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Introduction

This statement provides a background to the commercial harvest of kangaroos in Australia and addresses a number of issues relating to their management.

The harvest of kangaroos for meat and skins has a long history as does their conservation. Kangaroo management in Australia has evolved to a point where it is an internationally recognised example of the sustainable use of wildlife (e.g. Grigg and Pople 2001). There are strict regulations covering the humane taking of animals, regulations covering the handling and processing of meat, a system of quotas based on regular broad-scale aerial surveys and season declarations and closures based on harvest monitoring, all of which are supported by law enforcement. The management of kangaroos is supported by an extensive scientific literature.

The discussion below briefly covers first the species involved in the commercial harvest and then a history of harvesting. Next, the harvest strategy and monitoring described by programs of management are presented. This is followed by discussions of harvesting for damage mitigation, the side effects of harvesting, meat quality and disease. Finally, I offer an opinion on levels of cruelty in kangaroo harvesting from the perspective of a population ecologist.

Harvested species

Kangaroos and wallabies belong to the superfamily Macropodoidea or macropods, which contains some 48 extant species in Australia and a further 12 in New Guinea. Two species are common to both landmasses. Four species of kangaroos (red kangaroos, eastern and western grey kangaroos and common wallaroos) are harvested commercially on the Australian mainland. While there is a gradient of body size in the superfamily, only kangaroos have adult body weights in both sexes exceeding 20 kg. Two species of wallaby (red-necked wallabies and Tasmanian pademelons) are harvested commercially in Tasmania, although only wallabies harvested on one of Tasmania's offshore islands are actually exported.

All four of the kangaroo species that are commercially harvested are widespread and abundant. Within the semi-arid and arid sheep rangelands, kangaroo populations have almost certainly increased as a result of dingo control, artificial water provision and pasture improvement (Caughley *et al.* 1980, Pople *et al.* 2000). Harvesting is concentrated in these rangelands, which cover an area in excess of 2 million km^2. Numbers of kangaroos fluctuate in response to rainfall, with a run of good years leading to large increases and sharp declines in drought. Over the past 20 years, which has included periods of severe drought, numbers of all four species have fluctuated between 15 and over 40 million kangaroos. The harvest over that period has fluctuated between 1.3 and 3 million.

A number of species of macropods in Australia are listed as threatened. These are smaller species, all less than 10 kg. While some have ranges that overlap with areas where kangaroos are harvested, they are readily distinguished by their much smaller body size. Kangaroo shooters only take animals greater than ~20 kg, so there is no risk of threatened species being mistakenly shot. Causes of decline in threatened species of macropods in Australia include introduced predators, particularly foxes and cats, and habitat alteration through land clearing and overgrazing. Overhunting, presumably subsistence hunting, appears to be a factor in the decline of some New Guinea species of macropods, but not Australian species.

History of kangaroo harvesting

Kangaroo harvesting dates back to the early days of settlement at the start of the 19th century (see Pople and Grigg 1998 and references therein for details). In the latter part of the 19th century kangaroos were considered vermin and legislation encouraged their destruction. A number of methods of control were employed including kangaroo drives, poisoning and snares, all of which are now illegal. The commercial trade developed alongside these culling activities. The trade was initially for skins, but extended to meat in the 1950s.

Management programs

Regulation of the kangaroo industry in Queensland came with conservation legislation in the 1950s, requiring licensing and reporting. Quotas were introduced in 1975, along with numbered, self-locking, non-reusable tags that had to be attached to each animal entering the industry. By 1984, Commonwealth legislation required State management programs to be developed and approved by the Federal Environment Minister. These programs detail the regulations, monitoring, reporting, consultation, background information and risk of deleterious effects involved in the commercial harvest and the management actions to be taken to meet management objectives and minimise any negative effects. More recent legislation has strengthened the need to demonstrate sustainability and includes animal welfare.

Broadly, the objectives for kangaroo management in Australia are to:

1. **maintain viable populations of all exploited species over their current range;**
2. **allow for a sustainable and commercially-viable kangaroo harvest; and**

3. **allow for reductions in populations where they contribute to overgrazing.**

In all State management programs, the first objective always overrides the other two. There is some redundancy in the first two objectives, as, by definition, kangaroos need to be conserved if a harvest is to be sustainable. Importantly, Government departments primarily responsible for kangaroo management have been those responsible for nature conservation, as opposed to departments responsible for primary industries or agriculture, and have been entirely independent of industry.

