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Potential Use of Contraception for Managing Wildlife Pests in Australia

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Abstract: There is an increasing level of interest in contraception to manage wildlife pests in Australia, due mainly to concerns over high recurrent costs, animal welfare, and the failure of current control techniques to prevent damage in some instances. We have developed criteria that need to be met for contraception to be successful for pest control:

- Technology exists to reduce fertility.
- An effective delivery mechanism to treat wild animals exists.
- The end result of reduced animal damage is achieved.
- Effects are humane and nontoxic.
- Product is target specific, cost effective, and environmentally acceptable.

We assessed all available and proposed contraceptive techniques against these criteria to see if any were suitable or promising for use on Australian pests. The present role of contraception in Australia is extremely limited. The main barrier for widespread and abundant pests is the lack of suitable delivery techniques that are cost effective. The probable impact of contraception on wild populations is also poorly understood. High rates of infertility may be necessary to control pest populations and the damage they cause. Even if the fertility of wild pest populations can be reduced, there is no guarantee that this will be as effective as lethal techniques for reducing pest numbers. The longer term potential of contraception in managing wildlife damage will depend on the outcome of future research and development, particularly in the fields of contraceptive delivery and the effects of fertility control on population dynamics.

Introduction

The Australian government is interested in contraception to manage wildlife pests because of concerns over high recurrent costs of lethal controls, and their failure to prevent damage in some instances (Senate Select Committee on Animal Welfare 1991, Wilson et al. 1992). Also, many people are concerned about animal welfare issues associated with lethal techniques used to control vertebrate pests in Australia, particularly the shooting of kangaroos and feral horses. Wildlife contraception is often perceived as a more humane alternative. As a constructive response to this concern, we evaluated the scientific literature on the use of fertility control for wildlife management to assess the potential value of fertility control for wildlife management in Australia (Bomford 1990 and 1990 unpubl., Bomford and O'Brien 1990 unpubl. and 1992). This paper, which summarizes and updates the findings of these studies,

- describes the impacts of pest animals,
- identifies the objectives of wildlife contraception,
- identifies criteria for its successful use,
- evaluates its potential application in Australia, and
- identifies promising research directions.

Impacts of Pest Animals

Australia's main introduced vertebrates that have established wild pest populations are European rabbits *(Oryctolagus cuniculus)*, European red foxes *(Vulpes vulpes)*, horses *(Equus caballus)*, cats *(Felis catus)*, dogs and dingoes *(Canis familiaris)*, goats *(Capra hircus)*, pigs *(Sus scrofa)*, buffalo *(Bubalus bubalis)*, donkeys *(Equus asinus,)* house mice *(Mus domesticus)*, and European starlings *(Sturnus vulgaris)*. All these species are widespread and abundant, and many are perceived to cause losses to conservation values and agricultural production over much of their range, which makes their control expensive (Wilson et al. 1992).

Rabbits, Australia's most significant vertebrate pest, have been estimated to cost $50 million (U.S.) a year in lost agricultural production (Flavel 1988). This figure does not include the damage rabbits inflict by competing with our native animals and destroying their habitat, preventing tree regeneration, and contributing to soil erosion (Williams et al. 1995).

Foxes are major predators of wildlife (Kinnear et al. 1988, Saunders et al. 1995). Their distribution corresponds to areas where there have been many extinctions of small and medium-sized native mammals and where many more species are endangered (Wilson et al. 1992). Foxes also prey on lambs (Saunders et al. 1995), and there is a small risk that foxes could become a rabies vector should this disease be introduced to Australia (Forman 1993).

Feral horses are believed to compete with native species and livestock for pasture and water and cause soil erosion (Dobbie et al. 1993). There are estimated to be more than 300,000 feral horses in Australia, about four times the number in the United States (McKnight 1976, Clemente et al. 1990). They often inhabit remote regions, where they build up to high numbers during good years, and many starve during drought (Wilson et al. 1992).

Some native species are also a problem. For example, native parrots damage cereal and fruit crops (Bomford 1992). The large red and grey kangaroos *(Macropus rufus, M. giganteus,* and *M. fuliginosus)* have increased in range and abundance since European settlement due to the provision of livestock watering sites and extension of grasslands (Robertson et al. 1987). They compete with livestock for pasture and also reach extremely high densities in some national parks, sometimes threatening the survival of native plant communities in these reserves (Caughley 1987, Shepherd and Caughley 1987).

