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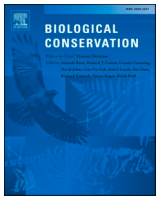

Knowledge and values drive acceptability of lethal control of kangaroos among the Australian public

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ABSTRACT

Wildlife management actions are increasingly contingent on acceptance by the broader public. Consequently, understanding factors that influence acceptability of different management options is important. In Australia, kangaroos (native large herbivores, *Macropus* spp., *Osphranter* spp.) are managed using lethal control for a range of context-specific reasons. We surveyed 1293 members of the Australian public to test whether acceptability of lethal control of kangaroos depends on the reason for the control, values towards wildlife (assessed using the Wildlife Values Orientation questionnaire), and knowledge about kangaroos. We also tested whether acceptability could be shifted by providing relevant information. Lethal control of kangaroos for biocentric reasons (i.e., agricultural protection, biodiversity conservation, animal welfare) was more acceptable than lethal control of kangaroos for anthropocentric reasons (i.e., human consumption, human safety). Acceptability was greater among survey respondents high on the domination orientation (i.e., valuing wildlife for human benefits), and lower among those high on the mutualism orientation (i.e., valuing wildlife for its own intrinsic value). Acceptability was also positively associated with knowledge of kangaroo ecology and management. Provision of information did not impact acceptability of lethal control for any reason except for human use, which, while not significant, showed promise that acceptability of lethal control for this reason could be influential to the public. Additionally, while the acceptability of lethal control varied widely among the Australian population, there was little evidence of polarisation, suggesting that large sectors of the public may be amenable to different perspectives.

1. Introduction

Effective wildlife management is contingent on public acceptance of proposed management actions (Zinn et al., 1998). Failure to garner public support, or at least to address opposition to them, can result in swift backlash and affect popular consent (often called 'social licence to operate') for wildlife management. Frequently, sectors of the community find lethal control methods for controlling species unacceptable, as demonstrated by opposition to some types of poison (Green and Rohan, 2012; Warburton et al., 2021) or lethal control methods more broadly (Drijfhout et al., 2020; Fix et al., 2010).

Conflict surrounding wildlife management actions may stem from a broad range of factors, including social norms relating to wildlife (Zinn et al., 1998), whether people live in close proximity to the species (Koichi et al., 2013), the species being controlled and whether that species is native (Boulet et al., 2021; Drijfhout et al., 2020), whether control is lethal or non-lethal (Fix et al., 2010), and the method used to control the species (Green and Rohan, 2012). For example, public desire to maintain populations of some introduced species for cultural reasons, such as feral horses in Australia and the United States (Linnell et al.,

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2016; Nimmo and Miller, 2007), or a lack of public awareness of the negative impact of introduced species (Dunn et al., 2018), can lead to conflict when control programmes are proposed.

The population size of kangaroos (*Macropus* spp., *Osphranter* spp.) has increased since European colonisation of Australia, primarily due to the increase in availability of permanent water for livestock provision (Dawson et al., 2006; Fensham and Fairfax, 2008; James et al., 1999), modification of vegetation (Newsome, 1975), and broadscale control of top-order predators (Caughley et al., 1980; Dawson et al., 2022; Letnic and Crowther, 2013; Pople et al., 2000). Recent estimates suggest there may be 40 million kangaroos in Australia (Wilson and Edwards, 2019), and in many areas they contribute to land degradation (Mills et al., 2020), compete with livestock for food (Norbury et al., 1993), and are involved in vehicle accidents (Green-Barber and Old, 2019). When kangaroo population crashes occur due to drought, individuals die in high numbers with poor welfare outcomes (Wilson and Edwards, 2019). Kangaroo harvesting, where kangaroos are commercially harvested for meat and leather (Wilson and Edwards, 2008), could be used to regulate their numbers and therefore mitigate poor animal welfare outcomes where their population size exceeds resource availability.

Control of charismatic native species, such as kangaroos, can evoke strong responses from sectors of the public (Boulet et al., 2021; Cawthorn and Hoffman, 2016; Wilson and Edwards, 2019), with controversy often stemming from objection to the motives and methods of control (Ampt and Owen, 2008; McLeod and Sharp, 2014; Sharp, 2015). In addition, an individual person's values towards wildlife and their knowledge about the species under consideration may influence acceptability of wildlife management actions, including lethal control measures. This paradigm has been explored under the Theory of Planned Behaviour (TPB), also known as the Theory of Reasoned Action (Ajzen, 1991), which argues that behavioural intentions depend on behavioural beliefs, normative beliefs, and control beliefs. The TPB is one of the most dominant theories of behaviour in psychology (Ives and Kendal, 2014). The relationship between a person's wildlife values and their behaviour or attitudes towards wildlife management has been explored across a number of different contexts (e.g. Dougherty et al., 2003; Drijfhout et al., 2020; van Eeden et al., 2017; Whittaker et al., 2006), with evidence that people who value protecting wildlife are less accepting of lethal control methods than those who value using wildlife for human purposes (Zinn et al., 1998).

Knowledge and understanding of the motivations for control are also likely to influence its acceptability. The impact of knowledge on attitudes is widely discussed in the literature as the 'knowledge deficit' model (Einsiedel, 2005; Irwin and Wynne, 1996). The link between knowledge and attitudes have been established for actions around other controversial issues, such as climate change (e.g. Douenne and Fabre, 2020; Schoenefeld and McCauley, 2016), genetically modified foods (e.g. Christoph et al., 2008), and health issues such as vaccines (e.g. Bonnevie et al., 2020). However, support for the 'knowledge deficit' model as a public engagement strategy is generally lacking (Hansen et al., 2003; Peters, 2005).

