National Environmental Science Program

Best-practice management of feral cats and red foxes:

Workshop 3 report

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Acknowledgement of Country

We acknowledge the Traditional Custodians of the lands where the workshop, planning and analysis of data took place, the Wurundjeri and Anaiwan peoples. We acknowledge and respect their continuing culture and the contribution they make to the life of Melbourne and Armidale and the surrounding regions.

We acknowledge the Traditional Owners of Country throughout Australia and their continuing connection to and stewardship of land, sea and community. We pay our respects to them and their cultures and to their Ancestors, Elders and future leaders. Our Indigenous research partnerships are a valued and respected component of National Environmental Science Program research.

Foreword

This report is an output of the NESP Resilient Landscapes Project 2.2: "Best-practice management of feral cats and red foxes". Using expert elicitation workshops, this project aims to identify:

- best-practice management methods for invasive mesopredators
- key knowledge gaps that require further research to inform best practice management

Phase 1 and 2 of Project 2.2 related the management of feral cats (Dorph and Ballard 2022; Dorph and Ballard, 2023)

In Phase 1, the project team coordinated a focused, proof-of-concept workshop for feral cat management with members of the National Feral Cat Taskforce, relevant key researchers from the Resilient Landscapes Hub and other selected expert practitioners from across Australia.

During Phase 2, the project team built an online decision tool for feral cat managers using a model that was developed via an expert-elicitation process.

This Phase 3 report describes the findings of a workshop on best-practice management techniques used to reduce red fox populations in Australia. These findings, combined with additional feedback from fox management experts, will be used to develop an online fox management decision tool.

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European red foxes (*Vulpes vulpes*) are considered a major threat to Australia's wildlife, as well as being a pest to livestock production industries. Consequently, the Commonwealth of Australia has developed a Threat Abatement Plan for the species (Department of the Environment Water Heritage and the Arts [DEWHA] 2008) and the *Threatened Species Action Plan 2022-2023* lists management of red fox populations as a priority.

Managers have access to a range of tools for reducing fox populations to reduce the species' impacts. Tools include aerial baiting, ground baiting, canid pest ejectors, trapping, shooting, den fumigation, and exclusion fencing. However, managers often lack clear guidance on how to design and apply best practice fox management programs for their local conditions.

This project brought experts together to quantify the effectiveness of different fox management scenarios, including those involving combinations of available management tools. Over two consecutive days, 13 experts spent 16 hours in a workshop discussing fox management options. Experts had experience in research and management, and were drawn from Australian Universities, Government, and organisations with a conservation focus. Two observers with a strong professional awareness of issues relating to fox management also attended the workshop and contributed to discussions.

Following the IDEA protocol (Investigate, Discuss, Estimate, Aggregate; Hemming et al. 2018), experts completed an online survey, discussed the results and then completed another survey. The surveys quantified the predicted outcomes of 28 different management scenarios, comprised of aerial baiting, ground baiting or canid pest ejectors, either used alone or in combination with leghold trapping and shooting.

Workshop participants were also asked to identify and prioritise key challenges and research gaps in Australia's fox management. Experts identified 13 key challenges and agreed that the greatest of these were: 1) securing adequate funding for long-term management, 2) maintaining long-term programs, 3) measuring the effectiveness, impacts and benefits of management, 4) managing foxes across tenures, and 5) achieving and maintaining social licence.

Among 24 knowledge gaps identified by the group, it was agreed that the most pressing concerns are: 1) identifying effective reduction targets, 2) measuring outcomes for native fauna, 3) enabling wildlife to persist with foxes, 4) methods for creating integrated management programs, and 5) the influence of conspecifics, habitat, and environmental conditions on management impact.

To improve the development of the fox management decision-tool, we recommend the results presented in this report be combined with those from additional surveys and interview with experts who were unable to attend the two-day workshop.

Introduction

Red foxes (*Vulpes vulpes*) were deliberately introduced to south-eastern Australia in the 1870s (Rolls 1969; Fairfax 2019). Since then, these ecologically flexible, generalist predators (and facultative scavengers) have spread across most of the mainland, except for the tropical north (Fairfax 2019; Fisher et al. 2014). Across their Australian range, foxes pose threats to native fauna and impose considerable socio-economic impacts on small livestock producers (Saunders, Gentle, and Dickman 2010). Many native mammals, birds and reptiles, including freshwater turtles, have declined or gone extinct from predation and/or competition by foxes (Woinarski, Burbidge, and Harrison 2015; Dickman 1996), making effective management of foxes a key conservation action (see the Commonwealth Threatened Species Action Plan 2022 – 2032). Consequently, foxes are listed Nationally as a Key Threatening Process under the EPBC Act (1995) and the current Threat Abatement Plan (Department of the Environment Water Heritage and the Arts [DEWHA] 2008) is currently under review.

Multiple techniques exist for managing red foxes but the primary means for population reduction is poison baiting using sodium fluoroacetate (Compound 1080) (Saunders, Gentle, and Dickman 2010). Other options include trapping (Meek, Ballard, and Fleming 2019), shooting (Mcleod, Saunders, and Miners 2011), den fumigation, exclusion fencing (Saunders et al. 1995) and canid pest ejectors (Busana, Gigliotti, and Marks 1998; Young et al. 2024). Each management tool is known to vary in its efficacy (Kirkwood et al. 2014). However, management is further complicated by jurisdictional differences affecting managers' access to fox control tools and how they may use them. Combined these factors can make generalisations around best practice management difficult as well as limiting across border programs.

In addition to jurisdictional barriers, a range of factors may influence the success of fox management programs in supressing populations to achieve impact reduction. The timing of fox management programs can increase the programs' success by targeting periods of juvenile dispersal (Berry et al. 2013), conversely periods of rainfall immediately following the implementation of a management program may decrease program success (Gentle, Saunders, and Dickman 2007a). Interannual fluctuations in average annual rainfall are also known to drive variability in fox management effectiveness, with lower reductions likely in wetter years compared to drier years (Geary et al. 2022). These added layers of complexity increase the uncertainty associated with making generalised estimates of fox management program effectiveness.

We conducted a two-day, structured expert elicitation workshop with researchers and practitioners in fox management using the IDEA protocol (Hemming et al. 2018). During the workshop we asked experts to quantify the expected reduction in fox populations in Australia for 28 different combinations of management actions comprised of aerial baiting, ground baiting or canid pest ejectors, either used alone or in combination with leghold trapping and shooting. Our aim was to identify the most effective management actions for reducing fox populations, as well as key knowledge gaps and challenges associated with fox management.

1 Methods

1.1 Workshop structure

We convened a 16-hour workshop over two consecutive days with 13 experts in the management of red foxes, as well as two observers. Six facilitators led the structured elicitation of expert knowledge about red fox management and its likely outcomes. Facilitators aided in the design and format of the workshop, led the discussion at each stage, and collated the results. They did not attempt to influence the discussion around the management techniques, knowledge gaps or challenges. The observers were people with a strong professional awareness of issues relating to fox management around Australia but were not considered practitioners or researchers in this area. These observers were welcome to contribute to group discussion and stimulate conversion around different scenarios or challenges but did not complete the expert surveys. The workshop was approved by the Human Research Ethics Committee at the University of New England (HREC Project Number: HE24-002, valid until 31/12/2025).

1.2 Workshop participants

Workshop participants were drawn from a range of universities, government agencies, and other conservation-focused organisations from around Australia (Table 1). All participants were required to have research, management, or policy experience relating to at least two of the five management techniques of interest (aerial baiting, ground baiting, leghold trapping, canid pest ejectors, and shooting). Participants had substantial experience in research, management implementation and policy, and their experience ranged from less than 5 years' experience, and up to 30 years' experience for the management techniques examined here. Prior to the workshop, the participants were asked to provide a self-rating of their experience in each of the five management techniques. These ratings (as well as State/Territory information) were used to split the participants in three groups for the discussion phases of the workshop, such that each group consisted of participants with a range of experience and from different jurisdictions. Three experts completed the pre-workshop surveys but were unable to attend the workshop and participate in discussions reviewing the outcomes of these surveys, and therefore are not included in the reporting of the results.

Table 1 Demographics of workshop attendees (including observers, excluding facilitators) showing the number of participants in each category and this number as a percentage of the 15 attendees at the workshop.

Category	No. of Participants	Percent
Organisation		
Centre for Invasive Species Solutions [AUS]	1	6.7
Department of Agriculture and Fisheries [Qld.]	1	6.7
Department of Biodiversity, Conservation and Attractions [WA]	2	13.3
Department of Climate Change, Energy, the Environment and Water [AUS]	1	6.7
Department of Energy, Environment and Climate Action [Vic.]	1	6.7
Department of Environment and Water [SA]	1	6.7

Department of Primary Industries and Regional Development [NSW]	1	6.7
Shoalhaven Landcare/ South-East Environmental Management Group [NSW]	1	6.7
Macquarie University [NSW]	1	6.7
Northern and Yorke Landscape Board [SA]	1	6.7
Parks Victoria [Vic.]	1	6.7
Phillip Island Nature Parks [Vic.]	1	6.7
University of Melbourne [Vic.]	2	13.3
University of Sydney [NSW]	1	6.7
Unaffiliated [NT]	1	6.7
Gender		
Female	7	46.7
Male	8	53.3
Type of Experience		
Research	8	53.3
Management	5	33.3
Both	1	6.7
Other	1	6.7
Years of Experience		
0-10	10	66.7
11-20	4	26.7
21-30	1	6.7
Experience within State/ Territory		
New South Wales	4	30.8
Victoria	4	30.8
Western Australia	2	15.4
South Australia	1	7.7
Northern Territory	1	7.7
Queensland	1	7.7

For 'Organisation', the relevant State or Territory of the organisation is provided in square brackets. ACT, Australian Capital Territory; NSW, New South Wales; NT, Northern Territory; Qld, Queensland; SA, South Australia; Vic., Victoria; WA, Western Australia; AUS, Federal government department.

1.3 Pre-workshop survey

We used a pre-workshop survey to introduce workshop participants to the IDEA protocol (Hemming et al. 2018), a protocol used later in the workshop to survey experts on fox management scenario outcomes (see section **1.5 Quantifying the impact of management scenarios**). In the pre-workshop exercise, experts were asked to complete and return a survey in which they considered a geographic region where they had experience managing foxes. For the management area they selected, experts were asked to 1) identify number of years out of five, key factors contributed to the success or failure of fox control programs, and 2) provide estimates for the most likely, fewest and greatest number of weeks for foxes to re-invade an area following a ground baiting or aerial baiting program. For point 2, experts were also asked to provide their confidence that their estimates would capture the true number of weeks to re-invasion.

Results from the pre-workshop surveys were anonymised using code names. During the workshop we provided experts with their code name, and presented all participants with the individual results so experts could see how their results compared to the groups responses. At this time, we held a facilitated discussion with the experts to determine if there were any clarifications or extra information we needed to provide the experts with to help experts answer the questions. Several points were raised during this discussion which led to refinement of the questions asked within the pre-workshop survey - the final questions used are provided in Appendix A. Following the facilitated discussions experts were asked to revise their answers.

The expert provided results from the final round of estimates for the key factors affecting the success or failure of a given fox control program was aggregated in a box-and-whisker plot using the 'ggplot2' (Wickham 2016) package in R (R Core Team 2023). In the plots, the boxes show the interquartile range (IQR) illustrating the lower (Q1), median (Q2) and upper (Q3) quartiles of the expert estimates. The whiskers of the plot show the dispersion of the provided estimates, spanning from Q1 – 1.5 x IQR to Q3 + 1.5 x IQR. Experts estimates of the time to fox re-invasion following ground or aerial baiting programs were aggregated and summarised using Microsoft Excel. First, expert estimates for the fewest and greatest number of weeks to re-invasion were corrected using their confidence level (Hemming et al. 2018). Then we used equal weight aggregation of the expert estimates by averaging the mean values for the most likely scenario and the corrected lower and upper confidence limits provided. This is a suitable method for aggregating expert estimates when calibration questions of expert accuracy are not used (Hemming, Hanea, and Burgman 2022).

1.4 Defining management techniques

Experts were split into their groups to discuss and describe the different management techniques used for foxes around Australia. To start conversations, experts were provided with brief definitions of five management techniques (aerial baiting, ground baiting, padded leghold trapping, cage trapping and shooting) based on the outcomes of previous workshops held for feral cat management (Dorph and Ballard 2023; 2022). In addition to these techniques, experts were asked to discuss the use of canid pest ejectors, den fumigation, and exclusion fencing. They were also asked to add and describe any additional techniques that they were aware of. During their discussions experts were asked to consider: the effort management programs used when deploying a technique; the scale at which it could be used; what season might be targeted; the frequency or return interval between uses; what Australian States or Territories were able to use the technique; and any restrictions associated with its use in different States or Territories. Experts were also asked to list any pros, cons or limitations associated with each management technique they discussed.

Following smaller group discussions, all experts were asked to participate in a whole group discussion to collaboratively describe five key techniques used in fox control, namely: aerial baiting, ground baiting, canid pest ejectors, padded leghold trapping and shooting. Within the descriptions for each technique, we asked experts to describe a defined time frame over which a fox management program would be run for that technique. This meant experts would only be considering only a distinct application of the management technique to the fox population, rather than considering the impact of an ongoing or continuous management program. The management technique descriptions generated are provided in Table 2.

Table 2 Management technique definitions provided to experts for consideration during the online management scenario survey.

Action	Definition and effort
Aerial baiting	Baiting applied in late-autumn or early winter at a rate of 10 - 20 baits/ km^2. Baits dropped from a fixed wing or helicopter. Flight lines are spaced at 500 m or 1 km intervals to meet density target for baiting region. Bait type varies based on State/Territory approvals. All baiting activity must avoid waterways and residential areas. *Assume all baits are deployed on a single day.*
Ground baiting	Baiting applied along vehicle accessible trails and other linear features in the landscape. Depending on State/Territory can be 1 bait per 500 – 1000 m. Bait type varies based on State/Territory approvals. All baiting activity must avoid waterways and residential areas. *Assume no ground baiting management in the previous 3 months. The program includes fortnightly replacement of baits for 3 months over winter.*
Canid pest ejectors (CPEs)	Mechanical device set into the ground which, when triggered, delivers the contents of a toxin capsule (1080 or PAPP) into the mouth of a target animal. Lure heads may be used to attract foxes, and collars/covers may be attached to deter non-target species. Deployed along roads or fence-lines. Can be used with a scent lure. Deployed at a rate of 5 CPEs / km or 20 CPEs / 100 ha. *Assume baits replaced every 1-4 week(s) for 3 months.*
Padded leghold trapping	Padded or soft jaw leghold traps installed as either single or paired units placed along or adjacent to tracks or linear features. Traps are distributed at a density of 50 traps within 10,000 ha separated by a minimum of 200 m. Traps remain open for 5-14 consecutive days. Traps may be lured with a scent lure. *Within this workshop, leghold trapping was assumed to be conducted within the two weeks after a poison baiting campaign.*
Shooting	Nocturnal shooting with aid of spotlight or thermal scope, either from back of vehicle or on foot. Involves a team made up of 1 shooter and 1 spotter. Shooting should occur for a minimum of 16 hrs within 2 weeks. This does not include opportunistic shooting of foxes – only targeted shooting. *Within this workshop, shooting was assumed to be conducted within the two weeks after a poison baiting campaign.*

1.5 Quantifying the impact of management scenarios

Structured expert elicitation, following the IDEA protocol (Hemming et al. 2018), was used to quantify the impact of 28 different management scenarios using poison baiting programs (aerial baiting, ground baiting or canid pest ejector) alone or in combination with two other methods – leghold trapping and shooting (techniques defined in Table 2). As per the IDEA protocol, experts were asked to complete two rounds of an online survey with a discussion phase between the two rounds. The survey was hosted on the online platform Qualtrics (2023). During the survey, experts were asked to answer questions considering the expected percentage reduction change in fox populations for a 10,000-ha area in which they have management experience. Due to differences between management approaches around the country, the participants were asked to provide information on the state or territory, vegetation class (survey round 1) or bioregion (survey round 2), land-use type, and bait type they were considering while answering questions. Vegetation class definitions were adapted from definitions provided for 'Australia's ecoregions' from the Department of Sustainability, Environment, Water, Population and Communities (2012). Bioregion definitions were provided from Geospatial and Information Analytics Branch Department of Agriculture, Water and the Environment (2012).