Wildlife managers currently control pests by poisoning, shooting, and habitat manipulation, with trapping, biological control, and exclusion being used to a lesser extent (Wilson et al. 1992). These are currently the only cost-effective means known for wildlife damage control.

Objectives of Fertility Control

The objective of fertility control for wildlife management may be one or more of the following:

- Reduce control costs,
- Achieve more humane control,
- Minimize impact on nontarget species,
- Reduce population growth, and/or
- Reduce animal damage.

When native species are a pest, the control technique used to reduce damage must not put the survival of the species at risk.

Criteria for Successful Use

We believe the following set of seven criteria need to be met for successful wildlife contraception. We examine currently available and proposed fertility control techniques to see how well they meet these criteria.

Criterion 1: Available Drug or Technique To Reduce Fertility

Many chemicals and techniques are known to cause infertility in captive animals (Kirkpatrick and Turner 1985, Marsh 1988, Kirkpatrick et al. 1990 and 1992, Bomford 1990). Much of this knowledge has been acquired from the huge investment in human contraceptive research. The use of contraception for wildlife management is not restricted by a lack of suitable techniques or drugs. So the availability of suitable agents for causing infertility in wildlife is unlikely to be a barrier for pest management.

Criterion 2: Effective Delivery Mechanism To Treat Wild Animals

The lack of practical techniques to deliver drugs to wild populations is a major obstacle to using contraception for controlling wildlife pests. Many tests on captive animals have relied on drugs delivered by surgical implantation, injections, biobullets, or by frequent oral dosing (Noden et al. 1974, Marsh 1988, Plotka and Seal 1989, Plotka et al. 1992). Such delivery techniques are either technically impossible or prohibitively expensive for reducing the damage caused by widespread and abundant wildlife, such as the estimated 200 million to 300 million wild rabbits that cause damage over much of Australia's rangelands (Flavel 1988, Wilson et al. 1992, O'Neill 1994, Williams et al. 1995). No remotely deliverable contraceptive agents cause infertility for more than 1 year, so delivery has to be repeated at least on an annual basis. Many orally active synthetic drugs require frequent ingestion, or delivery has to be precisely timed in relation to the breeding cycle, which may vary with environmental conditions. The suitable period may be as short as 2 weeks for some birds (Lacombe et al. 1986). It is extremely doubtful that these limitations to chemical fertility control could be overcome for effective pest management in Australia.

Development of a single-dose, long-acting or permanent contraceptive would reduce the difficulty and cost of delivery using the techniques described above (Marsh 1988, Berman and Dobbie 1990 unpubl.). The use of a live disseminating-recombinant virus for delivery, which is species specific to the target pest, could further reduce the technical difficulty and expense for some pests (Tyndale–Biscoe 1991 and 1994). But this technology is still under development and even if it is successful, it is unlikely to be available for another decade.

Criterion 3: End Result Is Reduced Animal Damage.

The focus of research on wildlife contraception has been on reducing fertility of pest animals. Doing that is not enough. The goal must be to reduce pest numbers and so reduce damage caused by the pest (Braysher 1993). We found no field studies that demonstrated such effects. Without field studies to examine, we turned to population theory to see what could be expected.

Australia has a highly variable rainfall. Many pest animals build up to high numbers in good seasons when food is abundant and then have their most severe impacts during droughts (Morton 1990, Dobbie et al. 1993, Williams et al. 1995). At these times, they compete with stock and native species for food and water, prey on native species in refuge habitats, and overgraze the land, causing erosion and killing tree seedlings. Many pests, such as feral horses, kangaroos, and rabbits, naturally stop breeding during droughts (Shepherd 1987, Wilson et al. 1992, Williams et al. 1995), so fertility control is not a useful population control tool at such times.

The theoretical effects of killing or sterilizing animals were compared to assess the potential value of contraception as an alternative to lethal controls (Bomford 1990, Bomford and O'Brien 1990 unpubl.). Expanding populations which were unlimited by resources were examined first (fig. 1). In such populations, it is usual for most healthy adults to breed, for juvenile survival to be high, and for the population to have exponential growth.

