Options for integrated kangaroo management in the Western region

A practical guide for active management

NSW GOVERNMENT

Kangaroo Management Taskforce

The Kangaroo Management Taskforce is funded by Local Land Services in partnership with all relevant agencies, stakeholders and industry.

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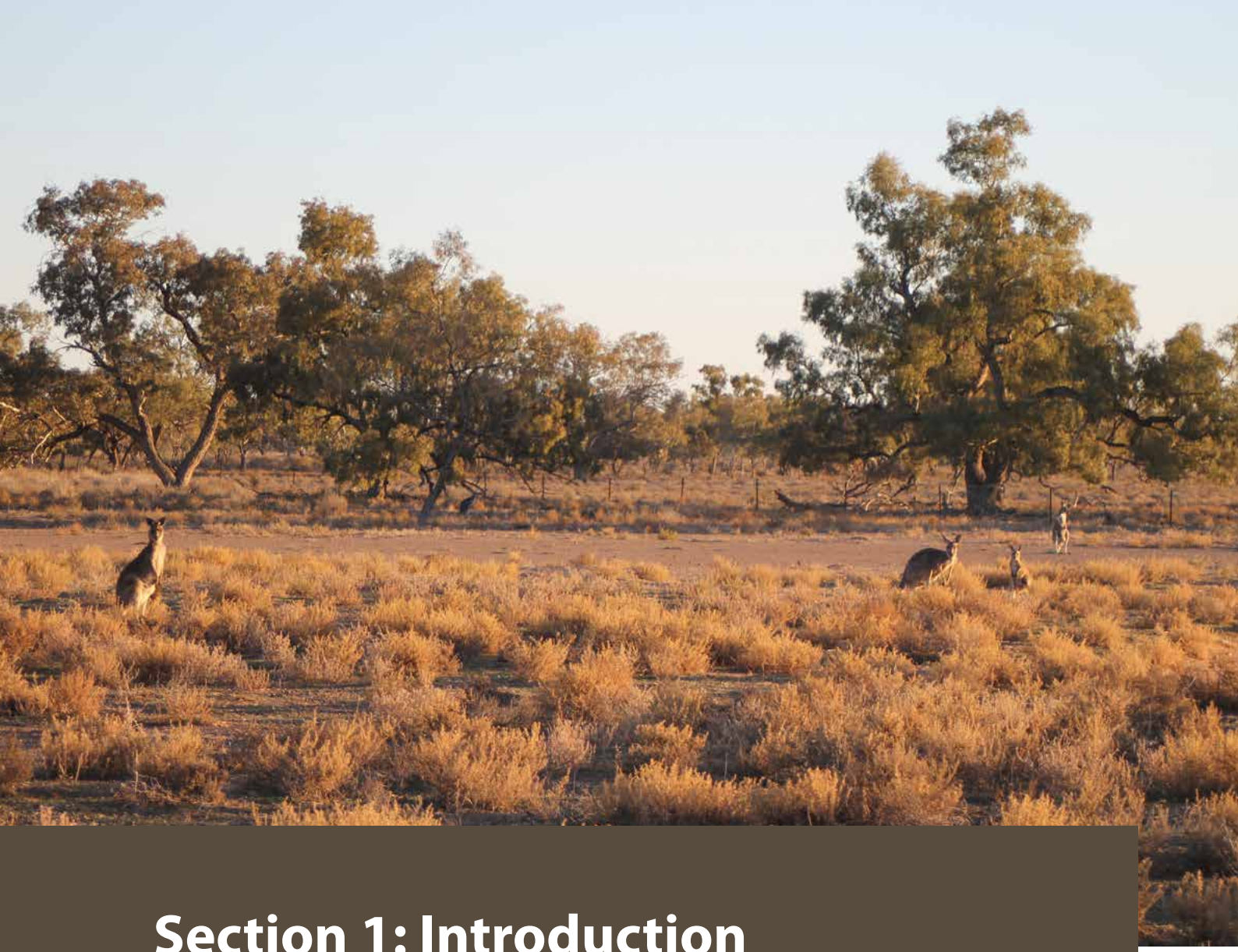

Section 1: Introduction

The focus of sustainable land management in the Western region (see Figure 1) is largely directed at maintaining critical levels of groundcover to prevent soil erosion, especially under dry seasonal conditions, regardless of the type of land use (Western LLS, 2016). Secondary objectives may include:

- in cropping areas - obtaining the best yield of grain or forage and building soil health
- in rangeland areas - maximising livestock production, enhancing the condition of soils or vegetation and ensuring that biodiversity is improved, not compromised.

Kangaroos are often considered an unmanageable aspect of Western region landholdings. Regional kangaroo populations are mostly predator-free and mobile across the landscape, numbers primarily responding to seasonal conditions and plant growth. Numbers sit at much higher levels than in naturally-regulated situations (Letnic and Koch, 2010). Consequently, kangaroo grazing pressure is a key influence on sustainable land management and production objectives, particularly when periods of peak population coincide with declining seasonal conditions and competition for grazing resources is high.

Figure 1: Map of the Western Local Land Services region.

Kangaroo welfare issues arise during these peak population periods as demand for feed and water requirements outstrip availability, resulting in catastrophic population declines. Landscape health also deteriorates during these periods, as uncontrolled grazing pressures reduce groundcover below levels needed to prevent erosion. High kangaroo grazing pressure can selectively deplete vulnerable plant species long after livestock have been removed. As groundcover declines, a broad range of native fauna species is affected, such as seed-eating birds dependent on grassy habitat.

Over past decades, policy on the management of kangaroos has largely been focussed on the implementation of the NSW Commercial Kangaroo Harvest Management Plan (OEH, 2017a). However, despite the fact that commercial harvest by professional shooting has higher social acceptability in terms of welfare than other cull methods (McLeod and Sharp, 2020; Sinclair et al, 2019c), the commercial industry has declining effectiveness as a land management tool due to low levels of offtake and an inability to meet the needs of many landholders to control total grazing pressure (Hacker et al, 2019). Increasingly, landholders are seeking alternative ways to manage the impact of kangaroo overpopulation at the paddock or property level.

a. Scope

The scope of this publication is to:

- describe current tools for controlling kangaroo populations at the property or paddock level
- outline property management factors that can improve the outcomes arising from control measures
- base the information on good evidence where available.

b. Disclaimer

The options detailed in this publication are not presented as "best practice" given that presently, active adaptive kangaroo management is an evolving field (McLeod and Hacker, 2019). While existing research underlies some aspects, substantial information gaps remain in quantifying the effectiveness of available practices. The Western region encompasses a wide variety of land types, so the options presented may have better application in some areas than others. Further research and evaluation may validate the options and provide a basis for better approaches to management in the future.

Photo: Alain Louvel

Section 2: Kangaroo management strategy at the property level

1. Principles for kangaroo management

Kangaroo management is subject to high levels of political scrutiny. Consequently, the building of a good reputation is paramount in maintaining social licence for managing kangaroos across all agricultural industries in the Western region. Publicised instances of bad or illegal practice, such as shooting outside of code requirements, has significant potential to adversely affect the reputation of agriculture within the Western region and provide strong leverage for interest groups to demand adverse statutory restrictions on the management of kangaroos (Sinclair et al, 2019a, Sinclair et al, 2019b).

Single-interest advocacy groups present strong, emotive messages to the public and governments that management actions to control kangaroo numbers are intrinsically inhumane. Such groups promote values beyond animal welfare, including individual animal rights, the protection of iconic fauna and the freedom of wildlife movement and can readily influence an increasingly urbanised public. These messages, delivered via a range of media, are promoted globally and can be very effective in influencing public sentiment and government policy. They have already substantially reduced marketing options for kangaroo products in Europe and the United States. At the paddock-level, the industry transition to a male-biased take has partly been in response to joey welfare concerns, which has significantly depleted the value of harvesting as a population control measure for landholders (McLeod and Sharp, 2020; Sinclair et al, 2019b).

Individual landholders have the foremost role in managing the reputation of agriculture through what happens on their own property. Effective self-regulation is extremely important.

The following broad principles are provided as a framework for responsible kangaroo management at the property-level to guide the approach landholders take on this important issue:

a. Healthy, viable kangaroo populations are a vital component of the Western region

Most landholders in the Western region enjoy the sight of kangaroos in their landscapes. Therefore, the intent of kangaroo management is not to fully exclude kangaroos from the landscape, but to regulate the large population fluctuations that negatively impact landscape condition and cause a large number of kangaroo deaths during drought.

b. Total grazing pressure control is necessary for sustainable pastoral production

The key goal of managing kangaroo populations involves controling total grazing pressure so that pastures can be managed to attain a level of at least 50 per cent groundcover, the threshold level for protection of soils from wind erosion (Cork et al, 2012). Higher aspirations may involve getting sufficient control of grazing to be able to spell paddocks to improve pasture condition, both to increase productivity and improve resilience to drought.

c. Best practice animal welfare is fundamental to kangaroo management

Most landholders believe in the humane treatment of all animals and this includes kangaroos. Science-based stakeholders (e.g. Australian Veterinary Association) are supportive of kangaroo management based on robust codes to ensure that practices are humane. Management practices, whether involving shooting, fencing or other approaches, should be undertaken with due consideration for any welfare risks that may arise for kangaroos or other affected animal life.

d. Biodiversity should be enhanced, not damaged

Overgrazing by kangaroos has been shown to adversely impact biodiversity, and culling can directly address this issue (TMS, 2010). The closure of water points and erection of exclusion fencing may have both positive and negative outcomes for native fauna and flora. For instance, exclosure can reduce the impact of feral animals such as pigs, and improve habitat quality for lizards, small mammals and seed-eating birds. However, fencing may also affect the movement of species such as emus, mallee fowl and echidnas. Such changes can be hard to identify over relatively short timeframes due to variation from changing seasonal conditions. Kangaroo management should seek to maximise benefits and minimise impacts on biodiversity. For instance, fence clearing operations should avoid destroying unusual vegetation and maintain habitat trees by realignment. Adopting fence designs that minimise wildlife injury can improve animal welfare and in turn reduce ongoing infrastructure damage.

e. Sites of Aboriginal cultural value should be protected

Aboriginal people of the Western region value their heritage and have a strong interest in the preservation of sites across the landscape. Respecting their interests builds the positive profile of agriculture. When undertaking clearing operations and earthworks, landholders must be mindful of legalities and the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales, as well as maintaining awareness of the potential for sites such as hearths and marked trees (DECCW, 2010).

f. Kangaroos should be managed as a resource

Kangaroo meat is a valuable source of nutrition in a world where protein is in increasing demand. Most landholders recognise the value of kangaroo meat and regret the wastage of this resource where non-commercial culling is necessary to reduce populations. Consequently, where possible, the commercial harvest industry should be the priority avenue for the removal of kangaroos.

g. Co-benefits should be maximised where possible

The control of kangaroo numbers can have a number of co-benefits beyond solely reduced competition with livestock for available pasture. These include reduced biosecurity risk through stock containment by exclusion fencing, increased long-term resilience to drought through regenerative pasture management, better soil stability through higher groundcover levels and improved wildlife habitat through enhanced vegetation condition. However, these co-benefits only arise if kangaroo control is undertaken in the context of a broader management plan, rather than ad hoc responses.

h. All aspects of kangaroo management must comply with current regulations and be transparent

The process of kangaroo management should be transparent, meaning that all activities are undertaken legally and in accordance with statutory codes of practice, so that they can be judged as robust in the face of public or legal scrutiny. Management operations should be undertaken in a professional manner, implementing best practice approaches to minimise animal welfare issues but also addressing other areas of public interest such as food safety, biodiversity conservation and sustainable land management. Poor practice and non-compliance risk the social licence of both land managers and the kangaroo harvest industry.

2. Goals for property-level kangaroo management

For many decades, the commercial harvest industry has been the focus of kangaroo management. Over the past decade, however, other options have become available. The wider use of prefabricated-mesh and electric fencing to control unmanaged rangeland goats and meat sheep, together with the marketing of new fencing products, has stimulated new approaches to managing total grazing pressure. This has been happening at a time when the commercial kangaroo quota approach has proven less effective in dealing with overpopulation issues (McLeod and Hacker, 2019; Hacker et al, 2019b). While the new approaches come at a cost, landholders now have more options to consider in kangaroo management. The selection of which management option suits a property ultimately depends on the goals for controling kangaroos, given that economics is always a consideration.

Landholders undertaking kangaroo management should consider their management objectives, either of:

I. Control of total grazing pressure to reduce competition with stock for available fodder

On grazing land, the traditional approach to kangaroo management has solely involved lowering densities to reduce short-term direct competition with livestock for forage and to a lesser extent water supply. This can be successfully achieved by shooting only, using commercial harvesting where available, as well as non-commercial culling when necessary. This type of management is often ad-hoc, and mobile kangaroo populations may readily immigrate into the treated area from adjacent land, necessitating ongoing culling activities.

II. Control of total grazing pressure for rotational grazing or regenerative management

Regenerative practices, such as rotational grazing or land rehabilitation earthworks, require the spelling of pastures over successive growing seasons to promote plant growth (Waters et al, 2019). Desirable plant species such as palatable perennial grasses usually fail to establish without spelling as they are selectively grazed by stock or kangaroos. Even low densities of grazing animals can adversely affect the establishment of these species as they are actively sought-out by herbivores. In this case, total exclusion of unmanaged grazing by kangaroos on a paddock-by-paddock basis will be necessary to achieve the management goal.

III. Control of grazing pressure for crop production

Where land use has changed and enterprises are based on long-term cropping or horticulture, any number of kangaroos is likely to be unwelcome. This is especially an issue in areas where cropping abuts grazing country or land allocated to conservation.

IV. Control of kangaroo populations to alleviate drought impacts

Western region kangaroo populations fluctuate significantly in a decadal timeframe broadly aligned to seasonal conditions (see Figure 1). Population crashes occurred during 2002 and 2017-19, as seasons rapidly transitioned from favourable rainfall to drought and animals struggled to survive on a dwindling feed base. Landholders often carry the responsibility for the management of kangaroos in poor or dying condition.

3. Assessing population impact at the property level

Various factors may affect total grazing pressure and before investing in a kangaroo management program, due diligence in understanding the impact of the population at the property level may be worthwhile. While kangaroo overpopulation issues may be highly-visible, other factors affect total grazing pressure at the paddock or property level. There are instances where removal of kangaroos has provided no improvement in pastures due to other issues, including:

- too many unmanaged rangeland goats. Other than the presence of browsing, unmanaged goat impact can be indistinguishable from that of kangaroos
- too many domestic animals. The impact of kangaroos can sometimes be replaced by overgrazing by stock. Reducing kangaroo numbers may have no effect on heavily-stocked pastures
- poor land condition and lack of response to rainfall. This is a long-term change in pastures and soils, often evident by the replacement of long-lived species with ephemeral plants, resulting in a transition to short growth periods and lower productivity.

Two approaches can be taken in identifying kangaroo impact at the paddock level:

- an assessment of pasture growth and composition. This is an outcome-focused approach
- an assessment of kangaroo density as a component of total grazing pressure. This is focusing on the potential driver of pasture condition, without considering the link to actual growth.

Both of these assessments can be either simple or more detailed for property management purposes. A simple approach to assessing pasture growth involves the use of exclusion cages, small structures which prevent all grazing. These can be particularly revealing when placed in destocked paddocks, where kangaroos and unmanaged rangeland goats comprise the greater part of grazing pressure (see Photo 1).

Photo 1: Exclusion cage utilising four gates to assess grazing impact. Credit: Alison Stokes (SA Dept. of Environment and Water).

Kangaroo numbers can be assessed using motion-sensing cameras placed in critical areas such as water points, providing an indication of animal abundance. A numerical approach to estimate density can also be taken, which involves counting kangaroo dung along a step-point transect (Campbell and Hacker, 2000).

