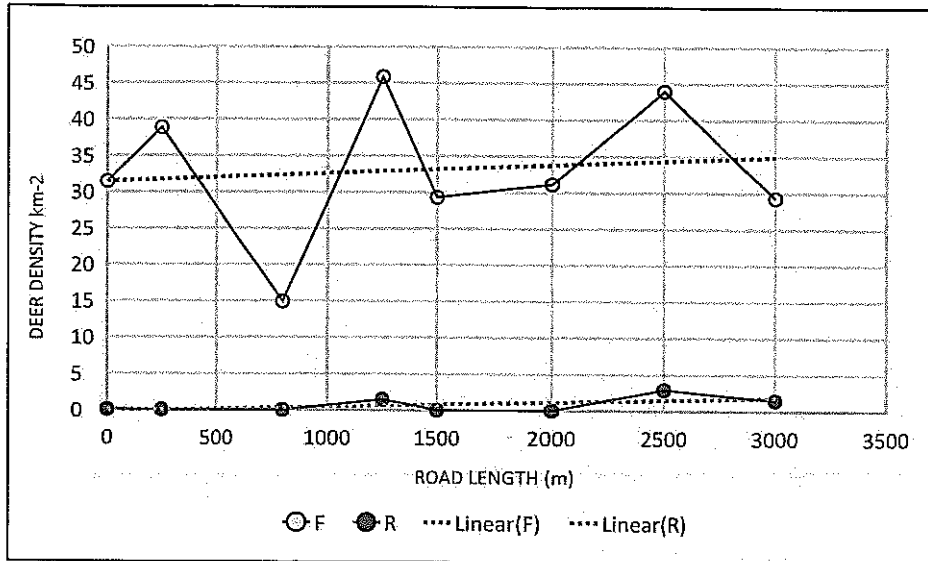


FIG 22 Red deer density (km⁻²) on each plot – Project area - image produced courtesy of google maps (Map data © 2021Google)



WP3.3b - DEER DENSITY(km⁻²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

FIG. 23 Fallow deer density (km⁻²) on each plot - Project area - image courtesy of google maps (Map data © 2021Google)



9.6 DEER MOVEMENT PATTERNS

9.6.1 Red deer

Evidence from observed extensive trail networks and faecal pellet deposition, indicated that red deer movement was relatively confined to specific areas of Zone 1, particularly along the north-eastern and eastern fringes of Abbeyleix bog. Further evidence indicated relatively infrequent movement across the bog and also that red deer only occasionally crossed the N77 into Zone 2 and Zone 3, but did not remain in either of these areas for prolonged periods. However, the evidence from trails and faecal pellet deposition, indicated that red deer were more inclined to move eastwards into abundant suitable habitat on the periphery of the project area. To date, two red deer have been detected on trail camera footage. From data collected so far, red deer at their current density, distribution and movement patterns, are unlikely to pose a significant risk in relation to DVCs.

9.6.2 Fallow deer

Fallow deer are the dominant species in the area, are more widespread and at higher densities than red deer. As a result, there is abundant evidence (from a network of trails and faecal pellet deposition) that fallow deer are moving freely within the project area from one Zone to another. However, because Zone 2 and 3 are contiguous, they could be considered as one entire area as deer are clearly moving freely within the area. There is also clear evidence that fallow deer are moving across the N77 from Zone 1 to Zones 2 and 3. Along the 3.0 kilometres of the N77, multiple crossing points were identified, but there are subtle differences in the exact location of crossings and the likely frequency and timing of crossings. For example there is a very well-defined crossing point located at GR S42998100 approximately 3.0 kilometres south of Abbeyleix. Also between GR S42908145 (Killamuck) and GR S43108308 (Colmans), there are only intermittent crossings, most likely individual animals crossing at infrequent intervals, whereas between this location and Abbeyleix there are indications of more frequently used crossing points, particularly around the Collins' Bog area.

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

FIG. 24 Deer Movement patterns – Red arrows denote main crossing points - image produced courtesy of google maps (Map data © 2021 Google)



9.7 DEER MOVEMENT IN RELATION TO HABITAT TYPE

The presence and abundance of woodland covered areas in the immediate vicinity of the N77 raises the probability of deer crossing and therefore a realistic expectation of higher collision risk. The extensive network of trails and the high density of Faecal Pellet groups (0.03m² – 0.19m²) and correspondingly high deer density within woodland on either side of the N77, suggests that there is likely to be a link between habitat type adjacent to the road edge and the potential for increased frequency of deer crossing the carriageway. It is notable that at two of the main crossing points, dense scrub woodland (where deer density is high 28.69km²) are adjacent to the carriageway, although only on one side. On the opposite side to both these patches of Scrub woodland (WS), are open canopy mature Mixed Woodland (WD2/4) where deer density is even higher (39.25km²). Also, along some sections the 3.0 kilometre length of the N77, dense vegetation and mature trees grow in close proximity to the edge of the carriageway.

9.8 DEER MOVEMENT IN RELATION TO SEASON

From the little data available in relation to the seasonality of DVCs, this project has indicated that thus far, DVCs may be only confined to specific time periods of the year. However, occasional DVCs are still likely to occur as sporadic events throughout the year and in multiple locations, although these are likely to be limited to relatively small numbers. It is more likely, that the majority of DVCs occur during the spring April / May and during a two-month period between early September and late October, related specifically to increased movement around dispersal of juvenile deer in the spring and the mating season in autumn. To date, camera traps have recorded some activity of individual animals (fallow and red deer) parallel to the N77 during daylight hours at known crossing points. However, deer are undoubtedly aware of traffic and appear to be reluctant to cross the road during the day. Activity patterns do not yet show any conclusive pattern.

9.9 INFLUENCE OF TIME OF DAY ON DVC RISK

Diurnal variation in deer activity periods are often likely to coincide with diurnal variation in traffic flows, which may potentially lead to an increased risk of DVCs occurring at particular times. However, without specific data on actual times of DVCs, even with data on traffic flow rates, it is impossible to predict when these collisions are most likely to occur. For many deer casualties, the times when most deer are seen dead at the roadside and therefore recorded may be biased towards daylight hours, contributing to potential observer bias in relation to actual times of DVCs. Camera traps have so far recorded deer activity at 2.25am, 5.54am, 7.14am, 8.03am, 11.50am, 12.00pm, 12.23pm, 14.44pm and 16.41pm.

9.10 DEER MOVEMENT IN RELATION TO CULLING ACTIVITY

The effects of culling activity on deer movement patterns and habitat use are unknown, but it is highly likely that localised culling may well displace deer from habitats in which they are being culled. Furthermore, deer control
 WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -
 RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

activity, particularly if it is intense and targeted on particular locations or habitats, will sometimes permanently displace deer, or at least acutely modify their behaviour until culling ceases. Culling in one area and not in another, is likely to increase the risk of enforced movement away from the source of disturbance, leading to more random and unpredictable patterns of movement. Therefore, if culling is being contemplated, prior planning and due consideration should be given to the manner in which it is carried out, particularly in relation to the proximity of the N77.

9.11 DEER DENSITY AND TRAFFIC VOLUME

Results of this study have shown that deer density is high in areas that are adjacent to the N77, with particularly high density on the western side compared to the eastern side. However, in the absence of accurate data on the location of DVCs along the 3.0km stretch of the N77, it is difficult to assess the actual effects of high deer density on the frequency and location of DVCs in the area. However, the more deer there are the greater the risk and there is no doubt that there is a strong relationship between high deer density and potential for increased frequencies of DVCs occurring.

9.12 EFFECTS OF ROADSIDE HABITAT

Of the habitats located along the N77 (on both sides) woodland habitats (all types) account for around 75% of the habitat, while agricultural land accounts for only 25%. On the western side of the N77, the entire length of the N77 is wooded with mixed conifer / broadleaved woodland accounting for around 70% of the woodland type, while scrub woodland makes up the balance (30%). On the eastern side of the N77, the situation is similar with 72% of the road edge woodland and the balance (28%) farmland. Further analysis of the habitats adjacent to the N77 reveal that only 30% of the total woodland cover is scrub woodland while the majority (70%) is mixed conifer / broadleaved woodland. Higher fallow deer density was found in mixed conifer / broadleaved woodland compared to scrub woodland and one of the main crossing points (Killamuck) is located between these two woodland types

From the limited amount of DVC data, it is difficult to assess conclusively to what extent accident risk is directly affected by habitat or whether DVCs are randomly distributed irrespective of the prevailing habitat type. Nevertheless, the results of this study have shown that deer density is high in woodland, that they have a clear preference for woodland habitats and, the majority of the habitat adjacent to the full length of the N77 is woodland. These factors in combination, are highly likely to be net contributors to increased risk of DVC occurrence.

9.13 IMPACTS ON DEER WELFARE AND POPULATIONS

Because of the inconsistent nature of data collection in relation to DVCs both nationally and at local hotspots and the lack of accurate information on deer population sizes, it is not possible to determine the impact either on deer welfare or on population size. Even with the limited data available locally, (12 reported collisions between 2014 and 2018, or around 3 per annum), which, even if these figures are correct, only represent a negligible (<1.5%) loss to the local population annually. In reality, the figures are likely to be higher, as there is an unknown proportion of accidents that are either unreported, or those where deer are hit by a vehicle, but are not killed outright and escape to die of their injuries and are never recovered.

9.14 OTHER FACTORS

There are a myriad of other factors that are likely to influence the frequency of DVCs and these include, driver speed and awareness, roadside vegetation, road tortuosity, deer species, species behaviour and the presence or absence of mitigation measures. It is difficult to separate out each of these factors as being solely responsible for DVCs and it is more likely that all of them contribute collectively, including the factors above.

