# Some aspects of the biology of the common brushtail possum (*Trichosurus vulpecula*) and the threatened western ringtail possum (*Pseudocheirus occidentalis*) in a pine plantation scheduled for harvesting and in adjacent tuart and peppermint woodland near Busselton, Western Australia.

**Report prepared for**
**the Forest Products Commission**
**Government of Western Australia**

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## Executive Summary

Funding was provided by the Western Australian Forest Products Commission (FPC), through the Western Australian Department of Environment and Conservation (DEC) Sustainable Forest Management Division and DEC's Science Division to assess the effect of pine harvesting on a population of the common brushtail possum (*Trichosurus vulpecula*) within Ludlow State Forest, near Busselton.

The focus of this assessment was to determine whether during, and immediately post harvesting, the resident brushtail possum population would disperse into the adjoining tuart (*Eucalyptus gomphocephala*) and peppermint (*Agonis flexuosa*) woodland within Tuart Forest National Park. Further, if this did occur, the focus was to assess the effect this had on the population of western ringtail possums resident within the adjoining tuart/ peppermint woodland.

The common brushtail possum and western ringtail possum occupy similar habitat niches in the forests of south-west Western Australia. Although there are recognised differences in food intake and behaviour, they commonly interact and may compete in areas where they both occur. It is not known exactly how and to what extent one impacts upon the other. However, the common brushtail possum is larger and more aggressive. Therefore, it is likely the western ringtail possum is the more vulnerable of the two to changes in the inter-species balance and habitat disturbance from harvesting. This is of management significance as the western ringtail possum is listed as a threatened species (vulnerable) nationally and internationally. In Western Australia it is listed as *"fauna which is likely to become extinct, or is rare"* (Western Australian Wildlife Conservation Act 1950).

The proposed pine harvesting was delayed and not undertaken during the period of this study. However, considerable information relevant to future pine harvesting operations was obtained and is reported, namely:

- assessment of habitat use patterns for both possum species demonstrated brushtail possums were using pine and the tuart/ peppermint woodland habitat and ringtail possums were restricted to the tuart/ peppermint woodland;
- the pine plantation is a significant habitat for the brushtail possum;
- there was considerable temporal and spatial overlap in home range and resource use between the two possum species within the tuart/ peppermint woodland; and
- both species showed a high seasonal mortality rate.

On the basis of the observed patterns of habitat use, there appears to be little evidence of existing competition for den sites as, in the presence of strong competition for den sites and dominance by brushtail possums, ringtail possums would be expected to show greater use of dreys and other alternative den/rest sites than was observed. However, the existing use of pines and tuart/ peppermint woodland by brushtail possums, combined with the observed movement of brushtails between habitat types and their minimal use of the interface between the habitat types (shown by the multimodal home ranges of brushtail possums using both habitat types) suggests, if pine harvesting occurs, brushtail possums can and will disperse from the pines to the tuart/ peppermint woodland.

The likely outcome from this dispersal is creation of competition for den sites within the tuart/ peppermint woodland, or an increase in the existing level of competition for den sites. This competition is likely to occur at the inter-species (brushtail/ringtail) and intra-species (brushtail/brushtail) level.

The observed patterns of nocturnal foraging / nocturnal use of the canopy appear to reflect habitat partitioning based on foraging preferences and/or nocturnal rest site preferences. However, it is unclear if this apparent partitioning reflects a real difference in preference for resources or competition for resources. If the latter, the proposed pine harvesting will increase this level of competition and will potentially jeopardise the viability of the western ringtail possum population within the tuart/ peppermint woodland.

## Recommendations

Detailed recommendations are provide in Section 7 (pages 26 to 27). In summary, it is recommended:

(i) harvesting does not occur in late summer or autumn, when mortality rates for both species, western ringtail possums in particular, are at their highest. The additional disturbance from harvesting in this period may result in an unsustainable rate of mortality for one or both species.

(ii) a monitoring program is established to determine if pine harvesting results in dispersal of the resident population of brushtail possums and, if so, to determine if there is a subsequent effect on the population of western ringtail possums within the adjacent Tuart Forest National Park.

(iii) the monitoring program incorporate at least one control site.

(iv) the monitoring program determine pre and post harvesting estimates of population size for both possum species.

(v) monitoring of both possum species incorporate an assessment of habitat use before, during and post harvesting.

(vi) the monitoring program assess the extent of dietary overlap between the two possum species to assist in differentiating between competition and habitat partitioning.

(vii) radio-telemetry monitoring be undertaken to assess if there are any differences in the frequency and nature (*i.e.* different predator species) of predation events between the treatment and control sites and, in doing so, determine if any differences are attributable to the harvesting operation.

(viii) protection measures are established pre harvesting to minimise physical disturbance to known brushtail possum den sites (e.g. disused rabbit warrens, fallen logs and remnant individual tuarts) within the harvesting area. These may serve as short and long term refuges from direct and indirect effects of pine harvesting.

(ix) the feasibility be assessed for incorporating measures to routinely retain potential den sites in pine harvesting operations generally.

## Disclaimer

This research was undertaken as part of a PhD program (Grimm, in prep) through Murdoch University, Perth, in conjunction with DEC. The research was primarily supported by the Australian Research Council (Linkage Project Grant # 0562099), DEC and Murdoch University. Supplementary funding was provided by the Forest Products Commission through DEC's Sustainable Forest Management Division (SFM) and DEC's Science Division to assess the effect of pine harvesting on common brushtail possum and western ringtail possum populations. The proposed pine harvesting operation within Ludlow State Forest did not occur within the originally anticipated timeframe and the conclusions from this report should not be seen as an assessment of the effect of pine harvesting. Pine harvesting within Ludlow State Forest is now scheduled for mid 2010.

The findings and recommendations presented in this report are preliminary and represent results from monitoring common brushtail possum and western ringtail possum populations within Ludlow State Forest and Tuart Forest National Park. Final research findings will be provided (Grimm, in prep) and progressively published in appropriate peer-reviewed journals. Submission for publication is anticipated to commence in early 2010. Therefore, the reader is directed to seek these papers, once published, for definitive conclusions on brushtail and ringtail possum survivorship, habitat use and home range within Ludlow State Forest and Tuart Forest National Park.

## Abbreviations

| | |
|---|---|
| DEC: | Western Australian Department of Environment and Conservation |
| DEWHA: | The Commonwealth Department of Environment, Water, Heritage and the Arts |
| EPBC Act: | The Commonwealth Environment Protection and Biodiversity Conservation Act, 1999 |
| FPC: | The Western Australian Forest Products Commission |
| SFM: | Sustainable Forest Management Division with the Department of Environment and Conservation |

# Some aspects of the biology of the common brushtail possum (*Trichosurus vulpecula*) and the threatened western ringtail possum (*Pseudocheirus occidentalis*) in a pine plantation scheduled for harvesting and in adjacent tuart and peppermint woodland near Busselton, Western Australia.

