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CONTROL AND ECOLOGY OF THE RED FOX IN WESTERN AUSTRALIA

FOX POPULATION DYNAMICS AND CONTROL

INVASIVE SPECIES PROGRAM, PROJECT #4

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BY
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PRECIS

The Fox Threat Abatement Plan identifies the development of immunocontraception as a possible new method of controlling fox populations to minimise their predatory impact upon native fauna. As part of the development of this technique, research was undertaken to investigate the response of a fox population to a substantial reduction in the number of vixens breeding. If substantial compensation for the effects of immunosterility are identified, the usefulness of the technique would be questioned.

The rates of fertility, fecundity and barrenness were compared between two populations: one population that was intact and one that had been substantially reduced using lethal baits. Potential compensatory increases in juvenile survival were also investigated. If proportionately more juveniles occurred in the reduced population, this would indicate that compensatory juvenile survival had occurred.

Both experimental populations were comprehensively sampled during August-December 1997 when vixens were pregnant or had recently whelped. The ovulation rate and litter sizes observed in the reduced population were significantly higher than in the intact population indicating that compensation had occurred. There were no significant differences in the number of barren vixens or in the number of vixens that resorbed their entire litters. When all foxes have been accurately aged, differences in the ages of vixens entering the breeding population will be identified and the presence of increased juvenile survival determined. The rates of increase of the populations will also be calculated. All data will then be analysed using mathematical models to determine whether immunocontraception will be an effective method of controlling fox populations.

As part of the above experiment, the effectiveness of baited buffer zones in preventing recolonisation of depopulated areas was investigated. A 15 km wide buffer zone was positioned around the 1000 km^2 reduced fox density site. Population changes in both the buffer zone and the central core site were monitored by means of fox track counts on sandplots, by catch-per-unit-effort live-trapping, and by cyanide baiting indices. Outer sections of the buffer (i.e. 10 km in width) were periodically re-baited using lethal 1080 baits (3 mg 1080 per bait; 5 baits km^{-2}). This buffer baiting proved to be very effective in preventing reinfestation of the entire baited area.

BACKGROUND

The research described in this document is part of the ecological work being conducted by the Co-operative Research Centre for the Biological Control of Vertebrate Pests (VBCRC). This CRC aims to develop immunocontraception as a new method of fox control. This new technology is being developed in an attempt to reduce fox populations and thereby minimise fox predation upon threatened species. This aim is consistent with the aims of the Fox Threat Abatement Plan.

As part of the development of this technique, the dynamics of fox populations are being investigated to determine whether sterilising a large proportion of vixens will result in a substantial fox population decline, or whether fox populations will compensate for reduced density and thus overcome the imposed level of control.

The experiment was set up near Carnarvon WA in June 1995 (Fig. 1). It involved collecting data under two regimes: one where the fox population was left intact and the other where the fox population was substantially reduced using aerially delivered 1080 baits. The two populations were comprehensively sampled in August-December 1997 when the vixens were either pregnant or had recently whelped. The ovulation rates, proportion of barren vixens and litter sizes were compared between the two populations. The age structures of the two populations are also being compared to determine if a greater proportion of yearling recruits occurs in the reduced population. If so, this will indicate that compensatory cub production and/or survival has occurred.

Other aspects of fox ecology have been examined. Buffer zones were investigated to determine their usefulness in preventing reinvasion of large baited areas by dispersing foxes. This information is needed because sterility baits may reduce a fox population in a specific area but unless recolonisation of the site is prevented, there will be no effective reduction in fox density. A 15 km baited buffer was placed around the main treatment area to prevent immigration by foxes from higher density, unbaited areas nearby. This buffer zone was baited to coincide with the timing of dispersal of juvenile foxes. The timing and incidence of dispersal into site was determined by monitoring the presence of fox tracks on sandplots, by trapping and by cyanide baiting.

