THINKK

THINKK, the think tank for kangaroos, University of Technology Sydney

Advocating kangaroo meat:
towards ecological benefit or plunder?

Authors: Dror Ben-Ami, David Croft, Daniel Ramp and Keely Boom

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Institute for Sustainable Futures

UNIVERSITY OF TECHNOLOGY SYDNEY

THINKK'S MISSION

The mission of THINKK is to foster understanding among Australians about kangaroos in a sustainable landscape, through critically reviewing the scientific evidence underpinning kangaroo management practices and exploring non-lethal management options that are consistent with ecology, animal welfare, human health and ethics.

THINKK SCIENCE AND POLICY

The think tank is governed by a Research Advisory Committee comprising of macropod experts, Dr Dror Ben-Ami and Dr Daniel Ramp, ISF sustainability expert Professor Stuart White and ISF animal and environmental law expert Keely Boom. ISF sustainability expert Louise Boronyak is THINKK's project manager. Expert advisors, macropod expert Dr David Croft, pioneering animal welfare expert Christine Townend and Indigenous elder Uncle Max Dulumunmun Harrison, inform and refine THINKK's research priorities and content.

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ABOUT THE AUTHORS

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Dr David B Croft
David holds a BSc. Honours degree and University medal from the Flinders University in South Australia, and a PhD from the University of Cambridge in England. David commenced research on the behavioural ecology of kangaroos (red kangaroos and euros) at the University of NSW Fowlers Gap arid zone research station in 1976. From then, David taught a popular course in Animal Behaviour and latterly a course about Life in Arid Lands at UNSW while continuing research on various species of macropods in temperate, arid and tropical regions. This research included the studies of a large number of Honours and PhD students under David's supervision and has produced many research papers and several edited books. These document the results of fundamental studies on macropod behaviour and ecology and applied studies of people-wildlife interactions in nature-based tourism and encounters such as wildlife road-kill. David finished his career with UNSW as Director of the Fowlers Gap Research Station while maintaining a teaching/research position in the School of Biological Earth & Environmental Sciences. David now lives on a tropical savanna block in the Top End and continues research and consultation on wildlife issues, and interests in the promotion of wildlife tourism with Australia's diverse kangaroo fauna.

Dr Daniel Ramp
Dr Daniel Ramp has a long interest in conservation, especially in relation to kangaroos. He has a PhD in macropod ecology from the University of Melbourne. His doctoral research examined patterns of kangaroo movement in semi-rural environments. This work was crucial in highlighting the self-regulating properties of temperate populations and implied that management through removal of individuals is both unnecessary and ineffective. Since 2001 Dr Ramp has been based in the School of Biological, Earth & Environmental Science at the University of New South Wales. He is a world expert in the field of road ecology, focussing on the impacts of roads on biodiversity. His current research aims to make critical advances in the science underpinning management of ecosystems with the potential for change, including climate change, fire, invasive species and water regulation. He is currently a Senior Research Fellow in the Australian Wetlands and Rivers Centre at UNSW.

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Keely Boom is a research fellow with THINKK and an animal law and environmental law expert. Keely graduated from the University of Wollongong with a Bachelor of Commerce and Bachelor of Law (Honours). She has a Graduate Diploma in Legal Practice and has been admitted to practice as a lawyer in NSW. Her research focuses on the law and policy governing the killing of kangaroos. Keely was the first intern to be taken on with animal protection institute Voiceless and served as an intern with the legal unit of Greenpeace International in Amsterdam. She is a PhD candidate at the University of Wollongong and is Executive Officer of the Australian Climate Justice Program.

EXECUTIVE SUMMARY

Australian consumers increasingly believe that eating kangaroo meat encourages destocking in the rangelands in favour of more harvesting of kangaroos. The replacement of livestock, particularly sheep, is perceived as a mitigation measure against ecosystem degradation, biodiversity loss, and greenhouse gas (GHG) emissions released by sheep. However, while kangaroo harvesting for meat has been conducted for over 20 years there is no evidence of sheep replacement. This is a significant challenge to the sheep replacement concept and its underlying environmental principles. Key assumptions in replacing sheep with kangaroos as a meat source have had little evaluation. With the advantage of hindsight we examine the four key assumptions and confront them with published scientific evidence to assess their bearing on the sustainability of kangaroo harvesting in Australia. These assumptions are: that (a) increased consumption of kangaroo meat by humans will lead to an increased value of kangaroo meat; (b) increased value in kangaroo meat will lead to sheep replacement; (c) destocking will lead to a sufficient increase in numbers of kangaroos to service demand for red meat currently supplied from sheep; and (d) proper regulatory mechanisms are in place to counter increased market demand for kangaroo products that may result in overexploitation.

Our assessment indicates that interactive forces between kangaroos, sheep, the land-scape and stakeholders are complex and uncertain. Current kangaroo industry meat marketing strategies and ongoing hygiene concerns suggest that an increased consumption by humans is unlikely to lead to an increased value of kangaroo meat for the shooter. Competing stakeholder interests, uncertainty around future kangaroo populations and small property sizes are likely to impede sheep replacement in spite of a hypothetical increase in value. Long-term studies indicate there is minimal competition between livestock and kangaroos. Short and long-term landscape-exclusion assessments suggest that destocking will result in only marginal kangaroo population increases. The number of kangaroos necessary to supplant meat production from sheep (greatly augmented if goats and cattle were also included) for an environmentally meaningful benefit is ecologically unfeasible. Lastly, an increased demand for kangaroo meat and high discount rates associated with uncertainty around kangaroo populations will increase the risk of over-exploitation. This will require the maintenance of stringent regulatory mechanisms which are mostly untested due to historically underutilised quotas.

The establishment of functioning rangelands in Australia remains an ecological and social imperative, yet the expectation of a panacea of reduced total grazing pressure and GHG abatement from kangaroo meat does not match the scientific evidence. Better outcomes for Australia's economic and sustainable future may be better achieved via a long-term decline in sheep numbers coupled with value driven non-consumptive mechanisms such eco-tourism, carbon crediting and improved livestock management.

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INTRODUCTION

The consumption of wild kangaroo meat (principally from four species – the Red Kangaroo *Macropus rufus* the Eastern Grey Kangaroo *M. giganteus*, the Western Grey Kangaroo *M. fuliginosus* and the Common Wallaroo *M. robustus*) has gained increasing acceptance in Australia. Long-term trends indicate increased production for human consumption and decreased pet meat production (Ampt and Owens 2008; ABARE 2010), while the international market has grown (albeit with a recent decline) (Kelly 2005; ABARE 2010). There are two primary motivations for eating kangaroo meat: (a) because they are a resource to be exploited; and (b) to enable a reduction in reliance on sheep and cattle which both incur substantial environmental damage. A common viewpoint is that "if it is there, use it", from which exploitation of the natural environment is justified. Concurrently, knowledge of the environmental impacts caused by livestock grazing has encouraged many to explore viable solutions to reduce those impacts while maintaining farming traditions and livelihoods. Eating kangaroo meat is promoted as pro-active environmental activity, where increased demand for kangaroo meat will encourage graziers to destock sheep on the basis of equal or better returns (Australian Conservation Foundation 1967; Grigg 1987). If it were possible and sustainable, the replacement of sheep may have the potential to bring forth a number of environmental benefits.