Education and information campaigns targeted at decreasing knowledge gaps may improve acceptance of actions around these issues (Ford et al., 2009; Latinopoulos et al., 2018; Ryan, 2012; Skupien et al., 2016), but there are also many examples of this approach exacerbating concerns of the public and increasing polarisation (Gaskell et al., 2000; Hornsey et al., 2016; Pauwels, 2013). While the level of knowledge an individual has about a species may impact their broad acceptability of wildlife management actions (Bremner and Park, 2007; Koichi et al., 2013), the effect of knowledge specifically on acceptability of lethal control methods remains poorly understood. If an individual's acceptance of wildlife management actions increases with their knowledge of the issue, then concerted public education campaigns may increase acceptance of control methods, including lethal control. It is also unclear whether education campaigns could have different effects on people with opposing wildlife values, which may necessitate more targeted approaches.

Control of kangaroo species (*Macropus* spp., *Osphranter* spp.) in Australia has sparked a reasonable amount of public controversy, resulting from objections to reason for, and methods of, control. Recently, in part due to pressure from animal rights campaigns, lethal control of kangaroos by commercial harvesting has declined, which reduces the viability for professional shooters and drives land managers (rarely trained and accredited in kangaroo shooting) to conduct kangaroo control themselves, often with worse welfare outcomes for kangaroos (Wilson and Edwards, 2019). Some scientists have argued against the commercial harvest of kangaroos on ethical grounds (e.g. Ben-Ami et al., 2014; Ramp, 2013); however, these views are not widely held among wildlife management scientists (e.g. Cooney et al., 2012). In addition, the public often hold views that are contrary to the prevailing view among experts; for instance the misconception that wild harvested kangaroos are 'farmed' (Ampt and Baumber, 2006; McLeod and Sharp, 2014). Such misconceptions can have important follow-on impacts in a person's viewpoint.

In Australia, research into the human dimension of kangaroo management has focused on the differences in acceptability between different control methods, or different species being controlled (Drijfhout et al., 2020; McLeod and Sharp, 2014; Sharp, 2015). However, our understanding of the underlying human characteristics that drive these differences remains poor (but see Boulet et al., 2021). The aim of the present study was to understand how such underlying factors impact acceptability of lethal kangaroo management, and if awareness raising and educational initiatives could influence this acceptability. Specifically, we tested the hypotheses that acceptability of lethal control of kangaroos 1) depends upon the reason for lethal control, 2) depends on an individual's demographics, level of knowledge about kangaroos, and general value orientation towards wildlife, and 3) can be influenced by providing basic information relevant to different reasons for lethal control. By understanding the human dimensions that drive differences in acceptability of management actions, managers will be able to communicate with the public more effectively.

2. Methodology

2.1. Recruitment

Participants were recruited online via Qualtrics (i.e., chosen by Qualtrics from a pool of pre-arranged respondents) and were eligible for the study if they were over 18 years old and lived in Australia. Qualtrics (https://www.qualtrics.com/au/strategy/research/) is an online survey platform, that hosts and coordinates surveys of the public, allowing recruitment to be targeted to avoid the bias often seen in surveys that use 'snowball sampling'. Qualtrics recruited a sample that was representative of the most recent (9th August 2016) Australian population census in three characteristics: gender, age, and state of residence (NSW: 32 %, Vic: 25 %, QLD: 20 %, WA: 11 %, SA: 7 %, Tas: 2 %, ACT 2 %, NT 1 %). There was no stratification of respondents by other demographics, or by locations with difference in expected kangaroo density. The minimum target sample size for the survey was 1200 respondents. Participants were provided with a small gift for their participation, and all provided informed consent prior to completing the survey.

2.2. Survey structure and measures

2.2.1. Part (1) demographics

All participants were asked a series of demographic questions at the beginning of the survey that captured information on their gender, age, state of residence, lifestyle (urban, semi-rural, rural/remote place of residence), occupation, and education.

2.2.2. Part (2) wildlife value orientations

Participants were then presented with a Wildlife Value Orientations

(WVO) questionnaire (Manfredo, 2008). This 19-item measure assesses participants' basic beliefs about wildlife and ways of valuing wildlife (Fulton et al., 1996) by asking them to rate their level of agreement to a series of statements about wildlife using a five-point Likert scale (from 1 = strongly disagree to 5 = strongly agree). This measure provides an indication about the strength of two wildlife values, each made up of two basic beliefs. The first value, 'Domination' incorporates beliefs that wildlife should be managed for the use and benefit of humans (made up of 'Appropriate use' and 'Hunting' beliefs). The second value, 'Mutualism', incorporates beliefs that wildlife have rights, deserve to be cared for, and should be treated as family (made up of 'Social affiliation' and 'Caring' beliefs). The questionnaire has been widely used when studying public support for wildlife management actions (e.g. Keener-Eck et al., 2020; Miller et al., 2018; Zinn et al., 2002). Drijfhout et al. (2020) used this tool in the Australian context and found a slightly different factor structure to that of the original WVO (Manfredo, 2008).

In the current study, one item from the original questionnaire that referred to 'fish and wildlife' was revised to mention 'wildlife' only, as this was more relevant to the current context. To confirm which items from the WVO questionnaire loaded onto the values of domination and mutualism, respectively, an exploratory factor analysis using the minimum residual factor method was carried out on all 19 items. The two factors accounted for 46 % of the total variance. For 17 out of the 19 items, factor loadings aligned to their original WVO subscale; however, there were two items which loaded very similarly onto both domination and mutualism, and which had factor loadings on each factor of <0.40. These two items were therefore removed, and a subsequent exploratory factor analysis was subsequently run on the new 17-item measure. Bartlett's test of sphericity ($\chi^2_{136} = 765.26$, $p < 0.001$), indicated that correlations between items were sufficiently large for the analysis. Loadings on the new model were generally high (ranging from 0.50 to 0.86), both factors had eigenvalues over 1, and the two factors in combination accounted for 48 % of the total variance. As such, this new model (with two items removed) was retained for subsequent analyses. All items, along with their factor loadings on both factor analyses, are presented in Table S1.