During 1995 and 1996 background data on the diet, general condition and breeding performance of foxes were obtained from fox populations near to the two main study areas. Fox carcases were retrieved using cyanide baits and data on age-specific fecundity and litter size were obtained. During 1995, 257 foxes were retrieved and during 1996 151 foxes were obtained. The results obtained from these foxes will be compared with those obtained from the experimental sites in 1997. This comparison will ensure that breeding success was not atypical in 1997 and will provide added scientific rigour to any conclusions made about reproductive compensation.

ADMINISTRATIVE BACKGROUND

This is the final report for research conducted in the 1996/97 financial year. When the contract for this research was originally drawn up it was recognised that the experiment would not be concluded until June 1998 (and hence the delayed reporting date). Consequently some aspects of the research have not yet been finalised and cannot be reported upon before the end of June 1998 when all work will be completed. The milestones for the 1996/97 contract remained the same for the 1997/98 contract and many of these rely upon the accurate ageing of all individuals before they can be completed. All foxes have now been aged and the data is being collated and analysed. All milestones will be addressed and reported upon in the final report for the 1997/98 financial year (due 30th June 1998) when all data has been analysed.

PROGRESS IN RELATION TO MILESTONES:
Determine changes in the relative density of foxes using sand plots in baited sites

The results of the sandplot investigations were reported to Environment Australia in May 1997 and March 1998. Sandplots were used to determine the efficacy of the original population reduction and to monitor any changes in the reduced and intact populations. The original population reduction was imposed using aerially delivered 1080 baits across the core and buffer sites (Fig. 1). The baiting was more effective than anticipated and most of the foxes in the site were killed (Fig. 2). There were too few foxes left remaining in the site for the experiment to continue. It was decided that immigrants would be permitted to reinvade the site until the fox population had returned to 20-25% of its original density. Any further immigration would then be restricted by baiting an outer buffer zone (see below).

The density of foxes in the baited site returned to 25% of its original density by March 1996 (Fig. 3). The number of foxes indicated by the sandplot data may appear to be higher but this can be attributed to the shortcomings of sandplot monitoring. Sandplots are only useful when fox densities are low to moderate. At very low densities the activities of individual foxes can be identified. As density increases the foxes that are present encounter few competitors and increase their activity and visit proportionately more sandplots. Consequently, a few foxes can incorrectly indicate a higher density of foxes. As actual density increases an asymptote occurs beyond which it is impossible to determine whether there are actually more foxes present or whether the foxes that are present are very active.

As a consequence of the sandplot monitoring producing ambiguous results, live-trapping was undertaken to ensure that the appropriate number of foxes was present in the site. At the commencement of the experiment, and before the population had been reduced, 52 foxes had been captured. The same trapping effort was used in June 1996 and 14 foxes were captured, or 27% of the original number. The density of the fox population during the breeding season of 1996 needed to be known accurately because this would greatly influence the extent of the compensatory breeding response. In August 1997 a further trapping exercise was undertaken before the final comprehensive destructive sampling was undertaken. This trapping exercise yielded 7 foxes, which was 13% of the original density. Although this result may appear to indicate a decline in fox density between 1996 and 1997, it is more likely that the trapping success rate was reduced because foxes had already been subjected to trapping in 1996 and thus were harder to catch. It is more appropriate in this case to compare between the number of foxes trapped in the baited and the unbaited areas. This approach is supported by data from the radio-collared foxes in the site. Of the original 14 foxes caught, only 2 were known to have died, suggesting that mortality was unlikely to have caused any apparent population decline.

A further index of fox density in the baited site was obtained by using CPUE cyanide baiting (Algar and Kinnear, 1992). Cyanide transects were used to estimate density in the baited site before the final destructive sampling in August-December 1997. An average of 0.11 foxes per kilometre was recovered and this result was compared with 0.55 foxes obtained per kilometre in the unbaited site (see below). This comparison indicated that the density of the fox population in the baited site was approximately 20% of that of the unbaited site and is consistent with expectations. Comparisons of these two density estimates using a t-test revealed a highly significant difference.

