FINAL REPORT

NATIONAL FERAL ANIMAL CONTROL PROGRAM

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Methods for determining feral goat abundance in rugged terrain

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Summary

Estimation of the abundance and density of vertebrate pests is difficult but critical for management. A study in the rugged terrain of central eastern New South Wales used and compared several techniques to estimate the abundance of feral goats (*Capra hircus*). These methods were:

- Aerial double-counts conducted with helicopters
- Aerial videography
- Ground-based area counts and area double-counts
- Minimum number known to be alive (MNA) estimates calculated from ground counts taken at fixed points
- Mark-recapture estimates resulting from musters.
- Mark-resight estimates gained from extensive field observations.

Aerial double-counting was found to be efficient and effective for rapidly obtaining estimates over large areas. This has application for research and management.

The use of aerial videography with a handheld camera was unsuccessful because of camera shake and slowness of autofocus. This method may be useful if expensive cameras and stabilising mechanisms were used but otherwise cannot be recommended.

Minimum number alive estimates were found to be variable but the maximum MNA underestimated mark-recapture estimates by about 15%. MNA was the cheapest method per survey and would therefore have application for measuring the effectiveness of control programs in hilly terrain.

Mark-recapture and mark-resight estimates were the most precise but the most expensive. These methods are most applicable to research where individual goats are marked and where the precision of estimates is valued.

1. Project Title and Principal Investigators

NFACP project title: "Radio-telemetry-determined correction factors for aerial survey of feral goats."

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2. Objectives

Determination of the abundance of vertebrate pests is critical to their management. Although there are many indirect methods of estimating abundance (see Caughley 1980 and Schwarz & Seber 1999 for some examples) with varied degrees of precision, rarely are these methods compared to known numbers to check the accuracy of each method (see Southwell, 1994, for an Australian exception).

Goats, being relatively tractable and visible, are ideal candidates for testing different counting methods and, as vertebrate pests, are often subject to control and accurate estimates of abundance would be beneficial to managers.
Hence, the objectives of this project were to:

- Conduct double-count visual and videographic helicopter surveys of goats,
- Obtain mark and recapture estimates of feral goat abundance,
- Obtain area counts and area double-counts of feral goats,
- Develop correction factors for correcting standardised helicopter counts and area counts of feral goats,
- Achieve accurate and complete ground counts of goats through intensive mustering, and
- Determine the accuracy of survey methods by comparing against known numbers of goats.
- Obtain comparative costings of survey methods.

These methods of measuring abundance potentially have application in mountainous terrain throughout eastern Australia.

This project was undertaken in conjunction with a Wildlife and Exotic Disease Preparedness Plan (WEDPP) project to determine the contacts between feral goats and domestic livestock for modelling foot-and-mouth disease: accurate density estimates are crucial for determining contact rates.

3. Project location

The field site was on private holdings adjacent to Coolah Tops National Park in the tablelands of central eastern NSW near Coolah (149º 43' E, 31º50' S). The terrain is steep and rugged and woodlands, shrubby woodlands and forests are predominant in the National Park. Adjacent holdings are a mix of open grasslands, woodlands, and forests. The soils are fertile, being derived from basalt (Banks 1998), and the climate temperate with approximately 740 mm mean annual rainfall. Good pasture production supports dense populations of feral and domestic goats, sheep, cattle and macropods. In the northern region of the site, goats were run for cashmere and meat production while in the southern region all goats were feral.

4. Methods

New and existing methods were used to estimate the abundance of feral and domestic goats from the air and on the ground, and these estimates were compared against known numbers of goats determined by complete musters.

The methods used were:

- Aerial double-counts from helicopters
- Aerial videography
- Ground-based area counts and area double-counts
- Minimum number known alive calculated from ground counts taken at fixed points
- Mark-recapture estimates
- Mark-resight estimates

Aerial double-counts from helicopters

Aerial double-counts have the advantages of being quick to conduct and of covering a large area in short time. The double-count method uses two observers counting the same area simultaneously and is an adaptation of the Peterson mark-recapture estimate (Seber 1982). The count of one observer is equivalent to the first capture and the count of the other observer is equivalent to the recapture/ resighting.