Section 3: Kangaroos in the Western region

1. Kangaroo ecology

The red kangaroo, euro, western grey kangaroo and eastern grey kangaroo are common and widespread within their preferred habitats in the Western region. These species are the focus of landholder management within the region.

Key aspects of the ecology of these species that influence management are outlined in the following section.

Red kangaroo (Osphranter rufus).

a. Red kangaroo

I. Description and distribution

The red kangaroo (*Osphranter rufus*) is the largest kangaroo, with males reaching up to 80 kg while most females are in the 25-30 kg range, but attain up to 40 kg. They are well adapted to semi-arid climates and occur widely across Australia in areas of less than 500 mm rainfall (Dawson 2012). As they prefer open habitats, they are most abundant in far western areas, but are present throughout the Western region.

II. Diet and water use

Red kangaroos eat mainly grasses, preferring young grass when available, but will utilise forbs and chenopods when seasonal conditions restrict grass growth (Underhill et al, 2007, Pahl, 2019). They have a highly efficient water metabolism, more so than other kangaroo species, which they achieve through a low basal metabolic rate and an ability to concentrate urine. Studies at remote waters have found red kangaroos return at five to 12-day intervals depending on weather. Body size influences water requirements and smaller kangaroos (younger males or females) are able to better survive water shortages, especially under cool, dry conditions. Clearly, the feed resource is the greatest limitation to red kangaroo distribution, not access to water (Dawson, 2012; Underhill et al, 2007).

III. Home range

Once considered to be nomadic, studies at Fowlers Gap, approximately 75 km north of Broken Hill, and elsewhere have verified that red kangaroos are largely sedentary, faithfully occupying home ranges of typically up to three kilometres in diameter, mature males occupying larger areas. However, they mobilise when forage resources are short to travel up to 50 km and beyond to chase green feed. The movement of sub-adults and young adult males is most pronounced, with mature females being relatively faithful to one area, returning even after months of movement seeking feed (Dawson, 2012).

IV. Reproduction

The typical social group size is three to four red kangaroos and a mature male may have up to five females. Male red kangaroos reach sexual maturity at three to four years but may not be fully mature until 10 years and can live beyond 20 years. Female sexual maturity is variable and dependent on seasonal conditions, ranging from 17 months to five years. Mature females are capable of breeding continuously while they meet a body condition threshold, which is linked to seasonal forage growth. Females can conceive shortly after giving birth, but have the capacity for embryonic diapause, where a viable embryo can be carried in the uterus for many months without development while there is a suckling pouch young or environmental conditions are poor. This permits a fast reproductive response when conditions become suitable. Pouch life is about 235 days, considerably shorter than grey kangaroos. The survival of young is usually low in poor seasons but up to 85 per cent of joeys survive under good conditions (Dawson 2012).

b. Euro

I. Description and distribution

The euro (*Osphranter robustus infrasp. erubescens*) is a subspecies of the broader wallaroo group. It is of the same genus as red kangaroos and therefore, shares characteristics such as embryonic diapause as an adaption to adverse habitats. It is a solid kangaroo and males can weigh over 50 kg, with females less than 30 kg. Euros are nocturnal, have a secretive nature and are largely solitary. Their favoured habitat is rough hilly country, occasionally occupying gullies and steep creek banks in adjacent flat terrain.

II. Diet and water use

Data from Fowlers Gap indicates that euros prefer young grass, then mature grass, herbage and dry grass before browsing on bluebush or saltbush. Since they prefer to graze in rough country, they may compete less with stock than other kangaroos (Dawson, 2012). During wet summers they tend to eat perennial grasses exclusively, while ephemeral forbs may comprise 25 per cent of intake during wet winters (Pahl, 2019b). They share the water efficiency of the red kangaroo and are reported to survive for greater than 12 days without a drink under warm conditions. A long colon may contribute to their efficiency in water metabolism (Dawson, 2012).

III. Home range

Euros generally remain in hilly terrain in home ranges recorded in the range of 116-283 ha, with weekly movements of no more than seven kilometres (Croft, 1991). They appear to seldom move about, although males will travel substantially further than females in winter. Most dispersal involves young males and there may be movement to recolonise areas where population has been depleted. Movements may occur during drought following thunderstorms, but individuals have been recorded as dying of starvation in their home ranges without moving (Dawson, 2012)

IV. Reproduction

Male euros become sexually mature at about two years and a weight of 15 kg. However, they do not have a significant breeding role until they mature in size at around seven years and 40 kg. Female development is variable, with breeding commencing at between two to four years depending on seasonal conditions (Dawson, 2012). The breeding of euros is similar to red kangaroos, in that it is continuous under favourable seasonal conditions. Mating can occur within three days of birth, but embryos undergo diapause if the newborn joey attaches to a teat. Breeding is deferred during poor seasons and reproduction ceases earlier than red kangaroos in these circumstances (Dawson, 2012).

Euro kangaroo (Osphranter robustus infrasp. erubescens). Photo: Ken Stepnell DPIE.

Western grey kangaroo (Macropus fuliginosus).

c. Western grey kangaroo

I. Description and distribution

The western grey kangaroo (*Macropus fuliginosus*) occurs across the southern rangelands, from Western Australia to the Western region of NSW, and is closely related to the eastern grey kangaroo. It is a darker colour than the eastern grey and has a dark brown face rather than pale grey. The western grey appears to have increased its range in the Western region in the latter part of the 20th century, following the increased provision of artificial watering points. They are nocturnal, tending to spend daylight resting in timbered or scrubby areas before feeding during twilight and darkness often in open areas (Dawson, 2012).

II. Diet and water use

The preferred diet of western grey kangaroos consists of annual grasses and ephemeral forbs, but they will exclusively eat green perennial grasses when abundant following favourable summer rainfall when annuals are unavailable. They have a higher preference for forbs than red kangaroos. During dry periods, when the quality and quantity of perennial grasses declines, they eat increasing amounts of perennial forbs such as saltbush and bluebush, as well as browsing shrubs such as hopbush (Pahl, 2019b).

The water efficiency of western grey kangaroos is superior to domestic animals but not as well-developed as in red kangaroos or euros. This is particularly evident when only dry feed is available. Under warm to hot arid conditions, they have been recorded as requiring a drink every two days and use shade to manage daytime heat (Dawson, 2012).

III. Home range

Western grey kangaroos are sedentary, with strong fidelity to their home range. Surveys at Kinchega National Park have relocated 90 per cent of kangaroos within six kilometres of their tagging site after five years. Mainly young males, less than five years old and 45 kg, tend to move but not far.

IV. Reproduction

Male western grey kangaroos reach sexual maturity at about 2.5 years and 25 kg but are not considered adults until they are 45-50 kg at about five years. They do not breed significantly until they are 55-60 kg at about seven years, but there is high mortality and possibly only five per cent reach this phase. Males older than 10 years are uncommon in the wild (Dawson, 2012).

About half of females die before breeding age at two to four years or 16 kg, depending on seasonal conditions. Once breeding has commenced, females have young annually, mainly during the summer so that joeys can become independent with the flush of spring growth. Pouch life is about 320 days. Grey kangaroos do not exhibit embryonic diapause.

Mating will occur when the pouch young is about six months old and the resultant embryo will be quiescent while lactation continues, developing so that birth is timed to coincide with the final pouch exit of the prior young at 10 months (Dawson, 2012).

d. Eastern grey kangaroo

I. Description and distribution

The eastern grey kangaroo (*Macropus giganteus*) is the most common macropod of temperate eastern Australia. The extension of its range into semi-arid areas has been a recent phenomenon commencing in the wet years of the mid-1970s, possibly due to the provision of artificial watering points. Eastern greys are large, with males recorded over 70 kg, while females reach 35 kg. These kangaroos have a light fleck in their fur and a pale grey face with light shading around the eyes, in contrast to western greys which have a dark brown face. They are nocturnal, tending to spend daylight resting in scrubland or woodland areas before feeding often in open areas during twilight and darkness (Dawson, 2012).

II. Diet and water use

In semi-arid habitats, eastern grey kangaroos have a similar diet to euros, with a high preference for annual grasses and ephemeral forbs when these are available. If not available, they eat large amounts of perennial grasses and a limited quantity of perennial forbs. They consume very little browse (Pahl, 2019). In assessments on green feed in winter, eastern grey kangaroos had a similar water balance to red kangaroos. However, with dry feed and summer temperatures, they used half a litre more water per day, largely due to a less-efficient kidney function and gut length than red kangaroos, which are better adapted to water conservation. Observations suggest that eastern grey kangaroos need to access water every second day under hot conditions and rely heavily on accessing shade for heat avoidance during summer (Dawson, 2012).

III. Home range

Annual home ranges of 530 ha for females and 1,180 ha for males have been recorded for this species at Yathong Nature Reserve. Eastern grey kangaroos are considered sedentary, especially amongst mature age classes, but data is generally lacking on their behaviour in the semi-arid zone.

IV. Reproduction

Male eastern grey kangaroos reach sexual maturity at about four years, later than western greys, while females mature at three to 3.5 years, possibly younger in good seasons. Eastern greys are seasonal breeders, births peaking in summer. Post-birth oestrus is not evident and the female will mate when the pouch young is about six months old. The resultant embryo will be latent while lactation continues, developing so that birth is timed to coincide with the final pouch exit of the prior young. Similar to western greys, eastern grey joeys permanently leave the pouch at about 319 days. Survival rates can be very variable under semi-arid conditions (Dawson, 2012).

Eastern grey kangaroo (Macropus giganteus). Photo: Nick Cubbin OEH.

Swamp wallaby (Wallabia bicolor).

Yellow-footed rock-wallaby (Petrogale xanthopus).

Brush-tailed rock wallabies (Petrogale penicillata). Photo: Michael van Ewijk DPIE.

Bridled nail-tail wallabies (Onychogalea fraenata).

e. Other species

In addition to kangaroos, several wallabies may be encountered in the Western region:

- swamp wallabies (*Wallabia bicolor*) can occur in the eastern margins of the region and favour thick undergrowth
- yellow-footed rock-wallabies (*Petrogale xanthopus*) were once widespread in rocky areas of the West Darling but are now endangered. They have been reintroduced to Mutawintji National Park
- brush-tailed rock wallabies (*Petrogale penicillata*) have been recorded in the eastern part of the region but are endangered or extinct. Their habitat is in rocky outcrops close to areas of grassland
- bridled nail-tail wallabies (*Onychogalea fraenata*) were recorded in the region during the 19th century but are now presumed extinct.

None of these wallabies are subject to overpopulation in the Western region. All kangaroos and wallabies are protected under the *NSW Biodiversity Conservation Act 2016* and certain species can only be harmed with appropriate licences.

f. Management implications

Key elements of kangaroo ecology outlined above have several important implications for the management of macropod densities at the property level:

- red kangaroos and euros are not dependent on regular access to water, so management of artificial water sources will have limited impact on the density of these macropods. They are more sensitive to forage availability
- the grey kangaroos do require regular access to water, so the control of artificial water sources will be more effective in controlling population density
- kangaroos selectively graze palatable perennial grasses. These grasses are a key factor in keeping rangeland pastures and soils in good condition. In a similar manner to livestock management, kangaroo grazing pressures should be managed to ensure palatable perennial grasses persist. These grasses give long-term groundcover protection to soils, provide habitat for native animals and reduce forage fluctuations under variable seasonal conditions
- rather than roaming widely, under most seasonal conditions grey kangaroos and euros remain in relatively limited home ranges. Most movement is associated with young males. On the other hand, red kangaroos will roam when seasonal conditions decline, but remain faithful to their original home ranges when forage growth improves.

A small number of older male kangaroos dominate breeding activities while most others have limited impacts on populations. Consequently male-only harvest will have little impact on numbers. Breeding is highly dependent on seasonal forage growth and the mortalities of young may be high if seasons deteriorate. As females commence to reproduce at two to three years of age, there is a lag between seasonally initiated breeding events and subsequent population growth.

2. Defining kangaroo overpopulation

a. Why is there overpopulation?

The urban public often wonders how a native animal such as the kangaroo can suffer overpopulation and cause ecological and economic damage. Public perceptions of kangaroo density are, however, mostly framed in the NSW context of a population largely free of wild dog predation and other habitat constraints. As wild dogs are mostly excluded from the Western region and elsewhere in NSW to ensure the viability of agriculture, seasonal conditions and culling are the only constraints on the populations of the four common species of kangaroos (Hacker et al, 2004).

By contrast, in the cattle-grazing areas of adjacent states where dingo predation remains a control factor, kangaroo populations are regulated at much lower densities than evident within the Western region. In South Australia, for instance, the wild dog fence provides for clear benchmarking between the predator-free kangaroo populations existing to the south and the naturally-regulated populations to the north of the barrier. In the latter case, kangaroo densities are significantly lower than in the predator-free sheep-grazing rangelands, which have periodic overpopulation (Caughley et al, 1980; DEWNR, 2017; Pople et al, 2000).

Locally, in the absence of predation, populations track seasonal pasture growth. Overpopulation and landscape damage eventuates when drought depletes pastures and the grazing pressure of kangaroos is regulated only by starvation, even long after domestic stock are removed. Access to artificial water sources supports population growth, but is not essential as kangaroos are mobile and have highly efficient water use.

The overpopulation of native herbivores and associated land management and animal welfare impacts is not a problem unique to Australia's southern rangelands and kangaroos. The process whereby herbivore populations that are freed from control measures such as predation tend to increase exponentially, then crash through starvation, has been termed "irruption". Irruption has been recognised globally, especially in deer (Takeshita, 2018; TMS, 2010). For example, the white-tailed deer (Odocoileus virginianus) population of the eastern United States has rapidly expanded since the 1930s as a result of protection, the elimination of predators, declining hunting and changing land use. Consequent overpopulation has resulted in widespread impacts to biodiversity, forestry, agriculture, road usage and residential living (Purcell et al, 2013; Cote et al, 2004).

I. Kangaroo population dynamics

The dynamics of the kangaroo population across the Western region are well documented through the NSW Commercial Harvest Plan and Quota Reports (Office of Environment and Heritage, 2019). The estimated NSW red and grey kangaroo population, harvest quota and take for the period 1982-2019 is presented in Figure 2. To provide a seasonal context to these trends, the annual rainfalls for Cobar and Broken Hill are provided in Figure 3. Kangaroo populations increased following good seasons in 2000-01, rapidly declined until 2005, then gradually rose again until 2010. Favourable seasons in 2010-11 initiated a rapid growth in numbers peaking in 2016 at 17.4 million.

At the property-level, population dynamics may be more complex due to the diverse response of pastures depending on type of country, the timing and distribution of rainfall, as well as the local movement of kangaroos seeking green growth.

II. Kangaroo behaviour

Most grazing animals are selective of both habitat and feed resources, so their impact is a factor of this behaviour as well as population density. This is evident in the well-known movement of kangaroos to areas of fresh growth and also their selectivity in feeding predominantly on green annual grasses, ephemeral forbs and the green leaf of perennial grasses when available. They continue to graze perennial grasses as feed quality declines, longer than other herbivores which switch to other sources (Pahl, 2019b). Rangeland ecological condition, assessed in terms of groundcover and perennial plant cover and diversity, can therefore be significantly depleted where paddocks are subjected to grazing by kangaroos long after the removal of livestock. Even low densities of kangaroos can adversely affect the condition of pasture through selective grazing, resulting in loss of palatable perennial grasses and exposure of soil surfaces.