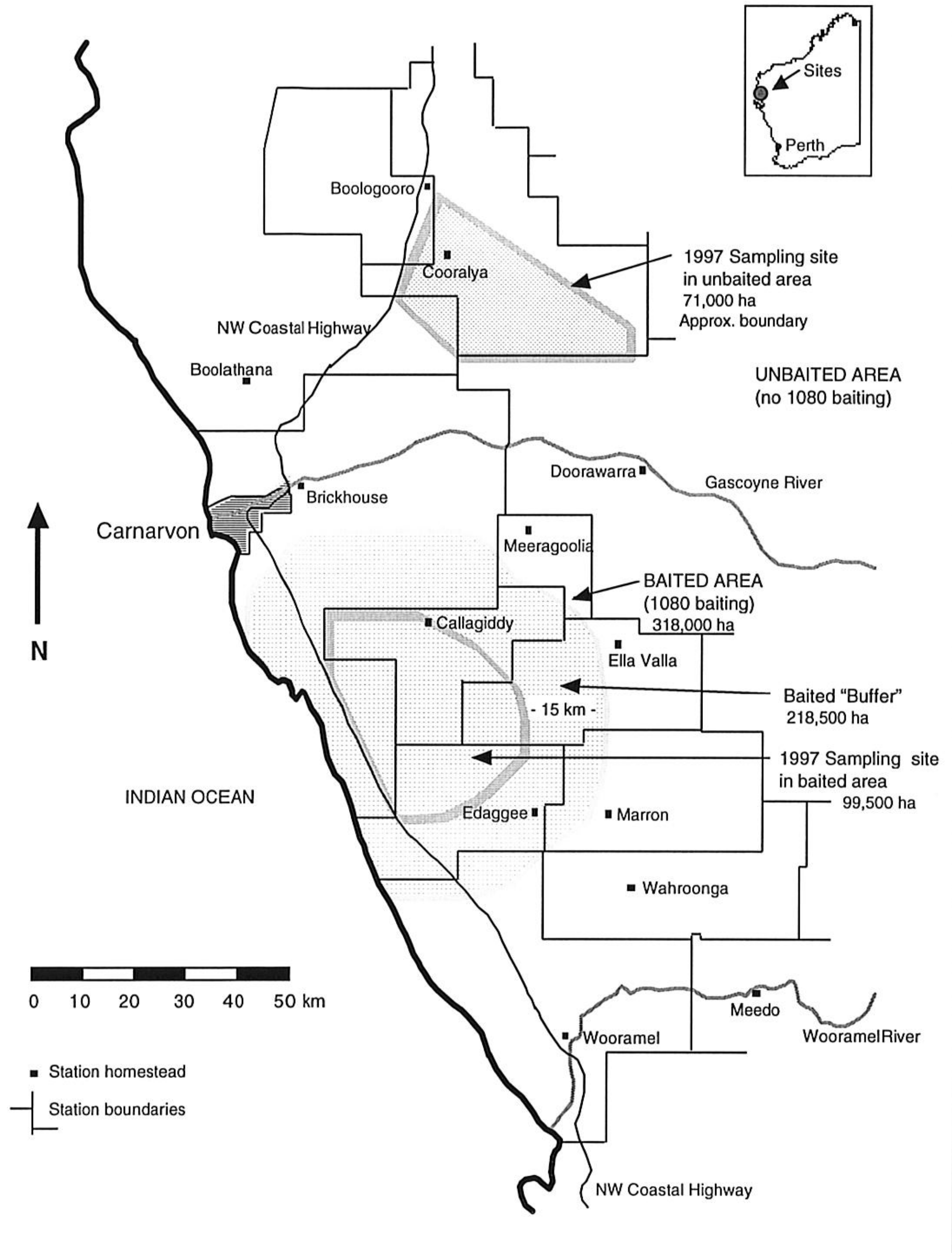

FIG. 1 CARNARVON FOX RESEARCH STUDY AREAS

Determine changes in the relative density of foxes using sand plots in the unbaited sites.