The technique in which two observers simultaneously count animals from an aircraft was first described and used by Caughley & Grice (1982). The visibility of the animals from the air differs under different conditions and correction factors need to be calculated to account for these visibility biases. Choquenot used helicopters to double-count feral pigs (1995a) and kangaroos

(1995b) in semi-arid regions and accounted for observer bias and visibility bias in different habitats.

In this study, the methods of Choquenot (1995a,b) were used to survey the northern region of the study site (~24 km^2) on 6 occasions. The sampling rate was approximately 40 % and transects (selected at random without replacement) ran latitudinally across the grain of the terrain (Choquenot 1995b). Transects of 200m effective width were flown at 150 feet in a Hughes 500C or Bell Jet Ranger helicopter while airspeed was kept as close to 45 knots as possible. All goats occurring within a transect were counted in subgroups and the vegetation type they were observed in was recorded (Choquenot 1995a,b). There were two observers on one side of the aircraft and a single observer on the other. Correction factors that accounted for habitat were determined using established mark-recapture theory for aerial surveys (Caughley and Grice 1982, Choquenot 1995a,b). These correction factors were applied to the survey data for both sides of the aircraft and the abundance and density of the feral goat population calculated. For purposes of comparison the study site was subdivided into three regions for aerial double-counts; however, only the abundance estimates of the northern region are presented here.

Aerial videography from helicopters

Aerial videography potentially offers a standardised method of counting from the air and removes the need for trained observers. On three surveys in the northern region, a hand-held Sony video camera was used to concurrently film transects flown while counting feral goats on the double-counting side of the helicopter. The rear observer used the auto-focus facility during filming and the camera was continuously pointed at the same angle with constant focal length. The search swathe covered was the same as that of an observer seated in the front of the aircraft. It was hoped that the video results could be used to calibrate the front observer, be used for double-counting or as a standardised substitute for experienced observers.

Ground-based area counts, area double-counts and minimum number known alive

Area counting in this case refers to randomly selecting, with replacement, a sample of unequally sized units and counting all animals visible within them. Although this technique is based on traditional sampling theory (Caughley 1980) there are no known applications using unequal sized polygons for estimating wildlife from the ground or air.

Ground-based area counts and area double-counts (using two observers to simultaneously count the same area) taken from high points, if successful, would provide very cheap methods of estimating feral goat abundance in hilly terrain. These estimates have precision estimators and detection probabilities can be calculated. Likewise, minimum number known to be alive estimates (MNA) (Caughley and Sinclair 1994) taken from high points would provide cheap indices of abundance prior to and following control activities.

Observations from high points, assisted by the use of panoramic photographs, were used to determine ground-based area and area double-counts, and MNA estimates. For each survey district, photos were taken in a right-to-left series from a high observation point with a camera mounted on a tripod. The photos were then joined to form a panorama of all the area that was visible on the opposite slope from the observation point. Subdivisions that were readily delineated and recognised in the field were drawn onto each photograph and individually numbered. For each district, the same observation point was used during all area counts and area double-counts and for MNA counts.

To conduct area counts, an observer counted all the goats in each delineated subdivision, one subdivision at a time, and grouped the goats into light, coloured and dark classifications. The subdivisions to be included in analyses were identified by randomly selecting points (e.g. map co-ordinates) across the survey district. Those subdivisions containing one or more points were included in the analyses. Subdivisions were included as often as the number of random points that fell within them, even though they are surveyed only once (Caughley 1980).

For double-counts, two observers seated beside but obscured from each other counted the same subdivision simultaneously and then compared results identifying which goats both observers had seen and which only one observer had seen. This process allowed Petersen estimates and MNA estimates.

More-detailed methods and analyses are being prepared for publication (Tracey in prep, Tracey, J.P., Fleming, PJS, and Jones, GR in prep) and will be forwarded to NFACP on completion. Only the MNA estimates are presented here.