A key point raised by experts during the discussions was whether they should consider fox management successful depending on whether it was a suppression or a maintenance management program. Suppression management of fox populations are "one-off" or single event management programs, that are not ongoing but may be implemented to cause a targeted reduction in the fox population at a point in time. A maintenance management program includes repeated annual management, which may include ongoing, repeated application of a technique to an area over several months of the year. The experts noted that the impact of management from these two program types could have vastly different outcomes for fox population reduction, as repeated management overtime leads to a decrease in management technique efficacy. Due to the nuance associated with ongoing management, for this workshop we asked experts to consider the impacts of a single suppression program when completing the survey.

Experts were provided with the online survey on the first day of the workshop to generate Round 1 estimates of fox population reductions. Experts were asked to indicate the number of foxes removed in each management scenario by providing estimates for their best guess of 1) the number of foxes removed and a credible interval range by providing the fewest number of foxes possibly removed; and 2) the most foxes removed possibly removed. For each best estimate and credible interval ranges, experts were asked to provide how confident they were that their estimates captured the true number of foxes removed. Experts were asked to provide their estimates based on the assumption they were taken at the conclusion of the defined time frame provided in the management technique description (Table 2). Experts were also asked to provide their estimates using one of three major vegetation classes: (1) Forests and woodlands, (2) Deserts and xeric shrublands, or (3) Grasslands. Once all survey responses were submitted, the results were anonymized and the credible interval provided for each scenario provided by the experts was corrected using their confidence level (Hemming et al. 2018). Graphs displaying the corrected responses of each expert to each scenario were then plotted using the 'ggplot2' package (Wickham 2016) (see **Appendix D**).

On the second day, experts were shown the anonymised results of the Round 1 estimates for each of the poison baiting techniques when used with no other management. A brief facilitated discussion was had for each of the three graphs to discuss potential reasons for variation among the experts and among the three techniques. Experts were then split back into their groups of 4-5 and provided the results from three additional management scenarios to discuss in more detail. At the conclusion of these discussions, experts were brought back together and asked to summarise the key factors leading to differences in how they responded to questions. Following these discussions, many experts indicated the three vegetation categories were too broad or that their management area did not fit into the broader classification that it was assigned. Therefore, in Round 2 experts were asked to provide the Interim Biogeographic Regionalisation for Australia (IBRA) classification for their management area to see if there were any trends among similar classification types. Experts were then provided access to their previous survey responses in Qualtrics and allowed to revise their estimates drawing on any insights from the group discussions. The expert provided results from the final round of estimates were corrected using their confidence level (Hemming et al. 2018). We used equal weight aggregation of the expert estimates for each management technique combination to summarise the relative impact of each scenario by averaging the values for the most likely fox reduction and the corrected lower and upper confidence limits provided by each expert. The results were graphed using the 'ggplot2' package (Wickham 2016) in R (R Core Team 2023).

1.6 Ranking Management costs, Challenges and Knowledge Gaps

Experts were asked to complete a survey on management costs. Participants were asked to rank all the management techniques described in the discussions outlined in section **1.4 Defining management techniques** in order from least expensive to most expensive. Additionally, participants were asked to rank the management techniques according to the level of fox population reduction for investment, from least effective to most effective at reducing the fox population relative to the money invested. The expert rankings were aggregated in a box-and-whisker plot using 'ggplot2' (Wickham 2016), where the boxes show the interquartile range (IQR) with the lower (Q1), median (Q2) and upper (Q3) quartiles of the expert estimates. The whiskers of the plot show the dispersion of the provided estimates, spanning from Q1 – 1.5 x IQR to Q3 + 1.5 x IQR.

Experts were asked to complete a survey identifying three to five key challenges associated with European red fox management in Australia. Facilitators reviewed the responses of participants and collated the responses to a single list of challenges which was provided to the participants for discussion and refinement. Once the list of challenges was agreed upon by the group, participants were asked to complete a second survey ranking the key challenges in order of importance, ranks were applied from 1 (least important) to 13 (most important). Following the ranking process, the challenges were grouped into three categories based on subject matter: (1) bureaucratic and administrative challenges, (2) ecological and scientific challenges, and (3) community engagement challenges. Box-and-whisker plots were generated in 'ggplot2' (Wickham 2016) displaying the rankings for each challenge split by these groupings.

Experts were asked to complete a survey identifying three to five key knowledge gaps associated with European red fox management in Australia. Facilitators reviewed the responses of participants and collated the responses to a single list of knowledge gaps which was provided to the participants for discussion and refinement. Once the list of knowledge gaps was agreed upon by the group, participants were asked to complete a second survey ranking the key knowledge gaps in order of research priority, ranks were applied from 1 (lowest priority) to 13 (highest priority). Following the participants ranking, the knowledge gaps were grouped into categories based on subject matter, these were knowledge gaps relating to: (1) inter-species interactions, (2) community engagement, (3) management program effectiveness and impact, (4) fox management tools and program development, and (5) fox population ecology. Box-and-whisker plots were generated in 'ggplot2' (Wickham 2016) displaying the rankings for each knowledge gap split by these groupings.

2 Results

2.1 Pre-workshop Survey

Fifteen experts originally provided rankings of the factors affecting management program success in their management area and the time to red fox re-invasion following management in the pre-workshop survey. However, during the workshop only 12 of the 15 experts were available to re-visit their surveys following a discussion around survey terminology and how the questions should be interpreted. The results from this second round of surveys are presented below.

2.1.1 Factors affecting management programs

Experts provided the number of years out of five in which their management programs were affected by seven factors that could lead to the success or failure of red fox management (Figure 1). Experts indicated that in most areas of Australia the factors most likely to contribute to a successful management program include conducting management during the 'breeding season', conducting management during 'juvenile dispersal', and conducting 'cross-tenure management' programs (Figure 1a). Experts considered these factors lead to increased program success as they increased trap success and bait uptake and allowed for more effective targeting of juveniles naïve to control efforts. Additionally, programs run across multiple land tenures were considered beneficial as they reduced re-invasion from neighbouring areas. Experts also indicated 'other' factors may contribute to the success of a control program (Figure 1a), including:

- The spatial and temporal scale of the program (larger areas covered over multiple years leads to greater success).
- Avoid implementing poison baiting programs when significant rainfall events are predicted within 10 days post-baiting.
- Regular baiting frequency.
- Co-ordinating baiting programs using both aerial and ground baiting with additional targeted techniques (e.g. den fumigation or trapping following broadscale control).
- Availability of funding.
- Availability of skilled staff.
- Integrating management programs with those for other pest species (e.g. controlling for cats at the same time).

The experts indicated 'above average rainfall' and the 'presence of wild dogs or dingoes' in their area did not contribute as highly to a successful program (Figure 1a). Note that many experts commented wild dogs or dingoes were not present or monitored within their management area so responded "Not applicable" to this factor.

Experts indicated 'above average annual rainfall' or 'other' factors (see the list below) as the most common factors leading to a management program failure (Figure 1b). One expert listed the 'presence of wild dogs or dingoes', and one expert listed 'cross-tenure management' programs as factors leading to program failure in all five years. These factors were outliers, however, and all other experts indicated they did not influence program failure in any of the five years (Figure 1b). As noted above, there were few responses from experts on whether wild dogs of dingoes impacted management programs in their area. Several experts also noted that an inability to run a program cross-tenure can lead to program failure, and that equally cross tenure programs can fail when some parties are unable to implement control in conjunction with other efforts. Some of the additional factor's experts listed that contributed to management program failure in their local area/ management area included:

- Logistical issues, e.g. access to the management area, access to or availability of skilled contractors to complete the work.
- Ineffective timing, intensity, and type of control used in the management program.
    - If foxes are not controlled during key periods, the efficacy of management techniques diminishes and the costs of implementing management may increase.
- The presence and uptake of poison baits or canid pest ejectors by non-target species.
- Social licence.

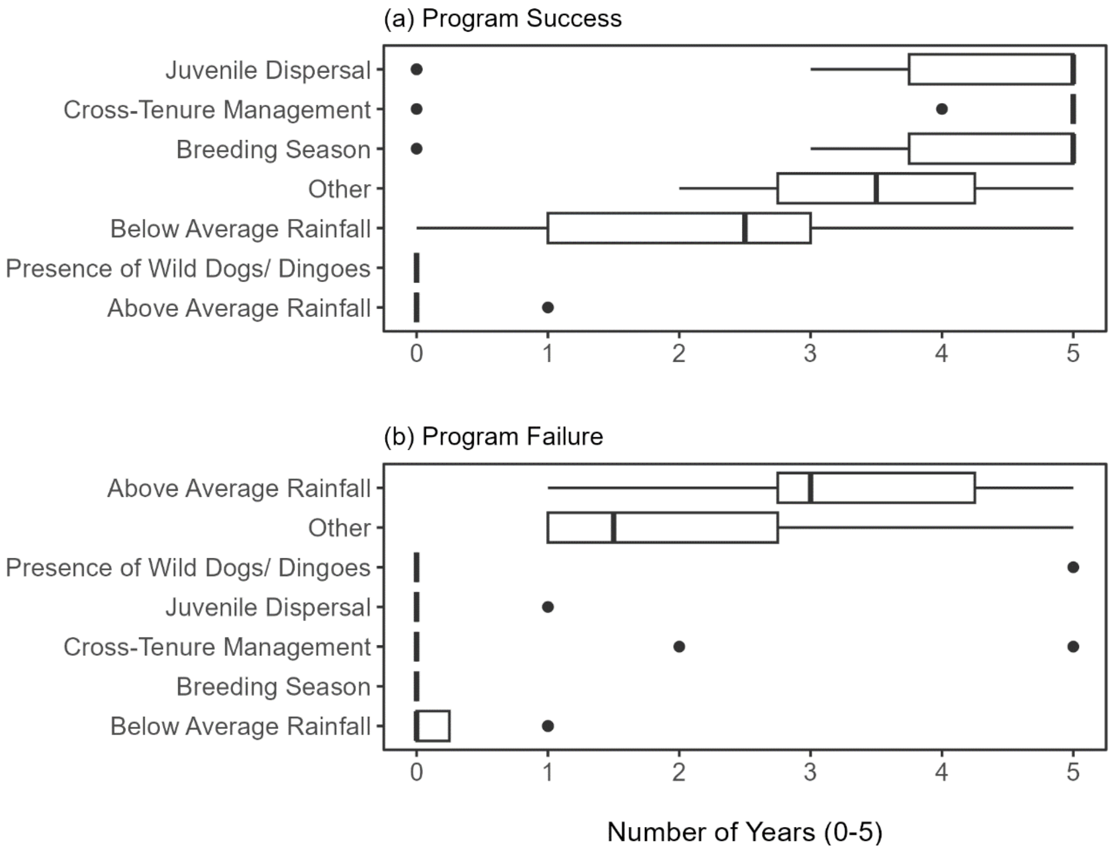

Figure 1 Box-and-whisker plots summarising the responses from round 2 of the pre-workshop survey. Participants were asked to estimate the number of years out of five in which each of the factors influenced the success or failure of a European Red Fox management program. Factors along the y-axis are ranked from most important (top) to least important (bottom) based on the medians for the box and whisker plots.

2.1.2 Time to re-invasion

There was no significant difference in the estimates of the time (number of weeks) for foxes to re-invade an area following either an aerial baiting or ground baiting management program provided by the experts. For aerial baiting, experts estimated time to re-invasion was 3.64 weeks (95% CL: 2.68 – 4.34, n=13) while for ground baiting experts estimated 3.42 weeks (95% CL: 2.60 – 4.22, n=13).

2.2 Identification and definition of European red fox management techniques

During round table discussions the experts identified and discussed 11 different techniques used in European red fox management. These techniques included: aerial baiting; ground baiting; canid pest ejectors; padded leghold trapping; cage trapping, shooting; exclusion fencing; den fumigation; Felixer grooming traps; guardian animals; and predator and prey aversion training. Table 2 above summarised the definitions for the management techniques used in the management scenario survey (described in section **1.5 Quantifying the impact of management scenarios**). The full detail provided by experts during discussions on all the management techniques is provided in Appendix C.

2.3 Management scenarios

Experts completed a survey considering 28 different management scenarios using poison baiting programs (aerial baiting, ground baiting or canid pest ejector) alone or in combination with two other methods – leghold trapping and shooting. For this survey, experts were asked to provide information about a landscape that most closely matched their experience. Eight participants selected an area that was predominantly native vegetation (> 60% of area); one participant selected an area that was predominantly agricultural land (> 60% of area); two selected an area that was a mix of native vegetation and agricultural land, and two indicated they managed a multi-use landscape. Vegetation within these landscapes was grouped into two ecoregion categories, with 11 participants responding for “Forests and woodlands” type vegetation and two respondents for “Deserts and Xeric Shrublands” vegetation. Experts were also asked to select the poison bait type for which they had the most experience, four participants selected Foxoff, three selected 60-100g fresh meat bait (1080); two selected 200-250g fresh meat bait (1080); two selected Probait; one selected unspecified dried meat bait 3.0mg 1080; and one selected 1080 Canid Pest Ejector capsule. Full details of the individual expert responses and the variables they choose to respond to the survey using are provided in Appendix D.

When asked about the number of young a vixen was likely to raise within a 12-month period, experts indicated that on average 3 young (s.d. = 0.87, range = 1 – 4) were raised each year. Figure 2 shows an average of the annual number of young raised be State or Territory in Australia. Many experts commented that litter size in their area was probably four with mortality from non-management related causes ~25%. However, many also indicated that estimating the number of surviving young was difficult to quantify due to a lack of field data for their area.

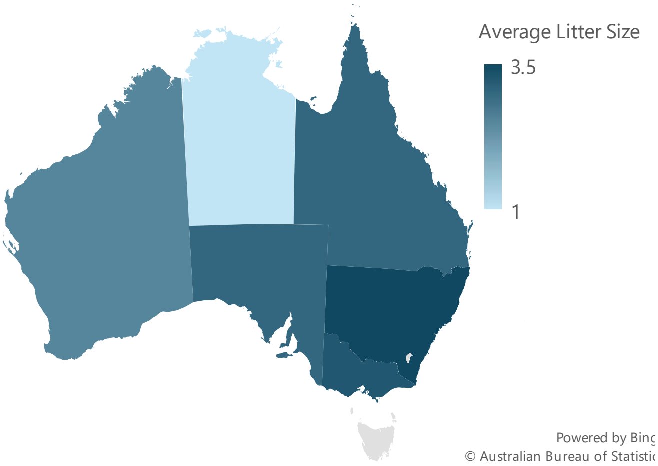

Figure 2 Expert estimates of the number of young per vixen raised to independence within a twelve-month period averaged by State/Territory.

The equal weighted expert responses for the expected red fox population reduction following each of the different management scenarios is provided in Figure 3. Expert estimates indicated management scenarios incorporating aerial baiting or ground baiting were on average more likely to cause a greater reduction in the feral cat population (Figure 3). Notably, only 75% of the experts had experience using aerial baiting, so the response sample size for scenarios including aerial baiting is reduced (Appendix D). Individually, some experts indicated ground baiting programs performed better than aerial baiting programs (Appendix D). However, on average experts indicated higher population reductions using aerial baiting programs. Management scenarios using both aerial and ground baiting performed slightly better on average, however, there was large overlap in the uncertainty estimates surrounding these three combinations of poison baiting (Figure 3).

On average, experts considered that use of Canid Pest Ejectors (CPEs) without another form of poison baiting had the lowest impact on fox populations (Figure 3). However, two experts considered CPEs two or three times more effective than their colleagues (Appendix D). On average experts also considered that there was little or no benefit of using Canid Pest Ejectors in combination with either aerial or ground baiting (Figure 3). When leghold trapping or shooting were used in conjunction with any of the poison baiting combinations, there were slight increases to the estimated average population reduction (Figure 3). This increase can mostly be attributed to the addition of leghold trapping to the management program (Figure 3). However, with all management scenarios there was large overlap in the uncertainty surrounding the average estimate.