To calculate a wildlife values score for each participant, average scores were calculated for each participant based on their responses to the specific items that aligned to either the domination or mutualism orientation, resulting in a domination and mutualism score for each participant.

2.2.3. Part (3) kangaroo knowledge

Participants were then assessed on their knowledge about kangaroos. This was done by presenting them with a series of 18 statements regarding kangaroos and asking them to select whether the statement was true, false, or if they were unsure. These statements covered topics such as kangaroo production and use, damage to agriculture, impacts on biodiversity, kangaroo welfare, interactions with vehicles, and general kangaroo biology. The full list of statements is shown in Fig. 1.

To calculate a kangaroo knowledge score for each participant, their response was compared to the correct response for each of the 18 statements. If they correctly identified whether the statement was true or false, they were given a score of 1 for that statement. If they were incorrect or selected the 'do not know' option, they were given a score of 0. Scores across the 18 statements were then summed to give a total score out of 18 for each participant.

2.2.4. Part (4) provision of information about kangaroos

To assess whether acceptability of lethal control of kangaroos for particular reasons could be influenced by the provision of information about that reason, participants were then randomly split into six groups (213–218 participants in each); five treatment groups and one control group. Each of the five treatment groups were aligned with one of five 'reasons' for which kangaroos are killed: (i) for human use, (ii) agricultural protection, (iii) biodiversity protection, (iv) human safety, and (v) animal welfare reasons.

Each of the five treatment groups were presented with a passage of text; one short generic paragraph about kangaroo biology, one short treatment-specific paragraph explaining why kangaroos are killed, followed by another short generic paragraph about general kangaroo biology (see Supp. Box 1 for an example, and Supp. Box 2 for other

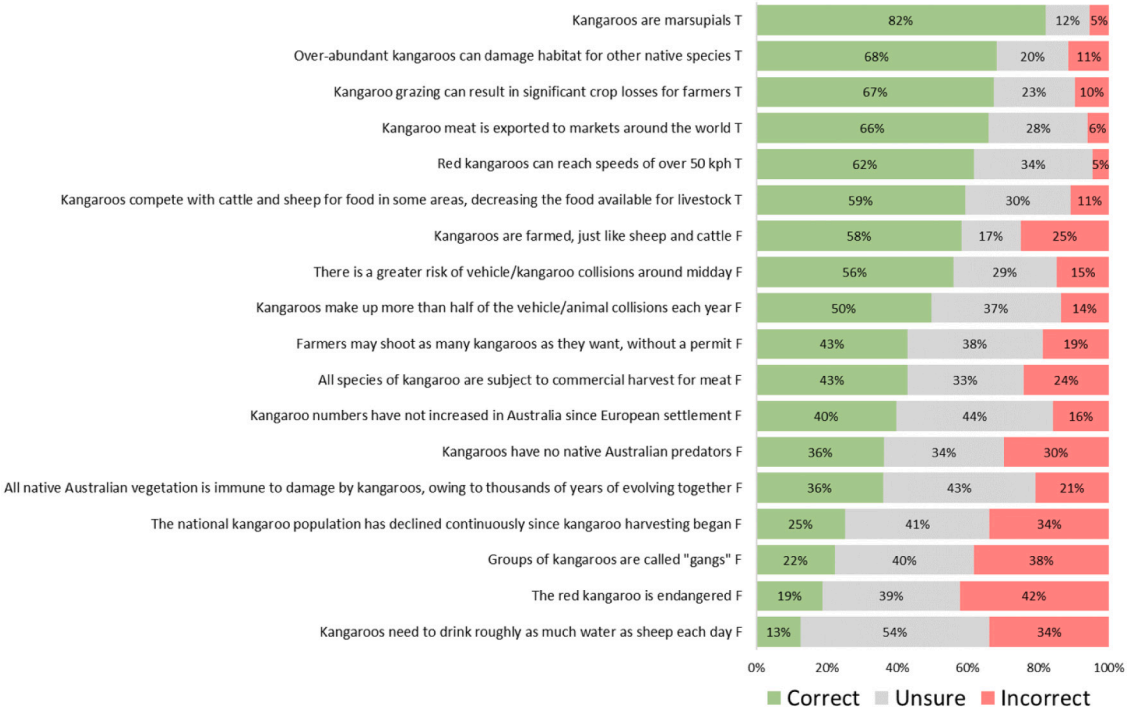

Fig. 1. Responses to Part (3) of the survey: Knowledge and values. Participants could respond that each statement was true, false, or they were unsure. Responses were used to allocate a 'Kangaroo knowledge' score for each participant. Accurate answers are provided after questions as T (true) or F (false).

treatment-specific information). The control group received only the two generic paragraphs. The inclusion of the general kangaroo biology information was as 'distracter text', designed to hide the fact that we were attempting to experimentally influence participants' views.

2.2.5. Part (5) distractor questions

Participants were then presented with four distractor questions, asking them to rate their agreement with statements about how informative and interesting they found the text, if the information was new to them, and whether they wanted to learn more about kangaroos. Similar to the inclusion of general information, these questions were designed to reduce the participants' awareness of the intended manipulation.

