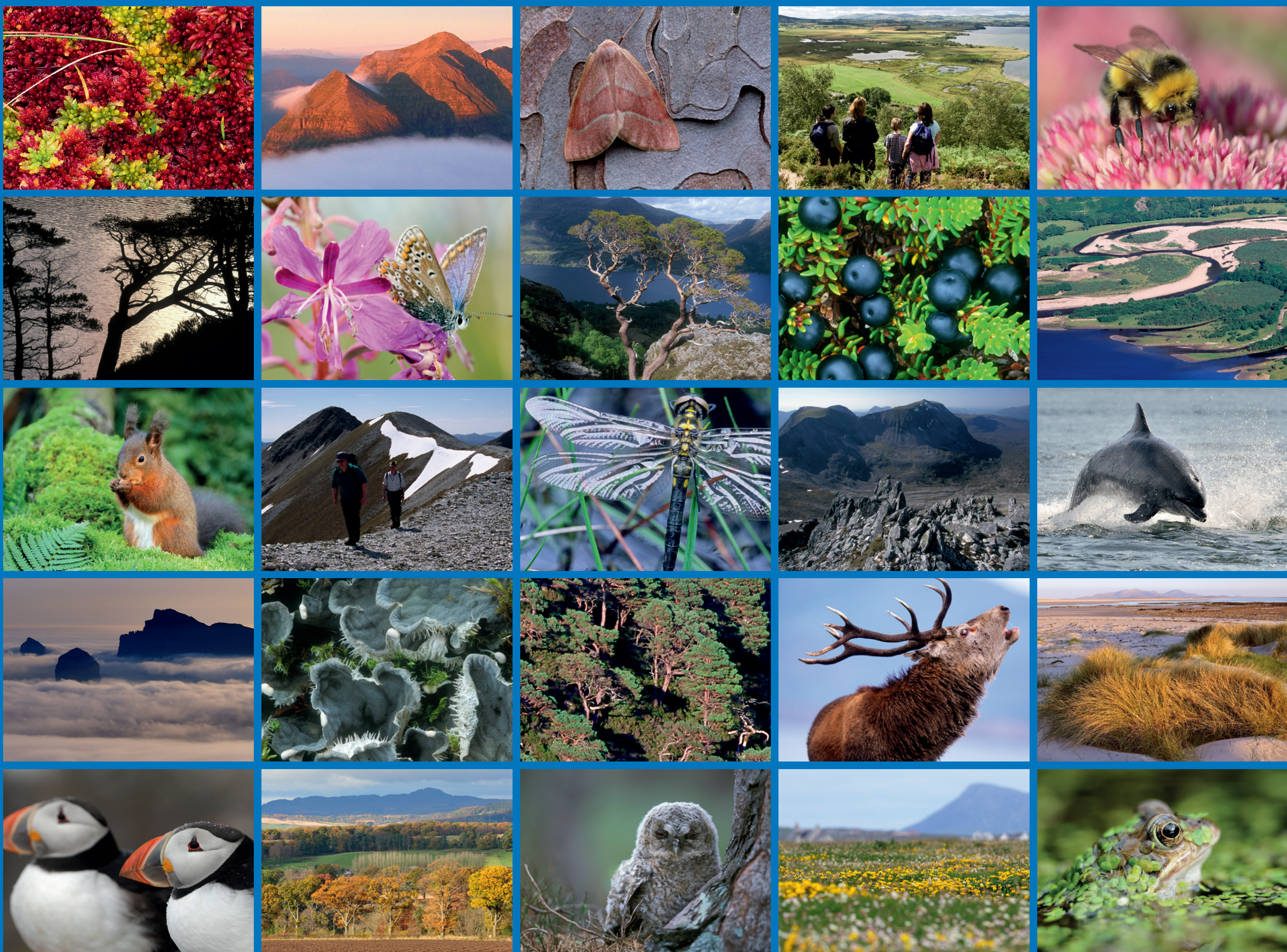
Scottish Natural Heritage
Research Report No. 1158

Deer-Vehicle Collision (DVC) data collection and analysis 2016 - 2018



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RESEARCH REPORT

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Deer-Vehicle Collision (DVC) data collection and analysis 2016 - 2018

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RESEARCH REPORT

Summary

Deer-Vehicle Collision (DVC) data collection and analysis 2016 - 2018

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Background

During the past five decades wild deer in Scotland have increased in range and numbers. Over the same period total annual volumes of road traffic have more than doubled, combining to make deer-vehicle collisions (DVCs) an increasingly common occurrence throughout the country. Following an initial assessment from 2003 to 2005, the Deer Commission for Scotland (now incorporated within Scottish Natural Heritage (SNH)) has since 2008 commissioned a number of consecutive projects to monitor trends and changes in the distribution of DVCs based on a more streamlined data collection regime. This report presents findings from the latest three-year data collection project for January 2016 to December 2018, and makes comparisons with results from earlier years. The prime purpose of the work is to provide further information to SNH, Transport Scotland, Trunk Road Operating Companies, local authorities and deer managers on the level of reported DVCs in different parts of the country and to help with prioritising the allocation of resources and action to reduce risk to public safety and safeguard deer welfare.

The term deer-vehicle collision (DVC) is used throughout the report to describe any incident where it may be concluded that a collision of a road vehicle with a deer occurred; as evident either from live injured or dead deer casualties found at the roadside, or from reported road traffic collisions in which deer were implicated. It is important to note that, as there is no legal requirement for DVCs to be recorded or reported to any authority (except for accidents involving human injury), the numbers of records obtained represent merely an annual sample of all DVCs that actually occur.

Main findings

- During this latest 3-year continuation project of the SNH DVC data collection and collation project in excess of 5550 new DVC records for January 2016 to December 2018 have been accrued and mapped. This represents an increase of 20% on the volume of records added during the previous three-year period.
- The SNH DVC database now includes over 17,000 mapped incident records for the period 2008 to 2018 in a format suitable for upload to the SNH Natural Spaces website. Of these, more than 92% come from among our four most consistent source categories

(Scottish SPCA, Trunk Road Operating Companies, Forestry and Land Scotland wildlife rangers, and human injury DVCs attended by police), with smaller numbers from other sources including individual deer experts and submissions by the general public.

- The largest increase in annual numbers of reported DVCs since 2009 has been in records from the SSPCA. The greatest levels of increase are apparent in South Lanarkshire, Clackmannanshire, Falkirk, and East Renfrewshire. This may reflect the overall expansion in range of deer especially in the Scottish Lowlands and urban fringes over recent years, but overall generally increased levels of reporting of injured animals to SSPCA by members of the public is likely also to have contributed in most areas.
- Incidents reported by trunk road operating companies by contrast have fallen by close to 10% during 2017 and 2018 compared to the previous three years, despite data recording procedures appearing to have remained relatively consistent across companies and years. The divergent trends among data from our two largest data sources emphasise that the above trends need to be interpreted with caution.
- Re-assessment of seasonal and diurnal patterns of DVCs continues to show that on all road types the most prominent peak in DVCs across Scotland occurs during May and into early June; with the increase most pronounced on motorways followed by A-class dual carriageways and A-class single carriageway trunk roads. DVCs in general are most common in the period between 18:00 hrs through to midnight, with a second peak between 06:00 – 09:00 hrs.
- A key information gap in relation to DVCs continues to exist around human injury accidents in which deer are implicated. Extraction of information from a number of Police Scotland legacy force areas has not been possible. Introduction of a specific category to record ‘deer’ as a contributory factor on STATS19 road traffic accident forms, or else a text box to log the ‘animal type’ in such incidents would help greatly in assessing the true extent of accidents involving wild animals.
- Previous analysis of Scottish DVC data has not fully considered differences in traffic flows between roads. Consequently, DVC hotspots have been identified purely on numbers of reported DVCs and tend to indicate the relative level of risk to deer, rather than the risk of a DVC per driver or driven mile. As part of this contract, DVC risk maps have been prepared based on trunk road DVC data for 2008 to 2016 but taking into account differences in annual average daily traffic flow. This has enabled calculation of a risk index for different road segments. The risk index maps, together with maps based purely on rates of DVC per kilometre, enable identification of areas of greatest risk to drivers, as well as providing an objective baseline for assessing future changes.
- Estimating the total number of DVCs across Scotland was not a specific project objective, as the sampling regime and records obtained are not well-suited to such extrapolation. However, based on the sample data accrued it is suggested that there are at least 4000 deer-vehicle collisions each year in Scotland, with the true total likely to be closer to 12,000.

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1. INTRODUCTION

In Scotland, as in the rest of the UK and many other European countries, the number and distribution of wild deer has increased significantly over recent decades. Whilst all deer species found in Scotland have expanded their range to some extent over the past thirty years, roe deer in particular have become well established throughout Lowland Scotland, including in the urban fringe of many major towns. They have spread also into parks and other green spaces close to the centre of cities such Glasgow, Aberdeen and Edinburgh (e.g. see Dandy *et al* 2009; SNH 2019). Continuing expansion of deer ranges has concurred with a period of renewed growth in Scottish road traffic, which by 2017 was 7% higher than at beginning of this project in 2008. Together, this has led to deer-vehicle collisions becoming even more common.

Deer-vehicle collisions, hereafter referred to as DVCs, is a broad term used in this report to describe any incidents where it may be concluded that a collision between a *road* vehicle and a deer has occurred; as evident either from live injured or dead deer casualties found at the roadside, or from reported road traffic collisions in which deer were implicated as an object or hazard in the carriageway (e.g. deer colliding with road vehicle, or deer presence causing drivers to swerve).

1.1 Past DVC assessments

Following an earlier investigation [funded via the Scottish Executive] to gather and collate available records of DVCs for 2003 to 2005 from a very wide range of potential sources (Langbein and Putman, 2006), from 2008 onwards the Deer Commission for Scotland (now incorporated within Scottish Natural Heritage (SNH)) commissioned a number of subsequent studies to update and monitor trends and changes in distribution of DVCs based on a more streamlined data collection regime. Between 2008 and 2012 this research was commissioned by SNH via the Deer Initiative Ltd., with the majority of the work subcontracted to Langbein Wildlife Associates (LWA). Thereafter, through to 2018, LWA have been commissioned directly by SNH. Findings based on data collection to end 2010, 2012 and to end 2015 are reported in Langbein 2011, 2013 and 2017 respectively.

1.2 Continuation project 2016 – 2018

1.2.1 Purpose

In 2016 SNH commissioned LWA to source and collate further data on numbers and distribution of DVCs for the period January 2016 to December 2018. The prime purpose is to provide further information to SNH, Transport Scotland (TS), Trunk Road Operating Companies (TROCs), Local Authorities (LA) and local deer managers to help with prioritising the allocation of resources and action to reduce risks to public safety and safeguard deer welfare.

1.2.2 Terms of Reference

Data collection and collation should encompass:

- Use of contacts established in previous projects to collect data on DVCs in Scotland, specifically, Trunk Road Operating Companies (TROCs), SSPCA, Forestry Commission and Police or Council Road safety teams STATS19 (personal human injury road accident) reports.
- Collection of additional data via the *Deer_Aware* web reporting form from a variety of known individuals with good knowledge of deer as well as the wider general public.
- Retain where available from TROCs also information on road kill records for large or medium size animals other than deer for context and for wider use by SNH.

- Collation and cleansing of the data received; checking grid references as accurately as is practical, in a format compatible with previous data for upload on SNH GIS system.
- Ad hoc provision of data extraction and analysis on an ad-hoc basis where enquires or concerns about DVCs for localised road sections are raised.

Main outputs:

- GIS format DVC data updated annually each spring for upload to SNH Natural Spaces web site.
- Provision of an annual interim report, providing basic analysis of this data for TROCs and council areas.
- A set of OS grid based maps (two for each Local Authority or City Council boundary) showing DVC hotspots and distribution in each LA for the most recent four or five years and comparison with data for the earlier years of the project.
- Over and above grid-based mapping based purely on relative numbers of reports by area, develop an approach to relative 'DVC Risk Mapping' of the Scottish trunk road network, that takes into account differences in average annual daily traffic as well as numbers of DVC reports per kilometre.
- Evaluation of habitat type in relation to identified low / medium / high risk trunk road sections
- Scope additional countrywide sources able to provide samples of DVCs for which reliable information on the deer species involved is included.

1.2.3 Final contract report

Following preparation of annual interim reports in line with the above, in this end of contract report, data from the most recent five years (2014 to 2018) are reviewed, primarily through comparison with data for the previous five years (2009 to 2013) collected in a directly comparable fashion. The data collection regime in 2008 was also the same as complete geographically coverage was not achieved that year. Evidence for broad trends in the scale and distribution of DVCs over the past decade is investigated and mapped for different regions of the trunk road network and in relation to Council administrative boundaries.

During this latest 3-year continuation of the DVC monitoring project 6070 new records for the period January 2016 to December 2018 were collated. Of these, 5577 had adequate location details; enabling at least approximate allocation of map references, to add them to the main DVC mappable database for further analysis. This represents an increase in usable records of 19% compared to the 2013 – 2015 period, and up 32% compared to 2010 to 2012.

It is important to note, however, that there is no obligation on the public to report nor for organisations to record DVCs, other than when involved in a road traffic collision that led to a human injury. Thus the number of DVC reports obtained by this project are merely an annual sample of all DVCs that actually occur. Nevertheless, as data collection has now used a closely comparable sampling regime throughout the past 11 years, the information gathered does provide broadly consistent indicators of the scale and relative distribution of DVC occurrences across Scotland over this period and allows identification of areas of highest or increasing incidence within different regions.

Recommendations are made on how monitoring could be refined and adapted to ensure continued consistency in future years, and suggestions for more in-depth future analysis, currently outside the scope of the present contract are presented. Perhaps more importantly, ideas as to how the now extensive information on DVCs could be used in identifying priority areas for practical action to reduce the annual toll of deer casualties and risk to public safety through DVCs on Scotland's roads are discussed.

2. DATA COLLECTION REGIME AND PROCESSING

Previous studies in Scotland showed that recording even the majority of DVC incidents would not be likely to be achievable without a very substantial annual input of resources (Langbein & Putman, 2006). As with the DVC data collection and collation projects that were undertaken on behalf of SNH from 2008 onwards, the primary focus of this contract has again been to continue collection of records focussed on the same four principle data types that together form the 'core sources' for our sampling regime (see 2.1).

Data from a number of supplementary data source types (see 2.2), which after 2007 were no longer requested or obtained consistently (mainly as they could not provide comparable widespread coverage across all of mainland Scotland), have nevertheless still been collected and collated on a more ad hoc basis, where they were thought valuable as separate data sets to help inform particular questions not well covered by data from the core sources alone.

2.1 Core data sources

2.1.1 Trunk Road Operating Companies

The records provided by TROCs of incidents involving injured deer or requests to clear deer carcasses from the road or verges provide the largest accessible source of information on DVCs on the Scottish trunk road network. Data gathering here encompasses requests for relevant information from each of the four major TROCs which manage the NW, NE, SW and SE trunk units on behalf of Transport Scotland, as well as from all additional Design-Build–Finance-Operate (DBFO) companies (currently six) that maintain smaller distinct sections. Together these sources provide comparable coverage of DVC data sampling across the entire Scottish trunk road network, made up of motorways and major strategic A-class routes. An up to date map showing the full extent of the Scottish trunk network and breakdown into the various TROC and DBFO sections referred to in this report is shown in Figure 1.

Either annually or six-monthly a request is made to each of the operating companies asking them to provide records of all deer road casualty or related collision incidents logged by them. A standard template of 'ideal' data submissions is provided with these requests. Although not yet taken up in all cases, this helps to standardise the inputs received; including as a minimum: the date, road number and location of any live or dead deer road casualty Ideally, the location should be determined at source using OS grid easting and northing, or else giving Marker Post numbers or landmarks than can be used by us to allocate approximate map references. Additional details about the incident or information on the deer species involved are also requested.

Figure 1. Scottish Trunk Road Map as at February 2019. (Map courtesy [Transport Scotland website] where a more detailed network map including fuller road number detail is available).

2.1.2 Scottish Society for the Prevention of Cruelty to Animals

The Scottish Society for the Prevention of Cruelty to Animals (SSPCA) is the main organisation that tends to be called upon by the public or police in incidents involving live injured or suffering deer including deer road casualties. Other smaller animal welfare organisations, wildlife rangers or individual deer managers also deal with requests to attend to deer casualties, but records from them are much more difficult to obtain in a systematic manner. Annual information from the SSPCA, on the other hand, provides a geographically wide spread and comparable data set across years, encompassing deer road casualties on any part of the Scottish road network, including unclassified minor as well as local and major roads. The great majority (> 80%) of SSPCA DVC records relate to those incidents where deer have been injured but not killed outright and where attendance is requested on welfare grounds. The SSPCA do not in general attend to animal road casualties that are already dead, and hence only a small proportion of their records relate to calls about dead deer, though these are of interest for the project when available.

The deer incident data received from the SSPCA for the most recent years included as many reports about non-road related incidents (e.g. dog attacks, fence entanglements, alleged ‘abandoned’ fawns etc.) as road related ones. Only individual incident logs that mention RTA or refer to being hit by a vehicle, injured deer by roadside, or other word strings indicative of incidents that are highly likely to have resulted from a DVC have then been extracted and retained by us for the DVC database. Note – in view of new regulations arising from the Data Protection Act 2018, data received for the latest year has been of a more restrictive nature, reducing the number of DVC records which were not already inputted at source for that year; see also Section 3.1.1.

2.1.3 Forestry and Land Scotland Wildlife Rangers

In parts of Scotland where there are substantial areas of the National Forest Estate managed by Forestry and Land Scotland (FLS), FLS’s wildlife rangers will often be contacted when a deer is injured on a road running close to their land. DVC casualties attended by the rangers tend to be logged under ‘RTA’(Road Traffic Accident) or ‘RTC’ (Road Traffic Collision) in their national cull database. These records provide only a comparatively small and geographically more restricted annual data set than the SSPCA’s. However, they have been retained as a regular annual data source for the project because

i. they help to supplement SSPCA records for more remote areas, where FLS rangers rather than the SSPCA may be the most common local organisation called on by police or public to attend to live deer road casualties, and
ii. they currently provide the most widespread sample of DVC reports with a high level of reliability as to correct identification of deer species involved.

2.1.4 Police and Road Safety Teams’ RTC records

Records of road traffic collisions attended by the police can potentially provide information on the most serious DVCs, i.e. those involving human personal injury accidents (PIA). Additionally, PIAs and also damage-only DVC incidents when attended by police are amongst the few data that reliably record information on the time-of-day of actual incidents (rather than of when a deer casualty is seen and reported) as well as other aspects such as accident severity. Information on any RTCs attended by the police and which mention deer (or stag) in the accident description has been sought annually, either directly from the eight former legacy forces (incorporated within Police Scotland from 2013), or else via Regional Council Road Safety teams that in some cases further process such accident data. However, as involvement of ‘deer’ is not a separate category in the ST19 police forms used for compilation of official human injury road accident statistics by the Department for Transport (DfT), these records have only been obtainable to date for around half of the eight legacy police force areas in most years. Nevertheless, gathering of these police data has continued to be attempted as far as possible, even though to date this still does not provide a complete countrywide coverage of such human injury DVCs.

2.2 Supplementary data sources

Although the four core source categories discussed above form the central part of the long-term monitoring of DVCs across Scotland (as commissioned by SNH since 2008) on average a further 200 or so records per data year have been accrued from various other sources. These include:

2.2.1 General public entries at online report form

On-line reporting by interested members of the public in earlier years was hosted on the deercollisons.co.uk website (that served also the parallel DVC project for England and Wales administered via the Deer Initiative). Since 2009 recording has been transferred to the Deeraware.com site. It provides a facility for members of the public to record DVCs they have seen or been involved with throughout the UK. However, overall input has never been extensive (with usually fewer than 50 records for Scotland submitted by the public per year). The level of such reporting tends also to be largely media dependant, with short peaks or increased localised reporting when seasonal deer-aware campaigns have taken place or DVCs have otherwise featured in the local or national media. As such they can provide additional information of interest but cannot readily be included in the core data sample used for analysis of temporal or geographic trends of DVC occurrence.

2.2.2 Individual 'Deer-knowledgeable' contributors

Scottish Natural Heritage's Wildlife Management Officers and a number of other private deer managers, stalkers or naturalists known to the project team have been encouraged also to submit records (via the above online report form) of any deer road casualties attended or seen while travelling. These additional records, whilst again not a systematic or regular source of data, are of value firstly to add to the overall volume of reports with reliable information on deer species by region, and secondly to offer a potential means of estimating the sampling intensity achieved by TROCs, on the basis of evaluating the proportion of reports recorded on trunk roads by these other contributors that are then also later reported within annual TROC data.

2.2.3 Local Authority road cleansing departments

From earlier DVC collection studies (Langbein & Putman, 2006) it was apparent that only a minority of Local Authority roads departments would be able to provide records of sufficient quality to be useable. In the majority of areas comparable and sufficiently detailed information to enable mapping of deer road casualty carcass uplifts (and consequently allow potential duplication with other sources to be identified) was not obtainable. It was therefore decided not to seek such information for the present project. Any such data provided via some LAs since 2008 has nevertheless been archived in case it becomes useful at a later point; for example, in the event of localised inquiries or the need for DVC risk assessments for specific routes.

2.3 Data quality and processing

In the case of DVC records obtained from TROCs, FLS and Road Safety teams the great majority (> 90%) tend to be provided either with Ordnance Survey grid references allocated at source or else with other details, such as a marker post or trunk road section reference. This enables allocation of map references to a reasonable level of accuracy (mostly better than to the nearest 1 or 2 kilometres, and often better than 100 metres).

SSPCA records tend to be more variable in the detail provided. Although a high proportion (c.60%) of those attributable to DVCs tend to give full postcodes of incident locations which enable ready conversion to map references. Around 25% require estimation of geographical locations based on only shorter 'postcode locale' information together with, at times, limited location details. A further 10 to 15% of SSPCA records have insufficient detail to allow allocation of map references to a reasonable degree of accuracy. Although retained and archived, these records are excluded from the main 'mappable' database on which further analyses and comparisons between areas are based.

Data from the other 'supplementary' sources have also been mapped as far as possible. However, for the majority of comparisons across years and between differing parts of Scotland, these other data are excluded, and drawn on only for assessment for specific issues; e.g. where they can add information on involvement of different deer species, or assessment of the sampling intensity achieved by the core sources.

For most purposes of basic analysis presented in this report, all mapped records for 2008 to 2018 were uploaded to a GIS, and then assessed foremost in relation to: a) the most recent (2017) version of the TS trunk network shapefile, b) OS grid squares overlays of variable sizes to provide an indication of hotspots, and c) the geographical boundaries of the 29 Scottish mainland unitary local authorities ("Councils"). Although some DVCs are also known to occur within the three Island Council authorities, only very few have tended to be captured since 2008 by our sampling regime. Consequently, results presented for the 2008 to 2018 project at present pertain largely to mainland Scotland (including Skye).

In addition, all the DVC records for the Scottish trunk road network accrued from 2009 to 2016 were used in additional analysis and modelling developed during the present contract. This work aimed to assess and map the relative risk of DVCs by different road sections of the network. For this purpose, each incident was allocated to one of the c.3900 different road sections into which the trunk road network is divided for administrative and management purposes by Transport Scotland; these sections average 1300 m in length, with fewer than 200 shorter than 100 metres. The frequency of DVCs for each section was then calculated and adjusted by length to derive rates per km. These were then further evaluated in relation to the reported 'annual average daily traffic' (AADT) for each section to derive a 'DVC risk' index score for each section. For further detail on data processing for DVC risk mapping see Section 4.

3. RESULTS

3.1 Change in volume and quality of data by source, type and years

Since its initiation in 2003, the project to collate and assess the scale and distribution of DVCs across Scotland has seen both the range of source organisations and individuals from whom data has been requested, and the volume and quality of the data obtained, vary considerably (Table 1).

Table 1. Number of DVC records with adequate location details for mapping retained for the main SNH DVC database and analysis during differing monitoring periods.

	DVC records retained for mapped database		
Period	**Core sources**	**All other sources**	**Total**
5yrs 2003 to 2007	2136	3702	5838
5yrs 2008 - 2012	5880	976	6856
5yrs 2013 - 2017	8083	339	8422
2018	1688	68	1756
Total	**17787**	**5085**	**22872**

During the years prior to 2008 just over a thousand records per year were being gathered. However, data at that time were biased towards over-representation of some localities or a few council areas for which useable records with dates and adequate location detail were available from council roads departments. In the initial 2003 to 2005 project, data collection was more intensive with more funding and resources available to the project. The collection and collation of data from numerous individuals, as well as a range of organisations increased the potential for duplication of records.

In 2008 a more streamlined data collection regime was introduced. This focussed on a smaller number of the most reliable and consistent data sources, which between them could nevertheless provide widespread sampling coverage throughout all mainland council regions. Since then the annual volume of data received has increased almost year on year. Among a total of over 17,000 DVC records mapped since 2008 over 15,500 have been provided from our “core data sources” (particularly the various Trunk Road Operating Companies and SSPCA, with smaller data sets from FLS rangers and the police or council Road Safety teams). Only around one to two hundred records each year have continued to be gathered from “all other sources” (including on-line submissions from known deer-knowledgeable individuals as well members of the general public). Though few in number, these records are valuable nonetheless for particular aspects of the project such as to augment other species-specific data, and to assist estimation of the likely levels of undercounting along specific routes if based on core source data alone.

The above figures exclude a few hundred further records obtained annually without or with only vague details on dates or locations, for which incorporation to the main database would increase risk of likely duplicate logging of incidents. Although unmapped records have been archived separately the vast majority of all data comparisons and analysis presented in this report are based on the mapped databased records as summarised in Table 1 above.

The breakdown by year of DVC records received from each of our different main source types is outlined in the sections below. It should be noted that generally it is best to consider data sets from the different source types separately, as for example our combined sample obtained from all TROCs is likely to represent a higher proportion of all DVCs that occur on trunk roads, than the samples we obtain for the remainder of Scottish (non-trunk) roads where our annual sampling is reliant to a very large extent on SSPCA records only and hence likely to capture a far lower proportion of incidents.

3.1.1 Core sources – Volume and trends across years

Despite our shift in 2008 to data collection from a more limited set of only the most consistent data sources, the number of DVC records has grown steadily. This increase has been achieved partly through a substantial improvement in the number, data quality and countrywide coverage of information obtained via the TROCs and the SSPCA.

Table 2. Number of DVC reports with sufficient detail for mapping obtained by year from among each of the four core data source categories and for all other sources combined. (Trunk road Operating Company TR_OC, Road Safety teams road traffic collisions RS_RTC, Scottish SPCA SSPCA, Deer Knowledgeable reporters – FLS Wildlife Rangers D-FC)

	Core Sources				**Total:**	
Year	**TR_OC**	**RS_RTC**	**SSPCA**	**D-FC**	**Core Sources**	**Total All Others**
2008	480	88	319	62	**949**	186
2009	652	75	291	101	**1119**	425
2010	717	64	349	68	**1198**	317
2011	593	72	419	104	**1188**	23
2012	745	74	666	84	**1569**	25
5-Yr Mean	637.4	74.6	408.8	83.8	1204.6	195.2
2013	638	81	698	73	**1490**	94
2014	674	47	475	76	**1272**	65
2015	660	30	883	62	**1635**	63
2016	672	24	1001	36	**1733**	64
2017	620	30	1255	48	**1953**	53
5-Yr Mean	652.8	42.4	862.4	59.0	1616.6	67.8
2018	530	nya	1102	56	**1688**	68
Grand Total	**6981**	**585**	**7458**	**770**	**15794**	**1383**

Table 2 provides a breakdown of records from among the four core source categories since more consistent monitoring in 2008. Overall records obtained from the core sources have almost doubled over the past ten years.