Over the past decade, there has been a shift in emphasis from harvesting kangaroos for damage mitigation to harvesting for sustainable use. Today, non-commercial shooting is permitted for damage mitigation, but only in situations where the industry cannot operate. It is well recognised that there are substantial animal welfare benefits of a commercial harvest over pest control operations.

Species-specific quotas have not been met at a national level, but have been met at a State and regional level. This has resulted in season closures. Currently, only about 50% of the national quota is taken. The size of the harvest is partly driven by demand for kangaroo products, but also by the industry's desire to maintain a relatively constant supply. There is reluctance by industry to increase supply during periods of high kangaroo abundance, because declines during inevitable droughts would leave them unable to meet market demand.

Community attitudes to kangaroo harvesting

Currently, Australian government policy is that large kangaroos represent a living resource that can be harvested sustainably and that the method of harvesting does not involve unnecessary levels of cruelty. Australian government policy on this issue can be found on the Federal Environment Department's website.

Societal attitudes towards kangaroo harvesting, as articulated by pressure groups, are essentially dichotomous. Farmer organisations and lobby groups all support the kangaroo harvest, largely because they see the industry as providing pest control. Supporting kangaroo harvesting on scientific grounds are professional groups such as the Ecological Society of Australia, the Royal Zoological Society and the Australasian Wildlife Management Society. The RSPCA, the Australian Association of Veterinary Conservation Biologists and some conservation organisations also support kangaroo harvesting. There are a number of groups opposed to kangaroo harvesting. The most strident are animal rights groups who are philosophically opposed to the commercial use of wildlife.

Harvest strategy and population monitoring

Overview

Sustainable harvesting refers to taking a regular harvest without jeopardising future yields (Caughley and Sinclair 1994). Further, there will be a range of yields that are sustainable and a range of harvest strategies that can achieve a sustainable yield. A viable harvest refers to the ability of a harvest to support a commercial industry (McCallum 1999). A harvest that is unsustainable will obviously not be viable in the long term, but not all sustainable harvests will be viable for economic reasons. Ensuring commercial viability is not an objective of the State kangaroo management programs. This is appropriate as there are good bioeconomic arguments that harvesting solely for economic gain will not ensure conservation of the resource or even sustainability of the harvest (Clark 1973, Caughley and Gunn 1996, Pople and Grigg 1998). Government agencies responsible for kangaroo management have been careful to avoid this pitfall.

Nevertheless, commercial viability will be influenced by the harvest strategy (see below) and so management needs to consider it without compromising conservation of the resource. Clearly, if a harvest is not viable, there is little point devoting resources to manage it.

Theoretically, kangaroo populations can sustain a viable harvest. They are widespread and abundant with moderate rates of increase, readily monitored and the harvest can be and has been regulated. Historical harvest data back to the early 1900s and aerial survey data back to the 1970s show that kangaroo harvesting has been both sustainable and viable (Pople and Grigg 1998). Furthermore, populations have behaved broadly in line with modelled predictions (Caughley 1987, McCarthy 1996, Jonzen *et al.* in press).

The debate over kangaroo harvesting, at least through the 1970s, has meant that viability of kangaroo harvesting has also required a demonstration of sustainability (McCallum 1999). In other words, the monitoring system must not only ensure that the harvest is sustainable, it must ensure that the harvest is seen to be sustainable. This is one attraction of regular estimates of population size using tangible counting methods such as aerial survey as opposed to complex population models based on harvest data.

In many wildlife-harvesting operations, particularly fisheries, harvest data (e.g. catch per unit effort) are used to indirectly monitor the population. Overexploitation of fish populations has often resulted from an inability to detect declining stocks in the catch data (Hilborn and Walters 1992). In stark contrast, kangaroo management uses data (primarily from aerial survey; see below) that are independent of the harvest and free of the usually untested assumptions associated with indirect monitoring. Management of large vertebrate populations in open habitats has the substantial advantage of being able to directly count individuals. For most fish populations this is not feasible.

An index of abundance is commonly used to monitor a harvested population. However, kangaroo surveys are used to provide an estimate of absolute population size. Without an absolute population estimate, any harvest policy can only be *reactive*, rather than *pro-active* (McCallum 1999). When populations fluctuate greatly in response to the environment, it is difficult to ascribe a change in an index to harvesting without control areas and a long time series. With estimates of absolute population size, the impact of a certain harvest can at least be predicted. This is not to say that monitoring trends is not important. If an absolute estimate is inaccurate or the impact of harvesting on a population is poorly known, then the ability to detect trends becomes particularly useful.

