The impact of wild dog control on cattle, native and introduced herbivores and introduced predators in central Australia.

Final Administrative report to Bureau of Rural Sciences

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The impact of wild dog control on cattle, native and introduced herbivores, and introduced predators.

Aims and Objectives

The aims of the study were:

1. To determine the impacts of wild dog control on livestock losses and damage
2. To determine the effect of wild dog control on the abundance of macropods and rabbits
3. To determine the relationship between the availability of alternative prey and dingo damage to stock
4. To determine the effect of wild dog control on the abundance of feral cats and foxes
5. To improve the knowledge base of pastoral land managers and wildlife managers so that they can make better informed decisions regarding management of wild dogs and cattle.

Project location

The project was conducted on three central Australian pastoral stations; Andado station (25^{o}25'S, 135^{o}17'E), Lyndavale station (25^{o}36'S, 132^{o}53'E) and Umbearra station (25^{o}45'S, 133^{o}41'). All stations are located in the Northern Territory south of Alice Springs (Fig. 1).

Methodology

Site selection

Because the aim of the project was to identify effects of poison baiting by comparing poisoned and unpoisoned areas, it was important that study sites were free from the impacts of recent poison baiting. The three properties mentioned above were selected as they had not been baited within the five years preceding the study.

Treatments

Two treatment areas (experimental units) were selected on each pastoral station, each separated by a buffer 40 km wide to ensure their independence with regard to dingo movement. Treated (dingo control) experimental units were baited with fresh meat baits containing 1080 (sodium monofluoroacetate) once per year in May/June prior to dingo breeding. In the untreated (no dingo control) experimental units, fresh meat baits containing no poison were laid once per year, also in May/June. Baiting methodology followed the draft Standard Operating Procedure of the Parks and Wildlife Commission of the Northern Territory, the authority responsible for dingo and wild dog control in the Northern Territory. Wild dog predation on cattle and the activity and abundance of wild dogs, native and introduced herbivores, and introduced predators were monitored between May 2000 and August 2002. Comparisons were made between poisoned and unpoisoned areas to determine the effects of 1080 baiting. The diet of wild dogs, feral cats and foxes was also monitored to determine the effects of poisoning on predator diet.

Monitoring the activity and abundance of wild dogs, native and introduced herbivores, and introduced predators.

1. Track surveys

In each treatment area, three permanent 10 km track-survey transects (*i.e*. spatial replicates) were established, each separated by a distance of at least 5 km. All transects were established along existing unsealed station roads with a surface substrate sandy enough to record tracks and other signs of animals. Transects were surveyed at approximately 4-monthly intervals. Animals recorded during track surveys were specifically large carnivores (dingoes, foxes, cats), rabbits, red kangaroos, large reptiles (goannas, snakes) and large birds (emus, bustards).

For each species, the total number of tracks was summed over the three sampling days for each transect. The transect mean (expressed as the number of tracks per kilometre) was used as an index of activity to enable comparison between poisoned and unpoisoned areas.

2. Spotlight surveys

Spotlight surveys were conducted at night on the track-survey transects. Each transect was surveyed for two nights at 4-monthly intervals, either before or after the track surveys were conducted. Animals recorded during spotlight surveys were specifically large carnivores, rabbits, kangaroos and nocturnal birds such as owls and nightjars. Spotlight data were used to calculate an index of abundance for each species, expressed as the mean number of animals observed per kilometre averaged over the three transects.

3. Rabbit activity monitoring

Twenty rabbit warrens were selected in each treatment area and monitored at four-monthly intervals. Rabbit activity was assessed by determining the proportion of burrows in each warren that were active.

4. Alternative prey surveys

Four sites were selected in each treatment area at the beginning of the project for the purpose of alternative prey base surveys. At each site, a line of three permanent pitfall traps and a permanent 400m transect were established. During each four-monthly survey, 25 Elliott traps were placed at 15 m intervals along the 400 m transect and set for three nights to monitor small mammal abundance. Pitfall traps were also set for three nights. Captured mammals and reptiles were identified, weighed, marked and released. Birds were recorded along the 400 m transect for three mornings. Observers walked the length of the transect recording all birds seen or heard within 50 m of the transect (*i.e*. 50 m either side).

Dietary analysis

Predator diet was monitored by analysing scats collected four-monthly on each treatment area for the duration of the project. Prey remains were identified from hair, jaw-bones, scales and feathers.

Monitoring wild dog predation on livestock

Two methods were used to monitor the level of wild dog predation on livestock. The first was to assess sub-lethal damage to cattle, and particularly calves. Yarded cattle were visually assessed at mustering time for signs of dog attack such as scarring on the hind quarters and scarring or missing tissue on the ears and tail. The number of damaged calves was used to calculate an index of actual calf loss expressed as a proportion of the total number of calves branded. This was then compared between treatment areas to determine the effect of poisoning.

The second method employed was to determine the proportion of non-lactating cows in each treatment area during annual mustering. Udder condition was assessed on yarded cattle and cows were scored as either 'wet' (lactating) or 'dry'. The proportion of dry cows was then compared between treatment areas in an attempt to identify the effects of poisoning on calf loss.

Monitoring wild dog movement

The movements of four dingoes were monitored using satellite telemetry. Each dog was fitted with a collar equipped with a satellite transmitter and a VHF transmitter to allow animals to be located using hand-held radio-telemetry equipment primarily for collar recovery. The dogs were captured using padded jaw traps in October, 2001, and their movements were monitored until December, 2002. The home range of each dingo was calculated using the 95 % minimum convex polygon method

Hybridisation within the study area

Throughout the project, records were kept of all wild dogs sighted within the study area, both dead and alive. Information on the condition of each dog was collected and coat colour was recorded as the main indicator of whether dogs were dingoes, hybrids or domestic dogs.