The presence of fox tracks on sandplots was used to obtain an index of fox numbers in the unbaited area from July 1995 to March 1997. The results of these investigations were previously reported to Environment Australia in May 1997. The results indicate that there were no significant changes in the numbers of foxes in this area and this is consistent with our expectations (Fig. 4). A calibration of the sandplot index was undertaken using trapping in this site. Half the trapping effort used to catch 52 foxes in July 1995, yielded 25 foxes in July 1996. Trapping was repeated in this site in August 1997 to further correlate sandplot indices, cyanide baiting and actual fox numbers. The trapping result for 1996 was 25 foxes and when the same effort was used in 1997 eleven foxes were obtained. Although this result may appear to indicate that a decline in density had occurred we knew that this was not the case because we could still monitor 21 foxes of the 25 that had been originally radio-collared in the area. Again, it is more likely the trap success rate was reduced because the foxes had already been subjected to trapping. A comparison between the number of foxes trapped in the baited and unbaited areas indicates that the population in the baited site was approximately 32% of that in the unbaited site. This result is consistent with our requirements of a relative density of the reduced population being between 20-30% of the intact population.

Cyanide transects were also used in the unbaited site in August 1997 to compare its final density with the original fox densities in areas surrounding the two experimental sites. A t-test was used to compare the numbers of foxes retrieved and no significant difference in density between the sites was observed. This result reveals that it was meaningful to compare the proportion of juveniles breeding in the baited and unbaited populations to reveal the presence or absence of compensatory breeding mechanisms.