Harvesting strategy

Since 1984, each of the mainland States has offered annual harvest quotas that are a constant proportion (10-20%) of the estimated population size. This strategy is well recognised as appropriate for harvesting populations in fluctuating environments (e.g. Caughley 1977, McCarthy 1996) as it is robust to uncertainty and has a low risk of overharvesting. The strategy ideally requires regular, accurate estimates of absolute population size. For many wildlife harvests, effort (e.g. number of harvesters) is regulated in an attempt to achieve a proportional harvest. In kangaroo management, this tactic and associated assumptions are not necessary because population estimates are usually available through direct counts such as by aerial survey.

Modelling studies suggest that harvest rates of 10-20% of kangaroo populations are sustainable in the long term (Caughley 1987, Hacker *et al.* 2003, Pople 2003). Rates above this will also be sustainable up to some level, but the average population size and harvest yields will be lower. Shooters are paid by carcass weight or skin size and so there is usually a strong male bias in the kangaroo harvest, because males grow up to three times the weight of females. A strong male bias allows higher yields to be achieved from populations at higher densities and the maximum yield will be achieved at a harvest rate greater than that for non-selective harvest.

The rationale behind a proportional harvesting strategy is that the quota will track population size. Even populations that are undergoing a temporary decline, such as during a drought, can be harvested sustainably so long as the decline is not permanent. Simulation modelling (Caughley 1987, Hacker *et al.* 2003, Pople 2003) has demonstrated that sustainable harvesting can occur during and after a major drought, and the long time series of survey data provide considerable empirical support.

Inaccurate population estimates will increase the risk of overharvesting. An overharvest involves harvesting at higher than desired rates leading to reduced yields and population size in the long term. The extent of the problem will be influenced by the size of the bias, the harvest rate, the frequency of population estimates and whether the direction (i.e. negative or positive) of the bias is consistent. Fluctuations in population size between surveys will also lead to variation in harvest rate.

In kangaroo management, these factors result in a low risk of overharvesting. Population estimates are conservative (i.e. underestimates of true population size), the male bias in the harvest effectively reduces the harvest rate, and annual surveys track populations that can fluctuate only moderately from year-to-year. In addition, a large proportion of the mortality during population declines, when the risk of overharvest is greatest, is likely to be ‘compensatory’ rather than ‘additive’ (Pople 1996). In other words, many of the animals that are harvested during steep population declines would have died anyway. Spatial refuges, such as inaccessible areas on properties, will further reduce the risk of overharvesting.

Direct monitoring methods

Currently, aerial survey is the most cost-effective and feasible method for monitoring kangaroos over the vast areas where they are harvested. Initially, most States relied on fixed-wing surveys using strip transect sampling (Pople and Grigg 1998). Not all animals are counted in the strip, either 100m or 200m, so correction factors are required to bring the raw counts to an estimate of absolute population size. Numerous factors influence the sightability of kangaroos from the air (e.g. speed, height above ground, vegetation cover, temperature, observer and side-of-aircraft) and these need to be standardised, randomised or corrected if results are to be repeatable (Pople 1999b). In the early 1990s, Queensland began using line transect methods from a helicopter. This method has a major advantage over fixed-wing surveys in that survey-specific correction is possible. By comparison with walked line transect counts, the method returned accurate population estimates for red kangaroos and eastern grey kangaroos, but underestimated wallaroo population size (Clancy *et al.* 1997). Unfortunately helicopters are about three times the cost of a fixed-wing aircraft with less range. This restricts their use to monitor blocks. However, by direct comparison with fixed-wing surveys, the method has allowed the determination of correction factors for fixed-wing surveys in a range of habitats on a large scale.

Southwell (1989), Pople and Grigg (1998), Pople (1999a) and Pople (2004) provide details on survey methods and references for the development of correction factors. The correction factors of 2.3-2.4 that were used for many years were based on work on red kangaroos by Graeme Caughley and co-workers in the 1970s in southern and western New South Wales (Caughley *et al.* 1976). Through the 1980s it became apparent that these were underestimating numbers in other regions, particularly for the two grey kangaroo species. This work was not conclusive as ground surveys using vehicles are prone to bias and the small scale of many studies meant the results did not necessarily translate to the broader scale of a statewide survey. Recent work, using helicopters as a benchmark, has largely circumvented these problems and has been applied across many regions. The population estimates from helicopter surveys are also likely to be underestimates on average, because walked line transect estimates are known to be negatively biased (Southwell 1994). Assessment using line transect double counting (Borchers *et al.* 1998) suggests grey kangaroos are underestimated in areas of southern Queensland by approximately 15% (Pople and Fewster, unpublished data), again highlighting the low risks associated with the harvest strategy.