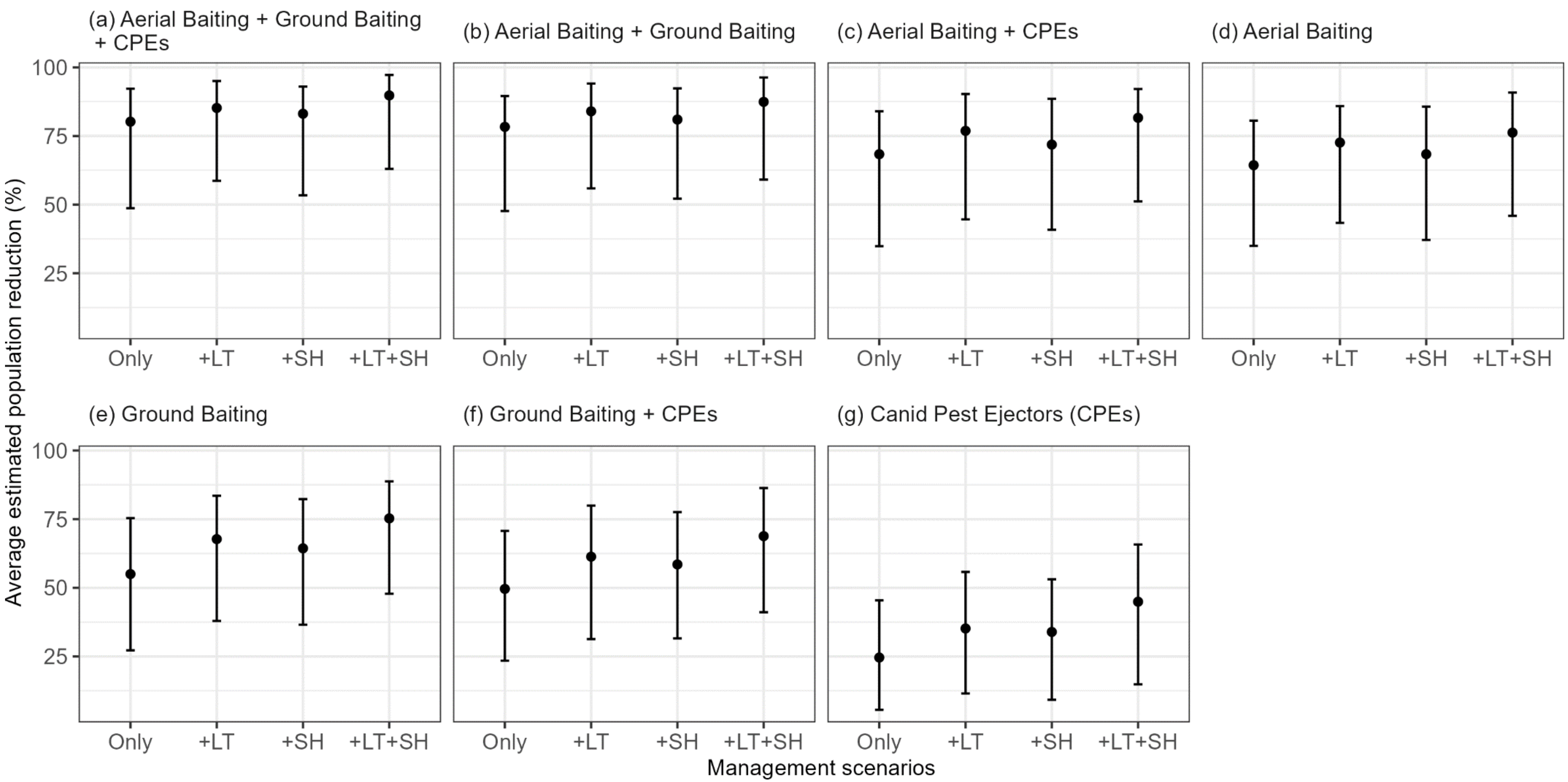

Figure 3 Average best estimate and 80% credible intervals for all expert estimates from the final survey for management scenarios using poison baiting techniques only and in combination with leghold trapping (LT) or shooting (SH). The survey questions asked for the percentage of the fox population that was removed one month after management was implemented. Responses to poison baiting campaigns are ordered from most to least effective as follows: (a) aerial baiting, ground baiting and canid pest ejectors (CPEs), (b) aerial baiting and ground baiting, (c) aerial baiting and CPEs (d) aerial baiting only, (e) ground baiting only, (f) ground baiting and CPEs and (g) CPEs only.

2.4 Costs and return for investment

Most experts ranked "fencing" and "predator and prey aversion training" as the most expensive management techniques to implement (Figure 4a). The median expert rank for the second most expensive technique was the Felixer Grooming traps, though the individual rankings of this technique varied widely (Figure 4a). Padded leghold trapping was considered the next most expensive technique, followed by canid pest ejectors, shooting and aerial baiting (Figure 4a). However, the range of ranks provided for aerial baiting varied widely between experts. Den fumigation, guardian animals, and ground baiting were considered the least expensive techniques to implement (Figure 4a).

When asked about the return for investment when implementing each management technique, experts ranked aerial baiting as the best "value-for-money", followed by fencing, ground baiting, and canid pest ejectors (Figure 4b). Experts ranked the remaining techniques in order from most effective to least effective as: shooting, padded leghold trapping, guardian animals, predator and prey aversion training, Felixer grooming traps, and den fumigation (Figure 4b).

2.5 Challenges

Experts generated a list of 13 different challenges of fox management in Australia. Experts were asked to rank all thirteen challenges simultaneously, from most to least important. After the experts ranked the challenges they were grouped into three categories based on common themes: (1) Bureaucratic and Administrative challenges (Figure 5a), (2) Ecological and Scientific challenges (Figure 5b), and (3) Community Engagement challenges (Figure 5c). The full list of challenges provided in Figure 5 are listed in text using theme and rank order under Appendix E.

There was large variation in the importance attributed to each of challenges by the experts. However, there was strong consensus regarding the top ranked challenge, which was "Budget: securing adequate funding for effective long-term management" (Figure 5a). In addition to budget, most experts ranked another challenge from the Bureaucratic and Administrative category, "Maintaining long-term management programs", as the next biggest challenge facing fox management programs (Figure 5a). "Measuring the effectiveness, impact and benefits of fox management", an ecological and scientific category challenge, was ranked third (Figure 5b). This was followed by the two community engagement challenges, "Implementing cross-tenure programs" and "Social licence" (Figure 5c).

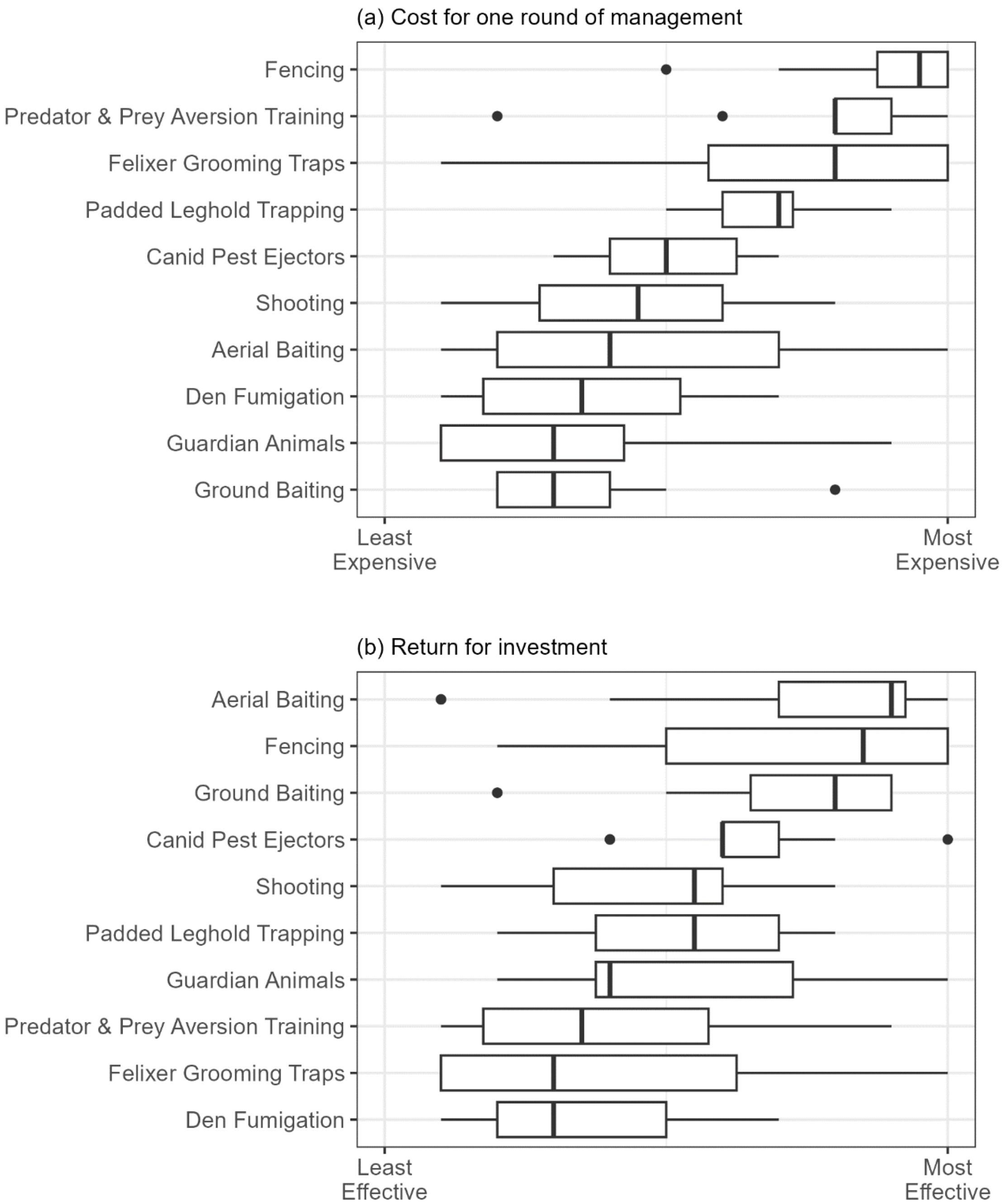

Figure 4 Box-and-whisker plots of expert rankings of European Red Fox management techniques (a) ordered from most to least expensive for the cost for one round of management as defined by the management scenario survey, and (b) the most to least effective techniques for reducing fox populations relative to the investment required. The thick black line indicates the median value of the expert estimates. Lower and upper limits of the box indicate the first and third quartiles respectively. Lower and upper whiskers extend to the minimum and maximum of 1.5 times the interquartile range. Black dots indicate outlying ranks.

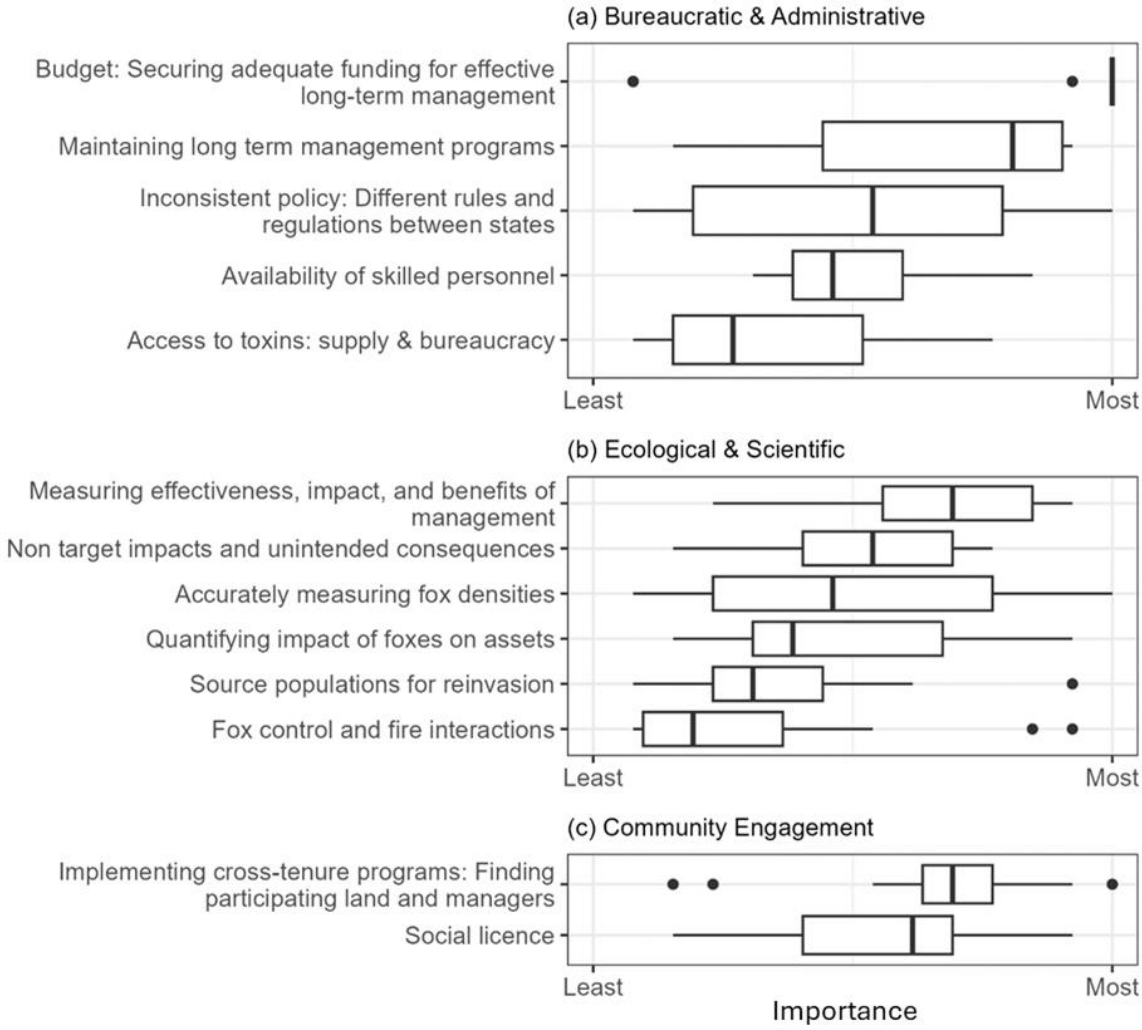

Figure 5 Box-and-whisker plots of expert rankings of challenges identified in European Red Fox management in Australia, ordered by the median expert rank from most to least important and grouped by subject area for (a) Bureaucratic and Administrative challenges, (b) Ecological and Scientific challenges, and (c) Community Engagement challenges. The thick black line indicates the median value of the expert estimates. Lower and upper limits of the box indicate the first and third quartiles respectively. Lower and upper whiskers extend to the minimum and maximum of 1.5 times the interquartile range. Black dots indicate outlying ranks.

2.6 Knowledge gaps

Experts established a list of 24 different knowledge gaps related to fox management in Australia. For the list of knowledge gaps, experts were asked to rank all the knowledge gaps simultaneously from highest to lowest priority. After experts ranked the challenges, they were grouped into five categories based on common themes, these were knowledge gaps relating to: (1) inter-species interactions (Figure 6 a), (2) community engagement (Figure 6 b), (3) management program effectiveness and impact (Figure 7 a), (4) fox management tools and program development (Figure 7 b), and (5) fox population ecology (Figure 7 c). The full list of knowledge gaps provided in Figures 6 and 7 are listed in text using theme and rank order under Appendix E.

There was large variation in the priority rankings provided by experts for all knowledge gaps. From the overall rankings it was agreed that the most pressing knowledge gaps are: 1) identifying effective reduction targets, 2) measuring outcomes for native fauna, 3) enabling wildlife to persist with foxes, 4) methods for creating integrated management programs, and 5) the influence of conspecifics, habitat, and environmental conditions on management impact.