Sheep have become an integral part of the Australian landscape since European settlement. Today there are some 73 million sheep (Pink 2010), the lowest number since 1905 (Australian Bureau of Statistics 2010). Variable and cyclically low rainfall, increased meat prices, low wool prices, and increased crop prices have encouraged large-scale destocking (Nicholls 2009). Not only do sheep erode soils with their cloven hoofs that break protective cryptogamic soil crusts which leads to sheet erosion and the formation of a hard pan (Freudenberger et al. 1997), but their heavy grazing pressure also removes vegetation and contributes substantially to biodiversity loss in the semi-arid rangelands of Australia (Fisher et al. 2003).

Emerging awareness about climate change has drawn attention to various anthropogenic-related sources of greenhouse gasses that can be mitigated. Burping sheep and cattle contribute 11% of Australia's greenhouse gas (GHG) emissions (National Greenhouse Gas Inventory 2005). It has been postulated that replacement of livestock with kangaroos as a source of meat (as kangaroos produce little GHG; e.g. Klieve (2009: 56)) might facilitate a reduction in Australia's GHG emissions (Wilson and Edwards 2008), although the numbers of kangaroos needed to be annually harvested to achieve this are vastly in excess of current total population size. As noted in the Garnaut Climate Change Review (Garnaut 2007), any reduction in livestock grazing would assist with achieving national targets for GHG emission reductions. There is also active research to retain livestock and reduce the methanogensis in the gut and so their production of GHG (Klieve 2009).

The "kangaroo industry", which represents the promotion and management of kangaroo harvesting, has had a long and varied history in Australia (Grigg 2002; Lunney 2010). In many respects, the industry has evolved from conflict between graziers and kangaroos. Historically, graziers have perceived kangaroos as competitors to sheep for resources (primarily food). Conjecture surrounds the abundance of kangaroos in the rangelands, with contrasting views on whether the installation of artificial watering holes and improved pasture for livestock grazing have resulted in increases in kangaroo populations. Considerable scientific research has been conducted to address pervasive perceptions of overabundance. Concern for losses in revenue due to perceived competition between kangaroos and sheep for resources has been used to justify large-scale culling of kangaroos, including the offering of bounties (Lunney 2010). By the 1960s widespread killing led to concern for the persistence of kangaroo populations and resulted in the regulation of culling and the harvest of meat and skins by state/territory authorities. On the back of the perceived need to manage kangaroo populations, acceptance of the use of kangaroo meat for pet food and later human consumption has promoted wide acceptance of the harvest of meat and skins in a commercial kangaroo industry on environmental and economic grounds.

Acceptance of the perceived environmental benefits of the commercial kangaroo harvesting has increased over time. Growing awareness of the damage caused by sheep and the mainstream acceptance of kangaroo culling have led to the concept of sheep replacement by kangaroos in the semi-arid zones for the betterment of the environment (Australian Conservation Foundation 1967; Grigg 1987). Energy and water requirements of the average kangaroo is a third or less than that of the average sheep, reinforcing the concept of the kangaroo's light ecological footprint (Grigg 2002; Munn et al. 2008). The conservation through sustainable use of wildlife concept has also been used to argue for the commercial kangaroo harvesting (Archer 2002; Grigg 2002; Ampt and Baumber 2006). More recently, the knowledge that kangaroos emit a fraction of the GHG of livestock has added another positive dimension to the sheep replacement concept (Wilson and Edwards 2008). Media uptake of the perceived environmental benefits and targeted promotion of the green credentials of the kangaroo industry have resulted in an increased human consumption of kangaroo meat in Australia for environmental reasons.

Over 20 years have transpired since the concept of sheep replacement by kangaroos has been a strategy to be pursued for the betterment of the environment. However, to date, no sheep replacement has occurred (Chapman 2003; Ampt and Baumber 2006; Thomsen and Davies 2007; Cooney et al. 2009). In fact, during the period 1990-2007, when sheep numbers decreased dramatically due to market forces (Nicholls 2009; Pink 2010) and the market for kangaroo meat for human consumption increased (Australian Bureau of Statistics 2010), kangaroo numbers declined across Australia (Russel 2008). Thus, if sheep replacement was a reliable environmental and economic concept, then destocking should have resulted in kangaroo population increases. The reality of ecological, environmental and economic arguments that underpin the promotion and acceptance of the kangaroo industry requires proper evaluation.

Whether eating kangaroo meat is a proactive environmental action depends on whether sheep can be replaced by kangaroos as a primary source of income to graziers. Is replacement a plausible reality or is it a false hope utilised to legitimise the kangaroo industry both to the public and the international ecological community that consider utilisation of wildlife to be appropriate where it supports conservation (Grigg 2002; Lunney 2010). In the following exposé, the benefits claimed from the sheep replacement concept are confronted by the collected scientific knowledge on kangaroos, and the economic necessities that would allow for continued 'farming' in the rangelands for meat production without sheep (or at least a reduced reliance on sheep) are discussed. This is achieved by examining what we perceive as the four key assumptions that underpin the sheep replacement concept and the eating of kangaroo meat on environmental grounds: (a) that an increased consumption of kangaroo meat by humans will lead to an increased value of kangaroo meat; (b) that an increased value in kangaroo meat will lead to sheep replacement; (c) that destocking will lead to a sufficient increase in numbers of kangaroos to service demand for red meat currently supplied from sheep; and (d) that the proper regulatory mechanisms are in place to counter an increased market demand for kangaroo products.

Assumption 1:

Will increased consumption of kangaroo meat by humans lead to an increased economic value of kangaroo meat?