If half the adult population is killed (fig. 1A), exponential growth resumes, and the population soon recovers to its original density. If half the adult population is sterilized (fig. 1B), using a technique that causes loss of fertility without altering behavior,

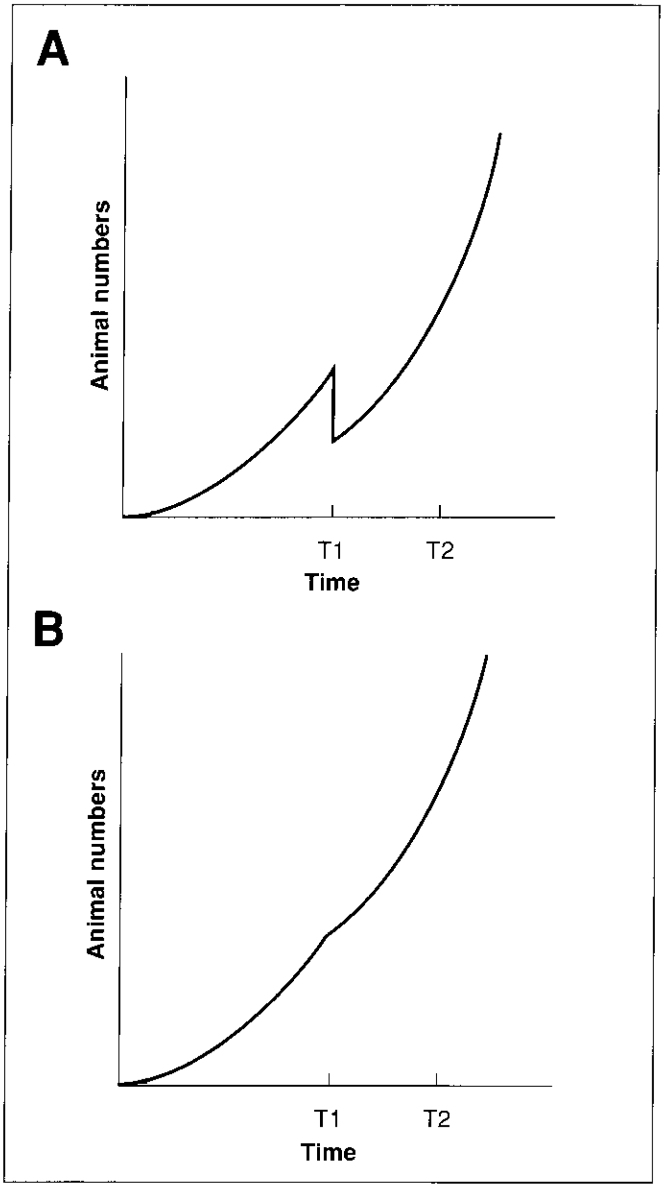

Figure 1. Exponential density-independent population growth. (A) Half population killed at time T1. (B) Half population sterilized at time T1. Killing is more effective for reducing population size.

population growth continues but at a slower rate than would have occurred in the absence of sterilization. Hence, for growing populations, killing or culling is more effective for reducing population growth rates than sterilizing an equivalent number of individuals. This conclusion was also reached by Garrott (1991) through mathematical modeling of the response of feral horse herds to changes in survival or fecundity.

If repeat treatments are used to kill or sterilize new animals over time, as opposed to the single treatment illustrated in figure 1, or if a higher proportion of animals is treated, population growth rates will flatten for both killing and sterilizing treatments, especially at low densities. But the same principle applies, and killing acts to double advantage: not only are dead animals removed from the population, they also do not breed. So by simple arithmetic, it is clear that killing will reduce the population more than contraception if the same number of animals are treated.

We concluded from this that sterilization is likely to be most effective to slow the rate of recovery of a population after some other factor, such as poisoning, shooting, drought, or disease, has reduced numbers to low levels. Hone (1992) also reached this conclusion from his mathematical modeling of population responses to contraception. Killing equal numbers of animals will be more effective than contraception for growing populations, irrespective of the proportion of the population treated.