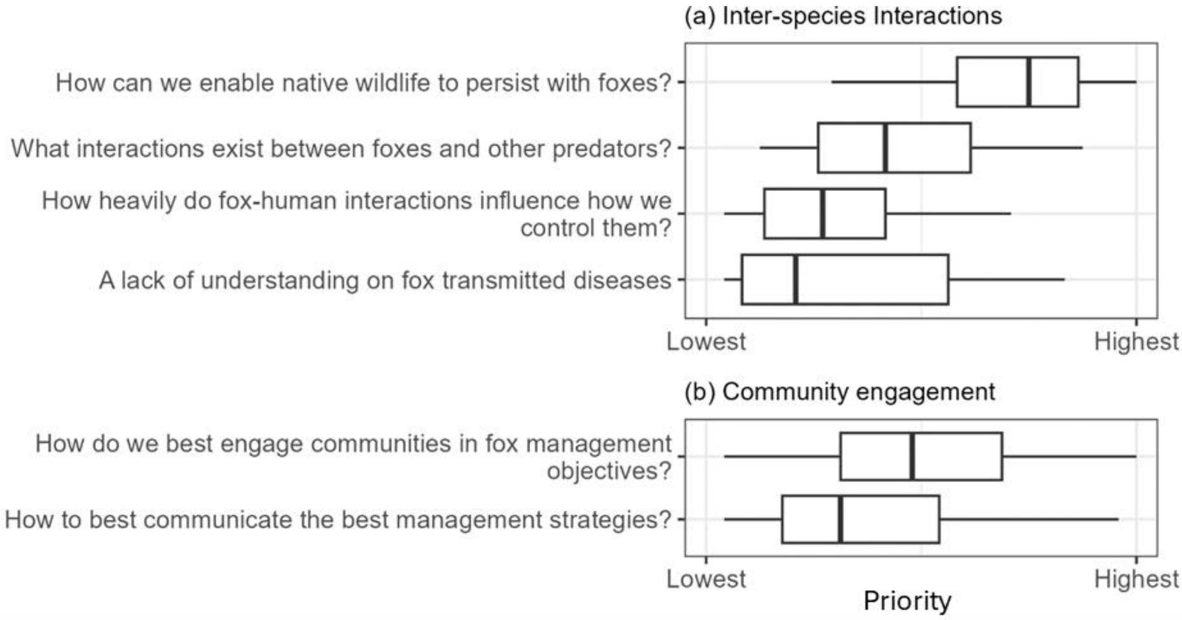

Figure 6 Box-and-whisker plots of expert rankings for knowledge gaps for European Red Fox management in relation to (a) inter-species interactions and (b) community engagement, ordered by the median expert rank from highest to lowest important priority. The thick black line indicates the median value of the expert estimates. Lower and upper limits of the box indicate the first and third quartiles respectively. Lower and upper whiskers extend to the minimum and maximum of 1.5 times the interquartile range. Black dots indicate outlying ranks.

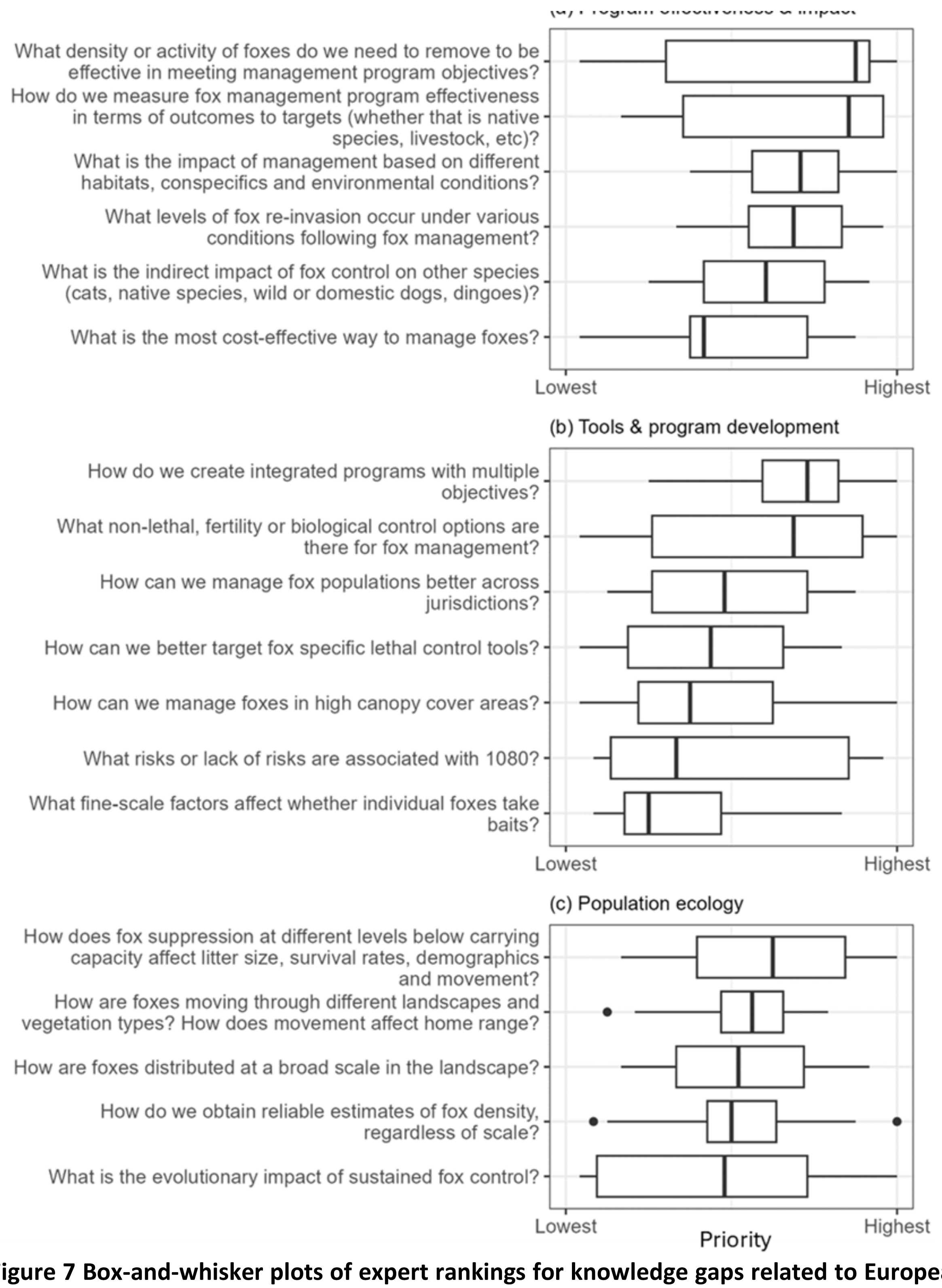

Figure 7 Box-and-whisker plots of expert rankings for knowledge gaps related to European Red Fox management in (a) program effectiveness and impact, (b) management tools and program development, and (c) fox population ecology, ordered by the median expert rank from highest to lowest important priority. The thick black line indicates the median value of the expert estimates. Lower and upper limits of the box indicate the first and third quartiles respectively. Lower and upper whiskers extend to the minimum and maximum of 1.5 times the interquartile range. Black dots indicate outlying ranks.

3 Discussion

3.1 Summary

Workshop participants provided estimates on the efficacy of red fox management scenarios under a range of different conditions for several bait types. There was variability in the expected reduction in fox populations due to the techniques, landscape features, and bait types used. Generally, an integrated management approach utilising all five management techniques (aerial baiting, ground baiting, canid pest ejectors, leghold trapping and shooting) was associated with the greatest reductions in fox populations, regardless of region or bait type. However, when supplementary techniques such as leghold trapping or shooting were used in addition to aerial and ground-baiting, most experts only estimated small increases to the expected population reduction.

On average, experts indicated management programs using a combination of aerial, ground and CPE baiting performed the best followed by programs using aerial and ground baiting; aerial and CPE baiting; aerial baiting; ground baiting; ground and CPE baiting; and finally, CPE only baiting. However, when examining individual experts' responses, not all experts reported the same trend in baiting program reduction. For example, some experts reported greater population reductions in programs with a ground baiting focus (Appendix D Figure S3) compared to programs with an aerial baiting focus (Appendix D Figure S2). During the workshop, experts raised concerns about the amount of variability in road access between the management areas they were considering. Road networks are essential to the implementation of successful ground baiting, CPE, and leghold trapping programs as adequate coverage of the area is required to increase the exposure of the fox population to these control techniques (e.g. Francis et al., 2020). Therefore, discrepancies in site access and road network coverage between management areas across Australia may have increased the uncertainty in the relative population reductions reported by experts.

Most experts considered management programs using CPEs to be less effective than programs using other forms of poison baiting. Further, they noted CPEs added little benefit to management programs when used in conjunction with other poison baiting techniques and there was potentially some redundancy using CPEs in conjunction with ground baiting programs. However, there was discussion around the added benefit of CPEs in areas when interference from non-target species with ground baits was high. It was also noted that in some areas CPEs are the only available poison baiting option to manage foxes, due to baiting restrictions in some jurisdictions to prevent the risk of dingos taking baits? as baiting can be restricted in some jurisdictions to prevent the risk of dingo uptake of baits. However, the use of CPEs was considered very cost and labour intensive, and alternative poison baiting programs were regarded as more effective in areas when non-target uptake of baits was reduced.

There was high variability and uncertainty in the estimates provided by individual experts that contributed to high uncertainty in the group average estimates. Experts indicated that the main drivers of this uncertainty were factors relating to the landscape, environmental conditions, fox population ecology, and how the management program was implemented. Landscape contextual factors that added to the expert uncertainty included the type of management being conducted in adjacent agricultural areas, the proximity of the management to urban areas, and site accessibility during the management program. Environmental factors influencing the expert uncertainty included weather conditions around management, the prey availability during management, and whether there were dingoes or wild dogs in the management area (see **Box 1**). Fox population ecology, in particular immigration and emigration rates of foxes from the management area were also noted as causing uncertainty in expected responses. Finally, information around the management programs implementation that impacted expert uncertainty included the experience of the trappers or shooters participating in management, whether the program was being conducted across tenures, the engagement of nearby landholders and what monitoring method was chosen to quantify population reduction.

Box 1 A note on terminology regarding wild dogs and dingoes during this workshop, and the concepts explored in relation to the species.

Wild dogs and dingoes

Wild dogs and dingoes (*Canis familiaris*) were briefly discussed at several points throughout the workshop. Here, we use the terms wild dog and dingo interchangeably to refer to these species, depending on the jurisdiction in which the species is being discussed. For example, "wild dog" is used to describe information provided from experts in jurisdictions that actively manage wild dogs to reduce their impacts on agricultural outputs, whereas "dingo" is used to refer to areas where the species is protected, and control programs are limited to not affect the species.

It is important to note that during the workshop we did not actively explore wild dog/ dingo impacts on the fox population or how wild dogs/ dingoes are managed in different areas. We did ask experts about the impacts of wild dog/ dingo presence on the outcomes of fox control programs. However, experts provided no advice on this impact with many commenting wild dogs/ dingoes were not present in the area where they manage foxes.

Some experts noted that regular wild dog control occurs within their management area. While they were not directly asked about how wild dog management impacted fox populations nor how fox management impacted wild dog populations, several experts commented that the presence of wild dogs did not impact the outcomes of fox management programs.

Conversely, other experts noted that dingoes are protected within their management area and emphasised this limited the options available to them for the control of fox populations.

3.1.1 The impact of landscape context

During the survey experts were provided with three options to provide some landscape context to the estimates they provided: native vegetation (>60% of the area); agricultural land (>60% of the area); or native vegetation and agricultural land mix. However, several experts noted concerns with this system suggesting that there was not enough information provided about the type of agricultural matrix being managed. Experts stated that fox population responses to management can vary depending on whether management occurs on or adjacent to agricultural crops, sheep or cattle farms. Experts also noted that the distribution of native vegetation within an agricultural matrix can also impact fox population responses to management. To understand the extent of these impacts, more targeted surveys exploring how the outcomes of management programs relate to the impact of variations in the landscape context surrounding the management area are required.

Landscape context also influences the extent to which cross-tenure management is required for a fox management program to be successful. Experts noted cross-tenure programs can increase the success of fox management programs as land holder participation in these programs can increase the size of the area being managed, increase the number of foxes removed, and reduce the time to fox re-invasion of a management area. However, some experts also noted cross-tenure programs have the potential to failure, due to factors such as the reliance on coordinating the management actions of stakeholders; varying amounts of stakeholder effort; and variable application of management actions across the landscape. These factors are influenced by the interest and investment of surrounding land holders into fox management, with private land holders' investment into a program depending on the potential risk to assets on their land. Additionally, experts noted that cross-tenure programs may lose efficacy as protection zones (e.g. waterways, housing) increase within the management areas meaning the coverage of baiting programs might be reduced.

3.1.2 The impact of environmental variables

Vegetation

Several experts noted the vegetation type and cover available within a management area affected not only the underlying fox population ecology in an area, but also the potential success of management tools and their impact on the fox populations. They noted that whether management was being conducted in more open, agricultural or grassland systems compared to denser, forested systems could impact the effectiveness of the management being conducted. For example, shooting success was expected to be greater in more open environments (e.g. agricultural landscapes, or xeric systems), as the increased openness resulted in increased visibility. Conversely, in very densely vegetated areas visibility is expected to be reduced, and the application of management programs may be hampered by vegetation. For example, in dense forest ecosystems aerial baiting may be less effective as baits can be caught in vegetation before reaching the ground and are therefore not available to foxes.

Rainfall

General climate trends and interannual fluctuations in weather were widely acknowledged to add uncertainty to the estimates experts provided for fox population reduction. In low rainfall years, they noted that fox activity can increase relative to other years as foxes search for resources, but that management program success is also more likely to increase in these years as fewer prey are available leading to higher bait uptake. Conversely, in wet years, fox activity is likely to reduce as prey availability increases ultimately reducing the impact of management programs. High rainfall years can also result in reduced accessibility to management sites and reduced longevity of baits during baiting programs. For example, rainfall immediately following the deployment of poison baits can reduce program success as the toxin decays faster reducing the longevity of the bait (e.g. Gentle et al., 2007). Consequently, annual rainfall can greatly impact the success of fox management programs.

Experts also noted an interaction between the landscape context and amount of rainfall, especially in agricultural ecosystems. Some experts indicated that within their management area, during wetter years the resources within the agricultural matrix of their ecosystems were likely to decline, leading to increased fox predation pressure within patches of native vegetation. When these factors are combined with a low fox population reduction in wet years the impact of foxes in native ecosystems may be larger than expected. Another view presented by experts in agricultural systems, suggested that in high rainfall years, agricultural cropping areas were more productive, which leads to increased rodent prey populations and ultimately reduced fox bait uptake in these landscapes. Some experts noted, in arid systems these fox population responses to management and rainfall may be heightened by the boom-bust-cycle. These observation by experts within their management areas highlight the complexity of fox management at the interface between management, rainfall and agriculture.

3.1.3 Fox density, immigration and emigration

Throughout the workshop there was discussion about the influence of the starting density of fox populations on the relative success of different management programs and how this varied among different areas. Experts noted that fox density can vary within and between management areas due to several factors including: (1) land use (e.g. agricultural land vs forested reserve), (2) vegetation type (e.g. foxes in the arid zone may have larger activity ranges and lower densities – particularly in "bust" years), and (3) history of land management. However, ultimately experts concluded that while fox density varies between different regions based on these factors, we might not have enough information about how populations vary and respond to management to examine in detail the impacts of different factors on population reduction.

Experts also noted that the tools or methods selected to effectively manage a fox population depended on the starting density of foxes in a management area. For example, managers may need to use more baits when the initial population density is high compared to when the population density is low to ensure similar number of baits are available per fox and achieve a similar reduction in population. When population numbers are lower, some methods such as shooting may also be more effective per unit effort in comparison to leghold trapping. Consequently, having some measure of the relative abundance or density of the population within the management area before commencing a program is prudent to choosing the methods for higher management success.

In addition to population density, fox movements, immigration, and dispersal from different areas can also impact how long management programs are able to successfully reduce population numbers. Re-invasion of foxes from surrounding landscapes can occur more quickly in landscapes with higher connectivity to adjacent areas. Further, the activity ranges of foxes within the management area may also impact re-invasion rates. For example, areas with increased productivity foxes may have lower activity ranges, increased densities and reduced dispersal distances as they are not resource limited. Conversely, in lower productivity areas foxes may have lower densities, increased activity ranges and bigger dispersal distances as they search for food resources. This is important as experts suggested that re-invasion rates might differ based on type of control that was implemented – for example, following a ground baiting only program, activity might go back to "normal" levels within a week, but following an aerial baiting program it might take a month. Understanding the population densities and activity ranges of the fox population within a management area will aid managers in understanding the effort required within management programs to keep fox populations at lower number for longer periods.