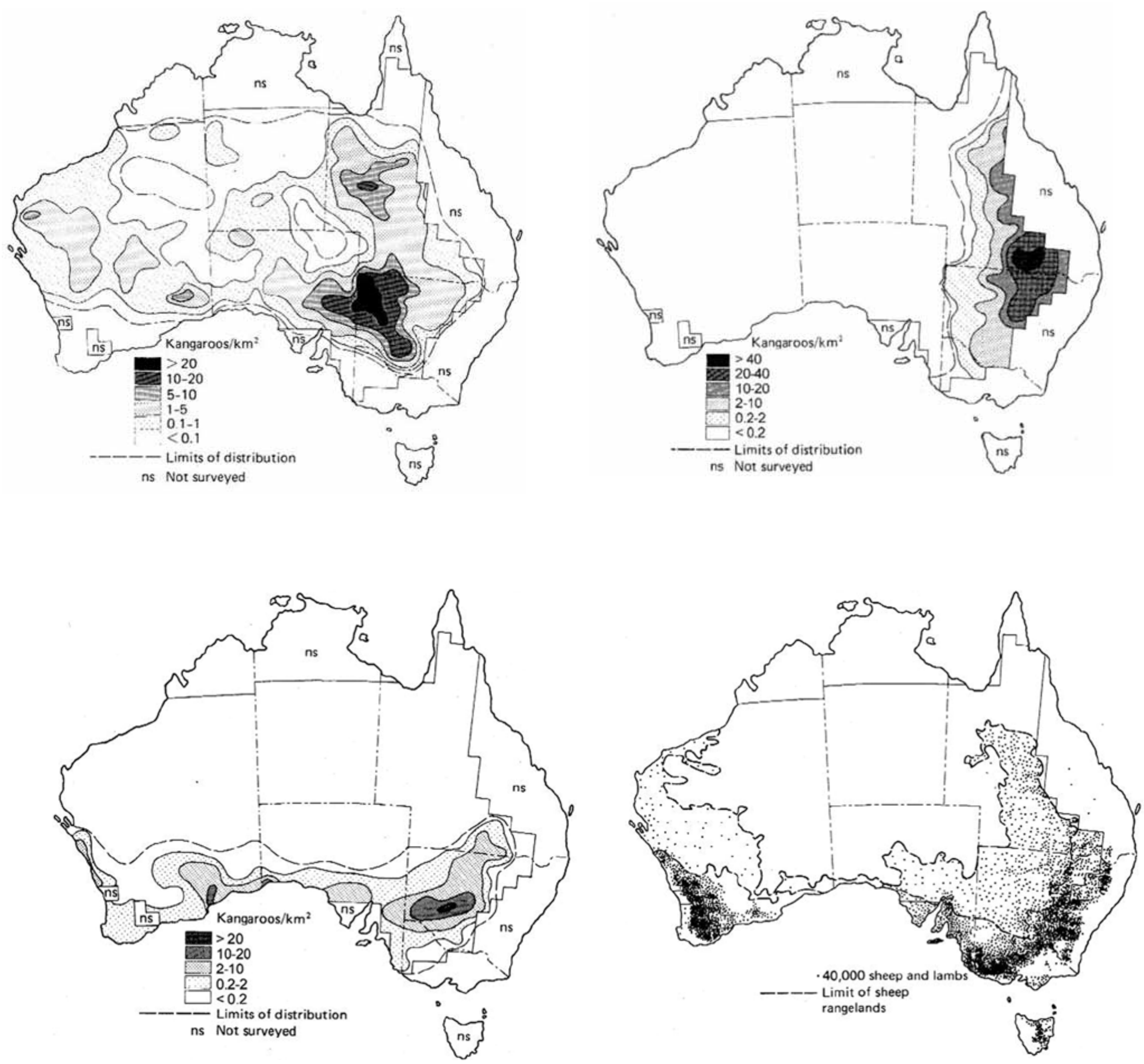

Figure 1. Density and distribution of (a) Red Kangaroos, (b) Eastern Grey Kangaroos, (c) Western Grey Kangaroos, determined from aerial surveys over 1980-82 and (d) sheep. Ground surveys of much of the eastern part of the Eastern Grey Kangaroo range over 1987-92 estimated a density of 10 kangaroos/km^2. Reproduced from Grigg (2002).

Central to the 'environmentally driven' theme of sheep replacement is the need to conserve and restore the ecological integrity and function of Australia's rangelands where the highest densities of kangaroos and sheep occur in the chenopod-dominated landscapes in the interior of South Eastern Australia (Grigg 1987; Fig 1). If the economic value of kangaroo products were to increase, Grigg has argued that graziers would be able to decrease total grazing pressure by destocking sheep and maintaining commercial return through the harvesting of kangaroos, either directly or through royalties from shooters (Grigg 1987; Grigg 1989). For this to happen there need to be financial benefits for graziers (replacing income from wool as well as meat), graziers would need to overcome negative perceptions associated with having free-ranging kangaroos roaming their properties, and increased human consumption of kangaroo meat would need to occur (Grigg 2002; Baumber et al. 2009). Currently, 60 - 80% of kangaroo meat is low value meat sold for pet food. Hence, given current harvesting rates, improved meat processing to produce high value kangaroo meat for human consumption is possible (Grigg 2002). Furthermore, this kangaroo meat would have to be produced from a lower total metabolically active biomass than that of sheep for total grazing pressure to actually be reduced.

The 'sheep-replacement' or 'going native' view side-steps a number of important issues which will be mentioned here and discussed later. First, recent long-term studies indicate that there is only minimal competition between sheep and kangaroos (Dawson and Ellis 1994; Edwards et al. 1996; McLeod 1996; Pople and McLeod 2000; Grigg 2002; Witte 2002; Jonzen et al. 2005), which for a marginal industry (Australian Natural Resource Atlas 2002) could lead to an additional rather than a replacement income source. If the lack of competition is accepted then kangaroos will be exploited as supplemental not replacement income in livestock industries. Second, experience around the world suggests that for wild-harvested species, over-exploitation is a strong possibility if prices are sufficient and regulation is not tightly managed (Fryxell et al. 2010). If the price of kangaroo meat increases to such a value as necessary for graziers to become shooters or benefit from royalties then the risks of overharvesting on remote properties may exceed precautionary levels (McCallum 1995). Third, the existing regulatory mechanisms have not been truly tested because harvest quotas, set by an annual state mechanism, have not been reached for kangaroos (summed over four species) (see DSEPC 2010). However, quotas for individual species in some states have been exceeded: for example, western grey kangaroos in Western Australia in 2002 (102% of quota killed) and 2003 (118% of quota killed); Red Kangaroos in NSW in 1985 (112% of quota killed) and 1996 (105% of quota killed). Grigg (1995) claims the primary cause of under-utilisation is the low product value per effort required to find kangaroos in remote locations. In support of the latter part of his argument, quotas are more likely filled in the more-populated 'inside' country closer to large markets (Hacker et al. 2004). Complete faith is given to the quota-setting process and the notion that the quota is not met because there are insufficient kangaroos in not canvassed. Regulations may be inadequate or weakened by political pressure to fulfil demand for a higher value kangaroo product unless proper enforcement and endorsement is in place.

Ecological benefit for the rangelands calls for the alignment of the commercial strategy of the kangaroo industry with the goals underpinning the environmental concept. Commentators have noted that the kangaroo industry's growth strategy cannot let the economic value of kangaroo meat decline, as a low value will hinder the sheep replacement concept (Grigg 2002). The market for kangaroo meat for human consumption has increased both locally and internationally in recent years. Whilst the value of exported kangaroo meat has increased somewhat, this growth has not materialised in the form of an increased value of kangaroo meat for shooters. In fact, returns to shooters over the past decade have been variable, ranging from 80 - 150 cents per kg (Thomsen and Davies 2007; Ampt and Baumber 2010). For comparison, November 2010 prices for mutton, heavy lamb and trade lamb were 356, 458, 473 cents per kg (http://www.mla.com.au/Prices-and-markets). The variability and low value of kangaroo meat are a consequence of new markets being established for low-grade kangaroo meat products (e.g. for mince and sausages) that compete in price with similar beef products (Ampt and Baumber 2006; 2010). The kangaroo industry is constrained by the low quality meat that is derived from the older and larger kangaroos (Ampt and Baumber 2010) as younger kangaroos cannot be harvested without reducing yield in the long term (Hacker *et al.* 2004) and also provide lower returns to shooters per unit taken. While a market path of underpricing beef presumably represents the one of least effort and maximal returns for wholesale distributors of kangaroo products, it also diminishes the possibility of graziers' commercial involvement in the industry.