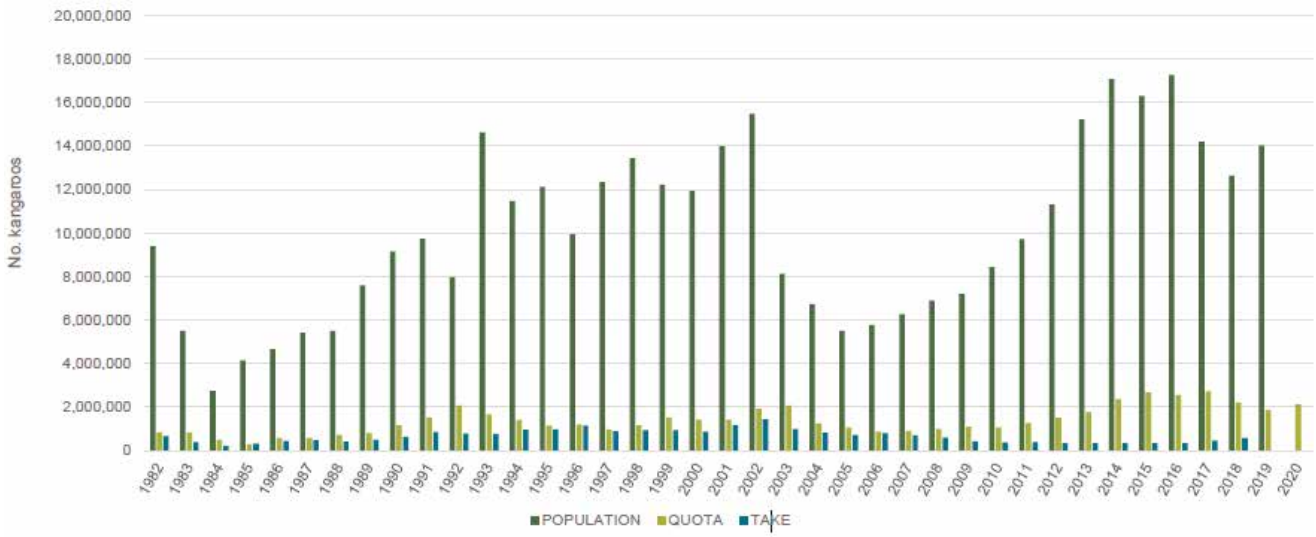

Figure 2: Combined NSW red and grey kangaroo population estimates, 1982-2019. Source: Office of Environment and Heritage (2019).

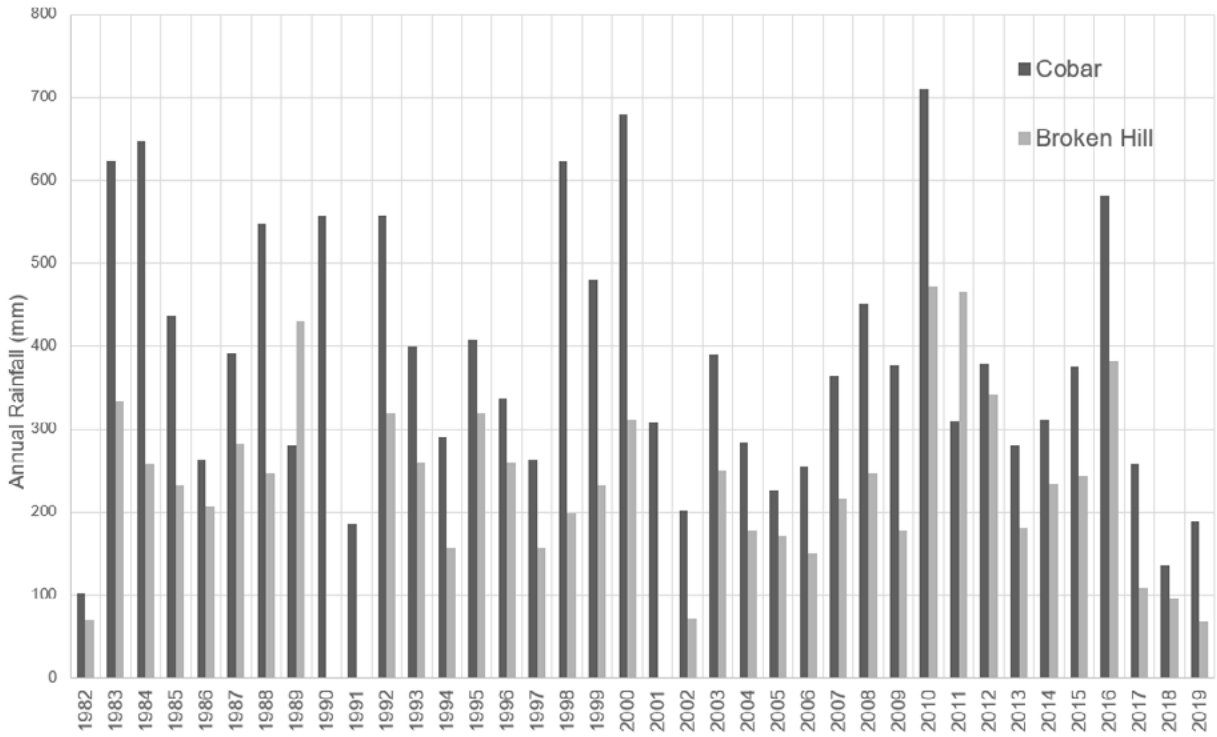

Figure 3: Annual rainfall for Broken Hill and Cobar, 1982-2019.

b. Impacts of kangaroo overpopulation

The impacts of kangaroo overpopulation in the Western region are summarised in the following sections. These stated impacts are often contested by interest groups that oppose kangaroo management, but understanding the local context is important in drawing valid conclusions from available data.

I. Landscape

Landscape function and stability in the Western region is significantly affected by the level of groundcover. In general, 50 per cent groundcover is accepted as a crucial threshold for wind erosion, with higher levels required to limit water erosion (Cork et al, 2012). In paddocks where unmanaged grazing animals (kangaroos and goats) are present, landholders have difficulty in controlling grazing pressures to maintain the minimum of 50 per cent cover, let alone higher levels. Controlling the grazing pressure of unmanaged rangeland goats and kangaroos by fencing improved perennial groundcover levels by 10 - 30 per cent and increased total groundcover by 20 - 40 per cent (Waters et al, 2017).

II. Biodiversity

The Western region has avoided the widespread fragmentation of native vegetation through clearing that is evident elsewhere in NSW, but biodiversity is widely depleted by poor habitat condition. High total grazing pressure is the major threat to biodiversity in suppressing habitat condition. The impact of high densities of kangaroos on biodiversity has been well-studied in the Australian Capital Territory and similar responses are likely in the Western region. In general, research has found that high kangaroo densities impact grassland structure, which significantly affects the abundance, species diversity and occurrence of reptiles, birds and certain insects as well as some plants (Howland et al, 2014; TMS, 2010).

III. Production

On average, kangaroos consume about 45 per cent of the forage produced on Australia's southern rangelands (Hacker, R.B., Sinclair, K., and Pahl, L. 2019b). As the grazing of these animals cannot be controlled by traditional means, landholders are constrained in managing forage utilisation in relation to groundcover thresholds and are unable to spell pastures (Waters et al, 2018; Atkinson et al, 2019). Spelling is desirable to maintain the vigour of selectively-grazed plants such as palatable perennial grasses. A recent review of dietary requirements concluded that a 50 kg kangaroo will consume one dry sheep equivalent (DSE, 50 kg wether equivalent) of forage when grazing on heterogeneous rangeland pastures. This assessment of consumption conflicts with previous estimates of about 0.45 DSE, as it recognises that the dry matter intake of kangaroos will be greater than that of ruminants in the case of low-quality forage (Pahl, 2019a). Significant overlap in diet and foraging areas in rangeland environments is also evident, especially when livestock and kangaroos are feeding on green annual grasses, perennial grasses and forbs. However, patterns of consumption do not always overlap as preferences for feed sources differ between stock and kangaroos as forage dries off. There is significant overlap in the use of perennial grasses (Pahl, 2019b).

In cropping situations, substantial losses in production have been recorded in situations where farming adjoins natural habitat areas (KMT, 2019).

IV. Welfare

Welfare issues associated with kangaroo management are mostly publicised in relation to lethal control measures. However the stresses of large fluctuations in the kangaroo population, in response to seasonal conditions, present major welfare issues for macropods which are not addressed by existing policy (Hacker, R.B., Sinclair, K., and Pahl, L., 2019b).

When peak populations are faced with declining forage conditions, following the onset of drought, large numbers of kangaroos die of starvation and associated stresses (Robertson, 1986; TMS, 2010)). For instance, in May 2018, following two years of dry conditions, red kangaroo populations across the Western Plains declined by 42.9 per cent (2,200,961 kangaroos) of which only 199,059 animals were taken by commercial harvest (Office of Environment and Heritage, 2018). An unspecified but low number would also have been culled by permit. Consequently, a very large number of kangaroos died of starvation or dehydration, a natural process, but by no means humane. Associated trauma and mortality occurs with increasing road deaths associated with concentrated feeding activity along roadsides, as well as bogging in dwindling surface water supplies.

These difficult welfare issues create anguish for property owners who witness the struggles of individual kangaroos, and it also creates a significant workload in dealing with problems, such as removing animals caught in the mud of drying water supplies.

V. Drought

After a long history of land degradation episodes and high levels of total grazing pressure, the pastures of the Western region are in relatively poor condition. Pastures have transitioned from being composed of mainly perennial forbs and grasses to a dominance of ephemeral species, such as barley grass, Ward's weed and wild turnip. These species provide quick flushes of green feed that deteriorate quickly with the first warm weather and, fail to support grazing or protect soils in drought.

Kangaroos have the capacity to detect and travel widely to find feed as drought develops. Their movement is unconstrained by traditional fence designs. This constrains landholder drought preparedness in several ways:

- removing domestic stock early fails to protect pastures, as mobile kangaroos can over-utilise remaining growth
- spelling pastures to rebuild the perennial forage component is ineffective as kangaroos access these areas and selectively graze perennials
- maintaining drought reserve paddocks is ineffective, as kangaroos can access these areas and utilise them fully before they are of use to stock.

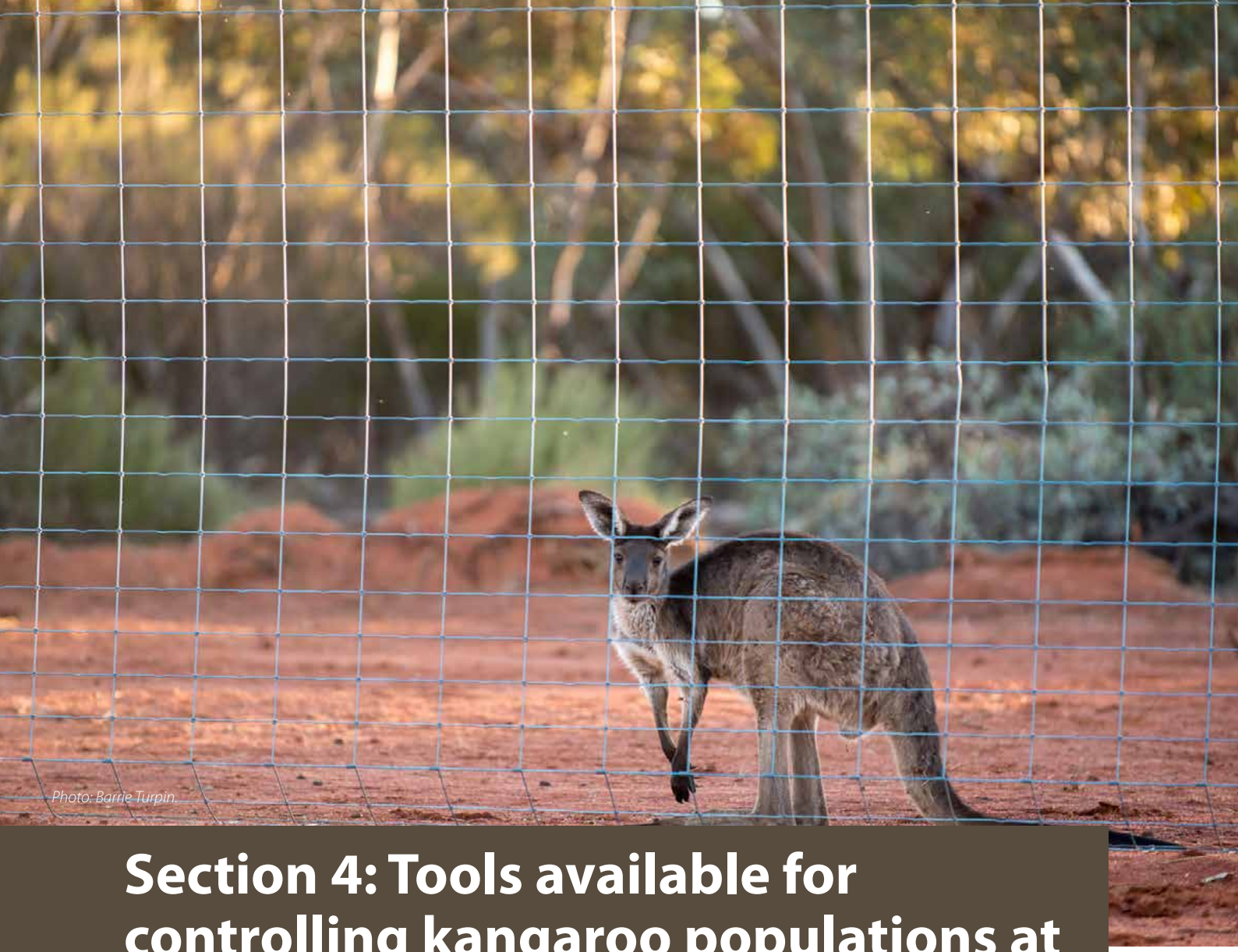

Photo: Barrie Turpin.

Section 4: Tools available for controlling kangaroo populations at the property scale

When kangaroo numbers are high, especially during drought, their management has most often been viewed from the point of view of reducing numbers through commercial harvest. However, increasingly over the past decade, purpose-designed fencing products have been marketed with a greater effectiveness to manage marsupials. Consequently, at the property or paddock scale there are additional tools to be considered as part of an active control program. The most regionally appropriate tools to manage kangaroo densities now include:

- commercial harvest
- non-commercial culling, under a licence to harm kangaroos for damage mitigation
- the control of artificial water-points to exclude kangaroos when livestock is not present
- the use of various types of fencing to control the movement of kangaroos.

Other tools are often suggested but are not practical at the scale of pastoral property management or are not legal.

The following sections consider aspects of commercial and non-commercial culling, water-point closure and various forms of fencing as practical tools for kangaroo management in the Western region. As well as effectiveness, they are considered in terms of social acceptability, which is of growing importance in terms of what is desirable or allowable on-farm (Sinclair et al, 2019c). The options are summarised in Appendix 1.

1. Commercial harvest

Kangaroos are a protected species under the *NSW Biodiversity Conservation Act 2016*, but policies for commercial utilisation and licensed culling have been adopted to sustainably manage populations. The licensed commercial harvest of kangaroos allows carcases to be sold to processors for pet food and human consumption as well as hides as a by-product for leather production. The commercial harvest industry has been the focus of kangaroo management policy for decades and continues to be a valuable tool for property managers in some parts of the Western region. Positive aspects of the kangaroo harvest include:

- a higher social acceptability of the use of professional shooters to cull kangaroos than other lethal control measures in terms of animal welfare (Sinclair et al, 2019c). Competency-tested commercial shooters are highly-regarded as providing the most humane measure for the lethal control of kangaroos
- the use of kangaroos as a resource avoids the wastage of carcases and produces a valuable product (Wilson and Edwards, 2019).

The quota-based NSW Commercial Kangaroo Harvest Management Plan has good outcomes for processers and for the conservation of kangaroos in terms of sustaining kangaroo populations. Unfortunately, the effectiveness of the harvest industry for managing total grazing pressure at the property scale is limited for reasons described by Hacker et al (2019b):

- the nominal harvest rate of 15 per cent (western grey, eastern grey kangaroos) or 17 per cent (red kangaroos) was developed to ensure maximum sustainable yield for processing and the conservation of kangaroos as a species rather than management of total grazing pressure
- only a small percentage of the available quota now is harvested, in response to declining product demand. This follows adverse animal welfare and rights activism at a global scale as well as market closure due to contamination and other factors
- a shift to predominantly male-biased harvesting. For instance, in 2019 the harvest of red kangaroos had a 90.2 per cent bias compared to a long-term average of 75.1 per cent (DPIE, 2019). While the male bias reduces joey welfare issues, it limits the effectiveness of culling in reducing overall populations and may produce no outcome in reducing total grazing pressure (Hacker et al, 2004; McLeod and Sharp, 2020).