3.1.4 Management program implementation

We asked experts to consider management techniques based on a range of parameters that did not account for variations in their management area. This led to some discrepancies in how they considered their results which, in turn, contributed to some of the uncertainty surrounding estimates. Differences in legislation, landscape context, and road access meant variability was introduced to the experts estimates or in some cases experts were unable to provide estimates for several of the scenarios as they had no experience for certain techniques within their management area. For example, in Queensland and Victoria aerial baiting for foxes is not permitted, meaning experts from these areas were less able to comment on the efficacy of aerial baiting programs. Similarly, there is no aerial or ground baiting permitted within the Northern Territory meaning consideration of these techniques in this area is difficult.

How experts considered the five management techniques to be applied among their different management areas also varied. For example, some considered aerial baiting to cover the centre of the management area and targeted ground baiting to the perimeter to reduce re-invasion. Others used the road network of the interior of the site to apply ground baits. We made no assessment of how these different approaches impacted the overall outcome of the experts' provided answers; however, further examination of these factors may contribute to our understanding of the potential efficacy of fox management in different landscapes.

The scale of application, skill associated with use, and existing knowledge around different management techniques were also considered by experts to increase the uncertainty in their estimates. Firstly, the density with which experts were asked to consider management techniques, such as leghold trapping or CPEs, was not feasible nor applicable to some management areas due to a higher road density in these areas. For example, if using 80 km of road some experts would be considering the application of 400 CPEs, for most managers this is not achievable in terms of effort or budget available. In addition to the scale of effort, experts frequently noted that the relative success of leghold trapping and shooting programs was highly dependent on the skill of the person implementing the management. Finally, in some areas, experts noted too little management, or research had been done using some technique to adequately comment on the return for effort you might expect for implementing the program.

3.1.5 Monitoring management impact

Experts emphasised monitoring of fox populations to accurately measure changes in population densities is critical to understanding the impact of management programs. Currently, many experts noted that program success is measured using the number of baits deployed during a poison baiting campaign. However, this approach does not reflect the fox population response to management and misses the nuance associated with fox population demographics and native fauna responses to the management action. Understanding how different types and levels of suppression influence fox population demographics and how new individuals re-invade an area following management were both noted by experts to be important components of monitoring often missed during fox management. Further, the ability to assess links between fox population activity or density and impacts on native species was also noted by experts to be useful for assisting managers in understanding the effectiveness of their management actions. In particular, understanding this link could help managers assess when greater effort needs to be employed in programs to reduce fox impacts. Developing methods to accurately measure fox population activity or densities and the changes in activity or abundance of the surrounding faunal community is therefore vital to understanding and assessing management program impact.

3.2 Limitations to management scenarios

A common limitation mentioned by experts, with regards to the management scenarios, was the variability in the scale of management required between different regions. Following discussion sessions, it was decided that experts would consider a 10,000-ha management area with a centrally located asset and a 20 km buffer around the site. However, this scale was problematic for some experts from more arid areas, who mentioned that 10,000 ha could be the size of a single fox's home range. Conversely, other experts mentioned that having 10,000 ha of land to manage in a cross-tenure program could be very difficult due to the number of land holders involved. Whilst this was a challenge associated with effective management, they also noted that management at this scale or larger was required for effective fox population control. Therefore, experts emphasized the importance of working with multiple land holders across multiple tenures to be able to implement a management program at a scale of sufficient size to reduce the impacts of foxes.

In the results presented in Figure 3 we have averaged all expert estimates across land-use, bait type and vegetation type. However, in doing so we have lost much of the variability between expert estimates that can be seen in Appendix D. We found that there was too much variability among the thirteen expert responses to draw generalisations based on grouping by bait type, vegetation type or land use. Consequently, it was difficult to draw strong conclusions about (a) whether fox population responses depend on the bait type, land-use and vegetation categorisation, and (b) whether different fox population responses are likely under different environmental conditions. Further, we lacked coverage for some of the different categories provided, for example, we had no responses for grassland dominated areas. This may have been a result of no experts attending the workshop having experience in these areas, most grassland/ savanna ecosystems occurring in tropical areas where fox density is lower, or because many grassland/ savanna landscapes are converted to agricultural lands. Further expert surveys would be beneficial to examine some of the trends in fox population responses that may happen based on the land use, vegetation and bait type classification.

4 Conclusions and recommendations

Red fox management is a complex issue requiring a combination of approaches under different scenarios to effectively reduce the impact of foxes on native species, agriculture, and other assets. The combination of techniques and approaches used in the control of red foxes is dependent on the aim of the management program and whether management for suppression, maintenance or eradication is the goal. The outcome of the program will also likely vary based on the duration of the management program, bait type, vegetation, climatic conditions, the abundance of non-target populations that may impact success and the skill of the personnel completing the management. Through this workshop, experts highlighted many of the complexities associated with fox management and provided a starting point for understanding how different factors affect the outcomes of different management scenarios. A key recommendation from experts was the need to encourage landholders to talk to their neighbours and work together to implement co-ordinated fox management and increase the size of the area being managed.

Further research investigating the effects of fox management under alternative conditions will help understand how population responses to management vary. One method to achieve this, and boost sample size, would be to conduct further surveys of experts with different backgrounds in fox management. Additionally, development of an alternative survey to quantify how the impact of management varies with different bait rates or variations in landscape context could help demonstrate the dependence of fox population responses on the context of management.

Appendix A

Pre-workshop survey questions. Red text indicates points of clarification added during the discussion phase at the workshop.

Factors impacting fox control program success

Questions 1 to 5 are about the factors impacting the success of European Red Fox control programs, where success is defined as a 70% reduction in fox activity following management.
Fox control programs often use integrated management to diminish fox populations and reduce their damage. Frequently control programs use some combination of ground baiting, aerial baiting, canid pest ejectors, shooting, trapping, exclusion fencing, and den fumigation. Programs may be repeated multiple times in a year and can be targeted to national park, pastoral land or may be cross-tenure.

Consider 10,000 ha area on public land surrounded by an agricultural matrix for a geographic region you are familiar with where control of fox populations is undertaken.

	Questions	**Answers**	**Notes/ comments**
1	Name the region that you are familiar with		
2	In how many of the last 5 years did any form of targeted fox control occur within your selected region		
3	What were the primary management techniques used in these targeted fox control programs?		
4	Consider up to 5 years of fox control programs in your selected region. In your opinion, in how many years did the following factors contribute to a control program being successful in that year. Where success is defined as a 70% reduction in fox activity following management. Note: More than one factor may be important in the same year, so the total can exceed 5.	**Best estimate of the number of years [0-5]**	
	Higher than average annual rainfall		
	Lower than average annual rainfall		
	Conducted during mating season		
	Conducted during juvenile dispersal		
	Presence of wild dogs or dingoes		
	Control program run across land tenure		
	Other		
5	Consider up to 5 years of fox control programs in your selected region. In your opinion, in how many years did the following factors contribute to a control program NOT being successful in that year. Where success is defined as a 70% reduction in fox activity following management. Note: More than one factor may be important in the same year, so the total can exceed 5.	**Best estimate of the number of years [0-5]**	
	Higher than average annual rainfall		
	Lower than average annual rainfall		
	Conducted during mating season		
	Conducted during juvenile dispersal		
	Presence of wild dogs or dingoes		
	Control program run across land tenure		
	Other		

Time to re-invasion - ground baiting

Questions 6 to 8 are about the time to European Red Fox re-invasion of an area following a ground baiting program Ground baiting programs are used on pastoral land, forestry land and national parks and can differ between States and Territories depending on legislation. Here we consider ground baiting programs as those in which baits are deployed along vehicle accessible trails. Here a ground baiting program is considered to consist of fortnightly bait replacement over three months in winter. Assume there has been no management for the three months prior to the program. Consider 10,000 ha area on public land surrounded by an agricultural matrix for a geographic region you are familiar with where ground baiting of foxes is undertaken.			
Questions		**Answers**	**Notes/ comments**
6	Name the region that you are familiar with (it can be the same region that you used previously)		
7	In how many of the last 5 years did targeted fox ground baiting programs occur within your selected region		
8	Consider up to 5 years of ground baiting programs in your selected region. In your opinion at the end of the three-month winter baiting program, how many weeks was it until you started seeing increased fox activity in your management area again? Note: Assume you deployed ground baits 2 weeks ago and are not deploying any more baits.		
	Best Guess (your best guess if you had to put a single figure on your opinion)		
	Lowest Guess (the fewest number of weeks before foxes re-appear)		
	Highest Guess (the greatest number of weeks before foxes re-appear)		
	Your Confidence (How confident are you that your interval from lowest to highest captures the number of weeks to re-invasion?)		

Time to re-invasion - aerial baiting

Questions 9 to 11 are about the time to European Red Fox re-invasion of an area following an aerial baiting program Aerial baiting programs are usually conducted over large areas on pastoral land or national park and differ depending on the State or Territory in which control is being undertaken. Here we consider aerial baiting programs as those in which baits are dropped from a helicopter or fixed wing aircraft with flight lines spaced at 500 m to 1 km apart. Assume only a single aerial baiting operation has been conducted in winter. Consider 10,000 ha area on public land surrounded by an agricultural matrix for a geographic region you are familiar with where aerial baiting of foxes is undertaken.			
Questions		**Answers**	**Notes/ comments**
9	Name the region that you are familiar with (it can be the same region that you used previously)		
10	In how many of the last 5 years did targeted fox aerial baiting programs occur within your selected region		
11	Consider up to 5 years of aerial baiting programs in your selected region. In your opinion, how many weeks following a targeted aerial baiting program was it until you started seeing foxes in your management area again? Note: Assume you deployed aerial baits 2 weeks ago and are not deploying any more baits.		
	Best Guess (your best guess if you had to put a single figure on your opinion)		
	Lowest Guess (the fewest number of weeks before foxes re-appear)		
	Highest Guess (the greatest number of weeks before foxes re-appear)		
	Your Confidence (How confident are you that your interval from lowest to highest captures the number of weeks to re-invasion?)		

Appendix B

Survey quantifying the impact of different management scenarios:

Think of a 10,000 ha area at which you have previously been involved in the management of European Red Foxes. Answer the following survey questions for this region.
In what State or Territory is the 10,000 ha area you are thinking of? ○ Australian Capital Territory ○ New South Wales ○ Victoria ○ Tasmania ○ South Australia ○ Western Australia ○ Northern Territory ○ Queensland ○ Other...
Is the 10,000 ha area you are thinking of predominately native vegetation or agricultural land? ○ Native Vegetation (>60% of the area) ○ Agricultural Land (>60% of the area) ○ Native Vegetation and Agricultural Land mix
What is the dominant vegetation in the 10,000 ha area you are thinking of?
For your 10,000-ha area, how many young does each vixen raise to independence in a twelve-month period?
Do you have any comments you would like to add about the number of young raised to independence you have provided?
Answer all questions in the survey related to baiting with the assumption you are using the bait type you are most experienced with. Which bait type would that be? ○ 1080 Fox baits ○ Foxoff ○ Foxecute ○ 1080 Dog baits ○ Doggone ○ Other...

CANID PEST EJECTORS

Answer the following questions for your **10,000 ha area** assuming you are **using a Canid Pest Ejector program with some combination of additional management actions**. Use the agreed upon definitions of the management programs defined earlier in the workshop.

For each combination of management actions in the following table provide estimates for European red fox population reduction one month after a management program has been completed. Assume 100% is total removal of the population following action 0% in none removed.

Best Guess (%): Realistically, what is your best guess if you had to put a single figure on your opinion of the reduction in the fox population that will occur following management?

Lowest (%): Realistically, what is the smallest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has less success than your best guess estimate)?

Highest (%): Realistically, what is the highest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has more success than your best guess estimate)?

Confidence: How confident are you that your interval, from lowest to highest, could capture the actual number of foxes removed from the region after one month? Please enter a confidence estimate between 0% and 100%.

Comments: There is a text box to enter any comments, additional knowledge or justification that you have about this question and/ or your estimate.

For the scenarios where the techniques occur together consider that: Aerial Baiting, Ground Baiting and Canid Pest Ejectors are used simultaneously while shooting and leg-hold trapping occur within four weeks of the baiting program.

	What % of foxes are REMOVED from the 10,000 ha area?				**Select if:**		**Comments**
	Best	**Lowest**	**Highest**	**Confidence**	**I don't know**	**Not applicable**	
CPEs							
CPEs + Leghold							
CPEs + Shooting							
CPEs + Leghold + Shooting							

AERIAL BAITING

Answer the following questions for your **10,000 ha area** assuming you are using the **[your bait choice] in an Aerial Baiting program with some combination of additional management actions**. Use the agreed upon definitions of the management programs defined earlier in the workshop.

For each combination of management actions in the following table provide estimates for European red fox population reduction one month after a management program has been completed. Assume 100% is total removal of the population following action 0% in none removed.

Best Guess (%): Realistically, what is your best guess if you had to put a single figure on your opinion of the reduction in the fox population that will occur following management?

Lowest (%): Realistically, what is the smallest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has less success than your best guess estimate)?

Highest (%): Realistically, what is the highest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has more success than your best guess estimate)?

Confidence: How confident are you that your interval, from lowest to highest, could capture the actual number of foxes removed from the region after one month? Please enter a confidence estimate between 0% and 100%.

Comments: There is a text box to enter any comments, additional knowledge or justification that you have about this question and/ or your estimate.

For the scenarios where the techniques occur together consider that: Aerial Baiting, Ground Baiting and Canid Pest Ejectors are used simultaneously while shooting and leg-hold trapping occur within four weeks of the baiting program.

	What % of foxes are REMOVED from the 10,000 ha area?				Select if:		
	Best	Lowest	Highest	Confidence	I don't know	Not applicable	Comments
Aerial							
Aerial + CPEs							
Aerial + Leghold							
Aerial + Shooting							
Aerial + CPE + Leghold							
Aerial + CPE + Shooting							
Aerial + Leghold + Shooting							
Aerial + CPE + Leghold + Shooting							

GROUND BAITING

Answer the following questions for your **10,000 ha area** assuming you are using the **[your bait choice] in a Ground Baiting program with some combination of additional management actions**. Use the agreed upon definitions of the management programs defined earlier in the workshop.

For each combination of management actions in the following table provide estimates for European red fox population reduction one month after a management program has been completed. Assume 100% is total removal of the population following action 0% in none removed.

Best Guess (%): Realistically, what is your best guess if you had to put a single figure on your opinion of the reduction in the fox population that will occur following management?

Lowest (%): Realistically, what is the smallest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has less success than your best guess estimate)?

Highest (%): Realistically, what is the highest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has more success than your best guess estimate)?

Confidence: How confident are you that your interval, from lowest to highest, could capture the actual number of foxes removed from the region after one month? Please enter a confidence estimate between 0% and 100%.

Comments: There is a text box to enter any comments, additional knowledge or justification that you have about this question and/ or your estimate.

For the scenarios where the techniques occur together consider that: Aerial Baiting, Ground Baiting and Canid Pest Ejectors are used simultaneously while shooting and leg-hold trapping occur within four weeks of the baiting program.

	What % of foxes are REMOVED from the 10,000 ha area?				Select if:		
	Best	Lowest	Highest	Confidence	I don't know	Not applicable	Comments
Ground							
Ground + CPEs							
Ground + Leghold							
Ground + Shooting							
Ground + CPE + Leghold							
Ground + CPE + Shooting							
Ground + Leghold + Shooting							
Ground + CPE + Leghold + Shooting							

AERIAL + GROUND BAITING

Answer the following questions for your **10,000 ha area** assuming you are using the **[your bait choice] in a combination baiting program with some combination of additional management actions**. Use the agreed upon definitions of the management programs defined earlier in the workshop.

For each combination of management actions in the following table provide estimates for European red fox population reduction one month after a management program has been completed. Assume 100% is total removal of the population following action 0% in none removed.

Best Guess (%): Realistically, what is your best guess if you had to put a single figure on your opinion of the reduction in the fox population that will occur following management?

Lowest (%): Realistically, what is the smallest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has less success than your best guess estimate)?

Highest (%): Realistically, what is the highest possible value for the percentage reduction in foxes are removed one month following management (i.e. the program has more success than your best guess estimate)?

Confidence: How confident are you that your interval, from lowest to highest, could capture the actual number of foxes removed from the region after one month? Please enter a confidence estimate between 0% and 100%.

Comments: There is a text box to enter any comments, additional knowledge or justification that you have about this question and/ or your estimate.