Mark-recapture and mark-resight estimates of abundance

A variety of mark-recapture estimates using models of varying complexity are possible but are labour intensive and expensive to obtain. The simplest of these estimates is the modified Petersen estimator (Bailey 1951), which applies to closed populations where immigration and births are nil, no marks are lost and individuals are equally catchable.

During the study, 984 feral goats were captured, individually marked and released. Estimates using the modified Petersen estimator were made on 6 capture occasions. On subsequent observations in the field, groups of goats were counted and the marked goats identified. These data were used to calculate mark-resight abundance estimates using a new hybrid model that combines the closed subpopulation model (Tuyttens *et al.* 1999) and Pollock's robust model (Pollock 1982). A paper outlining the new hybrid method is being prepared for scientific publication (Fleming, Tracey and Melville in prep.) and will be forwarded to NFACP on completion.

Briefly, field observations taken over four years were divided into 3-month seasons and the number of goats with and without individual marks were recorded for each observation in a season. These numbers were pooled for each season. For each season, the total number of marked animals in each subpopulation within the study site was estimated from observation records and survival rates calculated in the program MARK 3.1 (White 2002). These three numbers were then used in a Petersen estimator with Bailey's correction to estimate seasonal abundance and calculate seasonal density. Only a subsample of the results is presented here.

To enable comparisons, abundance estimates were standardised by converting them to densities (SE (Density) = SE (Abundance estimate)/ Area surveyed, Caughley and Sinclair 1994)

Total counts/ known numbers

Simultaneously with aerial surveys, total counts were undertaken for the northern region and two districts in the southern region. Total counts were achieved using mustering and aerially assisted mustering with simultaneous ground direction and observation. Corrected aerial double-counts and uncorrected Petersen estimates were compared with the total counts to determine the accuracy of the estimates of goat abundance for the northern region of the study site.

Relative costs

Calculations of the total costs per survey period (season) were conducted with the assumption that the whole of the southern region of the study site was surveyed to obtain one seasonal (the survey period) estimate for each method. To obtain equivalence of survey area with that achievable in an aerial double-count survey period, nine areas within the southern region would be required. The total cost per survey included the cost per hour of labour and helicopter hire (where applicable), and the minimum number of hours required to obtain useful estimates in a survey. Labour costs were calculated from average hourly rates paid to staff who conducted the work in each survey multiplied by the number of staff involved. The costing for the mark-resight estimate included the costs of two captures and releases.

5. Summary of Results

The mark-resight estimate data are from a thesis to be submitted by Peter Fleming for the degree of Doctor of Philosophy (Applied Science), University of Canberra (Fleming in prep, Appendix I). The data in the remainder of this section are from a thesis to be submitted by John Tracey for the degree of Master of Applied Science (Resource Management), University of Canberra (Tracey in prep, Appendix I).

Aerial double-counts from helicopters

Between April 1997 and October 1998, thirty-one aerial double-count surveys were conducted at the study site. This enabled calculation of estimates of visibility bias using the double-count technique (Magunsson *et al.* 1978; Caughley & Grice 1982; Choquenot 1995a,b). Preliminary multiplicative correction factors for one of the sites are given in Table 1 and preliminary population estimates for the northern region of the study site are shown below the table.

Table 1. Preliminary sighting probabilities and correction factors for each of the five vegetation types recognised at the study site near Coolah in north eastern NSW.

Vegetation type	Probability of sighting	Correction Factor
Forest	0.7559	1.323
Woodland	0.7576	1.320
Shrubby Woodland	0.7576	1.320
Shrubland	0.6897	1.450

Open	0.8688	1.151

Preliminary population estimates from double-count helicopter surveys on the northern region (Spring 1998) were:

- Uncorrected Peterson estimate from aerial double-counts N = **720 ± 114** goats
- Peterson estimate from aerial double-counts corrected for habitat N = **903 ± 151** goats.