The greatest increases in data input have been seen among SSPCA records. Data from SSPCA have increased almost year on year ever since 2009, with just one exception (2014) before further large increase from 2015 onwards. The average annual number of SSPCA DVC reports for the 5-year period 2013 to 2017 doubled compared to the previous 5-year average. It is likely that better recording and the ability to extract from improved digital storage of call logs may have contributed to the large increases, especially post 2011 and 2015 onwards. A temporary fall in 2014 is attributable largely to a lower level of incident description provided in raw data received during a change over to a new call recording extraction system. This meant that it was not possible readily to identify all road traffic related deer incidents from among ‘all deer’ related call-out requests that year. Provision of more comprehensive detail from 2015 has enabled us to identify close to 1/3 of 2000 to 3000 deer related incident logs received from the SSPCA as being road casualty related; based on using various key word searches on incident descriptions (e.g. deer + hit + car etc..) rather than relying only on incidents already identified as RTC at source.

While it is clear that a major increase in DVC related call-outs to the SSPCA has occurred over recent years, the trends are liable to be affected to some extent by the manner of recording calls at the switchboard; and in particular whether deer killed outright in collisions (not requiring action by SSPCA; c.15% of all records) have always been included in past data. Only records that confirm a deer was highly likely to have been involved in a vehicle collision have been retained by us for the DVC database. Other records relating to reports of live uninjured deer at the roadside and calls about deer injuries relating to other causes (fences / dog attacks etc.) have been excluded. However, it is notable in the full raw data sets of all 'deer' related SSPCA incident calls provided to the project, that not only has the number of incidents attributable to DVCs increased, but so has the total of all reports relating to deer injured from other causes such as fence entrapment, dog attacks and reports by the public of 'abandoned fawns'. Together with DVC records this is likely to reflect the overall range expansion of deer populations, especially in the Scottish Lowlands and urban fringe over recent years.

In 2018, records from the SSPCA were lower than in 2017, but still the second highest annual number overall. This reduction in the final year is attributable mostly to a reduction in the detail of raw information passed on to the project due to data protection regulations; providing only records already identified as DVC- related at source. We are now unable to run key word searches as outlined above on other deer incident records, which in previous years generally contributed to about 10% of all the SSPCA DVC incidents identified.

The number of reports received from TROCs and FLS rangers also increased significantly from 2008 to 2009 but remained relatively stable until 2016. A temporary reduction in TROC records in one year (2013) is largely attributable to a break in recording by one trunk unit (South West) for spring of that year during change over in contracts between operating companies. Overall, total numbers of TROC reports have otherwise mostly remained between 650 to 700 casualty reports per year. A first indication of a small reduction was apparent in 2017, with a more significant drop to 530 noted in the latest complete data year (2018). This decrease is apparent for most of the TROCs. Possible reasons for this are explored further in section 3.3 where a breakdown of data by TROCs is presented.

In the case of reported human injury and damage-only DVCs attended by the police, input has been lacking for several police regions and or study years. The total size of this sample has declined further in the three most recent years due to the reduced ability of road safety teams to provide information on vehicle damage-only incidents attended by the police. Police human injury STATS19 records are mostly reviewed and provided for us now via Transport Scotland but are not generally validated and available until the end of June, creating a gap in data for that category for the 2018 calendar year.

3.1.2 Supplementary data sources

A summary of the number of additional DVC records obtained from various supplementary sources available in the full database of mapped records is shown in Table 3. These sources do not form part of the main sampling regime, as they cannot provide consistent input across years or representative sampling across all of Scotland. They are nevertheless available to be drawn upon to provide some insights to specific questions less well addressed based on core data alone.

Up until March 2011, Deer Commission for Scotland roadside carcass data were available from a special project aimed at estimating the minimum actual level of deer casualty numbers for selected trunk routes in the Highlands when not reliant solely on reporting by TROCs (for results see Langbein, 2011).

Limited numbers of more ad-hoc deer casualty sightings obtained from a number of ‘deer-knowledgeable’ contributors (including SHN staff) and the general public are available for more recent years. These records can usefully help inform particular questions; e.g. likely levels of sampling achieved by TROCs alone for specific routes, and reliable detail of deer species mostly unavailable via our core sources. Records in Table 3 showing as from “Other deer experts” (i.e. deer managers, naturalists and other individuals known to the project to be deer knowledgeable) have in the past come mostly via the DeerAware.com on-line DVC report form. In this latest year, additional data has been provided via the Mammal Society from people submitting records via the Mammal Mapper Phone App, abstracting those deer species-specific sightings reported explicitly as road kills. Only entries from the ‘other deer experts’ and ‘general public’ public categories have continued to contribute regular extra data post 2010, producing on average 30 to 40 extra records each per year.

Table 3. Numbers of DVC reports available in database with sufficient detail for mapping from a range of supplementary source categories.

Year	DCS Roadkill searches	Other Deer-experts	General public	Police control	Council uplifts	Total
2008-2012	209	52	19	361	335	976
2013-2017	0	192	147	0	0	339
2018	0	36	29	0	0	65
Total	**209**	**280**	**195**	**361**	**335**	**1380**

3.2 Overview of Scotland-wide distribution of DVC records from core sources

Figure 2 provides a Scotland-wide overview of the distribution of all DVC locations reported by TROCs, the SSPCA and FC over the 11-year data period 2008 to 2018. Those records obtained from the TROCs for the trunk road network are shown overlaid on data from the SSPCA and the FLS. This illustrates the very widespread combined input from among these three sources. In addition, it shows that the SSPCA records provide good sampling from throughout all of mainland Scotland and are not restricted to the areas of highest human population and the densest road networks where the likelihood of an injured deer at the road side being reported is perhaps greatest. Furthermore, especially in the less densely populated areas of the country, where the SSPCA may not be the first point of contact for injured deer call-outs, their records are supplemented by extra records obtained via FC wildlife rangers (see also 2.1.3 above).

Only a low proportion of records from the SSPCA and FLS (~ 5 to 15% respectively) relate to trunk roads, with the bulk of records from these sources recorded on local authority roads (non-trunk A-roads, B-roads and other more minor public roads). Records of human-injury and other DVCs attended by the police are available in only some regions and are not included in the map but are discussed separately in section 3.5 below.

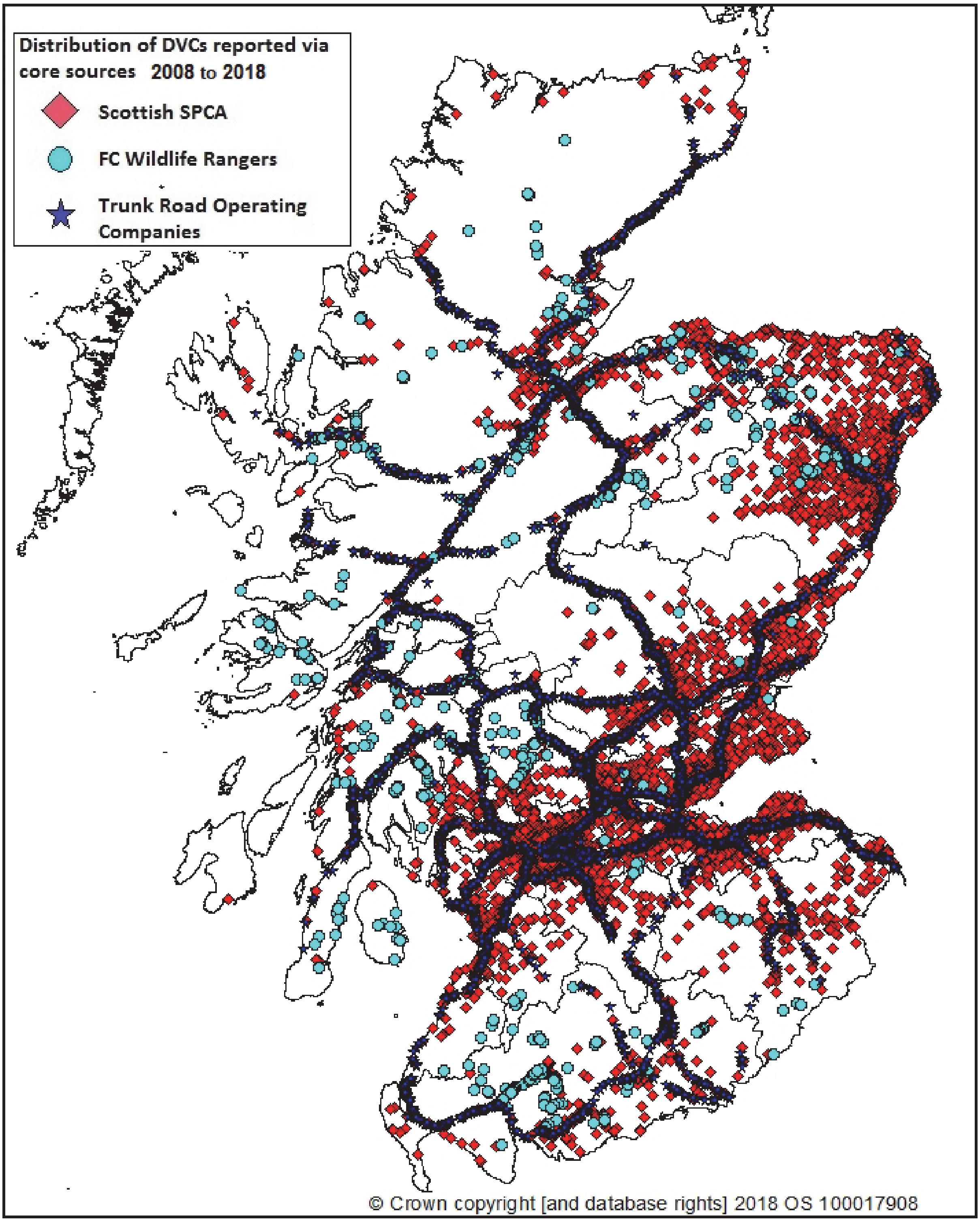


Figure 2. Locations of all mapped DVC reports obtained for 2008 to 2018 from Trunk Road Operating Companies shown overlaid on reports from Scottish SPCA and FC Rangers.

Figure 3.a and Figure 3.b overleaf show the data from all core sources combined, replotted to provide an overview of the frequency of records per 4 km by 4 km Ordnance Survey grid square. The two maps provide a comparison between the first 5-year period (2008 to 2012) of the project with the next five years (2013 to 2017), as per Table 2. A review of the latest data for 2018 (see Figure A.3 - ANNEX 1) shows a broadly similar distributional pattern

though with fewer prominent hotspots, which is not surprising given it is based on records from only a single year.

In these maps, grid squares with at least one record are shown , divided into categories from one to four/five records per square (grey and yellow) up to a maximum 25 to 95 records per 4km by 4km tetrad (maroon). The overall patterns are broadly similar for data from the two separate five-year periods. Total numbers of core records during 2013 to 2017 (8083) have however increased by 34% compared to 2008 – 2012 (6023). The greatest levels of increase are apparent in Aberdeenshire, Fife and The Central Belt, though the A9 north of Inverness also shows more records. These changes are explored in greater detail in the following sections, reviewing data broken down by Trunk road units and Unitary Council administrative areas.

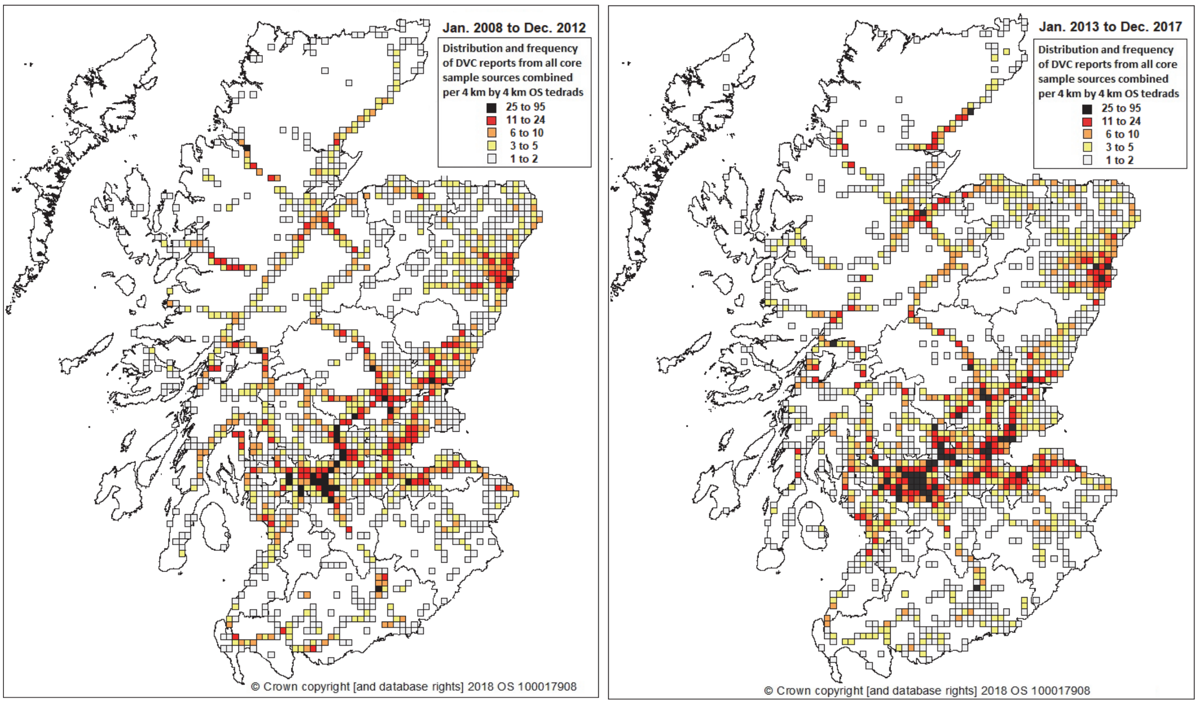


Figure 3.a & 3.b: Distribution and frequency by 4 km by 4 km OS tetrad for DVC data from all core sources combined for the first 5 years (left) and the second 5 years of study (right). For larger full page versions see ANNEX 1 - Figures A.1 and A.2).

A series of 29 pairs of similar maps based on data from all core sources and distinguishing between those records on trunk roads and non-trunk roads has also been prepared at a larger scale for every mainland council administrative area (see ANNEX 2); this is to enable closer inspection of areas of relative high, low and medium DVC occurrence.

3.3 Numbers and distribution of DVCs on the Scottish Trunk Road Network

The Scottish trunk road network is composed of motorways and major strategic A-roads and although making up only 6% of the total Scottish road network it carries 35% of all traffic and over 60% of heavy goods vehicles (Transport Scotland, 2019). A previous study showed that the total number of reported DVCs across Scotland mirrored closely differences in traffic volumes carried on different roads types (Langbein & Putman, 2006; and see section 3.5 this report). Major roads (all trunk *plus* non-trunk A roads *plus* motorways) contributed over 75% of all DVC reports despite representing only around 20% of the total road network. A major part of the present study has therefore focussed on monitoring of DVCs along the TS trunk road network, not merely because of the importance of those strategic roads, but also because it presents an opportunity for widespread data collection in a relatively standardised manner.

3.3.1 Changes in volume of TROC reports overall and by region

An overview of numbers of DVCs reported by the various operating companies on the Scottish trunk road network is provided in Figure 4.

Figure 4 shows that following a substantial increase in records in 2009 across all four network regions (possibly attributable to improved reporting following our initial request for more standardised data in 2008) the network-wide total of DVC reports has remained relatively stable.

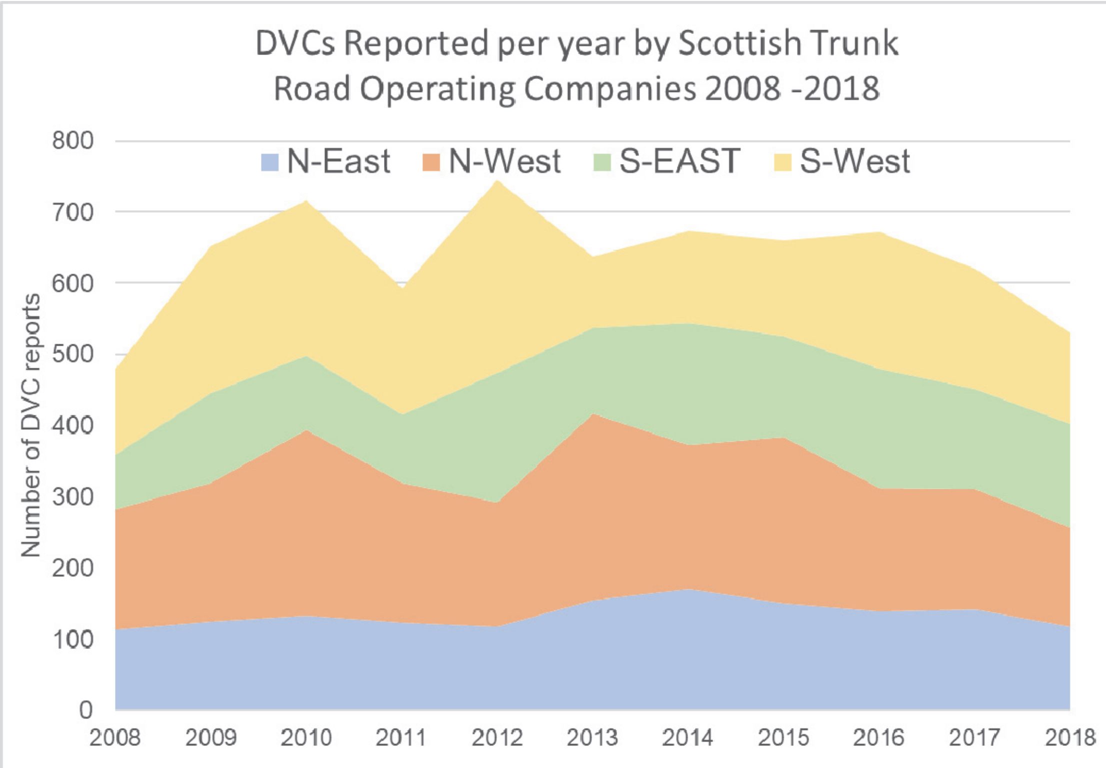


*Figure 4. Reported Trunk Road DVCs by year and region 2008 to 2018 *(Note – In 2013 only part-year data available for South West region – see Table 4)*

Greater fluctuation is however notable within the different regions. In the case of SE Trunk Unit the average number of DVCs per year was higher during 2013 to 2015 compared to the average over earlier years of the project, but returned to lower levels in the last three years. A similar pattern is apparent for the NW Unit with relatively high numbers in the three years to 2015 and falling back nearly 30% since.

By contrast, a 45% reduction was noted in SW Unit in 2013. However this was largely attributable to a three month gap in data logs for this unit in the season when DVCs are commonly at their highest. Numbers increased again in the South West by 2016 but a further fall occurred in 2018. In NE Unit numbers have fluctuated least, with numbers reported in 2017 and 2018 only slightly lower than the average over the previous three years.

The reasons for noticeable peaks in DVCs in some areas during individual years (e.g. in North West Unit 2010 and 2013) remain unclear. Factors such as differences between years in winter weather (snow cover reducing observations of road kill on verges) may possibly contribute. However, other factors such as transfer between operating companies which may handle and log call-outs slightly differently, expansion of the trunk network through new built roads, and a return to growth in road traffic that had stagnated from 2007 to 2011 may all contribute to some fluctuations seen between individual years.

The TROCs contracted by Transport Scotland to maintain the main NW and SW trunk units from early 2013 transferred from Transerv to Bear Scotland; and from Amey to Scotland Transerv respectively. In addition, during early 2014 SE Unit maintenance transferred from Bear Scotland to Amey. New DBFOs have also been established during the period of the present contract, including Aberdeen Roads Ltd. and Forth Bridges unit. In theory these changes should not necessarily affect overall numbers of records obtained by the project, as all the operating companies now have systems in place to record incidents such as removal of animal carcasses and other debris.

Table 4. Number of DVC reports logged by Trunk Road Operating Companies including DBFOs on trunk roads in differing regions of the Transport Scotland trunk road network by year.

DVC reports by Scottish Trunk Network Region									
Year	**South West**	of which DBFOs	**South East**	of which DBFOs	**North West**	of which DBFOs	**North East**	of which DBFOs	**Total**
2008	120	9	78		168		114		**480**
2009	207	13	125		195		125		**652**
2010	219	6	104		260		134		**717**
2011	177	9	97	2	195		124		**593**
2012	270	11	182	10	176		117		**745**
2013	100*	15	121	9	262		155		**638**
2014	129	14	172	51	203		170		**674**
2015	134	13	142	53	233		151	6	**660**
2016	192	25	168	45	173		139	4	**672**
2017	169	16	140	29	169		142	1	**620**
2018	128	18	146	49	139		117	3	**530**
Total	**1845**	**149**	**1475**	**248**	**2173**	**0**	**1488**	**14**	**6981**

Note: SW region figures include SW Unit as well as M6-A74M & M77 GSO & M8_A725 DBFOs data; SE incl. also M8_A725 DBFO, M80 DBFO and Forth Bridges Unit; NE incl. also Aberdeen Road Ltd. *Note SW 2013: 9 month data only (data gap Apr-Jun, when avg. 105 records logged in past years).

To assess whether there were any significant differences over time or between TROCs as to how DVCs were dealt with and logged, and to ensure consistency of recording, in 2017 Transport Scotland consulted with staff at each operating company on their procedures for logging animal road casualties, including which animal species were included. The responses obtained confirmed that not all deer and other animal casualties are recorded and that it is when they are lying on the carriageway or on verges close to the kerb or are in obvious view that they are most likely to be noted. Overall, the current approach to recording animal casualties appeared to be broadly similar within all the four TROCs as well as within the six DBFOs.

A decline in numbers of trunk road DVC reports in the South West and South East during 2017 was sustained through 2018. In this latest year numbers are noticeably lower also for the North West and North East. For the network overall, numbers in 2018 (530) declined by almost 20% compared to the average over the past five years. The reasons for these recent declines are not clear. It remains to be seen whether or not they are due merely to stochastic fluctuation or are a real reduction that is sustained over future years; in which case it may be attributable to changes in deer numbers and/or remedial measures introduced. For example, annual seasonal media DVC awareness campaigns commenced nearly ten years ago. These have been increasingly supported by seasonal safety messages such as 'high risk of deer on roads' displayed in late spring and autumn on Variable Message Signs on selected trunk routes where DVC rates have tended to be highest. Assessment of the effectiveness of these measures lay outside the scope of the present contract. If full logs of the times of day, duration and location where VMS Deer Warning messages were displayed in each year can be made available, this may be useful to assess in detail against changes in DVC rates along those routes since 2008.

3.3.2 DVC distribution and changes in relative hotspots on the trunk network

Since commencement of the present project in 2008, the distribution and frequency of DVCs recorded on the trunk road network and elsewhere have mostly been presented on an Ordnance Survey grid-base to help highlight and assess changes in relative hotspots and other areas with a lower level of DVC incidence. Use in this way of a somewhat arbitrary grid overlaid on a linear network does have some drawbacks, as the actual length of trunk road falling within particular cells will vary depending on whether the road runs centrally through a square or merely for a very short section; in addition, in many cases grid squares contain sections from just one trunk road, but in others more than one trunk road may be present, particularly at road junctions. Hence, there could be widely differing levels of traffic. A different approach to analysis of DVC rates which focusses more directly on distinct sections of trunk roads and which takes into account differences in traffic levels has been developed during the present phase of the project. This provides an index of relative DVC risk for drivers per driven kilometre rather than a risk rating based purely on the total number of DVCs recorded. Results of that 'index-based' analysis are presented in *Section 4*.

However, in the first instance, to provide continuity with results presented in previously published reports (see Langbein, 2011; 2017) the grid-based mapping and analysis as used in the past are updated below to include data from more recent years.

For this grid-based approach, a 2 km by 2 km Ordnance Survey grid was overlaid on the trunk road network to determine the number of DVCs within each grid cell in different time periods, as shown in sample Figures 5a & 5b. These maps have been prepared by first identifying all DVC records – based on our core source records only - mapped within a corridor of up to 250 metres to either side of the Transport Scotland trunk road GIS shape file (2017 version). This analysis 'corridor' was chosen as although the majority of trunk road DVC records are provided by TROCs with grid references allocated at source, the level of accuracy of such mapping does not always place the records on the actual line of the road. Whilst near 85% of DVC records were captured when using a narrower GIS analysis buffer of 150 m to either side of the trunk network, this increased to over 95% of all TROC records when extended to 250 metres. Using such a buffer provides a simple way of minimising the number of trunk road DVC records which are 'lost' from the analysis and is preferable to making artificial corrections to the reported locations which risk introducing 'false precision' if moving the record to the nearest point on the GIS line of the road.