## 1 Background and objectives

The research undertaken within Ludlow State Forest and Tuart Forest National Park is part of a larger PhD research program (Grimm, in prep). The overall aims of the PhD program are to investigate and evaluate features of the biology of the western ringtail possum, or ngwayir (*Pseudocheirus occidentalis*) and the common brushtail possum, or koomal (*Trichosurus vulpecula*) on the southern Swan Coastal Plain. The research was initiated to expand the knowledge on the biology of both species and, in particular, to provide:

- information on abundance of both possum species;
- information on habitat features important to the persistence of both possum species;
- spatial arrangement, size and variability in home ranges and diurnal and nocturnal activities;
- interspecies relationships in habitat use and home ranges;
- patterns of mortality;
- baseline values for haematology, biochemistry, urinalysis, cloacal microbiology and faecal parasitology in both species; and
- indications of the level of exposure to the infectious disease agents *Cryptococcus*, *Chlamydophila*, *Leptospira*, *Toxoplasma* and Ross River Virus.

The component of the research undertaken for the Western Australian Forest Products Commission (FPC) and the WA Department of Environment and Conservation (DEC) within Ludlow State Forest and Tuart Forest National Park and reported here, was intended to assess the effect of pine (*Pinus radiata*) harvesting on the resident population of common brushtail possums with Ludlow State Forest, near Busselton, south-west Western Australia. More specifically, the objective was to determine whether this harvesting and the subsequent dispersal of brushtail possums (if it occurred) would impact on the population of western ringtail possums known to be present within the tuart (*Eucalyptus gomphocephala*) and peppermint (*Agonis flexuosa*) woodland within Tuart Forest National Park, immediately adjacent to Ludlow State Forest. The research was initiated by the FPC and DEC in recognition of the potential effect on the western ringtail possum from the proposed pine harvesting.

The western ringtail possum is listed as a threatened species nationally and internationally and is listed in WA as *"fauna which is likely to become extinct, or is rare"* (WA Wildlife Conservation act 1950). It was unclear if the proposed harvesting would constitute a "matter of national environmental significance", as defined by the Commonwealth Environment Protection and Biodiversity Conservation Act, 1999 (EPBC Act). Therefore, the FPC sought to undertake a precautionary approach and assess the effect of the pine harvesting on the ringtail possum population and, in doing so, prepare a set of guidelines to minimise any potential effects where pine harvesting had the potential to affect western ringtail possum populations.

The proposed pine harvesting was delayed and is now scheduled for mid 2010. In the absence of harvesting, this report presents findings on population size, habitat use and home range of the common brushtail possum and the western ringtail possum within Ludlow State Forest and Tuart Forest National Park.

# 2 The study site

The study site is located within the south-west section of Tuart Forest National Park and Ludlow State Forest, approximately 8km east of Busselton (115°25'48"E, 33°38'30"S) (Fig. 1) and comprises an area of approximately 164ha. Of this, approximately 97ha are within Tuart Forest National Park and approximately 67ha within Ludlow State Forest. The study site is bounded by Tuart Drive, the Abba River, Bussell Highway and Bunyip Road (Fig 2).

The site is comprised of two distinct habitat types, separated by a sand track running longitudinally and approximately centrally through the site (Fig. 2). The vegetation to the north-west of the track (within Tuart Forest National Park) consists of tuart (*Eucalyptus gomphocephala*) tall woodland over peppermint (*Agonis flexuosa*) open forest (Keighery and Keighery, 2002) (Fig. 3). The vegetation to the south-east of the track (within Ludlow State Forest) consists of a plantation of Radiata pine (*Pinus radiata*) with occasional remnant tuart and peppermint. This vegetation was considered completely degraded from its natural condition (Keighery and Keighery, 2002) (Fig. 4).

Baiting for fox control has been carried out in Tuart Forest National Park for at least six years prior to the commencement of the current study and was maintained during and post completion of the study. Dried meat baits and/or Probait sausage baits were used, each containing 3mg of the toxin "1080" (sodium monofluoroacetate). Baiting of all blocks in the National Park is carried out monthly by DEC staff, with baits placed on the ground every 200m on perimeter tracks and major internal tracks within the Tuart Forest National Park (C. Prowse, personal communication).

# 3 Methods

## 3.1 Possum capture, processing and population estimates

Brushtail possums were trapped using standard wire cage traps (Sheffield traps) baited with universal bait (rolled oats, peanut butter and honey) set in a grid network. Traps were set at 50m spacings on parallel transects 100m apart and perpendicular to the centre track (Fig. 2). Grid networks of equal size were set within Tuart Forest National Park and Ludlow State Forest. Traps were set for six consecutive nights in July 2008, with a 10 day period between trapping each habitat type.

The trapping grids were originally established to enable a one-off "closed population" estimate (White, 2001) of the brushtail possum population size within each habitat type. Additional trapping, using part only of the grid network and usually targeting individual brushtail possums, was also carried out to recapture animals requiring a change of radio collar or to add new animals to the radio collared monitored sample to maintain sample size (see sections 3.2, 3.3 and 3.4 below).

Ringtail possums do not readily enter traps and were caught through use of a tranquiliser dart gun designed and developed specifically for capture of western ringtail possums (de Tores *et al.*, in prep). Darting was usually at night, while possums were actively foraging and were readily detected by use of standard spotlighting techniques. Zoletil® (Tiletamine hydrochloride and Zolazepam hydrochloride in a 1:1 combination), the intramuscular anaesthetic used in the dartgun, was administered at a nominal dose rate of 12mg/kg. The actual dose administered to each darted possum varied. In all cases it was within the therapeutic range. Therefore, the level of sedation for darted possums can vary from heavily sedated to a light plane of anaesthesia (de Tores *et al.*, in prep). Post darting, the recovery phase may take up to 15 minutes for first spontaneous movement. This provides enough time to secure the possum in a calico bag in preparation for transport to the field station. Heat pads (or more commonly, hot water bottles) were provided for warmth, as necessary. Full recovery from Zoletil can take up to two hours.

Following capture, each ringtail and brushtail possum was transported to a research facility for 'processing'. Processing was carried out when each animal was anaesthetised through Isoflurane gas inhalation. Isoflurane anaesthesia of previously darted ringtail possums was carried out a minimum of eight hours after darting and sedation with Zoletil.

Processing involved weighing, collection of standard morphometric data, collection of an ear tissue biopsy for subsequent DNA analysis (Wilson, 2009), examination of breeding status, collection of blood, urine, faeces and microbiological swabs (for the concurrent component of the research (Grimm, in prep)) and fitting of a radio collar. Processing occurred during the day. Full recovery from Isoflurane anaesthesia generally takes up to 15 minutes.

Each possum was released at its point of capture in the evening following trapping or darting. Possums were recaptured as necessary for collar replacement. Some opportunistic darting was carried out during daylight when western ringtail possums were in easily accessible rest sites or dreys. Opportunistic capture was used to maintain the sample size of radio collared ringtail possums.

Estimates of ringtail possum population size were derived from spotlight transects and use of Distance sampling methodology (Buckland *et al.*, 2005; Thomas *et al.*, 2005). "Zig-Zag" transects (Buckland *et al.*, 2005) were established within the tuart/ peppermint woodland and were repeatedly sampled to ensure a sufficient number of sightings was recorded to meet the assumptions of Distance sampling. The location of each sighting was determined through differential GPS (post processing) to enable calculation of the perpendicular distance of each sighting from the transect line. Data were also collected for each brushtail possum sighting to enable estimates of brushtail possum population size to be derived though Distance and compared with estimates derived from trapping.

