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Subsidized Commercial Harvesting for Cost-effective Wildlife Management in Urban Areas: a Case Study with Kangaroo Sharpshooting

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ABSTRACT The management of overabundant urban fauna is a contentious issue worldwide, particularly for populations of white-tailed deer (*Odocoileus virginianus*) in North America and kangaroos (*Macropus* spp.) in Australia. To be successful, management programs in such settings must be cost-effective, humane, and publicly acceptable. Here we describe the management of a fenced, urban population of western grey kangaroos (*M. fuliginosus*) in southwestern Australia, with an estimated population density of 189 kangaroos/km². After a period of >12 months of solicited public involvement by key stakeholder groups, a licensed professional shooting team, observing a national code of practice, conducted night-time sharpshooting. Over an 11-month period in 2006–2007, 1,009 kangaroos were shot in 43 shooting nights, a mean ($\pm$ SE) culling rate of 23 ± 3 kangaroos/night or harvest rate of 12 ± 2 kangaroos/hour. Inspectors under the relevant Western Australian legislation, functioned as animal welfare observers to ensure that the

methods employed for the culling program met the national code of practice and that all license conditions were met. No accidents or injuries occurred during the program. The program produced 17 kg/kangaroo of harvestable meat and biological samples for several research projects. The operational costs of the project were very low, at AU\$36/kangaroo, with payments largely limited to incentives paid to commercial harvesters and management staff monitoring public safety and animal welfare. This case study is an example of a publicly acceptable, cost-effective, humane, and lethal urban wildlife control operation. It demonstrates that public acceptance of a cull of wildlife can be forthcoming with appropriate prior consultation and high professional standards.

KEY WORDS animal welfare, consultation, human–wildlife conflicts, kangaroo, *Macropus fuliginosus*, sharpshooting, suburban, wildlife damage management.

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The management of fauna in urban settings poses some unique challenges to conservation and animal welfare (Adams 2005, Dandy et al. 2011). The level and intensity of interactions between humans and wildlife are influenced by the density of animals, proximity to dwellings, and habituation of animals to the presence of humans. Overabundant urban fauna often impose impacts on biodiversity values (primarily through overgrazing; Howland et al. 2014), private infrastructure, public health through disease transmission (e.g., Lyme disease in white-tailed deer (*Odocoileus virginianus*) in the USA; Kilpatrick and Walter 1997), and collisions with vehicles (e.g., Sullivan et al. 2004, Williams and Wells 2005, Rowden et al. 2008). Management of overabundant urban fauna is often highly contentious within local communities (see Kilpatrick and LaBonte 2003). This is particularly true of white-tailed deer species in North America (e.g., Kilpatrick and Walter 1997, Kloppers et al. 2005, Hygnstrom et al. 2014), and kangaroos (*Macropus* spp.; Richardson 2012, Descovich et al. 2015) in Australia. Public attitudes toward wildlife management techniques in such contexts are a vital consideration for the success of any program (Reiter et al. 1999).

Wildlife management in Australia has progressed more gradually than in North America in its human dimensions inquiry (Jones et al. 1998, Miller 2009), as demonstrated by the paucity of studies addressing attitudes to problem wildlife in Australia (Jones and Everding 1991, Thomas and Jones 1999, Miller and McGee 2001, Eymann et al. 2006, Nimmo and Miller 2007). Traditional wildlife management techniques used in rural or remote areas are often strongly opposed in urban settings, where they may not be perceived by the public to be safe, humane, or publicly acceptable (Muth and Jamison 2000, Caudell et al. 2009). A common misconception of the relationship between public attitudes and animal welfare outcomes has seen many lethal management techniques prematurely deemed inhumane, publicly unacceptable, or both (Chapple 2005). For charismatic species in Australia, effective lethal management techniques are increasingly being abandoned without rigorous analysis of public attitudes (e.g., Herbert 2004, Chapple 2005, Duka and Masters 2005, Nimmo and Miller 2007).

Kangaroos are iconic and valued species in Australia, but their management remains contentious. Their populations exist in a variety of environments, from arid rangelands (Short et al. 1983, Norbury et al. 1993) to urban conservation reserves (Herbert 2004). Kangaroos are also the only native megafauna species that commonly becomes overabundant in urban areas (Herbert 2004). Kangaroo species have high conservation and tourism value, but are also subjected to sustainable commercial harvesting, whereby their meat is sold for human and animal consumption (Department of Environment and Heritage 2008). As a consequence, there is ongoing contention surrounding the acceptability and humaneness of kangaroo management techniques in Australia (McLeod 2010, Richardson 2012, Descovich et al. 2015).

Overabundant urban kangaroo populations are often encountered inside fenced reserves. Many suburban nature reserves and golf courses are effectively isolated refuges from which resident terrestrial fauna cannot disperse (Garden et al. 2006, Tribe et al. 2014). In a fenced environment with no capacity for dispersal and limited or no human-induced

mortality their densities can reach unsustainable levels. In these situations, some species may experience rapid population growth, eventually leading to a perception that they are a problem in need of intervention. At very high densities, kangaroos can threaten biodiversity values (Norbury et al. 1988, Howland et al. 2014) and create nutritional stress for their own and other animal species, sufficient to necessitate population reduction on animal welfare grounds (McLeod 2010). Vehicle collisions involving kangaroos are common in Australia (Abu-Zidan et al. 2002, Klöcker et al. 2006, Rowden et al. 2008), and attacks on humans in urban areas are also reported (Moscardo et al. 2006), in a similar context to deer attacks in North America (Hubbard and Nielsen 2009).

Several studies have investigated the efficacy of various options for managing urban wildlife populations but the majority have focused on deer (e.g., Hansen and Beringer 1997, Kilpatrick and Walter 1997, Warren 2011). Doerr et al. (2001) recommended the following 4 criteria for evaluating the merits of any urban fauna management program: 1) cost, 2) effectiveness (as percentage population reduction), 3) efficiency (animals removed per unit of time), and 4) safety. Given the recent focus on animal welfare in wildlife management practices (Mellor and Littin 2004, Warburton and Norton 2009) there is a strong argument for the addition of a fifth criterion, humaneness. Here, we report the successful implementation of night-time sharpshooting for the management of an overabundant western grey kangaroo (*Macropus fuliginosus ocydromus*) population from an urban conservation reserve in southwestern Australia.