Guaranteeing product quality remains a challenge for the kangaroo industry (Ampt and Baumber 2006; 2010). Recent concerns about hygiene resulted in the cancelling of some international markets. High levels of *E. coli* bacteria, salmonella and other pathogens and a concern about the kangaroo meat production process have led to import bans by Russia, which comprised 70% of the market for high-value kangaroo meat sold for human consumption. Issues impacting hygiene are the lack of auditing at the point of kill where the kangaroo carcass is eviscerated, the long transport time without refrigeration from the point of kill to the chiller (remote meat holding facilities), the exposure of the eviscerated carcasses' internal organs to dust during transport to the chillers, insufficient hygiene auditing of chillers and insufficient auditing of carcasses at the meat processing facilities (Ben-Ami 2009). Maintaining product quality through reduced transport time to chillers was considered as key to increasing the value of kangaroo meat in the recently modelled best case scenarios for the uptake of kangaroo harvesting by graziers (Ampt and Baumber 2010).

In conclusion, increased consumption does not guarantee the increased value of kangaroo meat. The kangaroo industry must refrain from short term gains in selling kangaroo meat as a cheap replacement to beef. Second, the hygiene issues need to be resolved for kangaroo meat to truly market itself as quality meat. This process will incorporate a cost for the industry. For example, open bed utility vehicles used for transporting eviscerated carcasses may need to be replaced by vehicles with protective refrigerated storage. Industry transparency, particularly on returns to shooters and meat exports is vital for a monitoring of whether commercial interests are aligned with the environmental interests. Current industry references for returns to harvesters (Thomsen and Davies 2007; Ampt and Baumber 2010) and industry statistics (see above) are only available upon interview of stakeholders or specific request from ABARE, and so are not part of ongoing, publicly published statistics like those provided by Meat and Livestock Australia for other red meats. Further research should incorporate the costs of a product upgrade, the optimal pricing of kangaroo meat to increase returns to shooters and an assessment of profit sharing to meat distributors, meat processors and the shooters, into a financial modelling of the relationship between consumption and the commercial value of kangaroo meat.

Assumption 2:

Will an increased value in kangaroo meat lead to sheep replacement?

For graziers to replace income from sheep products with kangaroo products requires the promise of improved returns, particularly since the grazing industry is marginal in terms of per capita income (Australian Natural Resource Atlas 2002; Pink 2010). Altruistic purposes are unlikely to create change unless reciprocated by a subsidy (e.g. environmental benefit payment). The replication of farming models that are currently employed in Africa, where the utilisation of domestic and wildlife products are integrated, would likely have the most commercial profitability and sustainability (Croft 2000; Cooney et al. 2009). However, the free-ranging and roaming nature of kangaroos combined with the extremely high cost of the construction and maintenance of confining fencing, would necessitate the establishment of cooperatives of properties encompassing the kangaroos' range of movement (McCallum 1995; Croft 2000; Cooney et al. 2009). The utility of the kangaroo harvesting cooperative concept has recently been trialled in an ongoing field study conducted in the Barrier Ranges of north-western New South Wales (Baumber et al. 2009; Ampt and Baumber 2010). Findings have been mixed, as the mechanisms behind a cooperative model are complex and require the integration and change of current practices by a number of stakeholder groups (Baumber et al. 2009; Ampt and Baumber 2010).

Business case modelling has indicated that the most suitable cooperative model is one where landholders hire shooters, providing the highest and most consistent potential increase in economic return for landholders that could further sheep replacement efforts (Baumber et al. 2009; Ampt and Baumber 2010). Other cooperative models where graziers become shooters or where cooperatives are allowed to process and sell their own kangaroo products increase operational costs even more, diminishing profit margins, and would be strongly opposed by industry stakeholders (Ampt and Baumber 2010). Current kangaroo shooting is difficult for graziers to do as harvesting at night time is prohibitive, resulting in a strong preference for augmenting income by harvesting feral goats instead, since they are active during the day (Chapman 2003) and amenable to the same handling procedures as sheep. In South Australia, where landholders receive royalties from harvesters, harvester numbers are declining because of the low returns after royalties (Thomsen and Davies 2007).

The modelling of a mixed sheep and kangaroo harvesting cooperative is also informative in terms of the economic likelihood of sheep replacement (Ampt and Baumber 2010). The modelled scenarios included assumptions of a destocked conservation area equal to 23% of each member property in which kangaroos were assumed to increase by up to 300% (based on Norbury and Norbury 1993). The mean annual returns per property in the cooperative, under the most profitable scenario where graziers hire shooters, were $1250 and $2707 relative to a zero and three-fold increases in kangaroo numbers. These results, which incorporated carbon credits of $23 per tonne of CO_2 emissions avoided, a stewardship payment of $20,000 annually to manage 8,495 hectares as a conservation area (23% of property) and a NSW Western Lands Lease Rebate of $0.30/ha/annum, do not seem to account for the loss of projected income incurred by destocking. The noticeably low income expected from kangaroo harvesting is highlighted further in a bio-economic model of Fowlers Gap, a university run (for research) sheep station, where annual returns were readily available. Modelled kangaroo harvesting returns accounted for only 1.4% of the conservation area's income compared to 20% and 60% for hypothetical carbon credits and stewardship payments (see monetary values above).

The profitability of the industry will always have a close relationship with environmental and climatic conditions, and hence the concept of long-term sheep replacement must be examined within this context. Kangaroo populations in the rangelands decline dramatically during drought, while the recovery from drought-induced decline is prolonged when it is concurrent with a commercial harvest (Shepherd 1983). Modelling by Baumber et al. (2009) indicates that revenue loss due to variability in kangaroo populations may be offset by lower investment costs compared to livestock. However, practices used for domestic livestock, such as agistment or sale/restocking, are not viable or feasible for kangaroos. As witnessed in fisheries around the world, the risk of over-exploitation in times of natural