As a management tool, the ground-based shooting of overabundant wildlife populations is most effective when targeting spatially-restricted populations occurring at low densities in habitats offering little refuge (Bengsen, 2020). It becomes less effective where:

- operations are ad hoc or inconsistent over time
- target species can readily immigrate in from adjacent areas at a faster rate than the culling
- commercial harvesters have a threshold of numbers and weights below which further effort is unrewarding (Bengsen, 2020; Bengsen et al, 2016).

Photo: Ruth Sandow.

In many situations in the Western region, landholders are dealing with high population densities, lack any control of kangaroo movement from adjacent areas and are operating in shrubby or timbered habitats. Harvesters are restricted by minimum weight limits. Consequently, harvesting alone is unlikely to be effective, but it may be an essential component of a broader program incorporating other approaches for control to be effective.

Commercial harvesting ensures kangaroos are killed by professional, accredited and licensed harvesters and this is the basis of public acceptance of this option (Sharp et al, 2014; Sinclair et al, 2019c). Harvesters must adhere to the National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes (DEWHA, 2008a) and conditions on their licenses. The Code covers:

- technical specifications and procedures covering minimum standards for firearms and ammunition
- conditions and procedures for shooting and required competency testing
- conditions and procedures for the euthanasia of kangaroos and wallabies
- conditions and procedures for the euthanasia of pouch young and joeys
- provisions for special purposes such as circumstances where prescribed firearms may be unsafe
- Local Land Services maintains a register of licenced commercial harvesters. Landholders requiring the services of a professional kangaroo harvester can register to receive the contact details of those working in their area. Major kangaroo processors can also provide information to landholders on the availability of professional harvesters.

Factors influencing the effectiveness of harvesting in managing total grazing pressure are summarised in Table 1.

Effectiveness	No data is available on change of pasture condition, yield or stocking capacity in response to various levels of harvesting.
Acceptability	High social acceptability when harvest is conducted by professional shooters to the National Code of Practice.
Strengths	Kangaroos are treated as a resource so there is no wastage of red meat. No carcases are left in the field to attract potential predators of stock. Landholders do not need to undertake the activity and no cost is incurred for harvesters to operate. The harvest industry creates employment in regional areas.
Weaknesses	Commercial harvesters operate to meet processor requirements in terms of location and size or type of animal. Harvesting may fail to meet landholder requirements for grazing pressure control, especially in drought. Male-biased culling may not reduce populations. As kangaroos are mobile, localised culling can have minimal impact on paddock-scale grazing pressure due to new animals moving in to harvested areas. Landholders receive no return from harvesting and pasture utilised, except under innovative arrangements.

Table 1: Summary of effectiveness of commercial kangaroo harvesting.

2. Non-commercial culling

Where commercial harvest is unable to control kangaroo populations impacting on native pastures and livestock productivity, landholders are entitled to apply for a non-commercial "occupier licence to harm native animals on private property" under the *Biodiversity Conservation Act 2016*. Such circumstances may be when:

- it is not economically viable to take kangaroos commercially
- the commercial kangaroo industry is unable to fulfil the landholder's needs
- management zone commercial quotas are fully utilised
- kangaroo populations are causing extensive damage and competing with livestock for food, water and other resources (Office of Environment and Heritage, 2019).

Non-commercial licences were previously referred to as 'shoot and let lie' permits but the tagging and leaving lie condition has been removed to reduce biosecurity risks. This allows the landholder the option of disposing of carcases if desired to avoid feral animal scavenging. Limited non-commercial use of carcase parts is permitted.

To obtain a licence to harm kangaroos, wallaroos and wallabies, landholders must:

- complete an application form for a licence to harm kangaroos and submit with any required documentation to the local National Parks and Wildlife Service (NPWS) office by email, post or in person
- if the landholder has been granted a licence to harm native animals in the past few years, the information required in the application form may be provided by phone to the local NPWS office.

Changes to this system to assist landholders manage the impact of kangaroos during the recent drought include:

- ecologically sustainable limits on the number of kangaroos that may be culled under each licence, based on property size. Limits are reviewed annually according to kangaroo populations published in the Commercial Kangaroo Harvest Management Plan Quota report
- allowance of more shooters operating under each licence. Shooter details are to be provided to the NPWS after culling operations, rather than with the licence application
- landholders and shooters can use carcases for non-commercial purposes.

Licences to harm kangaroos are subject to conditions under the *Biodiversity Conservation Act 2016* to which the landholder is held responsible. In particular, culling operations must be undertaken in compliance with the National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes, (DEWHA, 2008b). Key elements of the Code include:

- technical specifications and procedures covering minimum standards for firearms and ammunition
- conditions and procedures for shooting
- conditions and procedures for the euthanasia of kangaroos and wallabies
- conditions and procedures for the euthanasia of pouch young and joeys
- provisions for special purposes such as circumstances where prescribed firearms may be unsafe, as well as shooting for scientific purposes.

Additional information on non-commercial kangaroo shooting is available in the NSW DPI Volunteer Non-Commercial Kangaroo Shooters Best Practice Guide (DPI, 2018).

The conduct of non-commercial culling operations according to the code is extremely important and landholders should be aware of compliance under the conditions of their licence. Recent information suggests that non-commercial culling has very poor social acceptability in terms of animal welfare, so it presents a high reputational risk for agriculture within the Western region (Sharp et al, 2014; Sinclair et al, 2019c). There is a wide perception that culling operations have been undertaken on an ad-hoc basis and code requirements have not been addressed. Key issues include the competency of shooters to reliably achieve a quick kill as well as the effective euthanasia of pouch young and joeys. Previous instances of poor practice where animal welfare was been compromised have been widely publicised by groups opposed to this type of cull.

There has been no data collected on the effectiveness of non-commercial culling in reducing total grazing pressure and the outcome of improving pasture condition or yield. Generally there is an assumption that removal of kangaroos from a population will reduce competition with stock as well as reducing grazing pressure. As indicated previously, the ground-based shooting of overabundant wildlife populations is most effective when targeting spatially-restricted populations occurring at low densities in habitats offering little refuge. It becomes less effective where operations are ad hoc or inconsistent over time, in scrubby habitats and where target species can readily immigrate from adjacent areas at a faster rate than the culling (Bengsen, 2020; Bengsen et al, 2016). Non-commercial culling is therefore likely to be most effective where it is a component of a broader program incorporating other approaches such as exclusion fencing.

The value of non-commercial culling is summarised in Table 2.

Effectiveness	No data is available on change of pasture condition, yield or stocking capacity in response to various levels of harvesting.
Acceptability	Low social acceptability when cull is conducted by untrained shooters. Social acceptability will be higher when culling is conducted by professional shooters to the National Code of Practice.
Strengths	Landholder has control of culling operation. Approval process is readily accessible. Code provides robust controls on method.
Weaknesses	Illegal operations and poor adoption of the mandatory Code of Practice are a significant risk to the animal welfare credentials of the grazing industry and social licence to manage kangaroos. As kangaroos are mobile, localised culling can have minimal impact on paddock-scale grazing pressure due to new animals moving in to harvested areas. Landholders must invest time in culling or seek other shooters. Carcases remain in the paddock, attracting potential predators of stock.

Table 2: Summary of effectiveness of non-commercial culling as a management tool.

3. Control of water-points

The increased abundance of artificial stock watering points across the Western region is regularly cited as one of the factors causing kangaroo overpopulation as animals are less constrained by distance from water in seeking forage. On this assumption it therefore makes sense that controling of artificial watering points (troughs, flowing bores and ground tanks) so that they can be closed when paddocks are destocked will reduce kangaroo activity. Kangaroos appear to preferentially graze destocked paddocks and this prevents effective spelling of pastures.

In reality, the outcomes of closing destocked water points are not clear cut. Research on the response of kangaroo grazing patterns to water point closure has been inconclusive to date. Reviews have found that existing studies have been based on water points too close to other water sources, in terms of kangaroo mobility and that the period of observation has been too short to detect responses either in the density of kangaroos or vegetation condition (Lavery et al, 2018; Fukuda, 2009). Additionally, studies have usually been undertaken in National Parks, where the intent is permanent removal of the water source for conservation purposes rather than temporary closure for grazing management. Therefore, the impact of short-term closures on biodiversity, for instance, has not been considered.

As previously indicated in Section 3, red kangaroos have highly efficient water metabolism, large home ranges and require infrequent access to water. Eastern and western grey kangaroos are also less water-focussed but have smaller home ranges and possibly a greater requirement for shade than daily drinking (Dawson, 2012; Letnic et al, 2014). Consequently, water point closure is most likely to bring about a decrease in grazing pressures in situations where the resultant distance between waters is greater than 10 kilometres and where grey kangaroos predominate (Lavery et al, 2018). Closing artificial water points could be most effective when kangaroos are on dry feed with the onset of summer conditions when air temperatures rise and animals require additional water for thermoregulation (Underhill, 2007).

Concerns for the welfare of animals denied access to water following closure are sometimes raised and a survey of social acceptability amongst various stakeholders rated this control practice lower than fencing or shooting for this reason (Sinclair et al, 2019c). This highlights the importance of managing water point closures to ensure no animals perish either through hanging on an empty trough or exclusion fence or alternatively getting trapped within a fenced area. In particular, closure of an existing water point may result in western or eastern grey kangaroos failing to move on. Management must be in place to cull kangaroos in this situation before welfare issues arise. Once a closure has been in place for some time, this issue should diminish as resident kangaroos adjust behaviour. The concerns around entrapment can be addressed by providing one-way swing gates or spears to allow stranded animals inside to exit the fenced area. Such gates should be a standard fitment to ground tank fencing.

The potential benefits from closing off artificial water points in paddocks that have been destocked include:

- discouraging use of pastures by kangaroos as they will have to travel further to find water. In particular, this is likely to move grey kangaroos to areas where they can have easier access to water as they tend to travel less than red kangaroos. Leaving waters open invites kangaroos in to paddocks that are otherwise free of stock
- the approach is a long-term management measure. Kangaroos will adjust their home ranges to accommodate the loss of a permanent water source
- water point closure is effective in discouraging the use of destocked areas by pest animals including feral pigs, wild dogs and unmanaged rangeland goats (Letnic et al, 2014)
- the capacity to manage biosecurity will be substantially enhanced. There will be an increased capacity to ensure that wandering stock are absent from destocked areas
- water supply will be preserved by reducing consumption by kangaroos and pest species. Water quality will also be improved as contamination by dead animals will be reduced
- during drought, kangaroos often bog and drown in ground tanks, contaminating water supplies. This is a factor for human as well as animal health as ground tanks are often the basis of homestead supplies. The bogging of kangaroos in drying tanks is also a significant animal welfare issue that also consumes the time and emotions of compassionate landholders who attempt to rescue them. There is a safety risk for landholders attempting to rescue bogged kangaroos as they may become aggressive when handled
- other wildlife impacts should be minimal. Emus will be excluded from water but are mobile. Concerns that exclusion fencing may affect echidnas have been raised, but these species do not require access to open water for survival.

A summary of the effectiveness of closing water points to manage kangaroo impact is presented as Table 3.

Effectiveness	Trial results are inconclusive. Anecdotes suggest some benefit.
Acceptability	Low social acceptability due to the welfare risk of wildlife being excluded from water or entrapped within an enclosure.
Strengths	The closure of water-points should discourage kangaroos from utilising destocked paddocks and allow for the maintenance or recovery of pastures. The practice has high biosecurity benefits as feral animals and wandering stock can be discouraged from inhabiting destocked areas. It prevents bogging and drowning in ground tanks, preserves water supply and may improve water quality. Western grey kangaroos are relatively sedentary and will be most affected by control of access.
Weaknesses	Red kangaroos require little water and resident animals may utilise pastures regardless of closure. Fences around ground tanks will be subject to high pressure unless sited at distance from the water. Closed waters will require regular monitoring to avoid animals perishing or getting caught inside a fenced enclosure. This can be minimised by one-way gates.

Table 3: Summary of effectiveness of water point closure as a management tool.

Where a piped reticulation system already exists, water point closure may simply involve closing off a tap on a trough when stock are removed. In other cases, getting control of a water point may involve a large project to cap a flowing artesian bore and installing pipes and troughs.

In the case of ground tanks, closure may involve the construction of a trap yard for managing goats or similar. A minimum setup could involve the construction of robust exclusion fencing situated at sufficient distance from the water supply to minimise localised pressure points and to ensure suitable terrain for erection, minimising weak spots where catch drains and other features are crossed.

Kangaroos can place heavy pressure on fencing, especially if desperate for water and sensing its close presence, so larger exclosures, keeping animals further from the water, are likely to be more effective and require less maintenance. One suggestion is to erect fences around waters before the need for access is high, so that animals are "trained" to a fence early on. The minimum fence design should include a height of 1,500 mm and a 300 mm apron, which is readily feasible using currently available exclusion fence products.

Table 4 provides estimates of the required fence length based on aligning the fence to be a certain distance from water at a ground tank.

Distance of fence from water	Side length	Total fence length	Area of closure
500 m	1,000 m	4,000 m	100 ha
375 m	750 m	3,000 m	56.25 ha
250 m	500 m	2,000 m	25 ha
125 m	250 m	1,000 m	6.25 ha

Table 4: Fence requirements for exclosures at various distances from water at a ground tank.

Two decades ago, a trough arrangement protected by an electrified ground wire (termed Finlayson trough) was widely-trialled as a water exclusion measure. This was found to be ineffective as kangaroos quickly learnt to avoid the live wire (King et al., 1996). Similarly, the use of machine vision technology to control gated access to fenced water points has been assessed but not progressed to practical implementation (Finch et al., 2006).

4. Fencing for kangaroo control

Fencing has been increasingly adopted for kangaroo control over the past decade in association with the increasing availability of prefabricated mesh products primarily marketed for wild dog control and a trend to better manage free-ranging goats. Fences provide for the long-term management of kangaroo populations whereas lethal methods involve ongoing short-term responses to fluctuating numbers. The main reasons to fence include:

- the control of several pest species including unmanaged rangeland goats, wild dogs and feral pigs as well as kangaroos. The effective containment of meat sheep breeds has also been a driver
- the establishment of a paddock or property perimeter to make culling more effective. Numbers can be reduced without the inwards movement of other kangaroos
- the exclusion of all unmanaged herbivores to permit the periodic resting of native pastures, an essential component of improving rangeland grazing systems and regenerative management. This addresses the selective grazing behaviour of kangaroos, which can occur even at low densities
- the absolute protection of crops and horticultural plantings from unmanaged grazing.

Fencing is a long-term solution, but ongoing maintenance and management is essential. Fences can be highly effective in controlling kangaroo access if of sound design, well-constructed and regularly maintained. They are a tool to control kangaroos, but not a management system. Better production and biodiversity outcomes will only be achieved if the improved control of grazing pressure is used to strategically manage pasture condition. In the absence of effective grazing management, fencing only results in shifting the cause of overgrazing and pasture decline from kangaroos to livestock.

Fencing has a secondary benefit. Landholders are gradually recognising the benefits of better fencing for animal biosecurity for both husbandry issues such as the segregation of flocks to avoid ovine brucellosis as well as potential emergency disease situations. Over the past decade, many landholders have developed dorper sheep enterprises, which require a higher standard of fencing than formerly required for traditional merino operations for containment of stock and in particular avoiding cross-breeding or wool contamination problems.