STUDY AREA

The study was conducted at Thomsons Lake Nature Reserve (TLNR), an urban conservation reserve near Perth, a city of approximately 1.3 million people, in Western Australia (32°09'S, 115°50'E). The TLNR was located 22 km south of Perth city center, covered an area of 5.5 km² (Fig. 1), and was surrounded by a kangaroo-, dog- and fox-proof fence (Mayberry et al. 2010). The reserve was part of Beeliar Regional Park and a RAMSAR-listed wetland (site 35; Anonymous 2010) of international significance.

The reserve supported 3 distinct vegetation types ranging from fringing riparian vegetation around the lake margin, *Banksia* woodland (midslope), and eucalypt woodland (upslope). The fringing vegetation was dense and consisted of flooded gum (*Eucalyptus rudis*), *Melaleuca* spp., and a dense understory of the rush *Baumea articulata* and the introduced *Typha orientalis* (Fig. 2). The *Banksia* woodland was dominated by *B. attenuata* and *B. menziesii*, with a patchy understory of grasses, as well as *Hibbertia hypercoides*, *Xantheorrhoea preissii*, and *Macrozamia reidleyi*. The eucalypt woodland possessed a similar understory to the *Banksia* woodland; however, the vegetation was more open with scattered Jarrah (*E. marginata*) and Tuart (*E. gomphocephala*; Department of Environment and Conservation 2009). The reserve was positioned predominantly over the Bassendean Dune system, with soils that were highly leached and poor in nutrients (McArthur and Bettenay 1960). The tree canopy varied in height from 2 m to 5 m in the *Banksia* woodland up to 20–25 m in the eucalypt woodland. The understory was dense enough to limit line-of-sight in many parts of the reserve to <10 m.

METHODS

Kangaroo Population Monitoring

The western grey kangaroo population at TLNR was a wild population confined within a predator-proof fence for 13 years prior to commencing the shooting program. Unreplicated helicopter flights over the reserve were conducted in 1996, 2002, and 2006 to provide data on the size of the resident kangaroo population. The flights were each flown in a R-22 helicopter (Robinson Helicopter Company, Torrance, CA, USA) at a height of 60 m and speed of 10–15 knots with the same observer (PRM) for all flights. This observation method was similar to that used for estimating deer abundance (Stoll et al. 1991). The flights were not intended to provide accurate estimates of the kangaroo population at each point in time, but did provide valuable data on the trend in the kangaroo population, existence of any major animal-welfare issues within the population (deduced from the no. of skeletons and carcasses observed), and provided an aerial view of the grazing impact of the kangaroos on sections of the reserve not

readily visible from the track network that existed within the reserve.

We estimated the kangaroo population size at the time of the commencement of the culling program using the Leslie method (Leslie and Davis 1939) where catch per unit effort (y) is plotted against the previous cumulative catch (x), which provides a straight line bisecting the x -axis at the population size prior to harvest (Caughley 1977). The population estimate at the start of the culling program allowed us to evaluate the effectiveness of the program.

Consultation

The community advisory committee that provides for wide community input into the management of TLNR raised concerns about the size of the western grey kangaroo population and the impact that the animals were having on the biodiversity values of the reserve in 2004. Western grey kangaroos can congregate in high densities, and have been shown to cause extensive damage to natural habitats in other parts of Australia (Coulson and Norbury 1988). Following extensive discussions with the managing authority (the Department of Conservation and Land Management [CALM]) and an examination of all available population reduction methods, a draft management plan was prepared for TLNR recommending a cull of the kangaroo population using lethal means. Recognition of problems being caused by the kangaroos and preferred means of managing the problem were set out in the draft management plan, which was released for public comment in 2005 (CALM 2005), with the final plan published in 2006.

Following a review of the public comments, which provided limited adverse feedback on the proposed cull, the management plan was finalized and endorsed by the relevant agencies. In conjunction with the management plan, a communication strategy for the cull was implemented well in advance of the beginning of the shooting operation. A solicited public-involvement strategy was used, taking the form of a classic survey approach to stakeholder input (Stout et al. 1996). The stakeholders notified under this strategy included community groups with interests in wetland management, the police department, the local

government authority in which the reserve is located, local residents, and the most prominent animal welfare advocacy group in Western Australia (de Witte 2009). Stakeholders were provided with information to explain the situation, planning undertaken to date, and outcomes to be achieved.

Field Protocol

The sharpshooting protocol followed was in accordance with the Australian national code of practice (Department of Environment and Heritage 1998; now superseded by Department of Environment and Heritage 2008), as described in McLeod et al. (2006). All shooting was done by a professional kangaroo harvester acting under licenses issued by the Department of Parks and Wildlife, formerly Department of Conservation and Land Management (Licenses SF005399, SF005436, SF005512, SF005522, SF005568 and SF005607). Shooting nights were chosen opportunistically with no preference given to moonless conditions. Shooting was permitted on a maximum of 2 nights/calendar week to minimize stress and the development of avoidance behavior in surviving animals. Shooting was performed between sunset and 2200 hours, and limited to Monday–Thursday nights to minimize disturbance to neighboring residents' amenity. A single-cab tray-back utility 4-wheel drive vehicle was used, with the shooter, a spotlihter, and an independent observer standing on the back. The vehicle was modified as per standard, commercial kangaroo-shooting specifications to allow the hanging of carcasses (Department of Environment and Heritage 1998). The spotlihter held a 100-W, 240-mm-diameter spotlight (Lightforce[®], Hindmarsh, South Australia, Australia) with a yellow filter. The shooter rested the rifle on a padded bar mounted at the rear of the vehicle's cabin. The vehicle was driven at 5–10 km/hour, with the spotlight sweeping back and forth over an arc of 180° but concentrating on the area in front of the vehicle.