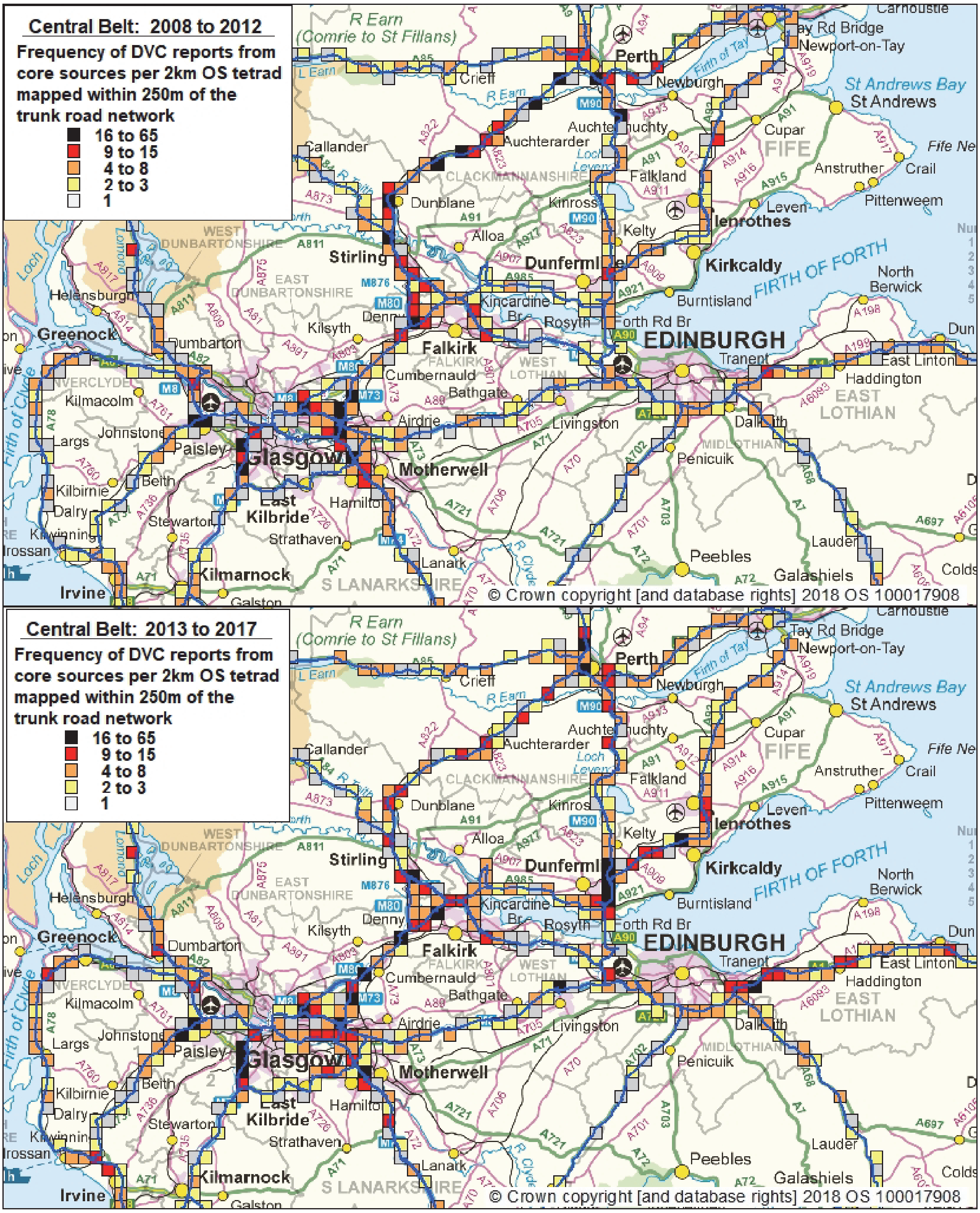


Figure 5.a & 5.b : Distribution and frequency of trunk road DVCs reported by core sources per 2km OS tetrad in the Central Belt region of Scotland during January 2008 to December 2012 (5.a above) and January 2013 to December 2017 (5.b below). Grid squares are used for ease of presentation, but only records reported / mapped within 250m to either side of the trunk shape file were included for analysis (see text).

Among all those grid cells shown on these maps with at least one DVCs record, only the top 2% with the highest frequency of records is shown in black (16 to 65 reports over five years). These black cells together with the next highest category (red = 9 to 15 records) make up 7% of all mapped grid cells (2008 – 2012) rising to 9% (2013 – 2017 maps). Between them the black and red categories thus provide a good initial indication of the main clusters or ‘hotspots’ of DVCs within different parts of the network; and where and how these have changed between the two five-year assessment periods shown.

The data captured along the trunk road network in this way are predominantly those from TROC records (81%). Those records from SSPCA (12.5%), RS-RTC (3.5%) and FC (2.5%) have also been retained if reported as occurring on the trunk roads, and not identified as likely duplicates. Among a total of 1628 records for the trunk road network reported by the latter three sources, only 110 (6.9%) were identified as likely / potential duplicates with TROC-recorded incidents logged on the same day and within 4 km.

This data set was then mapped and analysed to determine the frequency of DVC reports per grid cell, in different project periods. Figure 5a & 5b provide sample views of the resulting frequency maps for the Central Belt of Scotland. Records for the first five project years (2008 to 2012) and the second complete five-year period (2013 to 2017) are presented next to each other to help with visualising gross changes in the distribution of relative hotspots over time. Further pairs of these comparative trunk road DVC overview maps are provided in ANNEX 1 for the North of Scotland and South of Scotland for the two consecutive five-year periods as above, as well as for the most recent single (2018) data year (Figures A.4 to A.9).

General inspection of Figures 5.a & 5.b. (and see ANNEX 1 - Figures A.4 to A.7) show that the pattern of DVCs across the network are broadly similar in both periods. However, with an overall increase of over 20% of reported DVCs during the most recent compared to the earlier five-year period, many clusters of hotspots are rather more pronounced in the later period. Routes showing prominent increases during 2013 to 2017 compared to the previous five-year period include the A1 & A720 City of Edinburgh bypass and the A78 Greenock to Irvine; whereas on other routes a notable reduction compared with earlier years appears to have occurred along the A9 Dunblane to Perth, for example.

For 2018, the most recent data year, overall numbers of trunk road DVCs available from TROCs and the SSPCA fell by around 10% compared to the average over the previous five years (Table 2). Unsurprisingly, as based on only a single data year, hot spots for 2018 are rather less distinct, but the distribution of incidents is again very similar to previous years with most past hotspots identifiable again (ANNEX 1 – Figures A.8 & A.9).

As discussed earlier, DVC distribution, the rate of DVCs recorded per km for specific trunk road sections, and an estimation of the relative risk of DVCs along different parts of the trunk road network when taking into account differences in annual traffic levels, are explored in greater depth in *Section 4.* The results of preliminary DVC risk-based modelling and analysis are also presented there.

3.4 Numbers and trends of DVCs recorded by Unitary Council areas

3.4.1 Observed changes based on the Scottish SPCA (plus FC ranger) records

Whereas the distributional changes in DVCs discussed in the previous section were confined to incidents reported on Scottish trunk roads (motorways and major strategic A roads managed by Transport Scotland), records provided by the SSPCA (supplemented where available by records from FC wildlife rangers) offer an insight into occurrences of DVCs across the entire Scottish road network. Although a small proportion of DVC reports from the SSPCA & FC (~ 5% to 12.5%) also relate to incidents on trunk roads, the great bulk of records from these sources are recorded on non-trunk roads (i.e. non-trunk A-roads, B-roads, C-roads and also all other more minor public roads) managed by the local (Council) highways authorities.

SSPCA logs of requests to attend to live deer injured on roads rose steadily year on year from 2008/9 through 2011, with an even greater increase (58%) in 2012. Following a smaller increase in 2013, a drop by 30% in 2014 may be partly due to lesser level of incident description in the information received to help distinguish between road traffic and non-road related deer incidents. In contrast, more comprehensive detail again in 2015 enabled us to identify close to 1/3 (883) of over 2400 deer related incident logs received that year from the SSPCA as being road casualty related. This was achieved by using various key word searches on incident descriptions (e.g. ones containing <deer> + <hit> + <car>, or various other) rather than relying only on incidents already identified as a road traffic collision (RTC) at source. Similar detail and further increases in records were obtained in 2016 and 2017 (see Table 2). Unfortunately, more restrictive data protection regulations introduced during early 2018, have led to less detail being recorded for incident calls, some now occasionally just contain telephone numbers or names). Therefore, for 2018, there has been a consequent reduction in the total number of records identified. This reduction is attributable almost entirely to the reduction in records for DVC incidents not already identified as such at source. As shown in Table 5, while the total number of usable records in the DVC database has fallen, the number of incidents logged as RTC at source is almost the same in 2018 as it was in 2017.

Table 5. Changes in numbers of Scottish SPCA records received and possible to process for incorporation to database.

SSPCA DVC records 2016 to 2018

Year	Nos. logged as RTC at source	Extras from key word searches	Total	Nos. mapped
2016	962	130	1092	1001
2017	1297	163	1460	1255
2018	1293	Zero*	1293	1102

*Deer related call logs not already identified as RTC at source not available in 2018

It is clear that while a major increase in DVC related call-outs to the SSPCA has occurred over recent years, trends in the data are liable to be affected to some extent by changes in the manner of recording or in how individual operators log calls at the switchboard; in particular, whether or not deer killed outright in collisions (thus not requiring action by the SSPCA) have always been included in the data we received. In discussion with the SSPCA, it has been suggested that:

i. As their organisation now has a substantially greater number of inspectors and vans than ten years ago there is a greater overall capacity to attend to animal welfare call-outs;

ii. The significant rise in the number of people who carry 'smart phones' has contributed to an overall increase in call volumes to their national animal helpline.

The latter in particular is likely to have an effect on the proportion of all deer incidents that are reported to the SSPCA since our project began in 2008, partly as people are more readily able to search for e.g. SSPCA's helpline at the scene, when previously they might possibly have called the police or more likely no-one at all. According to Ofcom, 2008 was the year the smartphone took off in the UK. With the iPhone and Android fresh into the UK market, only 17% of people owned a smartphone a decade ago. That has now reached 78%, and 95% among 16-24 year-olds (Ofcom.org.uk, August 2018).

The extent to which increases in SSPCA records represent a real rise in DVC incidents, rather than our sampling recording an increased proportion of incidents, is very difficult to assess. However, the fact that TROC calls and also FC rangers' call-outs to deer injured in DVCs have remained relatively stable over the past decade, with possibly some indication of a decline in the last 12 to 24 months, suggests the increasing trend in the SSPCA numbers must be interpreted cautiously.

Forestry and Land Scotland wildlife ranger records of deer casualties were retained as part of the main sampling scheme for the present project, partly in case the SSPCA records alone would not adequately represent more remote regions. This approach also recognised that in some areas FLS rather than the SSPCA were the most common organisation called to deer casualties. With the significant rise in numbers and distribution of the SSPCA records obtained since 2008, samples of the SSPCA records now greatly exceed those obtained via FC in nearly all Local Authority areas, with the possible exception of Argyll & Bute and parts of Highland Region in some years. However, as FLS records rarely duplicate incidents obtained via the SSPCA, and are the only ones from the four primary data sources to reliably identify the species of deer involved in a DVC, they have been retained as part of main regular DVC sampling regime.

Table 6 provides a breakdown of the SSPCA and FLS DVC records obtained for within the boundaries of each of 29 Scottish Unitary Local Authorities (Council or City Council areas) since 2008. At least some SSPCA records are available for all mainland unitary Councils. Although DVCs are known to occur within the three Island Council authorities, none have tended to be captured by our SSPCA and other core samples since 2008, and separate enquiries would be required in future to fill that gap if DVC monitoring continues.

Table 6. Numbers of DVC related incidents from Scottish SPCA and FC wildlife rangers broken down by Council administrative boundaries, and comparison of average combined total from both sources per year in two 5-year periods and the latest study year.

UNITARY COUNCIL	2008 to 2012			2013 to 2017			2018		
	SSPCA	FC	**Combined Mean per year**	SSPCA	FC	**Combined Mean per year**	SSPCA	FC	**Combined Total for year**
ABERDEENSHIRE	272	31	**60.6**	613	22	**127.0**	139	3	**142**
FIFE	181	8	**37.8**	434		**86.8**	106	1	**107**
HIGHLAND	127	106	**46.6**	285	59	**68.8**	83	16	**99**
NORTH_LANARKSHIRE	131		**26.2**	299		**59.8**	64	1	**65**
PERTH_AND_KINROSS	130	1	**26.2**	278	1	**55.8**	75		**75**
GLASGOW_CITY	75		**15.0**	208		**41.6**	39		**39**
ARGYLL_AND_BUTE	46	142	**37.6**	87	103	**38.0**	17	11	**28**
ABERDEEN_CITY	107		**21.4**	183		**36.6**	33		**33**
SOUTH_LANARKSHIRE	48	1	**9.8**	174	3	**35.4**	49	2	**51**
STIRLING	62	22	**16.8**	139	25	**32.8**	55	8	**63**
ANGUS	56	2	**11.6**	152	1	**30.6**	30		**30**
DUMFRIES_AND_GALLOWAY	42	61	**20.6**	95	53	**29.6**	22	11	**33**
EAST_LOTHIAN	62		**12.4**	144		**28.8**	47		**47**
SCOTTISH_BORDERS	78	4	**16.4**	138	4	**28.4**	36	1	**37**
MORAY	51	35	**17.2**	128	9	**27.4**	35		**35**
FALKIRK	44	1	**9.0**	129		**25.8**	43		**43**
WEST_LOTHIAN	48	1	**9.8**	116	1	**23.4**	37		**37**
EAST_DUNBARTONSHIRE	76		**15.2**	109		**21.8**	25		**25**
MIDLOTHIAN	65		**13.0**	107		**21.4**	39		**39**
CITY_OF_EDINBURGH	33		**6.6**	80		**16.0**	30		**30**
RENFREWSHIRE	31		**6.2**	70		**14.0**	17		**17**
NORTH_AYRSHIRE	27	1	**5.6**	52	7	**11.8**	15	1	**16**
CLACKMANNANSHIRE	14	1	**3.0**	55		**11.0**	12		**12**
EAST_RENFREWSHIRE	15		**3.0**	50		**10.0**	4		**4**
EAST_AYRSHIRE	17		**3.4**	42	6	**9.6**	9		**9**
DUNDEE_CITY	21		**4.2**	42		**8.4**	8		**8**
SOUTH_AYRSHIRE	18	2	**4.0**	39	1	**8.0**	11	1	**12**
INVERCLYDE	9		**1.8**	32		**6.4**	12		**12**
WEST_DUNBARTONSHIRE	15		**3.0**	30		**6.0**	10		**10**
Total	**1901**	**419**	**464**	**4310**	**295**	**921**	**1102**	**56**	**1158**

The Local Authority where consistently the highest levels of SSPCA (+FC) reports have been recorded is Aberdeenshire Council, followed by Fife, and perhaps unsurprisingly given its relatively large size, Highland Council. Table 6 reveals that despite their comparatively small size, Aberdeen City and Glasgow City rank within the top ten Councils with most call-outs to deer injured in traffic collisions on council roads. In this context it should be noted that of the above, Highland, Fife, North Lanarkshire and Glasgow City are, along with Edinburgh City, the five local authorities with the highest total volumes of road traffic.

The figures in Table 6 also confirm the widespread sampling of DVC incidents achieved across Scotland using the SSPCA reports over recent years. Compared with more remote areas, there may be an element of relative over-sampling in urban and more populous parts, where the SSPCA may be more likely to be called upon by both the public as well as the police. However, the very wide distribution of the DVC incidents handled by the SSPCA does underline that these records do indeed provide good sampling across all mainland Council regions and road types.

Table 6 also provides council by council comparisons of the level of change in the average number of records per annum in each of the five-year periods 2008 – 2012 and 2013 – 2017 with those in 2018. The figures re-emphasise the increasing trend of DVC reports in most parts of the country over the past decade. This increase is unlikely to be attributable solely to improved reporting and recording. Within the majority of Council areas DVC incidents handled by the SSPCA more than doubled during 2013 to 2017 compared to the previous five years. Perhaps most notable are increases by over 2.5-fold in North Lanarkshire and South Lanarkshire, as well as similar rises in Aberdeenshire and Fife.

3.4.2 Combined records from all core sources by LA areas

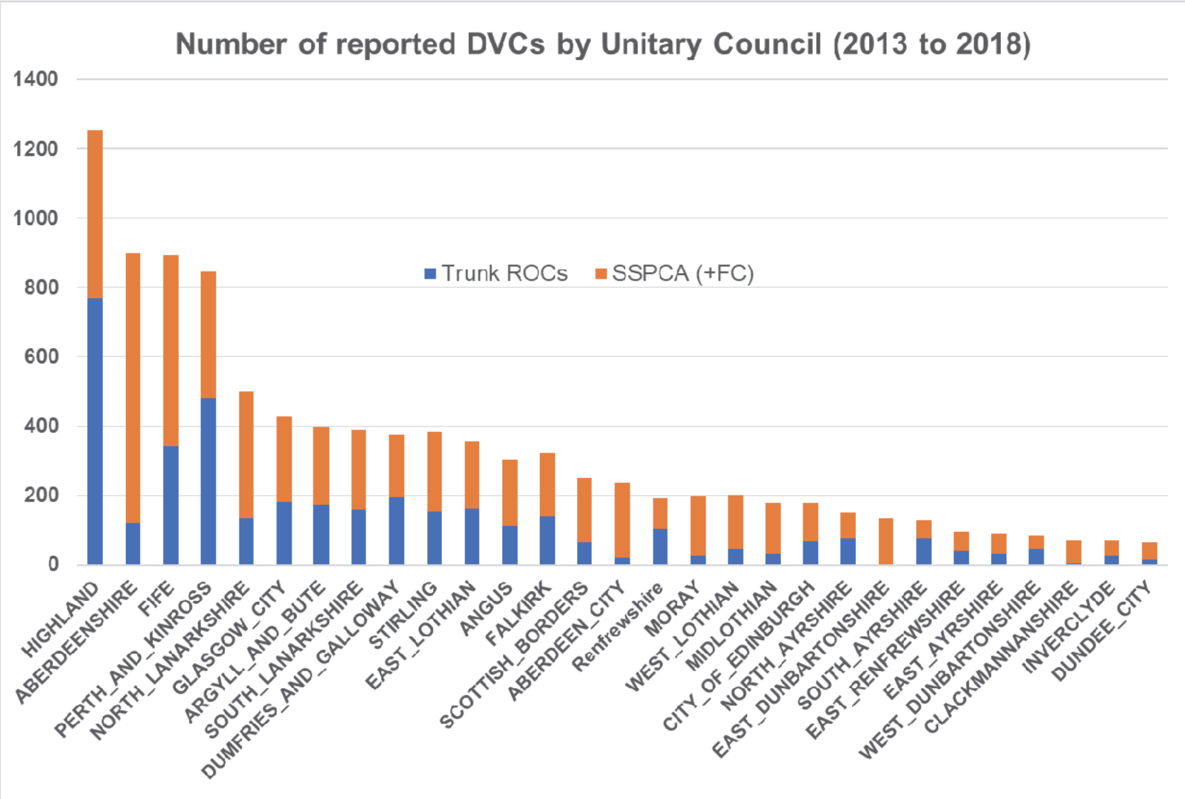


Figure 6. Total number of DVCs reported from all core sources within each Scottish mainland Council, and proportion of total sample made up by records from TROCs.

Whereas Table 6 is restricted to data from the SSPCA (supplemented by some from FC), of which over 87.5% relate to non-trunk roads, Figure 6 shows the combined total number of records for within each Council administrative boundary from all of our core sources including Trunk Road Operating Companies for the six most recent data collection years (2013 to 2018 inclusive).

Table 7. Number of DVC records obtained from all four core source types combined and proportion contributed by TROCs within each Council area during different time periods.

UNITARY COUNCIL	2008 to 2012 All Core Sources	2008 to 2012 *% from ROCs*	2013 to 2017 All Core Sources	2013 to 2017 *% from ROCs*	2018 only All Core Sources	2018 only *% from ROCs*
HIGHLAND	787	*64.3%*	1064	*64.0%*	189	47.1%
SOUTH_AYRSHIRE	67	*70.1%*	102	*60.8%*	27	55.6%
PERTH_AND_KINROSS	585	*77.6%*	715	*59.4%*	131	42.7%
RENFREWSHIRE	107	*71.0%*	164	*57.3%*	28	39.3%
WEST_DUNBARTONSHIRE	50	*70.0%*	69	*56.5%*	15	33.3%
NORTH_AYRSHIRE	87	*67.8%*	124	*52.4%*	66	50.0%
DUMFRIES_AND_GALLOWAY	378	*72.8%*	310	*52.3%*	27	40.7%
EAST_LOTHIAN	153	*59.5%*	278	*47.1%*	79	40.5%
FALKIRK	165	*69.7%*	258	*45.7%*	47	40.4%
ARGYLL_AND_BUTE	386	*51.3%*	348	*44.5%*	64	32.8%
STIRLING	338	*72.8%*	296	*43.9%*	67	41.8%
SOUTH_LANARKSHIRE	181	*72.9%*	312	*42.9%*	11	63.6%
GLASGOW_CITY	283	*73.5%*	362	*42.0%*	76	32.9%
INVERCLYDE	32	*71.9%*	55	*41.8%*	88	28.4%
CITY_OF_EDINBURGH	68	*51.5%*	135	*40.7%*	44	31.8%
FIFE	303	*32.0%*	738	*39.7%*	155	31.0%
EAST_RENFREWSHIRE	46	*67.4%*	82	*39.0%*	16	25.0%
ANGUS	141	*58.9%*	259	*37.8%*	44	31.8%
EAST_AYRSHIRE	37	*54.1%*	74	*35.1%*	14	35.7%
SCOTTISH_BORDERS	174	*52.9%*	207	*27.5%*	88	26.1%
NORTH_LANARKSHIRE	290	*54.8%*	413	*26.9%*	45	17.8%
WEST_LOTHIAN	81	*39.5%*	156	*23.1%*	14	42.9%
MIDLOTHIAN	97	*33.0%*	136	*19.1%*	45	17.8%
DUNDEE_CITY	25	*16.0%*	51	*17.6%*	43	9.3%
ABERDEENSHIRE	421	*22.6%*	741	*14.3%*	157	9.6%
MORAY	114	*21.1%*	158	*13.3%*	39	10.3%
ABERDEEN_CITY	127	*13.4%*	202	*9.4%*	34	2.9%
CLACKMANNANSHIRE	16	*6.3%*	59	*6.8%*	12	0.0%
EAST_DUNBARTONSHIRE	76	*0.0%*	109	*0.0%*	25	0.0%
Grand Total	**5615**	**56.8%**	**7979**	**40.9%**	**1690**	**31.4%**

While Table 7 is presented here for completeness, in interpreting the figures shown it is important to note that:

i. The proportion of the total road network made up of trunk roads varies greatly between differing Council administrative boundaries; and
ii. The proportion of all DVC incidents that occur which are captured by our core samples is likely to be rather better for trunk roads than for the non-trunk roads.

As a result mainly of the significantly increased volume of incidents handled by the SSPCA over more recent years, the proportion of our core sample made up of records from TROCs has fallen from over 55% to nearer 40%. Even now however, DVCs on non-trunk roads are very likely to remain relatively underrepresented in our data collection. Records from the SSPCA and FC which make up the bulk of our information for non-trunk roads, overwhelmingly (>90% of cases) relate to requests to assist with *'live'* injured deer on welfare grounds, as the SSPCA will generally not attend to deer killed outright. While there is no firm data available on the actual proportion of DVCs in which deer remain alive after a vehicle collision, previous research has shown this is likely to be up to 25% for all species combined. The true proportions of DVC incidents occurring on non-trunk roads are therefore likely to exceed the minimum figures shown in Table 7.

3.5 Human injury collisions and damage-only DVCs attended by police

3.5.1 Numbers of reported personal injury accidents in which deer implicated

Identification of Scottish personal human injury road traffic collisions (PIAs) in which deer were implicated has continued to prove difficult. Annual requests for such data were made to the eight former ('legacy') Scottish police forces prior to their merger into Police Scotland during 2010. It was hoped that following formation of Police Scotland such extraction would become simpler and more consistent. However, to date the availability of comparable data on road traffic collisions in which deer have been implicated is still only available for the 2008 – 2017 project period for two of the legacy forces (Northern and Fife) and in the case of a third (Central) for the Falkirk Council area only. Comparable records for the 2018 calendar year have been requested via Transport Scotland, but will not be available until after official statistics have been validated at the end June 2019.

Since before 2008 the most consistent data we have on PIAs have been supplied via Highland, Fife and Falkirk Council Road Safety Officers from their processed RTC records of all incidents in which accident descriptions mentioned 'deer' or 'stag'. Often the records provided also included details, when they were available, on vehicle damage-only collisions involving deer and attended by police. However, after 2014, damage-only incidents are generally no longer or only rarely obtainable due to more restricted statistics on such incidents being routinely collected by the police.

Since 2012, information on reported PIAs referring to 'deer' has been obtainable from a slightly wider range (5 of 8) of the legacy forces, aided by data drawn together recently for us by Transport Scotland. While they too have been unable to obtain this information in the past via Police Scotland (as the extra detail needed to identify 'deer' incidents does not form part of the official national statistics), it is expected that extraction of such PIA records across all of Scotland should continue to improve in future.

Table 8 summarises the PIA data available from the legacy forces. The figures shown represent the minimum numbers of such incidents, as the fact that a deer was or may have been implicated in a traffic collision is not retrievable from all accident records. In general the type of animal is only logged in official road accident records (STATS19) forwarded to DfT in cases of incidents involving ridden horses and dogs. Involvement of a deer can therefore only be identified where the textual accident description (that does not form part of the DfT collated official stats) recorded by the attending police officer can either be made available to us by the police or regional road safety teams or extracted by them on our behalf. Such searches, when possible, do also return incidents involving not only actual collisions with deer but also collisions caused or allegedly caused by swerving to avoid a deer on the road.

Table 8. Available police records on personal injury DVCs broken down by the eight former Scottish regional legacy forces (now all incorporated within Police Scotland).

Year	Fife	Northern	*Central	Grampian	Tayside	Lothian & Borders	Strathclyde	Dumfries Galloway	Total
2008	3	13	7	7	nd	nd	nd	nd	**30**
2009	3	9	0*	8	nd	nd	nd	nd	**19**
2010	2	9	1*	3	nd	nd	nd	nd	**13**
2011	5	10	1*	7	nd	nd	nd	nd	**21**
2012	4	7	4*	6	nd	nd	nd	nd	**21**
2013	0	14	3	nd	9	4	nd	nd	**30**
2014	1	6	2	nd	1	3	nd	nd	**13**
2015	2	8	3	nd	6	5	nd	nd	**24**
2016	1	9	2	nd	4	2	nd	nd	**17**
2017	4	5	8	nd	1	6	*(1)		**24**
Total	**25**	**90**	**31**	**31**	**21**	**20**	**0**	**0**	**218**

Comparable records for the 2018 calendar year have been requested via Transport Scotland but will not be available until after official statistics have been validated after the end June 2019. *indicates years when records available for Central region restricted to Falkirk only. *(1) Strathclyde 2017- represents one off record only from FOI request rather than full years data search.

In the case of Highland Region (Northern legacy force area), where consistent information is available for all study years, deer PIAs have averaged nine per year from 2008 to 2013 (and around 10 per year for 2003 to 2007) but dropped to five in 2017. For Fife, a much smaller local authority, deer related PIAs retrieved from official accident records have averaged 2.5 per year; and over the shorter time span for which data are available for Grampian, Tayside and Lothian & Borders Regions averages of around six, four and four PIAs, respectively, were logged.

A review of available accident descriptions for PIA records in which deer are believed to have been implicated, revealed that close to 60% mention swerving or other manoeuvres in an attempt to avoid deer on the road before then hitting another vehicle or object. Reference to a deer actually being hit by the vehicle is only confirmed in about 35% of cases, although from the short textual description, it is not always entirely clear whether or not a direct collision with the deer occurred.

Extending our sample to include several hundred damage-only accidents in which deer were implicated and which were logged over earlier years in the DVC database, revealed that half mention drivers attempting to avoid deer, but then hitting another object. Typical accident descriptions such as "*V1 travelling west swerved to avoid a deer lost control and crossed the carriageway then through a fence on the offside*", occur in roughly equal number to descriptions such as "*V1 was travelling east on A… when a deer ran in front of the vehicle directly into the path of the car and driver was unable to avoid colliding with the deer".*

An important point arising from this is that while the vast majority of our annual sample of DVC records are obtained from trunk road agents or the SSPCA based on deer casualties at the roadside, the figures above suggest that aside from those several thousand incidents where a deer is actually hit, there could be approximately as many deer-related accidents in which there is no deer casualty and hence most are not possible to capture via the major sources.