A selection of skulls from dead dogs was removed and returned to the laboratory for measurement to confirm the specimen's identity. Measurements and calculations were made according to Corbett (1995) to classify the skull as either a dingo, domestic dog or hybrid.

Results

Although the project ran approximately 6 months behind schedule, all aims and objectives were met. The commencement of the project was delayed by the initial personnel recruitment process and also by record rainfall in central

Australia early in 2000. It was May, 2000 before study sites became accessible, allowing field work to begin. After these early delays, the project progressed unimpeded until the wind-up of the first phase of the Natural Heritage Trust in December, 2002. This forced the early completion of the project in terms of its original schedule, however, only one project milestone could not be achieved. The eighth survey could not be conducted, but it is unlikely that this affected the project results. The study area remains under the influence of two years of above-average rainfall and the results of the final survey are unlikely to have differed significantly from those of previous surveys.

Impact of poisoning on dingo activity

Overall, the activity of dingoes was approximately 21 % lower in poisoned areas than in unpoisoned areas. Although this was not a major contrast, analysis of variance performed on pooled track survey data from all three study sites identified it as significant.

Dingo activity index was significantly lower in the period 3 – 6 months after baiting than the periods 0 – 3 months and 6 – 12 months after baiting.

Very few dingoes were observed during spotlight counts, making it difficult to identify the effects of poisoning on the abundance of dingoes. In fact, not a single dingo was recorded under the spotlight on Lyndavale station. Analysis of variance performed on the spotlight data identified no significant effect of poisoning on dingo abundance.

3.2 Impact of poisoning on cattle production

The levels of calf damage recorded throughout the study were relatively low, with scarring observed at only five of the twenty three yards where damage assessments were made. An overall percentage of 0.3 % of calves showed signs of sub-lethal dingo attack. Annual figures in some treatment areas were occasionally higher than this but they did not exceed 1.6 % in any treatment area.

Calf damage was slightly higher in poisoned areas than unpoisoned areas (0.34 % c.f. 0.23 %), however, this variation was not identified as significant by statistical analysis.

All cattle were assessed briefly for signs of dingo attack during mustering. A greater incidence of scarring was observed in older cattle aged between 2.5 and 7 years than in younger cattle. Up to 2.5 % of these older cows (born prior to the period of high rainfall) exhibited scarring attributable to dingo attack. Levels of damage in younger cows and heifers (aged under 2.5 years) were comparable to those observed in calves. This suggests that the severity of calf predation by dingoes varies and may increase when conditions are drier.

The proportion of non-lactating cows was highly variable both within, and between study sites. It also varied from year to year. The average proportion of dry cows was 22.4 % with a standard deviation of 12.7 %. The proportion did not vary significantly between poisoned and unpoisoned areas. This measure was found to be of limited use in identifying differences in calf losses between treatment areas as there are many other factors which may potentially contribute to variation in the proportion of dry cows.

Impact of poisoning on introduced predators

1. Cats

Cats were commonly recorded during track surveys at all sites. Their tracks were mostly recorded in areas of relatively dense vegetation affording greater levels of cover. In open areas, they were mainly associated with drainage and creek lines. However, despite being commonly observed, the number of cat tracks recorded per kilometre on track survey transects did not vary significantly between poisoned and unpoisoned areas.

Very few cats were observed during spotlight surveys, making it difficult to identify the effects of dingo control on their abundance. Statistical analysis identified no significant effects of poisoning.

There was a significant correlation between the number of cat tracks recorded during track surveys and the number of cats observed during spotlight surveys, indicating that track survey data were a good indication of cat abundance.

2. Foxes

Foxes were abundant at all study sites for the duration of the project, particularly on Lyndavale and Umbearra stations. However, statistical analysis identified no significant effect of poisoning on fox activity. Similarly, poisoning had no effect on fox abundance index calculated from spotlight counts.

At several locations throughout the study area, dingoes appeared to be excluding foxes. This was particularly noticeable in the vicinity of watering points such as bores and dams where dingo activity was relatively high. Very few fox tracks were observed at these locations. However, there was no significant overall correlation between the activity of dingoes and the activity of foxes.

There was, a significant correlation between the number of fox tracks observed during track surveys and the number of foxes observed during spotlight surveys, indicating that track survey data were a good indication of fox abundance.

Impact of poisoning on native and introduced herbivores

1. Red kangaroos

Red kangaroos were common at all study sites, but as was the case with foxes, they were particularly abundant on Lyndavale and Umbearra stations. Although red kangaroo activity was found to vary with season, there was no change in red kangaroo activity as a result of poisoning. The activity of red kangaroos was significantly lower 6 – 12 months after poisoning which corresponded to the Summer and Autumn months.

Red kangaroos were commonly observed during spotlight surveys. However, no poisoning-related trends could be identified. There was a strong correlation between the number of red kangaroo tracks recorded during track surveys and the number of kangaroos observed during spotlight surveys, indicating that the track survey data were a good indication of kangaroo abundance.

There was a significant correlation between the activity of red kangaroos and the activity of cats and foxes. As red kangaroo activity increased, so did the activity of cats and foxes. However, no such relationships occurred between red kangaroos and dingoes.

Data from spotlight surveys revealed a significant relationship between the abundance of red kangaroos and the abundance of foxes. No significant relationships were identified between red kangaroo abundance and the abundance of cats and dingoes. Recording frequencies for both dingoes and cats during spotlight surveys was low.

2. Rabbits

Surprisingly, the number of rabbit tracks recorded on track survey transects was found to be significantly lower in poisoned areas. Rabbit activity was also monitored by calculating the percentage of active burrows in warrens from each treatment area during four-monthly surveys. The analysis of these data also revealed significantly less activity in poisoned areas.