9.15 CAMERA DATA (to 22.09.21)

Data from trail cameras is ongoing. Trail cameras have been set at three known crossing points, one recurrent (Killamuck A), one intermittent (Colemans B) and one irregular (Collins Bog C). Thus far, a small amount of data has been captured from trail cameras and footage of fallow deer crossing have been recorded on only one of the three cameras (A). Two trail cameras A and C were initially operational between 21.00 hours and 06.00 hours daily, but were reset on the 15/09/21 to record over 24/7. The third is operational 24/7 and records both video and photo images. All cameras were operational 24/7 from the 15/09/21 until the they were retrieved on the 17/09/21.

CAMERA DATA – 09.08.21 TO 17/11.21

CAMER A	DATE	TEMP.°C	ACTIVITY (TIME)	SPECIES	ROAD CROSSING	FEEDING ADJACENT TO N77
A	18.08.21	12	02.25	F	YES	NO

CAMER A	DATE	TEMP.°C	ACTIVITY (TIME)	SPECIES	ROAD CROSSING	FEEDING ADJACENT TO N77
B	14.08.21	06	01.12	F	YES	YES
B	16.08.21	07	01.31	F	NO	YES
B	21.08.21	09	22.16 – 22.19	R	YES	YES
B	26.08.21	14	21.13	R	YES	YES
B	26.08.21	14	22.16	R	NO	YES
B	26.08.21	14	23.53 – 23.54	R	NO	YES
B	27.08.21	11	22.11	R	NO	YES

B	27.08.21	11	22.36	R	NO	YES
B	28.08.21	03	04.43 – 04.44	R	NO	YES
B	01.09.21	08	23.30	R	NO	YES
B	11.09.21	08	02.49 – 02.51	R	NO	YES
B	13.09.21	06	00.42	?	NO	YES
B	04.11.21	10	18.28	R	NO	YES
B	05.11.21	03	17.14 – 17.20	R	NO	YES
B	09.11.21	06	15.35	R	NO	YES
B	09.11.21	06	16.06 – 16.13	R, S	NO	YES
B	10.11.21	00	08.03 – 08.05	R	NO	YES
B	10.11.21	01	22.26 – 22.30	R	NO	YES
B	15.11.21	05	11.44	S	NO	YES

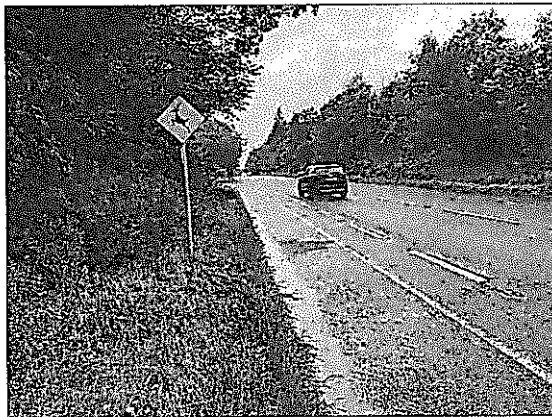
CAMER	DATE	TEMP.°C	ACTIVITY (TIME)	SPECIES	ROAD CROSSING	FEEDING ADJACENT TO N77
A						
C	14.08.21	14	16.41	F	NO	YES
C	16.08.21	16	07.14	F	NO	YES
C	20.08.21	11	05.54	R	NO	YES
C	02.09.21	14	12.00	R	NO	YES
C	02.09.21	15	12.23	F	NO	YES
C	02.09.21	15	14.44	F	NO	YES
C	08.09.21	14	11.50	F	NO	YES
C	10.09.21	12	08.03	F	NO	YES

R = RED DEER, F = FALLOW DEER, S = SIKA DEER

WP3.30 - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

9.16 ROAD SIGNAGE AND OTHER MITIGATION MEASURES

At the time of writing, existing mitigation measures that have been in place to help reduce Deer Vehicle Collisions on the N77 are limited. In advance of this project beginning and in response to growing concerns about the frequency DVCs in the local area, Laois County Council erected two large digital deer warning signs, one on exit from the town of Abbeyleix and a second one approximately two and a half kilometres further south along the N77. In addition to these warning signs, one standard deer warning sign is located on the western verge of the N77 approximately 40 metres south of the digital sign, but no visible speed limit. Both digital signs are on 24/7, flashing warnings "Warning Drive Carefully" and "Danger Deer Crossing". Also, to further confuse motorists, maximum speed signs of 100km/h are positioned beside the digital warning signs on exit from Abbeyleix. There are no other visible mitigation measures in place.



SECTION 10: DISCUSSION

In order to assess the scale of DVCs nationally, it is essential that data on the frequency, locations and timing of DVCs is routinely collected as without such data, it is virtually impossible to gauge the overall scale of the problem. Nevertheless, it is possible to collect enough circumstantial evidence by assessing a number of critical parameters such as deer ecology and habitat differences within the landscape, to begin to understand and assess the potential risk of DVCs occurring. Unfortunately detailed data on deer species densities are lacking, with available data on deer presence / absence largely restricted to 10km², rather than 1km² squares. The lack of specific data on deer densities either at a national scale or at local level will continue to hamper a broader analysis of the association between high deer density and high numbers of DVCs. In order to fully evaluate the scale of problem, it is essential that at known DVC hotspots, detailed data both on the location, time of year, time of day, species are routinely collected in addition to regular monitoring of local deer density and habitat associations. A centralised system of data collection and maintenance is required where data on DVCs are collected and stored. For example, in the United States, the National Highway Traffic Safety Administration (NHTSA) maintains both a Fatality Analysis reporting system WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

that records all fatal collisions involving deer and a General Estimates System that files police-reported collisions (Hedlund *et al.* 2003). In Finland all DVCs must be reported to the police and are then registered on the Finnish Collision Statistics database (Niemi *et al.* 2015). In the UK, the Deer Collisions Database is maintained by the Deer Initiative on behalf of Highways England and is able to provide geo-referenced records of DVCs within England (Nelli *et al.* 2018).

DEER DENSITY

Deer density was assessed using Faecal Standing Crop techniques in three Zones within an overall project area of around 8.50km² to determine the overall density, distribution, habitat use and movement patterns that might be associated with increasing numbers of DVCs in the Abbeyleix area.

Deer density in the overall project area was much higher than originally anticipated, with estimates of recorded fallow deer density over twelve times higher (24.35km²) than red deer density (2.53km²). However, an analysis of deer density, showed that there were considerable variations both within the project area as a whole and within each Zone. Zone 1, although the second largest zone within the project area, had the lowest density of both fallow and red deer. As in other Zones fallow deer density was higher than red deer density, with fallow deer being the predominant species. Both species shared common habitats throughout Zone 1, although red deer were mainly confined to the northern and eastern woodland fringes, while fallow

deer were found at higher density in the woodlands along the western edge of Zone 1. Zone 2 had by far the highest fallow deer density of the three Zones, while red deer were present but only transiting and not resident. However, the area consists of a large mosaic of habitats, over 60% of which is woodland of one type or another and fallow deer density was consistently high across all the plots sampled.

Zone 3, the smallest of the three zones and farthest away (<2.0km) from the N77, also had high fallow deer density and low red deer density. However, although land-ownership boundaries divided Zone 2 and 3 they were in effect, one contiguous area. As in the other zones, deer density varied according to habitat type and woodland of all types was the dominant habitat.

In the UK, research has revealed that areas of high frequencies of DVCs were not simply related in any direct way to deer density. They suggested that higher than average levels of DVCs at the landscape scale were determined not by the abundance of deer *per se*, but rather an interaction between high deer density in areas which also have high traffic volumes (Langbein *et al.* 2011). Nelli *et al.* (2018) found that in order to have a DVC at all, it is necessary for deer to be present in the surrounding area, but, beyond that, other factors were likely to have played a more significant role (Nelli *et al.* 2018).

DEER DISTRIBUTION

Both red and fallow deer are mobile species that have large home range sizes. Red deer females average range sizes of around 430ha. (range 275 - 711ha.) with one core area whereas males have larger range sizes of up to 1,200ha. usually with two core areas (Langbein 1997). In this survey, red deer were more or less confined to the north-eastern and eastern part of the project area, with only a minimal amount of movement westwards and it was evident that they were less widespread (and less numerous) than fallow deer due to fallow being particularly effective competitors where they are sympatric with intermediate feeders such as red deer (Dolman *et al.* 2008). Red deer showed a preference for the edges of heath and heath / mixed woodland habitats which were mostly found in Zone 1 which is not unusual as red deer are typically an ecotone species associated with woodland edge or the interface between woodland and open areas and will rarely occupy large tracts of dense forest (Dzieciolowski 1979; Mitchell *et al.* 1977).

Fallow deer, particularly in predominantly agricultural landscapes have ranges of 178ha. for females and 202ha. for males and are a species characteristic of mature deciduous or mixed woodland. They also feed on woodland rides or vegetation between trees and frequently in adjacent forage on open agricultural land. They prefer woodland cover more by day and open landscapes are used more at night (Wyllie *et al.* 1998; Waterfield 1987). Fallow deer distribution was identical to that found by other researchers with distinct preferences for mature mixed coniferous / deciduous woodland and the edges of woodland and open areas.

The core range of the fallow deer population is likely to be the combined area of Zones 2 and 3, in addition to associated lands further south at Dunmore and Moyne.