Stable populations with density-dependent regulation at environmental carrying capacity, limited by available resources, such as space, food, or nest sites, were also examined (fig. 2). In such populations, dominance or territorial behavior often prevents some healthy adults from breeding or causes them to breed in suboptimal habitat or under social conditions where success is low. Juvenile survival is usually poor.

If half the adult population is killed (fig. 2A), logistic growth occurs and the population recovers rapidly. If half the adult population is sterilized (fig. 2B), several different responses in the population are possible, depending on the nature of the density-

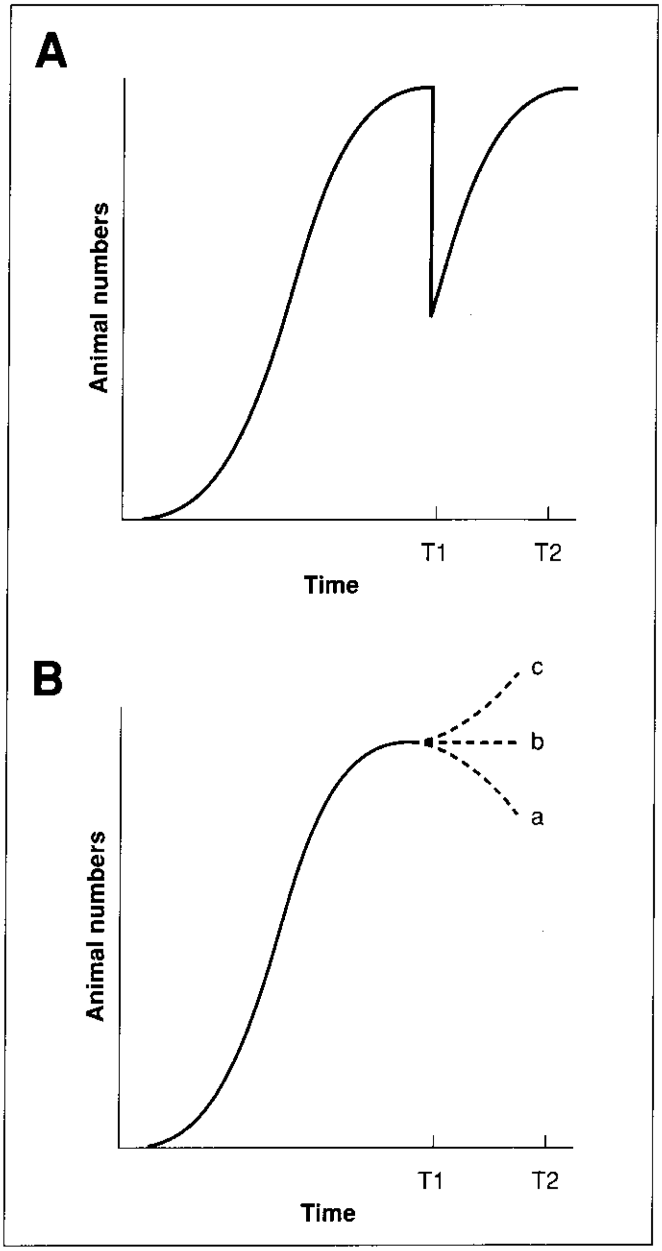

Figure 2. Logistic density-dependent population growth. (A) Half population killed at time T1. (B) Half population sterilized at time T1. In the short term, killing is more effective for reducing population size. In the longer term, the relative advantages of killing or sterilizing depend on the population response to the contraceptive treatment (B—lines a, b, and c), particularly in relation to the duration of sterilization, behavioral changes in treated animals, and compensatory changes in reproductive success of untreated animals and in survival.

dependent regulation and the response of the population to the treatment. A decline in population density (fig. 2B.a) is the response most people expect. Such declines may well occur in certain circumstances, but in some instances contraception may not cause a decline (fig. 2B.b), or it may even destabilize social behavior and lead to a population increase (fig. 2B.c).

Compensatory responses can prevent population declines, even if the contraceptive treatment does not interfere with sexual or social behavior. Compensatory responses may include increased survival, increased birth rates in untreated fertile individuals, increased immigration, and reduced dispersal. For example, many populations have high juvenile mortality. Sterilization may simply prevent the birth of young that would otherwise die or disperse without breeding. Even quite high reductions in fertility will not reduce population density if birth rates are still sufficiently high to allow normal numbers of young animals to join the adult population.