Kangaroos were seen either directly or by the reflection of light from their eyes. On sighting a kangaroo, the vehicle was stopped immediately. Animals were shot as they presented themselves and all adult and subadult animals were targeted such that no selection for size or sex occurred. During shooting, the spotlight was trained on the target animal. Shots

were taken that were considered within the “ethical range” (<120 m; Caudell et al. 2009), being the longest shot that would be likely to humanely kill the target animal and with a low chance of missing. The distance to target kangaroos was confirmed with hand-held optical rangefinders (operated by the person holding the spotlight) before each shot was taken. At no time was shooting undertaken from a moving vehicle, or at a moving kangaroo.

An experienced and accredited marksman (i.e., one who has passed an accuracy test under field conditions prescribed by the regulating authority, which is a prerequisite to obtaining a kangaroo shooter’s license in Western Australia) performed the sharpshooting of all animals. The shooter used a Winchester[®] Model 70 rifle chambered in .223 Remington[®] caliber (Winchester Australia Ltd., Moolap, Victoria, Australia), using 55-grain pointed-soft-point bullets (Winchester Australia Ltd.). It was fitted with a Simmons[®] Whitetail Classic 4–12 × 44 telescopic sight (Simmons Outdoor Products, Overland Park, KS, USA). The rifle was zeroed for 100 m prior to shooting. Carcasses were attached to the vehicle after shooting and processed on-site at irregular intervals dictated by the rate of harvest; viscera, heads, and feet were removed and buried as per Department of Environment and Heritage (2008), with all excised offal buried on-site. Kangaroo carcasses processed in the field were sold into the commercial trade in accordance with the approved kangaroo management plan in place at the time (CALM 2002). Toward the end of the culling program the value of the few kangaroos shot each night was insufficient to make participation in the program viable for the shooter.

Management staff were present for each night of shooting to ensure the integrity of boundary fences and protect public safety by preventing members of the public from entering the reserve during shooting hours. The reserve gates were locked during the shooting program and signs were posted at all public access points to the reserve stating that a nighttime shooting program was in effect. A Department of CALM Wildlife Officer was present during all shooting to ensure that all kangaroos were shot in the cranium, dependent young were euthanized with a single forceful blow to the base of the skull sufficient to destroy the functional capacity of the brain as per Department of Environment and Heritage (1998), and

that no shot animals escaped wounded. Wildlife Officers were appointed under the provisions of the Western Australian *Wildlife Conservation Act 1950*, and as General Inspectors under the provisions of the Western Australian *Animal Welfare Act 2002*.

We present data on the number of kangaroos culled during the program, the culling rate (no. culled/night), harvest rate (no. culled/hr), the total (kg) and mean (kg per carcass) of meat recovered during the program, the estimated level of reduction in the population, and the total and mean cost (AU\$)/kangaroo. We present summary statistics as mean $\pm$ standard error.

RESULTS

Population Trend

Preculling helicopter flights flown in 1996, 2002, and 2006 returned raw counts of 27, 141, and 216 kangaroos in the reserve, respectively. For the raw count of 2006, this equated to a density of 39.7 kangaroos/km² (ignoring any reduction in land area when the lake holds water during winter and spring; Fig. 2). The average density recorded for the species in the high-rainfall *Eucalyptus* forests of southwestern of Western Australia is 0.86 animals/km², with the maximum natural density in the region reaching 5–6 animals/km² in localized areas (Short et al. 1983). A final unreplicated driven spotlight survey was performed at the conclusion of the shooting program and returned a raw count of 68 (12/km²) animals. The catch-effort data collected provided a population estimate of 1,143 (208/km²) at the start of the culling program (Fig. 3).

Public Criticism

The managing agency received 21 submissions on the draft management plan. Eight submissions were in relation to the management of kangaroos, of which 6 were supportive of the proposed cull and 2 made no specific comment about the proposed cull itself. Another raised issues about the use of firearms within an enclosed urban reserve, but not about kangaroos specifically. Once the culling program had commenced, the Department (including via the relevant Minister's office) received 41 written complaints or comments. Those letters raised issues about philosophical objections to culling any animal, or kangaroos specifically;

concerns about the efficacy and humaneness of the program; concerns about cruelty toward pouch-young and compliance with Code of Practice; asking how the population would be managed in future after the cull was completed; and the equity of access to the program by other professional licensed shooters. There was also one noise complaint from a local resident during the shooting program. No wounded kangaroos were reported by the public. Protesting citizens interrupted shooting operations on one occasion.

Media coverage of the culling program was limited to an article in the major daily newspaper published on 24 April 2006, after which most of the written complaints were received. A second media enquiry on 20 July 2006 about the methods used in the culling program arose in relation to a separate kangaroo-management issue on a public golf course in the northern suburbs of Perth, Western Australia. In 2009, a local community newspaper ran a series of 3 articles (4 Jul, 19 Sep, and 19 Sep) about the culling program, which did not result in any correspondence being received by CALM.

Shooting Outcomes

The shooting program commenced on 5 May 2006 and continued for 330 days, finishing on 30 March 2007, with shooting occurring on 43 nights. A total of 1,009 animals were shot (88% of the estimated 1,143 total kangaroos; Fig. 3). The population of animals removed was male-biased (57 M:43 F). The mean culling rate (defined here as the average no. of kangaroos shot per night of shooting effort; see DeNicola and Williams 2008) was 23 ± 3 ($\bar{x} \pm \text{SE}$) kangaroos/night, and the harvest rate (defined here as the average no. of kangaroos killed per hour of shooting effort; see Doerr et al. 2001) was 12 ± 2 kangaroos/hour (Fig. 4). Throughout the life of the program, there was a mean interval of 7 ± 1 nights between successive shooting nights. The Wildlife Officer–General Inspector observer confirmed that all animals were shot in the cranium at shooting distances <100 m, and that no animals were observed to escape wounded. To facilitate collaborative scientific studies, the following samples were removed from a random subsample of shot animals: jaws and skulls for a demographic study (Mayberry 2011), ovaries for a reproduction study (Mayberry et al. 2010), heart valves for an

ongoing xenotransplantation study (Neethling et al. 2002), and fecal samples for parasitological study (Parameswaran et al. 2009a, b; 2010; Mayberry et al. 2014b). A total of 17,543 kg of meat was harvested at an average of 17.3 kg/animal. The presence of residential development immediately adjacent to the site increased the risks associated with firearm use, but the program was conducted safely with no incidents of property damage or injury reported from nearby residents because shooting was always undertaken toward the center of the reserve and took advantage of the prevailing natural amphitheater type of geography in the reserve.