3.5.2 Estimating actual numbers of deer related PIAs in Scotland per year

Based on the limited PIA data available (Table 8) for six out of eight of the legacy police force areas for between five to ten years, together with the assumption that the average figures from those police forces are representative of the rest of the country, we may estimate that at least 40 PIA records would be forthcoming if similar data were available for all eight legacy forces. This is a somewhat lower estimate than the 65 to 70 proposed previously (Langbein, 2011) based on available data for 2003 to 2010. While this may reflect a downward trend in injury DVCs (as is the case for PIAs from all causes on the road network over the past decade), figures for deer accidents must be interpreted cautiously in view of the relatively small samples involved.

Furthermore, the above estimate of 40 'reported' deer related PIAs per year in Scotland over recent years, derived through assessment of ST19 data, must be seen as a very conservative estimate of actual numbers of human injury accidents and casualties in which deer are implicated. Estimates from the National Travel Survey suggest ST19 figures are likely to record less than one third of all injury road accidents and casualties (DfT, 2011). On the basis of these NTS estimates, it is possible that the true annual number of deer related PIAs is likely to be around 3 times greater than our above estimate and may well exceed 120 per year across Scotland.

An estimate of nearer 120 PIAs relating to deer in Scotland per year would not seem unrealistic in the context of published figures for other countries. For example in Germany (ADAC, 2009), the total number of all DVCs has been assessed at around 220,000 per year and the number of injury accidents reported to police with the causation factor "wild game animal on the road" has consistently exceeded 2700 per annum over the last five years. Of these, close to 80% (c.2200 per annum) annually are believed to result from collisions with roe, red and fallow deer (DJV, 2010; 2011). This translates into c.1% of all DVCs leading to human injury. If we apply that 1% figure to the above Scottish estimates of around 40 recorded PIAs but more likely 120 actual PIA DVCs, this would suggest that Scotland-wide the annual toll of all PIA DVCs is likely to lie in the range of 4000 to 12,000.

3.5.3 Severity of reported deer related human personal injury road accidents

The sample of 218 PIA incidents in which deer were implicated, as shown in Table 8, included 166 accidents leading to 'slight' human injuries, and 45 classed as KSIs (killed or seriously injured), including three fatal accidents (one in each of 2008, 2016 and 2017). At least one further human fatality is known to have occurred in 2018 in a collision with a deer, based on information from Highland Council (although complete figures for there or other parts of Scotland were not available for that latest calendar year in time for this report).

In considering the severity of incidents it is noteworthy that in many cases there will be several factors contributing to fatal accidents, and confirmation that either a collision with a deer or swerving to avoid a deer contributed to a fatal accident may only be concluded during a Fatal Accident Enquiry, which could be quite some time after the accident, and then not necessarily be recorded as such in accessible statistics.

3.5.4 Distribution and continued value of collection PIA information

In order to obtain more comprehensive coverage across Scotland of these small but important (from the view of Road Safety evaluations) data sets, a number of discussions were initiated during 2014 via contact with Traffic Scotland, Police Scotland and Road Safety GB. Some progress was made via contact with Traffic Scotland Statistics section, who themselves had been trying to consolidate additional RTC data (over and above those published in standard DfT STATS19 reporting) for the various legacy police forces. However, they too have experienced difficulties in obtaining relevant information for previous years for all of the eight legacy police forces. In particular, two of the legacy police forces, while able to provide standard ST19 detail on all past accidents, are not able to provide the textual accident descriptions that were recorded by attending police officers, which are essential in order to identify those involving deer. It nevertheless seems likely that as data handling procedures become standardised across all of Police Scotland, ability to access these descriptions may improve in future.

However, full and comprehensive recording and ability consistently to extract information on the majority of accidents in which deer are implicated throughout Scotland remains unlikely, so long as this requires key word searches on the textual police accident descriptions, which do not currently form part of the official STATS19 data that are collated by DfT in national statistics. This could be readily achieved though by extending the boxes already available on STATS19 forms to record accidents with dogs or ridden horses and adding 'deer' as a single additional 'tick-box' category. Alternatively, consideration should be given to adding categories of animal on road 'live', and animal on road 'dead', with a box allowing the animal type when known to be entered. Distinction between 'live' and 'dead' categories is suggested as a proportion of PIA DVCs occur when a driver hits or swerves to avoid a dead deer carcass lying on the road after it has been hit by another vehicle; but in such a case again may not be recorded as an animal related accident but simply logged as due to debris on the road.

Adding deer to the STATS19 form has been suggested by us for many years, but has yet to be adopted. Wild animal collisions have generally been considered a low priority for road safety in Britain as a whole, perhaps because the proportion of all accidents in which wild animals are hit or involved as a hazard on the road continues to be under-recorded. In Scotland in particular however, calls for deer and or other wild animals to be added to STATS19 may be more justifiable, as the overall proportion of all road accidents which involve animals on the road in Scotland is almost certainly significantly higher than in England.

3.6 DVC frequency in relation to Time of day and Season

3.6.1 Diurnal patterns of DVC occurrence

Diurnal variation in traffic flows and deer activity may lead to certain times when DVCs are most likely. In order to investigate the distribution of DVC occurrence in relation to the time of day, it is important to focus on those records for which we may be most confident that times of actual incidents have been recorded accurately. For many deer road casualties the time when most are found may be biased towards the early hours of the morning simply as road kills may be more easily spotted then by greater numbers of drivers.

The data least likely to be affected by such observer bias are those obtained for human injury as well as damage-only DVCs at which the police attended. These are generally recorded most accurately with respect to time of actual incident and location. Overall, including latest records available for 2016 to 2018, we are now able to draw on over 1000 such police attended incidents (including c. 400 collected prior to 2008) to assess diurnal patterns of DVC occurrence (Figure 7). Time segments relate to time as recorded by the police without adjustments made to GMT/BST, in order not to skew information in relation to daily peaks in road traffic.

The same data used in Figure 7 are presented broken down for four different 'seasons' in Figure 8, as follows (Winter: Dec-Feb; Spring: Mar-May; Summer: Jun-Aug; Autumn: Sep-Nov). A broadly similar diurnal pattern is apparent in each of these seasons, with an early morning peak in incidents between 0600 – 0900 hrs, as well as an even higher peak early evening through to midnight. As may be expected as a result of shorter daylight, the evening peak occurs earliest during winter and latest during summer. In general the periods of highest incidence of DVCs in Scotland may be identified as occurring from early evening until midnight (1800-0000 hrs.) followed by early morning (0600-0900 hrs.).

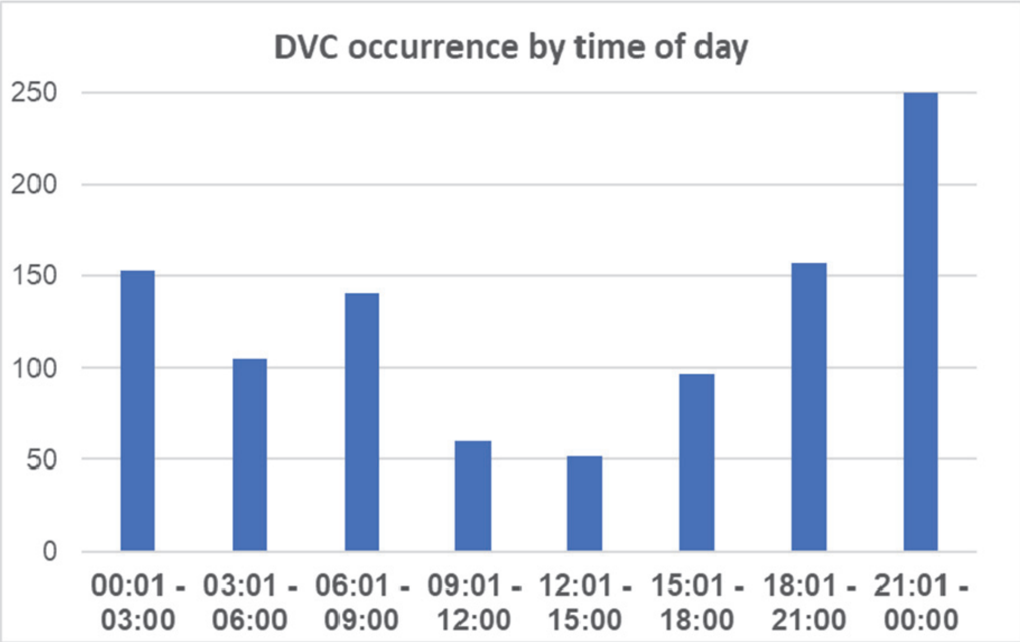


Figure 7. Relative frequency of DVC occurrence in differing time period of the day (based only on DVC incidents attended by the police and with hence the most reliable actual incident times (n = 1017).

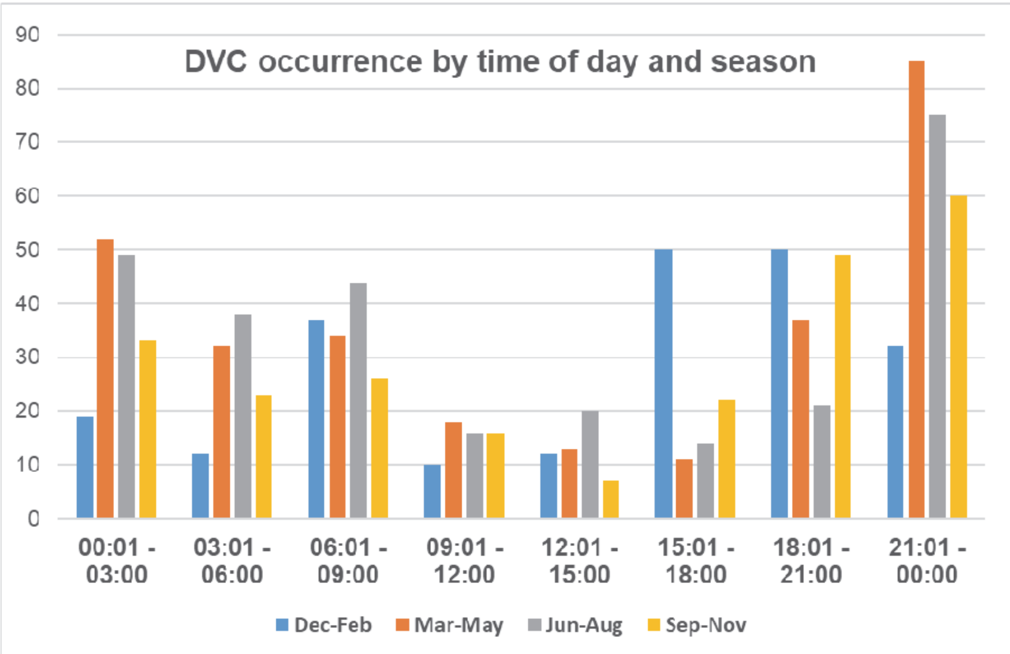


Figure 8. Relative frequency of DVC occurrence by differing time periods of the day in differing seasons (based only on DVC incidents attended by the police with hence the most reliable actual incident times (n = 1017).

3.6.2 Seasonal patterns of DVC occurrence by road type and region

The seasonal patterns of DVC occurrence were analysed and discussed in some detail for differing road types as well as different regions within Scotland in a previous contract report based on data for 2003 to 2010 (see Langbein 2011, Section 5.3). Summary results from that assessment are shown in the overview figure below (Figure 9), and in overall terms there is no evidence of a change in these patters over more recent years.

However, in view of the work undertaken by SNH with Transport Scotland to raise public awareness of the very strong DVC peaks apparent every May and June, which are by far most prominent on motorways and trunk A roads, it is of interest to consider whether or not there are any indications that these annual peaks have become less pronounced since these seasonal DVC awareness campaigns began around 2008.

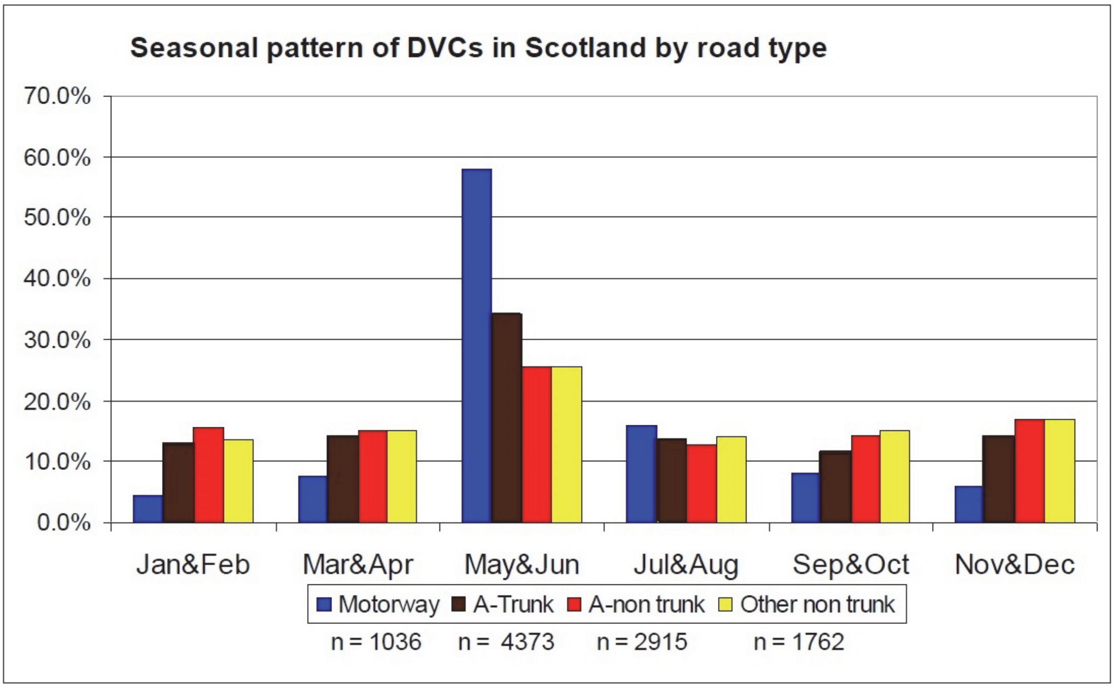


Figure 9. Seasonal pattern of DVCs in Scotland on trunk roads (motorways plus strategic A-roads), A-class non-trunk roads and minor roads (from Langbein, 2011).

In summary, as per Figure 9, prior to 2011 a major peak in DVCs tended to occur during May & June on all road types throughout Scotland. This peak was most pronounced by far for motorways when just over 55% of motorway incidents were reported during May and June, followed by A-class trunk roads (35% of all A-class incidents). In the case of other A-roads and all smaller roads a regular spring peak is still apparent but here made up under 25% of all incidents. The same overall pattern with just a single notable peak tends to be replicated for all regions of Scotland, with the exception of North West Scotland, where a significant proportion of incidents involve larger deer species (red, sika and sometimes fallow) which mate in autumn and at that time are increasingly on the move between summer and autumn ranges. In other regions, where roe deer populations predominate, the autumn peak in accidents is still noticeable but is less pronounced.

Re-examination of the seasonal breakdown of DVC records available from TROCs for motorways and A-class trunk roads since the project started in 2008 shows no indication of any significant changes in the seasonal pattern of accident occurrence over the past 11 years (Table 9). During the three most recent years, DVC incidents on motorways during May and June combined have continued to make up close to 55% of the annual toll of records obtained. On A-class trunk roads over 36% of incidents continue to be reported during May and June, with May the month with overall highest incidents on both trunk road types. These countrywide figures do not provide any clear evidence of a reduction in the size of the seasonal peaks at which the DVC awareness campaigns of the past decade have been targeted. That no clear effects are readily apparent from this gross analysis of national figures is not to say that such awareness raising may not nevertheless be having more significant effects at a regional or more localised level. To assess the impact of the campaigns more fully would require a much more detailed investigation of the routes, dates and diurnal periods targeted by the VMS messaging and media campaigns in terms either of reduction in DVC occurrence, or other measurable effects in, for example, public or driver awareness of a collision risk with deer.

Table 9. Seasonal distribution of DVCs reported by years and road types

Years	Road Type	Jan & Feb	Mar & Apr	**May &Jun**	Jul & Aug	Sep & Oct	Nov & Dec	Total	Sample size
2008 to 2011	Motorway	4.3%	10.0%	**56.1%**	14.6%	8.1%	6.9%	100.0%	651
	A-trunk	11.2%	12.3%	**36.5%**	14.3%	11.6%	14.1%	100.0%	712
	Non-trunk	15.2%	13.0%	**24.1%**	16.1%	14.2%	17.3%	100.0%	526
2012 to 2015	Motorway	8.0%	10.7%	**51.4%**	15.9%	4.4%	9.7%	100.0%	1791
	A-trunk	11.5%	10.2%	**39.0%**	15.2%	11.1%	13.1%	100.0%	2005
	Non-trunk	15.7%	12.1%	**25.8%**	14.7%	14.1%	17.5%	100.0%	1295
2016 to 2018	Motorway	5.5%	8.6%	**54.4%**	20.5%	5.3%	5.7%	100.0%	1397
	A-trunk	9.0%	13.7%	**39.0%**	17.3%	8.9%	12.1%	100.0%	2818
	Non-trunk	15.7%	12.3%	**24.9%**	16.1%	13.7%	17.4%	100.0%	3845

The large DVC peak in all project years is during May & June and it represent over a 3-fold increase in incidents for motorways, and over a 2-fold increase for A-class trunk roads compared to the proportion of incidents that would be expected for any two month period (c17%) if DVCs were spread evenly across each month. In contrast, in most years the May & June peak for non-trunk A-roads together with B-roads and minor road shows an increase of about 1.5 times over the two-monthly average.

From the very consistent patterns shown in Table 9, we may conclude that while deer will commonly cross more minor roads throughout the year, possibly on an almost daily basis, major roads that form a much more substantial barrier to them will tend to be crossed much more seasonally. The peak in spring coincides with the period when yearling deer, especially but not exclusively of territorial species such as roe deer will disperse to seek out new territories. Deer in general at this time may increasingly seek out the relatively secluded cover along road verges as this becomes denser during late spring and which although seemingly noisy to us will often be subject to less disturbance by, for example, dog walkers than other areas of woodland.

Table 9 also shows that on motorways DVCs are generally at their lowest levels during the winter months (November through February), when roadside vegetation will tend to be most sparse and offer least feed or shelter.

3.7 DVC reports with reliable detail of deer species

Reliable information on the species of deer involved has been available in only a minority of the DVC reports obtained since 2008. For our largest data samples (TROCs and the SSPCA), incidents tend to be first logged when a request to attend to an animal casualty on or at the side of a road is received from the public, police or another organisation, and will generally be referenced simply as ‘deer’. Detail of the species of deer concerned is rarely reported. In addition, even on occasions where TROC records contain deer species information, the reliability of that identification cannot be verified without knowing the individual expertise of the personnel involved. Information on deer species is only very occasionally provided in the SSPCA records but again, even where it is provided, it cannot be verified.

As such, most of our *reliable* species-specific DVC records from 2008 until 2015 were restricted largely to annual extracts taken from the DVC-related entries in FCS’s deer rangers’ deer cull database. This information was, supplemented with that from a number of known ‘deer-knowledgeable’ individuals (deer managers and naturalists, including members of SNH staff) who occasionally provide entries via the on-line incident report form when attending to or observing a dead casualty at the roadside.

With a gradual fall-off in incident reporting on-line by individual stalkers, a number of alternative potential sources of reliable species-specific DVC information were explored during the present 2016 to 2018 contract. These included the ‘Project Splatter’ citizen science project and the Mammal Society’s Mammal Mapper recording APP. Following discussion with Project Splatter (which attempts to obtain roadkill observations from the general public on all animal types, mainly via a ‘phone APP) the potential of a data sharing arrangement was considered. However, given that there would in general be no greater reliability or way of assessing the ability of most contributors to correctly identify deer species involved, it was decided not to pursue this at this time.

In the case of the Mammal Society’s Mammal Mapper recording APP, contributors are predominantly Mammal Society members. The APP contains reference photographs to assist with species ID, and specific entry options to confirm the sightings as road kills rather than live sightings. We therefore made a request to the Mammal Society asking them to extract for us any species-specific deer related road kill reports received by them on the APP during 2016 (when the APP was set up) through to 2018, which they kindly provided. To date this has only generated an additional 20 to 30 records a year falling within Scotland, though there is the potential for this to increase in future years.

To date the total number of mapped species-specific deer records from contributors with a high degree of reliability of species identification in the updated SNH DVC database for 2008 to 2018, , extends to just over 1300 (~7.5% of all records). A breakdown of these records by local authority is given in Table 10, to provide at least an indication of the proportion of DVCs made up by each of the differing deer species in different regions.

Figures in Table 10 indicate that red deer contribute to a significant proportion of reported DVCs in only four council areas, with most reports in Highland and Argyll & Bute, and smaller numbers in North Ayrshire and Stirling; Sika are also reported in a small proportion of DVCs in these same council areas.

Reports of the involvement of fallow deer in DVCs mostly relate to Dumfries and Galloway (especially A701 near St Anne’s) and Perth & Kinross (especially around Dunkeld to Blair Atholl). For the majority of other Council areas however, roe deer are the only species reported, although in many cases numbers of species-specific reports remain very low.

Table 10. Numbers of DVC records from 'deer-knowledgeable contributors' providing reliable species detail by Council areas based on available records for 2008 to 2018 inclusive.

Unitary Council AREA	Red	Sika	Fallow	Roe	Total
HIGHLAND	265	22		188	475
ARGYLL_AND_BUTE	133	9		174	316
STIRLING	12			48	60
NORTH_AYRSHIRE	9			7	16
DUMFRIES_AND_GALLOWAY	4		8	117	129
ABERDEENSHIRE	3			58	61
PERTH_AND_KINROSS	1		49	67	116
MORAY				66	66
NORTH_LANARKSHIRE				12	12
SOUTH_LANARKSHIRE				12	12
SCOTTISH_BORDERS				10	10
FIFE				10	10
ANGUS				10	10
EAST_AYRSHIRE				7	7
WEST_LOTHIAN				5	5
SOUTH_AYRSHIRE				5	5
GLASGOW_CITY				5	5
All Other Mainland Areas					<5
Total	**427**	**31**	**57**	**801**	**1315**

A deer sighting smart-phone recording APP is being developed during 2019 by the British Deer Society. This should have the potential to generate a greater volume of reliable species-specific information provided that, as in the case of the Mammal Mapper App, it can ensure road kill sightings can be logged and clearly distinguished from other sighting reports in the output data, and it includes an indication of the accuracy on the geo-referencing (i.e. location logged at actual location of incident, or location logged sometime later having only seen carcass at roadside while driving). If SNH DVC monitoring continues to collect and collate data for a further contract period for 2019 and beyond, early discussions with BDS should be undertaken by the contractors to maximise the potential of their new APP to contribute to this project via a data sharing agreement.

3.8 Estimation of actual annual number of DVCs in Scotland

Estimation of the true actual number of DVCs that occur nationally across Scotland was not a specific project objective. However, the question is often raised by the media and others. Such estimation remains extremely difficult, as the proportion of all actual incidents sampled by each of the core sources remains unknown.

3.8.1 Past estimates

Past estimates of the total number of DVCs in Scotland based on the 2003 to 2005 DVC study suggested it was likely there were in excess of 7000 and possibly as many as 12,000 per annum (Langbein & Putman, 2006). These estimates were derived partly from extrapolations from the numbers of PIA (human injury) DVCs and the 'estimated' proportion (c.1%) of the total numbers based on other studies in the UK and Europe (Langbein, 2007; ADAC, 2009; DJV 2011). Revised estimates based on more recent information on PIAs reported to the police and estimates of the actual proportion these represent (as discussed in section 3.5.2) still permit only a very broad estimation and continue to suggest that the total of all DVCs in Scotland (including any deer casualties with or without damage to vehicles) is likely to lie within a range of at least 4000 to around 12,000 per year.

Alternative results from an assessment by the Deer Commission for Scotland, based on a series of roadside-verge carcass searches for three substantial sections of A-class trunk routes in the Highlands between 2003 to 2010, determined that TROCs records on their own at best made up 64%, 57% and 24% of the minimum actual numbers of deer road casualty carcasses found on those three routes (see Langbein, 2011). On that basis, it was estimated that overall TROCs records are unlikely on average to record more than 50% of the true number of DVCs on such trunk roads. Using that as indicator of sampling intensity achieved it may be estimated that actual numbers of deer casualties on Scottish trunk roads were likely to have been in the region of 1500 per year. Trunk roads have previously been estimated to contribute to just over 1/3rd of all DVCs countrywide, leading to an estimate of around 4500 deer casualties overall. However, this figure excludes perhaps as many DVCs again arising from accidents caused by drivers swerving to avoid deer but hitting another object, or incidents involving only minor impact with the animal not leading to a deer casualty at roadside (see 3.8.2 below).

To provide further insights into the likely level of sampling achieved by TROCs, over the three years 2013 to 2015 a number of SNH deer officers and other deer managers were encouraged to provide information via an online report form whenever possible giving dates, location and species of any deer road casualties noted by them during car journeys. The returns received recorded 112 deer casualties seen on the side of trunk roads in various parts of Scotland. These records were assessed individually by us to check how many of these same deer casualties were later also reported to us in records provided by the relevant TROC. Incidents were marked as plausible or likely duplicates if logged with either the same day or within 24 hours to either side, as well as located on the same road and mapped no more than 4 km from the point reported by the TROC. The number of likely duplicates identified in this way was 19 out of the 112 reports (17%) This result suggests that an even lower proportion (possibly <20%) of the true number of DVCs is being captured by the TROC data. In that case, if TROC reports actually capture merely 20% of the actual numbers of DVCs on Scottish trunk roads, the true total would be calculated to be 3750 per annum for the trunk road network and 11,250 for Scotland as a whole.

3.8.2 Updated broad ranging estimates

Revised estimates based on more recent information on PIAs reported to the police (as discussed in section 3.5.2) still allow only a broad estimation of the true number of all DVCs (including any deer casualties, with or without damage to vehicles), indicating that it is highly likely to be no lower than 4,000 across Scotland but may well be nearer 12,000 per year.

Based on alternative information (3.8.1 above) which suggests that the trunk road reports are unlikely to represent more than 50% and possibly as few as 20% of actual numbers of deer casualties on the trunk road network, and applying this to the slightly reduced average number of TROC records for the Scottish trunk network over the most recent three years (610), provides revised estimates of 1220 to 3050 DVCs for trunk roads, and 3660 to 9150 for Scotland as a whole.

3.8.3 Proposed alternative independent assessment of national DVC figures.

While the above analysis gives only a very broad-brush indication of what may be the total number of vehicle collisions involving deer for Scotland each year, the present sampling regime was never designed to produce such total figures and the data accrued are not well suited for this. The above estimates therefore remain based on a rather weak foundation, using extrapolations from samples for which the true sampling intensity can itself only be estimated.

If it is considered important to obtain firmer figures for the true annual, Scotland-wide figures for DVCs, it is likely this would be better achieved through a one-off independent public questionnaire-based approach, possibly in conjunction with one or more national motoring organisations. That is because it has previously been shown that minor collisions (i.e. those below insurance claim thresholds and not reported to police) tend to make up the great majority of all DVCs and other wild animal collisions (Hartwig, 1991). These records are unlikely to be obtainable through any other source other than the persons affected.

