Wildlife-train collisions: modelling and analysis in space and time

Casey Visintin1, Rodney van der Ree2, Michael A. McCarthy3

1Quantitative and Applied Ecology Group, School of BioSciences, University of Melbourne, Parkville, VIC 3010, Australia - Email: cvisintin@student.unimelb.edu.au

2Australian Research Centre for Urban Ecology, Royal Botanic Gardens Victoria and School of BioSciences, University of Melbourne, Parkville, VIC 3010, Australia - Email: rvdr@unimelb.edu.au

3Quantitative and Applied Ecology Group, School of BioSciences, University of Melbourne, Parkville, VIC 3010, Australia - Email: mamcca@unimelb.edu.au

Corresponding Author: Casey Visintin, School of BioSciences, Bldg 122 - Rm 106A, University of Melbourne, Parkville, VIC 3010, Australia - Email: cvisintin@student.unimelb.edu.au, Phone: +61 4 34424084

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* 1. Summary

Collisions between and wildlife and vehicles has been widely studied, however, animal mortality from strikes by rail-based networks remains under-represented in the literature.

To assess the risk of collisions, we developed methods to quantify regional train movements in space and time, determine likelihoods of species occurrencce, and fit a model to reported collision data.

The model performance was...

Predictions from the model can help managers decide where, when and how best to mitigate strikes.

* 1. Keywords

animal, framework, train, risk, species distribution model, speed, track, crepuscular, WTC

Introduction

Linear infrastructure that carries moving vehicles such as road and rail developments cause both direct and indirect disruptions to ecological systems (Seiler & Helldin, 2006; van der Ree et al, 2015). Although transportation networks support human civilisations by moving goods, expanding services, and enabling recreational activities, they also introduce environmental impacts that must be managed (Spellerberg, 1998). One of the most visible impacts is the direct mortality of wildlife resulting from strikes that occur on transportation networks (Forman et al., 2003).

Collisions between animals and moving vehicles is a common problem throughout the world (Litvaitis & Tash, 2008). Larger wildlife are more problematic as they often pose safety concerns in addition to animal welfare and conservation issues (Langley et al., 2006; Rowden et al., 2008). For example, deer-vehicle collisions on roads are well-studied in North America () and Europe (). Moreover, as under-developed countries create infrastructure to match the intensity of developed nations in North America and Europe, management of wildlife-vehicle collisions will become increasingly important.

Information about the spatial and temporal distribution and magnitude of wildlife-vehicle collisions is useful to help managers address this issue (). Information derived from empirical, simulated, or modelled data may help to plan mitigation. For example, knowing a hotspot location along a transportation network for a particular species will assist managers to select and implement the most appropriate form of mitigation (e.g. animal exclusion or change in network activity). Statistical modelling has become a common method of predicting wildlife-vehicle collisions to inform management (Gunson et al., 2011).

The majority of wildlife-vehicle collision modelling deals with road networks (), however, the problem extends to other forms of vehicular networks such as air (van Belle et al., 2007) and rail (Wells et al., 1999) operation. Regardless of the mode of transport, the modelling of collisions share some common attributes. First, the movements or presence of animals are often considered in the models. This may also include behaviour traits (). Second, the presence or movements of vehicles are also considered and may be grouped into a larger category of human behaviour as speed and trajectory are ultimately controlled by us. These distinctions have been established in the road ecology literature (see Forman et al., 2003).

As wildlife-vehicle collisions occur in both space and time, models that respond to and predict in these dimensions are most useful to managers (). Spatial attributes of data are foundational to collision modelling () but temporal attributes are less commonly employed. As both wildlife and human behaviour exhibit temporal patterns, including model parameters to incorporate this data may improve the utility of model predictions - assuming a reasonable model specification.