DEER DENSITY (km²) ADJACENT TO THE N77

The N77 carriageway dissects part of the overall range of fallow deer within the project area, thereby, amplifying the likelihood that deer will cross the carriageway at some point or points along its length. Whilst deer density in the wider project area was high, these high densities were also reflected in the areas that were located adjacent to the N77 in both Zone 1 and 2. In these areas, average deer density was consistently high, particularly on the western side of the N77, but lower on the eastern side. Critically, deer density (particularly fallow deer) was high along the entire length (3.0km) of woodland adjacent to the western side of the N77 with average density estimated at 31.26km². Along a similar stretch of woodland habitat (although shorter 2.0km) on the opposite (eastern) side of the N77, fallow deer

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densities were considerably lower (4.16km²) whereas red deer were absent. Little difference in deer density estimates was observed between habitat types.

DEER MOVEMENT PATTERNS

In addition to the N77 dissecting part of the overall deer range, it also acted as a form of deterrent to deer movement across the carriageway. For example, while there was some as yet unquantified movement across the N77, evidence from field survey work identified a well-defined network of trails on both sides of the road which were orientated in a north / south direction parallel to the N77. Deer were clearly using these trails to move both northwards and southwards through the woodland parallel to the N77 and then using a small number of visible crossing points at specific locations on either side of the road. Away from the N77, deer movement patterns were also identified throughout the project area with considerable movement east and south in Zone 1 and east to west and vice versa in Zones 2 and 3. In the northern part of Zone 2 and Zone 3, there were also evident signs of movement north and south across the R433 Abbeyleix to Ballycolla road. Similarly, in Zone 2 there was evident movement in a south westerly direction along the River Nore towards Moyne and Dunmore, both of which contain satellite populations of fallow deer.

DEER MOVEMENT IN RELATION TO HABITAT

Data from Faecal standing crop counts revealed specific patterns of habitat use within the Project area and within each Zone. Red deer were found at higher densities in woodland habitats or the edges of woodland particularly in Zone 1 and to a lesser degree in Zone 2. Red deer were absent from large parts of the Project area and were limited to a relatively small section in the north and east of Zone 1. Fallow deer on the other hand were much more numerous and similar to red deer were also found in high density in woodland habitats. However, fallow deer densities differed according to

the type of woodland occupied. For example, highest densities of fallow deer were found in mature oak woodland (Park hill) with high densities also found in both scrub woodland and mixed conifer broadleaved woodland. Studies of fallow deer habitat use in the UK have found that deciduous woodland was actively selected (even though it was not equally available) both in the early spring and autumn with woodland use remaining high throughout the winter, particularly in good mast years as deer fed on the abundant beech mast and acorns. In addition, fallow deer made extensive use of woodland clearings, grasslands and closed woodland areas throughout the year and that areas of heathland were actively avoided (Jackson 1974; Thirgood 1995b; Putman 1995; Waterfield 1986; Wyllie *et al.* 1998). Habitat use patterns in this project showed similar trends with fallow deer selecting mature oak woodland, even though it only represented 6% of the total project area. Similarly in Zone 1 fallow deer were found to avoid areas of open heath and were found to occupy woodland areas at the edges of, or adjacent to open areas.

DEER MOVEMENT IN RELATION TO SEASON

Fallow deer are commonly regarded as one of the more social deer species and therefore are more likely to be encountered in large aggregations. However, these large aggregations often occur in more open habitats (usually agricultural), with large groups consisting of a number of distinct social groups that have come together in favoured feeding areas. In the UK, researchers found that sexual segregation between males and females in mixed vegetational mosaics was extremely marked, outside the breeding season and that bucks and does occurred in distinctly separate groups, even though in certain areas the actual geographical range of these groups overlapped to some degree (Thirgood, 1990, 1995b). Because indirect methods were used to determine habitat use, data from this project did not differentiate seasonal use of particular habitats by either males or females. However, observations of individuals and groups of individuals throughout the period of field work, revealed that both bucks and does occupied clearly separate ranges throughout the project area. From previous studies of DVCs (Staines *et al.* 2001; SGS, 1998; Langbein 1985; Langbein & Putman 2006b; Langbein *et al.* 2011) it is well known that although deer accidents take place in significant numbers throughout the year, there are two prominent peaks of occurrence. The first of these is around May followed by a secondary peak during the late autumn (October). Key factors contributing to the spring peak are known to be dispersal of juvenile deer (born the previous year) from their natal ranges, as well as females with young at foot. Several variable factors are likely to influence the size and occurrence of the autumn peak such as mobility of the larger species (fallow and red deer) and shorter day length which coincides with high "rush hour" traffic at dawn and dusk when deer are at their most active (Langbein *et al.* 2011). From observations (and camera data) deer have been observed feeding close to the N77 during the middle of the day. The deer appear to be conscious of passing traffic and are also likely to be aware of the risk of road crossing during busy traffic times. However, as the rut approaches, involuntary movement (particularly of juvenile males) often caused by the actions of mature males, is likely to increase the occurrence of road crossings in situations where individuals have little choice.

WP3.3o - DEER DENSITY (km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 - RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

INFLUENCE OF TIME OF DAY ON DVC RISK

In most deer species, peaks of activity occur late in the evening (dusk) throughout the night and during the early morning (dawn) and these patterns remain relatively consistent throughout the year. During the day, activity is likely to be at its lowest level. These activity periods are also likely to coincide with times when traffic volumes are greatest – during the early morning and during the evening resulting in a higher than normal risk of collision. Records of DVCs in the UK showed periods of highest incidence occurring from early evening until midnight (1800 – 2400 hrs) and early morning (0600 – 0900 hrs) with little deviation across the seasons. However, peak accidents tended to occur earlier in the winter and later in the summer (Deer Initiative Research Report 2007). To date, footage from camera traps in this project have only recorded deer activity (all fallow deer) at four different time periods. Of these two were in the early morning (5.54am and 7.14am), one was during the night (2.25am) and the fourth was during the late afternoon (16.41pm). In Germany, Kammerle *et al.* (2017) found that roe deer responded to changing day length by accentuating their crossing behaviour into darkness as day-length increases, while crossings occurred further into the afternoon and early morning on days with short daylight (i.e. in winter). As a consequence, crossing occurrence overlapped with commuter traffic peaks early in the morning and in the late evening, leading to potential increased risk of collisions (Kammerle *et al.* 2017)

DEER MOVEMENT IN RELATION TO CULLING

Deer culling with firearms is widely recognised as a disruptive activity and can frequently lead to temporary or permanent dispersal or displacement of deer away from their core ranges. In addition, culling with firearms can modify deer behaviour causing animals to shift their activity patterns, becoming shy, nocturnal and actively avoiding human contact. For example, Ikeda *et al.* (2019) found that culling activity changed the activity patterns of sika deer from diurnal to nocturnal in response to culling intensity (Ikeda *et al.* 2019). Other studies have also found an association between hunting activity and diel activity patterns of ungulates such as white-tailed deer (*Odocoileus virginianus*), red brocket deer (*Mazama americana*) and sika deer (Kilgo *et al.* 2018; Di Bitetti *et al.* 2008; Van Doormal *et al.* 2015). However, because the amount of culling that has occurred in the project area in recent years has been limited to Zone 3 only, it is unknown what effect culling is likely to have had on dispersal and movement patterns throughout the project area. Furthermore, the direct effects of culling on DVC risk are unknown.

DEER DENSITY AND TRAFFIC VOLUME

While the majority of recorded DVCs are likely to occur on secondary roads mainly due to their greater overall length within the national road network, actual accident frequency per unit of carriageway, is likely to be consistently higher on primary or major roads where traffic speed and volume s are higher. Research in Germany by Hartwig (1993) shows that motorways accounted for 21.2% of all wildlife related DVCs even though they only made up 7% of the length of major roads in the area of study (Hartwig 1993). Similarly in France, Desire and Recorbet (1990) found that accidents involving roe deer accounted for a disproportionately higher number of DVCs (5.3% of all roe deer killed) were on motorways, despite the fact that they only amounted to 0.8% of the total road network (Desire and Recorbet 1990).

The N77 is a busy road, with constant road traffic during the day and night. Current traffic volumes indicate that vehicle numbers on the N77 have fallen from 6,129 average daily traffic (ADT) in 2019 to 4,839 in 2020. Figures to date for 2021 indicate a rising ADT of 4,985 which is lower than the N22 (6,694) (TII.ie). A once off assessment of traffic volume during for one hour around midday was also undertaken during July and found that on average, 6.6 vehicles / minute were using the N77 in both directions.

