CENTRE FOR EVIDENCE-BASED CONSERVATION

SYSTEMATIC REVIEW No. 24

DO CONTROL INTERVENTIONS EFFECTIVELY REDUCE THE IMPACT OF EUROPEAN RED FOXES ON BIODIVERSITY AND AGRICULTURAL PRODUCTION IN AUSTRALIA?

REVIEW PROTOCOL

Lead Reviewer: **Dr Glen Saunders**

Postal Address: **Vertebrate Pest Research Unit**
NSW Department of Primary Industries
Forest Rd.
Orange NSW 2800
Australia

E-mail Address: **glen.saunders@dpi.nsw.gov.au**
Telephone: **+61 (0)2 6391 3890**
Fax: **+61 (0)2 6391 3972**

COVER SHEET

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Reviewer(s)	**Glen Saunders and Lynette McLeod (probable additional authors Tamara J. Kabat, Gavin B. Stewart, and Andrew S. Pullin from CEBC)**
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Contact address	**Vertebrate Pest Research Unit NSW Department of Primary Industries Forest Rd. Orange NSW 2800 Australia glen.saunders@dpi.nsw.gov.au**
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1. BACKGROUND

The European red fox (*Vulpes vulpes*) has been listed as one of the IUCN's top 100 worst invasive alien species (Lowe *et al.*, 2000). The species occurs naturally throughout the northern hemisphere, from North America through Europe, Asia, and the northernmost parts of Africa (Saunders *et al.*, 1995). While native to North America, European red foxes were introduced to other areas of the continent and subsequently interbred with native stock. Australia contains the only southern hemisphere introduction of the species (Saunders *et al.*, 1995). This systematic review will be restricted to operations undertaken to control fox populations in Australia only.

The fox was introduced into Victoria, southern Australia, in the 1870s for hunting purposes, and rapidly spread throughout the majority of all mainland states (Rolls, 1969). In 2001, they were detected in the island state of Tasmania for the first time, despite previous introduction attempts (Saunders *et al.*, 2006). The fox is now one of the most ubiquitous pest animals in the country, and its pattern of spread and current distribution closely mirror that of the introduced rabbit (Jarman, 1986). Fox density varies across the country, being absent from the northernmost tropical areas, to 4.6-7.2 km^{-2} in the northern Tablelands of NSW, and up to 12 km^{-2} in Victoria's largest city, Melbourne (Saunders *et al*,. 1995).

Predation by foxes has been listed as a key threatening process under the Australian Government's Environment Protection & Biodiversity Conservation Act 1999 (DEH website). The fox has major environmental impacts in Australia, as a predator of smaller native mammals, ground-nesting birds and turtles, and may be partly responsible for several extinctions (e.g. Lunney 2001). They also cause production losses in the agricultural sector due to predation on stock, particularly newborn lambs (Saunders *et al.*, 1995). Millions of dollars are spent each year in Australia to perform control operations on fox populations. AUD$37 million per year has been estimated for the economic costs of control and production losses, with environmental impacts raising that figure to AU$227 million (McLeod, 2004). Fox control operations are conducted for threatened species and livestock protection, and are carried out on over 10.5 million ha of land per year (Reddiex *et al*., 2004). The main control method used is ground-based poisoning with 1080-laden baits; other frequently used methods are aerial baiting, trapping, shooting, and den ripping and fumigation (Reddiex *et al.*, 2004). Immunocontraceptives have been investigated, but a product usable for control operations has not been developed.

There are no recommended levels of fox control within Australia. Most States and Territories have legislative requirements for landholders to undertake fox management, most supported by region-wide management plans, although enforcement is not usual (Saunders *et al*., 1995). The Australian Government's Threat Abatement Plan for Predation by the European Red Fox (1999) states, "the main priority during the life of the plan is to support on-ground control programs necessary to ensure recovery of endangered species", but does not provide any recommended control levels. The Invasive Animals Cooperative Research Centre has set an operational target of reducing fox and wild dog impacts by 10% (AU$27 million per year) as part of its Terrestrial Products and Strategies Program (Invasive Animals CRC website).

Using systematic review methodology, the most common interventions (poison baiting, trapping and shooting) used to control European red foxes to reduce impacts on biodiversity and agricultural production in Australia will be critically appraised (Table 1). The review will consider the best available evidence of the effectiveness of control methods in different situations. Other questions within this topic, including the effectiveness of different control interventions and the reduction of impacts on wildlife and domestic stock in countries other than Australia, will not be addressed in this review; however, such information will be collated and catalogued.

The review will limit bias through the use of comprehensive literature searching (both published and unpublished), specific inclusion criteria, and formal assessment of the quality and reliability of the studies retrieved. Subsequent data synthesis (qualitative and/or quantitative) will summarise evidence, guiding the formulation of appropriate evidence-based management guidelines and highlighting gaps in research evidence.