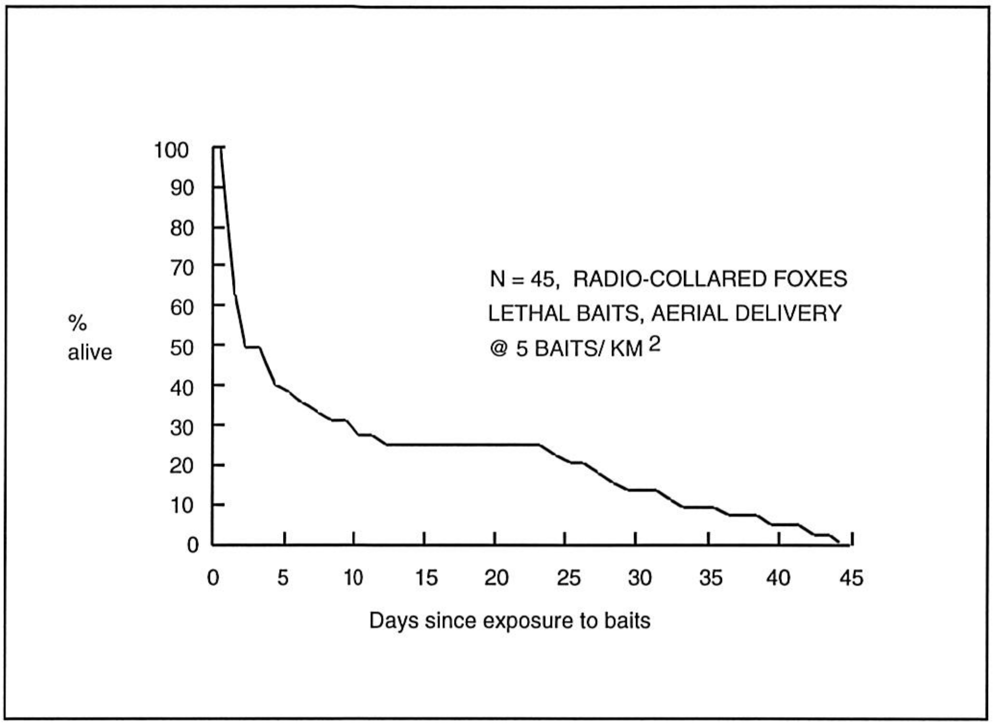

FIG. 2 TIMING OF LETHAL BAIT UPTAKE BY FOXES

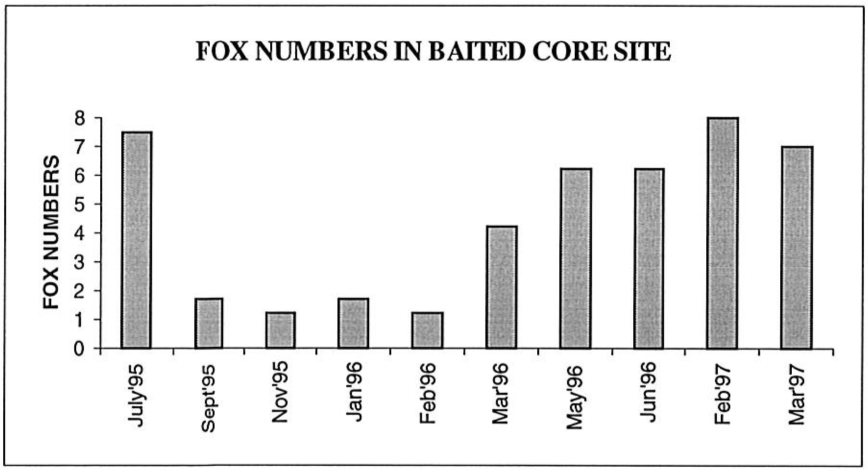

FIG. 3 TIMING OF REINVASION OF THE BAITED AREA

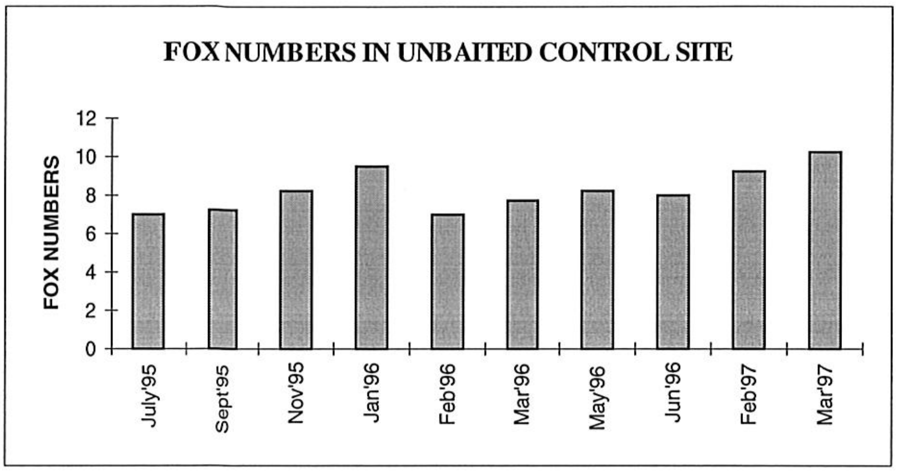

FIG. 4 SEASONAL FLUCTUATIONS IN FOX DENSITY IN AN UNBAITED AREA

Determine changes in the relative density of foxes using sand plots in the buffer zone.

The presence of fox tracks on sandplots was used to obtain an index of fox numbers in the buffer zone from July 1995 to May 1997. The results of these investigations were previously reported to Environment Australia in May 1997.

A 15 km wide buffer zone was set up around the baited treatment site (Fig. 1). Following the greater than expected population reduction immigrants were initially permitted to traverse the buffer zone so that they could restore the treatment site to 20-25% of its original density. Once that density had been attained the buffer was rebaited to prevent any further immigration from higher density areas outside the treatment and buffer zones.