Three main approaches to fencing for kangaroo management have been adopted in the Western region, predominantly east of the Darling River:

- total grazing pressure fencing
- enhanced total grazing pressure fencing, also termed density fencing
- exclusion fencing.

a. Total grazing pressure fencing

The term total grazing pressure (TGP) fence has been applied to fencing of 1.2 m height built to a goat-proof standard, which provides partial exclusion of kangaroos. This style of fencing is generally constructed of prefabricated mesh wire products such as Hingejoint™ but designs based on multiple electric wires such as Weston Fencing ™ as well as multiple (eleven) plain wire fencing are also in use. The cost of construction excluding labour is approximately $3,250 p/km and inclusive of labour up to $6,000 p/km (June 2020 rates). Table 5 provides a summary of the effectiveness of this approach.

TGP fencing is highly effective for controlling the movement of unmanaged rangeland goats and dorper sheep, but also provides exclusion of a large proportion of kangaroos. All but the larger kangaroos tend to move along TGP fences or attempt to push under, rather than risking jumping over the wire.

However, when stressed or under pressure, most kangaroos will attempt to clear the fence. Kangaroos desperate for feed or water will increasingly pressure these fences during drought. As TGP fencing provides partial exclusion only, enclosed areas require more management to remove kangaroos than paddocks surrounded by exclusion fencing

Landholder experience indicates that the culling of kangaroos within a TGP perimeter will be more effective if subdivided into smaller-sized paddocks, especially if the country is scrubby and provides cover.

TGP fencing has limited effectiveness in containing feral pigs and reportedly deters but does not exclude wild dogs.

A preliminary assessment of the effectiveness of this type of fence in controlling kangaroos was undertaken near Cobar through camera monitoring of animal responses to fencing. Eleven motion-sensing cameras were deployed at sites along two fence lines on the boundary of a paddock fenced with Hingejoint™ as well as a plain wire fence with leaning electric offsets over a period of several weeks. The analysis of images indicated that while kangaroos continuously investigated and patrolled the fence, very few instances of jumping were recorded (see Figure 4). No kangaroos were recorded colliding with the fence.

Most activity along the fence consisted of kangaroos patrolling, seeking pre-existing holes or breaches (see Photos 2, 3, 4 and 5). Movement through holes under the fence appeared to be a learned behaviour adopted by individual kangaroos and at certain sites only, where feral pigs had initiated the breach. Jumping events appeared to coincide with other stimuli such as nearby vehicle movements (Photo 6).

In summary:

- TGP-style 1,200 mm high fences provided for significant but not complete control of kangaroo movement around the paddock. Kangaroos are most likely to patrol fences looking for weaknesses rather than attempting to jump over
- an on-going maintenance regime, especially in repairing holes under the fence, is essential to maintain effectiveness
- under normal to dry seasonal conditions, the fences provide a level of movement control that is likely to assist in regenerative pasture management or improved livestock production as long as some regular culling is in place.

Table 5 provides a summary of the effectiveness of the TGP fencing approach.

Effectiveness	Moderately effective as provides partial exclusion. Potential pasture response can be significant, as validated by research. However, outcomes are dependent on individual landholder skills and commitment to grazing management.
Acceptability	Moderate social acceptability.
Strengths	Moderate cost, especially as an upgrade to existing fencing. Allows for some movement of kangaroos. Provides a basis for improved biosecurity as well as adequate containment for dorper sheep and managed goat enterprises. Effective control of TGP delays onset of drought if conservative grazing management is adopted. Facilitates the implementation of better grazing management to improve pasture condition.
Weaknesses	TGP fencing provides partial exclusion only, so during periods of drought there will be increasing kangaroos crossing the perimeter. Fences require ongoing maintenance, especially in relation to holes dug under the wire, to remain effective. However, aprons and electric offsets can address most issues. Some welfare issues with entanglement of jumping kangaroos, especially during the first six months after construction. Fences constrain emu movement, which has fence damage and animal welfare implications.

Table 5: Summary of effectiveness of TGP fencing as a management tool.

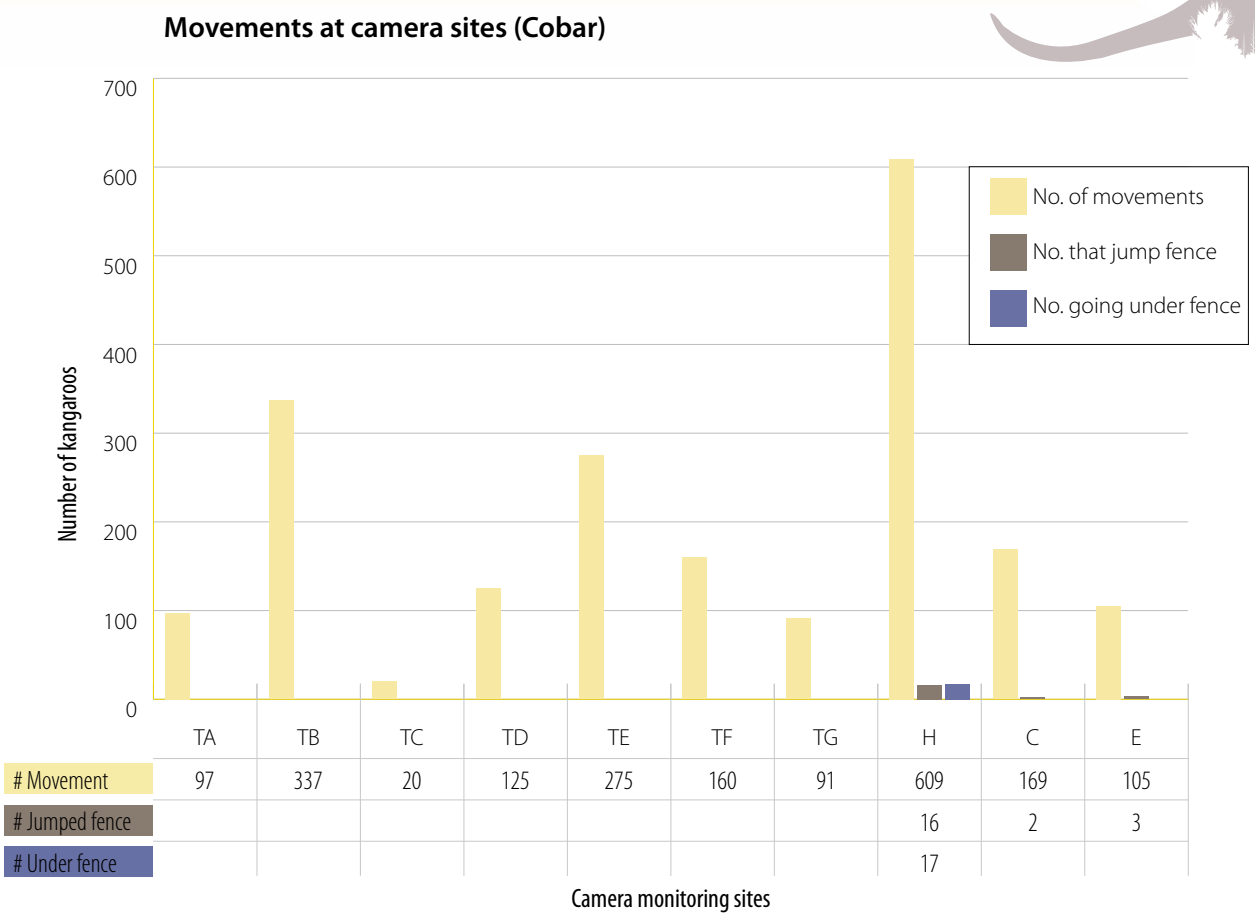

Figure 4: Camera records of kangaroo activity along a TGP fence. Monitoring occurred over 38 days in August-September 2017.

Photo 2: Large red kangaroo tests fence but does not jump.

Photo 4: Red kangaroo group patrols a fence but does not breach. Only certain individuals use a hole under the fence near the gate.

Photo 3: Red kangaroo investigates fence with trial reflectors to increase visibility. This type of visual enhancement provided little deterrent to the patrolling of the fence.

Photo 5: Kangaroos infrequently jumped the fences. When jumping did occur, it often correlated with nearby vehicle movements and was possibly a flight response.

Photo 6: TGP fence with prefabricated mesh, constructed 1,200 mm high with 50 mm ground clearance. A selvedge wire supporting the centre of the mesh would make this fence more robust.

I. Prefabricated mesh fences

Mesh-type TGP fencing based on products such as Hingejoint™ have been increasingly used in the Western region over the past decade to control unmanaged rangeland goats and dorper sheep. These fences are based on traditional designs augmented with mesh. Landholders adopting this type of fencing report a range of outcomes, however there is consensus that standard 1,200 mm high Hingejoint™ fencing significantly reduces kangaroo movement and makes cull operations more effective. The fences exclude goats, deflect the movement of wild dogs, but feral pigs have the strength to push underneath or through the mesh unless it has an apron.

Experience gained through a decade of incentive-funded projects across many landholdings in the Western region indicate several proven design elements of TGP fences:

- a mesh size of similar to 7/90/30 with 2.5 mm top and bottom wires. Goats tend to get their heads stuck in fences with vertical wires spaced at 15 cm, presenting a welfare issue
- mesh should be supported by 2.5 mm high tensile top and bottom selvedge wires and a belly wire to minimise damage from animals. This may be omitted only if superior quality mesh is installed
- 165 cm star pickets should be installed at a maximum 10 m spacing. Some soil types promote corrosion and this should be considered in selecting the quality of picket
- in-line strainers should be placed at a maximum spacing of 500 m
- the bottom wire of the fence should be no more than 100 mm above ground level. The use of a bottom 1.57 mm barbed wire will deter passage under the fence but will catch leaf litter in drainage areas
- the top wire may be 2.5 mm plain or 1.57 mm barbed wire. Barbed wire may be necessary in the presence of cattle but may also lead to more entanglements with kangaroos jumping the fence.

Kangaroos will seek to push or dig under TGP fences where opportunities arise, especially on sandy ground or where there is an uneven surface. This must be anticipated and can be managed by:

- installing apron mesh either locally or along the entire fence
- installing leaning poly offsets with hot wires
- regularly inspecting fences and blocking holes
- diagrams of these designs are presented as Figure 5 and an example illustrated in Photo 6. Further design considerations are presented in Part 5.

Mesh fencing has moderate social acceptability, but concerns exist about kangaroo entanglement, disruptions to the movement of emus or other wildlife and the potential build-up of kangaroo numbers on the outside of new TGP fences.

As well as being a welfare issue and reputational risk, entanglements damage fences. Design factors that may reduce entanglement include:

- improving fence visibility, especially in high traffic areas, by using methods such as a top horse sighter wire for instance
- use of short droppers between pickets to maintain the separation of the top wires
- minimising the use of barbed wire.

The potential build-up of kangaroos on the outside of a fence should be considered during the planning phase by having an arrangement in place to manage high densities preferably using a professional kangaroo shooter. Innovators are seeking a structure to pass emus through TGP fencing. A design for an "emu-stile", yet untried in this region, is presented in Part 5.

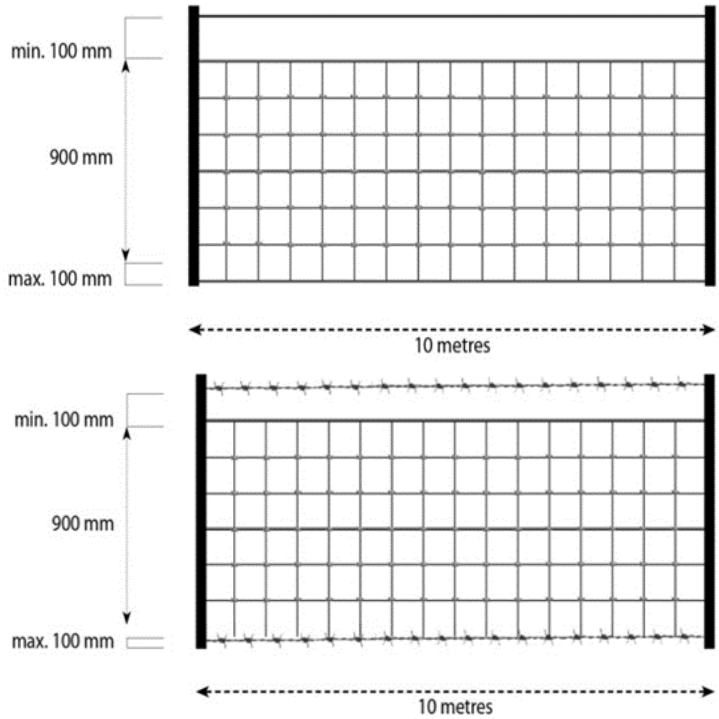

Figure 5: TGP fence designs using plain and barbed wires.

Photo 7: Ten wire fence including barb top and bottom.

II. Multi-wire fencing

Multi-wire fencing consists of up to 11 plain wires strained tight with closely-spaced droppers between the star pickets. The advantage of these fences over prefabricated mesh fences lies in their greater capacity to absorb animal impacts without damage and ease of repair. A minimum specification for such a fence should include:

- eleven lines of 2.5 mm plain wire. The bottom wire should be less than 100 mm above ground level
- 165 cm star pickets should be installed at a maximum 10 m spacing. Some soil types promote corrosion and this should be considered in selecting the quality of picket
- two full height droppers between each picket
- in-line strainers should be placed at a maximum spacing of 500 m.

A generalised design of this type of fencing is provided in Figure 6 and an example is presented in Photo 7.

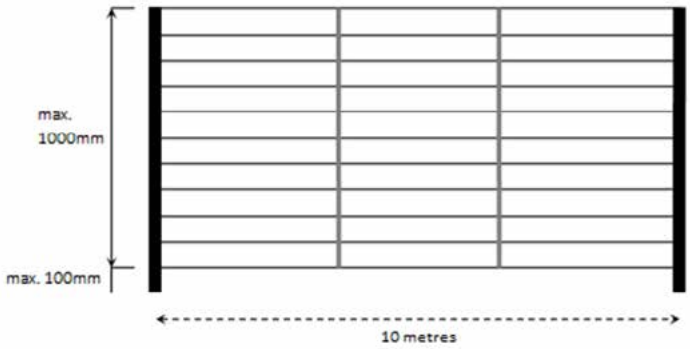

Figure 6: Design concept for 11 line plain wire TGP fence.

III. Electric fencing

Multi-line electric fencing systems using poly droppers (e.g. Westonfence™) have been used widely in the Western region and are highly effective in controlling kangaroo movement. These fences are effective in controlling kangaroos and unmanaged rangeland goats as well as excluding wild dogs if configured for this purpose.

The fences are cost effective, consisting of up to eight lines of plain wire attached to poly droppers supported by steel pickets at a maximum 10 m spacing. Up to three poly droppers are installed between star pickets.

Figure 7 provides a generalised design diagram for this type of fencing and an example is presented as Photo 8. Fences can be readily-erected using a mechanised construction system.

Existing fencing can be upgraded to control kangaroo movement by using leaning poly offsets to carry one or two electrified plain wires. This approach is highly effective in limiting kangaroos from digging under fences.

Electrified wires should not be used in a fence in proximity to barbed wire due to potential animal welfare issues in the case of entanglement (refer Australian/New Zealand Standard™ Electrical installations –Electric fences AS/NZS 3014:2003).

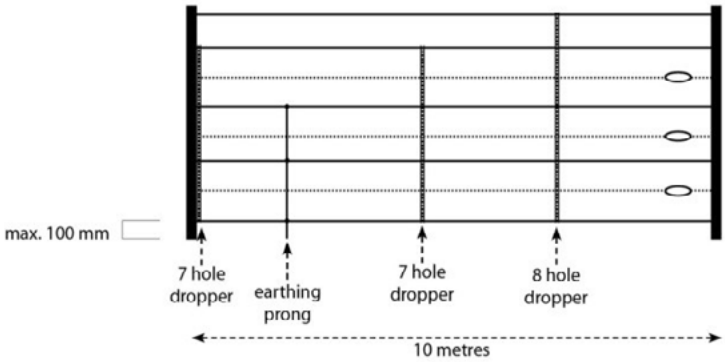

Figure 7: Design concept for eight line electric fence.