This review should be of use to practitioners carrying out, or advising on, fox control for Australian natural resource and environmental management organisations (statutory and non-statutory), and ultimately local authorities and landholder groups. It will have value at regional, state and national scales, informing local management or policy decisions, and has the potential to influence state and national policies and guidelines on fox management for reducing impacts on biodiversity and agricultural production.

2. OBJECTIVE OF THE REVIEW

2.1 Primary question

Do control interventions effectively reduce the impact of European red foxes on biodiversity and agricultural production in Australia?

Table 1. Definitions of components of the primary systematic review question

Subject	Interventions	Outcomes		
		Primary	**Secondary**	**Tertiary**
Biodiversity and agricultural production affected by introduced European red foxes in Australia	Methods to control foxes: Poison baiting (1080) Shooting Trapping	Change in abundance of prey species after fox control operations	Cost benefits of fox control methods for reducing impacts	Change in abundance of foxes Timescale of recovery of fox and/or prey species numbers if control ceases Cost effectiveness of fox control methods

2.2 Secondary questions

Do environmental and geographical factors (e.g. ecosystem, habitat, land-use, temperature, rainfall, longitude, island/mainland populations, food resources) alter the effectiveness of fox control for reducing impacts?

Do operational level variables (e.g. density of foxes, size of controlled area, previous control history, duration/effort/timing of control, fencing of controlled area, bait/poison application method, bait type) alter the effectiveness of fox control programs for reducing impacts?

3. METHODS

3.1 Search strategy

3.1.1 General sources

The following electronic or computerised databases and catalogues will be searched:

1. ISI Web of Knowledge (inc. ISI Web of Science and ISI Proceedings)
2. Science Direct
3. Scirus (All journal sources)
4. Scopus
5. Agricola
6. Digital Dissertations Online
7. CAB Abstracts
8. ConservationEvidence.com
9. COPAC
10. Index to Theses Online
11. English Nature's "Wildlink" catalogue
12. Australian Digital Theses Program (Council of Australian University Libraries)
13. CSIRO Library Network Catalogue
14. BIOSIS
15. Wildlife and Ecology Studies Worldwide (NISC)
16. Other databases and catalogues deemed relevant by experts

Up to two reviewers will search the electronic or computerised databases and catalogues, and the number of citations retrieved from each search will be recorded within an EndNote database.

An Internet search will also be performed using the meta-search engines www.alltheweb.com, www.dogpile.com, http://scholar.google.com and Scirus web search. Up to two reviewers will search these engines. The first 50 hits (Word and/or PDF documents where this can be separated) from each data source will be examined for appropriate data.

The search strategy will cover worldwide literature for the purposes of collecting the broadest scope of information possible. However, the systematic review itself will be restricted to Australia-only studies. Searches will include the following English language search terms (* indicates a wildcard):

1. Fox* AND control*
2. Fox* AND manag*
3. Fox* AND impact*
4. Fox* AND recover*
5. Fox* AND biodivers*
6. "*Vulpes vulpes*" AND control*
7. "*Vulpes vulpes*" AND manag*
8. "*Vulpes vulpes*" AND impact*
9. "*Vulpes vulpes*" AND recover*
10. "*Vulpes vulpes*" AND biodivers*

Where search engines lack the wildcard ability, the following search terms will be used in place of the wildcard term:

- fox OR foxes
- control OR controlled OR controlling
- manage OR managed OR managing
- impact OR impacts OR impacted OR impacting
- recover OR recovery OR recovering
- biodiverse OR biodiversity

3.1.2 Specialist sources

Bibliographies of articles viewed at full text will be searched for relevant secondary articles. Authors, recognised experts and practitioners in the field of fox control and wildlife/agricultural protection in Australia will also be contacted for further recommendations, and for provision of any unpublished material or missing data that may be relevant. Foreign language searches will not be undertaken.

Searches of publications from Australian organisations will be included, such as the relevant Australian State, Territory & Federal Government environmental and agricultural departments, the Invasive Animals Cooperative Research Centre (and predecessors), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Attempts will be made to identify environmental organisations that may hold information on fox control in North America. Organisational websites will be searched for potential data. Specialist sources such as proceedings of the Australasian Vertebrate Pest Control Conference, the Australasian Wildlife Management Society, and the Australian Mammal Society, will be searched. Relevant journal publishing websites (i.e. CSIRO Publishing) will also be searched. Up to two reviewers will search these sources, and the number of citations retrieved from each search will be recorded. The first 50 hits (Word and/or PDF documents where this can be separated) from each electronic data source will be examined for appropriate data.

Specialist websites will also be searched for relevant information, including: http://www.issg.org/database/welcome/, http://www.invasivespeciesinfo.gov/, http://www.nisbase.org/nisbase/index.jsp, http://invasivespecies.nbii.gov/ and www.feral.org.au.