An outline proposal for such a questionnaire-based study was previously drawn up but was not pursued. In brief, I would suggest such an investigation may best be undertaken for Great Britain as a whole and, in order to obtain unbiased returns, would ask questions of a large national sample (> 1000 to 10,000) of motorists; it would concern any animal related vehicle collisions they have been involved in over a set recent period of years, with entry boxes to state details of the animal type, as well as approximate month and location of each accident. Focus on deer alone should be avoided, as asking about all animal collisions would avoid bias and help to cross verify and put results into context. Results from such a fairly simple study, in combination with information from the present and past DVC monitoring work, and injury accident data available for 'animal hazard on road' incidents overall, should provide a much firmer basis from which to estimate the true UK total (and breakdown by devolved countries and local authorities) than is possible from existing data.

4. ASSESSING DVC RISK BY SECTIONS OF THE TRUNK ROAD NETWORK

Identifying hotspots for, and assessing the relative 'risk' of DVCs for different parts of the trunk road network in a systematic manner is complicated by numerous influencing factors such as differences in traffic volume and speed, as well as single and multi-lane trunk road sections. To help assess the relative frequency of DVCs along different parts of the trunk network, in our past DVC studies for Scotland we overlaid Ordnance Survey grids of variable size onto the road network to determine the number of DVCs per e.g. 4 km by 4 km OS grid cells (e.g. see Figures 11 to 15 in Langbein, 2017 – CR 950; and Section 3, this report). Such maps provide a ready visual guide to gross differences in the distribution of DVCs, but use of such an arbitrary grid overlaid on the linear trunk road network has the drawback that it does not relate the number of DVCs to the actual length of trunk road falling within particular cells, which varies widely depending on whether the road runs centrally through a square or merely for a very short section. In addition, in some cases grid squares will contain sections from just one trunk road but in others more than one trunk road may be present, such as around road junctions, and as a consequence there can be widely differing total levels of traffic.

For the present contract it was therefore proposed to begin to develop some additional GIS based approaches and preliminary analyses in order to:

- identify the frequency of DVCs reported per km per year for each separate trunk route 'section' segment (mean length 1300 metres) used by Transport Scotland for management purposes;
- evaluate DVC frequency within each such section in relation to differences in average annual traffic flow, to calculate a relative index of 'DVC risk' for differing parts of the Scottish trunk road network.
- assess whether differences are apparent in habitat and possibly other roadside characters between those sections identified as of high, low or medium risk.

4.1 Approach

The SNH Deer-Vehicle Collisions (DVC) monitoring project has accumulated a total of 11,491 'reported' DVCs between January 2008 and December 2016. Of these, 5,919 occurred on the trunk road network (Figure 1) managed by Transport Scotland. Data for 2017 and 2018 were not available at time of this modelling work.

The trunk road network shape file was split into segments, according to the classification used by Transport Scotland for management of the network. Transport Scotland also provided detailed information about average daily traffic flow for different routes and segments. The average length of the segments into which the network is divided is 1.3 km (± 0.02 SE). Each segment has its own specific reference number. We assigned any reported incident to one of these pre-defined road segments wherever possible. If insufficient locational data was available for a given incident, we assigned it to the nearest segment within a threshold of 150m.

For each road segment we calculated a normalized DVC risk index, by the following formula (as applied previously by Nelli *et al*. 2018):

$$Risk = \text{logit}\,\frac{DVC}{AADF \times L}$$

Where DVC is the average number of DVC between 2009 to 2016, AADF is the average annual daily traffic flow between 2008 to 2016 and L the segment length. We excluded 2008 from risk analysis because equivalent traffic data by trunk segment were not available.

In the case of motorways and dual carriageways, adjacent lengths of road in opposite directions are considered in the Transport Scotland shape file as individual segments. Adjacent segments in opposite directions are not necessarily of identical length and start / end points, and hence are not readily combined. However, this was not problematic as the average annual daily traffic flow (AADF) data, was available as a separate value for each direction on dual carriageways and in the majority of cases DVC data were sufficiently detailed too. For standard A-class single lane trunk roads, AADF values do represent traffic in both directions.

Therefore, the risk-index calculated is based on traffic in one direction only for dual carriageways and motorways but on traffic in both directions for normal A-single roads. Halving the AADF value for standard A-class single lane trunk roads will however reduce the likelihood of over representing the risk where deer casualties on both verges are included in the calculation.

The risk index calculated was then scaled from 0 to 1 and used to classify each segment of the trunk road network into one of five different categories (0.0 - 0.2: low risk, 0.2 - 0.4: medium-low risk, 0.4 – 0.6: medium risk, 0.6 – 0.8: medium-high risk, 0.8 – 1.0: high risk).

4.2 Results

4.2.1 DVC risk index in relation to traffic flow and DVC rates per km

The initial work of the DVC risk analysis was based on using all trunk road DVC records available for the eight-year period 2009 to 2016 inclusive.

By way of background to the data available for each road, Table 11 shows the number of DVC reports per road per year, as well as the average DVC/km rate and average risk index per road calculated on the full length of each separate road for the period 2009 to 2016 inclusive.

Based on the entire length of each of the different trunk roads, the average ‘reported’ DVC/km rate ranged from 0.00 (on the A972) to a max of 0.50 (on the A701), whereas the average risk index ranged from 0.00 (on the A972) to a maximum of 0.893 on the A894 (Table. 11).

Table 11 highlights the five trunk roads with highest average DVC index, and reveals the relatively stable number of DVC reports for each road across years in most cases; one main exception being the A701 where high annual incidents for many years have reduced significantly since 2012. Figures for the A92 by contrast have increased significantly. However, these figures for routes taken as a whole are provided mainly for context here, as due to the great differences in total road length between routes, hotspots are relatively diluted for longer roads.

Table 11. Number and rate of DVCs per km recorded by year on different major trunk routes between 2008 and 2016. Red and green cells highlight respectively the worst and the least affected five roads based on average DVC/km and averaged DVC risk index assessed over the entire road length. In the case of dual carriageways, road length refers to the sum of all road sections in both directions. (Numbers are presented here mainly for background context only, as due to the large differences in total length between routes, hotspots are greatly diluted in the case of longer roads)

Road	Average DVC/km	Average risk index	Length (km)	DVC counts								
				2008	2009	2010	2011	2012	2013	2014	2015	2016
A1	0.19	0.31	139	5	14	23	12	56	32	32	26	32
A6091	0.07	0.17	8	0	0	3	1	1	0	0	0	0
A68	0.08	0.18	82	7	4	8	10	7	8	5	5	3
A7	0.03	0.09	76	1	2	2	1	2	4	4	3	1
A701	**0.50**	**0.39**	30	17	24	22	29	13	6	7	6	8
A702	0.04	0.12	58	2	2	2	4	5	3	1	0	1
A720	0.12	0.14	55	3	2	2	1	19	7	7	4	13
A725	0.09	0.11	46	4	3	5	3	8	3	2	5	3
A726	0.03	**0.07**	30	0	1	0	0	0	0	0	2	5
A737	**0.23**	0.21	43	3	7	14	9	12	3	16	10	16
A75	0.12	0.24	163	15	30	31	24	28	11	7	12	19
A751	0.16	0.28	3	0	0	1	1	1	0	0	1	0
A76	**0.03**	**0.08**	90	1	3	2	2	1	2	6	0	4
A77	0.11	0.19	139	12	11	15	19	14	12	13	16	27
A78	0.16	0.21	102	7	10	17	18	25	6	18	23	19
A8	0.07	**0.06**	59	4	2	4	3	7	2	12	2	2
A82	0.16	0.30	277	36	47	60	28	36	46	47	56	49
A828	0.07	0.23	42	6	9	4	0	2	3	2	1	1
A83	0.10	0.31	164	16	15	28	7	17	25	12	22	11
A830	0.10	**0.35**	66	5	5	15	0	7	12	4	9	2
A835	0.16	**0.38**	79	17	12	21	1	8	12	18	13	11
A84	0.14	0.28	45	8	8	15	3	9	4	3	7	2
A85	0.14	0.31	140	29	21	29	7	17	23	17	16	22
A86	0.03	0.24	65	0	1	3	0	2	4	5	2	3
A87	0.04	0.14	161	9	8	3	2	2	8	7	5	9
A876	0.16	0.16	8	0	2	0	0	0	1	3	2	4
A887	**0.02**	0.23	24	0	1	2	0	0	0	0	0	1
A889	**0.02**	0.18	14	0	0	0	0	1	1	0	0	0
A898	0.14	0.13	8	2	1	2	1	0	0	1	2	1
A9	0.19	0.30	521	60	96	102	77	94	135	115	126	91
A90	0.11	0.14	411	30	53	47	46	49	38	52	48	44
A92	0.22	0.22	97	22	12	9	9	11	32	29	36	34
A95	0.04	0.23	75	2	6	3	1	3	2	5	4	2
A96	0.08	0.12	186	10	12	20	15	10	19	16	18	12
A972	**0.00**	**0.00**	4	0	0	0	0	0	0	0	0	0
A977	0.05	**0.06**	5	0	1	0	0	0	0	0	0	1
A985	0.16	0.22	23	4	2	1	1	8	2	5	4	7
A99	**0.02**	0.12	27	0	0	1	0	0	0	2	1	0
M73	**0.44**	0.21	34	18	18	14	13	26	5	23	10	6
M74	0.10	0.13	329	15	31	34	30	39	24	49	32	46
M77	0.20	0.20	67	8	16	15	15	21	10	7	11	17
M8	0.12	0.12	250	11	33	45	27	47	12	42	31	27
M80	0.21	0.19	84	19	20	15	13	22	21	10	16	24
M823	**0.41**	**0.46**	5	1	0	2	1	1	3	1	4	6
M876	**0.29**	**0.36**	30	3	2	9	9	15	10	8	11	13
M898	0.19	0.20	4	0	0	1	1	1	0	0	2	1
M9	0.19	0.16	117	13	27	25	33	26	16	21	16	18
M90	0.17	0.15	158	22	24	20	17	24	41	32	27	38

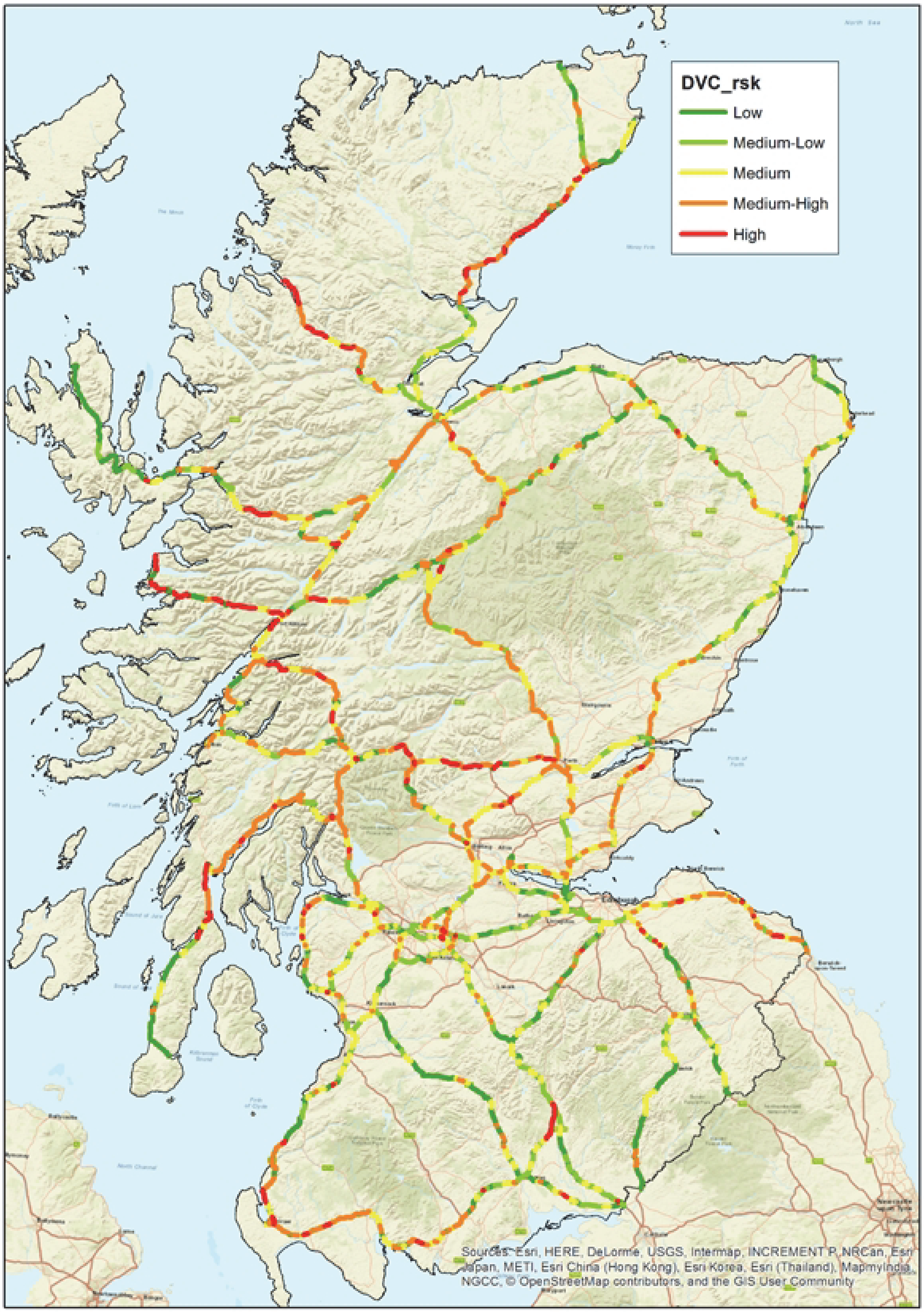


Figure 10. Global DVC risk index on trunk road network in Scotland, using data from 2009 to 2016 (Index takes into account differences in traffic flow as well as DVC/km; see text). ©Crown copyright [and database rights] 2018 OS 100017908

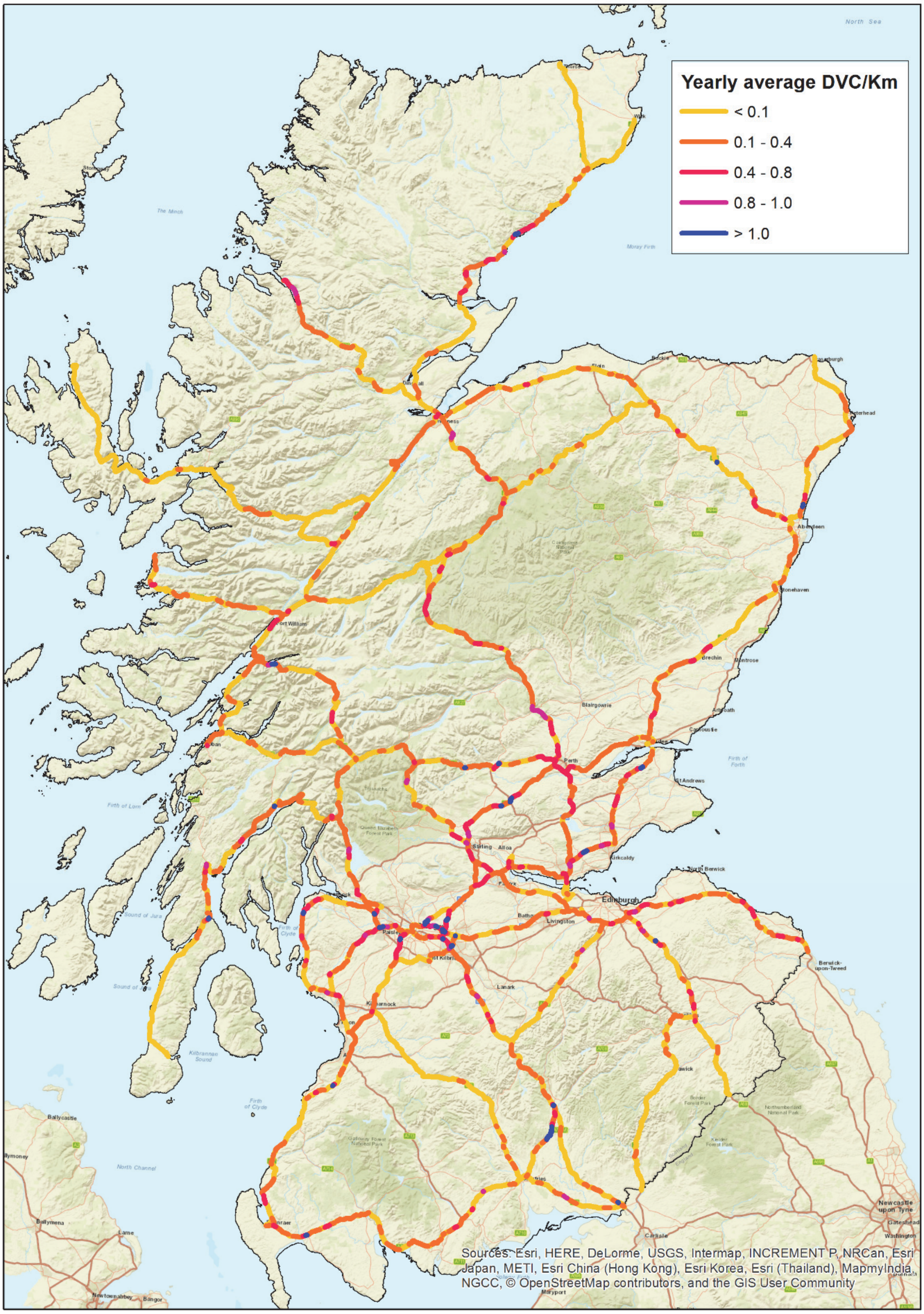


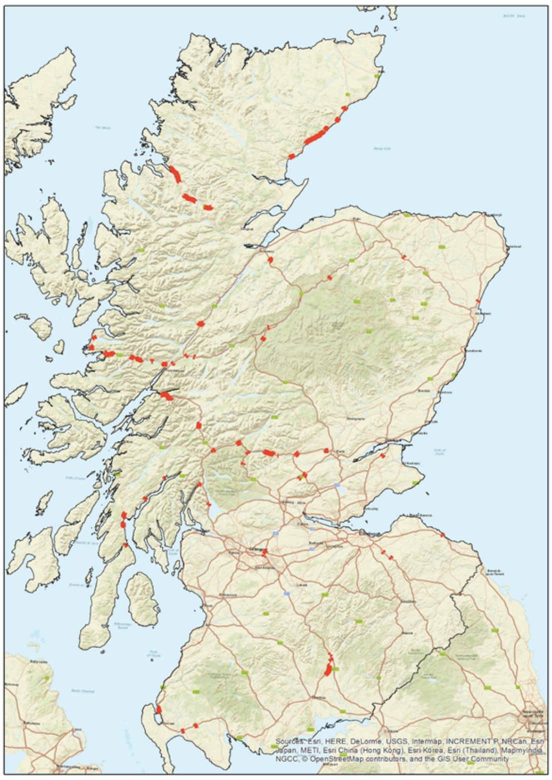
Figure 11. Yearly average DVC/Km 'reported' on trunk road network in Scotland, using data from 2009 to 2016 (not adjusted for differences in traffic). © Crown copyright [and database rights] 2018 OS 100017908

A network-wide overview map of DVC risk on trunk roads, based on the risk index calculated for the individual sections of each trunk road and adjusted for traffic flow, is provided in Figure 10. Figure 11, provided on the subsequent page, shows the DVC rates per km without the adjustment for traffic flow.

Note that Figures 10 & 11 may appear discordant to some extent. For some roads where a high number of DVCs were recorded, the DVC risk index (adjusted for traffic flow) may be low, as a result of division by a relatively high traffic flow. Conversely, roads where the number of DVCs recorded was high and traffic flow was low, show a high DVC risk index value.

Therefore, Figure 10 illustrates better the differences in the risk of a DVC to drivers, whereas Figure 11 better summarises where most deer casualties tend to be concentrated and hence shows the areas of highest overall risk to deer. Both are equally valid and useful; the first serves as a guide as to where the greatest benefit and returns in terms of road safety would occur from targeted DVC mitigation whereas the second one shows where the greatest benefit in terms of animal welfare would accrue from DVC reduction.

A series of additional maps are provided below and in ANNEX 1 highlighting only the top 100 and top 200 trunk road sections identified based on either i) the highest DVC index accounting for traffic flow differences (Figure 12 & Figure A.10) or ii) the highest DVC index when based only on the average number of DVCs per km (Figure 13 & Figure A.11). While areas highlighted by the average number of DVCs/km unsurprisingly highlight greater numbers of hotspots in areas of greatest traffic volume, especially throughout much of the Central Belt region, it is interesting to note that many of the same hotspots across the country remain included whether using either the DVC index or DVCs/km, in particular when extending consideration to the top 200 sections of highest risk (see Figures A.10 & A.11 - ANNEX 1).



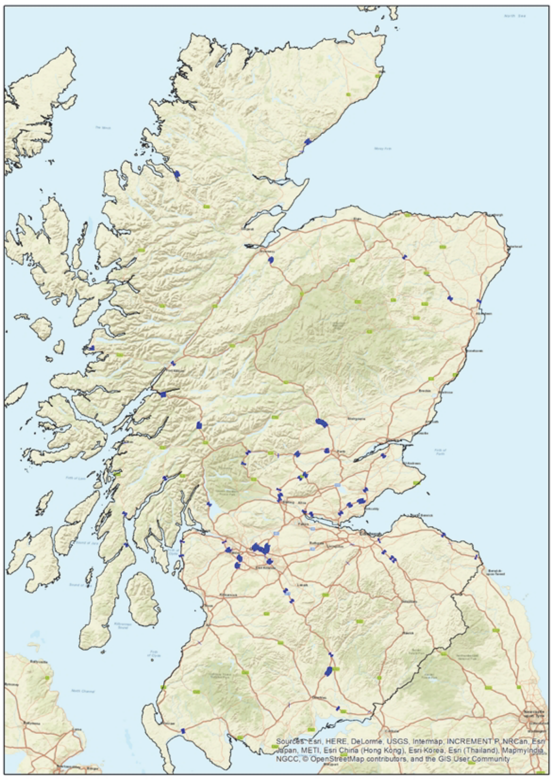


Figure 12. (left) Top 100 trunk road sections with highest calculated DVC Risk index.
Figure 13. (right) Top 100 trunk road sections with greatest average number of DVCs/Km. (see text). ©Crown copyright [and database rights] 2018 OS 100017908

4.2.2 Differences in habitat between low / medium / high DVC risk segments

Having identified the trunk road sections of relatively high / medium / low DVC risk discussed above, some further limited exploratory analyses were undertaken to assess the effect of the presence of differing road side habitats within different distances of the road on the risk category identified.

Three spatial scales were considered, at 200m, 500m, 1000m from the road. We used a non-parametric Kruskal-Wallis one-way analysis of variance for testing the differences in the proportion of each habitat category between trunk road sections in the low, medium and high DVC risk categories based on the risk maps derived previously. The habitat categories used were: broadleaf forest; conifer forest; arable land; improved grassland; semi-natural grassland; mountain, heath and bog; and built-up areas and gardens. The proportion of each habitat category to either side of our trunk road sections was derived from the Land Cover Map 2007 (Morton *et al*., 2011).

Broadleaf forest

Overall, road segments with a higher proportion of broadleaf forests were associated with a higher DVC risk at all three distances of 200m 500m and 1000m (*Kruskal-Wallis tests, respectively, P=0.025, P=0.002, P<0.001*) (Figure 14.a). At 200m the difference between medium and high-risk segments was however less evident.

Plots of the statistical out-put for the above as well as other habitat types considered in turn are shown in Figure 14 a to g, illustrating in each case the level and statistical significance of differences apparent from each comparison at different spatial scales.

Conifer forest

Results for conifer forest were similar to those above for presence of broadleaf forest. Road segments with a higher proportion of conifer forests were associated with a higher DVC risk at 200m, 500m and 1000m scales (Kruskal-Wallis P<0.001).

Arable land

The Kruskal-Wallis test showed that road segments with a lower proportion of arable land in the surrounding areas had significantly lower DVC risk (P<0.001). This pattern was essentially almost identical at all the considered spatial scales. This makes intuitive sense as higher amounts of agricultural crops near roads make it increasingly likely deer may cross the roads daily in some seasons to feed on maturing crops.

Improved grassland

Proportions of improved grassland were equal in low, medium and high DVC risk roads, without any significant difference at all the scales considered (Kruskal-Wallis tests for 200m, 500m and 1000m respectively P=0.600, P=0.614, P=0.168).

Semi-natural grassland

Road segments with a higher proportion of semi-natural grassland were associated with a higher DVC risk at all distances of 200m, 500m and 1000mm scales (Kruskall-Wallis tests respectively P=0.006, P<0.001, P<0.001). The increase of risk with the increase of proportion of such habitat was more evident when considering 500m and 1000m scales.

Mountain, heath and bog plants

Road segments with a higher proportion of mountain, heath and bog plants in the surrounding areas were associated with a higher DVC risk at all distances of 200m, 500m and 1000mm scales (Kruskall-Wallis tests P<0.001). At 200m the difference between medium and high-risk segments was however less evident.

Built-up areas and gardens
The Kruskal-Wallis tests showed that the proportions of built-up areas and gardens was significantly different between roads with low, medium, and high DVC risk (P<0.001). In particular, the a higher DVC risk was associated with a smaller proportion of built up area, at all the considered scales.

In summary, while deer are increasingly colonising peri-urban and built-up areas, the latter result indicates that in general urban areas are so far not associated with a higher DVC risk. Highest DVC risk remains associated most strongly with presence of woodland and other semi-natural habitats in the vicinity of major roads.

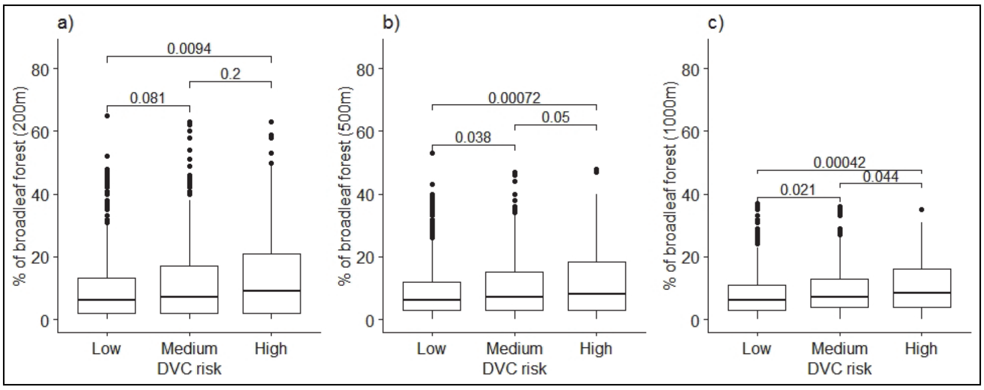


Figure 14.a Percentages of broadleaf forest around road segments and significance of pairwise Kruskal-Wallis tests at a) 200m scale, b) 500m scale, c) 1000m scale.