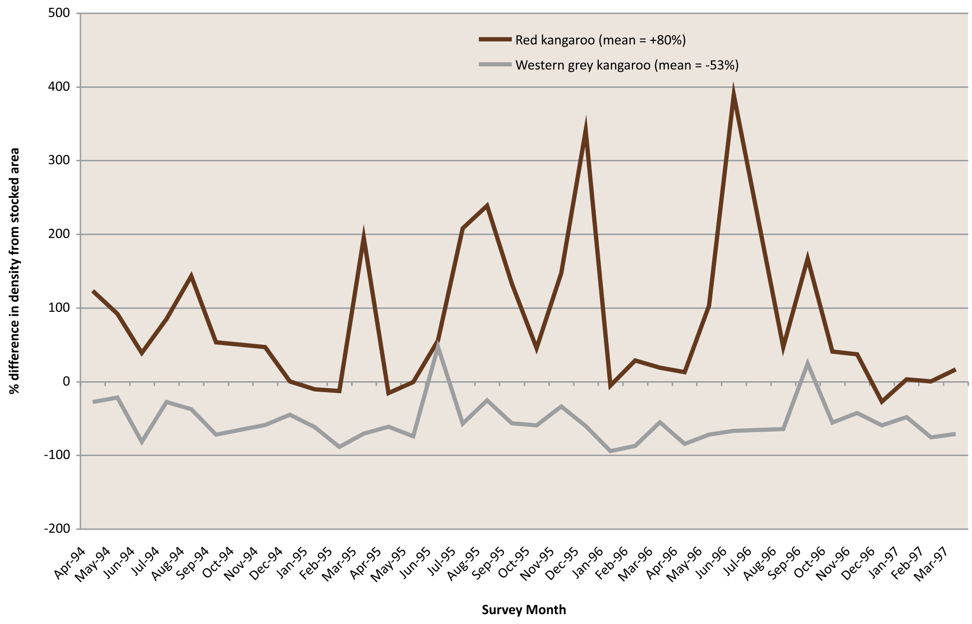

Figure 2. Percentage difference in Red and Western Grey Kangaroos densities between contiguous unstocked (920 ha) and stocked (1238 ha) paddocks on Fowlers Gap Station. Surveys were conducted monthly by ground-based line transect methods. Paddocks destocked for a minimum of 10 years (data from Witte 2002).

population decline can be high. It has been suggested that commercial pressure for harvesting of kangaroos during and after drought may lead to localised population collapses (McCallum 1995). Calls for caution on sheep replacement because of the large natural fluctuations in kangaroo populations in response to environmental and climatic conditions date back nearly three decades (Shepherd 1983) and were reinforced again by Tyndale-Biscoe (2005).

Other model assumptions raise concern about projected returns. A 300% increase in kangaroo populations following destocking is said to be conservative but is based on a short-term study in Western Australia using dung deposition as a proxy for kangaroo abundance (Norbury and Norbury 1993) or a potential to increase if the kangaroo population grew to exploit all the forage unconsumed after destocking. A 300% increase is in fact an exaggeration where long-term data from far western NSW (including Fowlers Gap) is used (Fig 2). These data show an average difference of + 80% for the more abundant Red Kangaroo and -53% for the western grey kangaroo over three years. Thus kangaroo species do not react equally to access to destocked landscapes. Furthermore there was considerable local scale movement for Red Kangaroos with large transient increases and decreases leading to a few months when their density in stocked paddocks exceeded those in unstocked ones.

At a much larger scale (330,000 ha), Sturt National Park was destocked in the early 1970s and there was a large population increase in Red Kangaroos and other species on the back of exceptionally high rainfall in that decade. It has often been assumed that these high densities persist but an aerial survey in the 1980s (unpublished but reported in the 1996 State of the Environment report (Taylor 1996)) show a substantial decrease in the kangaroo population. Croft *et al*. (2007) compared Red Kangaroo densities estimated by line transect counts in the vicinity of watering points on Sturt National Park and that estimated by aerial survey of the Tibooburra management block and found the latter generally higher. The aerial survey lines minimally overfly Sturt National Park (Dan Hough, personal comment) and so the density for the Tibooburra block best represents stocked areas.

When considering sheep replacement a grazier will have to assess the loss incurred due to destocking relative to benefits gained from destocking and kangaroo harvesting. Experience with the Enterprise Based Conservation scheme in far-western NSW is that it is the marginal sheep/wool production areas of properties that are normally set aside for conservation (the Sturts Meadows and Fowlers Gap areas). Hence, these landscapes are unlikely to support significant kangaroo population increases since they are relatively unproductive and have historically been lightly stocked. Moreover, current evidence indicates a high degree of uncertainty around localised kangaroo populations, due both to population fluctuations in response to environmental conditions and movement across the landscape. The somewhat over enthusiastic assumptions used in the commercial modelling of cooperative scenarios yield low returns, if at all, from harvesting of kangaroos; the only certainty comes from the various land conservation rebates. This is reflected in another theoretical model of a completely destocked property with kangaroo harvesting only. Surely, the pastoral industry will head down the path of irrelevance as it would be more economical in the long term for government to simply resume graziers' land leases. Perhaps the primary issue not considered in the cooperative scenarios is the issue of scale. Individual properties are simply too small to enable meaningful returns from kangaroo harvesting (as profits in the cooperative are still divided), which is why a fully professional shooter will have agreement with multiple properties to ensure a moderate income.

Assumption 3:

Will destocking lead to a sufficient increase in numbers of kangaroos to service demand for red meat currently supplied from sheep?

If sheep replacement were possible then benefits to Australia's effort to combat global climate change could accrue. This is because burping sheep and cattle contribute 11% of Australia's GHG emissions (National Greenhouse Gas Inventory 2005) while kangaroos are postulated to have only marginal emissions due to limited methanogensis in the gut (Kempton et al. 1976). To examine the validity of this concept it is necessary to quantify and contrast meat production from sheep and kangaroos and whether increased consumer demand for kangaroo meat could assist GHG reduction targets. By industry estimates there are 1.5 kg of quality meat per carcass (Kelly 2005) that constitute prime cuts from an average 12 kg dressed carcass (Hardman 1996; Hacker et al. 2004). Thus most of the meat is not premium grade and of low value for human consumption. Unlike domesticated livestock kangaroos have not been selectively bred for meat production (or dual purpose meat and wool production). As a result only loin fillet is of consistent quality in terms of tenderness, but other large cuts from older (larger) animals are tougher and therefore not sold for human consumption (Ampt and Baumber 2010). In contrast, the mean amount of quality meat per sheep and cattle carcasses are estimated to be 33 kg and 274 kg (Wilson and Edwards 2008). Thus under current practices to replace one sheep for the human consumption market, some 22 adult kangaroos need to be harvested if only prime cuts are used (the rest diverted to pet food) or around three adult kangaroos if all the meat found acceptance as a replacement for sheep meat. Evidence of declining abundance of large adult kangaroos due to shooters targeting larger individuals first (Pople 1996; Pople et al. 2010) has the potential to further reduce meat production as the harvesting of younger animals would not be consistent with a maximum sustainable yield (Hacker et al. 2004). Regardless of the uncertainty surrounding these figures, it is clear that many more kangaroos need to be harvested to replace meat from sheep. It should also be noted that kangaroos do not yield an equivalent product to wool. Yet natural fibres like wool are promoted as being 'greener' than petroleum-based fibres like nylon.

So how many kangaroos are there to harvest? The 30 year average of the estimated numbers (from aerial surveys) of the four harvestable kangaroo species is around 27 million. To ensure continuing populations, harvest quotas are set by state governments that are implemented to prevent over-exploitation based on modelling of the maximum sustainable yield (MSY). A species-dependent MSY of between 15% and 20% of the estimated population in the previous year is used to calculate the quota for the following year, and is governed by precautionary statistics (risk analysis and harvest statistics) and prevailing ecological relationships. Although conservative and thus far proven to be sustainable, it is not fail-proof (e.g. until the NSW Kangaroo Management Plan was challenged in the Administrative Appeals Tribunal in 2007, there was no minimum species abundance below which harvesting ceased) and should not engender complacency (e.g. the plans seemed to assume that harvesting of very low populations would presumably cease because it would be uneconomic). The annual quota, which is set independently for each kangaroo management zone (see DSEPC 2010), is frequently not reached by shooters. The reasons for this are complex and not just driven by consumer demand (Ampt and Baumber 2010). Over the last decade, approximately 34.5 million kangaroos were harvested in Australia (see DSEPC 2010). If limitations in harvesting were overcome, then the quota of about 54 million could have been harvested (although increased takes per year would likely result in lower sum total to the extent that harvesting reduces population size).