In contrast to the track survey results, there was no difference in the spotlight abundance index of rabbits between poisoned and unpoisoned areas. There was a significant direct correlation between the number of rabbit tracks recorded during track surveys and the number of rabbits observed during spotlight surveys, indicating that the track survey data were a good indication of abundance.

There was a direct relationship between rabbit activity and the activity of cats and foxes. As rabbit activity increased, so did the activity of cats and foxes. However, there was no significant relationship between rabbit activity and dingo activity.

Pearson correlation analysis performed on spotlight abundance indices identified a significant relationship between rabbit abundance and fox abundance. No significant relationships were identified between rabbit abundance and the abundance of cats and dingoes.

Alternative Small Prey

1. Small Mammals

A collective total of 12 small mammal species and 1416 individuals were captured over the duration of the project. This total comprised 1363 rodents (96.3 %) and 53 dasyurids (3.7 %). Capture rates for rodents were relatively high for the entire study period. Two threatened species, the mulgara (*Dasycercus cristicauda*) and the plains rat (*Pseudomys australis*) were captured during the study. The plains rat is classified in the Northern Territory as “Endangered” and the mulgara is classified as “Vulnerable”.

No significant relationships were identified between the number of rodents captured and the track count activity indices for dingoes, foxes, cats, rabbits or kangaroos. Similarly, no relationships were identified between the total number of mammals captured and the activity indices for dingoes, foxes, cats, rabbits or kangaroos.

No significant relationships were identified between mammal captures and the spotlight abundance index for dingoes, foxes, cats, rabbits and kangaroos.

2. Reptiles

A collective total of 32 reptile species and 221 individuals were captured over the duration of the project. In addition, two frog species were recorded. The captured rate varied significantly with season, with fewer individuals captured during the winter hibernation period.

There were no significant relationships between the number of reptiles captured and the activity or abundance of dingoes, cats and foxes.

3. Birds

A collective total of 91 bird species were recorded over the duration of the project. Many of these were nomadic species present in the study area following above average rainfall throughout 2000 and 2001.

There were no significant relationships between the number of birds recorded per survey and the activity of dingoes, cats and foxes. Similarly, no significant relationships were identified between the number of birds recorded per survey and the number of dingoes, cats and foxes observed during spotlight surveys.

Dietary analysis

A total of 1015 predator scats were collected and analysed over the duration of the project comprising 763 dingo scats, 208 fox scats and 44 cat scats.

1. Dingoes

On average, 97.64 % of dingo scats contained mammal remains. The most common mammalian prey items consumed by dingoes were rodents (42 %), macropods (39 %) and rabbits (29 %). An average of 18 % of dingo scats contained cattle hair but it was not possible to determine whether this was consumed as carrion. Analysis of variance identified no significant effect of poisoning on the proportion of dingo scats containing cattle. The only prey category apparently affected by poisoning was birds, with a greater proportion of scats collected in poisoned areas containing bird remains than in unpoisoned areas.

Pearson correlation analysis identified several relationships between the abundance and activity of prey categories and the presence of these prey in dingo scats. There was a significant direct linear relationship between the capture rate of rodents and the frequency of occurrence of rodent remains in dingo scats. There was also a significant correlation between the activity and abundance of red kangaroos and their frequency of occurrence in dingo scats. Similarly, the frequency of occurrence of rabbits in dingo scats was directly correlated with both the activity and abundance of rabbits.

2. Foxes

Mammal remains were present in a high proportion (96 %) of fox scats. By far the most common mammalian prey category consumed by foxes were rodents (present in 82 % of scats). The next most commonly consumed prey categories were invertebrates (45 %) and vegetation (32 %). Rabbit remains occurred in 19 % of scats. Cattle hair was present in 6 % of fox scats and it can be assumed that all of this originated as carrion. There was no significant effect of poisoning on the proportion of any prey categories contained in fox scats.

Pearson correlation analysis identified several relationships between the abundance and activity of prey categories and the presence of these prey in fox scats. There was a significant direct linear relationship between the capture rate of rodents and the frequency of occurrence of rodent remains in fox scats. There was also a significant correlation between the frequency of occurrence of rabbit remains in fox scats and rabbit activity. The frequency of occurrence of birds in fox scats was directly correlated with the number of birds observed during bird surveys.

3. Cats

A total of only 44 cat scats were collected during the study which was insufficient for statistical analysis. Mammal remains were present in 100 % of cat scats and rodents were by far the most commonly consumed mammalian prey item (present in 93 % of scats). Vegetation (25 %), birds (20 %), invertebrates (16 %) and rabbits (14 %) were the next most commonly consumed prey categories.

Movement Patterns

Three of the four satellite transmitters worked continuously for a 14 month period after collar attachment, enabling the movements of an adult male, an adult female and a sub-adult male to be monitored for this period. The fourth transmitter failed on 24 January, 2001, approximately two months after collar attachment for reasons unknown.

None of the collared dingoes ranged far enough to span between treatment areas. The adult female had the largest home range of 27210 ha (272.1 km^2). This dingo inhabited the unpoisoned area on Umbearra station and did not range further than 25 km from its point of capture. The adult male had a home range of 15750 ha (157.5 km^2) and did not range further than 16 km from its point of capture. The sub-adult male had a home range of 11670 ha (116.7 km^2) and did not range further than 13 km from its point of capture.

The collars remain attached to the dingoes and will be retrieved prior to the next financial year. The internal (NT government) component of the funding will be used to continue monitoring movements until retrieval.