The population was closed on account of the presence of the predator-proof fence, and western grey kangaroos are seasonally anestrus (Mayberry et al. 2010). Under these circumstances there was limited capacity for recruitment in the population during the period of the shooting program. The 88% reduction in the population over the 11-month program is likely to be an accurate estimate of the efficiency of the program.

Costs

The managing agency paid overtime for its operations staff to patrol boundary fences to ensure no unauthorized public access onto the reserve and monitor animal welfare standards during shooting activities. The cost associated with these 2 roles totaled AU\$26,790. The shooting team was paid incentives once the diminishing returns (Fig. 4) associated with declining harvest rates dictated that it was not commercially viable for shooters to operate solely on the basis of the financial return gained from harvested meat. The cost associated with paying incentives to commercial harvesters totaled AU\$9,817. The total operational costs of the program were thus AU\$36,607, or AU\$36/animal.

DISCUSSION

The shooting program that we describe provides a template for a publicly acceptable, cost-effective program to control overabundant species in an urban area. In addition, the program was demonstrated to be safe and humane. The program avoided many of the weaknesses and pitfalls in previous programs within Australia to cull overabundant native wildlife by

sharpshooting. First, public outrage or surprise was minimized by engaging in an extended, solicited community-consultation period commencing >12 months before operations began. Second, by having a Wildlife Officer–General Inspector scrutinizing animal welfare standards, community perceptions of inhumane practices were minimized. Thirdly, by performing the operation over an extended time frame, safety and animal welfare standards were not compromised. Fourthly, the costs of the program were kept very low by paying incentives to commercial harvesters, rather than utilizing agency staff to undertake the shooting program.

The program was assessed against the criteria designated by Doerr et al. (2001). We also argue for the addition of humaneness to those original 4 criteria:

1) Cost: The operational component of the program was extremely cost-effective, with the majority of costs incurred in the form of out-of-hours salary payments to management staff, the animal welfare assessor, and in incentives to commercial harvesters once declining kangaroo densities precluded financial viability.

2) Effectiveness (as percentage population reduction): Population reduction was estimated at 88% of the original population at the start of the program.

3) Efficiency (animals removed per unit of time): The program was deemed to be highly effective, with the observed harvesting rate of 12 animals/hour in the initial stages, being considerably greater than those reported for the urban harvesting of deer (0.02–0.59/hr; Doerr et al. 2001).

4) Safety: The safety levels of the program were observed to be high, with no adverse shooting incidents or injuries to staff, local residents, or nontarget animals. Noise levels from shooting (see Vos 2001) were not sufficiently audible to local residents to create public nuisance or sound pollution, evidenced by only one complaint from nearby residents about the noise from shooting.

5) Humaneness: The entire program was observed independently and confirmed to comply with the national code of practice designed to ensure humane standards (Department

of Environment and Heritage 1998). No animals were observed to escape wounded. Less precise or less tightly regulated lethal methods have been associated with regular wounding of animals (Kilpatrick and Walter 1997).

Regarding costs, it is important to note that the salary costs incurred in the planning and stakeholder discussion aspects of the program have not been included in the calculations of cost-effectiveness because those activities are considered to be within the normal duties of the staff who undertook them. By excluding those office-based operational costs from our figures, the calculation of the total cost-effectiveness of the whole program has been increased. The final operational cost of the program per animal was AU\$36. Overall, the program was cost-effective when compared with similar programs for deer culling (e.g., Doerr et al. 2001; AU\$108–\$121/animal), and the nonlethal population-management program reported by Tribe et al. (2014) for eastern grey kangaroos (*Macropus giganteus*; AU\$104–184/animal).

Our results are consistent with those of Nugent and Choquenot (2004), who demonstrated that commercial deer harvesting can be manipulated to achieve more cost-effective outcomes than state-funded culling. We were unable to make comparisons with alternative kangaroo management techniques, such as translocation (Keep and Fox 1971), because of a paucity of data on this method directly related to their cost-effectiveness. Kilpatrick et al. (2007) argue that educating local residents on the cost and effectiveness of various management strategies should be an important consideration of the planning process. The cost-effectiveness of this program was also a product of the relatively high density of kangaroos, the habit of the kangaroos of grazing in open habitats and on the dry lake bed, and the efficiency of shooting operations.

The relatively high efficiency levels achieved in this study were attributable to several factors. Marsupials have been shown to display less vigilant antipredator behavior compared with placental mammals, facilitating close approach for shooting (Short et al. 2002, Blumstein and Daniel 2003). In addition, fauna in urban areas that are habituated to human presence are

known to exhibit shorter flight distances (Kloppers et al. 2005, King et al. 2011, Hampton and Forsyth 2016). Shooting from a vehicle with the aid of a spotlight further increases the shooter's advantage because kangaroos are susceptible to the effect of spotlights (Robertson and Gepp 1982) and display shorter flight distances from vehicles than from humans on foot (Lee et al. 2009, Wolf and Croft 2010). This program was performed over an 11-month period of time, preventing surviving animals from developing stronger flight responses or extended flight distances. Finally, competency standards for licensed kangaroo shooters are rigorous under the national code of practice (Department of Environment and Heritage 1998), ensuring consistent firearms and ammunition specifications and high skill level in professional sharpshooting.

There is abundant evidence that lethal techniques can be effectively and safely applied to urban scenarios with appropriate planning and consultation (e.g., Doerr et al. 2001; Kilpatrick et al. 2002, 2007; DeNicola and Williams 2008; Hygnstrom et al. 2014). The use of solicited public involvement in this program provided the managing agency with a thorough understanding of the range of public interest in the program and contributed to contingency planning. Using solicited input from a variety of stakeholders ensures that an agency is responsive to a wide range of public needs (Stout et al. 1996). A lack of consultation, transparency, and consideration for animal welfare concerns have been common themes among discontinued Australian wildlife programs (Chapple 2005, Hampton et al. 2016).