3.2 Study inclusion criteria

The inclusion and exclusion criteria will be applied by one reviewer to all potential studies at the title or title & abstract stages. Where there is insufficient information to

make a decision regarding study inclusion, then relevance to the next stage of the review process (full text assessment) will be assumed. A second reviewer will examine a random subset of at least 25% of the reference list (up to a maximum of 300 references) to assess repeatability of the selection criteria. Kappa analysis will be performed, with a rating of 'substantial' (0.6 or above) being required to pass the assessment. Disagreement regarding inclusion or exclusion of studies will be resolved by consensus, or following assessment by a third reviewer. If the Kappa value is low, the reference list will be reassessed against adjusted inclusion and exclusion criteria. The same subset of references will be re-assessed by a second reviewer with Kappa analysis. Reviewers will then consider articles viewed at full text for relevance, either excluding them from, or admitting them to, the review.

- **Relevant subjects:** All studies looking at the control of European red foxes in Australia with the goal of reducing impacts on biodiversity and agriculture will be appropriate for inclusion into the systematic review. The scope will be Australia only. Studies will be included irrespective of habitat or spatial scale; however, the geographical area will be recorded in order to interpret any patterns of variation in the results.
- **Types of intervention:** Poison baiting, trapping and shooting interventions for the control of foxes will be considered valid for inclusion. The review may need to be restricted at a later stage if there is not enough literature available to assess the particular interventions, or if there is too much information available. If this is the case, a scope of the literature will be carried out and the intervention(s) with the most available literature will be the focus of the review.
- **Types of comparator:** Comparators (temporal or spatial) are not necessary for inclusion of material in the review. However, they are a prerequisite for studies to be included in any subsequent inferential meta-analysis. A complete lack of comparators or controls may result in a study being included in correlative or qualitative analysis.
- **Types of outcome:** Initially, any outcome will be considered for inclusion. Ideally, changes in abundance of prey species are the primary outcome measures so an evaluation of the success of the intervention(s) can be made. The definition of what constitutes an effective improvement in prey species abundance/recovery or economic return will need to be defined in consultation with subject experts prior to commencing data extraction. Such improvements will be dependant on the scope of the study and may result, for example, in the removal of a prey species from listing as threatened or rare, to the economic return at a property level in terms of increased lamb production. Other outcomes that refer to the cost effectiveness (as opposed to cost benefits) of different control methods, changes in fox abundance as a result of control, or the timescale of recovery of fox and/or prey species if control ceases, will not be included in a formal synthesis, but they will be catalogued as other outcome measures.
- **Types of study:** All studies with the object of control of European red foxes for reducing impacts on biodiversity and agriculture will be included if they present primary data about a relevant subject, intervention and outcome.
- **Potential reasons for heterogeneity:** It is hypothesised that the following factors (in no particular order) will impact on the outcome of the control method:
    - Ecosystem (e.g. arid, semi-arid, temperate)
    - Habitat (e.g. forest, grassland, woodland, wetland, coastal, alpine)
    - Land-use (e.g. conservation, agricultural, urban)

- Temperature
- Rainfall
- Longitude
- Island or mainland populations
- Food resources for foxes
- Density of foxes
- Size of controlled area
- Previous control history (same or different to present one?)
- Duration, effort (frequency of control) and timing (i.e. season) of control program or study
- Fencing of controlled area
- Bait/poison application method (e.g. ground or aerial baiting)
- Bait type

3.3 Study quality assessment

Reviewers will consider articles viewed at full text, excluding them from the review or admitting them to different categories of information quality. Where possible, study quality will be assessed according to a hierarchy of evidence adapted from models of the systematic review process used in medicine and public health (Stevens & Milne 1997; Pullin & Knight 2003); e.g. a randomised control trial would be weighed higher than a site comparison study. Study quality will be assessed by one reviewer with reference to a second reviewer in cases of uncertainty. Disagreement regarding study quality will be resolved by consensus, or following assessment by a third reviewer.

3.4 Data extraction strategy

Data will be extracted by one reviewer, and a subset of the selected studies will be checked by a second reviewer to check data hygiene and verify the robustness and repeatability of the data extraction. Data regarding the study characteristics, quality, design and results will be recorded using data extraction forms. It is likely that these forms will be subject to amendment following consultation with subject experts, statisticians and piloting the process of data extraction. Where information regarding the reasons for heterogeneity is presented in the studies, it will be recorded.

3.5 Data synthesis

Methods of data synthesis depend greatly on the type of data presented in the available studies. Attempts will be made to collect primary data from the author/organisation if it is not presented in the study write up. At the least, all studies that are selected for inclusion in the review will be summarised qualitatively. Summary tables of quantitative study characteristics, study quality and results will be presented, accompanied by critical appraisal and potentially a narrative synthesis. Quantitative analysis will be undertaken on any data that is suitable for formal statistical treatment. If possible, meta-analyses for each of the interventions will be carried out with reasons for heterogeneity assessed by meta-regressions (univariate or multivariate).

4. POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

There are no conflicts of interest to be recorded. Staff support will be provided by the CEBC (funded by English Nature), the NSW Department of Primary Industries and the Invasive Animals CRC.

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