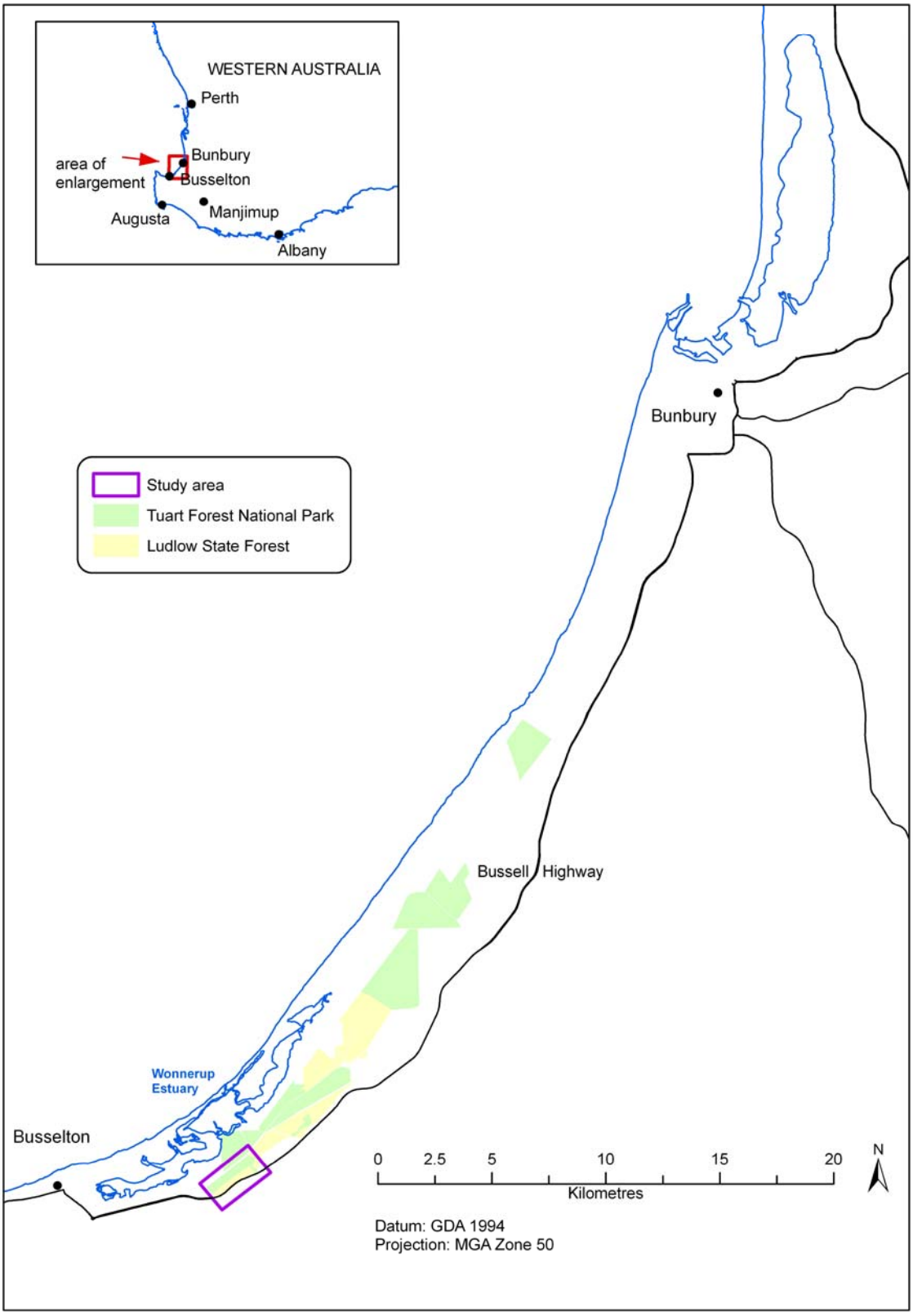



Figure 1: General location of the Tuart Forest National Park and Ludlow State Forest study area where populations of the western ringtail possum and common brushtail possum were monitored.

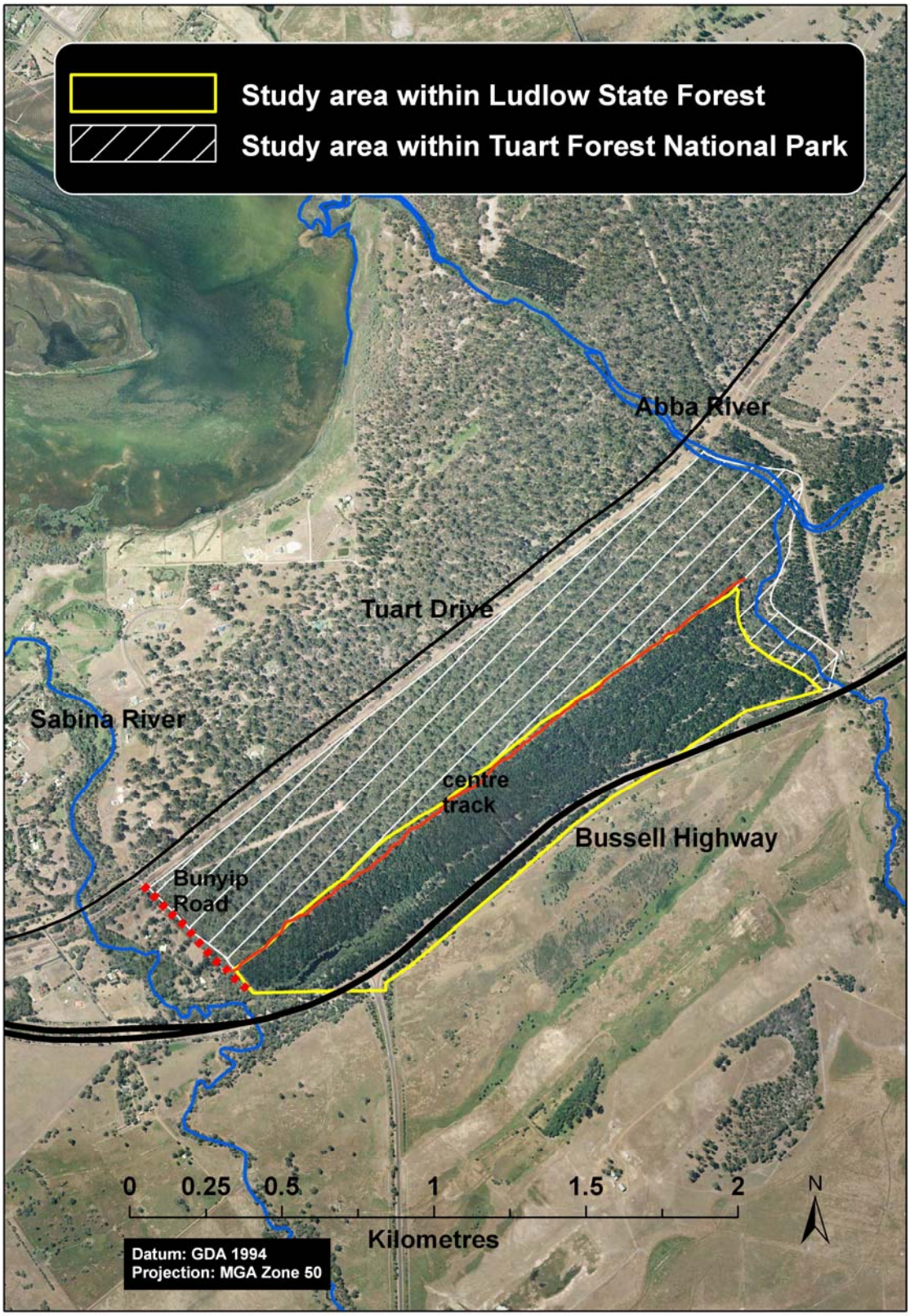



Figure 2: Orthophotograph of the Tuart Forest National Park and Ludlow State Forest study area where populations of the western ringtail possum and common brushtail possum were monitored.