Photo 8: Electric TGP fence with ten wires supported by poly droppers.

Photo 9: Enhanced TGP fence. Top two wires are supported by every third picket.

b. Enhanced TGP fencing (or density fencing)

For some time, innovative landholders have been constructing standard TGP fences with every second post being a tall 180 cm picket and running two additional plain wires at low tension above the standard mesh and wires. This approach costs slightly more than a standard TGP-standard fence but less than an exclusion fence.

The additional height discourages kangaroos from jumping and the fences are consequently more effective as well as being less prone to entanglement. The top wires experience little pressure but should be of high-tensile plain wire, that is strained sufficiently to avoid kangaroos getting caught in the wires if they do jump (Soils for Life, 2020).

Many landholders who have erected TGP-standard fencing to control unmanaged rangeland goats regret that they did not install a taller fence to control kangaroos. However, the taller configuration can be retrofitted to existing TGP fences by adding longer pickets to every second post or by installing steel or poly post extenders which are now marketed for the purpose. The effectiveness or cost-benefit of these fences has yet to be evaluated.

Table 6 summarises the key features of density fences and Photos 9 and 10 illustrate typical configurations.

Photo 10: Fence constructed with 900 mm mesh with additional plain wires to 1500 mm height.

Effectiveness	Provides a higher level of exclusion than TGP fencing. Pasture response appears to be significant, but is dependent on individual landholder expertise and commitment to grazing management. No structured evaluations have been done.
Acceptability	Anticipated moderate social acceptability similar to TGP fencing.
Strengths	Cost is only marginally greater than 1200 mm high TGP fencing but provides increased exclusion of kangaroos. Cheaper construction than exclusion fences. Provides a basis for dorper sheep and managed goat enterprises. Discourages jumping, so reduces the likelihood of kangaroos getting caught in fence. Control of TGP delays onset of drought and facilitates the implementation of better grazing management to improve pasture condition.
Weaknesses	Fences require ongoing maintenance, especially in relation to holes dug under the bottom wire, to remain effective. However, aprons and electric offsets can address most issues. Fences constrain emu movement which has animal welfare and fence damage implications.

Table 6: Summary of effectiveness of enhanced TGP fencing as a management tool.

c. Exclusion fencing

In recent years, increasing demand for predator-proof fencing to manage wild dogs has stimulated the development of new exclusion fence products from several manufacturers. Fences constructed of these materials are typically 1.5-1.8 m in height, with progressive mesh spacing and including either an integrated folded or hinged apron at the base. The purpose of the apron is to discourage pests or fauna from digging under the fence.

Exclusion fences are effective as a barrier to kangaroos but also have the benefit of controlling the ingress of wild dogs, unmanaged rangeland goats, deer and pigs. The cost of construction including labour is approximately $8,000-$11,000 per kilometre depending on product type. As with all fencing, the cost-benefit is dependent on the effectiveness of subsequent management. There are a range of pasture recovery outcomes reported from exclusion fencing associated with cluster groups in Queensland, but to date these have primarily reflected individual management styles and the dry seasonal conditions (Allen, L. R., 2017).

There is a range of exclusion fence products and minimum specifications vary. Picket spacing is generally eight metres or less, with a heavy duty post at every third or fourth interval. Quick-attach posts are favoured to minimise construction time. The apron is a critical component of the performance of these fences to prevent animals digging under. Fixed folding aprons are tensioned with the fence, while hinged aprons can be strained to maximise effectiveness (Kondinin Group, 2016). These aprons are illustrated in Photos 11 and 12.

Exclusion fencing has a moderate social acceptability, slightly lower than TGP fencing as a result of its perceived adverse impacts on wildlife (Sinclair, 2019c). These include:

- barrier effects, which could affect the long-term genetic viability of populations of fauna isolated within an exclusion fence. Kangaroos and emus are the main species likely to be affected, but these animals are abundant in the Western region, with population densities up to 500 per cent of those recorded in adjacent semi-arid areas where they are subject to predation
- mortality due to entanglements or collisions with the fence. However, kangaroo and emu mortality associated with entanglement may be lower than that associated with conventional or TGP fencing, as animals are less likely to attempt to traverse the fence
- stress on animals, especially kangaroos and emus, where movement patterns and access to water are blocked by the fence
- the use of mesh fences by predators to trap prey such as mallee fowl has also been suggested. However, ground-dwelling birds may actually benefit from the containment of predators by the fence
- bird and bat mortality through collision with exclusion fences. This is possible but not at a scale warranting remedial action (EnviroKey, 2017).

The juveniles of most small to mid-sized animals can pass through standard fence mesh sizes and the main species potentially impacted will be echidnas and large goannas (DEWNR, 2017; EnviroKey, 2017). The extent of exclusion fenced areas is a consideration in relation to the effect on wildlife movement, whether they form "islands" which species like emus can move around, or become connected, which will have a greater impact (Bradby et al, 2014).

Improved biosecurity is an important co-benefit of exclusion fencing. Good fencing suited to controlling the movement of feral animals as well as livestock is a key component of biosecurity planning (Animal Health Australia, 2012). The mobility of unmanaged rangeland goats, feral pigs and deer through areas with traditional pastoral fencing presents a substantial risk to exotic disease containment in the Western region. Exclusion fencing reduces such movement.

Photo 11: Exclusion fence with folded apron.

Photo 12: Exclusion fence constructed with hinged apron.

Table 7 summarises the value of exclusion fencing.

Effectiveness	Provides complete exclusion. Potential pasture response similar to TGP fencing which is validated by research. However, outcomes are dependent on individual landholder skills and commitment to grazing management.
Acceptability	Moderate social acceptability. Concerns focus on effect on movement of wildlife.
Strengths	Provides total control of kangaroo movement, as well as that of other pest species and is a long-term measure. Gives landholders complete control of grazing pressure and facilitates the implementation of better management to improve pasture condition. Co-benefit of improved containment for biosecurity purposes.
Weaknesses	Cost-effectiveness has yet to be established and will depend on grazing management, but anecdotal evidence suggests high return on investment. Requires strategies to address initial kangaroo and pest concentrations, both inside and outside of the fence. Long-term impacts on internal kangaroo populations and other wildlife need to be addressed. Proliferation of fences will impact mobile wildlife, especially emus.

Table 7: Summary of effectiveness of exclusion fencing as a management tool.

5. Fence legal, design and maintenance considerations

a. Statutory requirements

The fencing of land within the Western region is subject to several legal requirements, especially in relation to boundary fence issues. The statutory framework is defined by the *Dividing Fences Act 1991*. Other legislation relevant to the construction and maintenance of fence lines include the *Crown Land Management Act 2016* and the *Crown Land Legislation Amendment Act 2017* (which superseded the *Western Lands Act 1901*), the *Local Land Services Act 2013, Local Land Services Amendment Act 2016, Biosecurity Act 2015, Biodiversity Act 2016* and *National Parks and Wildlife Act 1974*.

I. *Dividing Fences Act 1991*

The *Dividing Fences Act 1991* is the primary Act covering boundary fencing in NSW. It defines the relationships between neighbours in erecting boundary fences, especially in relation to the type of fencing regarded as sufficient:

> Part 1 Preliminary
>
> 4. Determination as to "sufficient dividing fence". In any proceedings under this Act, the Local Court or the Civil and Administrative Tribunal is to consider all the circumstances of the case when determining the standard for a sufficient dividing fence for the purposes of this Act, including the following:
>
> (a) the existing dividing fence (if any), (b) the purposes for which the adjoining lands are used or intended to be used, (c) the privacy or other concerns of the adjoining land owners, (d) the kind of dividing fence usual in the locality, (e) any policy or code relating to dividing fences adopted by the council of the local government area in which the adjoining lands are situated, (f) any relevant environmental planning instrument relating to the adjoining lands or to the locality in which they are situated, (g) in the case of a dividing fence affecting land the subject of a lease under the Western Lands Act 1901, any order in force under section 18A of that Act.

In relation to erecting fences of a higher standard than a "sufficient dividing fence", such as an exclusion fence, the following applies:

> 7. Contribution as between adjoining owners—generally (1) adjoining owners are liable to contribute in equal proportions to the carrying out of fencing work in respect of a dividing fence of a standard not greater than the standard for a sufficient dividing fence. (2) An adjoining owner who desires to carry out fencing work involving a dividing fence of a standard greater than the standard for a sufficient dividing fence is liable for the fencing work to the extent to which it exceeds the standard for a sufficient dividing fence.

The implication of this are that there is no impediment to a landholder constructing a higher standard fence as long as they carry the extra cost.

Photo: Corey Stenhouse.

II. Other statutory requirements

Other NSW Acts that may influence exclusion fences in the Western region are indicated in Table 8.

Statute	Requirement
Crown Land Management Act 2016 *Crown Land Legislation Amendment Act 2017*	Lessee must carry out the repairs to improvements on the leased land. The Minister is taken to have given written consent on behalf of the Crown (as the owner of Crown land under a perpetual Western lands lease) for the lessee of that land to make a development application relating to any of the following kinds of development: (b) the erection, repair, maintenance or replacement of a fence on the land.
Local Land Services Act 2013 *Local Land Services Amendment Act 2016*	Clearing of native vegetation along fence lines. Adjoining controlled TSR, 100 per cent of cost.
Biosecurity Act 2015	Biosecurity plans, general biosecurity duty for pests.
Biodiversity Conservation Act 2016	Management of kangaroos within fenced areas.
National Parks And Wildlife Act 1974 *National Parks and Wildlife Amendment (Aboriginal Objects and Aboriginal Places) Regulation 2010*	Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales (DECCW, 2010). The location of Aboriginal objects must be reported regardless of whether they are on public or private land.
Heritage Act 1977	Items of state significance can be registered on the NSW State Heritage Register, including items of Aboriginal cultural significance.

Table 8: Other statutory requirements relevant to fence construction.

The potential for damage to Aboriginal cultural heritage sites during exclusion fence construction presents legal and reputational risks for individuals and cluster groups. The reputational risks include the alienation of local Aboriginal people as well as adverse media attention. The legal risks lie in contravening provisions of the *National Parks and Wildlife Act 1974*- Part 6 Aboriginal objects and Aboriginal places and the National Parks and Wildlife Amendment (Aboriginal Objects and Aboriginal Places) Regulation 2010. It is illegal to harm Aboriginal objects or places under Section 86 of the Act.

Fencing on land that has been disturbed ("...the subject of a human activity that has changed the land's surface...") is prescribed as a low impact activity under the regulation, which can be used as a defence to a prosecution under the Act. Clearing is not included as a low impact activity and specifically harm to an Aboriginal culturally-modified tree is also excluded.

The clearest defence for landholders undertaking fencing projects is to implement the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales (DECCW, 2010). This will provide certainty on the legality of the proposed works.

The clearing of native vegetation for the construction of fence lines is an allowable activity under the *Local Land Services Amendment Act 2016*. The clearing must be undertaken to the minimum extent necessary to build and maintain the infrastructure. The maximum distance of clearing for rural infrastructure in the Western Division is 40 m. Clearing advice should be sought through Local Land Services.

b. Fence design considerations

All fences should be designed and constructed according to the fencing material manufacturer's recommendations. However, gateways, grids, gullies, creek channels and overland flow areas are key weaknesses in fences as well as areas of erosion or disturbances from burrowing animals (Kondinin Group, 2016). These need special consideration generally not available in specifications from fencing material distributors.

I. Alignment

Determining the alignment of new fences may be simple, just following the line of an existing boundary fence for instance. However, if a new alignment is chosen, considering several factors can significantly reduce long-term maintenance costs, improve fence longevity and minimise erosion damage to adjacent areas:

- keep access tracks and fence lines out of areas where runoff is concentrated, even shallow depressions that may have heavier vegetation cover
- seek to use natural drainage to advantage by following high ground such as broad crests and rises, where runoff will disperse naturally
- cross drainage depression areas perpendicular to the direction of flow. Try to preserve natural flow patterns. Do not follow a drainage depression as runoff will concentrate along the fence
- where possible, keep gateways and other pressure points on stable areas such as the crest of a rise, away from runoff areas
- sharp fence direction changes can create pressure points where numbers of animals congregate and get caught, sometimes even perishing. Avoiding such corners can reduce welfare issues and also minimise fence damage
- aerial photography or satellite images, together with local knowledge, can assist in this sort of planning.

II. Overland flow areas

Consideration of overland flowlines and broad floodplains can minimise future flood or storm damage. These areas are not 'gullies' as such but include areas of shallow low-flow in heavy rain events, which carry large volumes of water and debris. Fence designs will need to accommodate the movement of debris and the additional pressure of flow and sediment. Designs may include a heavy top (hinge) wire with droppers suspended to support Hingejoint™ or Weldmesh™, with floats on the bottom wire. End assemblies or at minimum in-line strainers should be installed at each margin of the flow area.

III. Floodgates

Where there is a creek, stream or river with a defined channel, a floodgate will be required. A common approach is to install end assemblies or in-line strainers on each side of the waterway and swing sheep-yard mesh hinged from a 4 mm bull wire across the top. A weighted centre section (using 50 mm pipe or equivalent) will help keep the mesh in place (see Figure 8 and Photo 13).

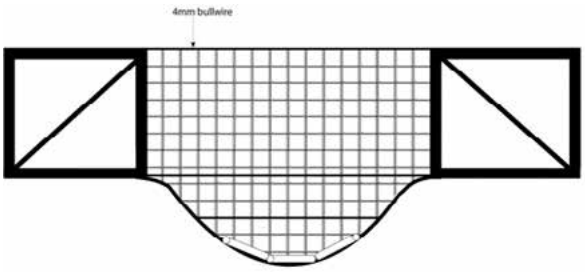

Figure 8: Design for floodgate.

Photo 13: Example of exclusion fence floodgate.

Photo 14: Trap yard with horse sighter wire to improve visibility of fence height.

IV. Gateways and grids

The infiltration of kangaroos can occur through gateways where there is a gap underneath created by soil erosion due to concentrated runoff. This can be addressed through installing trafficable banks on tracks leading to the gate to disperse rather than concentrate runoff. Gates need to be latched tightly enough to prevent kangaroos squeezing through. Movement sensors attached to alarms and light systems have been used to limit movement over grids.

V. Fence visibility

Having fences that minimise impacts on wildlife is beneficial in reducing fence damage and maintenance as well as reducing reputational risks if animal welfare issues are discovered. Fences that are readily visible to kangaroos and other wildlife may reduce entanglements and damage, especially if a new fence crosses a well-used access route. Approaches that can be taken include:

- the use of horse sighter wire on the top line of the fence to improve visibility of height (see Photo 14)
- the use of orange poly pickets, especially on electric fences, has been assessed as improving visibility and reducing damage. These are available from distributors in South Australia and Queensland.

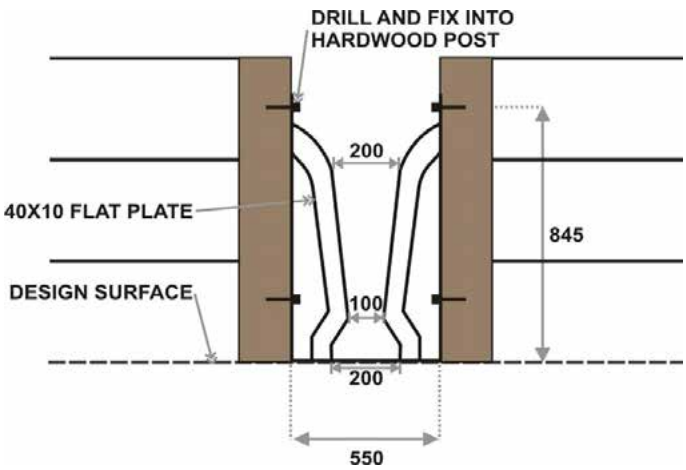

Figure 9: Emu exit point (Clarence Valley Council).