The extent of compensation determines whether fertility control will work and how well it will work. Unfortunately, we know little about the extent to which compensatory factors operate in pest populations following contraceptive treatment. We found many of the published models on the effects of contraception on population dynamics took inadequate account of such compensatory factors (Sturtevant 1970, Knipling and McGuire 1972, Spurr 1981, Bomford 1990, Bomford and O'Brien 1990 unpubl.).

Compensatory responses, such as increased breeding, survival, or immigration, can also be expected following population control by killing and can lead to rapid recovery of culled populations. Annual rates of increase in culled populations have been estimated at 20 percent for feral horses (Eberhardt et al. 1982), 23 percent for feral donkeys (Choquenot 1990), and 75 percent for feral goats (R. Henzell, pers. comm.). We could find no research that compared the extent of compensatory responses following killing or contraception in wildlife populations. Stenseth (1981), however, modeled pest control processes, including parameters for natality, mortality, dispersal, and immigration rates, all of which allowed for the effects of compensation. He found the higher the age-specific mortality rate (population turnover rate) of an uncontrolled population, the more likely it is that reduction in reproduction will be the optimal pest control strategy (as opposed to increased mortality or decreased immigration). If the equilibrium density of the population is low, the optimal pest control strategy will most often be to increase mortality rates as much as possible, especially if the mortality rate is naturally low. If, however, a pest species is long lived, and a contraceptive that lasts several years following a single treatment is used, the proportion of sterile individuals in the population may increase with successive treatments. In such circumstances, sterilizing animals may be more effective for reducing population growth rates than killing equal numbers.

When drugs used to sterilize animals cause a change in social behavior and territorial behavior or dominance is lost, a population could increase. This has been demonstrated in a model published by Caughley et al. (1992) showing that random contraception of a proportion of the females in a population could lead to increased production of young if the contraceptive treatment overrode suppression of breeding exerted by dominant females over subordinate females within social groups. The occurrence of this response would depend on social group and litter sizes, and in most circumstances the model of Caughley et al. (1992) indicated that contraception would reduce breeding.

A field study conducted on sheep on Soay Island showed that if contraception alters social behavior it may be counterproductive in terms of damage control (Jewel 1986). Male lambs were castrated in feral sheep flocks which had density-dependent regulation of numbers through food supply. After 4 years, 61 percent of castrated males had survived, in contrast to only 6 percent of untreated males. Sterilized males also spent more than twice as much time feeding as fertile males. Hence, in this study, sterilizing part of the population increased survival and may have increased food consumption. This important finding illustrates the need for contraceptive approaches that do not cause undesirable changes to endocrine function and behavior.

If damage mitigation rather than lower reproductive success is the objective, fertility control may not be an advantage. It may even be counterproductive, if it allows large numbers of nonbreeding individuals to remain in a population. So we concluded that scientists need to greatly improve understanding of the factors regulating populations of pest species and how these are affected by fertility control. Without precise information on these relationships, scientists cannot predict whether contraception will be an effective tool for controlling wildlife damage. More sophisticated models, based on good field data, are needed. In particular, investigators need a better understanding of the proportion of animals in pest populations that need to be rendered infertile to bring densities down to levels where damage is controlled.

Criterion 4: Humane and Nontoxic Effects

Fertility control drugs can affect animal health. Some have unpleasant side effects, and some are toxic or carcinogenic (Lofts et al. 1968, Cummins and Wodzicki 1980, Johnson and Tait 1983). But in general, this is an area where fertility control performs well relative to lethal control techniques.

Criterion 5: Target Specificity

Unfortunately, few fertility-control drugs are species specific, so nontarget wildlife, domestic species, or people could be affected. This is, of course, also true for many lethal control techniques (McIlroy 1986). The doses of chemosterilants necessary to cause infertility in target pests may be toxic or lethal for other species (Ericsson 1982, Johnson and Tait 1983, Saini and Parshad 1988). Immunological fertility-control agents spread by genetically engineered organisms could be made target specific for some species. But this may be a problem for feral pests with domestic counterparts, or those closely related to protected native species. There is also a risk that modified viruses could mutate to infect species other than their original hosts (Tiedje et al. 1989). But mutation would not cause the new hosts to become infertile if the virus were engineered to affect genes or proteins present in the target species only.