Urban hunting programs that maximize harvest opportunities have been demonstrated to increase community support for hunting as a management tool (Kilpatrick and LaBonte 2003, McLeod et al. 2011, Stewart et al. 2013). In our study, the use of a sharpshooting team with access to a commercial kangaroo processing industry achieved several goals. First, it improved the cost-effectiveness of the program by reducing contractor costs. Second, it reduced public health effects of decomposing biomass close to a human residential population because 17.5 t of meat was removed to processing facilities off-site and the remaining waste material was buried to a depth of 1.5 m. Third, it reduced the biomass required to be placed

into landfill or other disposal. Fourth, it reduced public perceptions of wasted resources or cultural opposition to 'shoot to waste' practices, a common impediment to lethal wildlife control in Australia (see Robinson and Whitehead 2003, Robinson et al. 2005, Albrecht et al. 2009, Vaarzon-Morel 2010), and finally it provided an opportunity to value-add to the whole project by providing researchers with access to a range of biological samples that generated valuable information about the western grey kangaroo population demographics and reproductive cycles, zoonoses in wildlife, and continued longer running research into xenotransplantation opportunities. It is important to note that kangaroos can be considered a renewable resource, and culling programs such as this one will have to be repeated at regular intervals to maintain population under critical density limits. The recurring nature of required culling programs allows managers to budget and plan for subsequent programs far in advance.

The claim has been made that kangaroo shooting in certain circumstances is 'publicly unacceptable' (e.g., Herbert 2004) despite the absence of published studies assessing public attitudes (Miller 2009). Such studies have been performed numerous times in the North American deer context (e.g., Zinn et al. 1998, Kilpatrick et al. 2007). Broad acceptance of this unqualified perception has led several recent studies to advocate nonlethal population control methods for urban kangaroos without adequate consideration for animal welfare outcomes, efficacy, or cost-effectiveness (however, see Descovich et al. 2015). Trialled nonlethal methods for urban kangaroos have included capture and translocation (e.g., Keep and Fox 1971); chemical contraception (e.g., Coulson et al. 2008, Wilson and Coulson 2016), and surgical sterilization (e.g., Herbert 2004); or both chemical contraception and sterilization combined (e.g., Tribe et al. 2014).

Previous studies have questioned the largely unquantified animal welfare outcomes of nonlethal animal removal methods applied to deer populations (e.g., Waas et al. 1999, Beringer et al. 2002). Whisson et al. (2012) demonstrated the capacity for nonassessed, nonlethal marsupial control methods to deliver very poor animal welfare outcomes. For kangaroos specifically, Tribe et al. (2014) indicated a 5–10% mortality rate associated with

complications before and after anesthesia of target animals and Mayberry et al. (2014a) demonstrated the potential for commonly used kangaroo capture regimes to produce prolonged duration of suffering. McLeod (2010) applied the animal welfare matrix developed by Sharp and Saunders (2011) to a hypothetical scenario similar to our study, and argued that professional shooting was the most humane control method available for kangaroo population management. The recent review by Descovich et al. (2015) reached a similar conclusion.

MANAGEMENT IMPLICATIONS

Sharpshooting can be a very effective control method for overabundant peri-urban kangaroos, and is not technically difficult, but requires thorough planning and courage from managers. We suggest that an important consideration for culling any charismatic peri-urban species is engaging adequately with the full range of stakeholders, as early as possible in the planning process. Adoption of the methods employed in the planning, administration, and verification of our program should assist managers to avoid pitfalls that have hindered past peri-urban wildlife sharpshooting programs.

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LITERATURE CITED

- Abu-Zidan, F. M., K. A. Parmar, and S. Rao. 2002. Kangaroo-related motor vehicle collisions. *Journal of Trauma and Acute Care Surgery* 53:360–363.
- Adams, L. W. 2005. Urban wildlife ecology and conservation: a brief history of the discipline. *Urban Ecosystems* 8:139–156.
- Albrecht, G., C. R. McMahon, D. M. Bowman, and C. J. Bradshaw. 2009. Convergence of culture, ecology, and ethics: management of feral swamp buffalo in northern Australia. *Journal of Agricultural and Environmental Ethics* 22:361–378.

Anonymous. 2010. Australia's RAMSAR sites.

http://www.environment.gov.au/system/files/resources/0d08923b-a60d-4564-9af2-a7023b7aaf29/files/ramsar-sites_0.pdf. Accessed 17 Dec 2013.

Beringer, J., L. P. Hansen, J. A. Demand, J. Sartwell, M. Wallendorf, and R. Mange. 2002.

Efficacy of translocation to control urban deer in Missouri: costs, efficiency, and outcome. *Wildlife Society Bulletin* 30:767–774.

Blumstein, D. T., and J. C. Daniel. 2003. Foraging behavior of three Tasmanian macropodid marsupials in response to present and historical predation threat. *Ecography* 26:585–594.

Caudell, J. N., B. C. West, B. Griffin, and K. Davis. 2009. Fostering greater professionalism with firearms in the wildlife arena. *Proceedings of the Wildlife Management Conference* 13:95–99.

Caughley, G. 1977. *Analysis of vertebrate populations*. J. Wiley and Sons, New York, New York, USA.

Chapple, R. 2005. The politics of feral horse management in Guy Fawkes River National Park, NSW. *Australian Zoologist* 33:233–246.

Conservation and Land Management [CALM]. 2002. Management plan for western grey kangaroos *Macropus fuliginosus* in Western Australia 2004–2008. Department of Conservation and Land Management, Perth, Western Australia, Australia.

Conservation and Land Management [CALM]. 2005. Thomsons Lake Nature Reserve management plan 2005. Conservation Commission of Western Australia, Perth, Western Australia, Australia.

http://www.dpaw.wa.gov.au/images/documents/parks/management-plans/dearchive/thomsons_lake.pdf. Accessed 17 Dec 2013.