EFFECTS OF ROADSIDE HABITAT

Deer-related traffic accidents are not randomly distributed in space and time and there are a number of environmental factors which affect the frequency of DVCs. The amount of woodland present in the project area was considerable (>60%) and the woodland habitats on either side of the N77 amounted to almost 100% on the western side and over 60% on the eastern side. Furthermore, along both sides of the carriageway woodland or heavy cover was found right up to the road edge. Many authors have already indicated that habitat composition is one of the main factors affecting DVC risk (Bashore *et al.* 1985; Malo *et al.* 2004; Montgomery *et al.* 2013; Seiler 2004; Neilli *et al.* 2018). More recently, Neilli *et al.* (2018) found that DVCs were more likely to occur when roads were close to or running through significant areas of woodland / forest. They also found that increasing distance from areas of both coniferous and broadleaf forest emerged as an important factor that lowered the probability of DVC risk (Hothorn *et al.* 2012; Uzal 2013; Neilli *et al.* 2018). Other studies by Bashore *et al.* (1985), predicted that the probability of DVCs decreased with an increasing number of homes, commercial buildings and other buildings within a buffer area and longer sight distance along the roadway (Bashore *et al.* 1985). In the USA, FINDER *et al.* (1999), measured topographical and habitat-related features within 0.8km radius of road segments in Illinois. He found that high accident rates for white-

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tailed deer (*Odocoileus virginianus*) were associated with woodland cover; a logistic regression model related accident frequency to landscape diversity and (shorter) distance from adjacent woodland cover (Finder *et al.* 1999). In a European context, Madsen *et al.* (2002), analysed 115 kills of roe deer at Kalo in Denmark between 1956 and 1985 and found no correlations between patterns of road-kills and mean daily traffic flows but noted that collision sites were strongly clumped and sites with higher road-kills tended to have denser vegetation (hedgerows, bushes etc.) present on one or both sides of the road (Madsen *et al.* 2002). In all these studies, particular features emerge as characteristic of sites that are likely to suffer a higher frequency of DVCs such as:

- The number of lanes of traffic
- The close association of accident sites with woodland or forest cover close to the carriageway
- Landscape diversity (variability in patch size)
- The presence of obvious travel corridors across the roadway or other linear features leading down at an angle to or perpendicular to the roadway (www.deercollisions.co.uk)

IMPACT ON DEER WELFARE AND POPULATIONS

Because of the lack of hard data on the frequency of DVCs nationally and the lack of data on deer densities both locally and nationally, it is impossible to determine the impact of DVCs on deer welfare or population size. From a welfare point of view, the concerns relate as much to the deer killed outright through collision, but also to those animals who suffer serious injury until a suitably qualified person is available to humanely dispatch them. In addition, there is another cohort of animals that may be involved in a collision, but run off to suffer and die of their injuries later. Research findings carried out by the Deer Initiative, indicate that up to 30% of DVCs involving fallow deer tend to leave live casualties needing dispatch at the roadside. Also, the total mortality imposed on fallow deer populations was found to be between 7 – 13%, making DVCs a major cause of mortality among wild deer populations (Deer Initiative Research Report 2007).

OTHER FACTORS

It is clear from the published literature (reviewed by SGS 1998; Staines *et al.* 2001; Putman *et al.* 2004b; Hedlund *et al.* 2004) that different areas or stretches of roads are likely to be affected by a wide range of contributory factors and these are more likely to influence the frequency when taken together, rather than individual factors alone. However, without detail on specific factors at the actual time of a DVC occurring, it is difficult to draw conclusions as to which factor or factors are primarily responsible for increased collision risk. Examples of some of the contributory factors include, deer density, season, time of day, species, traffic volume, road type, average road speed, driver visibility (related to road tortuosity), presence (and character) of roadside vegetation. Langbein (2007) in the Deer Initiative

Research Project suggests that a fuller understanding of all the contributing factors (and their interaction) may be helpful in predicting likely future problem areas to target alternative measures for mitigation (Langbein; in the Deer Initiative Research Project 2007).

CAMERA DATA

Data from trail cameras has the potential to identify specific patterns of deer movement that may lead to a better understanding of factors that trigger road crossing behaviour either temporally or spatially. Three trail cameras have been in operation since 16th July 2021, along the eastern side of the N77 at identified crossing points, some of which were well defined. To date only a limited amount of footage has been recorded suggesting that deer movement across the N77 is confined to a number of individual, sporadic crossings that most likely occur during darkness. Some camera data has shown deer activity parallel to the N77 during the day, but the animals appear reluctant to cross the road. However, the rut (or mating season) is due to begin in late September / early October and in advance of rutting activity, it is expected that deer movement (and therefore road crossing) is likely to escalate significantly.

CURRENT ROAD SIGNAGE AND OTHER MITIGATION MEASURES

The current extent of road signage and mitigation measures on the N77 are limited and sometimes contradictory. For example, on exit from Abbeyleix southbound there is a 60km/h speed sign followed within 40 metres by a large digital traffic warning sign which is adjacent to a 100km/h speed sign. The message to drivers therefore is confusing – while warning of deer crossing and to drive carefully, but that a maximum speed limit of 100km/h is acceptable. From observations of traffic and driver behaviour, the majority of drivers accelerate immediately after passing the deer warning sign. At the southern end of the N77, there are similar warnings, but no visible speed limits. As a result, traffic enters the Deer Crossing warning zone at maximum or above maximum speed. Critically, the southern Deer Crossing digital sign is located just 20m from a major crossing point. Observations of traffic speed and driver behaviour at this location, found that almost all traffic enters this critical zone at speeds of at least 100km/h or above.

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SECTION 11: SUMMARY OF MITIGATION MEASURES AIMED AT COLLISION REDUCTION

Collisions of vehicles with ungulates and in particular deer, represent a significant and growing problem. Therefore, mitigation should be specifically targeted at areas which already are known to have high accident rates, or which have landscape characteristics which may prove to be a problem in future. Ideally, measures designed to reduce or even eliminate the risk should aim in the first instance to ensure that animals cross the road safely rather than preventing them from doing so. Attempts to completely prevent crossing for long sections of roadway are likely to be ineffective and are also likely to result in animals actually breaking through fencing and then becoming trapped within the carriageway. Furthermore, if barriers are 100% effective at preventing movement, this is likely to result in isolation and fragmentation of previously intact populations of ungulates and other larger wildlife (Forman *et al.* 1997; Forman & Alexander 1998; Langbein *et al.* 2011). Therefore, the most successful mitigation measures will not prevent crossings completely, but will attempt to displace actual crossings in space or time. This allows animals to cross the road at periods of reduced (or even zero) traffic flow, or in locations where accident risk is reduced through enhanced visibility and / or driver awareness, or the provision of traffic-free wildlife passages (Langbein *et al.* 2011). There are broadly three options available to prevent or minimise DVCs suggested by (Putman *et al.* 2004b) in their review for the Deer Commission for Scotland.

These are:

11.1 Prevent or Control Crossing – Highway fencing, Wildlife warning devices, chemical deterrents, vehicle mounted whistles, reductions in local population density.

11.1.1 FENCING

There is a strong consensus amongst the research community, which concludes that high-tensile fencing is likely to remain the primary method used to try and reduce DVCs at identified sites of high risk. However, it comes with caveats which are, that fences must be constructed according to the latest specifications, using appropriate materials (correct height / mesh size) and most critically should aim not to prevent animals crossing the road entirely, but should be designed to specifically channel animals towards a dedicated crossing point.

Many authors have emphasised that where fencing has failed to prove effective, that it is related to poor construction, specification, inadequate planning, lack of maintenance or where fences are of insufficient length resulting in animals getting past the end of the fence-line and onto the road (Reed *et al.* 1979; Ward 1982; Clevenger *et al.* 2001, 2002; Staines *et al.* 2001). Therefore, the most effective application of barrier fencing, is to erect it in short lengths, combined with alternative safer means of crossing that are specifically designed and planned so that animals can be deflected towards actual designated crossing points.

11.1.2 WILDLIFE WARNING DEVICES

Wildlife warning devices can be divided into two distinct categories – optical reflectors and acoustic deterrents.

Debate on the effectiveness on optical reflectors is ongoing (Woodard *et al.* 1973; Gilbert 1982; Gladfelter 1982; Schafer & Penland 1985; Zacks 1986; Waring *et al.* 1991; Armstrong 1992; Ford & Villa 1993; Reeve & Anderson 1993; Pafko & Kovach 1996; Pepper *et al.* 1998; Jared 1992; D'Angelo *et al.* 2006; Voss 2007). From the literature, it seems clear that there are a

number of issues with optical reflectors. First, the installation of these devices is common, particularly in Continental Europe, most likely because they are cheap and easy to install and may have some (short-term) effectiveness in delaying road crossings, but over time deer are likely to become habituated to their presence. Second, deer biologists have long presumed that deer (as other ungulates) have comparatively limited (dichromatic) colour vision and this inability to see red (the colour of optical reflectors) has been confirmed by a number of recent studies (VerCauteren *et al.* 2003; Sheets & Cason 2005; Purstl 2006). This has led Luell *et al.* (2003), to the conclusion that, a thorough analysis of studies carried out over the last 40 years all over the world found little evidence for the effectiveness of wildlife warning reflectors (Luell *et al.* 2003; Langbein *et al.* 2011). Furthermore, a comprehensive re-analysis of DVC data based on 43 studies revealed no significant reduction in collision rates after placement of light reflecting devices (Brieger *et al.* 2017).

11.1.3 ROADSIDE DETERRENTS

In recent years, a number of more sophisticated roadside deterrents have been developed to try and overcome some of the drawbacks of optical reflectors. Some combine white or red optical reflectors with acoustic modules to produce a variety of acoustic sounds (WEGU-GFT or) or a series of signals at different frequencies ranging from infra sound through to ultrasound (EUROCONTOR Ecopillars). Other devices such as the WIWASOL-II device, produces a series of intermittent whistling sounds readily audible to humans in addition to a flashing blue light (Langbein *et al.* 2011). Evidence in the literature for lasting effects of these devices (mainly because deer become easily habituated), remains inconclusive or even contradictory.

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11.1.4 CHEMICAL DETERRENTS

Chemical repellents in the form of a slow release organic foam applied to roadside trees and other vegetation have been extensively trialled in Germany and Slovenia. However, despite the various trials, their efficacy was not convincing and Pokorny *et al.* (2008), stated that the positive influence of chemical repellents as countermeasures against DVCs was not confirmed (Pokorny *et al.* 2008).

11.1.5 VEHICLE MOUNTED DEVICES

A number of companies offer devices for attachment to the front of a motor vehicle which emits a high frequency whistle at speeds above 30km/h. However, there has been comparatively little research into the effectiveness of these devices and thus far no positive effects could be detected for any of the devices tested.

