Science for Saving Species

Research findings factsheet

Project 1.3.2

Threatened Species Recovery Hub

National **Environmental Science** Programme

FoxNet: A framework to support management of an invasive predator, the red fox

In brief

Red foxes (*Vulpes vulpes*) pose a serious threat to Australia's wildlife and livestock. Australia spends more than $16 million per year on fox control, primarily poison baiting. However, the effectiveness of these control programs is not always clear, particularly when baiting is intermittent or conducted at small-scales.

We have developed "FoxNet", a new fox population modelling tool to help land managers make optimal decisions around fox control. The research was led by the University of Melbourne and funded by the Threatened Species Recovery Hub and Victorian Government agencies.

FoxNet is spatially explicit. It simulates individual foxes, their territories and management actions at a fine resolution (e.g., 1 ha cells) across landscapes as large as 1,500,000 ha. It can be customised to local fox ecology and environmental conditions.

Land managers can use FoxNet to examine how different bait layouts, baiting frequencies and seasonal timings would affect fox density. FoxNet can also be used to estimate the annual cost of these management scenarios, helping optimise decision-making.

FoxNet is designed for users who are comfortable with modelling software and is free to download from https://doi.org/10.5281/zenodo.2572045. It is currently being used by government agencies to evaluate and plan fox management programs for biodiversity conservation across Victoria. Ultimately, we aim to extend FoxNet to incorporate disturbance processes such as fire, and integrate it with population models for other species including feral cats and threatened native mammals.

Fox in the Otways. Image: Mark Le Pla

Background

Invasive mammalian predators are among the leading causes of biodiversity decline worldwide. Understanding the effectiveness of predator control is therefore a key conservation issue. The red fox *Vulpes vulpes* is one of the world's most widespread predators. In Australia, predation by invasive red foxes negatively impacts 95 threatened species. Foxes also pose a major risk to livestock and host several diseases that can affect human health.

Fox control programs in Australia range from one-off, highly localised blitzes to long-term, landscape-scale programs. Nonetheless, foxes are highly mobile and breed rapidly, meaning that populations can recover rapidly after control ceases. Managers need better tools to help them evaluate the impacts and costs of different control approaches. For example, baiting programs that are too small-scale may kill individual foxes but not reduce fox density, if killed individuals are rapidly replaced through immigration or breeding. This wastes limited resources and impacts animal welfare without benefiting biodiversity. Decision-support tools need to be customisable because fox ecology is highly variable and managers may have different goals or resource limitations.

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Research aims and summary

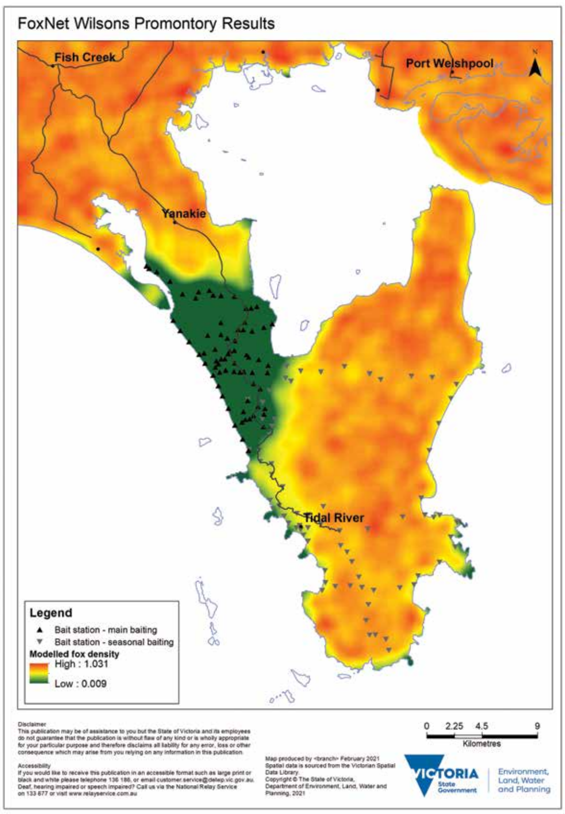
The aim of this research was to create a decision-support tool that would help managers plan efficient and effective fox control strategies, and so help them achieve lasting conservation outcomes.

Our tool, "FoxNet", is an individual-based, spatially explicit computer simulation model. It can be used to model fox populations in landscapes with and without fox control, and to test the outcomes of different control strategies (such as the location, density and frequency of poison baiting). FoxNet can be customised for a wide range of landscapes and climates using simple inputs and uploaded map files.

FoxNet has a visual interface which shows how fox populations change over time. It also provides estimates of fox density for specific subregions (such as conservation reserves) or whole landscapes at weekly or monthly timesteps, and can generate exportable maps of fox densities at specific points in time. If the cost of each aspect of management is provided (such as the cost of baits, daily labour costs and travel costs), FoxNet will also calculate the annual cost of the proposed baiting program.

These outputs and visualisation tools can help land managers better understand how fox populations respond to control and compare the cost of a control program to its impacts, enabling them to optimise management decisions.

FoxNet is open-source and free to download. We continue to extend and refine the model, based on new field research and the needs of land managers. This work is being done in close collaboration with the Victorian Government's Department of Environment, Land, Water and Planning, and Parks Victoria.



Customising FoxNet

As an individual-based model, FoxNet shows individual female and male foxes, who move around the model landscape, acquire territories, seek mates, have cubs and die. This makes it easy to customise the model for local fox populations if field data are available, via inputs such as fox home range size, the number of cubs per litter, and the time of year when behaviours such as breeding and dispersal occur. Default settings for urban and natural landscapes, and northern and southern hemisphere scenarios are provided.