Coulson, G., Nave, C. D., Shaw, G. and Renfree, M. 2008. Long-term efficacy of levonogestrel implants for fertility control of eastern grey kangaroos (*Macropus giganteus*). *Wildlife Research* 35:520-524.

- Coulson, G., and Norbury, G. 1988. Ecology and management of western grey kangaroos (*Macropus fuliginosus*) at Hattah–Kulkyne National Park. Arthur Rylah Institute for Environmental Research Technical Report Series no. 72. Department of Sustainability and Environment, Melbourne, Victoria, Australia.
- Dandy, N., S. Ballantyne, D. Moseley, R. Gill, A. Peace, and C. Quine. 2011. Preferences for wildlife management methods among the peri-urban public in Scotland. *European Journal of Wildlife Research* 57:1213–1221.
- DeNicola, A. J., and S. C. Williams. 2008. Sharpshooting suburban white-tailed deer reduces deer–vehicle collisions. *Human–Wildlife Interactions* 2:28–33.
- Department of Environment and Conservation. 2009. Ecological character description for the Forrestdale and Thomsons Lakes Ramsar Site.
http://www.dpaw.wa.gov.au/images/documents/conservation-management/wetlands/ramsar/forrestdale-thomsons-eed_final-with-disclaimer.pdf .
Accessed 22 May 2015.
- Department of Environment and Heritage. 1998. Code of practice for the humane shooting of kangaroos. Department of Environment and Heritage, Canberra, Australian Capital Territory, Australia.
- Department of Environment and Heritage. 2008. National code of practice for the humane shooting of kangaroos and wallabies for commercial purposes. Department of Environment and Heritage, Canberra, Australian Capital Territory, Australia.
- Descovich, K. A., I. J. McDonald, A. Tribe, and C. J. C. Phillips. 2015. A welfare assessment of methods used for harvesting, hunting and population control of kangaroos and wallabies. *Animal Welfare* 24:255–265.
- de Witte, K. 2009. Development of the Australian Animal Welfare standards and guidelines for the land transport of livestock: process and philosophical considerations. *Journal of Veterinary Behavior: Clinical Applications and Research* 4:148–156.
- Doerr, M. L., J. B. McAninch, and E. P. Wiggers. 2001. Comparison of 4 methods to reduce

- white-tailed deer abundance in an urban community. *Wildlife Society Bulletin* 29:1105–1113.
- Duka, T., and P. Masters. 2005. Confronting a tough issue: fertility control and translocation for over-abundant Koalas on Kangaroo Island, South Australia. *Ecological Management & Restoration* 6:172–181.
- Eymann, J., C. A. Herbert, and D. W. Cooper. 2006. Management issues of urban common brushtail possums *Trichosurus vulpecula*: a loved or hated neighbour. *Australian Mammalogy* 28:153–171.
- Garden, J., C. McAlpine, A. N. N. Peterson, D. Jones, and H. Possingham. 2006. Review of the ecology of Australian urban fauna: a focus on spatially explicit processes. *Austral Ecology* 31:126–148.
- Hampton, J. and Forsyth, D. 2016. An assessment of animal welfare for the culling of peri-urban kangaroos. *Wildlife Research* 43: in press.
- Hampton, J. O., B. Jones, A. L. Perry, C. J. Miller, and Q. Hart. 2016. Integrating animal welfare into wild herbivore management: lessons from the Australian Feral Camel Management Project. *The Rangeland Journal* 38: <http://dx.doi.org/10.107/RJ15079>
- Hansen, L., and J. Beringer. 1997. Managed hunts to control white-tailed deer populations on urban public areas in Missouri. *Wildlife Society Bulletin* 25:484–487.
- Herbert, C. A. 2004. Long-acting contraceptives: a new tool to manage overabundant kangaroo populations in nature reserves and urban areas. *Australian Mammalogy* 26:67–74.
- Howland, B., D. Stojanovic, I. J. Gordon, A. D. Manning, D. Fletcher, and D. B. Lindenmayer. 2014. Eaten out of house and home: impacts of grazing on ground-dwelling reptiles in Australian grasslands and grassy woodlands. *PLoS ONE* 9:e105966.
- Hubbard, R. D., and C. K. Nielsen. 2009. White-tailed deer attacking humans during the fawning season: a unique human–wildlife conflict on a university campus. *Human–*

Wildlife Interactions 3:129–135.

Hygnstrom, S., D. Drake, T. Van Deelen, and S. Vantassel, 2014. Managing overabundant white-tailed deer: is it time to consider regulated commercial harvest? *Outlooks on Pest Management* 25:11–16.

Jones, D. N., J. W. Enck, W. F. Siemer, T. L. Brown, and D. J. Decker. 1998. An introduction to human dimensions of wildlife management: taking the North American experience to Australia. Cornell University Human Dimensions Research Unit Series 98-7. Cornell University, Ithaca, New York, USA.

Jones, D. N., and S. E. Everding. 1991. Australian brush-turkeys in a suburban environment: implications for conflict and conservation. *Wildlife Research* 18:285–297.

Keep, J. M., and A. M. Fox. 1971. The capture, restraint and translocation of kangaroos in the wild. *Australian Veterinary Journal* 47:141–145.

Kilpatrick, H. J., and A. M. LaBonte. 2003. Deer hunting in a residential community: the community's perspective. *Wildlife Society Bulletin* 31:340–348.

Kilpatrick, H. J., A. M. LaBonte, and J. S. Barclay. 2007. Acceptance of deer management strategies by suburban homeowners and bowhunters. *Journal of Wildlife Management* 71:2095–2101.

Kilpatrick, H. J., A. M. LaBonte, and J. T. Seymour. 2002. A shotgun-archery deer hunt in a residential community: evaluation of hunt strategies and effectiveness. *Wildlife Society Bulletin* 30:478–486.

Kilpatrick, H. J., and W. D. Walter. 1997. Urban deer management: a community vote. *Wildlife Society Bulletin* 25:388–391.

King, W. J., M. E. Wilson, T. Allen, M. Festa-Bianchet, and G. Coulson. 2011. A capture technique for free-ranging eastern grey kangaroos (*Macropus giganteus*) habituated to humans. *Australian Mammalogy* 33:47–51.