Aerial videography from helicopters

Hand-held videography from a helicopter was unsuccessful because very few animals could be identified from the tapes and it was impossible to differentiate feral goats from other animals. Aerial videography using high quality hand held cameras was not effective for counting feral goats in the conditions we experienced. This method was abandoned after one trial.

Ground-based area counts, area double-counts and minimum number known alive

Although MNA estimates are relatively simple to calculate from ground-based area counts and area double-counts, the calculation of observable area requires considerable transformation of panoramic photos to fit onto maps. This is a specialist and time-consuming GIS task and has not been completed at this time. Therefore only MNA estimates are presented here.

Minumum number alive estimates calculated from data collected by two observers observing an area simultaneously showed considerable variation within seasons. For example, the mean MNA for Pyramids district in Spring 1999 was 47.6 goats (CV= 43.5%, n= 5 surveys) and the mean MNA for Sideagle district in Winter 2000 was 121.3 goats (CV= 34.7%, n= 3 surveys). Therefore the maximum number counted in a district within a season was used to estimate the MNA (Table 2).

Table 2. Minimum numbers of goats known to be alive (maximum MNA) in 6 districts at the study site near Coolah in north eastern NSW.

Season	**Year**	**District**	**MNA (max)**
Winter	1999	Gap Road	339
		Little Devils Hole	45
		No 23	172
		Snakey Creek	85
Total		**Northern Region**	**657**
Autumn	1999	Pyramids	71
Spring	1999		67
Winter	2000		91
Spring	2000		189
Summer	1998	Sideagle	68
Autumn	1999		193
Winter	1999		169
Spring	1999		132
Summer	1999		53
Winter	2000		141
Spring	2000	Sid eagle	171

Mark-recapture and mark-resight estimates

On 5 occasions, mobs of feral goats were captured, marked and released, then remustered immediately after release. This occurred in 3 districts and allowed modified Peterson mark-recapture estimates to be calculated (Table 3). These estimates were conducted at the same time as mark-resight estimates in Pyramids and Sideagle districts in the southern region of the study site.

Table 3. Mark-recapture estimates of feral goat abundance and density for the southern region of a site in near Coolah, NSW.

District	**Season**	**Abundance** (SE) (goats)	**District Area** (km^2)	**Density** (SE) (goats km^{-2})
Rotherwood Peak	Autumn 1997	**665.19**	6.8	***98.2***
		(82.14)		*(12.1)*
Pyramids	Summer 1999	**233.61**	6.2	***37.9***
		(37.02)		*(6.0)*
	Spring 2000	**220.79**	6.2	***35.8***
		(14.81)		*(2.4)*
Sideagle	Summer 1999	**275.79**	5.1	***54.6***
		(36.96)		*(7.2)*
	Spring 2000	**205.83**	6.6	***31.1***
		(12.86)		*(1.9)*

Using the new hybrid method, mark-resight estimates were calculated for 4 of the districts in the southern region of the site and a sample of the results for 3 districts are shown in Table 4. The standard errors were calculated from relative standard errors and the seasonal abundance estimates.

Table 4. A selection of mark-resight estimates of feral goat abundance and density for the southern region of a site in near Coolah, NSW, calculated with a new method (data from Fleming *et al*. in prep).

District	**Season**	**Abundance** (SE) (goats)	**Area surveyed** (km^2)	**Density** (goats km^{-2})
Rotherwood Peak	Autumn 1997	**1001.4** (41.0)	17.7	***56.5*** *(2.9)*
Pyramids	Autumn 1999	**210.8** (5.3)	6.1	***34.5*** *(0.9)*
	Spring 1999	**268.5** (16.0)	6.1	***43.9*** *(2.6)*
	Winter 2000	**398.6** (13.5)	7.9	***50.3*** *(1.7)*
	Spring 2000	**346.2** (2.8)	6.1	***56.6*** *(0.4)*
Sideagle	Autumn 1999	**294.1** (28.2)	9.3	***31.6*** *(3.0)*
	Spring 1999	**352.5** (19.3)	9.3	***37.6*** *(2.1)*
	Summer 1999	**140.2** (5.9)	12.4	***11.3*** *(0.5)*
	Winter 2000	**469.1** (19.7)	12.4	***37.9*** *(1.6)*
	Spring 2000	**354.6** (3.5)	12.4	***28.7*** *(0.3)*