There are a number of published studies that have now demonstrated a relationship between the frequency of DVCs and local deer densities (McCaffery 1973; Wisconsin Department of Natural Resources (data summarised on www.deercrash.com); Schwabe *et al.* 2002; Rondeau & Conrad 2003).

11.1.6 REDUCTIONS IN LOCAL DEER DENSITY

Whilst it is evident that there is some relationship between deer densities and the frequency of DVCs occurring at a local level, this relationship is unlikely to be linear, as the myriad of other factors in combination that are associated with high levels of DVCs are likely to be more important. Nevertheless, a number of published studies do show evidence of a reduction in the frequency of DVCs, in parallel with perpetual reductions in local deer densities (Jones *et al.* 1993; Danielson & Hubbard 1998; Rondeau & Conrad 2003; Jenks *et al.* 2002; Sudharsan *et al.* 2006). On the contrary however, areas where either hunting bans have been imposed or there has been a reduction or cessation of culling, have been correlated with an increase rather than a decrease in DVC occurrence.

However, these studies must be viewed with some caution, as there are so many additional factors that are likely to affect variations in accident frequency and reductions in local deer densities (even though persistent) are likely to be only one of many (Seiler 2004; Langbein & Putman 2006; McShea *et al.* 2008).

11.2 Increase Driver Awareness – Fixed Wildlife Warning Signs, Enhanced Driver Warning Systems, In-vehicle Detection Systems, Management of Roadside Vegetation to increase visibility.

11.2.1 FIXED WARNING SIGNS

Fixed deer warning signs are perhaps the most frequently used mitigation to reduce DVCs and these can be seen with increasing frequency on many roads (minor and major) throughout the country. These signs warn drivers that there is an increased risk of deer crossing the road along particular segments of roadway, but tend to be unspecific in relation to the actual location of the danger zone. Also, because these signs are permanent structures, drivers quickly become habituated to their presence particularly if not reinforced by an actual experience of seeing deer crossing the road, their overall effectiveness is greatly diminished (see Putman 1997; Hedlund *et al.* 2004; Stanley *et al.* 2006). Also, deer warning signs provide both County Councils and Roads Authorities with some degree of judicial protection.

11.2.2 ENHANCED DRIVER WARNING SYSTEMS

In addition to static wildlife warning signs, various types of more advanced signs such as dynamic digital message boards and animal activated warning systems, have been developed, with the specific purpose of increasing driver awareness of the potential danger (Huijser *et al.* 2006, Mastro *et al.* 2008). However, for these signs to be most effective, they should be erected at known regular deer crossing points and activated only at specific times of the year (e.g. autumn and spring) where accidents are known to be more frequent. For example, Sullivan *et al.* (2004) reported some success with temporary enhanced signage erected only during the autumn and spring migration of mule deer (*Odocoileus hemionus*) which resulted in a fall in the percentage of speeding vehicles from 19% to 8% and a reduction in DVCs estimated at 50% (Sullivan *et al.* 2004).

More advanced dynamic signage has also been recently developed (e.g. Flashing Light Animal Sensing Host or FLASH systems) that are activated when animals approach or are close to the roadway. These signs operate on the basis of either thermal detection, seismic ground vibrations or breaking laser or infrared beams located along the edge of the road. Also, these signs may be triggered by the speed of on-coming traffic which display intermittent messages either on portable trailers at the road side, or message boards mounted above the carriageway. According to Langbein *et al.* (2011) numerous different versions of these systems have been operational in Europe and North America although definitive data on their effectiveness is limited at present. Nevertheless, several studies have demonstrated that drivers do pay attention and slow down in response to activated systems (Gordon *et al.* 2001; Hammond & Wade 2004; Hardy *et al.* 2006; Huijser *et al.* 2006; Langbein *et al.* 2011).

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11.2.3 IN-VEHICLE DETECTION SYSTEMS

According to Langbein *et al.* (2011) two in-vehicle 'vision systems' have been designed to enhance driver detection of deer (or other ungulates) along the roadside, particularly at night. These systems use infra-red sensors to alert early detection of animals either on the road itself or at the edge by displaying continuous images on a screen on the dashboard of the vehicle. In addition, there are some promising developments being considered which include wildlife accident hot-spot maps for in-car satellite navigation systems (i.e. Google maps) that provide alarms when drivers approach road sections of known high risk for DVCs (Langbein *et al.* 2011). Many of the factors that help predict the risk of collisions on roads, such as land cover, road type and traffic volume, are already recorded in digital mapping systems and additional information on deer population density and activity, from projects that collect this kind of data, could also be added. In an analysis of 85,000 DVCs over 17 years by Meyer *et al.* (2021), they found that factors related to infrastructure and land cover were most important in explaining patterns of DVCs, but seasonal and diel changes, deer activity and population density were also important in predicting DVC occurrence. They proposed that their findings could be used to develop a spatio-temporally flexible warning system for smartphones and navigation systems based on existing map providers making it a cheap and widely available mitigation measure (Meyer *et al.* 2021).

11.2.4 MANAGEMENT OF ROADSIDE VEGETATION

The management, or removal and maintenance of roadside vegetation is a relatively straightforward mitigation measure that can be implemented quickly and relatively cost-effectively. The benefits include increased driver awareness and visibility of animals along each side of the road, while at the same time increasing visibility of ungulates themselves of on-coming traffic (Waring *et al.* 1991). According to Lavsund & Sandergrén (1991), clearance of a 20 metre strip either side of the highway decreased moose collisions by almost 20% (Lavsund & Sandergrén 1991). However, where vegetation removal is proposed, it is important to consider the timing, as the cutting of low growing vegetation (grasses / herbs etc) and their subsequent re-growth, may prove attractive to grazing deer, which may also increase the number of animals using the road verge.

11.3 Provide Safer Crossing Points – Underpasses / Overpasses, Creation of dedicated 'cross-walks'.

11.3.1 UNDERPASSES / OVERPASSES

In continental Europe the concept of underpasses or overpasses is becoming more acceptable and they are becoming widely used, mainly to improve road safety but with the added benefit of reducing the potential for fragmentation of wildlife populations and their associated habitats. However, there are relatively few examples of how wildlife underpasses or overpasses can be modified from existing structures and most of these are likely to be built as part of new road infrastructure schemes rather than retro-fitted to existing roads. In Germany, Giorgii *et al.* (2007) investigated the use a range of different structures by animals, built specifically for wildlife during over the last 20 years. He used mapping of tracks and other signs including filming by infra-red cameras either on or below the structures themselves. He found that green. Bridges and viaducts were the most widely used (85% of all records) and using multiple regression analysis, that the older and wider the structure the more intensive the use (Giorgii *et al.* 2007).

From the many extensive reviews (Reed *et al.* 1975; Hedlund *et al.* 2003; Luell *et al.* 2003; Giorgii *et al.* 2007; Olson *et al.* 2008) both on specification of underpasses and overpasses and their effectiveness, it is clear that a number of factors are important, for example, it takes time for wildlife and deer in particular to acclimatise to new structures but over time as vegetation grows and the structures become part of the overall landscape they begin to use them more

frequently. Also, to be most effective underpasses and overpasses need to be located in relation to natural deer paths or migration routes and factors such as size (wide openings and short lengths), design (earth floors), visual appearance (exit clearly visible from entrance) and woody vegetation cover at the entrance should be considered (Danielson & Hubbard 1998; Hartman 2003). Fencing to be most effective, should be used to channel deer to overpasses and underpasses. For example, Ward (1982) describes how a system of fencing and six underpasses were used along a 7.8 mile section of interstate highway that crossed a mule deer migration route. The system did not disrupt deer movement and virtually eliminated DVCs (Ward 1982; Hedlund *et al.* 2003).

11.3.2 CREATION OF DEDICATED CROSS-WALKS

Dedicated cross walks (where deer are directed by funnel fencing to specified crossing points) are often used as DVC mitigation measures. However, in order for these structures to be effective, additional important infrastructure is required, such as funnel fencing and the use of animal-activated detection systems.

In central Arizona, Gagnon *et al.* (2018) aimed to achieve modified motorist behaviour without long-term habituation while allowing wildlife (elk and white-tailed deer) to cross the highway via a dedicated crosswalk. In conjunction with a designated at-grade crosswalk, they installed an animal-activated detection system (AADS) and motorist alert

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signage to prevent collisions when animals crossed. They documented wildlife use of the crosswalk zone between 2007 and 2014 using video cameras and over that time, recorded 1,719 individuals crossing at the cross walk. They found however, that increasing traffic volumes reduced the frequency of successful crossings and that almost three-quarters of elk crossings occurred between 23.00 and 03.00hours when traffic volume averaged just 0.6 vehicles/min (Gagnon *et al.* 2018).

SECTION 12: CONCLUSIONS

The findings of this work are in common with research in many other countries, particularly in the UK where deer species are identical and there is a high degree of similarity between habitats, overall landscape features and road infrastructure. Nationally, deer numbers and distribution have been increasing steadily over the last two decades to the extent that deer of all species are now being recorded in areas where they were previously absent. In tandem with this increase in numbers and distribution, the country's national road infrastructure continues to improve, vehicle numbers and speeds are increasing, leading to a steady escalation in the reported numbers of DVCs. However, in both cases (deer numbers and DVC numbers) it is essential that efforts are made to both temporally and spatially determine (and fully document) the degree to which deer density and DVC occurrence is either increasing or decreasing. Also, as reported DVCs continue to increase, so too will the cost in terms of human life and serious injury, vehicle damage and ultimately increased insurance costs. In the absence of this information, the success or failure of mitigation measures aimed at reducing DVC occurrence, will be virtually impossible to quantify with any degree of confidence.