Extensive rail networks with considerable activity exist on every continent in the world, and although broader ecological effects have been discussed (De Santo, 1993; Givoni, 2006) and analysed (Waller & Servheen, 2005), very few studies model wildlife-train collisions. Perhaps due to their size, moose have gained attention in both North America (Belant, 1995) and Europe (Gundersen & Andreassen, 1998) and have also been the focus of management (Andreassen et al., 2005). Deer have also been studied in Japan (Onoyama et al., 1998). In Oceania, train collisions with kangaroos (analogues to deer in road collision modelling) and other Australian species have yet to be modelled. We aim to develop a modelling framework that predicts the rate of collisions across the regional passenger train network in Victoria. We envisage these methods to inform rail operators of potential dangers as well as generalise to other species (e.g. wombats) and rail operations (e.g. freight transport).

* 1. Materials and Methods
     1. STUDY AREA

We use a 1712-kilometre Victorian regional passenger rail network (operated by V/line) in south-east Australia to conduct our study (Figure 1). Trains operate on all sections of the network between the hours of 4am and 2am with the largest volume occurring Monday through Friday between the hours of 7am and 9am and 4pm and 6pm.

* + 1. DATA PREPARATION

To organise our spatial data and modelling, we overlay a spatial grid of one square kilometre resolution on the rail network (Figure 2). Each grid cell is used as a modelling unit for species occurrence and as a micro-site for quantifying the regional train movements and speeds.

We use Eastern grey kangaroos (Macropus giganteus, Shaw) as our case study species ("kangaroos", hereafter) as they are the most frequently struck wildlife and large enough to cause significant damage to trains. We obtained 439 kangaroo collision records from V/line spanning a six year period between 1 January, 2009 and 31 December, 2015. Each record had a corresponding incident date, incident time, name of service line, and nearest fraction of a kilometre post. Using geographic information system (GIS) data on the regional rail network, we determined spatial coordinates (GDA94 MGA zone 55 projection) from the reported kilometre post and service line.

To represent kangaroo distribution in the landscape, we use species distribution modelling to predict relative likelihood of occurrence in each grid cell (see Visintin et al, 2016).

To determine train movements across space and time, we used a spatial database to interpolate locations and times of unique train routes from V/Line general transit feed specification (GTFS) data (accessed online 3 March, 2016). GTFS is a standard publishing format for public transport agencies for scheduling and spatial data. This data allows software developers to write applications for mobile devices that track and report the locations of public transportation. Our query returned the weekly average number of trains, the total length of track, and average train speed in each grid cell for each hour of the day where trains occurred.

We also considered the coincidence of peak periods of train movements with daylight by adding a

* + 1. STATISTICAL MODELLING

We adapted a formerly developed single-species quantitative risk model (see Visintin et al, 2016) to fit and compare the relationship of species presence and characteristics of the rail network to collision likelihood expressed as:

|  |  |
| --- | --- |
|  | (1) |

where is the relative likelihood of a collision equal to one, is species occurrence, is average number of trains moving through the cell, is average train speed, in a given place .

* 1. Results
  2. Discussion

Model fit...

Train speed...

EGK presence...

Crepuscular activity and temporal...

Detection issues...

Implied management...

Reduce animal presence (e.g. deterrents or exclusions) or reduce train threat (e.g. adjust schedules or speeds)...

* 1. Data Accessibility

Model Dataset -

R Code -

* 1. Acknowledgements

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* 1. Tables

Table 1: Top six native mammal species involved in WVC in Victoria. Species observations are used for the species occurrence models and recorded collisions for the collision risk models. The datasets used in the models are comprised of both presences (P) and background (B).

|  |  |  |  |
| --- | --- | --- | --- |
| Species Name | Species Code | n Species Observations (2000-2014) | n Recorded Collisions (2010-2014) |
| Eastern Grey Kangaroo | EGK | 12175 : 2414P / 9761B | 615951 : 3160P / 612791B |
| Common Brushtail Possum | BTP | 13582 : 3821P / 9761B | 613180 : 389P / 612791B |
| Common Ringtail Possum | RTP | 13382 : 3621P / 9761B | 613123 : 332P / 612791B |
| Black Swamp Wallaby | BSW | 13841 : 4080P / 9761B | 613082 : 291P / 612791B |
| Common Wombat | WOM | 12060 : 2299P / 9761B | 613044 : 253P / 612791B |
| Koala | KOA | 12485 : 2724P / 9761B | 612949 : 158P / 612791B |