2.2.6. Part (6) acceptability of lethal control of kangaroos for different reasons

Participants were then asked to rank how acceptable (on a 5-point Likert scale where 1 = "completely unacceptable" and 5 = "completely acceptable") they found it to kill kangaroos for each of five reasons: (i) for human use and consumption (e.g. meat and leather), (ii) to reduce their impacts on agriculture (e.g. crop damage, competition with stock), (iii) to reduce their impacts on biodiversity and habitat (e.g. reducing overgrazing of native plants), (iv) for human safety (e.g. to reduce vehicle collisions), and (v) for animal welfare reasons (e.g. to reduce unnecessary suffering of kangaroos).

2.2.7. Part (7) Kangaroo consumption

Finally, participants were asked how frequently they consume kangaroo meat, consisting of five choices (ordered 0 to 5 from least to most likely to eat kangaroo); 1 = '*I object to the consumption of kangaroo meat and would never try it*', 2 = '*I have never tried kangaroo meat*', 3 = '*I have tried kangaroo meat but wouldn't eat it again*', 4 = '*I have occasionally consumed kangaroo meat*', and 5 = '*I regularly consume kangaroo meat*'.

2.3. Survey respondents

All responses were checked for completeness and random responding, and no cases of incomplete or non-random responses were detected. Screening and stratification of participants by demographics to be representative of the Australian public was conducted by Qualtrics, and therefore no further stratification was required. The total number of responses was 1293 participants aged 18–89 years, with a mean of 45.3 ± 18.2 years. Consistent with 2016 Australian census data, 52.7 % of participants were female, 46.7 % were male, and 0.6 % identified as 'other'. Given the low proportion of respondents that selected 'other' (8 responses) this group was excluded from analysis, giving a final sample size of 1285.

2.4. Analysis

2.4.1. Acceptability of lethal control of kangaroos for different reasons

To test whether the reason for lethal control influenced overall acceptability of lethal control of kangaroos, we compared acceptability scores (response categories scored as 0 = completely unacceptable to 5 = completely acceptable) as the response variable and each reason as the predictor by ordinal regression analysis using the *clmm2* function in the 'ordinal' package (Christensen 2015) in R (R Core Team, 2018).

2.4.2. Demographic influences and the relationship between values, knowledge, and acceptability

To test which factors influenced participants' responses to the acceptability of lethal control of kangaroos, we used a cumulative link mixed model for ordinal data for each of the potential reasons for control, with acceptability scores as the response variable, and with predictors: sex (0 = female, 1 = male) and age of the person, where the person lived ('Lifestyle': 0 = metropolitan, 0.5 = semi-rural or 1 = rural/remote), education (1 to 5 from no high school through to postgraduate qualification), their kangaroo knowledge score (out of 18), wildlife values score, and whether they consumed kangaroo (1 to 5 from least to most likely to eat kangaroo) using the *clmm2* function in the 'ordinal' package (Christensen 2015). Predictor variables were mean standardised for this analysis, so that effect sizes are comparable between predictors.

An exploratory factor analysis was carried out, using the minimum residual method, with an oblimin rotation, using the *fa* function from the 'psych' package (ver 2.1.9; Revelle, 2021). Bartlett's test of sphericity was used to test if correlations were factorable (Revelle, 2021; Table S1).

To map the relationships between knowledge, values, and acceptability of lethal control of kangaroos for each reason, a structured equation model (SEM) was fit using the *sem* function in the 'lavaan' package (Rosseel, 2012) within R, using a maximum-likelihood estimator. The model was then optimised by removing regressions with little weight of support (Burnham and Anderson, 2002). Goodness of fit was assessed by using the root mean square error of approximation (RMSEA; which should be below 0.06) and the root mean squared residual (SRMR; which should be <0.08) (Hu and Bentler, 1999).

2.4.3. Does providing relevant information influence perceptions of acceptability of lethal control of kangaroos for different reasons?

To test whether the effect of provision of information influenced the acceptability of lethal control of kangaroos, a second set of cumulative link mixed models were carried out, testing the additional effect of provision of information for the subset of participants who were provided with the information relevant to the specific reason for lethal control (before/after), and comparing their responses with the control group (treatment group: informed or control). In this test, we specifically compared the acceptability of lethal control of kangaroos for each reason between the control group and the group that received information aligned with reason for lethal control. For example, acceptability of lethal control for biodiversity protection only included data from the group that received information about 'biodiversity protection', compared with the control group.

3. Results

3.1. Acceptability of lethal control of kangaroos for different reasons

Overall, the acceptability of lethal control differed significantly between each of the five different reasons (pairwise ordinal analysis, $P < 0.001$). Within each reason, there was broad variation in level of acceptability (Fig. 2). Lethal control of kangaroos was more acceptable for the protection of agriculture or biodiversity, and for animal welfare reasons. Lethal control of kangaroos for human consumption was overall neutral, while lethal control of kangaroos for human safety was

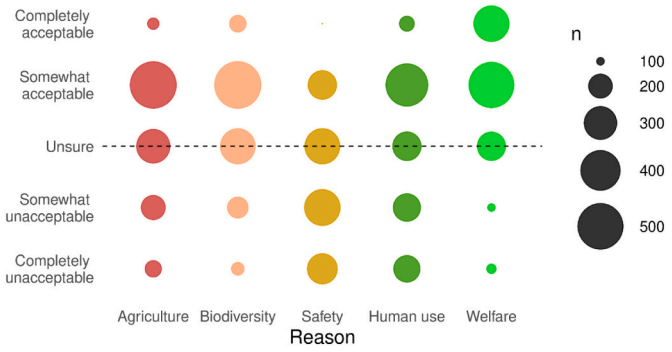

Fig. 2. Acceptability of kangaroo lethal control for different reasons. The size of the dots indicates the count of respondents. The horizontal dashed line indicates a neutral response, above the line indicates greater acceptance while below the line indicates greater lack of acceptance.

perceived to be most unacceptable (Fig. 2).