The first buffer baiting was undertaken in May 1996, covering the outer 5 km of the buffer (Fig. 4). The number of foxes present at sandplots decreased after this baiting but the change was not significant. This phenomenon can be attributed to the shortcomings of sandplot monitoring rather than to a lack of decline in fox numbers.

The outer 10 km of the buffer zone was aerially baited again in February 1997. The number of fox tracks on sandplots in March indicated a decline and we were confident that the number of foxes had been sufficiently decreased. We anticipated that the number of foxes recolonising the buffer could increase between March and May which is the peak time for juvenile dispersal. Therefore the buffer sandplots were monitored and another baiting was undertaken in April. This baiting involved hand laying cyanide capsules on the buffer sandplots to determine the number of tracks represented by the number of foxes killed. After three days of cyanide baiting, a single 1080 bait was left on each sandplot and left undisturbed for one week. The number of 1080 baits removed was determined and the number of foxes killed estimated. The number of foxes remaining in the site was then re-determined by sandplot monitoring. The number of foxes remaining was concluded to still be too high and so a further reduction in the density of foxes in the buffer zone was undertaken in May 1997 using aerially delivered 1080 baits. The outer 10 km of the buffer was baited.

A fox density estimation was undertaken in the buffer zone just prior to the final comprehensive destructive sampling that was done in August- December 1997. Cyanide transects were used to compare the density of foxes in the buffer zone with that in the unbaited site and the baited site (see above). The density of foxes was revealed to be 0.05 foxes per kilometre which is considerably less than the 0.55 foxes/km in the unbaited site and approximately half of that of the baited site (0.11 foxes / km). This result is consistent with our expectations and indicates that the buffer was sufficiently devoid of foxes to act as a dispersal sink and to protect the core site from reinvasion by dispersing juveniles.

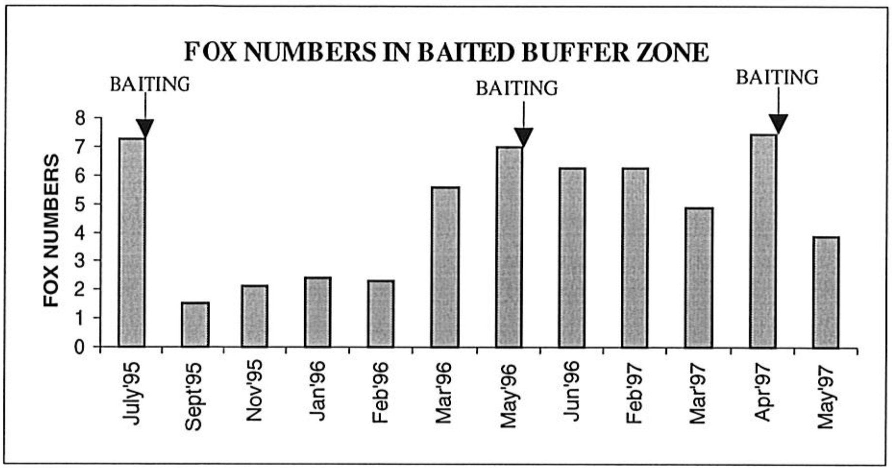

FIG. 5 CHANGES IN FOX NUMBERS IN THE BUFFER ZONE

Collate data from foxes collected to determine the proportion of yearling vixens breeding in baited and unbaited populations.

In 1995 and 1996 cyanide baiting was used to sample fox populations near to the experimental sites. These intensive kills were timed to coincide with the breeding season and to maximise the data obtained on the proportion of vixens breeding in each year. These data will be compared with those obtained from the population sampling undertaken in the experimental sites when all foxes have been aged.

A comprehensive population sampling was conducted in the baited and unbaited sites from August to December 1997. Intensive cyanide baiting, trapping and shooting were used to obtain a large sample of foxes from both sites. In the unbaited site 237 foxes were recovered (110M: 127F). Of these 202 (85%) were cyanide baited, 19 (8%) were trapped and 16 (7%) were shot. In the baited site 64 foxes were obtained (39M: 25F). Of these 40 (63%) were cyanide baited, 19 (29%) were trapped and 5 (8%) were shot. A final comparison of juvenile vixens breeding between the two populations will be made when all foxes have been aged, expected by the end of June 1998.