* 1. Figures

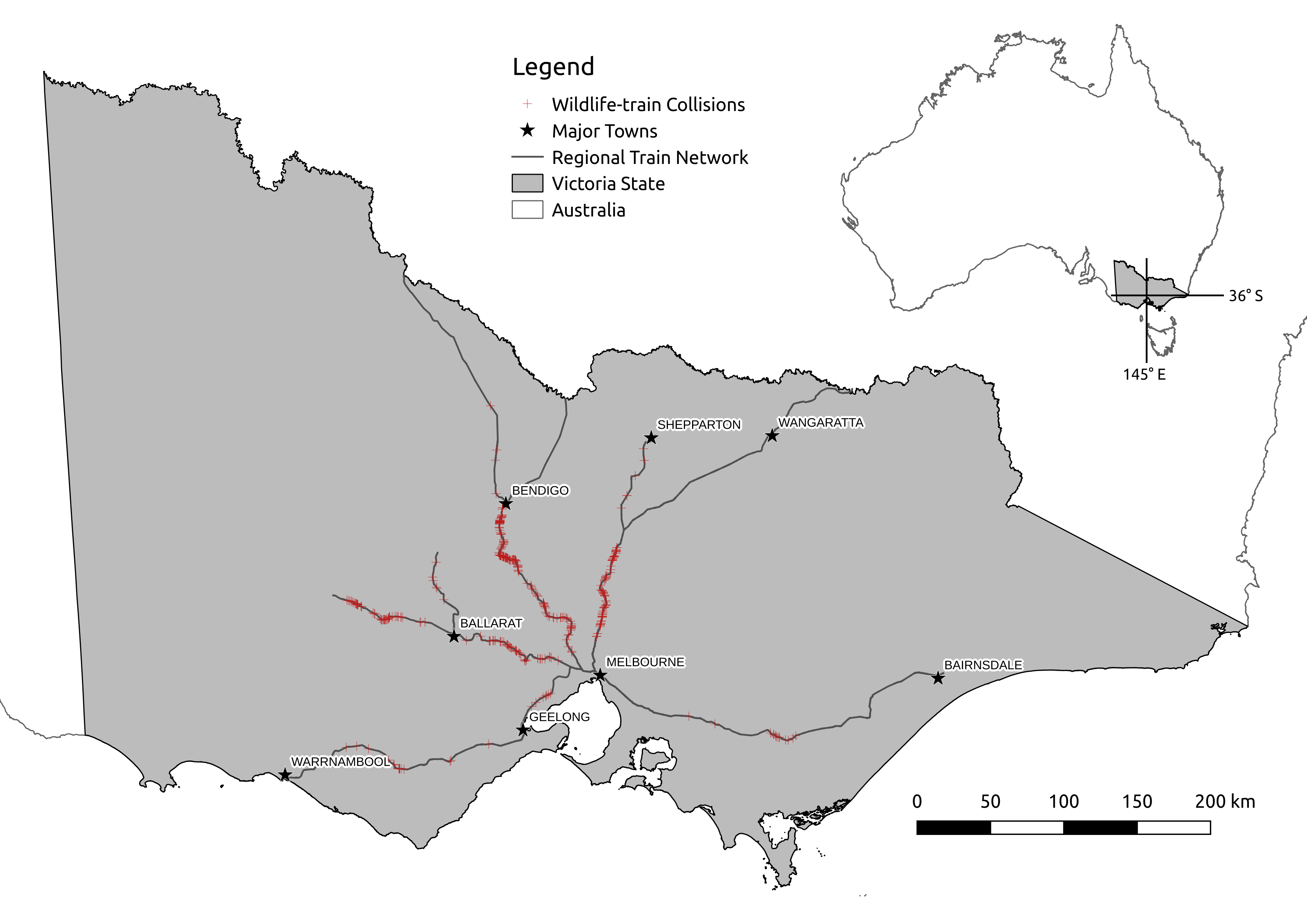
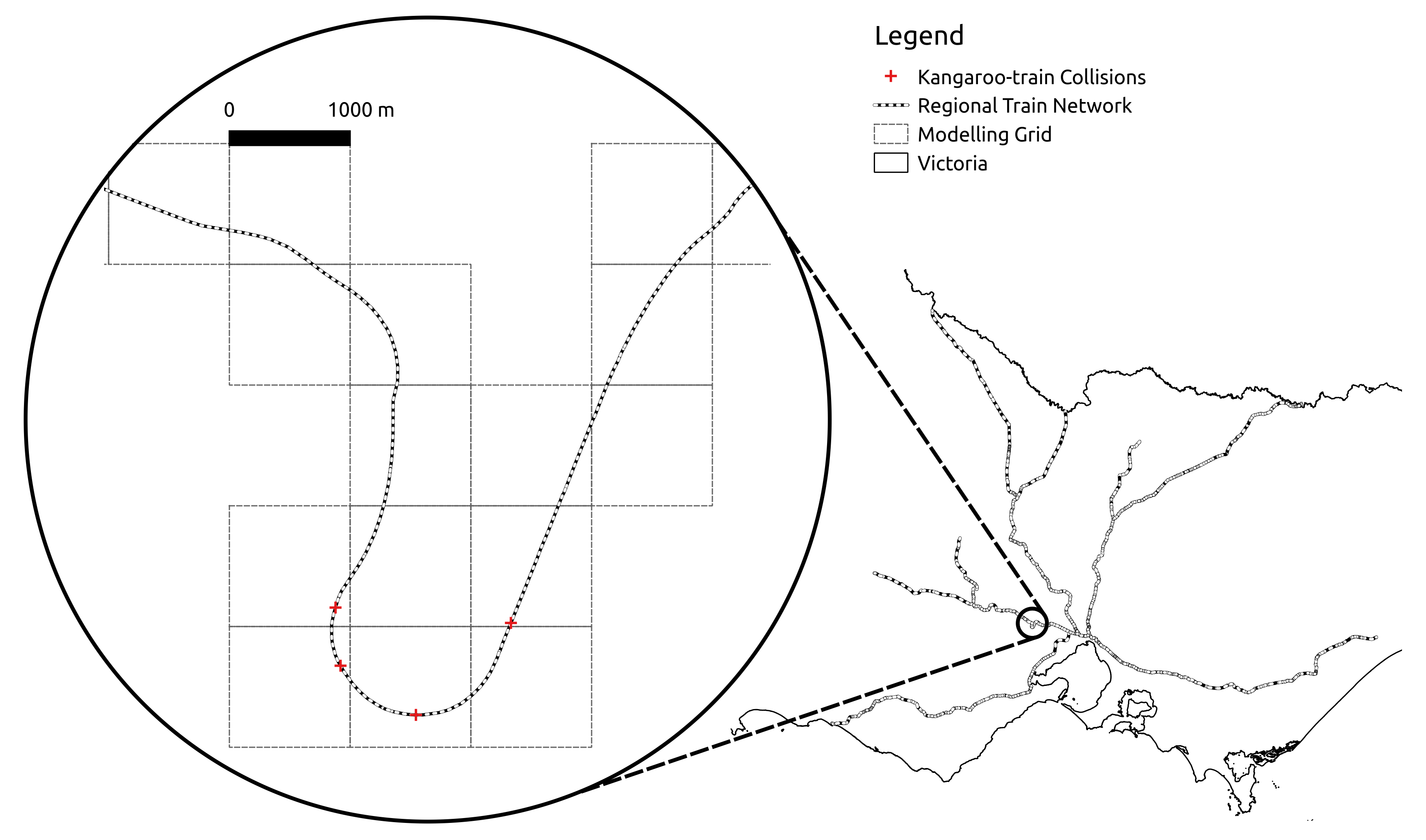


Figure 1: Wildlife-train collisions reported between 2009-2014 in Victoria.



**Figure 2:**  Grid used to organise modelling data (number of cells: 2015; extents: 104000,5741000 x 556000,6084000; projection: GDA94 MGA zone 55)