For the scenarios where the techniques occur together consider that: Aerial Baiting, Ground Baiting and Canid Pest Ejectors are used simultaneously while shooting and leg-hold trapping occur within four weeks of the baiting program.

	What % of foxes are REMOVED from the 10,000 ha area?				**Select if:**		
	Best	**Lowest**	**Highest**	**Confidence**	**I don't know**	**Not applicable**	**Comments**
Aerial + Ground							
Aerial + Ground + CPEs							
Aerial + Ground + Leghold							
Aerial + Ground + Shooting							
Aerial + Ground + CPE + Leghold							
Aerial + Ground + CPE + Shooting							
Aerial + Ground + Leghold + Shooting							
Aerial + Ground + CPE + Leghold + Shooting							

Comments

Do you have any additional comments you would like to add before submitting your responses?

Appendix C

Table S 1 European red fox management techniques identified during workshop discussions. Definitions are provided and include the: (1) effort invested, (2) scale of operation, (3) seasonality, (4) frequency of application, (5) State or Territory restrictions, and (6) the pros, cons and limitations associated with each technique.

Technique	Description
Aerial Baiting	Baits dropped from a fixed wing or helicopter. Flight lines are spaced at 500 m or 1 km intervals to meet density target for baiting region. Bait type varies based on State/Territory approvals. All baiting activity must avoid waterways and residential areas. Rate of application: 5 – 20 baits/ km^2 (often 10 baits/km^2). Can depend on bait product being used. Presence of water bodies can increase the density of baits within a target zone. Scale of activity: Requires patches large enough to make it cost-effective. Minimum required is approximately 10,000 – 20,000 ha. Can be used to cover thousands of kilometres squared. Season: Typically, colder seasons (late autumn or early winter) to target breeding and dispersal. May occur across all seasons in some regions. Interval before repeating management: Varies by region. Minimum of twice annually is good practice. States/Territories where it is not permitted: Victoria, Queensland, Northern Territory. Restrictions associated with each State/Territory: Bait type varies by State/Territory: • South Australia allows 1080 toxin only (PAPP not permitted), uses red meat or fish-based bait. • Western Australia uses 1080 based toxic baits (usually Probait). • New South Wales uses 1080 fresh meat baits. Pros: • Highly effective and scalable. • Provides high coverage – remote areas are more accessible particularly when tracks are scarce. • Low cost per unit effort (value for money). Cons: • Bait degradation is quicker in wet years and if rain happens immediately after baiting – choice of bait type may change the rate of bait degradation. • Unconsumed baits – non-target impacts are likely and greater than ground baiting efforts as baits are not buried. • Buffer restrictions around certain areas limit programs to chunks of land that are big enough to make aerial baiting cost effective. • Difficult to determine bait uptake. • Only permitted in certain states. Limitations: • Timing of baiting relative to rain. Rain shortly after can reduce effectiveness and a higher propensity for animals to get non-lethal doses. • Naïve fox populations are highly susceptible but becomes less effective over time. • Areas with high canopy cover are not ideal for aerial baiting programs – baits often do not reach the ground.

Ground Baiting	Baiting applied along vehicle accessible trails and other linear features in the landscape. Depending on State/Territory can be 1 bait per 500 – 1000 m. All baiting activity must avoid waterways and residential areas. <u>Rate of application:</u> 1 – 5 baits per linear km. Rate can be controlled by legislative restrictions based on fox caching of baits, potential non-target impacts, and land-use type (e.g. agricultural areas may bait at higher rates). Effective density will depend on road or track availability. <u>Scale of activity:</u> Targets smaller areas than aerial baiting, usually relies on a track network. Minimum area of 10,000 – 30,000 ha to have an impact. In cross-tenure programs areas of up to 250,000 ha may be achievable. <u>Season:</u> Typically, colder seasons (autumn or winter). May occur across all seasons but it is rarer to bait in summer. <u>Interval before repeating management:</u> Highly variable based on: (1) management program objectives, (2) the State/ Territory, (3) available funds, or (4) land tenure (e.g. farmers will bait only in the lead up to lambing, conservation programs may bait continuously). Some programs bait continuously with daily, fortnightly or monthly bait replacement. <u>States/Territories where it is not permitted:</u> n/a (Permitted in all States and Territories except Tasmania where there is no foxes) <u>Restrictions associated with each State/Territory:</u> Bait type and toxin concentration varies by State/Territory. All States/Territories allow 1080 baits, some allow PAPP baits (Queensland, Victoria). <u>Pros:</u> • Burying baits provides a highly targeted method. • Recording bait locations means it is possible to check bait uptake and estimate efficacy – monitoring baits also allows a better estimation of potential non-target impacts. • Tailored implementation – Baits can be applied at specific target densities. • Lower cost per unit effort. • Good for multi-tenure areas – in some areas, use of PAPP specific baits at land tenure boundaries reduces risks to pet dogs who may take baits (the effects of PAPP can be reversed if the antidote is administered within one hour of exposure). <u>Cons:</u> • Implementation is harder than aerial baiting – it can require multiple vehicles and personnel, cross-tenure programs might lead to restricted area access, deployment times may vary. • Surface laid baits are fast to deploy, buried baits take more time. • In some States/Territories, baits are required to be checked to reduce non-target impacts. • Difficult to standardise implementation – highly dependent on practitioner. • Faster bait degradation rates in winter and potentially when baits are buried. • Non-target species (e.g. ravens) may learn locations and take baits based on human monitoring. • Efficacy depends on prey availability (high prey availability means lower bait uptake). • Not effective over smaller areas, but this depends on the region being managed. <u>Limitations:</u> • Quality and work ethic of field staff is highly variable but limits the success in some circumstances. • Cannot bait in windy or wet conditions due risk of vehicle bogging, etc. • May require cross-tenure programs to be effective. • Dependent on road access.

Canid Pest Ejectors (CPEs)	Spring loaded piston set into the ground which, when triggered, delivers the contents of a toxin capsule (1080 or PAPP) into the mouth of a target animal. Lure heads may be used to attract foxes, and collars/covers may be attached to deter non-target species. Deployed along roads or fence-lines. Can be used with a scent lure. Rate of application: 5 – 20 CPEs / 100 ha. 5 CPEs per linear kilometre. Scale of activity: 2 – 200 ha. Small scale application due to high maintenance requirements. Season: Year-round deployment is possible. Some areas restrict use in summer when there are more people and dogs out. Interval before repeating management: Baits replaced every 1 – 4 weeks depending on the environment. Knockdown of target species declines after 3 weeks, so ideally one month between deployments. States/Territories where it is not permitted: n/a (Permitted in all States and Territories – dependent on toxin type) Restrictions associated with each State/Territory: • Northern Territory use is not permitted during the dingo breeding season. • Some States/Territories do not permit the use of PAPP in the toxin capsule. Pros: • Prevents foxes from caching the bait and not consuming it while the toxin is still effective. • High target specificity – in most areas' canid species are the only species able to activate them and receive the toxin. • Ability to modify the design can be good in areas with dingoes or nearby domestic dogs (e.g. peri-urban areas). • Can use the toxin PAPP as the risk to non-target species is negligible and there is an antidote for domestic dogs who may take baits (the effects of PAPP can be reversed if the antidote is administered within one hour of exposure). • More social licence for use of CPEs compared to other poison baiting techniques. • Bait head lure is interchangeable. • Encapsulated toxin means degradation is not as fast as aerial and ground baiting. Cons: • Relatively expensive compared to aerial and ground baiting (five times more expensive than ground baiting). • Labour intensive – requires frequent replacement, mechanical moving parts need to be maintained with servicing every two weeks. • Not applicable as a broadscale technique. • CPEs can fill with water when there is high rainfall. • Non-target species can take the meat lure (without activating the toxin capsule), some non-target species may be able to activate the toxin capsule (e.g. spotted-tailed quolls). • Often only suitable as an auxiliary technique. • Required more training than other forms of poison baiting. Limitations: • Each CPE kit costs $60 – $80 – and the quality of CPEs can be variable. • Can only be used for canid species, therefore is not useful as a technique in integrated management programs also targeting cats. • More research required into the potential effects for non-target species.

Padded Leghold Trapping	Padded or soft jaw leghold traps installed as either single or paired units placed along or adjacent to tracks or linear features. Traps remain open for 5-14 consecutive days. Traps may be lured with a scent lure. May be used in conjunction with PAPP putty. <u>Rate of application:</u> Traps are distributed at a density of 50 traps within 10,000 ha separated by a minimum of 200 m (two-week trapping period minimum for 10,000 ha area). In many programs, the deployment may be targeted around an asset. <u>Scale of activity:</u> Highly variable, not much more than ~10,000 ha. <u>Season:</u> Year-round, but success can be greater during breeding periods or juvenile dispersal (late autumn – early winter). Often also timed to seasonal road closures so public access to roads is reduced. <u>Interval before repeating management:</u> Often ad-hoc or dependent on available funding. Can be integrated as a "mop-up" tool following an aerial or ground baiting program. <u>States/Territories where it is not permitted:</u> n/a (Permitted in all States and Territories) <u>Restrictions associated with each State/Territory:</u> Allowed in most jurisdictions, but legislation dictates the type and size of the trap allowed to be used. <u>Pros:</u> • Used in eradication programs to "mop-up" areas. • Targets individuals that will not take a bait. • Can target specific locations – potential to remove problem animals. • More species specific – non-target animals can be released. • Can be targeted to specific demographics (e.g. different olfactory lures to capture males or females). • High value in research programs – animal in hand for collaring, or to take stomach contents and samples. <u>Cons:</u> • Quite labour intensive – traps require checking every day but can be difficult to check regularly when used over large areas. • Can have very low return rates (i.e. low capture success). • Success is highly dependent on the skill of the user – "Art" of staging a trap is highly variable. • Cleaning and maintenance are required between deployments. • Native non-target species or pet domestic dogs can be easily trapped – land holders often do not want them used near their dogs. • Anyone can buy or use one, with proper training – people can order and teach themselves online, then set them up incorrectly. <u>Limitations:</u> • Logistical constraints to application as it is labour and cost intensive (~$1000 / day for trappers) • Social license – often receives negative attention from the public. • Must have another method for euthanasia (e.g. firearm, captive bolds, lethal injection), which have their own restrictions in each State/Territory. • Only applicable at smaller scales. • In some States/Territories, you can only use leghold traps to capture foxes, but cannot use them to target other predators (e.g. cats) – they may not be suitable for integrated predator control programs. • Potential ethical issues with pups – small size means they may be more likely to get injured or escape. • Potential for animals to dig out stakes anchoring the traps in place.

Cage Trapping	Wire cage traps located within 50 m of tracks or linear features (e.g. creek lines, fire breaks, fence lines). Traps are baited with a food lure (e.g. chicken or fish), scent lure or both and remain open for 5-10 consecutive days. Rarely used in fox management as animals are wary or avoidant of them, except in some peri-urban programs where foxes are more accustomed to structures. Rate of application: Targeted in peri-urban settings based on sightings. Can also be placed along fence lines. Scale of activity: Not recommended for use at most scales. Limited circumstances where they are used. Season: Reactive or year-round, but rarely used. Interval before repeating management: No strategically implemented cage trapping programs, would only be used as a reactive technique. States/Territories where it is not permitted: n/a (Permitted in all States/Territories) Restrictions associated with each State/Territory: No restrictions around use but, there must be a plan in place to deal with any captured animals. Pros: • Seen as a more humane method to catch animals. • Any non-target species captured can be easily released. • Useful when you have no method of euthanasia other than lethal injection as animals can be transported. • Traps can be leased out to land holders to set and monitor traps – takes some pressure off council and government agencies to check those traps. • May be effective in peri-urban management. • May be better in area where risk of trapping non-target species is high (lower risk of injury than leghold traps). Cons: • Largely ineffective in rural/ natural landscapes – can take a long time to catch any foxes. • Labour intensive and expensive – traps require checking every day. • Non-target animals are easily captured. • Presence of cage traps can increase fox wariness overall, decreasing effectiveness of the overall program. • Standard traps are often too small – but larger traps can be harder to transport. • Compared to other methods, traps are highly visible and may be stolen. • Need to ensure whoever is running the program has a method of dispatch to deal with any captured animals. Limitations: • Most likely only useful in urban areas or where there is human activity, so animals are accustomed to foreign smells. • Size of cages is highly variable and may impact success rate of tool. • Difficult to standardise use – every trapper will have different preferences for setting and baiting traps.

Shooting	Nocturnal shooting with aid of spotlight or thermal scope, can occur from back of vehicle or on foot. Involves a team made up of one shooter and one spotter (optional). Can be used in conjunction with an scent or audio lure (e.g. animal caller) to draw individuals closer. Incidental shooting of foxes can occur during aerial shoots for other species, but this is not considered an effective targeted method for foxes. <u>Rate of application:</u> Highly variable and depends on the program – often a full two nights over a week or two is a better use of effort then returning for a few hours multiple nights in a row. For example, shooting should occur for a minimum of 16 hrs within 2 weeks. <u>Scale of activity:</u> Very small scale. Useful for targeting specific areas. <u>Season:</u> Year-round but can be limited by lambing season and land tenure. Success may be higher during juvenile dispersal. <u>Interval before repeating management:</u> Usually ad-hoc. Often repeated every 5-6 months or can be useful following an aerial baiting program. <u>States/Territories where it is not permitted:</u> n/a (Permitted in all States/Territories) <u>Restrictions associated with each State/Territory:</u> Governed by firearms registrations in each state. <u>Pros:</u> • Highly species specific and when done correctly is very humane. • Good for removing the last few animals after trying everything else. • Reasonably cheap and effective in open areas (e.g. agricultural areas or deserts). • Can use thermal scope if individuals get spotlight shy. • Good for targeting high resources areas (e.g. around rubbish tips). <u>Cons:</u> • Visibility issues - Limited application in heavily vegetated environments. • Success is highly dependent on the skill of the shooter. • Mostly limited to tracks. • Often opportunistic or where there is a reported sighting. • Mostly targets male animals (2/3 animals shot are male) – females and younger individuals can be harder to target. • There is a small margin of error – if a fox is missed, the animal will likely become highly cautious and difficult to remove. • Can only be done at night. • Only effective when used as part of a bigger program. <u>Limitations:</u> • Effective area covered by shooting is very low. • Reduced application around urban areas (although there may be exceptions). • Cost for shooting is similar to leghold trapping (~$800/ night). • Always night work. • Important to have time interval between shooting programs – animals can be scared off if shooting is too intensive. • Thermal gear can increase visibility and success but is very expensive.

Exclusion Fencing	Heavy duty physical barrier to prevent the movement of animals into and out of an enclosed area. Fence needs to be dug into the ground and electrified to prevent animal incursion. Works best when the fence is established first, then targeted management to remove unwanted species occurs. Typically, fencing is a last point of call to protect an asset. Can be limited by the landscape, for example, fencing off an isthmus may increase value for money. <u>Rate of application:</u> n/a <u>Scale of activity:</u> Minimum of 50,000 ha to be worth the investment. <u>Season:</u> n/a <u>Interval before repeating management:</u> n/a <u>States/Territories where it is not permitted:</u> n/a <u>Restrictions associated with each State/Territory:</u> n/a <u>Pros:</u> • Good for small areas of high value protection. • Effective for peninsulas where there is already a natural barrier. <u>Cons:</u> • Expense makes it hard to finance at a useful scale over a long term. • Requires certain design features to ensure foxes remain excluded from the area. • Restricts the movements of native animals and increases the risk of predation around the outside of the fence. • Prey species within the fenced area may become naïve to predators outside the fence. • Soil chemistry impacts fence longevity – for example, highly saline areas might require the bottom part of the fence to be replaced every five years. • Requires high degree of monitoring. • Typically, only used in arid environments. • Requires commitment to a long-term conservation program as species movements are restricted. <u>Limitations:</u> • Some other predators (e.g. birds of prey) can still access the fenced area. • Scale of application and required maintenance. • Cost – can be $15,000 – $30,000 per kilometre to construct plus maintenance costs. • Can take years to remove target species from within the fenced area.
Den Fumigation	All entrances to a fox den are blocked and a cannister containing carbon monoxide gas (Den-Co-Fume®) is released into the den. Sometimes the den is ripped following fumigation to prevent new foxes moving into the area. <u>Rate of application:</u> n/a <u>Scale of activity:</u> Targeted method – applied to known dens within a small area. <u>Season:</u> Used only during the breeding season when foxes are denning (late winter – early spring).