Deduce life tables for baited and unbaited populations.

The ageing of all foxes obtained during 1995, 1996 and 1997 is underway.
Each fox had its canine teeth removed and stored in formalin. These teeth are being examined to determine age by counting the number of cementum annuli. To reveal the number of annuli, transverse sections are made using a diamond bladed isomet saw. Sections are taken from the apical region of the root but avoiding the extreme tip. Six sections from the upper left canine tooth are examined. If this tooth is damaged, the upper right tooth is used. The sections are decalcified using EDTA decalcifier for 5 minutes. Sections are then stained for 21 minutes using toluidene blue (0.01% conc) The maximum reliable number of annuli observed is recorded as the age for the individual. Life tables for all of these populations will be calculated. A final report on this work will be prepared in late June 1998.

Productivity changes between years, rate of increase, and stability of demographic parameters in relation to rainfall.

The calculation of these parameters relies upon knowing the age structures of the populations being compared. This milestone cannot be completed until all age data have been analysed. This work will be completed by the end of June 1998 when the final report for 1997/98 will be prepared and submitted.

Sex ratios and cub-vixen ratios.

The sex ratios of the fox populations sampled during 1995 and 1996 are not significantly different to 1:1 (M: F). This result suggests that there is not a significantly higher proportion of vixens in the population as might occur if dominance hierarchies were the predominant social organisation of these populations. The social organisation of fox populations is an important factor to consider when the use of immunocontraception to reduce the population density is being considered. If dominance hierarchies are prevalent, and if there is some dominance related avoidance of baits, then it is possible (Caughley *et al.* 1992) that the reproductive suppression of subordinate vixens by dominant vixens may be reduced and the net result will be more rather than less cubs produced.

There is an apparent difference in the sex ratios between the two experimental populations. In the intact population the sex ratio was 1:1.1 whereas in the reduced population the ratio was 1: 0.6. This result may have occurred if the individuals that recolonised the baited site after the July 1995 baiting were predominantly male. When all age data have been analysed it will be possible to determine if there were significantly more males in the founding population and if so this can be accounted for in all analyses. The sex ratio of 1:1.1 in the intact site is not significantly different to the ratios observed in populations examined in areas sampled just outside the experimental sites.
Cub to vixen ratios will also be calculated for the baited and unbaited populations.

Difference in age specific fecundity between baited and unbaited populations.

Although the age-specific fecundity for the intact and reduced populations cannot be calculated until the analysis of age data has been completed, the relative productivity of both populations has been calculated. The reproductive tracts of vixens were examined and the number of embryos or recent placental scars recorded. The number of corpora lutea present in each ovary was counted. Differences between the study sites in the production of cubs, number of corpora lutea and number of resorptions were examined using t-tests.

In the unbaited site, the average number of implantations per vixen was 3.9 and the average number of corpora lutea was 4.7. The resorption rate was 17%. The proportion of vixens that did not ovulate was 6.5% (i.e. were totally barren) and 10.6% (total) did not produce viable cubs.

In the baited site the average implantation rate per vixen was 6.1 and the number of corpora lutea per vixen was 7.2. The resorption rate was 12%. The rate of barrenness was 8% and in total 20% did not produce cubs.

There is a highly significant difference in the number of implantations per vixen between the sites ($p<0.001$) and in the ovulation rate ($p<0.001$). There is no significant difference in the resorption rate between the two populations.