Figure 3: The tuart/ peppermint woodland within Tuart Forest National Park, adjacent to a central track dividing the two habitat types within the study area.

Figure 4: *Pinus radiata* plantation within the study area and forming part of Ludlow State Forest, south-west Western Australia.

## 3.2 Radio-telemetry – location records and habitat use

Radio collars were fitted to a subset of captured ringtail and brushtail possums to enable collection of location data and assessment of home range and habitat use for both species. A combination of movement sensitive "mortality" radio collars and contact/ proximity radio collars was used for both possum species. Location data were collected between December 2006 and January 2009. Each radio-collared animal was monitored a minimum of once (usually twice) weekly to record diurnal and nocturnal locations. Nocturnal observations were confirmed by visual sighting. Diurnal records were pin pointed to an individual tree or other den site.

A differentially corrected (post processed) GPS determined location (or "fix") was recorded for each diurnal and nocturnal radio tracking record. The data collected for each diurnal den or rest site included:

- the type of den site (e.g. tree hollow, fallen log or other den site such as a burrow, disused rabbit warren or, in the case of ringtail possums, the type of rest site or drey used and the extent of drey construction);
- tree species;
- tree height and diameter at breast height, over bark (DBH (OB)); and
- the height of the tree hollow entry, or height of the rest site, or for nocturnal locations, height of the observed animal.

Additional information was recorded when den sites were within tree hollows, including:

- the angle of lean of the tree;
- the tree form and dead wood order (after Whitford, 2002);
- hollow characteristics, including the location of the hollow on the branch and position in the tree, orientation, size and shape of the hollow opening and the size of the cavity if discernible;
- the extent of connectivity with neighbouring vegetation; and
- density of surrounding vegetation.

## 3.3 Radio-telemetry – survivorship and causes of mortality

Survivorship data were also collected at least once (usually twice) weekly for each radio collared possum. Use of mortality collars enabled collection of additional survivorship data, as it was sufficient to detect the signal only to confirm each animal was alive (*i.e.* there was no requirement to track to the location of the animal). Data were collected to enable subsequent analysis using the known fate model from Program MARK (White, 2001). The "known fate" model also incorporates staggered entry, whereby the monitored sample size can be maintained by addition of new animals at any stage of the study. When combined with other concurrently collected data, survivorship modelling can assess the relative importance of variables (*e.g.* seasonal effects) and can identify and factors which directly and/ or indirectly influence survivorship.

For each known mortality of a radio collared possum, data were collected on the condition of the retrieved carcass and the condition of the retrieved radio collar to attempt to determine the cause of death. Although frequent monitoring and use of mortality collars enables rapid detection of a mortality event, the assessment of the cause of death involves some degree of subjectivity and it is difficult to unambiguously differentiate between predation and scavenging. Similarly, attributing what appears to be a predation event to a

particular predator species is, to some extent, subjective. Identification of the predator species responsible for a predation event has conventionally relied upon a subjective assessment or scoring scheme, whereby different characteristics are considered to be indicative of different predators. These characteristics include the size of tooth marks left in a radio collar, the way in which the carcass has been dismembered or the way the carcass is buried, etc. Not all characteristics are present when each carcass and/or radio collar is recovered. The number and combination of characters present on any individual carcass and radio collar determines the degree of confidence in the identification of the species responsible for each predation event.

To reduce the subjectivity associated with identifying predators, any visible tooth marks or wounds on carcasses and/or tooth marks on recovered radio collar were "swabbed", using a sterile medical swab, in an attempt to collect saliva left by the predator species responsible for the wounds or tooth marks. Each swab was subsequently examined and, where possible, DNA recovered and amplified utilising polymerase chain reaction (PCR) procedures. Melt curve analysis recently developed through collaboration between DEC and the Invasive Animals Cooperative Research Centre (IA CRC) (Oliver Berry, unpublished) has enabled relatively rapid and reliable differentiation between DNA left by foxes, cats, dogs and chuditch.

### 3.4 Radio-telemetry – home range and choice of home range estimator

The field of home range analysis has become much more sophisticated over recent years. Several modes of analysis now relate the home range to the probability of finding an animal at a particular location on a plane, represented by a density function or "utilisation distribution" (Anderson, 1982; White and Garrott, 1990). The home range is thus defined as "the extent of area with a defined probability of occurrence of an animal during a specified time period" (Kernohan *et al.*, 2001). Given the utilisation distribution is a bivariate probability density function, it can be calculated from the data and isopleths (contours) drawn enclosing a volume under the function (Horne and Garton, 2006; White and Garrott, 1990). The core area within a contour enclosing an arbitrary level of probability, commonly 95%, is considered to be the 'normal' home range. However, isopleths can be drawn at any probability level producing internal contouring which represent differential density of animal activity, and which can be related to habitat features.

We used the kernel density estimation method for producing home ranges, utilising the likelihood-cross validation (LCV) method for choosing the smoothing parameter (Horne and Garton, 2006). Due to apparent over smoothing, all utilisation distributions were eventually produced using $0.75h_{LCV}$ as the smoothing factor. We selected the 50% and 90% areas to represent the central area of activity (or core home range) and overall home range, respectively. The output enabled distinction between home ranges with one (unimodal) or more than one (bimodal, etc) focus of animal activity.

## 4 Results

### 4.1 Possum capture and estimates of population size

A total of 25 ringtail possums and 66 brushtail possums was caught and marked during the study period. Of these, 23 ringtail possums and 30 brushtail possums were radio collared.

The 30 brushtail possums trapped and radio collared and three additional trapped and uncollared brushtail possums with multiple trapping records, were placed into one of three categories based on habitat affiliation as indicated by radio-telemetry and trapping location records:

(i) brushtail possums using only the pine plantation for all den and foraging resources (animals with majority affiliation with the pine plantation and with very few fixes in the tuart/ peppermint woodland were included in this group) – 8 animals;

(ii) brushtail possums using both the pine plantation and the tuart/ peppermint woodland for den and foraging resources – 18 animals; and

(iii) brushtail possums affiliated with the tuart/ peppermint woodland – this includes those brushtail possums using both the pine plantation and the tuart/ peppermint woodland for den and foraging resources and with the majority of locations indicating affiliation with the tuart/ peppermint woodland and with very few location records in the pine plantation – 7 animals.