For every Australian (currently around 21 million people) to eat one portion (0.25 kg) of kangaroo meat per week at the conservative upper estimate of a yield of 12 kg of acceptable meat per carcass, a total of 437,500 kangaroos would need to be harvested per week, or just over 22 million per year. Assuming an average take of 15% (within a 15-20% quota), the total population of kangaroos in Australia would need to be around 151 million to support this offtake. This is about 5.6 times the 30-year average of 27 million. In contrast, sheep carcasses yield around 68% quality meat from the 49 kg average dressed weight (Hopwood et al. 1976), meaning that one 0.25 kg portion per week requires just over eight million to be slaughtered annually.

An analysis of the feasibility of replacing sheep and cattle with kangaroos to reduce greenhouse gas emissions was undertaken by Wilson and Edwards

(2008). They argued that an equivalent amount of meat could be produced by replacing 93% of cattle and sheep in the rangelands with 175 million kangaroos. Controversy around the amount of consumable kangaroo meat produced marred the study (see Russel 2008; Wilson and Edwards 2008), as the authors assumed that each kangaroo provided three times the relatively optimistic yield (compared to the kangaroo industry's estimate) proffered by ecological modellers (Hardman 1996; Hacker et al. 2004). As stated earlier the industry value for kangaroo meat for human consumption is 1.5 kg. If the modeller's value of 12 kg per carcass is assumed, then 100 million rather than 36 million kangaroos would need to be harvested annually to produce the 1.2 million tonnes of red meat required in Wilson and Edwards' GHG reduction scenario. This would necessitate over 660 million kangaroos in the landscape.

One of the primary concerns of the sheep replacement concept is the potential environmental benefit that would accrue from removing livestock from the rangelands. There is no doubt that reducing livestock numbers would have this benefit, as there is also little doubt that kangaroos have a smaller per capita ecological footprint based on the comparative unit, the Dry Sheep Equivalent, used in livestock management in Australia (Munn et al. 2010). However, at no time in Australia's history that we know of have the four large kangaroo species in the current mainland commercial industry existed in the numbers being speculated to be necessary to replace sheep and cattle with kangaroo meat. At best a minor increase in production could be achieved if the species were expanded to include the larger wallabies (e.g. meat from Tasmania and Kangaroo Island in SA), the territories and Victoria opened commercial markets (currently rejected in their KMPs because of low and uneconomic kangaroo populations in the NT and VIC and high density living in the ACT), and the export market ceased in order to supply only a domestic one. Rightly or wrongly, kangaroos are currently 'culled' to reduce their perceived excessive grazing pressure in all of Australia. If kangaroo numbers increased substantially in response to consumer demand and grazier destocking of sheep, then there must be some review and scientific analysis regarding whether this level of kangaroo density will negatively or positively impact on the land and biodiversity.

These discussions assume that an increase in kangaroo numbers to the required levels is actually plausible. There are two primary mechanisms by which current populations of kangaroos may be being suppressed, such that removal of sheep would lead to their increase. These are competition for resources and landscape exclusion. Much is made of the competition between kangaroos and sheep, although the scientific evidence from long-term studies suggests that the emphasis on competition is misplaced. Where chenopod shrubs are retained under conservative stocking regimes, Red Kangaroos and sheep exploit different food niches (Dawson and Ellis 1994; Dawson 1995). There is little evidence of competition beyond very low pasture biomass (Shepherd 1987; Edwards et al. 1996; McLeod 1996); while long-term studies indicate that competition is intermittent, occurring only during a period of climatically driven food depletion (Dawson and Ellis 1994; Edwards et al. 1996; McLeod 1996). The presence of kangaroos has been reported to have no negative impact on the number of lambs born to the flock, their body size or growth rate (McLeod 1996), and wool production was unaffected by kangaroos (Edwards et al. 1996; Grigg 2002). When competition occurred it was reciprocal and sheep lost condition and kangaroos shifted away from sheep but did not lose significant condition. Therefore, destocking is unlikely to result in substantial increases in kangaroo numbers. Exclusion from resources is another competitive interaction (Dawson and Ellis 1994) that may be argued as contributing to the suppression of kangaroo numbers. However, as described earlier it seems probable that large-scale destocking will lead to a marginal increase in kangaroo densities in the short term, but in the long term kangaroo numbers are likely to remain unchanged.

Those arguing that replacing kangaroos with sheep is a simple mathematical equation based on how much food they eat (Dry Sheep Equivalents) (e.g. Wilson and Edwards 2008) appear to be ignoring the complexities of environmental constraints that may govern kangaroo populations. More research is needed to properly identify whether replacement can occur and on what spatial and temporal scale. Whether kangaroo populations could increase to sufficient levels to be enough for a meaningful reduction of GHG emissions is questionable. Fine-scale details need to be addressed, such as under what condition and what proportion of the stock needs to be removed to mitigate for competitive exclusion of kangaroos by livestock.

Assumption 4:

Are the proper regulatory mechanisms in place to counter an increased market demand for kangaroo products?

Increasing the economic value of kangaroo carcasses is frequently proposed as the optimal strategy to facilitate sheep replacement. However, the push for a profitable return has led to the over-exploitation and collapse of wildlife populations historically in Australia (e.g. koala skin trade) and elsewhere (e.g. American bison, rhinoceros species), with similar suggestions of a risk of localised population collapse with kangaroos (McCallum 1995). There are two competing harvesting scenarios that have different implications for how market forces will likely impact on kangaroo populations. The currently employed scenario is open access harvesting, where kangaroos do not belong to a single owner. Depending on the cost of harvesting and the market price for meat and secondary products, kangaroos may be either under- or over-exploited. As the resource value increases so too will the risk of over-exploitation as shooters will be more motivated to search for kangaroos, leading to a "Tragedy of Commons" (Harding 1968). To prevent this, an increase in human consumption and product value must be linked to a strong regulatory mechanism that adequately protects against quasi-cyclic fluctuations in populations in response to environmental and high climatic variability.

An alternative harvesting scenario is to allow for private ownership of kangaroos through a common property system (McCallum 1995; Croft 2000; Cooney et al. 2009). This system is recognised as providing the most certainty in harvesting returns to graziers (Croft 2000; Cooney et al. 2009). The sole ownership model calls for the owner to harvest slightly below the maximum sustainable yield, dependent upon having certainty about the location and growth of next year's population (Clark 1976). There are a number of caveats to this that must be considered: (1) bio-economic modelling of other wildlife has shown that extinctions are possible under sole ownership, for both whales (Clark 1973; Clark and Munro 1978) and elephants (Caughley 1993); (2) a closed kangaroo population is unlikely on a given property or cooperative; and (3) kangaroo population dynamics are governed by stochastic, not deterministic, forces.