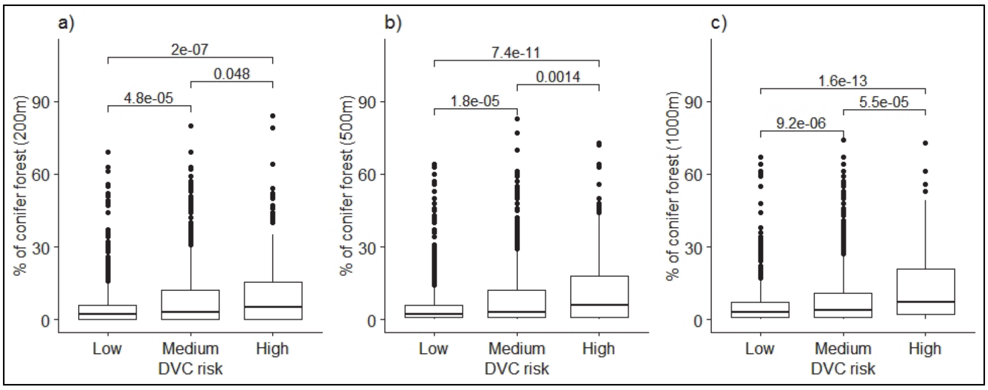


Figure 14.b Comparisons as above when based on Percentages of conifer forest.

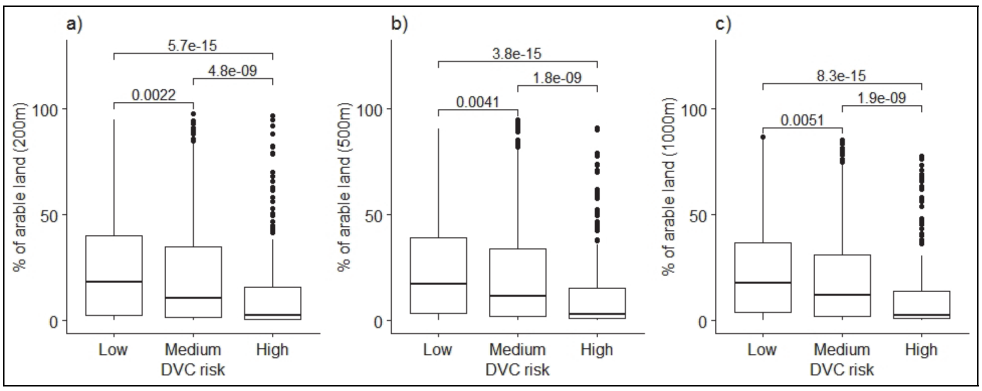


Figure 14.c Comparisons as above when based on Percentages of arable land

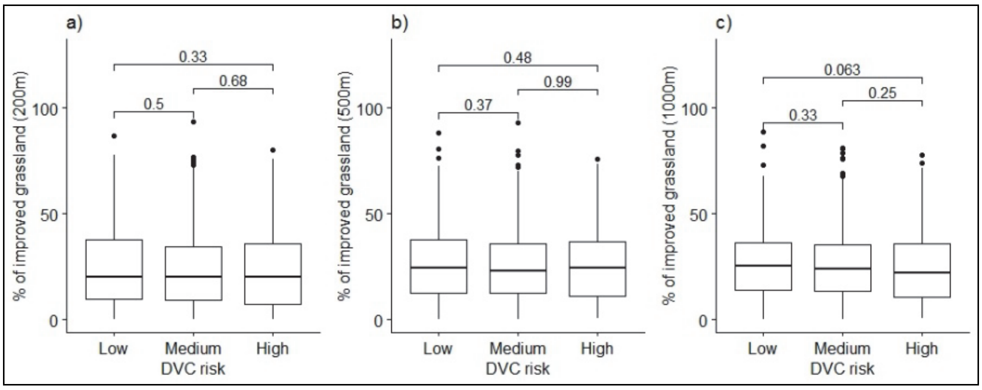


Figure 14.d Comparisons as below when based on Percentages of improved grassland.

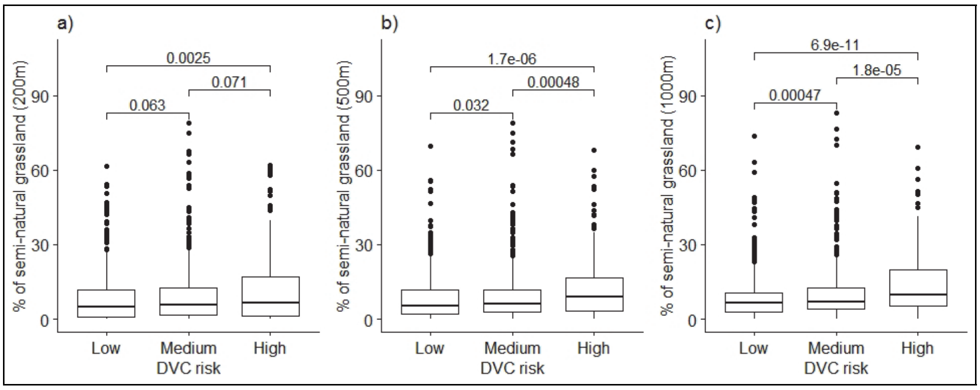


Figure 14.e Comparisons as below when based on Percentages of semi-natural grassland.

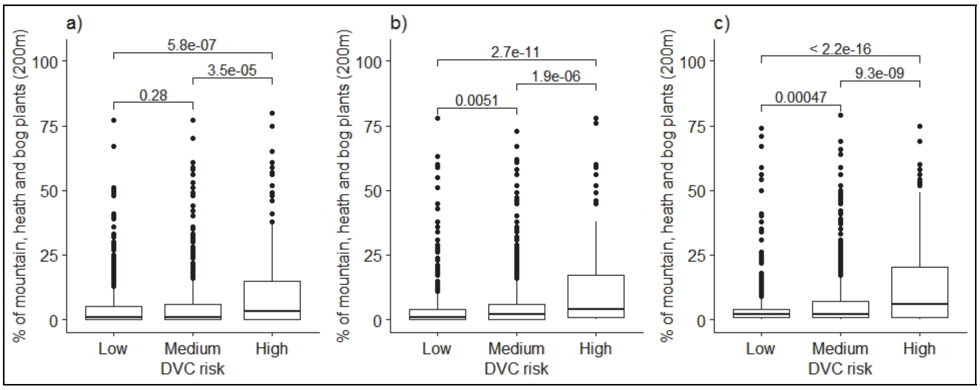


Figure 14.f Comparisons as below when based on Percentages of mountain, heath &bog.

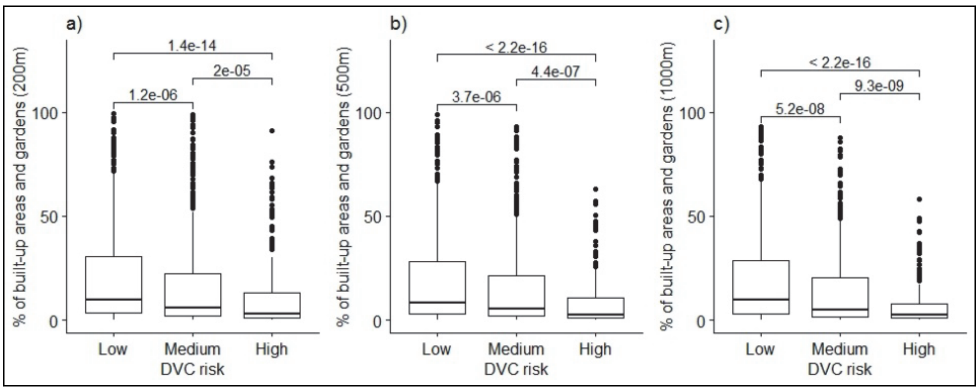


Figure 14.g Percentages of built-up areas and gardens around road segments and significance of pairwise Kruskal-Wallis tests at a) 200m scale b) 500m scale c) 1000m scale.

4.2.3 Additional findings from preliminary predictive modelling of DVCs based on traffic and environmental conditions

During our parallel studies collecting information on DVCs in England we have previously attempted to develop predictive generalised linear models (GLMs) for DVC occurrence on major roads (Nelli *et al*., 2018). These models were developed using a range of environmental variables and traffic conditions, as well as deer presence / absence data. In the case of DVCs recorded on the English trunk road network between 2008 and 2014 we were able to create predicative GLMs that could explain up to 82.6% percent of variation in the data available. Undertaking similar comprehensive modelling work for the present study lay outside the remit and resources available for the contract. However, some comparative predictive modelling was undertaken during 2017/2018 for a BSc Honours student project (Heckels, unpublished) on the same 2008 to 2016 data set of Scottish DVCs, used for our risk mapping outlined in *Section 4.2.1* above. The approach and some of the main findings from that exploratory modelling are briefly outlined below.

Generalised linear models, generalised additive models and generalised linear mixed effect models were explored to investigate the relationships between DVC occurrence on Scottish trunk roads and information about road characteristics, adjacent habitat and bioclimatic variables at three different spatial scales. Of these the generalized additive modelling produced the best fit, though it explained only between 36% and 37% of the variability in the data at the scales considered. The residual variability in these models was not however characterised by highlighting spatial hotspots of DVCs, but instead showed an increasing gradient in the number of DVCs from the northwest to southeast of Scotland, most likely influenced predominantly by the increase in traffic volumes along that bearing. Heckel (unpublished) concluded that, in contrast to England (Nelli *et al*., 2018), where a broadly similar approach had been taken, neither the distribution of deer nor distribution of DVCs was adequately explained by any of the predictive models produced so far for Scottish trunk road DVCs.

An unexpected result from this project was that the posted speed limit (PSL) was not found to have a significant impact on the number of DVCs at any spatial scale, despite the wide range of motorways, A-dual and A-single road sections within the Scottish trunk network. This was in contrast to some past studies in the literature that have found speed to be an important contributing factor to DVC risk (Ng *et al*. 2008, Zuberogoitia *et al.,* 2014, Meisingset *et al*., 2014). Bisonette & Kassar (2008), however, also found that while posted speed limits may be a useful explanatory variable, predictions limited to average annual daily traffic (AADT) and / or PSL tend to produce unreliable results. It is likely also that limiting modelling to incidents on the trunk road network, where the PSL is either 60 or 70 mph for the majority of road segments, with only some localised reduction, means the range of the PSL may have been too narrow to show an effect. The inclusion of minor roads in the models could help address this issue, although DVC data available for minor roads tends to be far less comprehensive and of lower location accuracy and traffic flow figures not always readily available.

In conclusion, in contrast to the findings from a broadly similar approach taken by us in England (Nelli *et al*., 2018), neither the distribution of deer nor DVCs was adequately explained by the initial predictive models produced to date (Heckels, unpubl.) for our Scottish trunk road DVC data. The relatively low explanatory power of the models created suggests environmental conditions restrict deer distribution to a lesser extent across Scotland than in England, and that to improve their predictive power, information on at least relative deer density in different areas would need to be incorporated.

5. DISCUSSION AND RECOMMENDATIONS ARISING

The SNH DVC Data collection and collation project is currently in its 11th year. It has attempted to collect information on deer road casualties and related traffic collisions in as comparable format as possible throughout the past decade. For the most recent 2016 to 2018 continuation contract, the main purpose of the work has continued to be "*to provide further monitoring and information to SNH, Transport Scotland (TS), Trunk Road Operating Companies (TROCs), local authorities and local deer managers to help prioritise allocation of resources and action to reduce risks to public safety and safeguard deer welfare*".

Primary outputs sought from the latest project included:

- Collection, collation and basic analysis by source type and region of new DVC records obtained for 2016 - 2018, based on the same core source organisations able to provide comparable records to past years (*Section 3*), and annual update of the DVC database each spring, including all new grid-referenced records for upload to the SNH Natural Spaces web site.
- A set of 29 pairs of OS grid overlay 'heat' maps (one for each Council or City Council boundary) showing relative DVC frequency and distribution of recorded incidents within each Local Authority, enabling ready comparisons of the distribution of hotspots and areas of lower DVC incidence between the first five years of the project (2008 to 2012) and the following five years (2013 to 2017) (ANNEX 2).
- A review of past DVC data for the Scottish trunk road network, taking into account differences in average annual daily traffic. To include OS grid-based presentation as in the past, but also the development of new approaches that enable assessment and mapping of the relative 'DVC Risk' per driven kilometre for particular segments of each road within the trunk network (*Section 4*).

Progress on DVC data collation, overall trends in DVC numbers and emerging changes in DVC distribution, and the limitations and difficulties of obtaining consistent information on DVC occurrence year on year are each reviewed and discussed in the sections below.

In addition, now that we are over ten years into the project, recommendations are made regarding the need, to: review the objectives of continued countrywide DVC monitoring; consider whether consistency of data input can be assured over the coming years; and agree whether the present monitoring scheme remains fit for purpose to meet future objectives.

An extensive volume of information is available on the numbers and distribution of areas of high, medium and relatively low DVC incidence at various scales. Greater consideration should now be given to how this information can be better utilised in order to help stimulate actions to prevent further increases in the number of deer involved in collisions and, ideally, begin to reduce the risk to public safety in known hotspots.

Continued national monitoring of DVCs is likely to remain valuable to SNH and stakeholders for a range of purposes. However, the monitoring programme should be reviewed periodically and, if necessary, modified to ensure the data collected are as useful as possible for objective assessment of the effectiveness of any regional or localised measures that are taken to minimise the frequency of collisions such as: raising public awareness of DVCs at high risk times or locations; installing roadside measures (e.g. fencing, signage, verge clearance, deterrents) or undertaking deer management.

5.1 Progress of data collection and collation

Data collection during the latest contract period (2016 to 2018) has continued mostly along the same lines as in past years. Some small additions were made to the list of data contributors in an attempt to increase the volume of data from sources able to provide reliable information on the species of deer. The updated SNH DVC database now includes over 17,250 mapped incident records for the period 2008 to 2018. Of these, just fewer than 16,000 were supplied by the four core source types that provide our most consistent sampling across Scotland. A further 7000 Scottish records for which at least approximate map references have been allocated are available for 2000 to 2007, when data were collected from more diverse sources.

Regular annual input of DVC records has been obtained for the latest years not only from the four main Trunk Road Operating Companies, but also for all the six smaller DBFO companies, not all of which had provided records consistently at the beginning of the study in 2008, or were even in existence (e.g. Aberdeen Road Ltd for AWPR). Together, the above sources have provided sampling coverage across all roads forming the Scottish trunk road network, with broadly comparable records now available for the network from 2008 through to 2018. Data from call-out requests received by the SSPCA and FLS rangers to attend to deer injured in DVCs have also been obtained annually in a comparable manner and incorporated to the database for all of these eleven years.

While the two largest data suppliers (TROCs and the SSPCA) rarely provide reliable details on the deer species involved in DVCs, such information is available from the smaller, regular data sets provided from FLS rangers and through the more occasional input by SNH deer officers and other 'deer-knowledgeable' people when recording their deer road casualty sightings. In addition, for 2016 to 2018 species-specific DVC records were provided for the first time via the Mammal Society from records submitted to their Mammal Mapper smart phone APP.

One key gap in relation to data collection for recent years continues to be the paucity of accessible information on DVCs that lead to personal human injury accidents (PIAs). Although these incidents are the only collisions with deer that are likely to be recorded in a consistent manner by the police, they remain difficult to access and extract from official accident statistics. As the species of wild animal implicated as having led to a collision is not recorded as part of the official STATS19 form used for compiling national statistics on injury road accidents, obtaining this information involves making a direct request to each of the eight legacy Scottish police forces or council road safety teams. To date this has provided data coverage for only half of Scotland in most data years, leading on average to information on just 30 such injury accidents reports each year. More recently Transport Scotland's road accident statistics section have helped to consolidate our records on human injury DVCs retrospectively back to 2013, but they too have so far only been able to obtain useable (deer specific) PIA records for six of the eight legacy force areas. Nevertheless, based on the currently limited information, we may confidently estimate that during the past ten years of the project there will have been over 400 PIAs in which deer have been implicated, including close to 100 people killed or seriously injured (KSI). Present information available includes at least three fatal accidents where a deer was implicated in the last three years, one in each of 2016, 2017 and 2018.

Information on the true numbers and hence trends in PIA incidents in which deer are implicated are unlikely to be obtained in a consistent manner across all of Scotland unless steps are taken to add deer as a specific item on the official STATS19 road accident recording form; as is the case for e.g. dogs and ridden horses, but not for any wild animals.

5.2 Basic analysis, trends and distribution of DVC occurrence

5.2.1 Evidence for DVC Trends

The annual total of records available from all our core data sources has risen steadily since 2008 (<1,000) to 2012 (>1,500), declined slightly in 2013 & 2014, before rising to a high of over 1,900 in 2017 (Table 2). In the most recent data year (2018), however, there has been a decline in records from both the SSPCA and from three of the four largest TROCs.

In the case of the SSPCA, the reduction in data in the latest year is attributable mainly to more restrictive general data protection regulation (the GDPR) introduced in 2018, which have reduced the detail passed on to us for each incident compared to previous years; thus reducing our ability to identify DVCs not already logged at source from among all the deer incidents handled by the SSPCA. In contrast to other recent years, when the number of reported incidents had continued to increase year on year, this has led to a reduction from 1,255 mappable SSPCA DVC reports in 2017 to 1,102 in 2018. However, the underlying trend based on the proportion already logged at source as road traffic collisions is that the actual frequency of DVC incidents reported may have started to level off but without sign of any significant decline.

In the case of TROCs, however, where DVC reports have declined by about 10% compared to previous years, it is more likely to reflect an actual reduction in numbers of deer casualties on the trunk network in this latest year, as similar declines are notable for three of the four main TROCs in 2018, with a decline in the case of a fourth already noted in 2017 (see Figure 2).

In addition to the breakdown of data by source types and mapping to help identify hotspots the figures and tables prepared for this report generally include, comparisons between the first five years and subsequent five years of the project. It is apparent from those comparisons that the overall pattern of DVC distribution has remained broadly similar for both periods. Over the 10 years the average annual numbers of mappable DVC records from our core sources for the five years for 2013 to 2017 (1,616) have increased by 33% compared to the previous five years (1,204) and levelled off to some extent in 2018 (1,688). The greatest overall increase in DVCs over recent years has continued to occur particularly in Aberdeenshire, Fife and The Central Belt, but with notable increases also in north and west Scotland: including e.g. on the A9 north of Inverness towards Helmsdale. After a fall in incidents around 2011 to 2012, more recent records indicate a return to rather higher DVC occurrence along parts of the A835 and A830.

Data from the SSPCA had increased year on year since 2009, with just one exception (2014) before another large increase in data from 2015 onwards. Improved computer storage and extraction may have contributed to some extent to this increase, as may the overall expansion in population ranges by deer, especially in Lowland Scotland and the urban fringes over recent years. Whilst at the outset of the project it was feared that the SSPCA's coverage might possibly be rather limited outside of peri-urban and urban areas, it has been particularly encouraging that a significant number of their records have been obtained from right across all of the 29 mainland local authorities (Table 6; Figure 2, Figure 6).

A significant increase in the number of people carrying smart phones over recent years has contributed to an increase in the overall number of calls to the SSPCA's national animal helpline. As a consequence, the proportion of all deer incidents that are likely to be reported to the SSPCA since our project began in 2008 is likely to have increased to some extent without there being an underlying increase in DVC occurrence. This could occur because people nowadays are more readily able to search for contact information e.g. the SSPCA's helpline while at the scene of an incident, when previously they might possibly have called the police or not bothered calling anyone at all. According to Ofcom, 2008 was the year the smartphone took off in the UK. With the iPhone and Android fresh into the UK market, only 17% of people owned a smartphone at that time, but this has now reached 78%, and 95% among 16-24 year-olds (Ofcom.org.uk, August 2018).

The extent to which increases in the number of SSPCA records represents a real rise in DVC incidents, rather than our sampling being able to pick up an increased proportion of incidents is difficult to assess. The fact that TROC reports and also FLS rangers call-outs to deer injured in DVCs have remained relatively stable over the past decade, with possibly even some indication of a decline in the last one to two years, suggests the increasing trend in the SSPCA data should be interpreted cautiously.

5.2.2 Diurnal and seasonal distribution and species involved

Analysis of diurnal patterns of DVCs for the year as a whole, as well as in separate seasons, has consistently shown early morning peaks in incidents between 06:00 to 09:00 hrs, and an even higher peak from early evening through to midnight (18:00 to 24:00; Figures 7 & 8). Re-examination of these data including information for the most recent years shows that these patterns continue to hold true. As might be expected, as a result of shorter daylight, the evening peak in DVCs occurs earliest during winter and latest during summer.

Seasonal patterns of Scottish DVC occurrence and how these vary by road types and regions were discussed in some detail in an earlier report (see Langbein 2011, section 5.3) and re-examined and updated in section 3.6.2 of this report. In general a prominent peak in DVCs occurs every May through into early June on all road types throughout Scotland. That peak continues to be most pronounced for motorways, where over 55% of annual incidents occur during those two months alone, followed by A-class trunk roads (35%) (Figure 9; Table 9). An additional prominent autumn peak and generally wider spread of DVCs across the year is in the main apparent only for NW Scotland and some other localised areas where the populations of large deer species (red, Sika and fallow) are greater.

On the basis of the seasonal patterns, two public-awareness DVC media releases by SNH and Transport Scotland have targeted these incident peaks every spring and autumn over the past ten years. The media campaigns have been backed by concurrent seasonal use, on selected parts of the network, of roadside Variable Messaging Signs (VMS) displaying messages at peak times alerting drivers to the high risk of deer on the road. Given these sustained awareness-raising initiatives each spring and autumn, we postulated that the prominence of these annual peaks would start to reduce relative to other months. However, examination of the seasonal patterns during three successive three- or four-year periods since 2008 (Table 9) show no clear evidence of a change in the prominence of either the late spring or autumn DVC peaks. That no clear effects are readily apparent from this gross analysis of national figures is not to say that such awareness raising may not nevertheless have more significant effects at a regional or more localised level. To assess the impact of the awareness raising more fully a more in-depth investigation would be required of the routes, dates and diurnal periods targeted by the VMS messaging and media campaigns. In addition to DVC occurrence, such an investigation would need to look at other measurable effects too, such as increases in public or driver awareness of DVC risk that could be established through interview or questionnaire type approaches.

Reliable information on the deer species involved remains available for less than 8% of all our DVC records for the last eleven years. A breakdown by council areas of the proportional representation of different deer species among the species-specific records (Table 10) shows confirmed incidents with roe deer in 17 council areas. Red deer have only been regularly confirmed as involved in and making up a significant portion of DVCs in seven council areas, primarily Highland, Argyll & Bute, Stirling and North Ayrshire. Sika have also been recorded in DVCs in the first two of these areas. Fallow deer feature in DVCs mostly in Dumfries & Galloway and Perth & Kinross. Roe are likely to be the predominant species involved in most of the other councils where we currently have few or no species-specific DVCs currently logged. The Mammal Society's Mammal Mapper APP has enabled us to increase DVC records with 'reliable' species information to some extent. In addition, development by the British Deer Society (BDS) of their own Smartphone APP for recording deer sightings is due to be launched during 2019 and may have the potential to contribute additional records of DVCs with reliable species detail. We are discussing with BDS ways to maximise the potential of their APP to assist with national DVC monitoring, for example by highlighting the importance of being able to distinguish between deer road casualties and other deer sightings, and by encouraging members to submit regularly the majority of deer casualties that they observe for at least one or more full years.

5.2.3 National estimates

Estimation of the total number of DVCs that occur annually across Scotland was not a specific project objective and the present sampling regime design and subsequent records are not well suited to such extrapolation. However, as this question is regularly raised by the media, some cautious minimum countrywide estimates were discussed in *Section 3.8.2*.

Recently updated but still incomplete information on PIAs reported to the police, which are likely to represent no more than 1% of all DVCs (as discussed in *Section 3.5.2*), allow only a vague estimation of the true number of all DVCs. Including all deer casualties, without or with damage to vehicles, it is highly likely that there are no fewer than 4,000 DVCs across Scotland and may well be nearer 12,000 per year.

Alternative estimators suggest that trunk road reports are unlikely to represent any more than 50% and quite likely as few as 20% of the actual number of deer casualties on the trunk network (see 3.8.2). Applying these proportions to the average annual number of TROC records for the Scottish trunk network during the most recent three years (610), provides estimates of from 1220 to 3050 actual deer casualties on Scottish trunk roads per year. This in turn would translate to cautious estimates of from 3660 to 9150 DVCs countrywide if upscaling to the road network for Scotland as a whole on the basis of relative traffic volume, for which a clear relationship was evident from our past research (Langbein & Putman, 2006; Langbein, 2011).

In considering estimates based on reported deer road casualties alone, it should be borne in mind that a deer casualty is actually likely to arise from fewer than half of all traffic accidents in which deer are involved. In more than 50% of incidents logged by police where deer are implicated in either a damage-only or human injury accident, the drivers' report having swerved or lost control of their vehicle due to deer being on the road before then colliding with another object or vehicle. On that basis even the higher end estimates discussed above are likely to be quite conservative.

To put our estimates into context, Austria – a country just 1.07 times larger than Scotland by area and of a similar predominantly rural character, recorded on average close to 40,000 DVCs per year between 2010 to 2015 (KFV, 2015). This figure is restricted mainly to roe deer, which make up 52% of all large mammal roadkill in Austria, with additional smaller numbers of red deer, fallow deer, wild boar, and other smaller mammals. These traffic collisions with deer in Austria lead to around 125 human injury accidents per year including one to two fatalities (KFV, 2015). The approximate size of red deer population in Austria is around half that of Scotland (c. 150,000 vs. 350,000), but in the case of roe deer it is roughly twice as high (c. 750,000 vs. 300,000 in Scotland) (Burbaitė & Csányi, 2009; 2010). The comparatively high DVC statistics for Austria may be attributed foremost to better recording, as there is an obligation on drivers to report DVCs to the police, and a police log tends to be required by insurance companies in Austria as part of evidence when claiming for damage resulting from a collision with a wild animal. The above figures emphasise that even our higher end estimate of 12,000 DVCs annually within Scotland is likely to be a conservative figure.

Given that the introduction of compulsory reporting of DVCs for Scotland is unlikely, if SNH nevertheless wish to underpin and firm up the ability to produce more accurate countrywide and regional estimates, we suggest the best way to achieve this would be via a well-designed, large-scale questionnaire survey of motorists. As outlined further in *Section 3.8.3*, this might best be undertaken jointly with a major national motoring organisation, and be based around questions relating to involvement in accidents with any type of animal on the road, as this would remove bias towards deer. In addition, understanding the proportion and context of deer among other animal related accidents would itself be useful in interpreting the results of past studies and national accident statistics relating to animal hazards in general.

5.3 Recommendations for future monitoring and utilisation of existing information

Data on DVCs for the present project have now been gathered in a broadly consistent manner for eleven years, providing a database of substantial size and countrywide coverage. The general consistency of sampling across most years has been one of the main assets of the study. With the passing of time and significant changes in how organisations handle and store data in the digital age, it is however all the more important to ensure methods of data collection remain as comparable as possible into the future. There is a risk that minor changes in how data are recorded, and hence the volume of date retrievable, may mask true trends in DVC occurrence. In the event that DVC monitoring via SNH is to continue, we would make a number of recommendations as below.