Total counts/ known numbers

The numbers of goats mustered from paddocks in the northern region of the study site for the period corresponding with aerial double-counts from Spring1998 are shown in Table 5. Note that no estimate of precision was possible for these counts.

Table 5. Total counts of feral goats mustered from paddocks in the northern region of a study site near Coolah in north eastern NSW.

Paddock	Count
Snakey Creek	88
Number 23	280
Ration Paddocks	240
Little Devils Hole	170
Cox Creek/ Calamity gorge	50
Calamity Paddocks	100
Total	**928**

Relative costs

The cost of each method was restricted to labour and helicopter expenses and these along with the total cost per survey period are shown in Table 6. These costs apply only to the study site and otherwise will vary according to terrain and vegetation and the experience of ground staff.

Table 6. Estimated costs of each method of estimating abundance at a study site near Coolah in NSW.

Survey method	Helicopter ($ per hr)	Labour ($ per hr)	Total per hr ($)	Total per survey ($)	Total per season ($)
Aerial double-count	700	108	808	8 484	**8 484**
MNA		504	504	1 512	**13 608**
Mark-recapture	700	160	860	2 580	**23 220**
Mark-resight		108	108	4 320	**41 460**

6. Discussion

As previous researchers (Southwell 1994, Pople *et al*. 1998) have found, aerial surveys are an effective way of counting feral goats. The double-counting technique (e.g. Choquenot 1995) enabled correction factors for different habitats to be incorporated in the count, potentially improving the accuracy of the count. Although expensive, this method is probably the most effective in establishing the abundance and dispersion of feral goats over large areas (=100km^2). The correction factors obtained here are site-specific and at most can be applied to the study site, its surrounds and similar sites in the biogeographic region. Unfortunately, this will always be the case for aerial surveys of any animal. A logical step to generalising correction factors would be to standardise habitat type to some measurable component (such as percent tree cover) and obtaining a continuous scale rather than the discrete scale used in this study.

Aerial videography using high quality hand held cameras was not effective for counting feral goats in the conditions we experienced. Camera shake caused by the vibrations and movement of the helicopter, and slowness of autofocus probably contributed to failure in this trial. A higher quality camera capable of recording more frames per second and housed in a gimbal (stabilising pod that eliminates vibration and allows better focus) may enable aerial videography for counting animals as these modifications have been successfully used for television and thermal imaging. Such equipment is expensive and therefore increases the hourly cost of helicopters substantially (Grant Halverson helicopter operator, personal communication, 1998) and should be objectively assessed before aerial videography can be recommended.

As with all incomplete counts, there are limitations to the interpretation of MNA estimates. While it is essential to have estimates of precision around counts, it is logical that at any time the maximum MNA represents the minimum number of animals that are present in the subject area. The maximum MNA has no precision and cannot be validated except by comparison with known numbers. However, if MNAs are regularly close approximates (underestimates) of known numbers or other estimates, then they can be used as a cheaply gained surrogate for known numbers. Given the variability identified earlier, we suggest that a number of MNA estimates be conducted in order to establish the precision of MNA estimates and to gauge the accuracy of the maximum MNA.

Mark-recapture and mark-resight estimates were precise (Tables 3 and 4). Because the surveyed areas were different in size, comparisons between estimates were best undertaken after standardisation by converting abundances to densities.

Comparison of methods

Not all methods were used in all areas. Therefore, aerial survey methods were compared with known numbers in the northern region of the study site, mark-recapture and mark-resight estimates were compared at one district in the east of the southern region, and mark-recapture, mark-resight and MNA estimates for districts in the west of the southern region were compared with each other .