Over-exploitation or extinctions may occur when the discount rate (the value of the product-in-hand as opposed to in the paddock) is greater than the harvested population's intrinsic growth rate (Clark 1976 in McCallum). At such a point it is better to have a profit now than to wait for it, thus future profits need to be 'discounted' relative to present ones. McCallum (1995) asserts that the best estimate for the intrinsic growth rate (r) for Red Kangaroos lies within the range of $0.12<r<0.3$ (Caughley 1987). These values should be treated with caution because they are an average of positive growth rates and do not reflect year to year occurrences of no population growth or declining kangaroo populations which occur frequently in response to environmental conditions (Fig 3). Modelling indicates that the maximum sustainable yield occurs at double the intrinsic growth rates; therefore over-exploitation would be likely under a sole ownership model at discount rates of at least 25%. A nominal discount rate for a grazier could be at least 5% (under current market conditions) with money in the bank; corporations generally have a nominal discount rate after inflation of 10%. When considering increased interest rates and other pressures such as loan repayment, foreclosure and uncertainty about next year's population, the discount rate could easily increase to such levels that make over-exploitation likely.

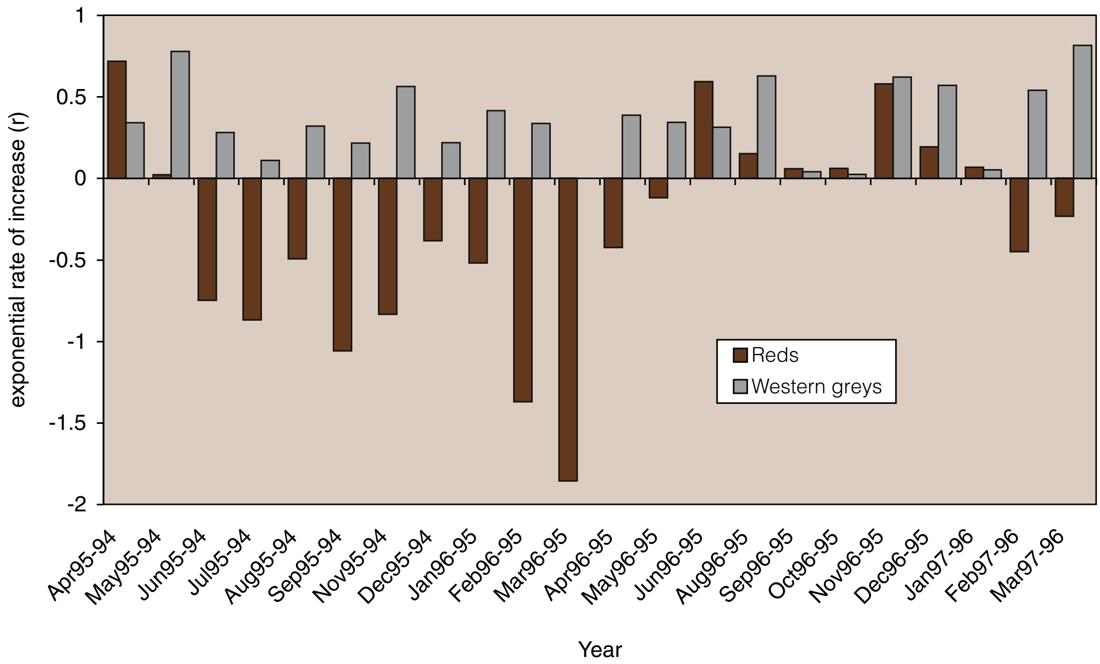

Figure 3. Monthly variation in annual rate of increase of a Red and Western Grey Kangaroo populations in a 2158 ha area of Fowlers Gap Station, NSW (data from Witte 2002).

Uncertainty about next year's population stem from drought episodes that result in kangaroo population declines at both local and regional scales (Bayliss 1985). Where modelling studies have been conducted, the impact of drought and the high unpredictability of rainfall in the arid environment of the rangelands has highlighted the fragility of kangaroo populations and the risk that harvesting might contribute to potential population collapse (McCarthy et al. 1996; Pople 2004; 2008; Jonzen et al. 2010), adding to the aforementioned discount rate (McCallum 1995). That is, increased uncertainty about next year's returns from the kangaroo population increases the population's value in the present to secure returns in a different way. Therefore, stringent regulatory mechanisms are required to prevent discount rate consideration resulting in over-exploitation.

If the sole ownership concept were to be assessed in terms of known grazier practices then McCallum (1995: 221) states:

> "there is no doubt that, in some circumstances, economic forces drive Australian graziers to exploit their land, a privately owned resource, in an unsustainable manner. The chronic overexploitation and extent of land degradation in the semi arid region (Castles 1992) are direct evidence of this. Effectively high interest costs increase graziers' discount rates and lead them into …overexploitation of the land. Might identical considerations apply to wildlife on that land?"

Industry advocates argue that the kangaroo industry is well regulated (Grigg 2002; Lunney 2010; Pople et al. 2010). However, current regulatory systems are untested due to historic and current under-utilisation of harvest quotas (see http://www.environment.gov.au/biodiversity/trade-use/wild-harvest/kangaroo/stats.html). Can they function adequately under the pressure of increased market demand? In a recent ruling an Administrative Appeals Tribunal concluded that the NSW Kangaroo Management Programme must adopt trigger points for the cessation of harvesting because the densities of some harvested species were of concern (AAT 2008). This counters the view by industry proponents that conservation outcomes through increased pastoralist involvement may be improved through more relaxed regulation (Thomsen and Davies 2007; Baumber et al. 2009). Although localised examples exist of closures of harvesting zones where the decline of kangaroo populations became a concern, trigger points have not so far been instituted outside of NSW.

Other issues of concern in the current regulatory framework include rapid declines of kangaroo populations during drought (Pople 2004), the impacts of selective harvesting on genetic diversity (Croft 2000; Croft 2005; Carlson et al. 2007; Sasaki et al. 2009) (addressed by Hale (2004) and Tenhumbeg *et al.* (2004)) and demographic composition within populations (Fryxell et al. 2010), and the reliance of migration to repopulate over-harvested zones (Pople pers. comm. in Grigg G (2002)). Population collapses in wild-harvested fisheries have been linked to quasi-cyclic fluctuations in environmental conditions that are difficult to regulate (Mora et al. 2009; Worm et al. 2009; Fryxell et al. 2010). Major difficulties lie in preventing reactionary management interventions that occur after changes to populations have been detected: a lag that can contribute significantly to increased extinction risk. There is no doubt that kangaroos in the rangelands are also subject to quasi-cyclic fluctuations like drought, and that sophisticated and enforced regulation will be necessary to ensure population and harvest longevity.

As an increased proportion of the quota is taken, increasing pressure to harvest may compound existing concerns (stated above) and current regulation will need to resist political and commercial pressures to liberalise. Such pressures already exist as expressed in Ampt and Baumber (2006) of FATE, the Future of Australian Threatened Ecosystems, whose aim is to create value in kangaroo harvesting for graziers. They argue that although the various state management plans are achieving their goals of sustaining viable kangaroo populations, a more flexible approach is needed that removes barriers to landholder involvement. At what point of regulatory relaxation and increased market forces will the risk of over-exploitation become unacceptable? Unlike livestock, kangaroo populations cannot be readily enhanced through investment in a new flock. Therefore particular consideration through bio-economic modelling must be given to the harvesting of free-ranging kangaroos under varying degrees of market pressures (McCallum 1995).