The results of this project, have shown that estimated deer densities (fallow more than red deer) were exceptionally high within the general project area and that this is likely to be one of many contributory factors associated with increasing occurrence of DVCs on the N77. The project area consists of a rich mosaic of many different habitat types, particularly dominated by woodland and these woodland habitats are in the immediate vicinity of the N77. Many deer species show a distinct preference for woodland habitats in favour of more open habitats, although habitat structure at the landscape scale is likely to influence overall habitat use, movement patterns and distribution. In this project, the habitat landscape is favourable to the perpetuation of higher than normal deer density, particularly if little or no control is being exercised. This does not necessarily suggest that high deer densities on their own are the sole cause of elevated numbers of DVCs, nevertheless, there is little doubt that higher than normal deer density, coupled with favourable habitats are likely to be significant contributory factors in the increasing occurrence of DVCs.

In keeping with other research findings, deer biology was found to be a fundamental part of their overall ecology (dispersal, distribution and density) largely associated with the dispersal of juvenile deer in the spring and mating behaviour during the autumn. These two aspects of deer biology, are also associated with peak DVC occurrence and the risks of increased DVCs are likely to be greater in areas where woodland habitats predominate and deer density is high. Whilst there will always be a risk of DVCs occurring at other times of the year in high deer density sites, these can be mitigated against by significantly reducing deer density locally.

Having established high deer density, seasonality of movement patterns and favourable habitat as being critical elements in DVC occurrence, there are many other equally important factors that are also likely to contribute to increased numbers of DVCs. For example, improvements in road infrastructure, coupled with increasing traffic volumes, increased speed where road surfaces have been enhanced, driver behaviour, poor or inappropriate signage and a general lack of awareness of the dangers of deer crossings, are all equally likely to feed into the potential risk of increased numbers of DVCs.

Therefore, in order to reduce or even eliminate the potential risk of collisions occurring, a holistic approach to mitigation is required, which deals with each of the above factors in a systematic and targeted manner that is appropriate to the overall scale of the problem. In tandem with this approach, it is essential that deer densities and distribution are determined both nationwide and at local levels and a system put in place that enables the collection, storage and access of detailed DVC data (locations,

time of year, time of day etc.). Over time, these data will assist in identifying the scale, locations and severity of the problem, both at local and national scales and as a consequence, drive a proactive (rather than reactive) approach to mitigation.

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SECTION 13: PROPOSED MITIGATION MEASURES AND RECOMMENDATIONS FOR THE N77

13.1 Hierarchy of proposed mitigation

Where (economic) resources have been, or are likely to be allocated to DVC mitigation, it is critical that they are directed to actions and measures that have the potential to produce tangible results. Furthermore, actions need to be appropriate to the scale of the problem, rather than spending limited resources on large-scale, but largely unnecessary mitigation measures. In particular, efforts should concentrate on specific sections of road or identified hot-spots on which there is a high likelihood or incidence of DVCs occurring or having occurred in the past.

The 3.0km section of the N77 south of Abbeyleix, is a high traffic volume, high speed, straight and well-surfaced section of carriageway. Added to this, is a diverse habitat mosaic of woodland, agricultural fields and heathland, amplified by a high density fallow deer population within the immediate environs of the carriageway. These factors together, create the ideal mix that significantly increases the probability of DVCs occurring along this section of road.

Thus, the consideration of any mitigation measures, needs to take account of all the factors involved, so that a holistic approach to reducing DVC occurrence can be successfully implemented.

The following hierarchy of proposed mitigation measures are recommended, with the most appropriate mitigation measures ranked 1 – 5 in order of priority. Those ranked 6 – 9 are measures that may need to be considered in the longer term, in the event that those ranked 1 – 5 prove ineffective, or increased frequencies of DVCs occur.

RANK (in order of priority)	MITIGATION MEASURE	ACTIONS	POTENTIAL ADVANTAGES	DISADVANTAGES
1	SPEED LIMITS	REDUCTION IN OVERALL SPEED LIMIT FROM 100KM/H TO 80KM/H. STRICT ENFORCEMENT OF SPEED LIMITS – SPEED CAMERAS/ MOBILE SPEED VANS.	EASY TO IMPLEMENT - REDUCE POTENTIAL FOR SERIOUS COLLISIONS AND/OR FATALITY	LACK OF ENFORCEMENT
2	IMPROVE ROAD SIGNAGE	USE DIGITAL WARNING SIGNS ONLY AT HIGH RISK PERIODS INSTALL MORE EFFECTIVE SIGNS e.g. DYNAMIC SENSOR SYSTEMS	FOCUS DRIVER AWARENESS & ATTENTION	POSSIBLE DRIVER HABITUATION OVER TIME
3	CUTTING OF ROADSIDE VEGETATION	REMOVE ALL ROADSIDE VEGETATION UP TO 15 METRES FROM ROAD EDGE ON BOTH SIDES	ALLOW ENHANCED DRIVER VISIBILITY – ALSO EASIER FOR ANIMALS TO SEE ONCOMING TRAFFIC	MUST BE DONE CORRECTLY AND WITH EXISTING WILDLIFE / HABITATS REGULATIONS – FELLING LICENCE ALSO A REQUIREMENT
4	DRIVER AWARENESS	IMPLEMENT A DRIVER AWARENESS CAMPAIGN – LOCAL / NATIONAL MEDIA & OTHER APPROPRIATE PLATFORMS	EFFECTIVE ONLY IF IN CONJUNCTION WITH OTHER MITIGATION MEASURES	DRIVER HABITUATION OVER TIME
5	REDUCTION OF DEER DENSITY	AGREE A PLAN WITH LOCAL LANDOWNERS TO REDUCE DEER DENSITY IN THE IMMEDIATE VICINITY OF THE N77 AND SURROUNDING AREA	MUST BE COLLABORATIVE & WELL-PLANNED EFFORT = HIGH DEGREE OF SUCCESS	NO COLLABORATION = FAILURE TO ADEQUATELY REDUCE DEER DENSITY – LIKELY TO ESCALATE THE PROBLEM

RANK (in order of priority)	MITIGATION MEASURE	ACTIONS	POTENTIAL ADVANTAGES	DISADVANTAGES
6	RUMBLE STRIPS / SPEED RAMPS	FORCED REDUCTION IN SPEED	RELATIVELY EASY TO INSTALL ON EXISTING ROADS	MAY DISRUPT TRAFFIC FLOW
7	LEAD-IN FENCING TO DEDICATED CROSSING POINTS	PLAN FENCING TO LEAD-IN TO DEDICATED CROSSING POINTS. CREATE DEER CROSSING ON ROAD SURFACE AND REDUCED SPEED ZONE WITH RAMPS. INSTALLATION OF DEER GRIDS TO PREVENT DEER ACCESSING CARRIAGEWAY. INSTALL APPROPRIATE SIGNAGE / LIGHTING	HIGHLY EFFECTIVE IF ALL MEASURES ARE IN PLACE FENCE MAINTENANCE CRITICAL	VERY HIGH COST UNLIKELY TO BE APPROPRIATE FOR THE FREQUENCY OF DVCs
8	CONSTRUCTION OF DEER CROSS-WALKS	CONSTRUCT DEDICATED CROSSING POINT ACROSS CARRIAGEWAY ACCOMPANIED BY DEER GRIDS, SPEED CONTROL, SIGNAGE AND OTHER NECESSARY MITIGATION	HIGHLY EFFECTIVE IF PLANNED AND CONSTRUCTED CORRECTLY	HIGH COST & DISRUPTIVE TO TRAFFIC FLOW DURING AND AFTER CONSTRUCTION. UNLIKELY TO BE APPROPRIATE FOR THE FREQUENCY OF DVCs
9	TOTAL FENCING	PLAN POTENTIAL FENCE LINE ON BOTH SIDES OF THE CARRIAGEWAY – ROUTE WILL HAVE TO EXCLUDE PRIVATE PROPERTY TO BE 100% EFFECTIVE	HIGHLY EFFECTIVE BUT AT VERY HIGH COST – IF NOT MAINTAINED AT 100%, FENCE BECOMES TOTALLY INEFFECTIVE	VERY HIGH COST HIGH MAINTENANCE DEER GRIDS, GATES PRIVATE PROPERTY CONCERNS, ACCESS

				POTENTIAL TO EXCLUDE OTHER WILDLIFE END RUNS ESCAPE ROUTES MAY BE INAPPROPRIATE FOR THE FREQUENCY OF DVCs
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**WP3.3o - DEER DENSITY (km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -
RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)**

13.2 DETAILS OF PROPOSED MITIGATION MEASURES – (Ranked in order of priority)

1. SPEED LIMITS

Reducing overall vehicle speed can help reduce both the likelihood and severity of DVCs occurring. A reduction in overall speed along the 3.0km section of the N77 is suggested from 100km/h to 80km/h. In addition increased presence of mobile speed vans and for the installation of speed cameras, is likely to have a significant effect on the reduction of overall vehicle speed and have a major effect on modifying driver behaviour on this section of road. This measure should have a positive effect in a relatively short time space.

2. IMPROVED ROAD SIGNAGE

Static road signage in its own tends to be ignored by most drivers, unless they have had a negative experience that causes them to be more cautious around particular warning signs. Therefore to have maximum effect, warning signs should be deployed at times and at locations where they can be most effective. For example, because of the seasonal nature of deer movement and road crossings, signs should be positioned and switched on at known times and seasons of high risk (e.g. autumn and spring / dusk and dawn). The static digital sign at the southern end of the N77 needs to re-positioned 50 – 60m south of its' current position to give drivers enough time to react to the warning.