3.2. Demographic influences and the relationship between values, knowledge, and acceptability

The only responses that differed by gender was for the lethal control of kangaroos for human use, with males more likely to indicate that this reason was acceptable ($P = 0.011$) (Table 1a). There was no significant effect of a respondent's age on their scores for the acceptability of lethal control for human safety ($P = 0.945$) or biodiversity ($P = 0.100$), but for the other three reasons, acceptability scores increased with respondent's age ($P < 0.002$) (Table 1a; Fig. 3).

The majority of respondents (73.4 %) lived in metropolitan areas, with the remainder living in either semi-rural (17.7 %) or rural/remote areas (8.9 %); there was no significant effect of 'Lifestyle' on any of the responses (Table 1a). There was a significant positive effect of education on responses to the acceptability of lethal control for biodiversity reasons ($P = 0.044$) but no effect of education on any other reason (Table 1a).

Overall, the level of knowledge about kangaroos within the surveyed population was highly variable, with knowledge scores ranging from 0 to 100 % (46.9 ± 19.9 % SD) (Fig. 1). The accuracy of knowledge was also highly variable between questions. For example, 82 % of respondents correctly identified that kangaroos are marsupials, while 42 % of respondents incorrectly believed that the red kangaroo was endangered. Although there was no significant effect of kangaroo knowledge on acceptability of lethal control for human safety ($P = 0.887$), there was a significant increase in acceptability of lethal control for all other reasons for participants who scored higher in their knowledge about kangaroos ($P < 0.001$) (Table 1a).

There were a wide range of experiences when it came to eating kangaroo meat. Approximately half of the participants (51.3 %) responded they had either never tried kangaroo or that they object to the consumption and would never try it. A further 21.9 % said they had tried it but would not eat it again and 23.7 % said they occasionally consume kangaroo meat. Only 3.1 % said they regularly consume kangaroo. Participants who were more likely to consume kangaroo meat gave higher acceptability scores for all reasons for lethal control of kangaroos ($P < 0.004$) (Table 1a).

Overall model fit for structural equation modelling (SEM) testing the relationships between wildlife values (mutualism and domination), knowledge about kangaroos, and acceptability of lethal control, was satisfactory (RMSEA = 0.021, SRMR = 0.011). Kangaroo knowledge scores were significantly and positively associated with acceptability of lethal control for all control reasons, except human safety (Fig. 4), indicating that participants with a greater knowledge about kangaroos tended to rate lethal control as more acceptable than those with less knowledge. The domination values orientation was significantly positively associated with acceptability of lethal control for all control reasons, indicating that those who had stronger domination values tended to find lethal control more acceptable. Similarly, the mutualism values orientation was significantly negatively associated with acceptability of lethal control for all reasons, except animal welfare, indicating that individuals with higher mutualism values tended to find lethal control less acceptable overall. There was no significant interaction between knowledge and values (either mutualism or domination).

3.3. Does providing relevant information influence perceptions of acceptability of lethal control of kangaroos for different reasons?

The effect of provision of information was tested by comparing the subgroups of participants that were provided with information relevant to each of the reasons for lethal control of kangaroos (i.e. informed) with the control group that were not given any information. Although there were no significant differences in acceptability between informed and control groups, the effect sizes for the experimental treatments were

Table 1
Summary of ordinal analyses for (a) all participants overall, and (b) the subsets of participants allocated to each experimental treatment group. Predictor variables were mean standardised for this analysis, so that effect sizes are comparable between predictors.

	Reason for lethal control																					
	Agriculture				Biodiversity				Safety				Human use				Welfare					
(a) All participants' responses to each acceptability question	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**		
Gender	−0.04	0.06	−0.56	0.572	0.06	0.06	0.89	0.372	0.03	0.06	0.49	0.623	0.16	0.06	2.54	**0.011**	−0.08	0.06	−1.23	0.217		
Age	0.31	0.06	5.02	**<0.001**	0.10	0.06	1.64	0.100	0.00	0.06	0.07	0.945	0.33	0.06	5.30	**<0.001**	0.20	0.06	3.32	**0.001**		
Lifestyle	0.08	0.05	1.53	0.126	0.02	0.05	0.29	0.770	0.03	0.05	0.50	0.620	0.07	0.05	1.28	0.200	0.05	0.05	0.92	0.357		
Education	0.02	0.05	0.34	0.737	0.10	0.05	2.01	**0.044**	0.09	0.05	1.82	0.069	0.02	0.05	0.44	0.657	0.07	0.05	1.40	0.163		
Knowledge	0.45	0.06	7.78	**<0.001**	0.45	0.06	7.83	**<0.001**	0.00	0.06	0.05	0.961	0.34	0.06	5.87	**<0.001**	0.44	0.06	7.83	**<0.001**		
Consumption	0.34	0.06	5.86	**<0.001**	0.39	0.06	6.69	**<0.001**	0.17	0.06	2.95	**0.003**	0.86	0.06	13.92	**<0.001**	0.34	0.06	5.95	**<0.001**		
Domination	0.75	0.07	11.09	**<0.001**	0.53	0.07	8.11	**<0.001**	0.93	0.07	14.09	**<0.001**	0.78	0.07	11.50	**<0.001**	0.14	0.06	2.26	**0.024**		
Mutualism	−0.27	0.06	−4.46	**<0.001**	−0.09	0.06	−1.47	0.141	−0.25	0.06	−4.30	**<0.001**	−0.20	0.06	−3.32	**0.001**	0.03	0.06	0.59	0.556		
(b) Participants allocated to the five relevant treatment groups each compared with the Control group	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**	**Est.**	**SE**	**z**	**p**		
Gender	−0.12	0.11	−1.16	0.246	0.17	0.11	1.49	0.136	0.05	0.11	0.46	0.647	0.23	0.11	2.05	**0.040**	0.21	0.11	1.87	0.062		
Age	0.39	0.11	3.59	**<0.001**	0.31	0.11	2.91	**0.004**	0.00	0.11	−0.02	0.986	0.39	0.11	3.58	**<0.001**	0.16	0.10	1.55	0.122		
Lifestyle	0.10	0.09	1.02	0.307	0.06	0.09	0.72	0.469	0.14	0.09	1.51	0.132	0.13	0.10	1.40	0.161	0.07	0.09	0.74	0.458		
Education	−0.10	0.09	−1.12	0.261	−0.16	0.09	−1.74	0.082	0.05	0.08	0.61	0.540	−0.06	0.09	−0.66	0.507	0.15	0.09	1.66	0.096		
Knowledge	0.52	0.11	4.87	**<0.001**	0.30	0.10	2.85	**0.004**	−0.09	0.10	−0.98	0.328	0.36	0.10	3.54	**<0.001**	0.39	0.10	3.95	**<0.001**		
Consumption	0.19	0.10	1.96	0.050	0.41	0.10	4.03	**<0.001**	0.26	0.10	2.56	**0.010**	0.81	0.11	7.47	**<0.001**	0.24	0.10	2.38	**0.017**		
Domination	0.86	0.12	7.18	**<0.001**	0.52	0.11	4.65	**<0.001**	1.01	0.12	8.27	**<0.001**	0.85	0.12	7.07	**<0.001**	−0.01	0.11	−0.14	0.889		
Mutualism	−0.27	0.11	−2.52	**0.012**	0.10	0.10	0.96	0.335	−0.25	0.10	−2.42	**0.016**	−0.14	0.10	−1.38	0.167	−0.02	0.10	−0.19	0.849		
Treatment cf. Control group	0.07	0.18	0.37	0.711	−0.09	0.18	−0.53	0.598	0.06	0.18	0.34	0.731	0.35	0.18	1.91	0.056	−0.05	0.18	−0.25	0.803		