SUMMARY

Effectiveness of buffer zones in preventing recolonisation of depopulated areas

The results of this trial confirm that aerial baiting in sections of the buffer zone was effective in producing a marked reduction in fox numbers in the buffer (cyanide indices). Immigration permitted in early 1996 apparently helped raise the population of the core area to about 27% of its former level. A year later, with the buffer baiting regime in place, the population was still 25-32% of its former level. This suggests that the baited buffer minimised further immigration. Any minor population increase in the core area could be explained by breeding. These results support the notion that a baited buffer zone can minimise immigration of foxes into protected areas such as fauna reserves, similar to the strategy for preventing dingo incursions into livestock grazing areas (Thomson *et al.* 1992).

Whether or not a buffer zone strategy would be appropriate in all situations needs to be considered. In the present study, a 15 km wide buffer of approximately 2000 km^2 (with the ocean acting as a barrier to immigration on one side), rebaited in up to 10 km of the periphery (1480 km^2), appeared to act as an effective 'dispersal sink' (*sensu* Thomson *et al.* 1992). Whether a narrower buffer would have been as effective is unknown. Clearly, if the width of the buffer remains constant but the size of the core protected area declines, the ratio of buffer to core area increases disproportionately. Depending on the frequency of baiting required, it may be economically and logistically more feasible to simply rebait smaller core areas more frequently, rather than bait over much larger areas in nominal buffer zones.

Population compensation

The results indicate that there has been a compensatory change in ovulation rate in the reduced population. This was accompanied by a significant compensatory change in the viable litter size. A similar increase in litter size in response to intense fox control measures was observed by Voigt and Macdonald (1984) where they recorded average litter sizes of up to 8.5 cubs. The extent of this compensatory response, and its influence on the number of juveniles entering the breeding population in the following year will be revealed when the age data have been fully analysed. This will indicate whether there has also been a quantifiable increase in the survival of cubs.

There was no significant difference in the number of resorptions observed in the two populations, although the rate was slightly lower for the reduced population (12%) than for the intact population (17%). This result indicates that there is some level of naturally occurring resorptions that did not decrease in response to reduced population density.

The number of barren vixens present in the reduced population was larger than that in the intact population. This result was unexpected because the number of barren vixens usually decreases as density decreases (Lloyd 1980). This result may be a reflection of the reduced population having a younger age structure. Young vixens may proportionately produce smaller litters or not breed at all in their first season. Further insight into this result will be obtained when the age-specific fecundity of both populations is revealed.

All samples have now been aged and analyses will be complete by the end of June 1998. The age structures and age specific fecundity for both populations will then be assessed. Age specific fecundity will reveal whether the observed increase in litter size occurred in a specific age class and whether vixens in the reduced density population are breeding at an earlier age. The age of the barren vixens will be revealed and it can then be determined if the larger number of barren vixens in the reduced population is due to that population having a younger age structure.

Differences in the age structures between the two populations will indicate whether there were more male foxes in the founding population in the reduced site as assumed. From the age structures it will be possible to determine whether there is an increased proportion of juveniles present in the reduced population. The difference in the size of the juvenile age class will reveal the extent to which the population has compensated for reduced density. This data will be combined with the data obtained on litter size, rate of barrenness and rate of increase for the population and then all data will be mathematically modelled. The results of these analyses will reveal the extent of the compensatory response and will indicate whether immunosterility will be a viable method of controlling fox populations.

CONCLUSIONS

The research described in this report has led to an increased understanding of fox ecology and has helped to identify and fill some gaps in our knowledge of fox control. The results of the research investigating the effectiveness of buffer zones in preventing reinvasion of depopulated areas are applicable to sites where lethal and/ or immunocontraceptive control is to be used. In either case a buffer area that is repeatedly baited with lethal baits will significantly reduce recolonisation of that area by foxes and thus will reduce fox predation upon desirable species therein.

The capacity of a fox population to compensate for fewer vixens breeding will influence the effectiveness of both lethal and immunocontraceptive control. When the results of the mathematical modelling of the compensation data is complete, we will have a greater understanding of the effect of compensation on fox population dynamics and this will influence the development of immunocontraception as a control technique and may lead to the alteration of current lethal baiting regimes.

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