VI. Exit points

A significant criticism of TGP and exclusion fencing as well as the enclosure of ground tanks with fences is the welfare impact on wildlife, especially in relation to disruptions to emu movement. Engineering innovation to develop species-specific fence gaps or gates may be a way to reduce wildlife trauma as well as minimise damage to fences:

- an emu-stile has been developed on the NSW coast for use along major highways to allow the movement of locally-endangered emus off roadways (https://www.clarenceconversations.com.au/40677/documents/127521#:~:text=AVOID%20DANGEROUS%20FENCING,%2C%20owls%2C%20and%20macropods). This approach is untried in the Western region but the design could be adapted to suit local requirements (see Figure 9)
- one-way kangaroo flap gates should be installed in fences around ground tanks to allow escape for an animal that inadvertently finds itself trapped inside. Existing designs are of simple construction (see Figure 10; DEC, 2009). These gates are successful if installed over existing holes under a fence, but otherwise kangaroos are more likely to find escape through a corner gate than through a side gate.

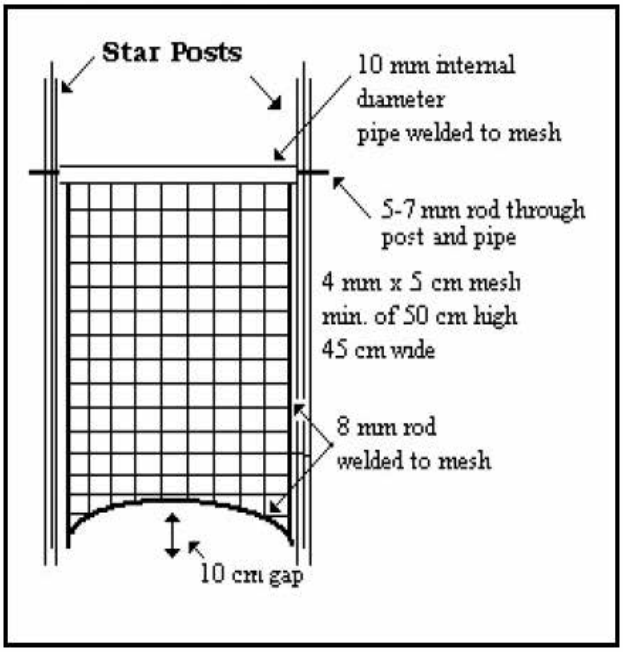

Figure 10: Specifications for kangaroo access gate. (From Fencing and gates to reduce kangaroo damage DEC, 2009

Photo 15: Trafficable diversion bank (whoa-boy) installed along a TGP fenceline, constructed as the fence was built. The bank is installed using survey equipment to ensure runoff from the fenceline and track is safely dispersed.

VII. Fence longevity

The longevity of the prefabricated mesh exclusion fencing products currently on the market has yet to be validated through long-term performance. Fence life may be influenced by:

- corrosion of aprons, especially where in contact with damp or corrosive soils (Kondinin Group, 2016)
- fence design and strength based on the quality of end assemblies and intermediate posts. In particular this affects resistance to wind loading, especially with the build-up of wind-blown material such as buckbush (Kondinin Group, 2016)
- the extent of clearing to minimise damage from fallen timber (Kondinin Group, 2016)
- damage from contact from wildlife and livestock.

Regular inspections of fences and maintenance is critical especially in the first months that the fence is in place while animals test and learn to accept the barrier. Signs of digging should be addressed even if an apron is in place. Sagging wires should be tightened as they increase the chance of entanglement and further fence damage (Kondinin Group, 2016).

c. Construction earthworks

A significant threat to long-term fence integrity comes from soil erosion undermining the barrier as well as creating difficult access. Many erosion problems arise as a result of inappropriate earthworks and can be readily avoided:

- grader windrows created during the clearing process concentrate runoff along the cleared line, creating large quantities of fast erosive flow that cannot escape
- grader blade cuts below the soil surface level can create a "nick point" that initiates rilling, steadily eroding upslope from the cleared line
- the crowning of fence alignments, popular in some circles, concentrates and diverts sheet flows along the fence line, causing rather than preventing erosion.

These issues can be addressed by ensuring that earthworks undertaken during cleared line preparation have minimal impact on the natural movement of sheet flow runoff or the function of undisturbed drainage depressions. Cross-flow across the cleared line should be maintained and runoff concentration along the fence avoided. Approaches that work include:

- installing erosion control structures during construction, rather than waiting to fix problems later. Surveyed trafficable diversion banks (whoa-boys) are a good option (see Photo 15)
- build surveyed banks rather than cut drains. Drains cause erosion as the lowered surface initiates rilling. Survey using a level as suitable grades to prevent erosion (0.2 per cent or 20 cm in 100 m) cannot be estimated by eye
- be prepared to deviate from the "straight line" to avoid difficult soil types and drainage areas. The cost of extra strainer posts is always less than the expense of stabilising gully erosion.

Details on techniques to minimise erosion along fence lines and access tracks can be found in the Managing Outback Roads Manual (Pringle et al, 2019).

Photo 16. Gilgunnia cluster exclusion fence covering 22 properties. 210 kilometres of fencing encloses 177,000 hectares.

6. Cluster groups

The term "cluster group" refers to co-operative arrangements where an incorporated group of landholders develop a multi-species management zone surrounded by a perimeter exclusion fence to encompass multiple landholdings under different ownership. The advantage of this approach is the reduction of per hectare construction costs when the outcomes are spread over broader areas. A body corporate entity is required to manage communal construction and maintenance issues as well as to ensure compliance with ongoing management of pest species and kangaroos.

Cluster groups require good governance structures and management to:

- establish and maintain commitment among neighbours, including internal participants, to mobilise significant funding from participants to finance and build the fence. For instance there may be varying commitment from internal participants not actually hosting the fence, those who run alternative enterprises or absentee landholders with hunting blocks
- ensure ongoing commitment to group-based integrated pest control and fauna management as well as property-level management of groundcover to agreed target levels
- encompass ongoing commitment through change of ownership or management of participating landholdings
- provide an ongoing framework for the auditing and maintenance of fence integrity
- provide robust processes for non-compliance with contracted obligations.

The Western Local Land Services Board has developed a position on cluster group projects which is based on a review of experience in partially-funding a range of fencing projects as well as assessing interstate outcomes. The operational aspects of this position provide useful advice for project proponents as follows:

- project proponents must assume all responsibility for the financial, social and legal outcomes of projects in perpetuity and succession in land title
- Aboriginal cultural heritage must be considered in fence construction. Landholders undertaking projects must implement the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales
- proponents need to demonstrate a commitment to integrated pest management. All participant landholders should join or be part of a pest management group
- project proponents must develop a coordinated, integrated pest animal management plan for the cluster area to be implemented throughout the life of the project. Impacts on areas external to the cluster perimeter must be considered
- project proponents must develop a fauna management plan for the cluster area to be implemented throughout the life of the project. This will address kangaroo and emu population management and consider impacts on areas external to the cluster perimeter
- the erection of exclusion fencing under a cluster project proposal must be undertaken by a contracted provider to ensure consistency of construction, compliance with design specifications and adherence to funding milestones.

The long-term effectiveness of cluster groups in achieving groundcover, production and biodiversity outcomes through managing a zone surrounded by exclusion fencing has yet to be comprehensively established. Results of assessments to date are inconclusive in terms of managing kangaroo numbers and improving land condition as drought, varying land types and a diversity individual management approaches have confounded clear trends (Allen, 2017). However, positive outcomes are expected inside fences where the grazing pressures of stock, fauna and pests are well-managed.

Table 9 summarises the effectiveness of cluster groups in kangaroo management.

Effectiveness	Potential for success but dependent on individual grazing management. Evaluations ongoing.
Acceptability	Moderate social acceptability.
Strengths	Fencing facilitates the potential implementation of better grazing management to improve pasture condition. Per-hectare costs for individual participants are reduced as the cluster perimeter treats a large area. Clusters provide opportunities of co-ordinated management of kangaroos and pests across neighbouring properties.
Weaknesses	There may be varied levels of expertise and commitment within the cluster, influencing overall results. Insufficient attention to pre-planning may lead to unresolved pest management issues both inside and outside of the perimeter. Robust governance is essential to accommodate long-term issues such as property transfer to ensure commitments to maintenance and management are upheld. Internal fencing may be necessary to achieve issues of scale of management as well as addressing social problems.

Table 9: Summary of effectiveness of cluster groups in kangaroo management.

7. Other options

A range of other options are often promoted or implemented for kangaroo control.

a. Relocation

Kangaroos subjected to capture and translocation suffer high levels of stress which results in capture myopathy. This is a physiological condition potentially involving muscle damage, renal dysfunction, metabolic acidosis and cardiac dysfunction that may result in rapid death or longer-term decline and mortality. The stress experienced through mustering, herding or other handling is likely to initiate myopathy in some animals. Susceptibility varies between individuals but mortality rates of up to 10 per cent can be expected (AVA, 2009; Ralph and Austen, 2010). Consequently, routine husbandry operations involving the movement of kangaroos in a similar manner to livestock are unlikely to have satisfactory welfare outcomes even if practically feasible.

b. Fertility control and sterilisation

Fertility and sterilisation practices are not at all feasible at the spatial and population scales encountered in rangeland management settings. In general, fertility control is too expensive for broad-scale kangaroo management (Olsen and Low, 2006). Male castration is unlikely to reduce population growth unless all males are treated.

c. Poisoning

There is no legal, humane, safe and environmentally-sound method to poison kangaroos. No poisons are approved for this purpose. Shooting in compliance with either the commercial or non-commercial national codes of practice is the only legal method of conducting lethal control of kangaroos. As well as breaching the *Biodiversity Conservation Act 2016*, poisoning kangaroos could be prosecuted under the *Prevention of Cruelty to Animals Act 1979*. Poisoning has been assessed as having a very low social acceptability from an animal welfare perspective (Sinclair et al, 2019c; McLeod and Sharp, 2020).

Anecdotes suggest that, in the past, urea has been added to stock water supplies to poison kangaroos within the Western region. Information on the specific effect of urea on kangaroos is unavailable, but they are likely to experience similar clinical signs of toxicity to sheep, including problems with walking followed by collapse, tetanic spasm of the legs, laboured breathing, frothing at the mouth, bloat and paralysis prior to death. After collapse they will be exposed to predation (including crow attack on the eyes) and unable to seek shelter from extremes of weather.

Poisoning with urea is inhumane, illegal and a threat to the reputation of the grazing industry (McLeod and Sharp, 2020).

d. Use of livestock guardian dogs

Livestock guardian dogs have been used to discourage kangaroos from pastures in certain situations, acting as surrogate predators (i.e. dingos) to keep them moving. Dogs such as maremmas can function in this role, controlling the local distribution and behaviour of kangaroos by creating a "landscape of fear", resulting in significant declines in activity where dogs are stationed (van Bommel and Johnson 2016).

Livestock guardian dogs have been used in the Queensland pastoral zone to control dingo predation and at the same time a significant reduction in kangaroo activity has been observed (van Bommel, 2010).

e. Do nothing

The "do nothing" approach to kangaroo management has the advantage of little outlay, but can involve substantial opportunity costs. These costs may include:

- the value of up to 50 per cent of the pasture produced is lost through consumption by unmanaged herbivores
- there is no potential for implementing regenerative management approaches such as rotational grazing and providing paddocks with a genuine spell
- there is also the cost of overgrazed pastures, which become dominated by ephemeral plants and have lower productivity than areas in good condition
- grazing enterprises have greater exposure to drought as ephemeral-based pastures in poor condition quickly deteriorate and disintegrate with the onset of dry conditions
- the direct competition for feed between kangaroos and livestock increases with the onset of drought, so climate resilience is further reduced
- under drought conditions, destocked land continues to be overgrazed by unmanaged grazing animals. They can deplete groundcover levels below the 50% groundcover threshold and be exposed to wind and water erosion.

Table 10 summarises the preceding considerations of the other options.

Effectiveness	Unknown, as data on relocation, fertility control and livestock guardian dogs is based on more intensive management systems than the Western region.
Acceptability	Fertility control, relocation and livestock guardian dogs are likely to have high social acceptability. Poisoning has low assessed acceptability.
Strengths	The use of livestock guardian dogs has the co-benefit of suppressing predation by wild dogs and foxes on livestock. "Do nothing" has low up-front costs but high opportunity costs in lost production and resource condition.
Weaknesses	Relocation and fertility control are too expensive and labour-intensive for rangeland-scale management operations. Poisoning is illegal and inhumane. Livestock guardian dogs require a good skill set to establish and only provide partial control of kangaroos. "Doing nothing" exposes the landholder to the opportunity costs of high total grazing pressure including increased drought susceptibility.

Table 10: Summary of effectiveness of other options as management tools.

8. Integrated management- making the most of kangaroo control

The options presented in Parts 1-7 above can be regarded as stand-alone aspects of kangaroo management. However, rather than alternative approaches, they may work best if considered as integrated components of an overall management plan:

- harvesting or non-commercial culling work best within a defined TGP or exclusion fence perimeter that limits immigration
- water point closure is a supplementary control to reduce impact on spelled areas even if kangaroo management fencing is in place
- fencing provides a perimeter but requires culling to manage internal populations to desired levels.

A progressively implemented integrated management plan based on property requirements and the principles discussed in Section 2 will potentially have the most effective outcomes. Unfortunately, despite the logic of this approach, to date a cost-benefit analysis of integrated management has yet to be undertaken.

In terms of the Principles for Kangaroo Management outlined in Section 2, an integrated plan may have the following features:

- healthy, viable kangaroo populations are a vital component of the Western region
- even if a grazing property is exclusion fenced, maintaining a nucleus of kangaroos is feasible. However, in cropping or horticultural situations lacking native vegetation, this may not be possible. Paddock-level monitoring of population density could assist in maintaining a suitable number of animals
- total grazing pressure control is necessary for sustainable pastoral production
- focus of activities is control of grazing pressure for better groundcover and yield, considering the overall impact of kangaroos, unmanaged rangeland goats and domestic stock
- best practice animal welfare is fundamental to kangaroo management
- lethal or non-lethal controls are undertaken in the best possible manner. Harvest is preferred over non-commercial culling. Fencing is implemented with consideration of animal welfare
- biodiversity should be enhanced, not damaged
- good grazing management is closely-linked to improved biodiversity in the Western region
- fence construction is mindful of the impact of clearing and potential effects on non-target species
- sites of Aboriginal cultural value must be protected
- fencing operations are undertaken with awareness of potential Aboriginal cultural heritage sites and respect for requirements
- kangaroos should be managed as a resource, rather than a pest
- harvest has first preference in culling numbers within fenced or unfenced areas
- co-benefits should be maximised where possible
- the closure of destocked water points is undertaken for feral animal and disease control as well as to reduce kangaroo impacts. The welfare of kangaroos can be improved through active management during drought conditions
- all aspects of kangaroo management must comply with current regulations and be transparent
- responsibility is taken to maintain the reputation and social licence of agriculture in the region by ensuring compliant practices and maintaining full documentation.

9. Considerations in managing kangaroo populations with fences

I. Planning in the short-term

When fencing is used to manage kangaroo populations, the initial impact of the fence barrier on the movement of both macropods and pests, is of conern. Recent projects have demonstrated that closure of an exclusion fence can cause immediate concentrations of large numbers of pests such as feral pigs along the barrier, providing either a fortuitous opportunity to control these animals or an unfortunate legacy for a neighbour. When fencing, be aware of the likely impacts on animal populations before the fence is complete and have an established plan to deal with internal and external pests in conjunction with neighbours.