	<u>Interval before repeating management:</u> Return weekly during the breeding season to monitor den use and re-treat if necessary. <u>States/Territories where it is not permitted:</u> n/a (Permitted in all States/ Territories) <u>Restrictions associated with each State/Territory:</u> No state specific restrictions but not federally funded or regularly integrated into fox management programs. Den-Co-Fume® is the only approved fumigant – it is available everywhere but might have restrictions or recommendations on where to use. <u>Pros:</u> • Considered a humane method, generally has good public licence and land-owner support. • Can be value for money with multiple individuals removed per den if applied at the right time. • Can be used in peri-urban and urban environments. • Can target specific individuals if you know where it is denning. <u>Cons:</u> • Difficult to find dens. • Not all dens can be fumigated. • Monitoring the dens can be labour intensive. • Not federally funded as some other methods are. • Risk of scaring fox away into other dens. • High cost (~$120 / cannister) and effort to apply. • Currently undersold as an available method. • Requires training – the method is very toxic and potentially dangerous to humans. <u>Limitations:</u> • Not effective over broad scales. • Den monitoring must be carried out as pups within the den must be 4 weeks old (otherwise fumigation will not euthanise them). • Only effective if you can locate a den an know a vixen has pups – there are active and non-active dens so multiple visits need to be made to confirm a den is being used.
Guardian Animals	Training other animals to reside with an asset (e.g. sheep) and protect them against foxes. Commonly used guardian species include specialised dog breeds (e.g. Maremma's), alpacas, and donkeys. *No additional information discussed.*
Felixer Grooming Trap	Highly localised and targeted method where foxes are identified from camera imagery triggering the release of a gel-based toxin. Still in development for foxes. *No additional information discussed.*
Predator and Prey Aversion Training	Prey aversion training: Feeding foxes eggs or meat laced with nausea inducing products to produce a learned response resulting in reduced consumption of certain prey species. Predator aversion training: Conditioning prey species to recognise foxes as a threat and increase their avoidance behaviour toward foxes. *No additional information discussed.*

Appendix D

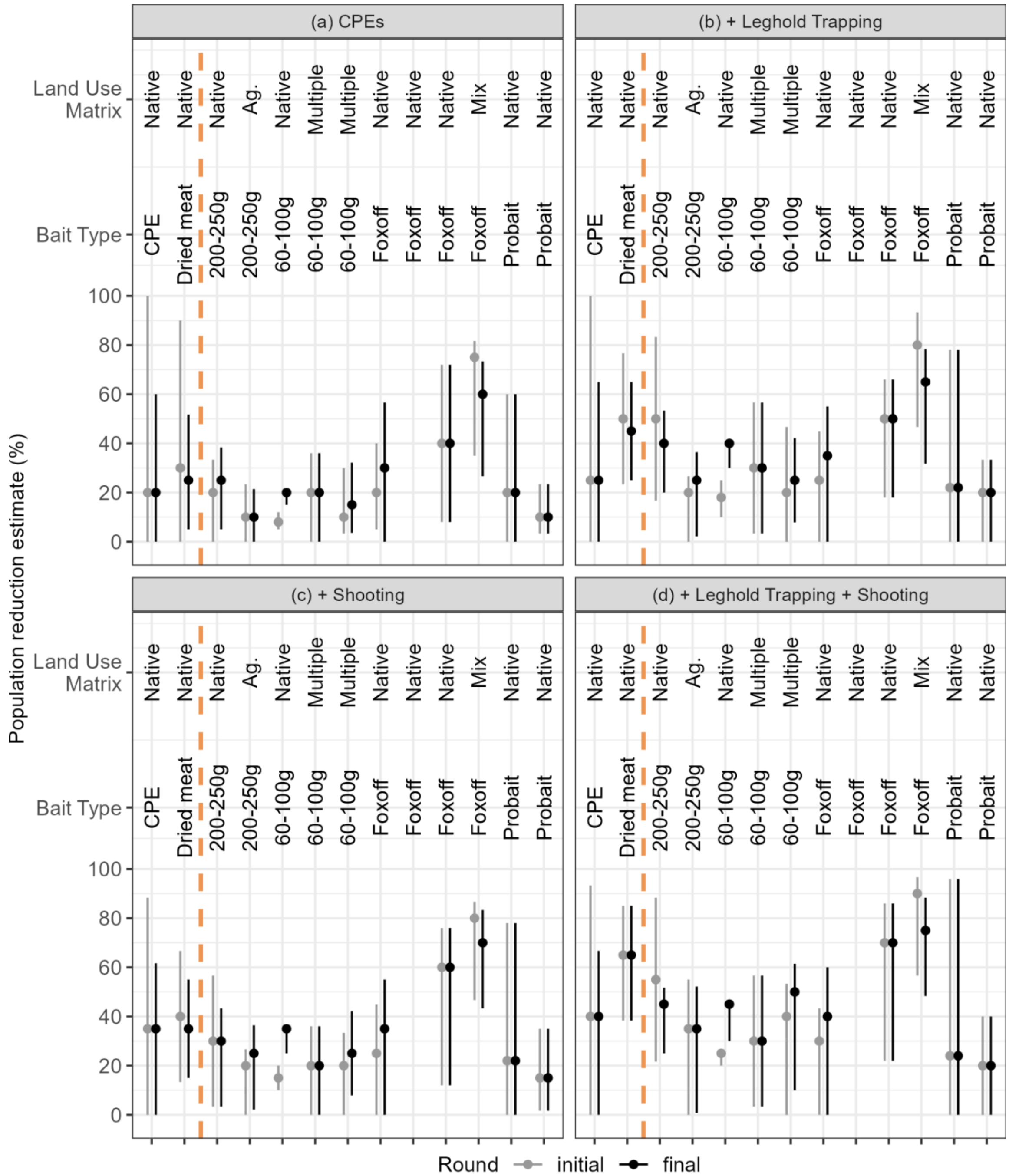

Figure S 1 Estimates provided by each expert for management scenarios using canid pest ejectors (CPEs) (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for "Desert and xeric shrublands", estimates to the right of the dotted line are for "Forests and woodlands". Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

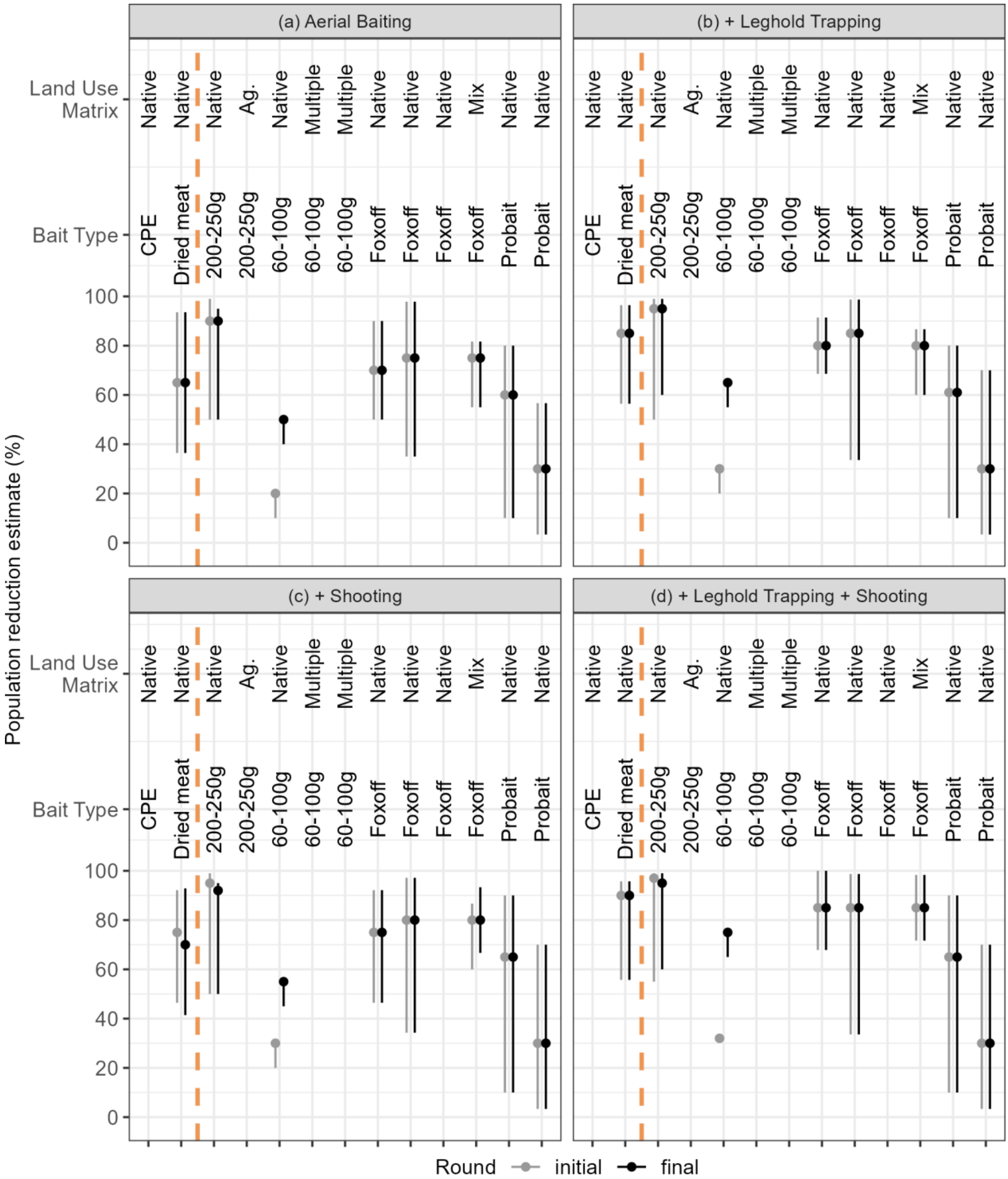

Figure S 2 Estimates provided by each expert for management scenarios using aerial baiting (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for “Desert and xeric shrublands”, estimates to the right of the dotted line are for “Forests and woodlands”. Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

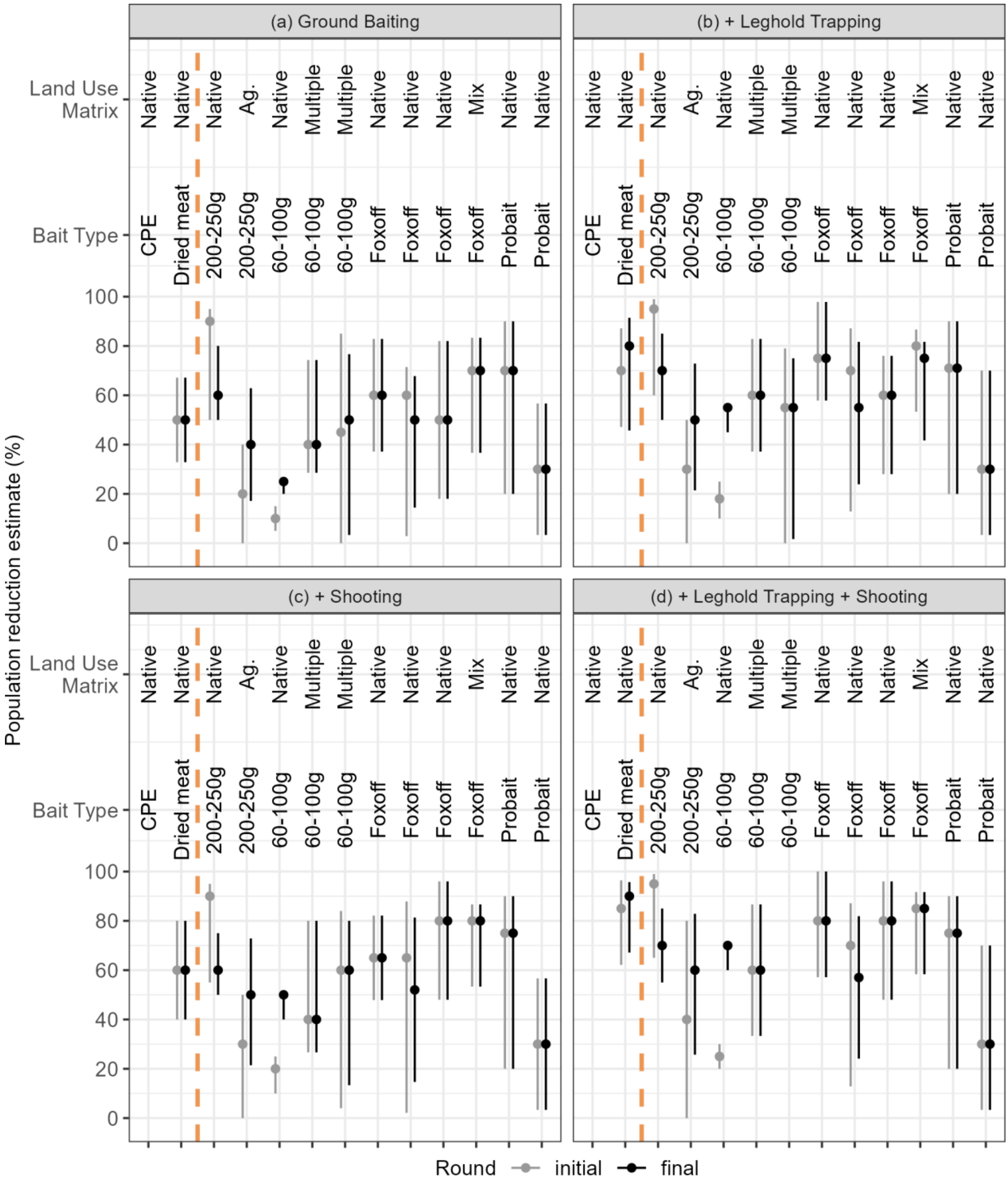

Figure S 3 Estimates provided by each expert for management scenarios using ground baiting (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for "Desert and xeric shrublands", estimates to the right of the dotted line are for "Forests and woodlands". Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

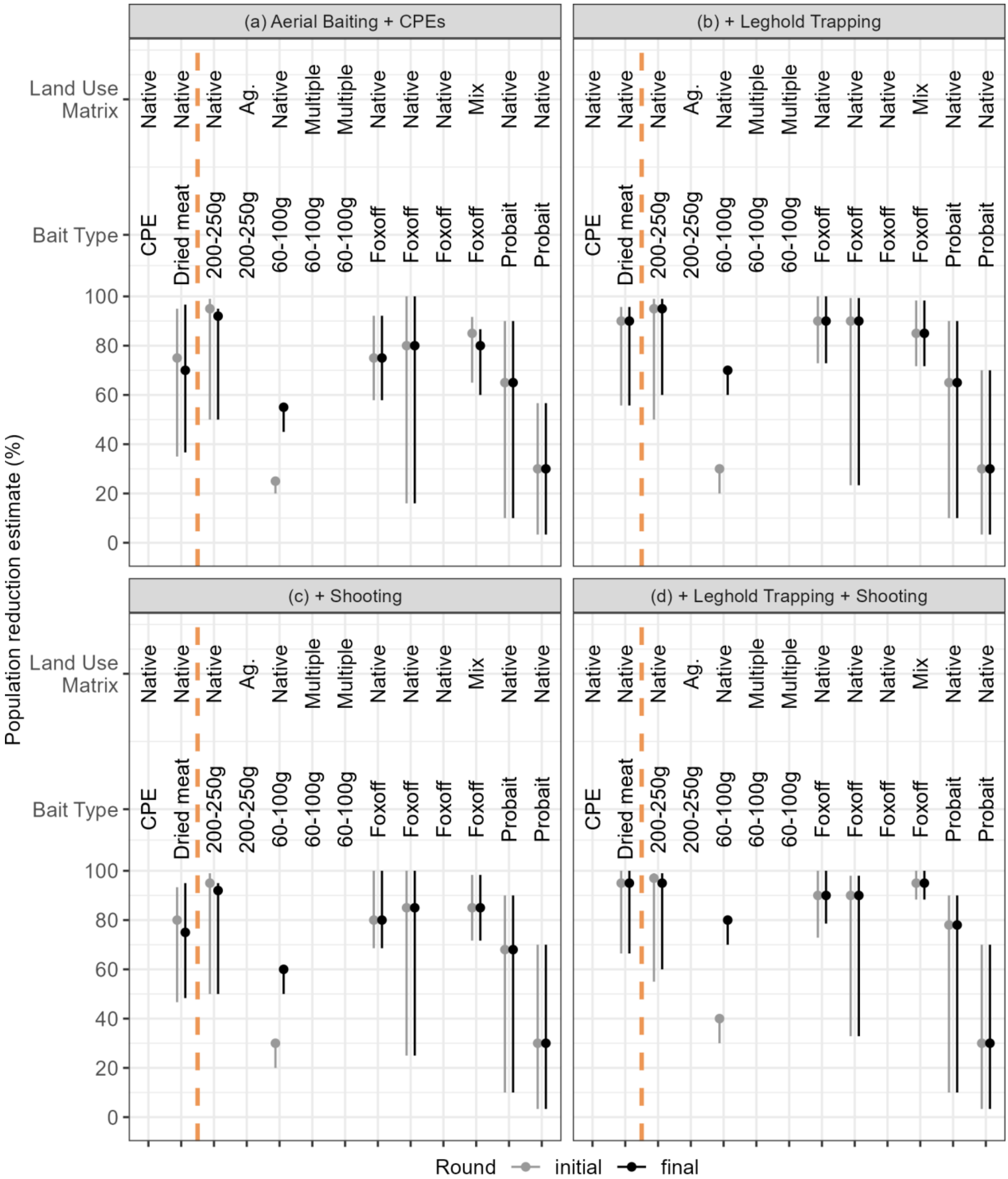

Figure S 4 Estimates provided by each expert for management scenarios using aerial baiting and canid pest ejectors (CPEs) (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for “Desert and xeric shrublands”, estimates to the right of the dotted line are for “Forests and woodlands”. Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