Eastern and western grey kangaroos cannot be distinguished easily from the air. Therefore, where the two species overlap, the overall density of grey kangaroos needs to be broken down into the two species. This requires the ratio of eastern greys to western greys, which has been determined by ground surveys in the early 1980s (Caughley *et al.* 1984) and again in 2000-2003 (Cairns and Gilroy 2001, Graham 2003). While there has been some change, the relative distributions of the two species are remarkably similar between the two surveys. At a coarse level, the relative distribution of the two species can also be indirectly monitored using the harvest data.

Some areas (e.g. forests, ranges) are not amenable to aerial survey so ground surveys or indirect monitoring methods are required to monitor populations. These areas generally have a low harvest and low harvest rate, primarily because of their difficult access. They include areas of the Great Dividing Range where populations will also be more stable than in the arid zone. Nevertheless, conservative population estimates and harvest rates can be applied in these areas. Currently, State government agencies do not rely solely on ground surveys or indirect monitoring when setting harvest quotas for any region.

Harvesting for damage mitigation

A reduction in the average kangaroo density will reduce grazing pressure and competition with domestic stock to some extent. However, the level to which kangaroos need to be reduced so that the benefits of reduced grazing pressure equal the costs of the reduction is not known (Pople and McLeod 2000). Some reduction is no doubt achieved through harvesting, so the relevant costs, including lost revenue to kangaroo harvesters, are those associated with reducing kangaroo numbers below those achieved through harvesting.

The benefits of reducing kangaroo numbers are difficult to quantify. Competition with sheep is likely to be greatest during dry times (Edwards *et al.* 1996, McLeod 1996), but the kangaroo industry is unlikely to be able handle a relatively large volume of animals in a short period of time. The present strategy of allowing a constant proportion of the population to be harvested each year will lower average population size, producing a lower density than if the population were only harvested at the onset of drought.

(Shepherd and Caughley 1987) view this suppression of density as a form of insurance against intermittent but inevitable droughts.

Side effects of harvesting

Overview

The potential side effects of harvesting are well recognised (e.g. Caughley 1983, Pople and Grigg 1998), and include reductions in average population size, increases in the resource base, and changes in age structure, gene frequencies and a population's dynamic behaviour. For kangaroos, the likely effects appear to be of little conservation concern (Pople and Grigg 1998). Many of the effects have been identified in kangaroo populations through comparison with unharvested populations (Pople 1996). The latter should not be considered 'natural' or 'pristine' populations. The Australian landscape, particularly the semi-arid and arid regions, has been dramatically altered since European settlement. The resulting increases in kangaroo numbers and an expansion in their range will have also resulted in changes to kangaroo demography (Pople *et al.* 2000) and gene frequency.

Genetic effects

Changes in the genetic composition of populations are well known from selective breeding of domestic animals. Hence, there is concern that harvesting of wild animals may have similar effects. There is certainly evidence for changes in body size in fisheries (Ratner and Lande 2001) and traits in some terrestrial species (Hundertmark *et al.* 1993, Jachmann *et al.* 1995). Harvesting, particularly selective harvesting, can potentially lead to two related impacts on a population's genetic composition. Firstly and more generally, there may be changes to genetic diversity. Secondly, there may be directional change in one or more traits. These changes may not necessarily be deleterious. Both Hale (2001) and Tenhumberg *et al.* (in press) concluded that the effects of harvesting upon kangaroo genetics would be negligible, under present conditions. Their views were based on genetic theory, empirical data and modelling.

Changes in the mortality rates in a population are likely to lead to changes in gene frequencies. Fixation (i.e. a permanent change) generally requires a considerable number of generations, no immigration and small populations. Life history theory predicts that an increase in mortality rates will lead to reduced growth, earlier age at sexual maturity and smaller body size (Stearns 1992). Without such trade-offs, there would be fixation at the optimum trait. In kangaroos, the reduction in dingo predation following pastoral development would have *reduced* mortality rates, resulting in a selection for larger body size. Harvesting, in contrast, would lead to a selection for smaller body size. The net result is unclear, although the dramatically lower population densities in the presence of dingoes (Pople *et al.* 2000) suggest that dingo predation is the stronger of the two selection pressures. Within their distribution, all kangaroo species are evolving under at least three predation regimes: commercial harvesting, dingo predation or neither (e.g. some National Parks).