New dynamic crossing sign and sensor systems have been developed that use infra-red light beam on both sides of the roadway to detect animal movement. These alert the driver through flashing lights, when an animal has been detected and when sensors are activated, a battery operated transmitter turns on amber warning lights on top of traditional deer crossing signs. (See www.dot.state.mn.us)

3. CUTTING OF ROADSIDE VEGETATION

Cutting roadside vegetation, particularly in locations where vegetation is close to the road verge, should be carried in the autumn or winter and all necessary legislative requirements should be adhered to (Wildlife Acts, Habitats Regulations, Forestry Act) prior to works beginning. Trees and heavy vegetative cover (bushes, bracken etc) should be cut back to a distance of at least 15 metres from the road verge. Low lying vegetation such as grasses should be maintained by cutting throughout the year to avoid increased usage of deer at road verges. In some cases, for example in the US, boulder fields or hardstanding were used along road verges as a deterrent to deer usage. With regard to the N77, the focus should be initially on sections where deer crossings are most frequent, whereas there are other sections where cutting of vegetation may not be necessary or at least limited.

4. DRIVER AWARENESS

A campaign to increase driver awareness of the dangers of DVCs should form part of the overall strategy to help reduce occurrence. Local or National media (radio or television), including other appropriate platforms should be considered as avenues to get the message out regarding the dangers of deer on roads and these should be particularly targeted at specific times of the year.

5. REDUCTION OF DEER DENSITY

In areas where there is available data on local deer densities and where these are found to be too high, a collaborative approach to managing over-abundant deer populations should be undertaken. In some cases short-term strategies aimed at initial sharp reductions in density can be contemplated, but this must be considered in the overall context of the potential effects of modifying movement or dispersal and the consequent potential increase in DVCs. Deer control programmes can be highly effective but it is essential that they are carried out correctly with the appropriate level of planning. Failure to properly plan and execute deer control programmes, almost always lead to an escalation of the problem rather than a resolution.

In some exceptional cases, the lethal control of deer on roads can be carried out by highly trained professional sharpshooters operating within specifically designated safety zones, but legislative constraints and public acceptance make this option challenging.

The deployment of the above mitigation measures in combination should see a positive response in the reduction of DVC occurrence, but some measures are likely to take effect over a more protracted time period, whereas others are likely to be effective almost immediately. For example, an aggressive reduction in deer density, even if acted upon immediately will probably take up to 12 months before the true effect will begin to become noticeable. Actions involving the control or manipulation of wildlife are notoriously unpredictable for a host of reasons, but these can often be offset by judicious planning, knowledge of deer behaviour and adroit execution of the physical aspects of mitigation measures.

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SECTION 15: APPENDICES

APPENDIX 1 - Overview of approaches to deer collision mitigation and their advantages and disadvantages in different contexts (after Langbein *et al.* 2011).

MITIGATION MEASURES	SUITABLE SITUATIONS AND SUPPORTING MEASURES	POTENTIAL EFFECTIVENESS / ADVANTAGES	DISADVANTAGES
FENCING	Major high risk roads of high traffic flow; most effective when leads to safer crossing points and contains escape ramps / leaps	Well proven effectiveness where of appropriate mesh size and height and sufficient length to prevent 'end runs' [1,2,3,4,5]	High erection and maintenance costs; barrier effect also to other wildlife [6]
OVERPASSES / GREEN BRIDGES	Major high risk roads; most effective with lead-in fencing and natural ground cover	Well proven effectiveness; ungulate usage increases with width; smaller structures can also help alleviate wildlife collisions [7,8,9]	High cost; feasibility dependent on landscape. More readily installed on new-build than for existing roads. [8]
UNDERPASSES / VIADUCTS	Major high risk roads; most effective with lead-in fencing and natural ground cover	Good - where of adequate specification. Mostly lower costs than overpasses of similar size. [7,9,10]	High cost; feasibility dependent on landscape. Often longer delay before used by ungulates than in case of overpasses. [7,9]
HIGHWAY CROSSWALKS	Low to medium speed routes; needs to be supported by fencing, signage, speed restriction and ideally deer-grids.	Good - if well signed. [11]	Not likely to be acceptable on major routes where traffic must be kept flowing
OPTICAL WILDLIFE WARNINGS	Roads of low traffic volume providing some traffic free periods. Vegetation around reflectors needs to be kept clear	Limited convincing evidence of success. Relatively low cost; do not prevent normal range use. [12,13]	Rapid habituation where lit up by frequent traffic. Can at best only function during night. Many trials indicate ineffective. [14,15,16,17,18]
ACOUSTIC WILDLIFE WARNING	Roads of low traffic volume, where habituation least likely & providing safe crossing periods	Variable evidence. Lasting effects likely to depend on type and variability of signals. [19,20]	General effectiveness remains unproven. Limited potential on roads of higher traffic volume. Much higher (x10) cost than optical reflectors. [17,21]
CHEMICAL OLFATORY DETERRENTS	Roads of moderate to low traffic flow	Limited convincing evidence of success. Most intent to raise level of alertness; rather than prevent animals crossing. [22]	Limited independent evidence of effectiveness. Requires renewal at regular intervals. Likely habituation. [17,19,23,24]
VEHICLE MOUNTED ULTRASOUND WHISTLES / ELECTRONIC HORNS		Limited effectiveness. Some types very cheap to install. [25]	No convincing evidence of effectiveness. Requires renewal at regular intervals. Likely habituation [17,19,23,24]
STANDARD WILDLIFE WARNING SIGNS	Any road type, but should be targeted to forewarn of short, well-defined sections of risk	Can help to absolve legal responsibility of road authorities or population managers. Moderate cost	Over-abundance of wildlife and other signage leading to reduced effect on driver behaviour. Low effectiveness (if any) at reducing collisions. [29,30,31]
INTERACTIVE SPEED-ACTIVATED SIGNAGE	Any road type, but should be targeted to forewarn of short, well-defined sections of risk	Some potential, but yet unproven for DVC reduction. Increased driver perception. [32,33]	Driver habituation over time, if not reinforced by seeing animals near crossing the point and as digital signage becomes more common [34,35]
INTERACTIVE WILDLIFE ACTIVATED SIGNAGE	Major well-defined animal crossing points on roads of moderate traffic flow	Promising effects on driver awareness and local speed reduction. [36,37,38]	High cost compared to standard or speed activated signage. Variable reliability of differing sensor types

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77-
RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

APPENDIX 3 – FAECAL STANDING CROP FIELD DATA

RED DEER DENSITY IN ZONE 1 – SUMMER
2021

ZONE	S	P	TS/ID	GRID REF.	2	4	6	80	ΣPG	Area	HT
					0	0	0			ha.	
1	R		ZI/03	S	0	1	0	0	1	135	HH
1	R		ZI/06	S	0	0	1	0	1	135	HH
1	R		ZI/09	S	1	0	1	0	2	135	HH
1	R		ZI/12	S	0	0	0	0	0	135	HH
1	R		ZI/14	S	0	0	0	1	1	135	HH
1	R		ZI/15	S	0	0	0	1	1	135	HH
1	R		ZI/17	S	2	1	1	1	5	135	HH (E)
1	R		ZI/07	S	1	0	2	1	4	135	HH (E)
1	R		ZI/04	S	2	1	2	1	6	135	HH (E)
1	R		ZI/02	S	2	0	1	1	4	135	HH (E)
1	R		10		8	3	8	6	25	135	

ZONE	S	P	TS/ID	GRID REF.	2	4	6	80	ΣPG	Area	HT
					0	0	0			ha.	
1	R		ZI/10	S	1	0	0	0	1	112	WD4
1	R		ZI/11	S	0	1	0	0	1	112	WD4
1	R		ZI/16	S	1	2	1	2	6	112	WD4
1	R		ZI/13	S	2	0	1	2	5	112	WD4 (E)
	R				4	3	2	4	13	112	

ZONE	S	P	TS/ID	GRID REF.	2	4	6	80	ΣPG	Area	HT
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				P	0	0	0	ha.		
1	R	ZI/08	S	0	0	0	0	0	112	WD2
1	R	ZI/05	S	0	0	0	0	0	112	WD2
1	R	ZI/01	S	0	0	0	0	0	112	WD2
1	R	ZI/19	S	2	3	1	2	8	112	WD2
1	R	ZI/18	S	2	2	3	2	9	112	WD2 (E)
R				4	5	4	4	17		

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -
RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

**FALLOW DEER DENSITY IN ZONE 1 - SUMMER
2021**

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT	
1	F	ZI/03	S	1	0	1	1	3	135	HH	
1	F	ZI/06	S	0	1	1	1	3	135	HH	
1	F	ZI/09	S	1	1	0	0	2	135	HH	
1	F	ZI/12	S	1	0	0	0	1	135	HH	
1	F	ZI/14	S	0	0	0	0	0	135	HH	
1	F	ZI/15	S	1	0	0	0	1	135	HH	
1	F	ZI/17	S	2	2	2	3	9	135	HH (E)	
1	F	ZI/07	S	1	3	2	2	8	135	HH (E)	
1	F	ZI/04	S	2	0	2	2	6	135	HH (E)	
1	F	ZI/02	S	1	0	1	0	2	135	HH (E)	
1	F	10		1	0	7	9	9	35	135	HH

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT
1	F	ZI/10	S	1	0	0	0	1	112	WD4
1	F	ZI/11	S	1	0	1	1	3	112	WD4
1	F	ZI/16	S	3	2	0	4	9	112	WD4
1	F	ZI/13	S	3	3	0	3	9	112	WD4 (E)
1	F	4		8	5	1	8	22	112	WD4