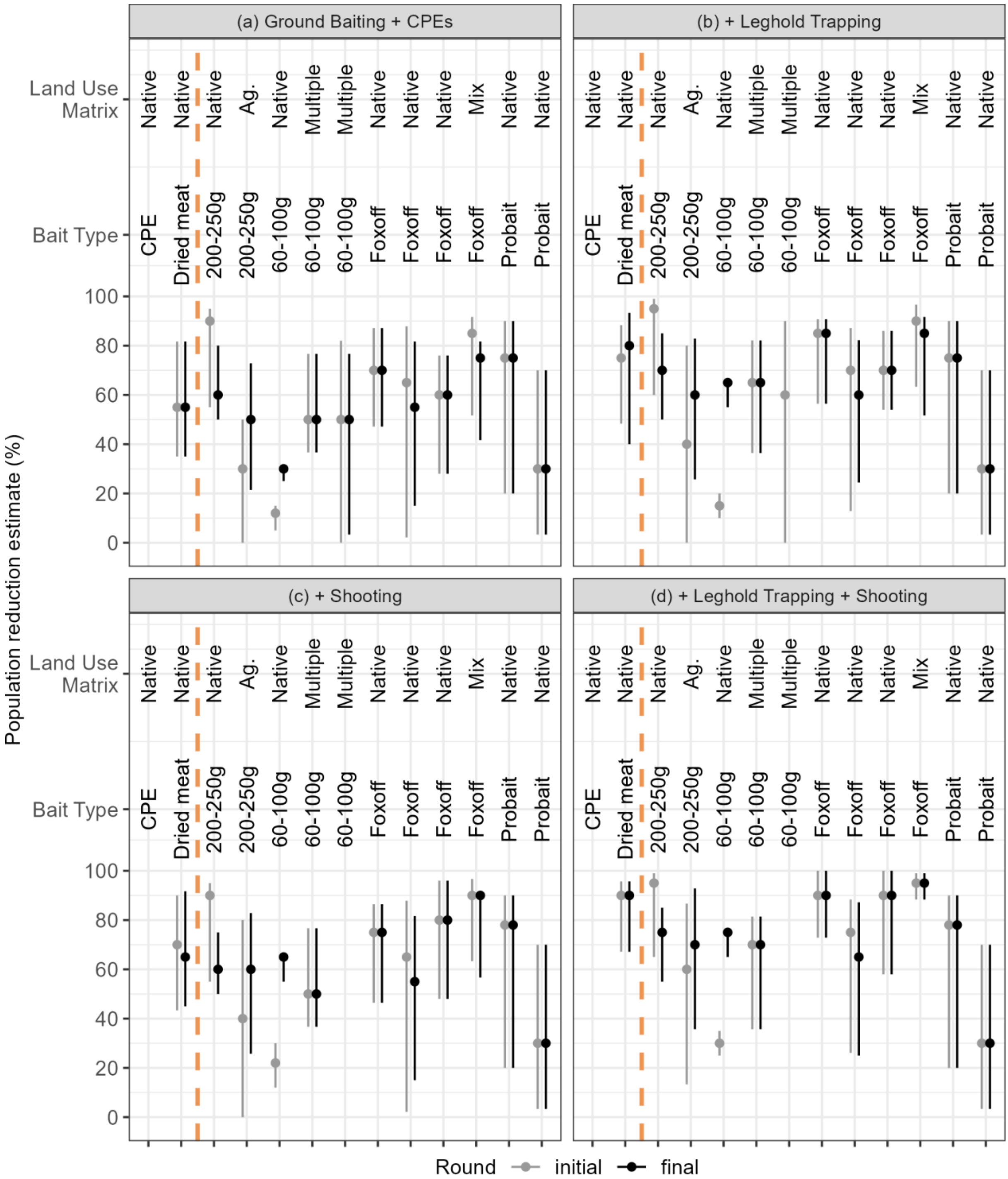

Figure S 5 Estimates provided by each expert for management scenarios using ground baiting and canid pest ejectors (CPEs) (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for “Desert and xeric shrublands”, estimates to the right of the dotted line are for “Forests and woodlands”. Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

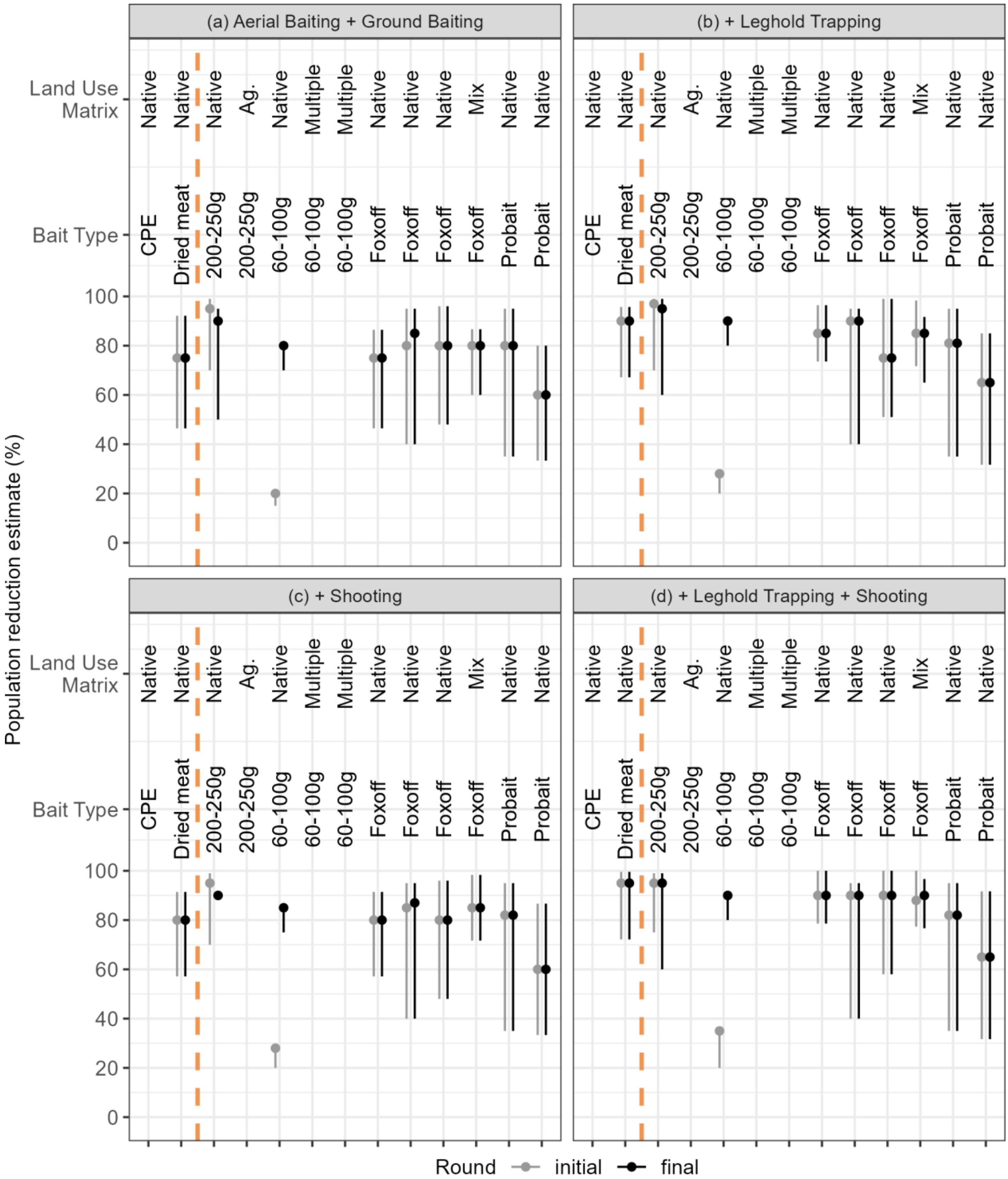

Figure S 6 Estimates provided by each expert for management scenarios using aerial and ground baiting (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for “Desert and xeric shrublands”, estimates to the right of the dotted line are for “Forests and woodlands”. Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

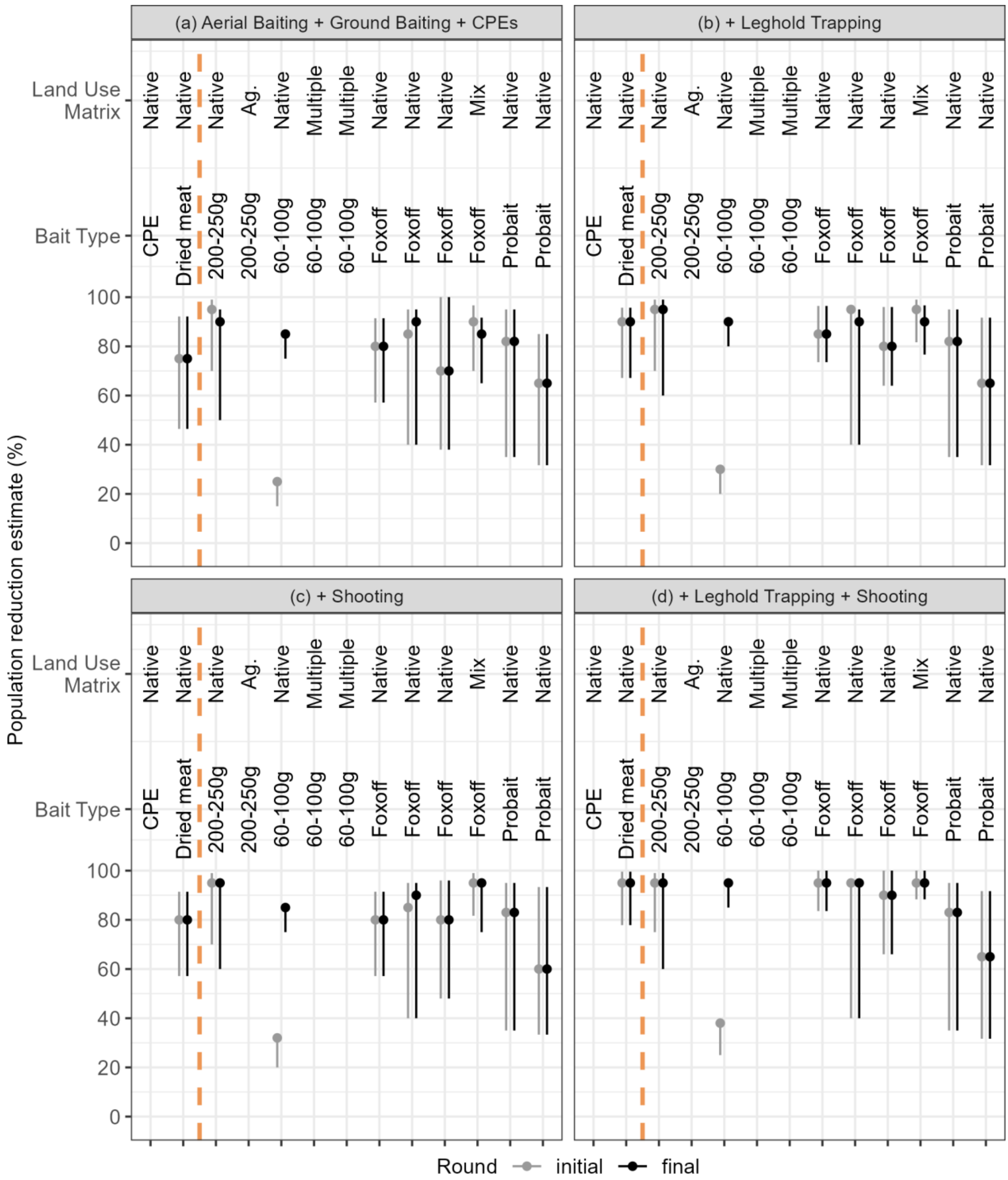

Figure S 7 Estimates provided by each expert for management scenarios using aerial baiting, ground baiting and canid pest ejectors (CPEs) (a) only, (b) with leghold trapping, (c) with shooting, and (d) with leghold trapping and shooting. The questions asked for the percentage of the fox population that was removed one month after management was implemented. Estimates on the left of the dotted line are for "Desert and xeric shrublands", estimates to the right of the dotted line are for "Forests and woodlands". Graphs show the best estimate with 80% upper and lower credible intervals provided by experts in the initial and final survey rounds. Graphs indicate the abbreviated bait type and land-use matrix considered by experts when answering the questions.

Appendix E

Challenges

(a) Bureaucratic and Administrative Challenges

1. Budget: securing adequate funding for effective long-term management
2. Maintaining long-term management programs
3. Inconsistent policy: different rules and regulations between States and Territories
4. Availability of skilled personnel
5. Access to toxins: supply and bureaucracy

(b) Ecological and Scientific Challenges

1. Measuring effectiveness, impact, and benefits of management
2. Non-target impacts and unintended consequences
3. Accurately measuring fox densities
4. Quantifying impact of foxes on assets
5. Source populations for re-invasion
6. Fox control and fire interactions

(c) Community Engagement Challenges

1. Implementing cross-tenure programs: finding participating land and managers
2. Social licence

Knowledge Gaps

(a) Program effectiveness and impact

1. What density or activity of foxes do we need to remove to be effective in meeting management program objectives?
2. How do we measure fox management program effectiveness in terms of outcomes to targets (whether that is native species, livestock, etc)?
3. What is the impact of management based on different habitats, conspecifics and environmental conditions?
4. What levels of fox re-invasion occur under various conditions following fox management?
5. What is the indirect impact of fox control on other species (cats, native species, wild or domestic dogs, dingoes)?
6. What is the most cost-effective way to manage foxes?

(b) Management tools and program development

1. How do we create integrated programs with multiple objectives?
2. What non-lethal, fertility or biological control options are there for fox management?
3. How can we manage fox populations better across jurisdictions?
4. How can we better target fox specific lethal control tools?
5. How can we manage foxes in high canopy cover areas?
6. What risks or lack of risks are associated with 1080?
7. What fine-scale factors affect whether individual foxes take baits?

(c) Population ecology

1. How does fox suppression at different levels below carrying capacity affect litter size, survival rates, demographic rates and movement?
2. How are foxes moving through different landscapes and vegetation types? How does movement affect home range?
3. How are foxes distributed at a broad scale in the landscape?
4. How do we obtain reliable estimates of fox density, regardless of scale?
5. What is the evolutionary impact of sustained fox control?

(d) Inter-species interactions

1. How can we enable native wildlife to persist with foxes?
2. What interactions exist between foxes and other predators?
3. How heavily do fox-human interactions influence how we control them?
4. A lack of understanding on fox transmitted disease

(e) Community engagement

1. How do we best engage communities in fox management objectives?
2. How to best communicate the best management strategies?

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