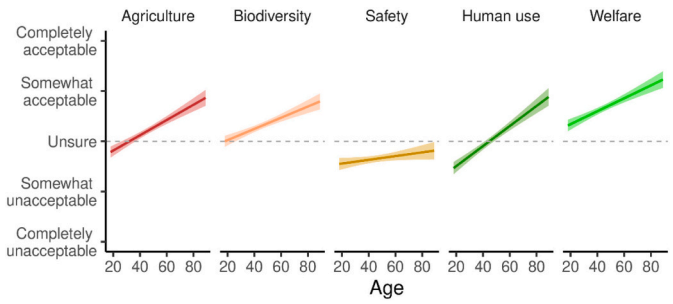

Fig. 3. The relationship between acceptability of kangaroo lethal control for different reasons, and the age of the respondent. The plotted line is a regression line with the shaded area indicating the 95 % confidence interval.

markedly different between reasons, and suggest meaningful differences in results (Table 1b; Fig. 5). The effect sizes for agriculture (est. 0.07 ± 0.18 SE, $z = 0.37$, $P = 0.711$), biodiversity (est. -0.09 ± 0.18 SE, $z = -0.53$, $P = 0.598$), human safety (est. 0.06 ± 0.18 SE, $z = 0.34$, $P = 0.731$) and even animal welfare (est. -0.05 ± 0.18 SE, $z = 0.25$, $P = 0.803$) reasons were completely neutral, but the responses for human use (est. 0.35 ± 0.18 SE, $z = 1.91$, $P = 0.056$) showed promise that acceptability of lethal control for human use could be improved with additional information provided to the general public.

4. Discussion

This study examined the influence of wildlife values, knowledge about kangaroos, and reasons for control on levels of acceptance towards the lethal control of kangaroos among the Australian public. We found that acceptance of lethal control of kangaroos is strongly dependent on the reason for the control. Responses were also highly variable, indicating very little polarisation of views. Biocentric reasons for lethal control of kangaroos, such as animal welfare or biodiversity conservation, were identified as the most acceptable reasons for lethal control, with anthropocentric reasons, such as human safety or consumption, being rated as less acceptable overall. Demographic influences on responses included the respondent's gender and age, but also their level of

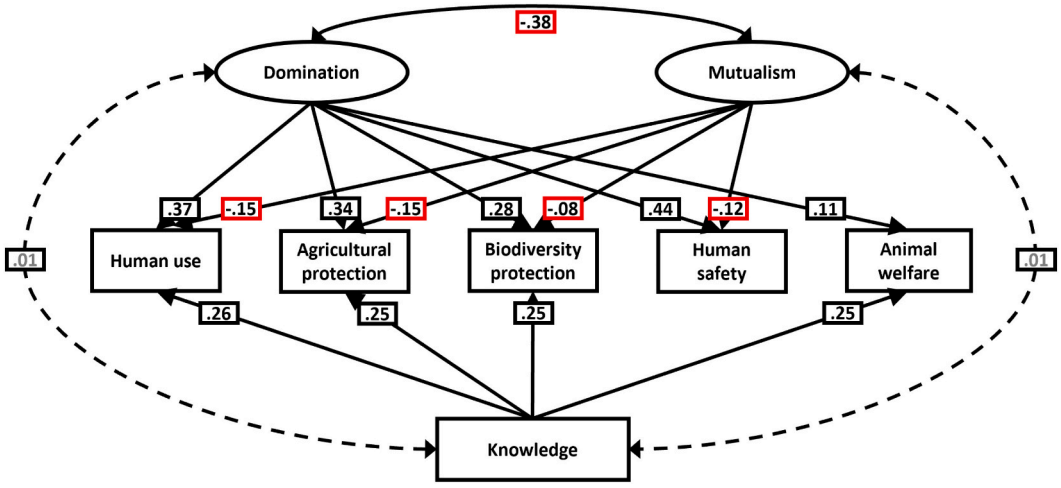

Fig. 4. Structural Equation Model showing the relationships between value orientations, knowledge, and the acceptability of lethal control of kangaroos for five reasons. Standardised regression coefficients are shown for each path (black boxes are positive relationships, red boxes are negative relationships, black text is significant relationships, and grey text is non-significant). The mutualism/animal welfare, and knowledge/human safety relationships were non-significant, and therefore were not included in the model. Relationships between reasons for lethal control of are not shown in this plot. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