Only animals with a sufficient number of fixes obtained from radio-tracking or trapping were included in these categories. A further 33 brushtail possums were trapped at least once during the course of the study but had too few fixes to give an indication of habitat preference (although most were trapped in the tuart/ peppermint woodland).

Trap success rates and the number of individual brushtail possums caught over equivalent areas and time periods was less in the pine plantation than the tuart/ peppermint woodland. Interim analysis suggests the brushtail possum population within the tuart/ peppermint woodland is approximately three times larger than the population within the pine plantation. Final estimates of brushtail possum population size will be derived through mark-recapture techniques and reported in Grimm (in prep) and subsequent publications.

Ringtail possums were present in the tuart/ peppermint woodland only. Final estimates of ringtail possum population density will be derived (Grimm, in prep) using Distance sampling techniques (Buckland *et al.*, 2005) from pooled data collected in spotlighting surveys from within the study area and from concurrent spotlight surveys outside the study area.

## 4.2 Radio-telemetry – location records and habitat use

The majority of animal location data was obtained from a 30 hectare cross section of both blocks. Most den sites used by both possum species in the tuart/ peppermint woodland were tree hollows, with very few records of ringtails using dreys.

### *4.2.1 Habitat use – den sites*

Brushtail possums used multiple den sites within the pine plantation. These included 6 different tree hollows, 3 hollow logs, 9 disused rabbit warrens/ warren systems and 6 miscellaneous den sites (“rest sites”) (Fig. 5). All tree hollows used within the pine plantation were in mature remnant tuarts. These trees generally had canopy contact with multiple other trees; mostly pines but also peppermint. Five of the six miscellaneous rest sites used by brushtail possums were within clumps of dense foliage (live and dead needles, mistletoe) on the branches of pine trees. The sixth was in accumulated leaves in a *Banksia attenuata*.

Within the tuart/ peppermint woodland, ringtail possums were found to use tree hollows in tuarts and peppermints.

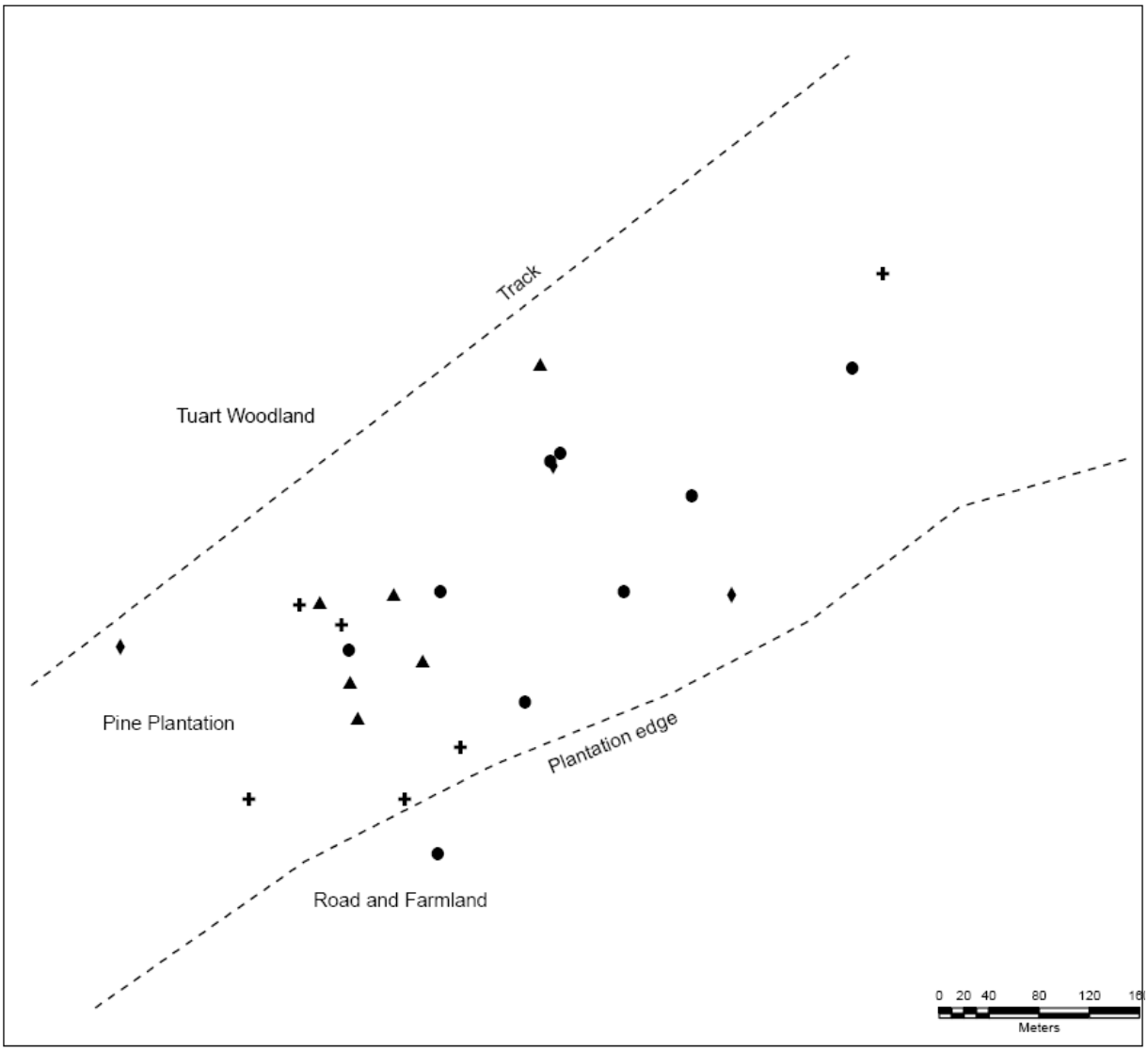
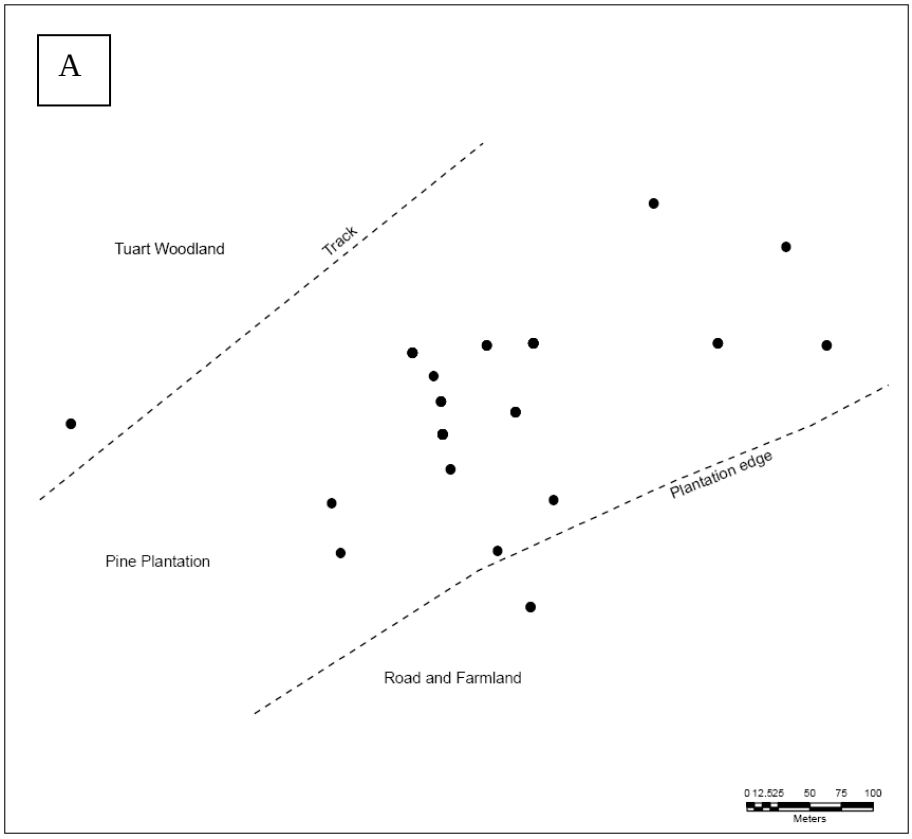