5.3.1 Review of data collection, consistency across years and adequacy for the future

The total number of TROCs and DBFOs involved in managing the Scottish trunk network has increased in recent years. In addition, there have been changes to which companies manage different parts of the network, introducing potential changes to incident logging. However, thanks to staff of Transport Scotland all of the TROCs were consulted during 2017 and asked to provide details on their procedures and recording of animal carcasses and how these are handled on the network. This in fact confirmed that the approach and systems for doing so were actually much more in line with one another than we had expected. Nevertheless, going forward we would recommend that in future DVC records (and information on other animal road kills) are provided to the project via a senior ecologist or other environmental lead (as is already the case with some TROCs), rather than direct from a network control manager. This would enable some initial review of the information before it is passed on to the DVC project, ideally together with any information on whether and when any significant changes likely to have affected animal casualties / incident recording have occurred (e.g. major road improvements, new deer or sound barrier fencing, major scrub clearance, or significant changes in how animal carcasses are / are not removed from site).

Information gathered from the SSPCA has been discussed already in some detail in previous sections of this report. Records provided by the SSPCA continue to be the major and thus key source of widespread information, in particular for non-trunk roads, which are not sampled by input from TROC data. It appears that an increase in the number of records received from the SSPCA partly reflects a general increase in call volumes to animal cruelty helplines as result of increased smartphone use among the public. On the other hand, new data protection regulations (the GDPR) have reduced the detail of information from the call logs the SSPCA had previously been able to share with us. We would recommend that those taking forward future SNH DVC data collection should meet directly with the SSPCA to review how best to ensure all incident logs where a deer is known or is highly likely to have been injured or killed by a vehicle are recorded in a way that allows these to be readily identified and extractable, as they were prior to 2018, but in a manner fully compliant with GDPR.

Information on human injury collisions involving deer is a small but important sub-set of data, which to date has lacked countywide coverage. Improved coverage and regular extraction should continue to be pursued with TS and Police Scotland for future years, not least to see if comparable information can be obtained from regions where little past information on injury DVCs has been obtainable (Dumfries & Galloway and Strathclyde). However, the best way to ensure better information on actual numbers of human injuries relating from traffic incidents in which deer are implicated, would be if deer can be added by DfT as a specific category on the UK-wide STATS19 road accident recording forms, or else via a special study within Police Scotland's own data collation systems.

The proportion of all accidents in which wild animals are hit or involved as a hazard on the road continues to be greatly under-recorded, as neither human injury accident recording nor Insurance companies tend to record the type of animal involved. Even when accidents are reported to insurance companies by phone claims, most will simply be recorded via a tick-box as 'animal', without further detail on type of animal.

The advances and take-up by the public of digital technology does have the potential to provide new data sources for the project, including at times already georeferenced information where people reporting incidents have GPS phone access at the scene. The technology has led to increasing numbers of Citizen Science animal road-kill projects, and suggestion by others that these should be utilized more in the SNH DVC project in future. This is being taken forward through liaison with the Mammal Society and use of data from their Mammal Mapper APP, and liaison and data sharing with BDS on a similar deer sighting APP they are currently developing. These projects do have the potential to provide useful additional information on DVCs. However, with any such Citizen Science Approach careful consideration needs to be given to the likely high variability in quality of data, and in particular fluctuation in the numbers and spread of records that would be received. It is noticeable for example that our existing on-line DVC reporting facility for public data submission experiences surges in reports lasting just a few days after national or regional DVC related press releases are issued. Therefore, while Citizen science type sources are worth exploring, they need to be carefully considered and data collection needs to be combined and calibrated against other control sources able to provide more stable and reliable input year on year.

5.3.2 Utilisation of DVC Risk Maps by ROCs and other map outputs by Local Authorities

Initial work has produced preliminary 'DVC Risk maps' that help to identify more readily the level of DVC incidents for specific segments of the trunk road network. The output can be utilised readily to identify the top 50, 100 or more locations of consistently highest DVC risk from view of driver safety (after accounting for differences in traffic volumes), or else based on the relative levels of DVC/km per segment.

We would suggest that one or perhaps both approaches are utilized to decide on a number of initial DVC priority areas (perhaps one or more in each Trunk Unit), where Traffic Scotland together with TROCs could focus initial efforts to initiate consideration (in discussion with other stake holders such as deer managers / local authorities / SNH etc.) as to how some of the areas of highest DVC concern may best be tackled. In any priority areas where action is considered, local site visits would then likely to be needed to decide which of the wide range of different DVC mitigation measures available (see e.g. on-line overview table from

Langbein *et. al*. 2011) may be best suited to the type of road and local habitats in that area. In most cases it is likely that best results will be achieved from a combination of approaches, rather than reliance on any one single measure.

In addition, the risk maps prepared and changes in the total number or rate of DVC/km for specific trunk roads or sections within them (Table 11) can provide a basis for assessing the effectiveness of mitigation where it is undertaken. This could include, for example, retrospective examination of changes that have occurred in those years and areas of the TS trunk network where seasonal VMS '*high risk of deer on road*' messaging has been focussed, compared to other routes without such DVC mitigation efforts.

A further output requested from the present project were the 29 pairs of OS grid-based maps (one per council area) showing the relative distribution and hotspots of DVCs during the first and second 5-year periods of the SNH DVC data collation study (ANNEX 2). As in case of the trunk network above, we would suggest these details should be made readily available to each Local Authority, so that they have ready access to this information, so as to help inform and initiate local DVC reduction strategies. Here again action might best be taken forward by selection of initial DVC priority areas, and possibly be evaluated by Councils in relation to others complementary needs identified in the same locations for other reasons (e.g. traffic calming, sight lines etc.). The maps may in the first instance simply be made available for viewing and download on-line from the SNH website. In addition, we would suggest it could be useful to develop an interactive on-line map based on the background shape file of DVCs, so that users can zoom in to inspect areas of particular interest at finer scales.

As in the case for trunk roads, if and where priority areas for action on DVCs within any local authority are identified, it may be best to set up a local panel / working groups including e.g. Local Authorities, Transport Scotland, DMGs and British Deer Society and SNH Wildlife Officers, to decide on the best joined-up approach; i.e. as above for trunk roads, to combine as appropriate action on deer management, with habitat management, other road side measures, and public / driver awareness, rather than reliance on a single measure.

6. CONCLUSION

Following 11 years of DVC data collection and collation in Scotland, generating over 17,000 mapped records, an extensive information base showing the distribution of DVCs by regions, council administrative areas and more localised areas across mainland Scotland now exists. Maintaining monitoring on the number and distribution of DVCs using the best available indicators may continue to be of value. However, over a decade into the project, it is important to review whether past data sources are able to provide consistent and comparable information into the future. Any continuation of monitoring should not be undertaken for its own sake but be designed and adapted to ensure that it remains fit for purpose for future objectives, including objective assessment of the effectiveness of DVC reduction strategies where these can be implemented.

Most importantly, consideration should be given now as to how the extensive information already gathered can best be used to help stimulate practical actions to reduce DVCs. That is both to bring the issue in general to greater attention among road authorities and other decision makers, and also to begin to address at least some of those areas where the highest incidence of DVCs has consistently been identified. Using the existing database, the mapping of DVC hotspots by council areas and the generation of a relative risk rating for segments of the trunk road network that takes into account differences in traffic flows, already provide a basis to help guide and prioritise where mitigation action may achieve greatest road safety benefit and where the likely limited resources available to address this widespread issue may best be targeted. It is hoped that this study can be used to initiate greater action not only to prevent still further increases but ideally to begin to reduce the numbers of DVCs and associated risk to public safety.

7. REFERENCES

ADAC, 2015. Wildunfälle. Table 9.6 (On-line statistics of reported road accidents with wild game 1975 – 2015 based on official German Bundesamt national accident statistics). Available at: https://www.adac.de/_mmm/pdf/statistik_9_6_wildunfaelle_42885.pdf

Apollonio, M., Andersen, R. & Putman, R. eds. 2010. European Ungulates and their Management in the 21st Century. Cambridge University Press, Cambridge, 604 pp.

Bissonette, J.A., Kassar, C. and Cook, L.J. 2008. An assessment of costs associated with deer-vehicle collisions: human death and injury, vehicle damage, and deer loss. *Human–Wildlife Conflicts,* 2, 17-27.

Burbaitė, L., & Csányi, S. 2009. Roe deer population and harvest changes in Europe. *Estonian Journal of Ecology*, 58, 169-180.

Burbaitė, L., & Csányi, S. 2010. Red deer population and harvest changes in Europe. *Acta Zoologica Lituanica,* 20, 179-188.

Dandy, N., Ballantyne, S., Moseley, D., Gill, R. and Quine, C. 2009. The Management of Peri-Urban Roe Deer in Scotland. Report of the Forest Research Agency of the Forestry Commission.

DJV (Deutscher Jadgschutz Verband), 2010. Daten und Fakten zu Wildunfällen in Deutschland. Wildunfallgeschehen – Bilanz 2009.

DJV (Deutscher Jadgschutz Verband), 2011. Wildunfall-Statistik 2010/2011.

Hartwig, D. 1991. Erfassung der Vekehrsunfälle mit Wild im Jahre 1989 in Nordrhein-Westfalen im Bereich der Polizeibehoerden. Zeitschrift fuer Jagdwissenschaft, 37, 55-62.

Heckels, A. 2018. The Use of Predictive Modelling to Assess the Risk of a Deer-Vehicle Collision Under Varying Environmental and Traffic Conditions. BSc Zoology Investigative Honours Project. University of Glasgow. Unpublished.

KFV, 2015. Wildunfälle in Österreich. Kuratorium fuer Verkehrssicherheit (*Austrian board for Transport Safety).* Available at: Wildlife Collisions summary table).

Langbein, J. & Putman, R.J. 2006. National Deer-Vehicle Collisions Project: Scotland 2003 to 2005. Report to the Scottish Executive, June 2006. Available at: http://www.deercollisions.co.uk/web-content/ftp/DVC_Scot_Final_MainComb.pdf

Langbein, J. 2011. Deer Vehicle Collisions in Scotland Monitoring project 2008 – 2011. *The Deer Initiative Research Report 11/2.* The Deer Initiative, Wrexham. Available at: https://www.nature.scot/sites/default/files/2018-05/Deer-Vehicle-Collisions-Project-2008-2010.pdf

Langbein, J. 2013. Deer Vehicle Collisions in Scotland Monitoring 2008-2012. End of contract Report. The Deer Initiative, Wrexham. Available at: https://www.nature.scot/sites/default/files/2018-05/Deer-Vehicle-Collisions-Project-2008-2010.pdf

Langbein, J. 2017. Deer-vehicle collisions in Scotland: data collection and collation to end 2015. *SNH Commissioned Report 950.* Scottish Natural Heritage. Available at:

https://www.nature.scot/snh-commissioned-report-950-deer-vehicle-collisions-scotland-data-collection-and-collation-end-2015

Meisingset, E. L., Loe, L. E., Brekkum, O. & Mysterud, A. 2014. Targeting Mitigation Efforts: The Role of Speed Limit and Road Edge Clearance for Deer-Vehicle Collisions. *Journal of Wildlife Management*, 78, 679-688.

Morton, D., Rowland, C., Wood, C., Meek, L., Marston, C., Smith, G., Wadsworth, R. & Simpson, I. C. 2011. Final Report for LCM2007 - the new UK Land Cover Map, *Countryside Survey Technical Report,* 11/07.

Nelli, L., Langbein, J., Watson, P. and Putman, R. 2018 Mapping risk: quantifying and predicting the risk of deer-vehicle collisions on major roads in England*. Mammalian Biology*, 91, pp. 71-78. Available at: https://doi.org/10.1016/j.mambio.2018.03.013

Ng, J.W., Nielsen, C. & St. Clair C.C. 2008. Landscape and traffic factors influencing deer–vehicle collisions in an urban environment. *Human–Wildlife Conflicts,* 2, 34-47.

OFCOM, 2018. *UK Communications Market Report 2018. OFCOM, UK.*

SNH, 2019. Lowland Deer Panel Report to Scottish Natural Heritage. February 2019. Scottish Natural Heritage. 95pp. Available at: https://www.nature.scot/report-lowland-deer-panel-2019

Statistik Austria, 2018. Fallwild 2017/2018: Haarwild (Rot-, Reh-, Gams- und Muffelwild) nach Bundesländern. Bundesanstalt Statistik, Vienna.

Zuberogoitia, I., del Real, J., Torres, J., Rodríguez, L., Alonso, M., and Zabala, J. 2014. Ungulate Vehicle Collisions in a Peri-Urban Environment: Consequences of Transportation Infrastructures Planned Assuming the Absence of Ungulates. *Plos One*, 9, e107713.

ANNEX 1: ADDITIONAL FULL PAGE MAPS REFERRED TO MAIN REPORT

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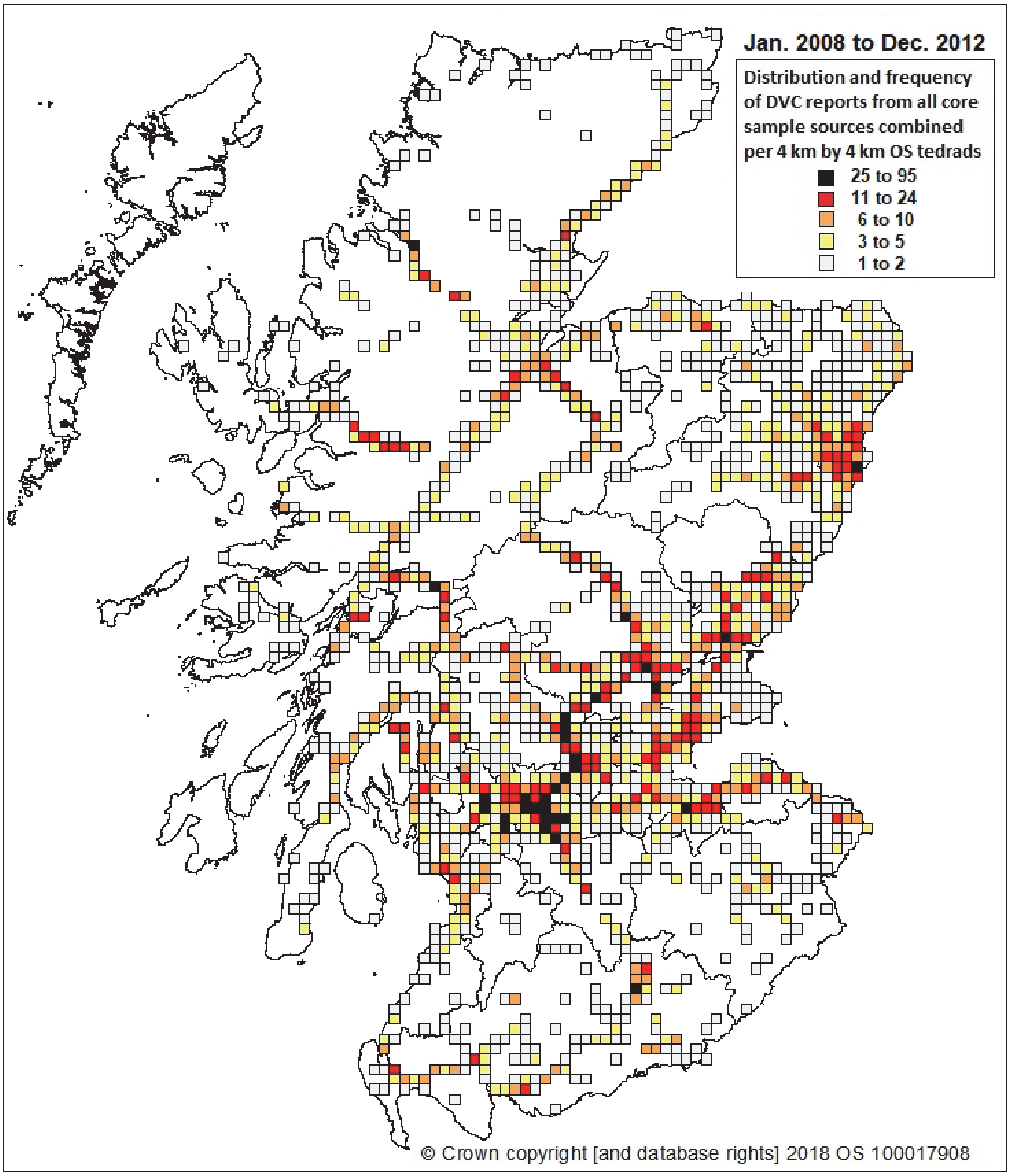

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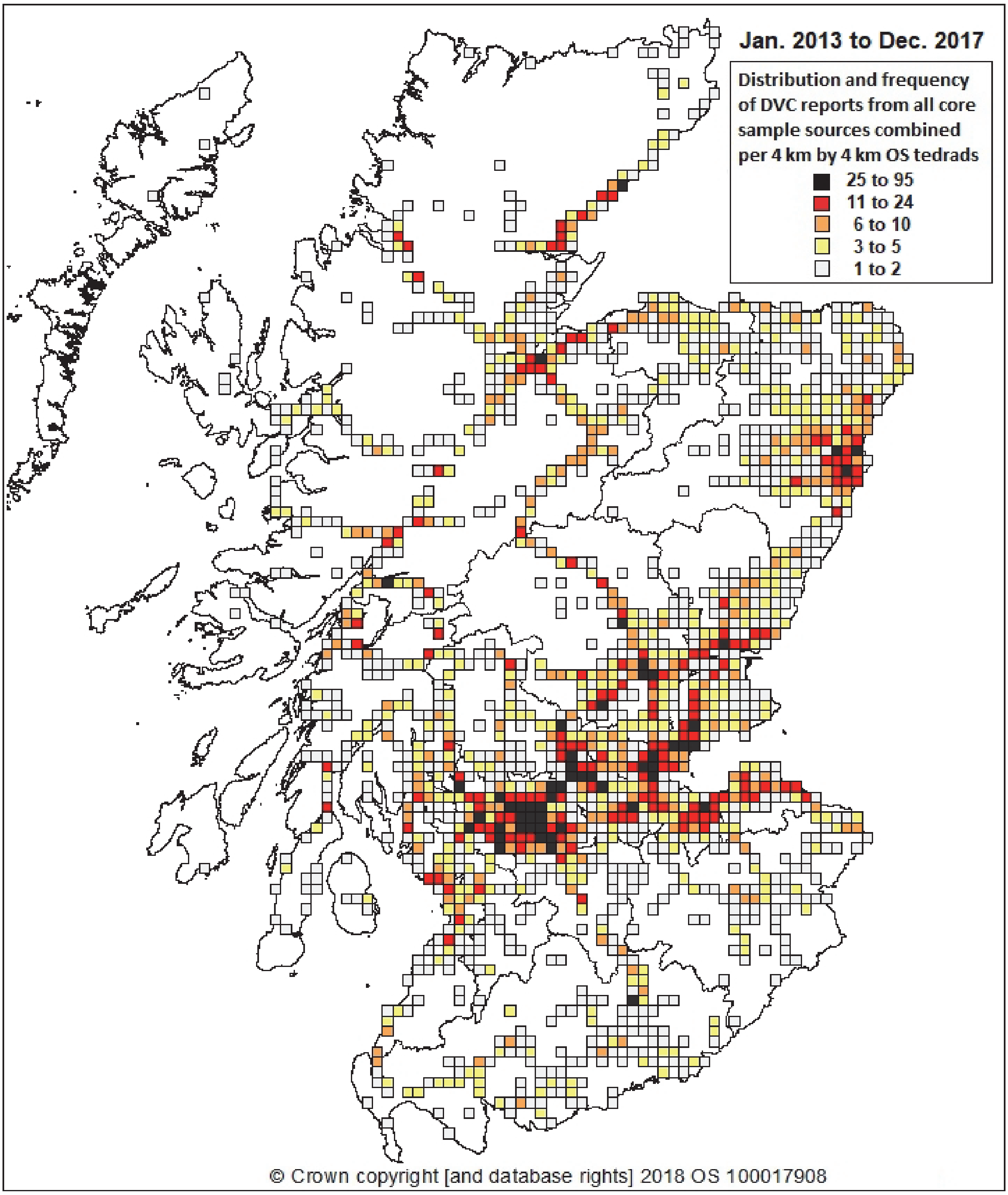

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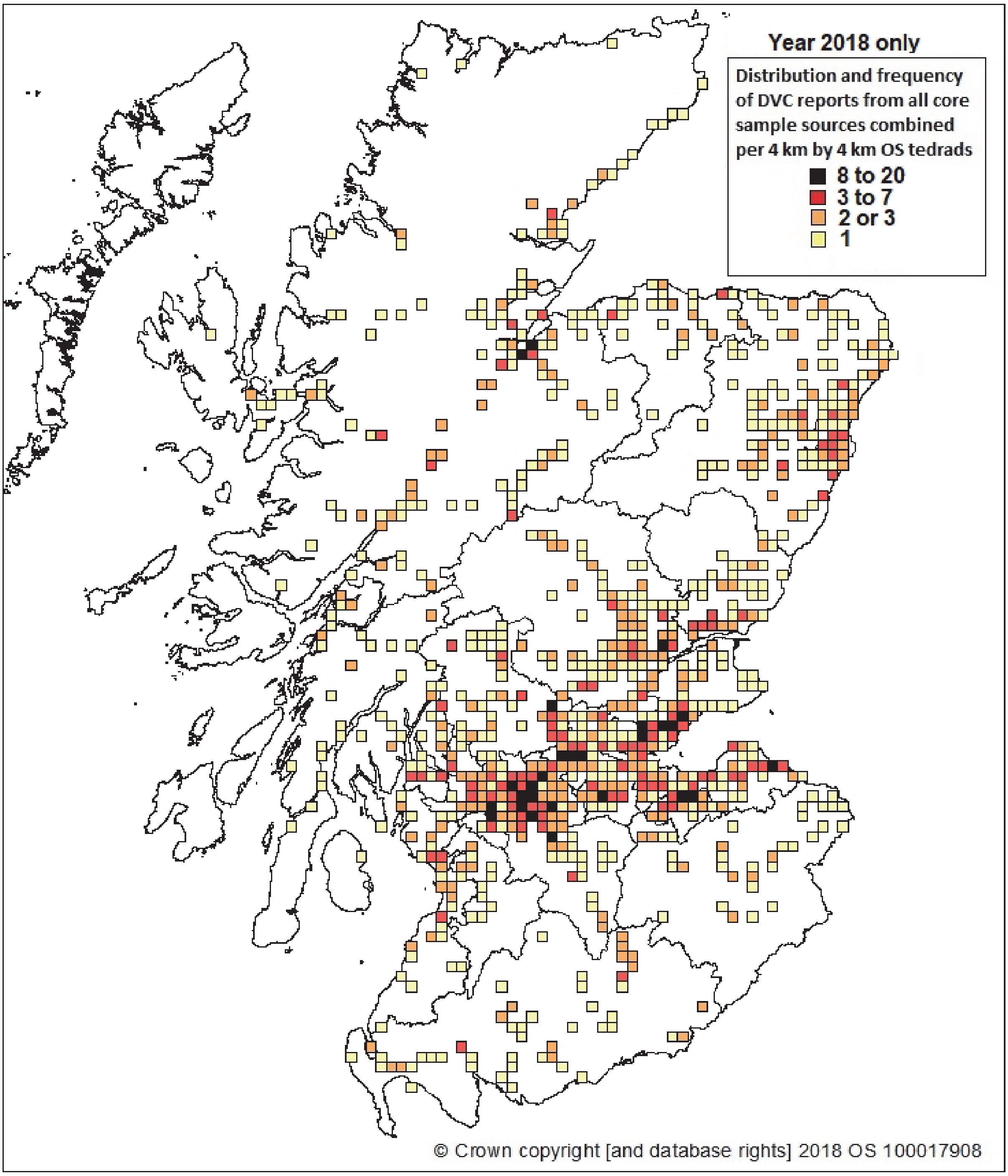
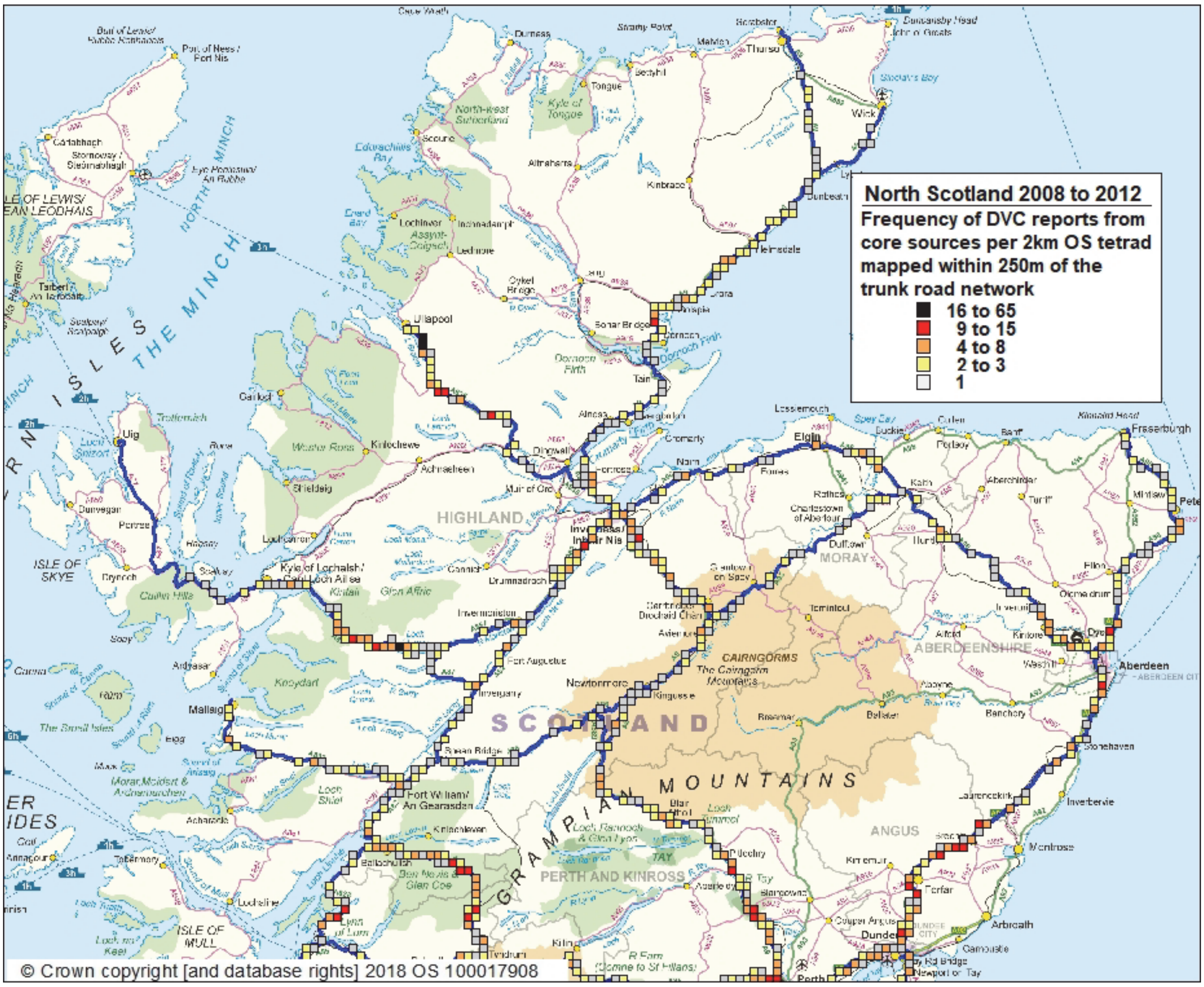