Preliminary analyses of these data indicate that aerial double-counts that fail to account for differences in habitat underestimate population size. Although the variation around the estimate in this study was about 17%, the known count was within the confidence limit of the corrected abundance estimate but not that of the uncorrected estimate for the northern region of the site. Further analyses are being conducted using different models (e.g. Alho 1990) to incorporate more variables likely to affect sighting probability, such as the type of helicopter used, the slope and aspect of the terrain, animal colour, site, time of day, direction of travel, observer experience and observer position in the helicopter.

In our study, MNA counts were conducted of comparable areas in the same season as mark-recapture estimates for Pyramids and Sideagle districts in Spring 2000 (Tables 2 and 3). MNAs were close to but underestimated mark-recapture estimates for both districts (189 vs 221 goats and 171 vs 206 goats respectively). This was expected because MNAs are by nature underestimates. However, it was reassuring that both underestimates were of a similar magnitude (approximately 85% of the mark-recapture estimates).

For Autumn 1997, mark-recapture and mark-resight estimates were comparable for Rotherwood Peak district (Tables 3 and 4). The mark-recapture density estimate was 1.7 times the mark-resight estimate and well outside the standard errors. However, the capture and recapture events were aimed at an area of known high density, positively biasing the mark-recapture estimate. The area surveyed in the mark-resight estimate was much (2.6 times) larger than for the mark-recapture estimate, encapsulated the whole district and included the capture area. The mark-resight estimate is therefore a better estimate of the density of the Rotherwood Peak district.

In Summer 1999, mark-recapture and mark-resight estimates of density were made for Sideagle district and in Spring 2000 both estimates were made for Pyramids and Sideagle districts. Similarly to Rotherwood Peak in Autumn 1997, the mark-recapture estimate for Summer 1999 was substantially higher than the mark-resight estimate. The latter Sideagle estimate was conducted over 2.4 times the area of the mark-recapture estimate of density and encapsulated the whole district and included the capture area. The mark-resight estimate is therefore likely a better estimate of the density of the Sideagle district in Summer 1999.

A similar area was surveyed for both estimates in Pyramids district in Spring 2000 and the mark-resight estimate was 1.6 times larger than the mark-recapture estimate and outside the standard errors of the estimates. As with Rotherwood Peak district in Autumn 1997,district, the mark-recapture density estimate for Sideagle in Spring 2000 was larger than the mark-resight estimate and outside the standard errors of both. The area surveyed in the mark-resight estimate in Sideagle was nearly twice that of the mark-recapture estimate.

The mark-recapture estimates are likely to be underestimates because the assumption of equal catchability between capture events is probably violated. Although this assumption is unlikely to be violated for mark-resight estimates, the method of calculating the number of marked animals in the population may be subject to error; these postulations require further analysis. However, mark-recapture estimates were higher than mark-resight estimates in all cases except Pyramids district in Spring 2000. This was the only case where the area surveyed was equivalent for both estimates. As Gaston *et al.* (1999) have observed, estimates of density are negatively related to the area surveyed. This comparison emphasises Caughley's (1980) discussion on the limits of a population and that the area selected for survey has to be appropriate for the dispersion of the population of interest.

Relative costs and logistics of obtaining estimates

Aerial survey was the most time-efficient method of estimating abundance, occupying three observers and a helicopter unit for two days in each survey period. Three surveys were conducted in each period and approximately 40% of 100 km^2 was covered in each survey. Obviously, greater area could be covered in the same time if the percentage cover was decreased. This was the most costly method in terms of cost per hour, but was the cheapest method per season.

Obtaining a minimum number alive estimate was the least expensive per survey and is probably the most accessible method for ground-based surveys. The most expensive of the ground-based methods was the mark-resight method. However, this method was likely to give the most accurate estimates and gave the most precise estimates. Although this method is not suitable for control programs because of the extensive time and physical exertion required it is very applicable to research where animals are captured, marked and then observed in the field.