Figure 5: Den sites known to be used by brushtail possums within Ludlow State Forest (pine plantation)
tree hollows ▲, burrows ●, hollow logs ♦, rest sites ✚

Den sites used by brushtail possums with an affinity with the pine plantation are shown in figure 6A and those with an affinity for both habitat types in figure 6B.



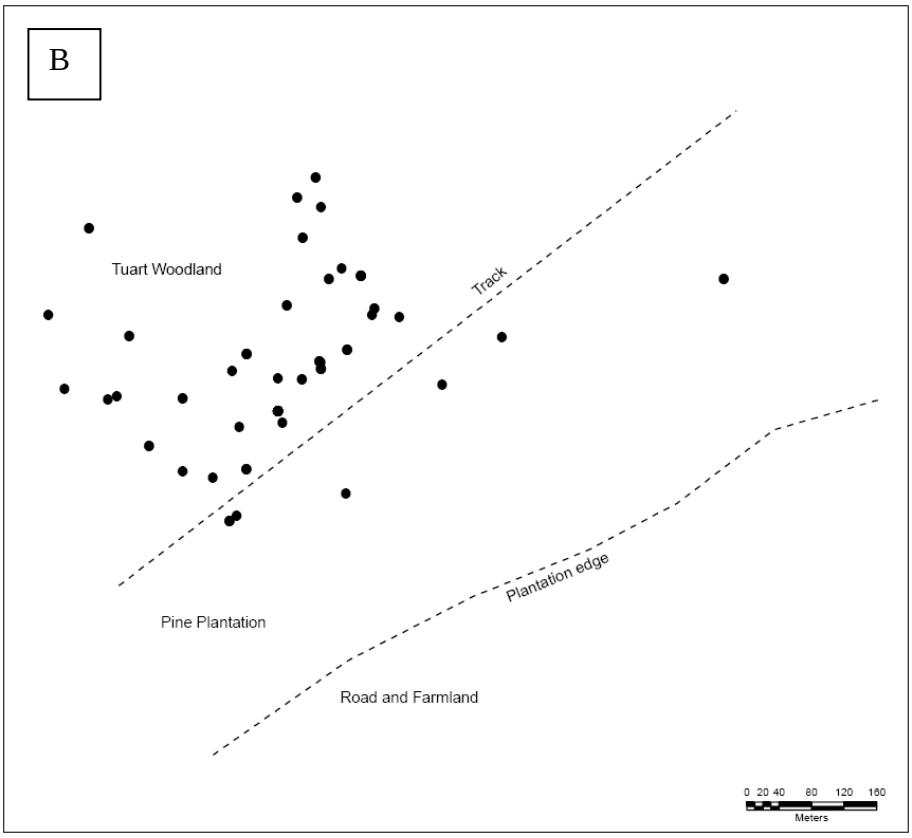




Figure 6: Den sites used by brushtail possums with
A: an affinity with the pine plantation
B: an affinity for both habitat types

### *4.2.2 Brushtail possum habitat use – nocturnal foraging sites*

Nocturnal foraging sites for brushtail possums with an affinity for the pine plantation are shown in figure 7A. The majority (90%) of nocturnal observations of brushtails in the pine plantation (n~85) were in a *Pinus radiata*. Nocturnal foraging sites for brushtail possums with an affinity for both habitat types are shown in figure 7B.

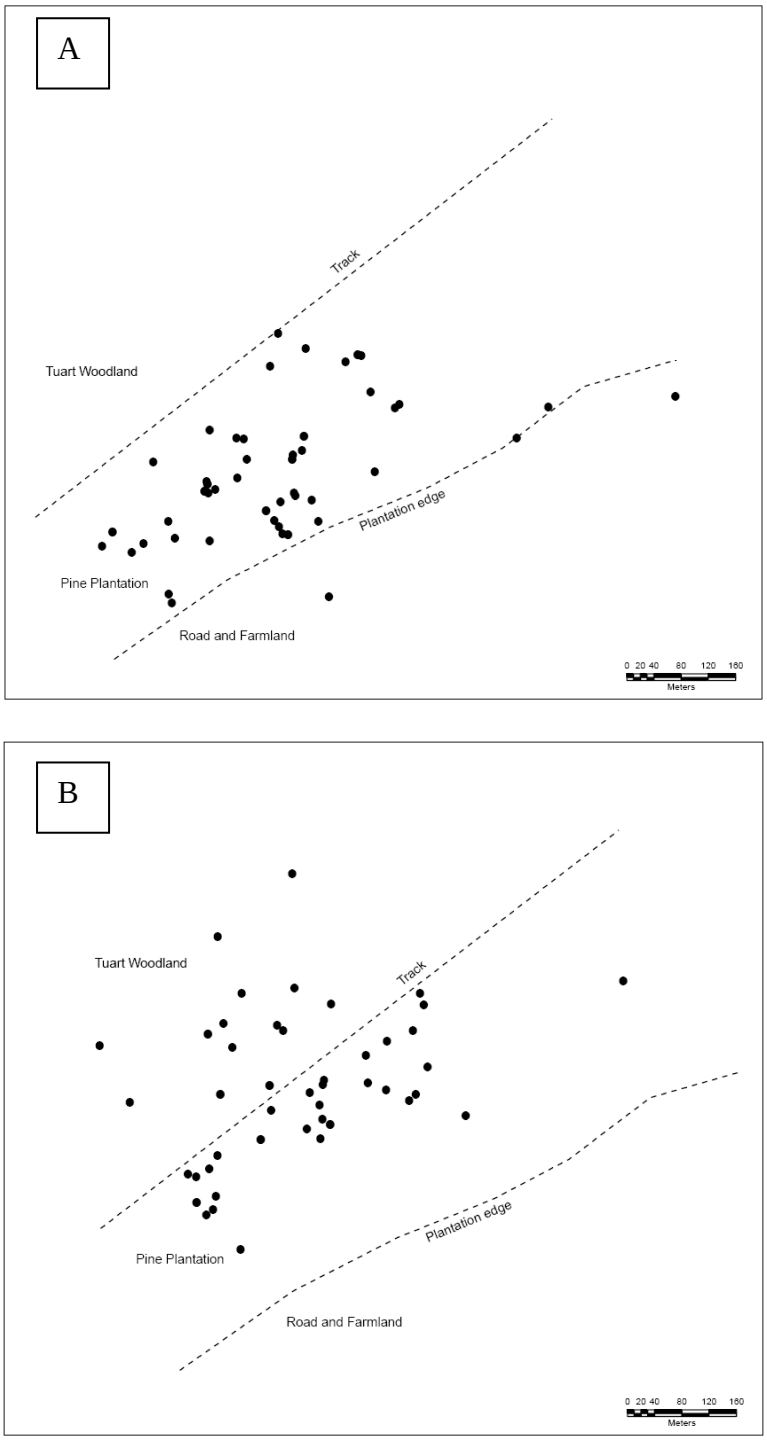



Figure 7: Nocturnal foraging sites used by brushtail possums with
A: an affinity with the pine plantation
B: an affinity for both habitat types

### 4.2.3 Foraging tree species preference and foraging heights for brushtail and ringtail possums

Nocturnal observations of brushtail possums made during radio-tracking and spotlighting surveys (n~81) revealed 58% were in tuart and 42% were in peppermint. Contrasting with this, nocturnal records for ringtail possums were most frequent (93%, n=307) in peppermint.