Figure A.3: Distribution and frequency by 4 km by 4 km OS tetrad for DVC data from all core sources combined for year 2018 only. (see A.1 & A.2 for previous years)



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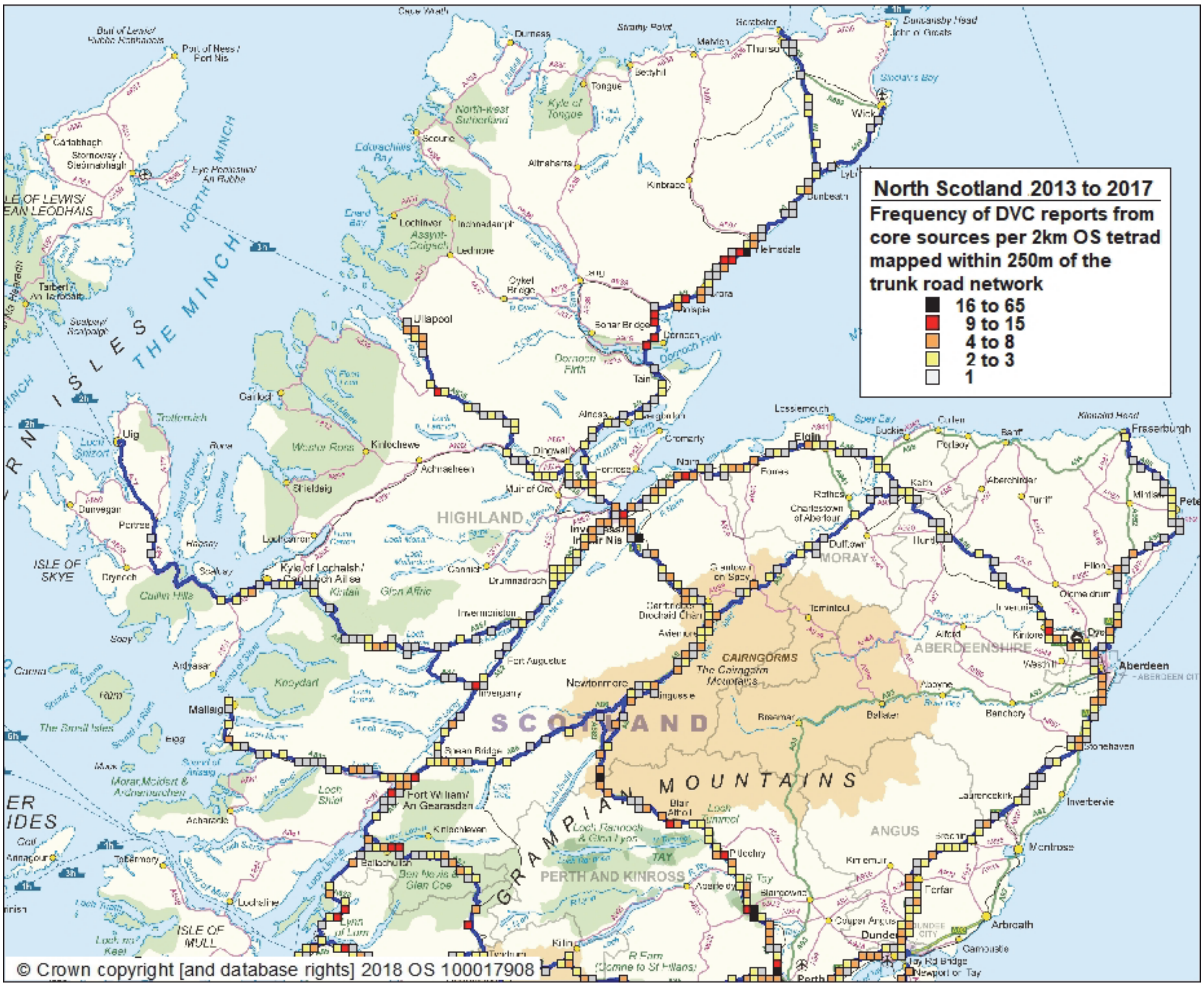

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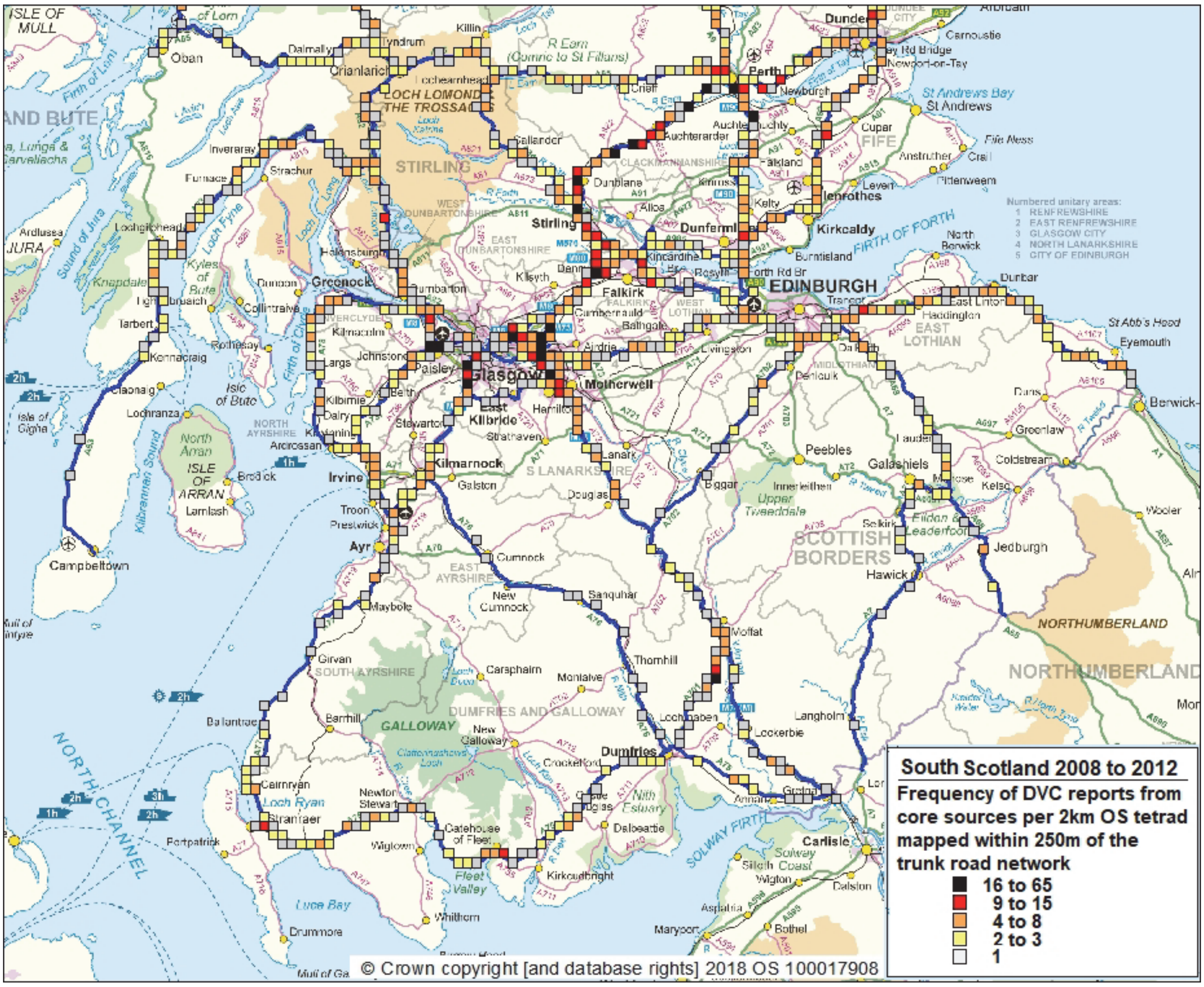
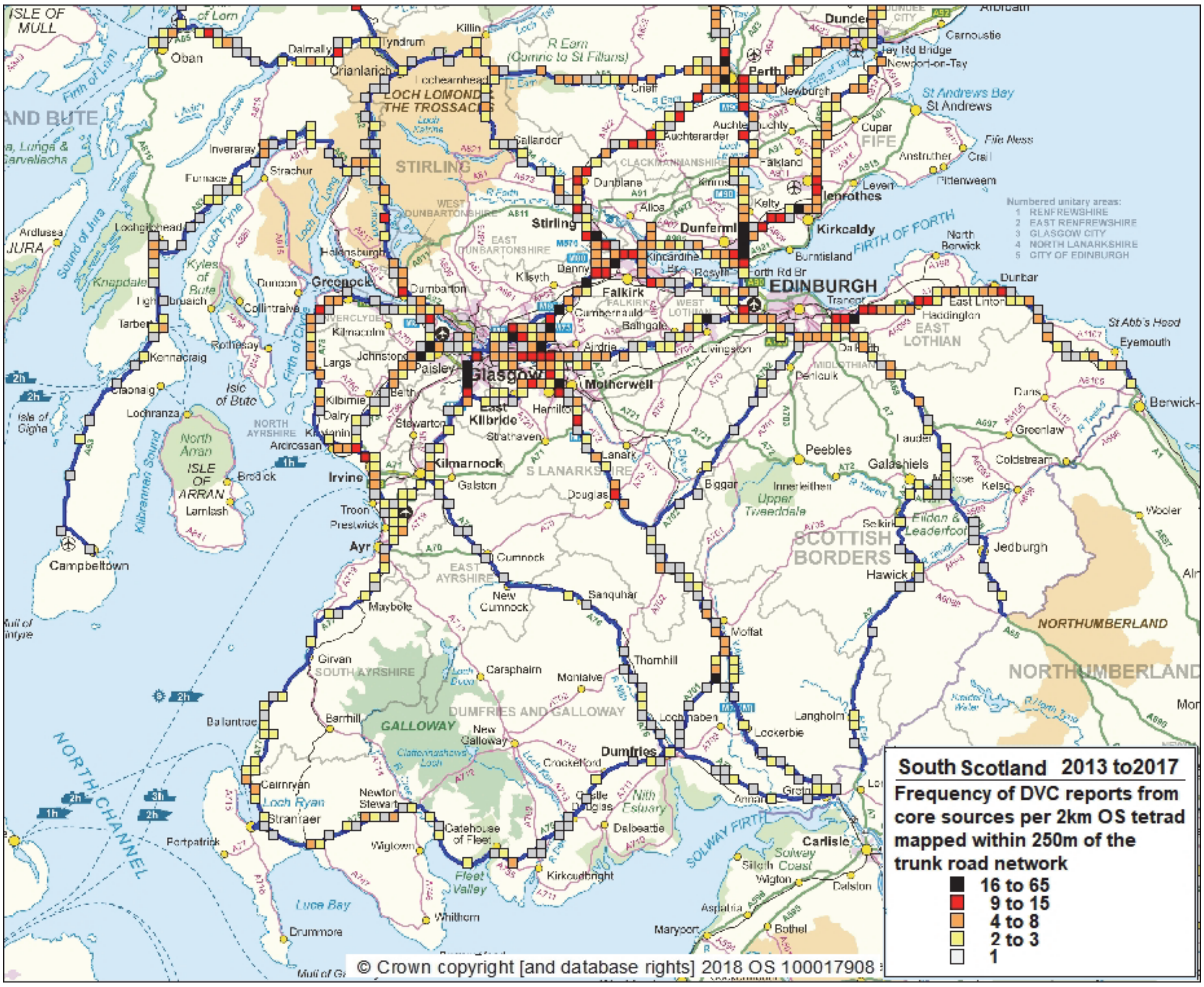


Figure A.6: Distribution and frequency of trunk road DVC reports falling per 2km tetrad in Southern Scotland for the 5-year period 2008 to 2012.



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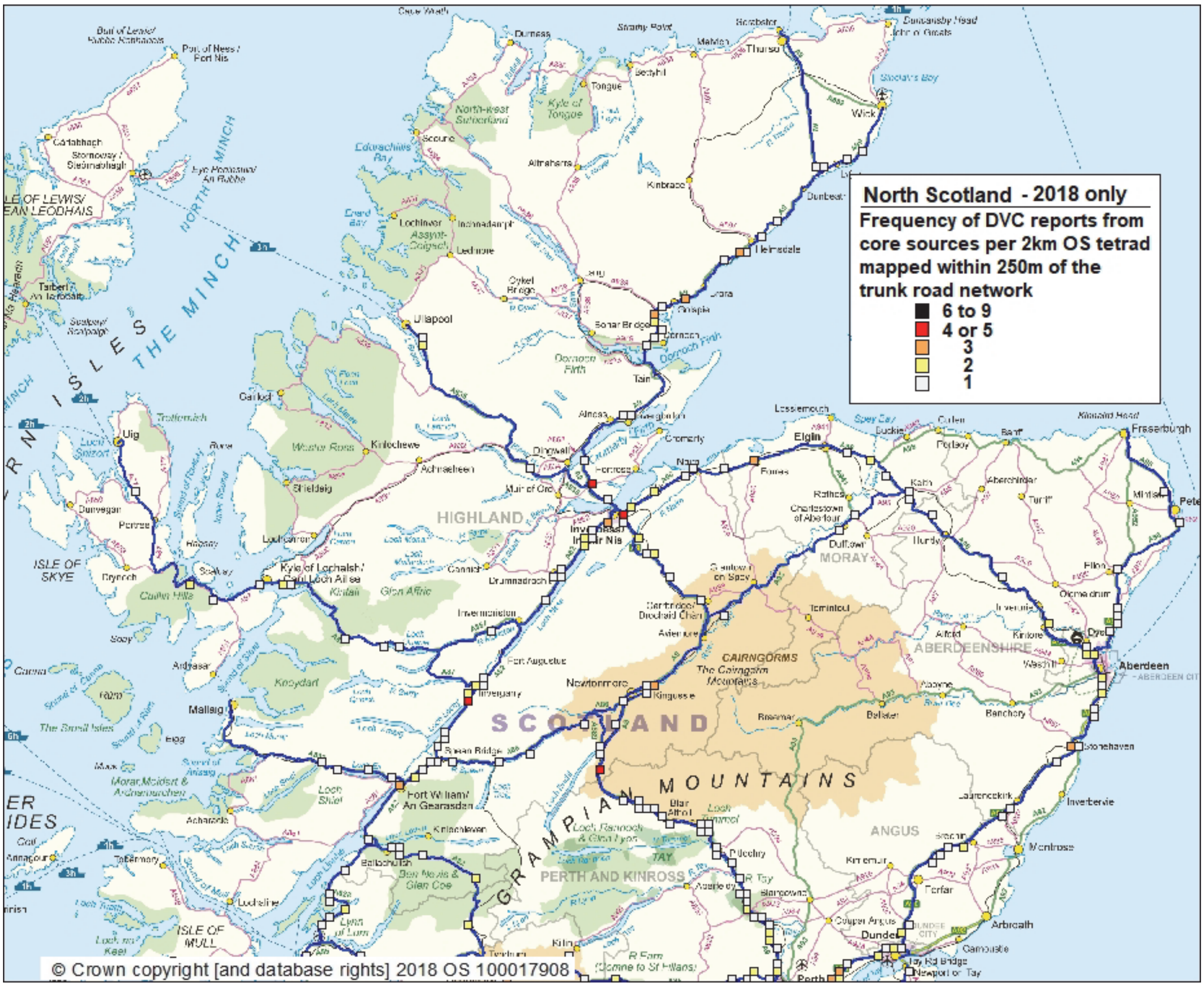

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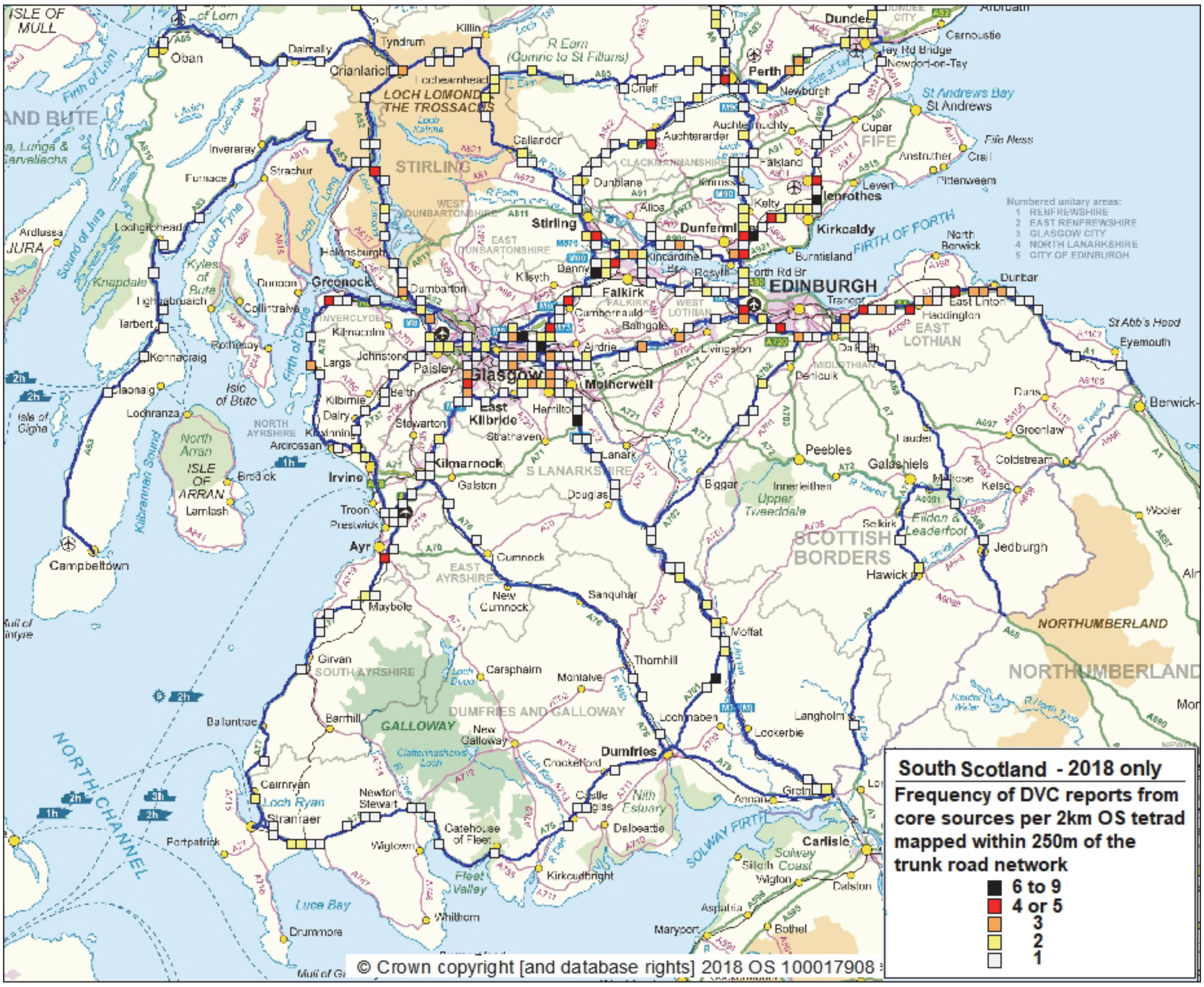

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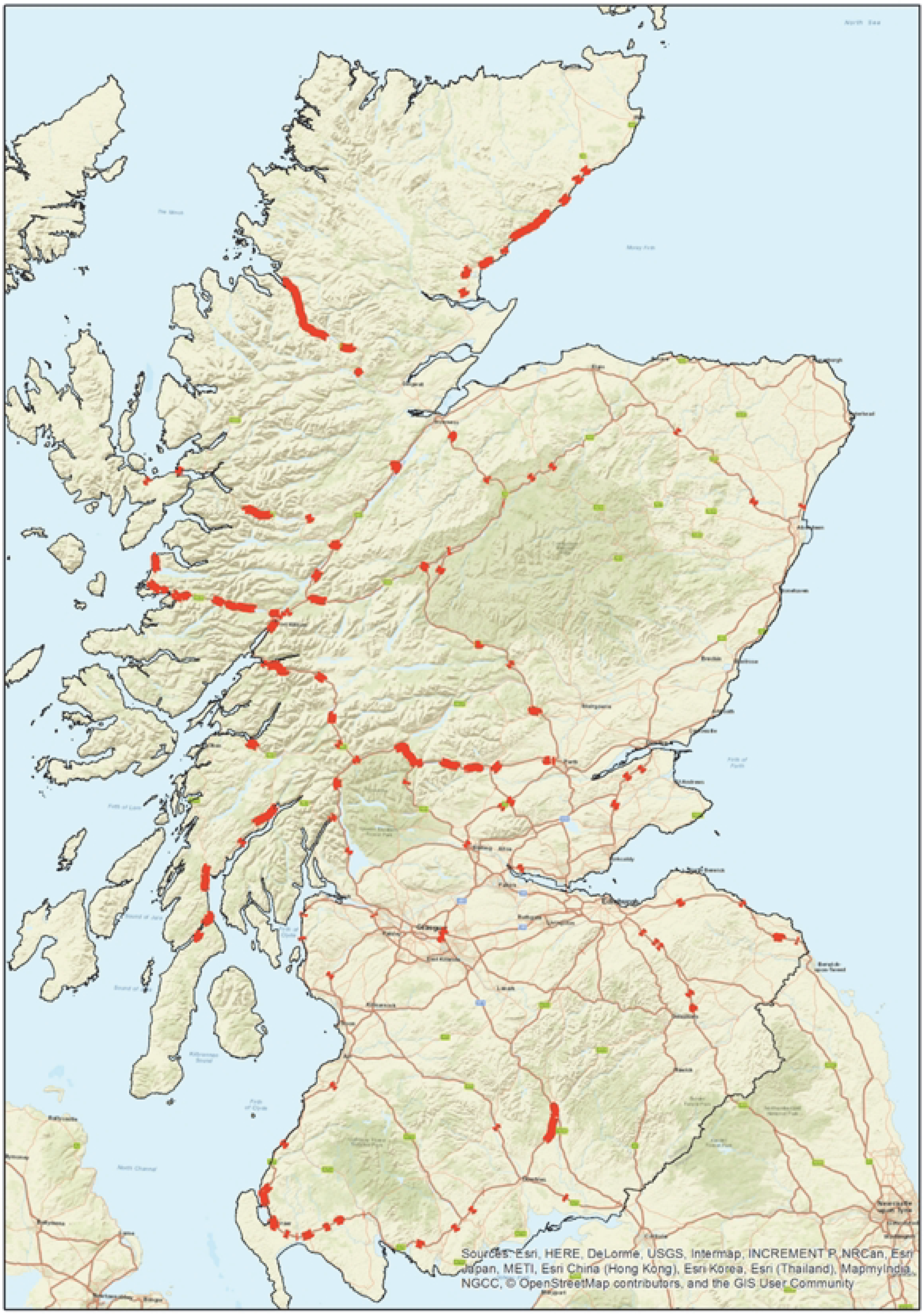

Figure A.10: Top 200 trunk road sections with highest calculated DVC Risk index. ©Crown copyright [and database rights] 2018 OS 100017908.

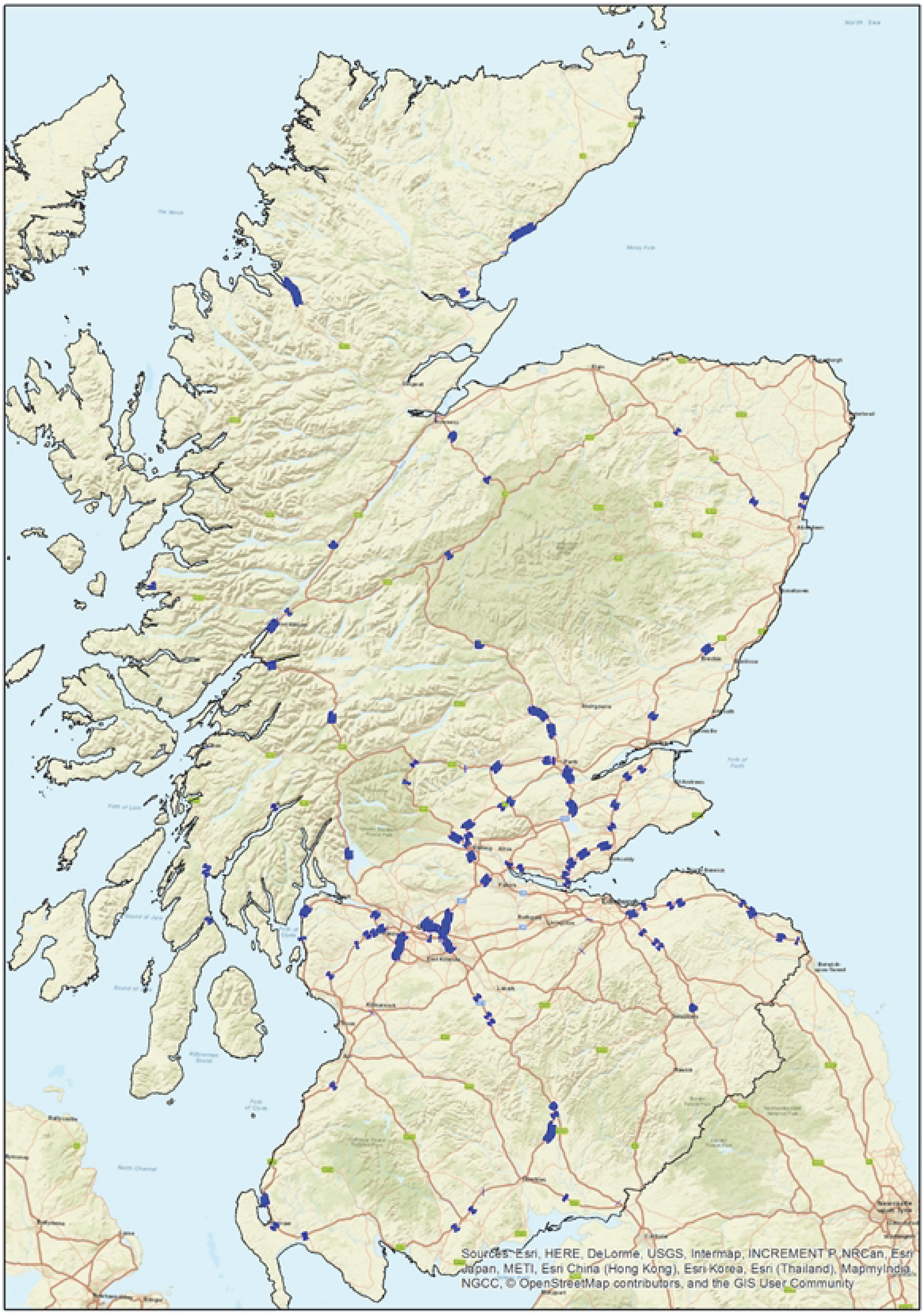

Figure A.11 Top 200 trunk road sections with greatest average DVC/Km. ©Crown copyright [and database rights] 2018 OS 100017908.

ANNEX 2: HEAT MAPS

Folder of 29 pairs of grid-based heat maps comparing in each case DVC distribution and hotspots for each Scottish Mainland Council area during a) 2008 to 2012 and b) 2013 to 2017

(In view of large file size please see separate download link on SNH website to access ANNEX 2).

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