Hybridisation

Details of 84 wild dogs observed throughout the project were recorded. Of these, 7 individuals (8.3 %) were hybrids. Five hybrids were recorded on Umbearra Station, two on Andado and none on Lyndavale. Almost all of these were recorded from areas associated with high levels of human activity (e.g. roadhouses, highways, railway lines, aboriginal communities *etc*.). This is consistent with similar observations made elsewhere in central Australia over the same period using the same data collection *pro formae* (Eldridge & Shakeshaft unpublished data). On the basis of these results, it appears that the wild dog population of central Australia comprises mostly pure dingoes with hybrids occurring in isolated pockets in areas mainly associated with human habitation.

Discussion

Rainfall over the entire study area greatly exceeded mean annual rainfall for the duration of the study. For example, the mean annual rainfall at Kulgera, near Lyndavale and Umbearra is 262 mm. Total rainfall at Kulgera in 2000, the first year of the project, was 467 mm and in 2001, 652 mm. The unusually high rainfall caused a flush of growth and increases in the populations of many dingo prey species, both native and introduced. This meant that prey were readily available to dingoes which is likely to have affected the results of this study. Thus the study’s results can be applied only to flush seasons such as that which prevailed during the study period.

Impact of poisoning on dingo activity

Poisoning was not particularly effective at reducing the abundance of dingoes, with dingo activity only 21 % lower in unpoisoned areas. It is likely that the impact of poisoning was affected by the atypical climatic conditions prevailing throughout the study. The results of the small prey surveys and the abundance of kangaroos recorded at all sites for the duration of the study would indicate that prey was readily available. Dingoes, therefore, may have been less inclined to ingest a cube of beef with an unfamiliar scent and appearance than during periods of food shortage.

Impact of poisoning on cattle production

The analysis identified no significant impact of poisoning on the level of calf damage. This was mainly due to the very low incidence of scarring observed in calves from both poisoned and unpoisoned areas. Overall, the percentage of calves with scarring and other signs of dingo attack was approximately 0.3 %. With the exception of one occasion in the unpoisoned area on Umbearra station when 1.6 % of calves were damaged, the proportion of calves exhibiting damage was considerably less than 1 % at all times. In fact, on one property, Lyndavale, no calf damage was recorded for the entire study. Anecdotal evidence from the central Australian pastoral industry would suggest that these figures are considerably lower than average. This is supported by the increased incidence of scarring in cows aged greater than 2.5 years during the present study. These cattle were born prior to the flush season which suggests that dingo predation rates were greater at this time.

Previous studies have illustrated that climatic conditions and associated variations in alternative prey abundance affect the level of calf predation (Corbett and Newsome 1987; Thomson 1992b; Allen and Gonzales 1998). The results of the small prey surveys indicated that there was a general abundance of small mammals (particularly rodents) throughout the study area and kangaroos were recorded at average densities of up to 6 individuals km^{-2}

(SD = 4.5) during spotlight surveys. Rabbits were also common. This indicates that alternative prey were readily available. The analysis of dingo scats during the present study indicated a very strong relationships between the activity and abundance of rodents, red kangaroos and rabbits and the amount of each species consumed by dingoes (see below). Therefore, the abundance of alternative prey during the present study is likely to have resulted in reduced predation pressure on calves.

Measuring wet-dry ratios in cows to identify variations in calf losses between poisoned and unpoisoned areas proved to be uninformative as there are many other factors known to influence calving rate that could have masked any variations associated with dingo predation. These include the quality and breed of cattle, the ratio of bulls to cows, the age of the bulls, the average age of the cows, the frequency that dry cows are trucked away and the number of sexually immature heifers present. Calving rate is also known to be strongly influenced by rainfall and pasture condition. With the patchy nature of rainfall in central Australia, it is quite common for some areas on a property to receive significantly more rainfall than others and thus pasture condition may vary widely within a property. Another problem with the technique is that the assessment is subjective unless cows are run through a race and physically checked (by stripping teats). This is not possible at many yards because they are not equipped with races large enough to accommodate adult cattle.

The only method guaranteed to identify calf predation by dingoes is to pregnancy test individual cows, then monitor the cows throughout their pregnancy and subsequently monitor the fate of the calves once they are born. Unfortunately this was not possible during the present study.

Impact of poisoning on the activity of introduced predators.

1. Foxes

For foxes, neither activity nor abundance was significantly affected by poisoning. Other studies have identified inverse density relationships between dingoes and foxes, with fox density increasing when dingo density is reduced (Jarman 1986; Thomson 1992a). In the present study, despite the poisoning-related reduction in dingo activity after baiting, there was no corresponding trend in fox activity or abundance. Dietary analysis of dingoes found no evidence of predation of foxes by dingoes during the present study.

2. Cats

The activity and abundance of feral cats was not affected by dingo poisoning. Feral cats and dingoes co-existed across the entire study area and no obvious interrelationships were identified. Feral cat fur was, however, identified in dingo scats indicating that a predator-prey relationship existed between the two species.

Impact of poisoning on native and introduced herbivores

Although poisoning caused a significant reduction in dingo activity, the activity and abundance of kangaroos and rabbits was unaffected. In addition, there were no significant correlations between dingo activity and the activity of rabbits and red kangaroos, nor between dingo abundance and the abundance of rabbits and red kangaroos. For the duration of the project, both rabbits and red kangaroos were relatively abundant throughout the study area (as a result of the flush season) and it is likely that this abundance masked any effect of poisoning.

Alternative Small Prey

We found no effect of poisoning on small prey despite dingo activity being significantly lower in poisoned areas. Rodents were also relatively abundant for the duration of the study and it is likely that this abundance masked any effect of poisoning.

Diet

Mammals predominated in the diet of foxes, cats and dingoes. However, whereas overall, dingo and fox diet contained approximately equal proportions of macropod, rabbit and rodent, cats focused on small mammals, particularly rodents.