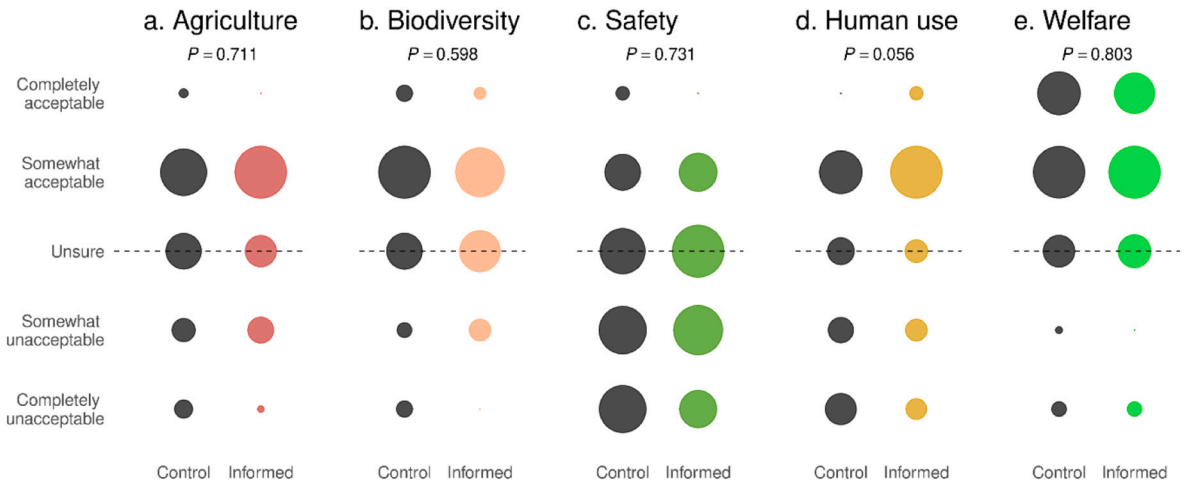

Fig. 5. Acceptability of lethal control of kangaroos for five different reasons, comparing the control group, which was provided no information, and the 'informed' groups that were provided information specific to that treatment. Note that the raw data for acceptability scores are plotted here, which do not take into account demographic influences, while the *P* values provided represent the treatment effects once all demographic influences are accounted for.

education and knowledge about kangaroos and whether they consume kangaroo meat. Finally, we also tested whether acceptability of lethal control could be influenced by providing information relevant to different reasons for lethal control, with strong effect size for human use but no indication that the information we provided that was relevant to the other reasons (agriculture, biodiversity conservation, human safety, or animal welfare) influenced acceptability scores.

4.1. Acceptability of lethal control of kangaroos for different reasons

Previous studies have focused on differences in acceptability between a variety of lethal and non-lethal control methods, including professional shooting, non-professional shooting, capture and euthanasia, fertility control, and translocation (Drijfhout et al., 2020; Sharp, 2015), but only recently have investigations compared different reasons for control of kangaroos (Boulet et al., 2021). Decker et al. (2006) described how acceptability of lethal control of grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*) is influenced by the perceived impact of the predator and termed the phrase 'impact dependency' to describe this difference. In the current study, the variation in acceptability observed was largely driven by the proposed reason for the lethal control, and we therefore describe it as 'reason dependency'.

4.2. Demographic influences and the relationship between values, knowledge, and acceptability

As expected, wildlife orientation values were significantly associated with acceptability of lethal control of kangaroos for nearly all proposed reasons, with positive correlations between the Domination value and acceptability of lethal control, and negative correlations between the Mutualism value and acceptability of lethal control. These correlations between values and lethal control is consistent with findings from other studies (Dougherty et al., 2003; Drijfhout et al., 2020; Sijtsma et al., 2012). Manfredo et al. (2017) argue that wildlife values in the western United States are shifting from traditional Domination values to Mutualism orientations, possibly driven by a modernised lifestyle in which people are often removed from direct contact with wildlife (Manfredo et al., 2009), and such a trend is likely to also be present in Australia (Miller, 2003). Societal shifts in the way people value wildlife will require an adaptable approach by wildlife managers when seeking acceptance of wildlife management actions.

We found a positive relationship between participant's knowledge about kangaroos and their scores for the acceptability of lethal control. We also found a positive relationship between level of education and acceptability of lethal control for biodiversity conservation. While a positive association between knowledge and acceptance of action around controversial issues has been identified (Bremner and Park, 2007; Koichi et al., 2013), the role that knowledge plays in driving attitudes towards wildlife management actions, particularly lethal control, is rarely investigated (see Bremner and Park, 2007). The positive relationship between knowledge and acceptability identified in the current study provides some initial support for the use of information and education campaigns to influence or shift public perceptions and attitudes towards wildlife management actions. However, it is important to caution that the use of education campaigns as a public engagement strategy, leveraging the 'knowledge deficit' model, is not well supported (Hansen et al., 2003; Peters, 2005), and such campaigns have often resulted in exacerbating the concerns of the public and increasing polarisation (Gaskell et al., 2000; Hornsey et al., 2016; Pauwels, 2013).