7. Education/extension activities

There was no formal education component to this project. However, the VPRU worked in the Coolah Tops area for four and a half years and developed an excellent working relationship with landholders and land managers in the region. There were 3 formal meetings with groups of landholders and Rural Lands Protection Board and National Parks and Wildlife Service personnel at which the methods of counting were explained and discussed. We have further ensured results from this study will be applied in a practical and theoretical level by:

- Presentation of a paper at Australasian Wildlife Management Society (AWMS) Conference, 1998 at Gatton.
- Working in co-operation with Ken England, Pest Control Officer with NSW National Parks and Wildlife who is closely involved with the project and assists with aerial counts.
- Working in co-operation with Mal Leeson and Robert Snellgrove of Mudgee/ Merriwa Rural Lands Protection Boards and Ken England on co-operative feral goat control programs.
- Holding meetings and contributing to information displays at the Cassilis, Murrurundi, Orange Agricultural Institute and Orange National Field days explaining current feral goat research to the public.
- Presenting lectures on aerial survey techniques to the annual Vertebrate Pest Management Courses run for pest control officers by VPRU (1998-2003).
- Presentation of 2 seminars to postgraduate students at Applied Ecology Research Group, University of Canberra (1999 & 2002).
- Co-operating in two Feral Goat Management committees in the Coolah Tops for the ongoing control of feral goats and ovine footrot in the area (1997-2002). An estimate of abundance from aerial double-counts was used to determine the number of goats remaining after initial control efforts.
- A paper outlining the relative costs of different methods of capturing feral goats in mountainous terrain was presented at the NSW Pest Animal Conference in Dubbo (2002).
- A paper presenting some of the counting methods developed in this project has been accepted for the International Wildlife Management Congress in Christchurch in December 2003.
- A series of publications, currently in preparation, will be made available to wildlife managers and researchers internationally (***Appendix I***).

*8. **Statement of expenditure to date signed off by Financial Controller** (if there is significant under-expenditure - i.e. less than 75% of projected expenditure spent - provide an explanation)*

A signed statement of expenditure has been sent separately from NSW Agriculture, Administration section. Nil balance remaining.

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Appendix I: Relevant publications in preparation

Fleming, PJS (in prep.) Relationships between feral goats (Capra hircus) and livestock in a high-rainfall, tableland environment with reference to disease transmission. Unpublished Ph D thesis, University of Canberra.

Fleming, PJS, Tracey, J.P., and Melville, G. (in prep) A modified closed-subpopulation/ robust method for estimating the abundance of feral goats using capture-recapture and ancillary data.

Tracey, J.P. (in prep) Assessing estimators of feral goat (*Capra hircus*) abundance in the Coolah Tops. Unpublished M. Appl. Sc. (Resource Management) thesis, University of Canberra.

Tracey, J.P., England, K., Fleming, PJS, Gentle, MN, Jones, GR and Melville, G. (in prep) A comparison of methods for estimating the abundance of feral goats (*Capra hircus*) against a known number.

Tracey, J.P., England, K., Fleming, P.J.S., and Melville, G. (in prep) Evaluation of the aerial double-count method for estimating the abundance of feral goats in mountainous terrain.

Tracey, J.P., Fleming, PJS, Gentle, MN, Jones, GR, and Melville, G. (in prep) Testing assumption violations in aerial survey using independently derived data.

Tracey, J.P., Fleming, PJS, and Jones, GR (in prep) A ground-based technique for estimating the abundance of feral goats in mountainous terrain.

Tracey, J.P., Fleming, PJS, and Melville, G. (a, in prep) Factors influencing sighting probability for aerial surveys of feral goats.

Tracey, J.P., Fleming, PJS, and Melville, G. (b, in prep) Counts and indices of feral goats in hilly terrain: a comparison of techniques. *Proceedings of the 3rd International Wildlife Management Congress*

Tracey, J.P., Fleming, PJS, and Melville, G. (c, in prep) The application of ground and aerially acquired indices of abundance for feral goats.