1. Dingoes

The major mammalian prey categories were macropods, rabbits and rodents although their percentage occurrence in dingo scats varied considerably between sites. The percentage occurrence of all of these prey categories in dingo scats was strongly correlated with their abundance (or availability). These results differed somewhat from previous diet studies conducted in central Australia prior to the establishment of rabbit haemorrhagic disease (RHD) in 1996.

Prior to 1996, rabbits were recognised as the staple prey of dingoes (Corbett and Newsome 1987) as they comprised the bulk of the dingo's diet at all times, even during drought. The outbreak of the disease caused the rabbit population in central Australia to decline by 85 % (Edwards *et al*. 2002) and numbers remain at 10 – 15 % of previous levels. This decline in the abundance of rabbits, the dingo's staple prey, appears to have significantly affected the diet of dingoes in the study area.

Prior to RHD, the average percentage occurrence of rabbit in dingo stomachs from the study area varied from 43 % during drought to 73 % during flush periods (Corbett and Newsome 1987). The average frequency of occurrence of rabbit in dingo scats during the present study (conducted during a flush period) was 29.1 %. Thus, the occurrence of rabbit in the dingo's diet is now considerably less than in flush years prior to RHD.

The lack of rabbit in the dingo's diet post-RHD has been compensated for by an increase in consumption of several other prey categories. The two mammalian prey categories with significantly increased percentage occurrence post RHD were macropods (262 %) and rodents (221 %). These prey categories were regarded by Corbett and Newsome (1987) to be supplementary prey for dingoes as, unlike rabbits, they did not comprise major proportions of the diet at all times. They found the percentage occurrence of red kangaroos in dingo diet to be highest during drought periods when rabbit numbers were relatively low. Our results indicate that post-RHD, dingoes have been forced to supplement their diet with red kangaroos even during flush periods. Presuming that kangaroos would also comprise a major proportion of dingo diet during drought periods, it is reasonable to assume that kangaroos have become staple prey for dingoes post-RHD. Rodents, however, can probably still be regarded as supplementary prey due to the irruptive nature of their populations. On Andado, 'rodent' was the most frequently occurring prey category in dingo scats. This was largely due to the presence of the plains rat (*Pseudomys australis*) in large numbers for the duration of the study. *P. australis* is known to be a "plaguing" species and its population will crash with the onset of drought, after which dingoes will be forced to switch to other prey categories. The increased percentage occurrence of rodents in dingo diet post-RHD suggests that dingoes have been forced to rely more heavily on these supplementary prey items.

Interestingly, we found percentage occurrence of cattle in dingo scats to be the same as that reported by Corbett and Newsome (1987) pre-RHD. This indicates that, at least during flush years, apparent prey switching by dingoes after the decline in rabbit abundance has not affected cattle. In periods of drought, this situation may change, although reductions in kangaroos and rabbits associated with the drought may be compensated for by an increase in carrion (dead cattle), particularly in the latter part of the drought period.

2. Foxes

The percentage occurrence of rabbit in fox scats observed during the present study was approximately 25 % of that previously reported from pastoral country in central Australia (Corbett 1995). This indicates that the diet of foxes in the region has been severely affected by RHD. The presence of fox tracks on track survey transects was strongly associated with the presence of rabbit tracks on the transects, indicating that rabbits may still be the preferred prey. However, we found rodents to be the most commonly consumed prey, with percentage occurrence figures approximately twice those reported by Corbett (1995). Other significant components of the fox diet were vegetation and invertebrates. The vegetation consumed by foxes was mainly the bush tomato (*Solanum* spp.) which is an annual plant that flourishes after rain but disappears during drought. Insects are also much more abundant during flush periods than during drought. These results suggest that in drought conditions, with rabbit and rodent numbers low, foxes would find it difficult to obtain adequate food. It is likely that carrion would become a major component of the fox's diet during drought periods.

3. Cats

The percentage occurrence of rabbit in cat scats observed during the present study was also approximately 25 % of that previously reported from pastoral country in central Australia (Corbett 1995). However, although rabbits are known to be an important prey group for cats in central Australia (Paltridge *et al*. 1997), cats tend to focus on smaller mammals (Corbett 1995). The percentage occurrence of rodents in cat scats was similar in magnitude to that reported by Corbett (1995) prior to RHD. Thus, the impact of RHD on cats in the study area is likely to have been less severe than that on foxes

Home range

Home range sizes for dingoes in the present study were considerably greater than those reported previously in central Australia (Corbett 1995). However, similar home range sizes have been reported from other arid regions throughout Australia (Fleming *et al*. 2001). None of the collared dingoes ranged further than 25 km from their point of capture which indicates that the separation distance between treatment areas on each property of at least 35 km was sufficient to ensure their independence. Thus, legitimate comparisons could be made between treatment areas on each property.

Hybridisation

Traditionally, dingoes in remote areas of Australia such as central Australia have been regarded as essentially pure (Fleming *et al*. 2001). Corbett (1995) found that according to skull measurements, 98 % of wild dogs in central Australia were pure dingoes. On the basis of coat colour and morphology, we found that 8.7 % of wild dogs in the study area were hybrids which suggests that the level of hybridisation in central Australia may be increasing. It currently appears that the trend is localised to the vicinity of human habitation, however efforts are required to ensure that the high degree of purity in central Australian dingo populations remains.

Conclusions

It should be noted that the following conclusions are applicable only to flush seasons, such as those which prevailed during the study period. They should not be extrapolated to drought situations without further research.

1. Poisoning of dingoes during flush seasons does not affect cattle predation when rabbits and kangaroos are abundant. Although poisoning significantly reduced dingo activity, calf damage was not affected. The

percentage occurrence of cattle in dingo scats was identical in both poisoned and unpoisoned areas.