Discussion

Assessment of the assumptions underpinning the environmental return on increased human consumption of kangaroo meat indicates that interactive forces between kangaroos, sheep, the landscape and stake-holders are complex and uncertain. Current kangaroo industry meat marketing strategies and ongoing hygiene concerns suggest that an increased consumption by humans is unlikely to lead to an increased value of kangaroo meat for the shooter. Competing stakeholder interests, uncertainty around future kangaroo populations and small property sizes are likely to impede sheep replacement in spite of a hypothetical increase in value. Long-term studies indicate there is minimal competition between livestock and kangaroos. Short and long-term landscape-exclusion assessments suggest that destocking will result in only marginal kangaroo population increases. The number of kangaroos necessary to supplant meat production from sheep (greatly augmented if goats and cattle were also included) for an environmentally meaningful benefit is ecologically unfeasible. Lastly, an increased demand for kangaroo meat and high discount rates associated with uncertainty around kangaroo populations will increase the risk of overexploitation. This will require the maintenance of stringent regulatory mechanisms which are mostly untested due to historically underutilised quotas.

Much effort and academic rigour have been expended on assessing the lack of stakeholder value in kangaroo harvesting (Chapman 2003; Thomsen and Davies 2007) and establishing harvesting frameworks for increasing that value (Baumber et al. 2009; Cooney et al. 2009). However, new frameworks will not diminish the uncertainties around sheep replacement without addressing key issues such as landscape replacement of sheep (and goats and cattle) by kangaroos and the ability of graziers to sustainably integrate a highly variable product into a bankable business plan. Grigg (2002) maintains that the harvesting of kangaroos is within the IUCN guidelines of sustainable use of wildlife, which must add value to conservation efforts. However, the greater the uncertainty around sheep replacement by kangaroos the less conformity there is with the IUCN guidelines.

Lunney (2010) maintains that objecting to the harvesting of kangaroos lacks historical perspective of the Australian relationship with kangaroos. The prevailing views hold that kangaroos benefit from human-caused landscape alterations and that harvesting keeps the populations from irrupting. Hence harvesting is thought to be essential and beneficial to the reduction of total grazing pressure. However, the comprehensive Olsen and Low (2006) review has found little evidence in support of kangaroos being pests as the impacts of artificial watering points and land conversion may have been overstated. For instance, a long term study of a Red Kangaroo population's distribution in a rangeland landscape showed that the distribution was correlated to high quality forage and rest habitats, not watering holes (Montague-Drake and Croft 2004). A more recent study has shown that the closure of watering holes in outback Queensland does not impact either the distribution or densities of kangaroo (Fukuda et al. 2010). The key predictor of kangaroo population dynamics is the previous year's rainfall (Caughley et al. 1984; Bayliss 1985; Cairns and Grigg 1993; McCarthy 1996), which determines the amount of food (grasses and forbs) that will be available to kangaroos. A number of morphological, physiological and behavioural factors decrease the kangaroos' dependence on artificial watering holes including a long snout that allows access to water unavailable to sheep (Croft 2005), low water requirements (Hume 1999; Munn et al. 2008), the behavioural traits of digging for water (Croft 2005) and readily drinking muddy and algae-infested water that is unacceptable to sheep (Croft 1985). More kangaroos or not, the assertion that we cannot rely on reserves alone to maintain habitats and biodiversity is correct and remains unchallenged (Grigg 1995).

If kangaroo harvesting diminishes or ends two issues remain unresolved: (1) the graziers' perception of kangaroo as pests that impinge on farm income; and (2) we cannot rely on reserves alone to maintain habitats and biodiversity (Grigg 1995) and need the alleviation of grazing pressure in dysfunctional landscapes where overgrazing is the cause of such dysfunction (Freudenberger et al. 1997). A possible way forward is to assess the actual impact of kangaroos on graziers and the environment through available scientific information and technologies. Current scientific knowledge can help quantify (and perhaps predict) when competition is likely to occur, how to measure the conditions leading to it, to what extent it may impact graziers, and how to mitigate for it. Rather than implementing a coarse treatment of an annual 3-4 million kangaroo quota, such knowledge should be utilised to achieve a property or management zone-specific best outcome for graziers, kangaroos and the maintenance/restoration of landscape function and biodiversity.

Olsen and Low (2006) speculated that total grazing pressure is reducing due to a long-term trend of decreasing sheep numbers, which has continued due to a shift from wool to meat (Nicholls 2009), and has resulted in the lowest size of the Australian flock since 1905 (Australian Bureau of Statistics 2010). One could argue that this is a turning point at which graziers may consider a supplemental income source such as kangaroo harvesting (Ampt and Baumber 2006). However, why supplement one uncertain product for another? McCallum (1995: 210) cautions that "Whatever the nature of ownership, increasing the value of the resource, as would happen if production of meat for human consumption became the driving force behind kangaroo harvesting, is more likely to increase the conservation problems than decrease them". A non-consumptive industry such as ecotourism (Croft 2000; Higginbottom et al. 2004), combined with carbon credits for destocking and land conservation incentives would in the very least avoid the conservation concerns associated with over-exploitation. Serious effort should also be made to research and encourage grazing management systems that lighten the total grazing pressure and balance grazing to something more akin to a natural guild of mammalian herbivores. Underpinning this is the need to accept that market forces are not always compatible with conservation values (Noss 1991; Croft 2000; Freese and Trauger 2000; Grigg 2002; Fryxell et al. 2010), and the maintenance of the environment is the responsibility of all (not just graziers in this case). Such a view could lead to more generous financial assistance for destocking such as a subsidy for emissions reduction and ecological restoration.

Pople et al. (2010) argue that there is no need to further question the harvesting of kangaroos, presumably because populations persist after over 30 years of managed harvesting, but rather engage in adaptive management. In lauding the ecological sustainability of the kangaroo industry (Lunney 2010; Pople et al. 2010), advocates fail to acknowledge that a court intervention was necessary to prevent over-exploitation of kangaroos under the NSW Kangaroo Management Programme. Moreover, the long-term implications of selectively removing top native herbivores from the landscape are unknown. Finally, if the dimensions of a sustainable industry are taken to include a commercial value (in addition to an environmental value) then surely they should also include social values that account for society's attitudes (both urban and rural) to wildlife (Chalk 2007). All issues, and particularly the latter dimension, can only be achieved through a well informed debate about the issue. THINKK, the think tank for kangaroos, proposes several key areas of research to address the role of kangaroos, icons of Australia, in the rangelands: (1) To what extent do kangaroos impinge on grazier income? (2) What non-lethal means can be pursued to mitigate conflict where it occurs? (3) What non-lethal land management policies can be pursued to alleviate total grazing pressure and retain value for graziers? (4) What policies could be implemented to reflect more up-to-date findings?

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