Adjoining properties can be adversely affected by the construction of an exclusion fence where mobile animals accumulate on the outside. A proactive approach to manage any build-up of numbers will build goodwill and minimise pressure on the fence infrastructure.

As indicated previously, TGP fencing provides partial exclusion only and enclosed areas require more management to remove kangaroos than paddocks surrounded by exclusion fencing. Internal subdivision into smaller-sized paddocks will permit better management, especially if the country is scrubby or heavily timbered and provides cover.

II. Planning in the longer-term

Maintaining kangaroos within a fenced area also requires consideration. In the absence of controls, numbers will tend to rise especially with good seasons, so ongoing monitoring and management is essential. There are concerns that in the long-term, confined populations of kangaroos can eventually lose genetic diversity. Research on managing confined populations is essential to support the development of management guidelines covering such issues.

10. Managing pastures

Controlling the total grazing pressure of unmanaged grazers (goats and kangaroos) through total grazing pressure fencing, when actively managed under a rotational grazing system, can result in:

- a groundcover increase of 20-40 per cent
- a doubling of plant species diversity
- a doubling of perennial grass cover
- pasture yield improvements of up to 600 per cent depending on land type.

This is based on research conducted at four sites in the eastern portion of the Western region where total grazing pressure fencing and rotational management has been implemented (Waters et al, 2012; Waters et al, 2017; Waters et al, 2018).

- Waters et al (2012) found that pasture biomass was increased six times and groundcover doubled with fencing in the Cobar area
- more detailed research found increases in soil organic carbon, perennial groundcover and plant diversity associated with fencing and rotational grazing, varying according to soil type (Waters, 2017; Waters et al, 2018).

McDonald et al (2020) compared a rotationally-grazed property managed with total grazing pressure fencing and stocked with goats to an adjacent unstocked nature reserve. At the paddock scale, plant diversity and groundcover were comparable between the rotationally-grazed areas and the nature reserve.

Such results support widely-sourced anecdotal observations of pasture response to fencing and provide a significant motivation for landholders to construct fences to manage kangaroos. Greater control of pasture management, including the ability to totally destock country in reserve, has significant ramifications in terms of livestock productivity, landscape condition and drought resilience.

11. Drought resilience

The management of total grazing pressure is of particular importance with the onset of drought conditions. Early identification of impending dry conditions through increasing access to predictive climate modelling provides an opportunity to manage grazing levels and kangaroo populations in advance to avoid over-utilising pastures and the animal welfare issues associated with crashes in numbers. Gaining full control of grazing pressure will be especially effective in providing resilience during short-term dry spells.

Where fencing is used to exclude kangaroos, the opportunity exists for maintaining destocked drought reserve areas as the better-quality grasses and forbs can maintain integrity for over 12 months as "standing hay". This is in contrast to the "blow-away" character of overgrazed pastures dominated by ephemeral herbage and weeds which provide little drought forage.

Photo 17: Curly windmill grass, an indicator of moderate grazing pressure.

12. Identifying successful outcomes

Even the simplest monitoring of responses to kangaroo management can provide valuable feedback on whether a control strategy adopted is working or not. For instance, most landholders recognise an immediate change in pasture response to rainfall following fencing and this can be recorded by photographing contrasts across a fence line or at a permanent photo-point site established for the purpose of longer-term monitoring. Advice on the setting up of photo-points for monitoring can be obtained from Western Local Land Services.

More detailed incremental changes are hard to document over relatively short time-frames due to variables such as changing seasonal conditions resulting from a semi-arid climate and the slow or episodic nature of some plant responses. Often changes in pastures, production or biodiversity take several years to eventuate as certain seasonal conditions must occur for a response to happen. For instance, summer-growing perennial grasses will not germinate until sufficient warm season rains occur to stimulate growth.

This limitation is well evident in science-based monitoring programs. For example, the preliminary monitoring of wildlife population response to the fencing of the Morven cluster detected no significant difference in rabbit, cat, bird, lizard, echidna and emu numbers between the inside and outside of the fenced area over the first three years of exclusion (Allen, 2017).

There are several options available for landholders interested in monitoring the condition of their country and responses to changed management in a more detailed manner:

- field-based methods and recordings are detailed in The Glove Box Guide to Tactical Grazing Management for the Semi-Arid Woodlands (Campbell and Hacker, 2000)
- groundcover measurements from satellite data are now readily available via subscription or attendance at an organised workshop (e.g. see https://www.farmmap4d.com.au).

The simplest method of assessing the trend in pastures is to look for indicator plants, although selecting such plants can be problematic at regional scales with variable land types and rainfall. The best indicator of improving condition is an increased abundance of palatable perennial grasses (Waudby et al, 2013). Naturally, type of country also dictates the presence of certain grass species. Most persist in very low abundance in overgrazed areas, but are able to re-establish with moderate grazing pressures, periodic rest and rainfall occurring in the right growing season.

In the Western region, one such species is curly windmill grass (*Enteropogon acicularis*) which is a robust indicator that grazing pressures are moderate and suited to the recruitment of perennial grasses (see Photo 17). Other valuable indicator species include bandicoot grass (*Monocather paradoxa*), mulga Mitchell grass (*Thyridolepis mitchelliana*), cotton panic (*Digitaria brownii*), kangaroo grass (*Themeda triandra*) and barley Mitchell grass (*Astrebla pectinata*), depending on type of country.

Many of the perennial grasses will only respond with summer rains and are depleted by successive years when rainfall mainly occurs in winter. In this situation, the abundance of palatable sub-shrubs such as ruby saltbush (*Enchyleana tomentosa*), climbing saltbush (*Einadia nutans*) and satiny bluebush (*Maireana georgei*) can indicate whether grazing pressures are allowing palatable species to re-establish.

Section 5: Knowledge gaps

As indicated in the disclaimer, active adaptive kangaroo management is an evolving field and there are numerous information gaps in addressing the problematic issue of kangaroo management. This is compounded by the variability of landscapes and land uses within the Western region as well as the availability of new fencing products.

Knowledge gaps apparent in the information presented in this report include:

- methods to estimate kangaroo populations at a paddock or property level, suitable for practical management use
- understanding of regionally specific relationships between kangaroo population densities and resource condition, livestock production and kangaroo welfare outcomes. This requires the development of existing research to better define the thresholds or trigger points at which kangaroo numbers should be reduced to minimise negative effects on these outcomes
- approaches to managing kangaroo populations to reduce large spikes then crashes in numbers, to improve animal welfare and protect native vegetation, whilst also ensuring the long-term viability of species
- the effectiveness of commercial harvesting in managing kangaroo populations at the property level to influence total grazing pressure and pasture growth. This key piece of information requires the investigation of the resource condition outcomes of harvesting in the overall context of regionally-based quotas and male-biased take
- the effectiveness of non-commercial culling in managing kangaroo populations at the property level to influence total grazing pressure and pasture growth. This requires identification of the parameters necessary to manage culling for a total grazing pressure and pasture response, in contrast to ad-hoc approaches
- the effectiveness of water point closure as an influence on total grazing pressure and pasture growth, assessed at an appropriate scale and time frame for the regional context. This requires identifying pasture responses and biodiversity outcomes, as well as effective fencing configurations to minimise animal welfare issues
- the effectiveness of different types of fencing infrastructure in managing total grazing pressure. This will involve understanding the performance of the fencing types as an exclusion barrier, as well as their potential impacts on biodiversity and animal behaviour or welfare
- replication of existing TGP research to assess the outcomes of fencing and rotational grazing across the Western region. Existing research on TGP fencing documents the potential pasture and carbon response from effectively managing total grazing pressure using rotational systems in the eastern part of the region. It does not discriminate between the impact of unmanaged rangeland goats and kangaroos. Replication of this research in other parts of the region would test the use of fencing in other landscapes and determine its broader application as best practice
- methods to manage kangaroos within a perimeter-fenced area, including the moderation of population fluctuations and the maintenance of genetic diversity
- the biodiversity co-benefits of controlling total grazing pressure through kangaroo management. This would involve fauna and flora assessments of a range of species over an appropriate timeframe to identify responses in the context of variable seasonal conditions
- cost-benefit analyses of regionally-appropriate and integrated kangaroo management approaches. Beneficial outcomes are strongly-connected to the grazing management regime following fencing or other kangaroo management and controlling this variable would be the key to these analyses
- the role of integrated kangaroo management as an approach to improving drought resilience through providing greater control of grazing pressure as seasons deteriorate, as well as improvements in pasture condition and persistence
- the need for a practical means of getting emus through fences to improve their welfare and reduce damage. This could involve further development of the "emu-stile" to suit regional conditions.

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Appendix 1: Summary of management options

Tool	Strengths	Weaknesses	Requirements	Effectiveness	Acceptability
Commercial harvest	Kangaroos are treated as a resource so there is no wastage of red meat. No carcases are left in the paddock to attract potential predators of stock. Landholders do not need to undertake the activity and no cost is incurred for harvesters to operate. Strict protocols ensure humane destruction including competency testing of shooters.	Commercial harvesters operate to meet processor requirements in terms of location and type of animal. Harvesting may fail to meet landholder requirements for grazing pressure control, especially in drought. Male-biased harvesting may not reduce populations. As kangaroos are mobile, localised harvesting will have minimal impact on paddock-scale grazing pressure due to new animals moving in to harvested areas. Landholders receive no return from harvesting and pasture utilised, except in under innovative arrangements.	Licenced shooter under the *Biodiversity Conservation Act 2016*. Mandatory National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes.	No data available on change of pasture yield, land condition or stocking capacity in response to levels of harvesting.	High social acceptability when harvest is conducted by professional shooters to the code.
Non-commercial harvest	Landholder has control of harvesting operation. Approval process is readily accessible. Mandatory code provides robust framework for method.	Poor adoption of mandatory Code of Practice is a risk to animal welfare credentials of the grazing industry and social licence to manage kangaroos. As kangaroos are mobile, localised harvesting can have minimal impact on paddock-scale grazing pressure due to new animals moving in to harvested areas. Landholders must invest time in harvesting or seek other shooters. Carcases remain in the paddock, attracting potential predators of stock.	Occupier licence to harm native animals on private property under the *Biodiversity Conservation Act 2016*. Mandatory National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes. NSW DPI Volunteer Non-Commercial Kangaroo Shooters best practice guide.	No data available on change of pasture yield, land condition or stocking capacity in response to levels of harvesting.	Low social acceptability when cull is conducted by untrained shooters.
Water point closure	Control of water-points has high biosecurity benefits as feral animals and wandering stock can be discouraged from destocked areas. Prevents bogging and drowning in ground tanks, preserves water supply and may improve water quality. Grey kangaroos are sedentary and will be most affected by control of access. Goat trap yards are a cost-effective approach.	Red kangaroos require little water and resident animals may utilise pastures regardless of closure. Fences around ground tanks will be subject to high pressure unless sited at distance from the water. Closed waters will require regular monitoring to avoid animals perishing or getting caught inside a fenced enclosure.	PestSmart Standard Operating Procedure: GOA004: Trapping of feral goats- provides guidelines for trapyards.	Numerous trial results are inconclusive on pasture response due to insufficient spatial scale or response period. Anecdotes suggest some benefit at larger scales.	Low social acceptability when there is a welfare risk of wildlife being excluded from water or trapped within an enclosure.

Tool	Strengths	Weaknesses	Requirements	Effectiveness	Acceptability
TGP fence *(Includes either 900 mm prefabricated mesh plus plain, multiple plain wire or multiple electric wire designs to 1.2 m height)*	Moderate cost, especially as an upgrade to existing fencing. Provides for some movement of kangaroos. Provides a basis for dorper sheep and managed goat enterprises. Works best if paddock size is manageable for adequate control of kangaroos that get in, especially in scrubby country.	TGP fencing provides partial exclusion only, so during periods of drought there will be increasing numbers of kangaroos crossing the perimeter. Ongoing maintenance required to remain effective, especially in relation to holes dug under the wire. Aprons and electric offsets can address most issues with holes. Some welfare issues with kangaroo entanglement, especially during the first months after construction. Fences constrain emu movement which has damage and welfare implications.	*Dividing Fences Act 1991.* *Crown Land Management Act 2016.* *Crown Land Legislation Amendment Act 2017.* *Local Land Services Act 2013.* *Local Land Services Amendment Act 2016.* *Biosecurity Act 2015.* *National Parks And Wildlife Act 1974.* *Biodiversity Conservation Act 2016.* National Parks and Wildlife Amendment (Aboriginal Objects and Aboriginal Places) Regulation 2010. Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales. *Heritage Act 1977.*	Moderately effective as provides partial exclusion. Research validates that potential pasture response can be very significant. However, outcomes are dependent on individual landholder skills and commitment to grazing management.	Moderate social acceptability.
Enhanced TGP fence *(Includes 900 mm prefabricated mesh with plain wires to minimum 1.5 m height)*	Cost is only marginally greater than 1,200 mm high TGP fencing but provides increased exclusion of kangaroos. Cheaper construction than exclusion fences. Provides a basis for dorper sheep and managed goat enterprises. Discourages jumping, so reduced likelihood of kangaroos getting caught in fence.	Fences require ongoing maintenance, especially in relation to holes dug under the wire, to remain effective. Aprons and electric offsets can address most of these issues. Fences constrain emu movement which has damage and welfare implications.		Provides a higher level of exclusion than TGP fencing. Pasture response appears to be significant, but is dependent on individual landholder expertise and commitment to grazing management. No structured evaluations have been done.	Moderate social acceptability similar to TGP fencing.
Exclusion fence *(Includes prefabricated exclusion mesh to minimum 1.5 m height)*	Provides total control of kangaroo movement, as well as stopping pest species (pigs, deer and wild dogs). Acts as a long-term control measure. Addresses digging and discourages jumping. Gives landholders complete control of grazing pressures. Co-benefit of improved containment for animal and plant biosecurity.	Cost-effectiveness has yet to be established and will depend on grazing management. Requires strategies to address initial kangaroo and pest concentrations both inside and outside of the fence. Long-term viability of internal kangaroo populations needs to be addressed. Proliferation of fences will impact mobile wildlife, especially emus. Creates traffic hazard on adjacent roadways.		Provides complete exclusion with ongoing maintenance. Potential pasture response similar to TGP fencing which is validated by research. Outcomes are dependent on individual landholder skills and commitment to grazing management.	Moderate social acceptability. Concerns focus on effects on movement of wildlife.

Tool	Strengths	Weaknesses	Requirements	Effectiveness	Acceptability
Cluster group	Per-hectare costs for individual participants to erect exclusion fencing are reduced as the cluster perimeter treats a large area. Clusters provide opportunities for coordinated management of kangaroos and pests across neighbouring properties. Opportunity to maintain a stable managed kangaroo population across a large area.	There may be varied levels of expertise and commitment within the cluster, influencing overall results. Insufficient attention to pre-planning may lead to unresolved pest management issues both inside and outside of the perimeter. Robust governance is essential to accommodate long-term issues such as property transfer to ensure commitments to maintenance and management are upheld.	Legal issues as above. Good governance structure, such as a body corporate, to ensure commitment, financial capacity, adequate pest and fauna management, achievement of groundcover targets, change of ownership protocols, maintenance and audit arrangements, as well as non-compliance processes across all participant landholdings in perpetuity.	Potential for success but is dependent on individual kangaroo, pest and grazing management. Evaluations ongoing.	Moderate social acceptability. External neighbours may have concerns about pest and kangaroo management.
Other options: - Relocation - Fertility control - Guardian dogs - Poisoning - Do nothing	No assessments relevant to the region available.	Relocation and fertility control not suitable for rangeland scale operations. Possibly some potential for the use of livestock guardian dogs. Poisoning (e.g. use of urea) is illegal and inhumane. Do nothing has a high opportunity cost.	Poisoning kangaroos is illegal under the *Biodiversity Conservation Act 2016* and *Prevention of Cruelty to Animals Act 1979*.	No assessments relevant to the region available.	Non-lethal options have high social acceptability. Poisoning is not acceptable.

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