4.3. Does providing relevant information influence perceptions of acceptability of lethal control of kangaroos for different reasons?

Our experimental manipulation involved providing targeted information about reasons for lethal control that was constructed around our own knowledge basis. We found that this information did not shift acceptability scores for agriculture, biodiversity conservation, human safety, or animal welfare, but the effect size for the response to information around human use is promising (est. 0.35 ± 0.18 SE, $z = 1.91$, $P = 0.056$). This shift could be improved with different modes of presentation, as we only had a very short length of time (a single paragraph of text) embedded within the whole survey during which this information was presented. This study also represents a single exposure to information, of which the participant had no knowledge about the authority or accuracy of the source. Future studies should investigate the use of alternative methods for communicating information, such as videos (McLeod et al., 2017). For example, the short video entitled 'The True Roo Story – Australia's Hidden Shame' (Ninti Media and CoriolisFilms.com 2017) explores the poor animal welfare implications of overabundant kangaroo populations.

4.4. Misconceptions about kangaroo management

In this study, while scoring knowledge of kangaroos, we used the opportunity to assess the understanding of certain misinformation that has recently been widely published in an effort to discredit the commercial harvest of kangaroos (Ben-Ami et al., 2010; McCosker and Cooper, 2023). Firstly, 42 % of respondents incorrectly believed the red kangaroo is endangered and 39 % were not sure, with only 19 % correctly identified that they are not. Similarly, 34 % of respondents incorrectly believed that the national population of kangaroos has declined since the commercial harvest began, 41 % were unsure, and only 25 % correctly identified that this was false. This is indicative that some key misconceptions about the national kangaroo population and the commercial harvest are prevalent among the Australian public, and many have indeed been promoted in the literature (see Ben-Ami et al., 2010). Less than half of the respondents accurately identified that the kangaroo population had increased since European colonisation of Australia, indicating that wildlife management organisations, government, and industry must communicate more effectively with the Australian public.

Under the premise that management of kangaroo populations is required, in some form, to minimise the negative impacts of overabundant populations (Wilson and Edwards, 2019), public support, or at least acceptance, is critical to the sustainability of management actions. The common misconceptions about kangaroos in Australia, and the positive relationship between knowledge and acceptability of lethal control, suggests that a key avenue for increasing support for effective management of kangaroos in Australia involves increasing the level of public knowledge of kangaroo status, ecology, and management.

4.5. Management implications and future work

The outcomes of the current study indicate that when lethal control of kangaroos is undertaken, the stated motivation behind the control, and the underlying values of individuals within the community have a significant impact on public acceptance. The reasons behind management actions must therefore be communicated in a context- and scale-specific manner (Decker et al., 2006; Riley et al., 2003). While much of the scientific dialogue surrounding kangaroo control in Australia focuses on the environmental benefits of kangaroo as an alternative source of red meat (e.g. Wilson and Edwards, 2019), in the current study, lethal control for human use was the least acceptable reason presented. We argue that a shift in messaging towards outlining the potential agricultural and biodiversity conservation benefits of effective kangaroo control, and potential animal welfare improvement, may be more acceptable to the Australian public, and therefore gain increased social licence to operate.

The marginal level of support for lethal control of kangaroos suggests that public support for some wildlife management actions is tenuous and may be vulnerable to controversies and negative coverage. The public outcry following the aerial shooting of feral horses in Guy Fawkes

National Park in north-east New South Wales in 2000 provides an example of high-profile outrage and backlash against a wildlife management action that can have long lasting ramifications (Nimmo and Miller, 2007). Following the cull, the New South Wales National Parks and Wildlife Service was charged (but acquitted) with animal cruelty, and aerial shooting of feral horses was subsequently banned in New South Wales (Nimmo and Miller, 2007). The 2000 Guy Fawkes National Park feral horse cull is still evoked as a justification for the recently tabled 'Brumbies Bill', which seeks to protect feral horses as heritage items in Kosciuszko National Park (Hagis and Gillespie, 2021). The feral horse situation may provide a cautionary tale for kangaroo management and encourage wildlife management agencies to proactively seek avenues for increasing public support for management actions.

Future research could build on the current study to include the international community. The demand for kangaroo skins declined significantly following the collapse of the market in California, following the 2016 ban on import of skins (California Penal Code, 2016). In 2021, a bill was tabled in the US Congress to prohibit the importation of all kangaroo products (Carbajal, 2021). Given the role that knowledge plays in driving acceptability of management actions, investigating how acceptability of lethal control of kangaroos differs for international populations is important. Increasingly, wildlife managers must manage the perceptions of not only the local and national population, but also the international community (e.g. Macdonald et al., 2016).

4.6. Conclusions

The level of acceptability of lethal control of kangaroos by the Australian public is dependent on the reason for control, the level of kangaroo knowledge of the individual, and the values of the individual. Knowledge was positively associated with acceptance of lethal control for all reasons, and education was positively associated with acceptance for biodiversity conservation. Provision of short new information showed some effect in increasing the acceptability of lethal control for human use, which could be expanded in further studies, perhaps using videos and other media. In order to ensure that acceptability of lethal control for wildlife management is maintained, community awareness and education campaigns should highlight biocentric reasons for management actions, present context-specific messages that account for underlying values and seek to increase the knowledge of species' ecology. Finally, exploration of the acceptability of lethal control of kangaroos within the international community is important for avoiding backlash and ensuring continued social licence.

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CRediT authorship contribution statement

Stuart Dawson: Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. **Courtenay Dawson:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Malcolm S. Kennedy:** Methodology, Supervision, Writing – review & editing. **Tracey L. Kreplins:** Supervision, Writing – review & editing. **John D.C. Linnell:** Conceptualization, Supervision, Writing – review & editing. **Patricia A. Fleming:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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