2. The staple prey for dingoes was rabbit and possibly kangaroo. More research is required during drought to confirm kangaroo as staple prey. Rodent was also an important prey item but was classified as supplementary prey.
3. Poisoning had no discernible impact on populations of rabbits and kangaroos, despite them being the prey most commonly consumed by dingoes.
4. Poisoning had no discernible impact on populations of cats and foxes. The abundance and activity of dingoes was not related to the abundance and activity of foxes or cats. All predator species co-existed throughout the study area, although there was anecdotal evidence to suggest that dingoes were excluding foxes at a local scale.
5. Of the alternative small prey, rodents were the most important prey for all three predators; dingoes, foxes and cats. Lizards and birds also featured prominently in the diet of the predator species. Dasyurids were almost completely absent from predator scats. There were no impacts of poisoning of dingoes on alternative small prey.
6. Dingoes in the study area have stable home ranges which suggests that the social structure of the population is intact and territories are being adequately defended.
7. Hybridisation is limited to localised areas, mostly in the vicinity of human habitation. However, there are indications that the level of hybridisation amongst dingoes in central Australia is increasing.

Outputs and outcomes

This study has significantly improved our knowledge of the relationships between dingoes and cattle predation, particularly during flush seasons. The major finding of the study, that there is no requirement to bait dingoes during flush seasons provided that kangaroos and rabbits are present, will result in better informed decisions being made by pastoralists and wildlife managers in respect of when and where to implement wild dog control. It shows the importance of considering such factors as i) rabbit, red kangaroo and rodent abundance and ii) the likely effects of wild dog control on stock losses and damage when making decisions on wild dog management. Currently, dingo control in central Australia is often conducted annually as a preventative measure and the decision to bait is often made with very little regard to actual levels of calf predation. By taking a strategic approach to dingo management and imposing control measures only when necessary, land managers stand to benefit in a number of ways. The first and most obvious is through the economic benefits that flow from reducing the frequency of baiting. When all factors are considered, the cost of a single 1080 baiting exercise is significant. Costs are partially borne by the land manager and partially by the NT government and it has been estimated that the cost to the pastoralist of baiting a cattle property in central Australia is over $1,100 (Eldridge and Bryan 1995). The less obvious benefits are associated with maintaining the stability and social structure of resident dingo populations. In stable dingo packs, breeding is successful only between the dominant male and the dominant female (Fleming *et al*. 2001), limiting the number of pups born each year. The number of pups born in an unstructured population in which several females may reproduce is potentially much higher, ultimately resulting in more dingoes and potentially higher rates of cattle predation. Stable dingo packs are also highly effective at defending their territory and prevent dispersing dogs from colonising. They effectively prevent hybridisation between stray or feral domestic dogs and pure dingoes (Fleming *et al*, 2001). They are also known to limit the population growth of native herbivores such as red kangaroos which may compete with livestock for food (Caughley *et al*. 1980).

Although this study has significantly filled many gaps, the results are only applicable to flush seasons. Research is required when conditions become drier to determine how relationships change and to provide the information necessary to develop effective and strategic approaches to dingo management during these periods. More information is required on the changes in dingo diet as conditions become drier. Although this has previously been researched in detail (Corbett and Newsome 1987), the major decline of rabbits, regarded by Corbett and Newsome (1987) to be the dingo's staple prey, has changed the situation significantly. We also require accurate information about what happens to the level of calf predation in periods of drought. In the meantime, a scaled-down program of monitoring calf damage should continue on Lyndavale and Umbearra stations. It is planned that monitoring will be conducted annually by Parks and Wildlife staff in cooperation with the respective pastoralists. Both properties are relatively easily accessible and a calf damage monitoring program would require minimal resources.

If dingo management is to be more strategic in future, calf losses or damage needs to be monitored reasonably closely in order to determine when dingo control is necessary. This will require improvements in current monitoring techniques. The improvements will simply involve more detailed record keeping and will not require significant investments in time and resources. It would involve visually assessing calves for damage at branding and recording the percentage of damaged calves at all mustering points during every muster. It may also involve paying closer attention to dead calves at bores or in the paddock to identify dingo attacks. Monitoring the levels of calf damage enables managers to easily decide if, when and where dingo control is necessary. It also enables the effectiveness of the control effort to be evaluated.

Education / Extension

The education and extension component of the project is ongoing. Several media interviews have been conducted to raise awareness of the project and its aims, however the nature of the project meant that results were not available until the final stages of data analysis. Thus, education activities could not commence until the project was nearing completion. The main education tool will be the release of a short (20 minute) video describing the project and its results and explaining how the results can be used to improve dingo management in central Australia. This will be distributed to as many land managers as possible through various representative organisations. The video is yet to be completed and is planned for release early in 2003.

A media release will be issued early in 2003 to publicise the results of the project and how they can be applied to dingo control in central Australia. It is envisaged that footage from the extension video will be used for television interviews. Results will also be publicised through newsletters of relevant land management organisations (*e.g*. Centralian Land Management Association, NT Cattleman's Association) and through scientific publications in relevant wildlife management and research journals. The Wildlife Operations Unit of the Parks & Wildlife Commission of the Northern Territory (PWCNT) in Alice Springs (responsible for wild dog management in central Australia) have been kept fully informed of the findings of the research and will communicate results and recommendations to their clients. The PWCNT dingo policy will be reviewed to incorporate the recommendations arising from the project to ensure the adoption of 'best practice' wild dog management in central Australia.

Expenditure

A financial statement prepared by the NT Government Accounting System detailing expenditure for the project is attached (Table 1). The original NFACP grant was $93,285 per year for a total of three years ($279,855). The NFACP component of the expenditure is therefore underspent by a total of $46,642. This is a result of the wind-up of the first phase of the Natural Heritage Trust prior to the project's revised completion date. Thus, the final six-monthly payment was not received.

Recommendations

This section has been extracted from the final scientific report which is to follow.