Drought is likely to provide a strong selective influence on life history traits in kangaroos, potentially overwhelming any effect of harvesting. Larger males appear to have poor survival in drought relative to smaller animals. The trade-off here is with mating success. In other words, large body size increases the probability of reproductive success at the cost of reduced drought survival.

It is important to recognise that changes in gene frequencies in response to environmental changes (e.g. predation, drought) are not detrimental *per se*. On the contrary, they reflect an adaptive response by the population, thereby increasing its viability (i.e. probability of persistence).

Genetic diversity

Genetic diversity is synonymous with a population's evolutionary potential. Loss of genetic variation can occur when populations are very small and there is no immigration into the population (i.e. it is closed). This is obviously not a problem for kangaroo populations that number in the many millions. Given the sheer numerical size of kangaroo populations, the occurrence of unharvested areas or refuges, the limited ability of the kangaroo industry to harvest populations at even moderate rates for extended periods and the regular dispersal of individuals allowing interchange of genetic material, loss of genetic diversity in kangaroo populations seems highly unlikely. Hale (2001) reported no differences between the genetic diversity of heavily harvested and unharvested red kangaroo and wallaroo populations. However, the differences in harvesting rates between the populations have only existed for about 10 years. Gene frequencies under selection are likely to change slowly, so differences may only become apparent in the longer term.

Directional selection

There has been recent concern that selective harvesting of large male kangaroos will alter the genetic composition of the population and risk its long-term persistence (e.g. Croft 1999, Croft 2000). Tenhumberg (2002) addressed four assumptions behind this assertion:

- **High fitness leads to high population viability**. Natural selection favours individuals with high inclusive fitness. Those traits that increase an individual's fitness do not necessarily translate to increased population viability. In other words, large males may not be critical to population viability simply because they have high mating success.
- **Older males are genetically better than young males**. This proposition is currently being debated. The empirical evidence suggests that males of young to intermediate age have the highest genetic quality.

- **Smaller kangaroos have lower fitness**. Because of the trade-off between growth and survival, it is not possible to equate size with lifetime reproductive success. The fitness associated with size will depend on prevailing environmental conditions (see above).
- **Size-selective harvesting results in smaller body size**. Modelling suggests that this may be possible if the whole population is subject to harvesting. However, the change in body size is very gradual and is negated with modest, infrequent rates of immigration from unharvested areas.

Hale (2001) reached similar conclusions, although arguing that the intensity of selection for large body size and the heritability of body size would be lower than that modelled by Tenhumberg *et al.* (in press), which would further reduce the impact of harvesting on genetics. While there may be some debate over the impacts of harvesting in closed populations, immigration from unharvested areas can clearly negate any potential effects. Hacker *et al.* (2003) suggested such refuges were extensive, occurring within harvested properties as inaccessible areas, resulting from some areas being too remote from dealer sites and including National Parks and State forests where harvesting is not allowed.

Meat quality and disease

Field dressing may pose greater hygiene problems than abattoir processing. However, since free-ranging kangaroo populations have fewer disease problems than domestic stock (Andrew 1988), there is less potential for disease transmission. Kangaroos are hosts to a number of parasitic worms, but only one, *Dirofilaria* (now *Pelicitus*) *roemeri*, can occur commonly. It poses no zoonotic risk and is removed at processing. The meat inspection process for kangaroos is similar to that for domestic stock. The differences are in the details that differ to account for such things as different lymphatic drainage patterns. Kangaroo meat is processed for human consumption under rigorous quality assurance protocols, which are required for licensing of operators and their equipment. Dr Paul Hopwood (Veterinary Science, University of Sydney) argues that consumption of meat from all animal species can cause problems, but there are no reasons to consider kangaroo any differently to that of domestic stock. Andrew (1988) found that kangaroo carcasses presented for meat inspection compared favourably with post-mortem findings in domestic stock processed at abattoirs. He also argued that there were no public health reasons why kangaroo meat could not be considered on a par with meat from domestic stock.

Animal welfare

Adults

The main animal welfare body in Australia, the Royal Society for the Protection of Cruelty to Animals (RSPCA), has conducted two audits of the level of cruelty involved in the commercial and non-commercial killing of kangaroos. One audit was published in 1985 and another published in 2002. In the 1985 report, it was concluded that kangaroo harvesting could be considered one of the most humane forms of animal production.