Nocturnal observations also indicated a preference by brushtail possums for the upper stratum of the pine plantation (Fig 8A). In the tuart/ peppermint woodland, nocturnal observations of brushtail possums indicated activity in both the lower peppermint canopy and the higher tuart canopy (Fig 8B). Twenty-three western ringtail possums were radio-tracked for varying amounts of time during the study. Western ringtail possums showed a preference for the lower stratum (peppermint) in the tuart/ peppermint woodland (Fig. 8C).

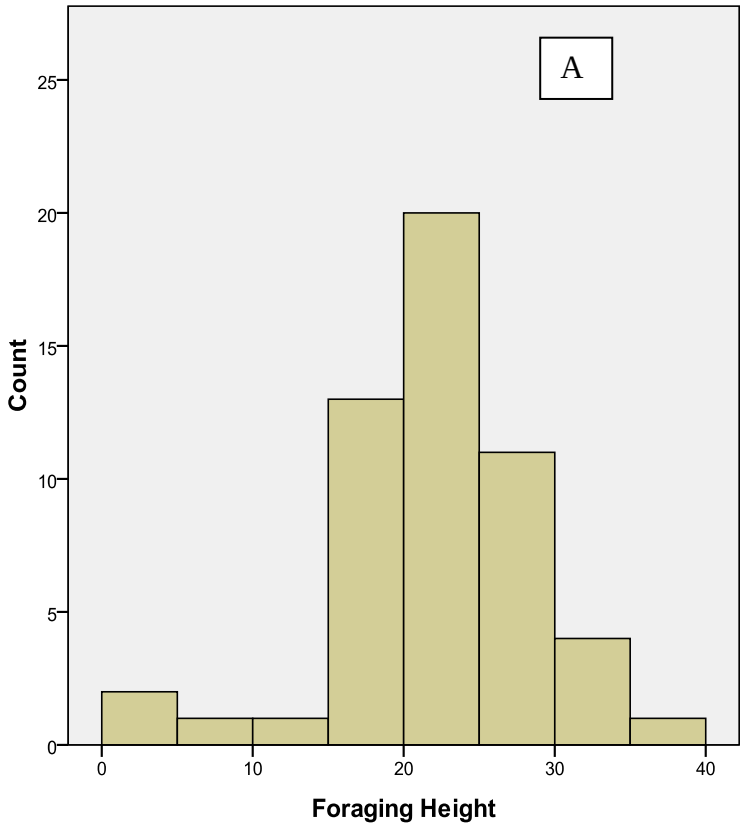
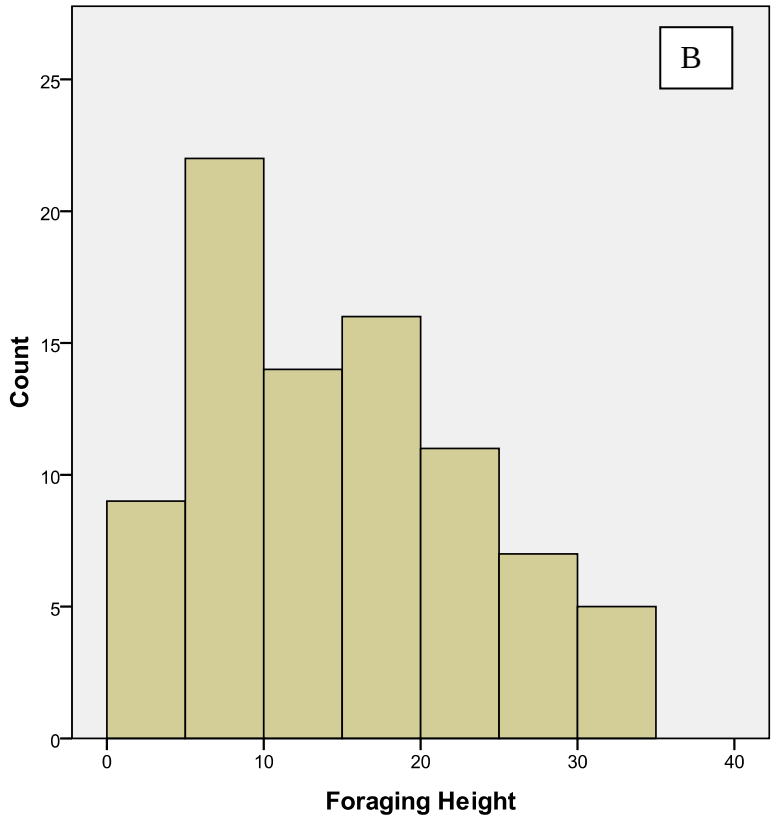



Figure 8: Vertical height (in metres) of foraging observations from radio-tracking and spotlighting
A: all observations of brushtails in the pine plantation



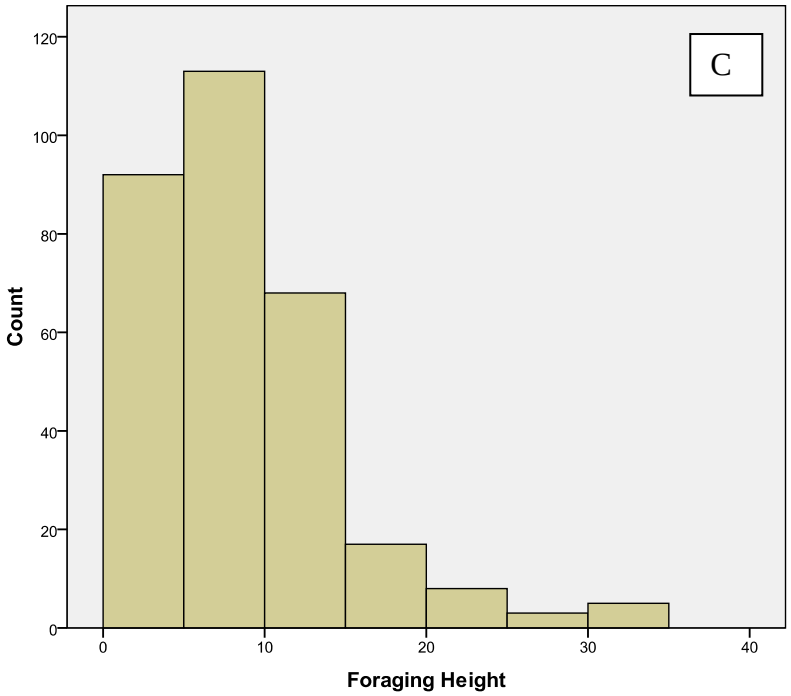




Figure 8 (… cont.): Vertical height (in metres) of foraging observations from radio-tracking and spotlighting:
(B) all observations of brushtails in the tuart woodland
(C) all observations of ringtails in the tuart woodland