1. A strategic approach to dingo management is required.

Dingo control in central Australia is often conducted annually as a preventative measure. It is a routine entrenched in the pastoral management regime to prevent an increase in dingo abundance and hopefully minimise calf losses. The decision to bait is often made with very little regard to actual levels of calf predation. By taking a strategic approach to dingo management and imposing control measures only when necessary, land managers stand to benefit in a number of ways. The first and most obvious are the economic benefits that flow from reducing the frequency of baiting. When all factors are considered, the cost of a single 1080 baiting exercise is significant. Costs are partially borne by the land manager and partially by the NT government and it has been estimated that the cost to the pastoralist of baiting a cattle property in central Australia is over $1,100 (Eldridge and Bryan 1995). The less obvious benefits are associated with maintaining the stability and social structure of resident dingo populations. There are, however, remaining knowledge gaps which make it difficult to make informed strategic decisions in regard to dingo management, especially during drought.

2. More research is required, particularly during drought periods

Although this study has significantly improved our knowledge of the relationships between dingoes and cattle predation, the results are only applicable to flush seasons. The research should be continued when conditions become drier to determine how relationships change and to provide the information necessary to develop effective approaches to dingo management during these periods. More information is required on the changes in dingo diet as conditions become drier. Although this has previously been researched in detail (Corbett and Newsome 1987), the major decline of rabbits, regarded by Corbett and Newsome (1987) to be the dingo's staple prey, has changed the situation significantly. We also require accurate information about what happens to the level of calf predation in periods of drought. In the meantime, a scaled-down program of monitoring calf damage should continue on Lyndavale and Umbearra stations. This should be conducted annually by Parks and Wildlife staff in cooperation with the respective pastoralists. Both properties are relatively easily accessible and a calf damage monitoring program would require minimal resources.

3. There is no requirement to bait dingoes during flush seasons

This study has shown that during flush seasons, when red kangaroos and rabbits are present, 1080 baiting has no impact on calf damage. Dingo activity was significantly reduced after poisoning but this did not result in less calf damage. It should be remembered, however, that the abundance of rabbits, macropods (kangaroos) and rodents typical of flush seasons throughout the study area may not occur in flush seasons elsewhere in central Australia, particularly to the north of Alice Springs where rabbits are generally less abundant. There will also be isolated locations within the study area with low prey populations which may result in increased cattle predation. Therefore, it is necessary to monitor calf damage and even prey populations to ensure that dingo management is implemented at the appropriate time.

4. Improve monitoring and evaluation techniques for dingo management

In order to determine when dingo management is required, the level of calf loss or damage needs to be monitored reasonably closely. This would involve visually assessing calves for damage at branding and recording the percentage of damaged calves. This should be done at all mustering points during every muster. It may also involve paying closer attention to dead calves at bores or in the paddock to identify dingo attacks. Monitoring the levels of calf damage enables managers to easily decide if, when and where dingo control is necessary. It also enables the effectiveness of the control effort to be evaluated.

It would also be useful for land managers to monitor prey populations, as a decline may indicate an imminent increase in cattle predation. The methodology could be as simple as counting and recording the number of kangaroos and rabbits seen along a particular stretch of road, or checking for fresh tracks along a particular stretch of road.

5. Maintain the stable pack structure in dingo populations

A primary aim of dingo management in central Australia should be to maintain the stable pack structure of dingo populations. In stable dingo packs, breeding is successful only between the dominant male and the dominant female (Fleming *et al*. 2001). Breeding between subordinate pack members is prevented by the dominant male physically blocking copulation (Corbett 1995) or infanticide if subordinate females give birth (Corbett 1988). Dingo control can cause the male-female hierarchy in a dingo pack to collapse which can result in multiple females giving birth. Average litter size for dingoes in central Australia is 5 with a range of 1 to 9. Thus, the maximum number of pups born each year in a stable dingo pack is 9. The number of pups born in an unstructured population in which several females may reproduce is potentially much higher, ultimately resulting in more dingoes and potentially higher rates of cattle predation. Stable dingo packs are also highly effective at defending their territory and prevent dispersing dogs from colonising. This effectively prevents hybridisation between stray or feral domestic dogs and pure dingoes (Fleming *et al*, 2001). Dingoes are also known to limit the population growth of native herbivores such as red kangaroos which may compete with livestock for food (Caughley *et al*. 1980).

Future programs to control other predators, such as foxes on national parks, should ensure that stable dingo pack structures are maintained. Control techniques should be highly target-specific and dingo populations should be monitored for the duration of the control program to ensure resident dingo populations are unaffected.

6. Target problem dingoes or problem areas

Recognising the importance of maintaining the stable pack structure of dingo populations, dingo management should target problem dogs or localised areas either with increased cattle predation or low prey abundance. This study has shown the home range of dingoes during flush seasons to be up to 270 km^2 which indicates that to remove a problem dog, an area equivalent to this may need to be poisoned. This approach will require ongoing monitoring as described above, but a broadscale approach such as baiting the entire property may result in the collapse of the dingo's social structure. There may be times, such as when prey numbers decline across the entire property, when broadscale baiting is necessary. However, further research is required during drier times to verify when (or if) broadscale control is required.

7. The hybrdisation process should be prevented

There are many reasons for the prevention of hybridisation between dingoes and domestic dogs in central Australia. In addition to valid conservation reasons, it has the potential to greatly increase cattle predation. Hybridisation in central Australia is most likely to occur in the vicinity of human habitation (e.g. towns, communities and roadhouses). In remote areas such as central Australia, the behavioural differences between dingoes and domestic dogs seems sufficient to make it difficult for domestic dogs to infiltrate dingo society (Fleming *et al*. 2001). However, if domestic dogs are resident in a particular area, hybridisation is ultimately inevitable. Once hybrids become more abundant, the resultant lessening of behavioural differences will expedite the hybridisation process. An important first step to limit hybridisation would be to ensure that the stable pack structure of dingoes in the surrounding area is maintained. This will maximise the chance of behavioural differences preventing interbreeding. Ideally, domestic dogs should be controlled but this would not be possible in towns and communities, at least in the short-term.