Klöcker, U., D. B. Croft, and D. Ramp. 2006. Frequency and causes of kangaroo–vehicle collisions on an Australian outback highway. *Wildlife Research* 33:5–15.

- Kloppers, E. L., C. C. St. Clair, and T. E. Hurd. 2005. Predator-resembling aversive conditioning for managing habituated wildlife. *Ecology and Society* 10:31.
<http://www.ecologyandsociety.org/vol10/iss1/art31/>. Accessed 30 Nov 2013.
- Lee, E., D. B. Croft, and D. Ramp. 2009. Flight response as a causative factor in kangaroo–vehicle collisions. Pages 301–312 in G. Coulson and M. D. Eldridge, editors. *The biology of kangaroos, wallabies and rat-kangaroos*. CSIRO, Collingwood, Victoria, Australia.
- Leslie, P. H., and P. H. Davis. 1939. An attempt to determine the absolute number of rats on a given area. *Journal of Animal Ecology* 8:94–113.
- Mayberry, C. 2011. Fertility control of western grey kangaroos (*Macropus fuliginosus ocydromus*). Dissertation, University of Western Australia, Perth, Western Australia, Australia.
- Mayberry, C., R. Bencini, P.R. Mawson, and S. K. Maloney. 2014a. Sedation of western grey kangaroos (*Macropus fuliginosus ocydromus*) with tiletamine–zolazepam. *Animal Welfare* 23:141–144.
- Mayberry, C., S. K. Maloney, P. R. Mawson, and R. Bencini. 2010. Seasonal anoestrus in western grey kangaroos (*Macropus fuliginosus ocydromus*) in south-western Australia. *Australian Mammalogy* 32:189–196.
- Mayberry, C., S. K. Maloney, J. Mitchell, P. R. Mawson, and R. Bencini. 2014b. Sero-prevalence of *Toxoplasma gondii* and *Neospora caninum* in western grey kangaroos (*Macropus fuliginosus ocydromus*) in south-western Australia. *Journal of Wildlife Diseases*. 50:364–368.
- McArthur, W. M., and E. Bettenay. 1960. The development and distribution of the soils of the Swan Coastal Plain, Western Australia. CSIRO Soil Publication, Perth, Western Australia, Australia.
- McLeod, L. J., G. R. Saunders, and A. Miners. 2011. Can shooting be an effective management tool for foxes? Preliminary insights from a management programme.

Ecological Management and Restoration 12:224–226.

- McLeod, S. R. 2010. Is kangaroo management justified and humane? What are the concerns and how can they be addressed? Pages 14–24 *in* M. Tensen and B. Jones, editors. Proceedings of the RSPCA Australia Scientific Seminar, 23 Feb 2010, Canberra, Australian Capital Territory, Australia. Royal Society for the Prevention of Cruelty to Animals Australia, Deakin West, Australian Capital Territory, Australia.
- McLeod, S. R., J. P. Druhan, and R. B. Hacker. 2006. Estimating the age of kangaroos using eye lens weight. *Wildlife Research* 33:25–28.
- Mellor, D. J., and K. E. Littin. 2004. Using science to support ethical decisions promoting humane livestock slaughter and vertebrate pest control. *Animal Welfare* 13:127–132.
- Miller, K. K. 2009. Human dimensions of wildlife population management in Australasia—history, approaches and directions. *Wildlife Research* 36:48–56.
- Miller, K. K., and C. T. K. McGee. 2001. Toward incorporating human dimensions information into wildlife management decision-making. *Human Dimensions of Wildlife* 6:205–221.
- Moscardo, G., M. Taverner, and B. Woods. 2006. When wildlife encounters go wrong: tourist safety issues associated with threatening wildlife. Pages 209–228 *in* Y. Mansfield and A. Pizam, editors. *Tourism, security and safety: from theory to practice*. Elsevier, Burlington, Massachusetts, USA.
- Muth, R. M., and W. V. Jamison. 2000. On the destiny of deer camps and duck blinds: the rise of the animal rights movement and the future of wildlife conservation. *Wildlife Society Bulletin* 28:841–851.
- Neethling, W. M. L., S. Cooper, J. J. Van Den Heever, J. Hough, and A. J. Hodge. 2002. Evaluation of kangaroo pericardium as an alternative substitute for reconstructive cardiac surgery. *Journal of Cardiovascular Surgery* 43:301–306.
- Nimmo, D. G., and K. K. Miller. 2007. Ecological and human dimensions of management of feral horses in Australia: a review. *Wildlife Research* 34:408–417.

- Norbury, G. L., G. M. Coulson, and B. L. Walters. 1988. Aspects of the demography of the western grey kangaroo, *Macropus fuliginosus melanops* in semiarid north-west Victoria. *Australian Wildlife Research* 15:257–266.
- Norbury, G. L., D. C. Norbury, and R. B. Hacker. 1993. Impact of red kangaroos on the pasture layer in the Western Australian arid zone. *The Rangeland Journal* 15:12-23.
- Nugent, G., and D. Choquenot. 2004. Comparing cost-effectiveness of commercial harvesting, state-funded culling, and recreational deer hunting in New Zealand. *Wildlife Society Bulletin* 32:481–492.
- Parameswaran, N., R. M. O’Handley, M. E. Grigg, S. G. Fenwick, and R. C. A. Thompson. 2009a. Seroprevalence of *Toxoplasma gondii* in wild kangaroos using ELISA. *Parasitology International* 58:161–165.
- Parameswaran, N., R. M. O’Handley, M. E. Grigg, A. Wayne, and R. C. A. Thompson. 2009b. Vertical transmission of *Toxoplasma gondii* in Australian marsupials. *Parasitology* 36:939–944.
- Parameswaran, N., R. C. A. Thompson, N. Sundar, S. Pan, M. Johnson, and M. E. Grigg. 2010. Non-archetypal Type II-like and atypical strains of *Toxoplasmosis gondii* infecting marsupials in Australia. *International Journal of Parasitology* 40:635–640.
- Reiter, D. K., M. W. Brunson, and R. H. Schmidt. 1999. Public attitudes toward wildlife damage management and policy. *Wildlife Society Bulletin* 27:746–758.
- Richardson, K. 2012. Kangaroos and humans today. Pages 195–214 in *Australia’s amazing kangaroos: their conservation, unique biology and coexistence with humans*. CSIRO, Collingwood, Victoria, Australia.
- Robertson, G. G., and B. Gepp. 1982. Capture of kangaroos by ‘stunning’. *Wildlife Research* 9:393–396.
- Robinson, C. J., D. Smyth, and P. J. Whitehead. 2005. Bush tucker, bush pets, and bush threats: cooperative management of feral animals in Australia's Kakadu National Park. *Conservation Biology* 19:1385–1391.