Criterion 6: Environmental Acceptability

In contrast to many vertebrate poisons, most fertility-control drugs do not leave residues that are harmful to the environment, though some chemosterilants could be unsuitable for use in food crops (Marsh and Howard 1973).

Criterion 7: Cost Effectiveness

Pest-control benefits must exceed costs. Preferably, the technique chosen and level of application should maximize the benefit–cost ratio. In calculating the relative costs and benefits of alternative techniques, assessments of the value of moral and animal welfare issues need to be considered. Some benefits may be difficult to quantify, such as the benefits of protecting endangered native species. Cost effective damage control occurs when the cost of pest control is more than met by savings in protecting all values society wants (Braysher 1993).

Cost is a major obstacle in the employment of fertility control as a wildlife management technique using current technology. Although the technology for fertility control of individuals does exist, contraceptive chemicals and their delivery can be prohibitively expensive for widespread and abundant pests (Matschke 1980, Berman and Dobbie 1990 unpubl.). Most of the more expensive techniques for fertility control, such as those requiring surgery, implants, or frequent or continuous dosing over extended periods, are likely to be cost effective for only small numbers of valuable animals, such as those in exhibition parks or small private collections. In contrast, lethal control techniques are often cost effective for pests such as rabbits, feral horses, and foxes (Dobbie et al. 1993, Bomford and O'Brien 1995, Williams et al. 1995).

Application to Australian Pests

Control on a National Scale

For widespread and abundant pests, such as rabbits, rodents, foxes, and feral cats, horses, and pigs, no currently available contraceptive technique can provide cost-effective damage control. Only research into contraceptives disseminated passively by live organisms has promise for wide-scale control of such pests in the future. Research is currently being conducted in Australia on viral-vectored immunocontraception for the control of rabbits and is planned for wild house mice. Viral-vectored immunocontraception has the potential to bring great benefits to wildlife pest management in Australia and its development is a current research priority. There are, however, many technical hurdles to be overcome, and it is too early to predict whether the research will be successful. In addition, there are social considerations that may impede the development and use of viral-vectored immunocontraceptives. For example, there is a risk that a live immunocontraceptive virus for rabbits could be accidentally transported to other countries where lagomorphs are not pests. It is also probable that some sections of the community would oppose the release of an immunocontraceptive virus due to perceptions of risk to nontarget species.

Control on a Local Scale

Contraception could also be used in Australia for localized control of relatively small numbers of pest animals. Contraceptives delivered through baits, implants, or injections might be used to reduce the damage caused by small numbers of pest animals such as kangaroos, feral horses, or foxes in a localized area. An example might be to use contraceptives to reduce pest numbers to protect endangered flora or fauna in a reserve. The technology is certainly achievable. Delivery would be a major expense, but in an intensively managed area, where shooting or other lethal controls are unacceptable for public-safety or public-relations reasons, or due to the risks to nontarget species, the high cost of delivery using baits or remotely delivered injections might be acceptable. Contraceptives are most likely to be suitable for species with short breeding seasons, where drug delivery is necessary for only a few weeks each year. For species with longer breeding seasons, a contraceptive would need to be developed for which a single dose lasts for at least 3 years to reduce delivery costs.

Research is currently being conducted to develop an immunocontraceptive for fox control. Despite an extensive search, no suitable live vector has been found for its delivery. But if a fox immunocontraceptive is successfully developed, it may be possible to use a bait delivery system for fox control in localized areas.

Conclusion

Currently available contraceptive techniques cannot be used to control Australia's widespread and abundant pest animal species. There are two main problems for using contraception for wide-scale control of any of our major pests. First, there are no suitable techniques for cost-effective delivery, which will be prohibitively expensive for broad use unless passive delivery via a live agent becomes available. Second, researchers lack knowledge about the factors regulating pest populations and the potential effect of fertility control on pest population dynamics. Field experiments are needed to determine if immunocontraceptives can reduce pest populations to the extent needed to control damage. Australian research is focused in these priority areas, but there are many technical hurdles, and success, if it comes, will not be for some years.

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