8. Research results should be communicated to land managers.

Results of research applicable to dingo management in central Australia should be communicated more effectively to all land managers in the region. The regional feral animal officer, Parks and Wildlife, should ensure that land managers receive as much relevant information as possible to help them make informed decisions regarding dingo management. An extension video is currently being produced which describes all aspects of this study and how the results can be applied to dingo management in central Australia. Land managers have been informed of the project through the media and through representative land management organisations. Further communications and media interviews are planned for the near future.

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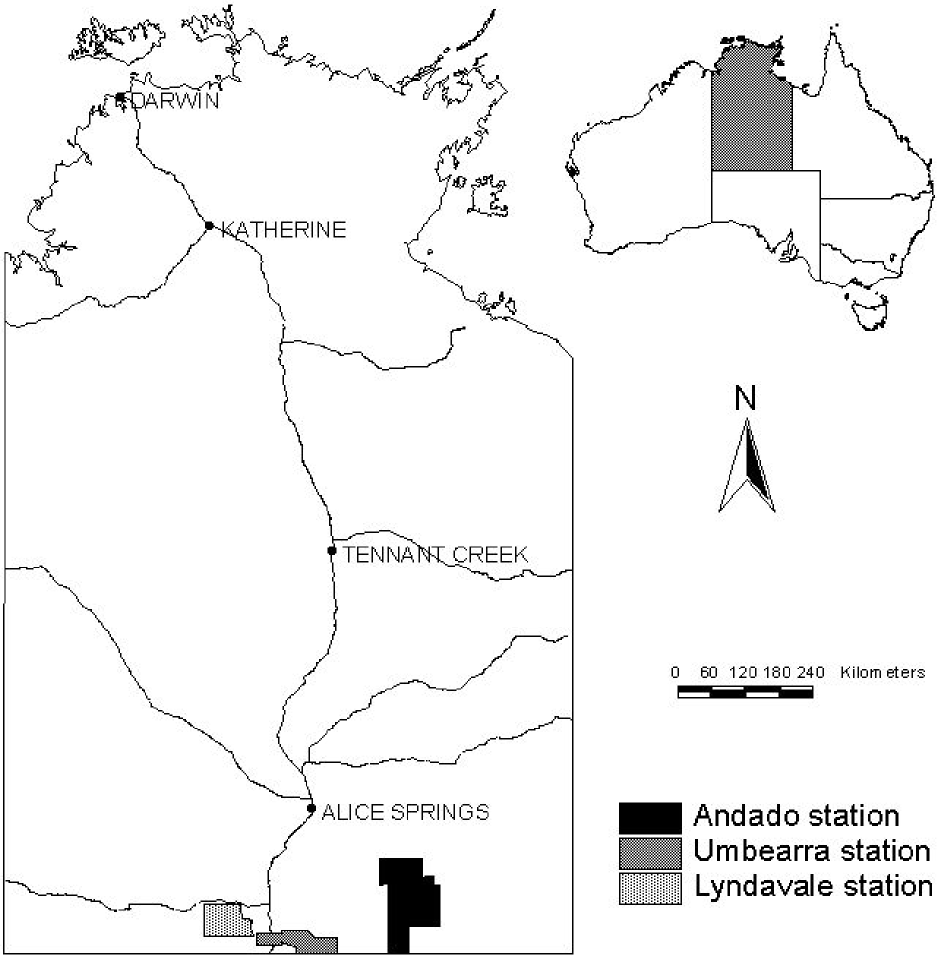

Fig. 1 Map showing the location of study sites

Table 1. Statement of expenditure for the project "The impact of wild dog control on cattle, native and introduced herbivores, and introduced predators. Statement prepared by NT Government Accounting System and includes expenditure to 31/12/2002.

	YEAR 1 (2000)			YEAR 2 (2001)			YEAR 3 (2002)			TOTAL		
SOURCE	**BRS**	**PWCNT**	**IN-KIND**	**BRS**	**PWCNT**	**IN-KIND**	**BRS**	**PWCNT**	**IN-KIND**	**BRS**	**PWCNT**	**IN-KIND**
Salary												
1. P2 scientist	44601	0	0	51022	0	0	37725	6642	0	133348	6642	0
2. P1 scientist	0	10770	0	17079	17079	0	13204	17815	0	30283	45664	0
3. T2 ranger	0	2000	0	0	0	0	0	0	0	0	2000	0
4. P3 scientist	0	6374	0	0	12748	0	0	12748	0	0	31870	0
5. Consultant scat analysis	0	0	0	0	1000	0	0	10319	0	0	11319	0
6. Pastoralists	0	0	4000	0	0	6000	0	0	4000	0	0	14000
On costs	5334	2012	0	6733	2891	0	5301	3365	0	17368	8268	0
Travel	8629	0	0	9909	4881	0	1865	4610	0	20403	9491	0
Operating (including fuel and vehicle operating costs)	2495	13275	0	18966	24700	0	10350	34455	0	31811	72430	0
Capital	0	0	0	0	0	0	0	0	0	0	0	0
Administration (including communication, information technology, property management and insurance)	0	8500	0	0	17000	0	0	17000	0	0	42500	0
Publications/extension materials	0	0	0	0	0	0	0	3282	0	0	3282	0
TOTAL	**61059**	**42931**	**4000**	**103709**	**80299**	**6000**	**68445**	**110236**	**4000**	**233213**	**233466**	**14000**