- Robinson, C. J., and P. Whitehead. 2003. Cross-cultural management of pest animal damage: a case study of feral buffalo control in Australia's Kakadu National Park. *Environmental Management* 32:445–458.
- Rowden, P. J., D. A. Steinhardt, and M. C. Sheehan. 2008. Road crashes involving animals in Australia. *Accident Analysis and Prevention* 40:1865–1871.
- Sharp, T., and G. Saunders. 2011. A model for assessing the relative humaneness of pest animal control methods. Second edition. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australian Capital Territory, Australia.
- Short, J., G. Caughley, D. Grice, and B. Brown. 1983. The distribution and abundance of kangaroos in relation to environment in Western Australia. *Wildlife Research* 10:435–451.
- Short, J., J. E. Kinnear, and A. Robley. 2002. Surplus killing by introduced predators in Australia—evidence for ineffective anti-predator adaptations in native prey species? *Biological Conservation* 103:283–301.
- Stewart, C. M., B. Keller, and C. R. Williamson. 2013. Keys to managing a successful archery deer hunt in an urban community: a case study. *Human–Wildlife Interactions* 7:132–139.
- Stoll, R. J., Jr., M. W. McClain, J. C. Clem, and T. Plageman. 1991. Accuracy of helicopter counts of white-tailed deer in western Ohio farmland. *Wildlife Society Bulletin* 19:309–314.
- Stout, R. J., D. J. Decker, B. A. Knuth, J. C. Proud, and D. H. Nelson. 1996. Comparison of three public-involvement approaches for stakeholder input into deer management decisions: a case study. *Wildlife Society Bulletin* 24:312–317.
- Sullivan, T. L., A. F. Williams, T. A. Messmer, L. A. Hellinga, and S. Y. Kyrychenko. 2004. Effectiveness of temporary warning signs in reducing deer–vehicle collisions during mule deer migrations. *Wildlife Society Bulletin* 32:907–915.

Thomas, L. K., and D. N. Jones. 1999. Management options for a human-wildlife conflict:

Australian magpie attacks on humans. *Human Dimensions of Wildlife* 4:93–95.

Tribe, A., J. Hanger, I. J. McDonald, J. Loader, B. J. Nottidge, J. J. McKee, and C. J. C.

Phillips. 2014. A reproductive management program for an urban population of eastern grey kangaroos (*Macropus giganteus*). *Animals* 4:562–582.

Vaarzon-Morel, P. 2010. Changes in Aboriginal perceptions of feral camels and of their impacts and management. *The Rangeland Journal* 32:73–85.

Vos, J. 2001. On the annoyance caused by impulse sounds produced by small, medium-large, and large firearms. *Journal of the Acoustical Society of America* 109:244–253.

Waas, J. R., J. R. Ingram, and L. R. Matthews. 1999. Real-time physiological responses of red deer to translocations. *Journal of Wildlife Management* 63:1152–1162.

Warburton, B. and B. G. Norton. 2009. Towards a knowledge-based ethic for lethal control of nuisance wildlife. *Journal of Wildlife Management* 73:158–164.

Warren, R. J. 2011. Deer overabundance in the USA: recent advances in population control. *Animal Production Science* 51:259–266.

Whisson, D. A., G. J. Holland, and K. Carlyon. 2012. Translocation of overabundant species: implications for translocated individuals. *Journal of Wildlife Management* 76:1661–1669.

Williams, A. F., and J. K. Wells. 2005. Characteristics of vehicle–animal crashes in which vehicle occupants are killed. *Traffic Injury Prevention* 6:56–59.

Wilson, M. and Coulson, G. 2016. Comparative efficacy of levonogestrel and deslorelin contraceptive implants in free-ranging eastern grey kangaroos (*Macropus giganteus*). *Wildlife Research* 43: in press.

Wolf, I. D., and D. B. Croft. 2010. Minimizing disturbance to wildlife by tourists approaching on foot or in a car: a study of kangaroos in the Australian rangelands. *Applied Animal Behaviour Science* 126:75–84.

Zinn, H. C., M. J. Manfredo, J. J. Vaske, and K. Wittmann. 1998. Using normative beliefs to determine the acceptability of wildlife management actions. *Society & Natural Resources* 11:649–662.

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Figure 1. Location of the study site, Thomsons Lake Nature Reserve, southwestern Australia, where subsidized commercial harvesting of western grey kangaroos was performed in 2006–2007. The proximity of the field site to the city of Perth, Western Australia, is displayed (adapted from CALM 2005).

Figure 2. Daytime photograph, taken in April 2005, of the overabundant western grey kangaroo population within Thomsons Lake Nature Reserve, in southwestern Australia, that was subsequently subjected to subsidized commercial harvesting in 2006–2007.

Figure 3. Catch-effort data displaying the number of western grey kangaroos culled across 43 nights of sharpshooting at Thomsons Lake Nature Reserve, southwestern Australia, in 2006–2007. Catch-effort data were used to estimate the population at the start of the culling program (after Leslie and Davis 1939).

Figure 4. Harvest rate (kangaroos shot/hr) of western grey kangaroos subjected to subsidized commercial sharpshooting in each month of a control program at Thomsons Lake Nature Reserve, southwestern Australia, 2006–2007.

Figure 1 .

Figure 2 .

Figure 3 .

Figure 4 .

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