FoxNet is spatially explicit, with a default resolution of 1-ha cells. The total size of the landscape can be specified by the user, and can exceed 15,000 km^2. The layout of the landscape can also be customised by uploading map files (asci rasters and shapefiles). For example, FoxNet can incorporate habitats with different productivity for foxes, such as townships and forests, as well as lakes and oceans where foxes can't live, and rivers or other barriers that may restrict fox movement.

The locations of bait stations can either be generated within the model as a grid or random scatter, or uploaded via shapefiles. Similarly, baits can be deployed at these stations at regular intervals (weekly, fortnightly, monthly) or in custom weeks, and the toxicity of the baits can be specified by the user.

MAP LEFT: A sample heatmap of predicted fox density in response to a hypothetical baiting program near Wilsons Promontory. Bait stations are shown as crossed circles. The green areas indicate no or very low number of foxes, while red indicates high fox density. Image: Victorian DELWP.

Model evaluation and applications

We used data from field studies in the northern hemisphere and Australia to evaluate and validate FoxNet[1]. These case-studies showed that FoxNet was able to reproduce the structure of fox populations from diverse landscapes, such as a city in the UK and the arid rangelands of Carnarvon, Western Australia. It also did a good job at estimating the density of fox families from home range data across a wide range of observed values, from 100 to 960 ha. Based on realistic assumptions about the efficacy of baits, FoxNet was also able to reproduce the response of a fox population to pulse baiting in Carnarvon, including population decline and recovery. In the short term, however, modelled population recovery at Carnarvon was somewhat slower than field observations, indicating an opportunity to improve the model, potentially by incorporating compensatory breeding and immigration processes.

Mt Clay

Mt Clay State Forest forms part of Glenelg Ark, a 90,000 ha fox control program for biodiversity conservation in south-western Victoria. We used Mt Clay as a case study to demonstrate the utility of FoxNet for planning fox control programs[1]. FoxNet showed that this relatively small nature reserve needs to be baited frequently to combat recolonisation from the surrounding landscape. The current baiting strategy was predicted to suppress maximum fox population densities by approximately 70%. This was consistent with annual motion-sensing camera surveys conducted between 2013 and 2015, which detected foxes at 66% to 91% fewer sites at Mt Clay than at a nearby unbaited reserve. FoxNet showed that foxes remained present within Mt Clay at low densities, which again was supported by the detection of foxes at 8% to 28% of baited sites in annual surveys.

Modelling alternative management scenarios for Mt Clay showed that increasing the density of bait stations to 4 baits per km^2 or establishing a 1-km wide baited buffer around the reserve would improve efficacy, reducing fox densities to approximately 60% of current levels. Predictions were relatively robust to most assumptions, but sensitivity analysis showed that overestimating fox home range size would result in fox densities remaining much higher than predicted after control.

Analysis of Victorian government's fox control programs

The Department of Environment, Land, Water and Planning's Arthur Rylah Institute for Environmental Research (ARI) recently used FoxNet to analyse the efficacy of 14 state-funded fox control programs at different spatial and temporal scales[2]. The study defined effective control as a predicted reduction in fox density by more than 65% over at least half of the area of conservation interest. FoxNet showed that several factors interacted to affect the success of fox control, including the spatial scale, bait layout, bait density and timing of baiting. In general, for control to be effective, the study found that the area of conservation interest needs to be at least 30,000 ha, baits must be deployed as a network across the area, and baits need ongoing replacement at fortnightly intervals. The scale and the shape of the area of conservation interest also has an influence on efficacy, with areas with high perimeter-to-area ratios likely to need more closely spaced baits and more frequent replacement to compensate for the increased immigration of foxes.

Otway Ark

The Conservation Ecology Centre, ARI and Parks Victoria used FoxNet to design an expansion of the Otway Ark, a 100,000-ha landscape-scale fox control program. The expansion increases the size of the Ark by 20% across strategically selected sites, so that the Ark encompasses national park, state forest, other public land and private properties. This will help achieve best-practice cross-tenure fox control in the Otway Ranges and protect threatened species such as long-nosed potoroos, southern brown bandicoots and dusky antechinus from fox predation.

CEC Ecologist Mark Le Pla handling a southern brown bandicoot. Image: Lauren Halstead

Key findings and future advances

FoxNet provides a new tool to support the management of red foxes, a significant pest species. It represents a significant advance over previous models for fox population control, as it captures the dynamic nature of fox territories and densities, the effects of habitat heterogeneity, and is highly customisable for different landscapes and management scenarios. The success of our case-study models in reproducing field observations indicates that FoxNet is likely to provide useful insights into the effectiveness of fox management, at scales relevant to policy and on-ground management.

Work is currently underway to individually identify foxes using DNA from scats collected before and after management programs in several parts of Victoria. This will provide high quality data on fox densities which can be used to compare with FoxNet predictions, helping us further test and refine the model.

We also aim to extend FoxNet to incorporate competitor and prey species, and the effects of disturbance events such as fire on wildlife populations. This will facilitate the prediction of complex responses across the food chain to management actions, helping the design of integrated threat management programs.

Long nosed potoroo. Image: Kristian Golding Flickr CC BY-NC 2.0

Further reading

[1] Hradsky, B. A., Kelly, L. T., Robley, A. & Wintle, B. A. 2019. FoxNet: An individual-based model framework to support management of an invasive predator, the red fox. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.13374

[2] Francis, L., Robley, A., Hradsky, B. 2020. Evaluating fox management strategies using a spatially explicit population model. Arthur Rylah Institute for Environmental Research Technical Report Series No. 304. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

FoxNet is open-source and comes with a user manual. It can be downloaded from https://doi.org/10.5281/zenodo.2572045.

Further Information

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