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT
1	F	ZI/08	S	0	0	0	1	1	112	WD2
1	F	ZI/05	S	1	0	1	0	2	112	WD2

1	F	ZI/01	S	1	1	0	1	3	112	WD2
1	F	ZI/19	S	1	1	1	1	4	112	WD2
1	F	ZI/18	S	2	1	2	3	8	112	WD2 (E)
1	F	5		5	3	4	6	18	112	WD2

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -
RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

**RED DEER DENSITY IN ZONE 2 - SUMMER
2021**

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT
2	R	Z2/01	S41818193	0	0	0	0	0	170	WD2/4
2	R	Z2/02	S42108134	0	0	0	0	0	170	WD2/4
2	R	Z2/03	S42148092	0	0	0	0	0	170	WD2/4
2	R	Z2/04	S42948106	0	1	0	0	1	170	WD2/4
2	R	Z2/05	S42958177	0	0	2	0	2	170	WD2/4
2	R	Z2/06	S42428248	0	0	0	0	0	170	(E)
2	R	Z2/07	S42998299	0	0	0	0	0	170	WD2/4
2	R	Z2/08	S42888286	0	0	0	1	1	170	WD2/4
2	R	Z2/09	S42908358	0	0	0	0	0	170	WD2/4
2	R	Z2/10	S42958399	0	0	0	0	0	170	WD2/4
2	R	Z2/11	S42528398	0	0	0	0	0	170	WD2/4
2	R	Z2/12	S42468368	0	0	0	0	0	170	(E)
2	R	Z2/13	S42268339	0	0	0	0	0	170	WD2/4
2	R	13		0	1	2	1	4	170	WD2/4

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT
2	R	Z2/14	S43128436	0	0	0	0	0	67	WS
2	R	Z2/15	S43008398	0	0	0	0	0	67	WS
2	R	Z2/16	S43488390	0	0	0	0	0	67	WS
2	R	Z2/17	S43308367	0	0	0	0	0	67	WS
2	R	Z2/18	S43118212	0	0	0	0	0	67	WS (E)
2	R	5		0	0	0	0	0	67	WS

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80 0	∑PG	Area ha.	HT
2	R	Z2/19	S41558307	0	0	0	0	0	52	WN
2	R	Z2/20	S41668258	0	0	0	0	0	52	WN
2	R	Z2/21	S41698215	0	0	0	0	0	52	WN
2	R	Z2/22	S41918247	0	0	0	0	0	52	WN
2	R	4		0	0	0	0	0	52	WN

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -
RECOMMENDATIONS FOR MITIGATION MEASURES TO REDUCE DEER VEHICLE COLLISIONS (DVC)

**FALLOW DEER DENSITY IN ZONE 2 - SUMMER
2021**

ZONE	S P	TS/ID	GRID REF.	20	40	60	80	∑PG	Area ha.	HT
2	F	Z2/01	S41818193	4	6	6	4	20	170	WD2/4
2	F	Z2/02	S42108134	4	5	4	4	17	170	WD2/4
2	F	Z2/03	S42148092	6	7	8	5	26	170	WD2/4
2	F	Z2/04	S42948106	3	6	4	3	16	170	WD2/4
2	F	Z2/05	S42958177	4	8	9	3	24	170	WD2/4
2	F	Z2/06	S42428248	5	2	4	6	17	170	WD2/4 (E)
2	F	Z2/07	S42998299	3	4	3	6	16	170	WD2/4
2	F	Z2/08	S42888286	2	6	8	9	25	170	WD2/4
2	F	Z2/09	S42908358	8	10	12	5	35	170	WD2/4
2	F	Z2/10	S42958399	6	4	3	4	17	170	WD2/4
2	F	Z2/11	S42528398	4	3	2	6	15	170	WD2/4
2	F	Z2/12	S42468368	6	4	4	4	18	170	WD2/4 (E)
2	F	Z2/13	S42268339	4	8	8	2	22	170	WD2/4
2	F	13		5	7	7		268	170	WN

ZONE	S P	TS/ID	GRID REF.	20	40	60	80	∑PG	Area ha.	HT
2	F	Z2/14	S43128436	4	4	6	7	21	67	WS
2	F	Z2/15	S43008398	3	3	4	8	18	67	WS
2	F	Z2/16	S43488390	2	5	5	9	21	67	WS
2	F	Z2/17	S43308367	5	6	8	7	26	67	WS
2	F	Z2/18	S43118212	3	2	2	3	10	67	WS (E)
2	F	5		1	2	2		96	67	WS

ZONE	S P	TS/ID	GRID REF.	20	40	60	80	ΣPG	Area ha.	HT
2	F	Z2/19	S41558307	5	6	6	11	28	52	WN
2	F	Z2/20	S41668258	8	9	8	8	33	52	WN
2	F	Z2/21	S41698215	7	6	5	8	26	52	WN
2	F	Z2/22	S41918247	5	7	10	9	31	52	WN
2	F	4		2 5	2 8	2 9	36	118	52	WN

WP3.3o - DEER DENSITY(km²), DISTRIBUTION AND MOVEMENT PATTERNS IN THE VICINITY OF THE N77 -
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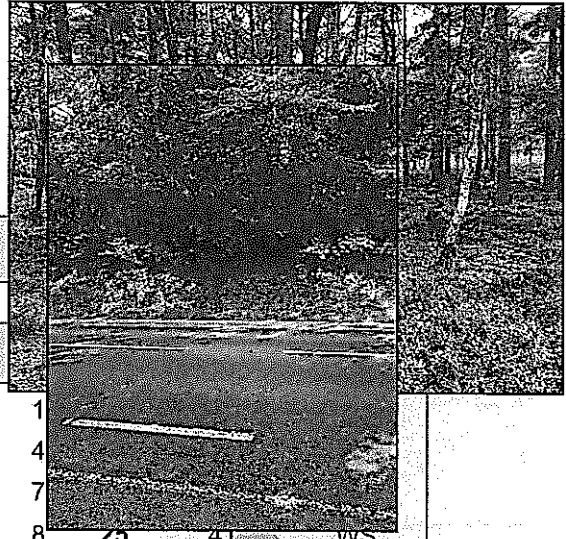
**RED DEER DENSITY IN ZONE 3 - SUMMER
2021**

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT
3	R	Z3/01	S40948368	0	0	0	0	0	105	WD4
3	R	Z3/02	S41198302	0	1	1	0	2	105	WD4
3	R	Z3/03	S40348308	0	0	2	0	2	105	WD4
3	R	Z3/04	S40628298	0	1	2	0	3	105	WD4 (E)
3	R	Z3/05	S40838231	1	0	1	0	2	105	WD2
3	R	Z3/06	S40998209	0	0	2	0	2	105	WD2
3	R	Z3/07	S41798199	1	0	0	0	1	105	WD2 (E)
3	R	Z3/08	S41298308	0	0	1	0	1	105	WD2
3	R	8		2	2	9	0	13	105	WD2/4

ZONE	S P	TS/ID	GRID REF.	2 0	4 0	6 0	80	ΣPG	Area ha.	HT
3	R	Z3/09	S41408351	0	1	1	0	2	7	WS5
3	R	Z3/10	S40358282	0	1	0	1	2	41	WS (E)
3	R	Z3/11	S41238218	1	0	2	0	3	41	WS
3	R	Z3/12	S40628227	0	0	0	0	0	41	WS
3	R	4		1	2	3	1	7	41	WS

**FALLOW DEER DENSITY IN ZONE 3 - SUMMER
2021**

ZONE	S P	TS/ID	GRID REF.	20	40	60	80	ΣPG	Area ha.	HT
3	F	Z3/01	S40948368	1	3	3	3	10	105	WD4
3	F	Z3/02	S41198302	2	2	3	3	10	105	WD4
3	F	Z3/03	S40348308	1	2	4	6	13	105	WD4
3	F	Z3/04	S40628298	4	4	6	3	17	105	WD4 (E)



3

3

2

4

2

8

60

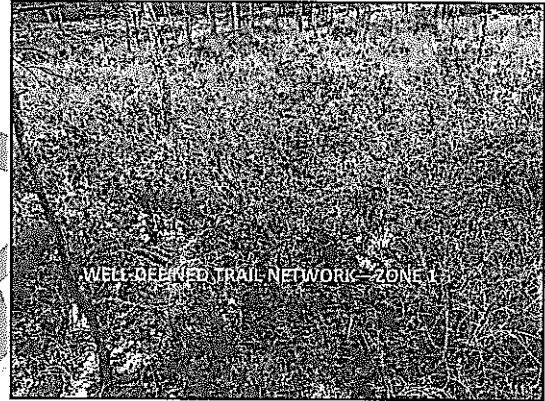
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3	F	Z3/10	S40358282	7	6	5	4			
3	F	Z3/11	S41238218	6	5	5	7			
3	F	Z3/12	S40628227	5	4	8	8			
3	F	4		1	1	2		20	76	41 WS

ZONE 1 - REDDEER BOG (HW)

ZONE 1 - MIXED WOODLAND (WS/A)



ZONE 1 - RED DEER CALF



WELL-DEVELOPED TRAIL NETWORK - ZONE 1

MIXED WOODLAND (WS/A) - ZONE 3

OAK WOODLAND (WS) - ZONE 2





TRAIL NETWORK SCRUB WOODLAND WS - ZONE 1
TRAIL NETWORK MIXED WOODM AND WOODS -
ZONE 2

DEER TRAIL AT EDGE

DEER TRAIL