In 1985, 86% of kangaroos entering the kangaroo products trade had been headshot (RSPCA 1985). It was deemed acceptable at that time that some 14% of animals entering the trade had been body (heart) shot. A second audit, found that the proportion of head shot animals entering the trade had now risen to 96% (RSPCA 2002). This has to represent a substantial gain in terms of animal welfare. There is considerable practical experience that shows that shooting an animal in the head is a humane form of euthanasia (Gregory 2003). There is also a strong incentive for performing headshots because it is illegal to do otherwise. Lack of compliance results in strong penalties for both dealers, who buy the carcasses from shooters, and the shooters themselves. These include heavy fines, loss of licence and imprisonment. Compliance with the Code of Practice for the Humane Shooting of Kangaroos (CONCOM 1990) is monitored routinely. The advantage of a commercial harvest over sport hunting and shooting solely for damage mitigation is that there is both a financial incentive to comply with the Code of Practice and this compliance is enforceable by monitoring carcasses and skins at dealer sites.

Processed animals will largely have been dispatched with a single shot to the head (they are not saleable otherwise), but an unknown number may have been wounded or missed altogether. However, there is a strong financial incentive for shooters to not waste shots (i.e. to head shoot). If body-shot kangaroos are refused entry into dealer sites, then it seems logical to assume that the point of aim, but not necessarily the resulting shot, of commercial shooters is going to be in the head. The true proportion of kangaroos that are not headshot or only wounded by commercial shooters would be difficult to assess. Nevertheless, there is a strong argument based on high compliance rates with the Code of Practice (RSPCA 2002), personal observation and anecdotal evidence that this proportion would be extremely low for commercial shooters.

Pouch young and young-at-foot

Kangaroo juveniles go through two distinct stages before they are weaned. Pouch life extends for two thirds of their development with the remainder spent as a young-at-foot. Kangaroos experience relatively high and variable mortality as juveniles and this is well documented (see Pople and Grigg 1998 for references) and is a typical life history pattern for large mammals (Gaillard *et al.* 1998). Mortality rates are highest in large pouch young and young-at-foot as this is where the cost of lactation is greatest. However, in dry times, pouch young die at increasingly younger ages, leading to cessation of breeding (anoestrus) in drought. As a result, on average, young-at-foot are suckled by less than one third of mature females at any one time. Average annual survival rates in juvenile kangaroos are probably < 50% (Kirkpatrick 1965, Arnold *et al.* 1991, Pople 1996).

The survival rate of young-at-foot whose mothers have been shot is unknown, but is presumably low. Shooters will try and avoid taking females with young-at-foot or large pouch young, but this is not always possible. Nevertheless, it is worth noting that young-at-foot represent only a small proportion of a population and have a low survival rate in the absence of harvesting.

Central to harvesting theory is an improvement in survival and fecundity as a result of greater resource availability following a reduction in population density. For large mammalian herbivores, there should be improved survival in all age classes, but particularly juveniles. There is some empirical support for this in red kangaroos (Pople 1996). In contrast to an unharvested population, a harvested population will have fewer individuals, a likely higher proportion of juveniles (largely because of the male-biased harvest), but a likely lower absolute number of juveniles. For example, harvesting may reduce average population density from 20 to 12 kangaroos km^{-2}, but the proportion of juveniles (pouch young and young-at-foot) in the population may increase from 30 to 40% (data from Pople 1996). However, the absolute number of juveniles will be 20% lower in the harvested population. Whether the harvest-related mortality of some of these juveniles is any worse than the mortality of a larger number of juveniles in an unharvested population from starvation or thirst is a judgment of value.

Summary

Kangaroos are commercially harvested in Australia under a government-run management system that includes strict regulation of harvest offtake, humane methods of harvest, quality-assured meat handling and inspection and a low risk of deleterious side effects to the ecosystem. Monitoring methods for kangaroos, particularly aerial survey, have been carefully and successfully developed by a number of scientists over almost three decades. Methods have been tailored to species and regions. This work has lead to improvements in accuracy and repeatability of population estimates. Conservative population estimates have always been used, further ensuring low risks of overharvesting. Continued improvement is likely through the use of recently developed methods in population assessment and long time series (>20 years) of kangaroo abundance and distribution that is now available for assessment (Pople 2004).

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