## 4.3 Radio-telemetry – survivorship and causes of mortality

Interim analysis of brushtail possum survivorship suggests a difference in mortality rates between brushtails using only the pine plantation from those using both habitat types, although the low sample size confounds interpretation. The first cohort of brushtail possums recruited into the study was captured in late November to mid December, 2006 and showed a high mortality rate with most deaths in late summer and autumn (Fig. 9). This may have been a result of severe environmental (drought) conditions. Coinciding with this was a noticeable decline in tree health, particularly in peppermints.

Of the four brushtails in the first cohort categorised as inhabiting only the pine plantation, three were known to survive this period (Fig. 9). The fate of the fourth animal was unknown, there was no evidence of mortality and the loss of the radio collar signal may have been due to collar failure. Although also reflecting a high mortality rate, only 55% (6 from the sample size of 11) of brushtails categorised as inhabiting both the pine plantation and tuart/ peppermint woodland died during autumn 2007.

There was a higher rate of survival of brushtail possums inhabiting both the pine plantation and tuart/ peppermint woodland after autumn 2007.

The first cohort of 11 ringtail possums recruited into the study was captured in January and February 2007. Seven of these died and one was censored (missing/ lost contact) within the following 8 weeks (Fig. 10). Mortality of ringtail possums was again high in the corresponding period (late summer to autumn) in the following year.

All mortality events for which intact carcasses were retrieved showed evidence of significant loss of body condition. Fox predation was implicated in all cases where DNA was successfully recovered and the predator identified through melt curve analysis (Table 1). The predator thought to have been responsible for the predation event and/or scavenging as determined by the subjective scoring method was not consistently the same as that identified from DNA analysis.

Table 1: Mortality events for ringtail possums and brushtail possums where the evidence of predation was analysed through DNA techniques (Melt Curve Analysis) and the outcome compared with that derived through scoring of characteristics recorded from examination of the recovered carcass and/or radio collar.

| **Animal ID** | **Predator / scavenger considered responsible (or present) as determine through:** | |
|---|---|---|
| | **scoring of characteristics** | **DNA melt curve analysis** |
| Brushtail M07 | Raptor | Fox |
| Ringtail F31 | Unable to determine | Fox |
| Ringtail F38 | Unable to determine | Fox |
| Ringtail F61 | Unable to determine | Unable to determine |
| Ringtail M29 | Cat predation | Unable to extract sufficient DNA to determine predator / scavenger present |
| Ringtail M32 | Possibly fox | Fox |
| Ringtail M35 | Causes other than predation | Unable to determine |
| Ringtail M40 | Raptor | Unable to determine |

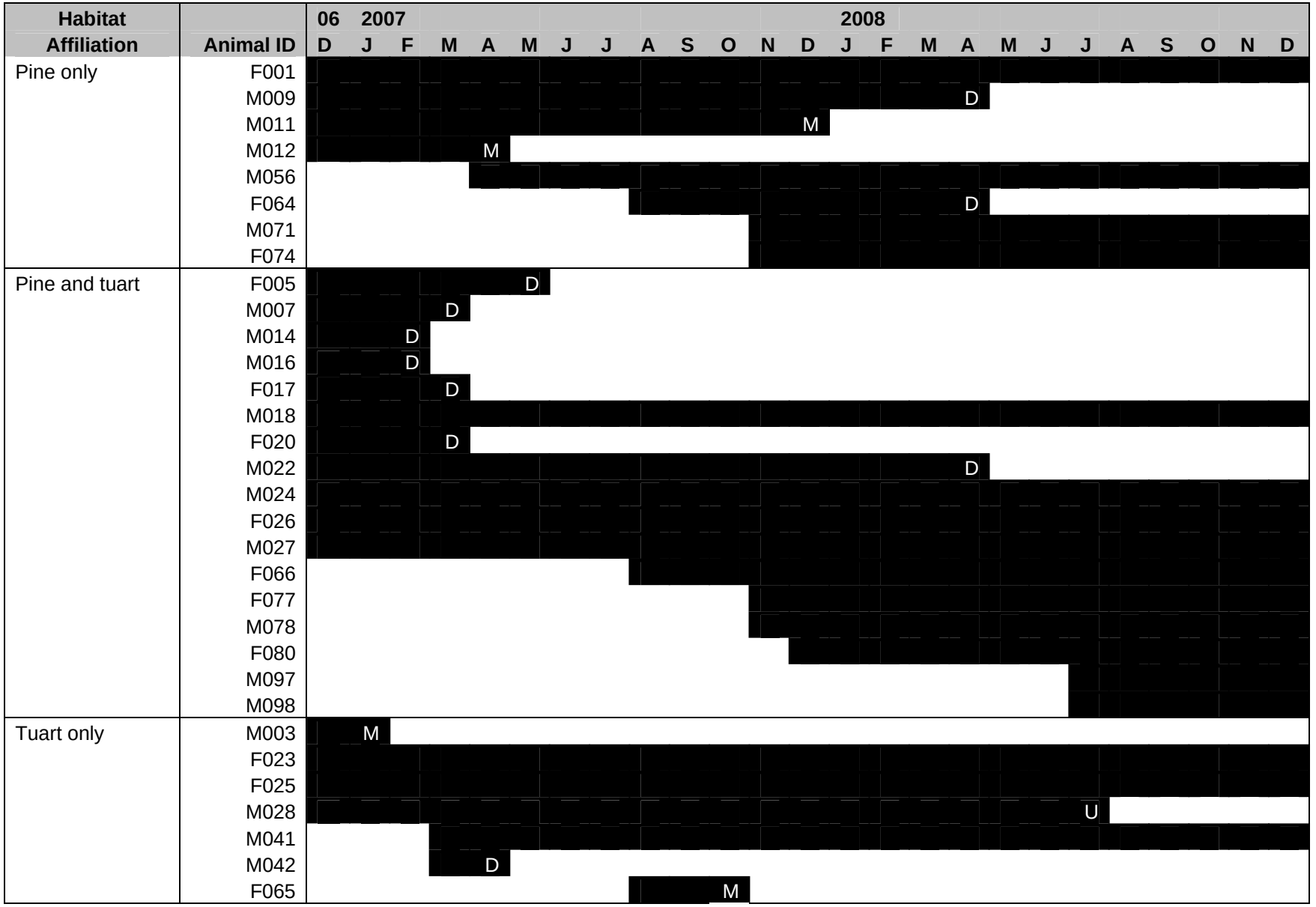



Figure 9: Survival histories for radio collared brushtail possums, grouped by habitat affiliation.
Survival history recorded only from the point of first capture. D: died; M: missing (lost signal); U: unknown (not collared)

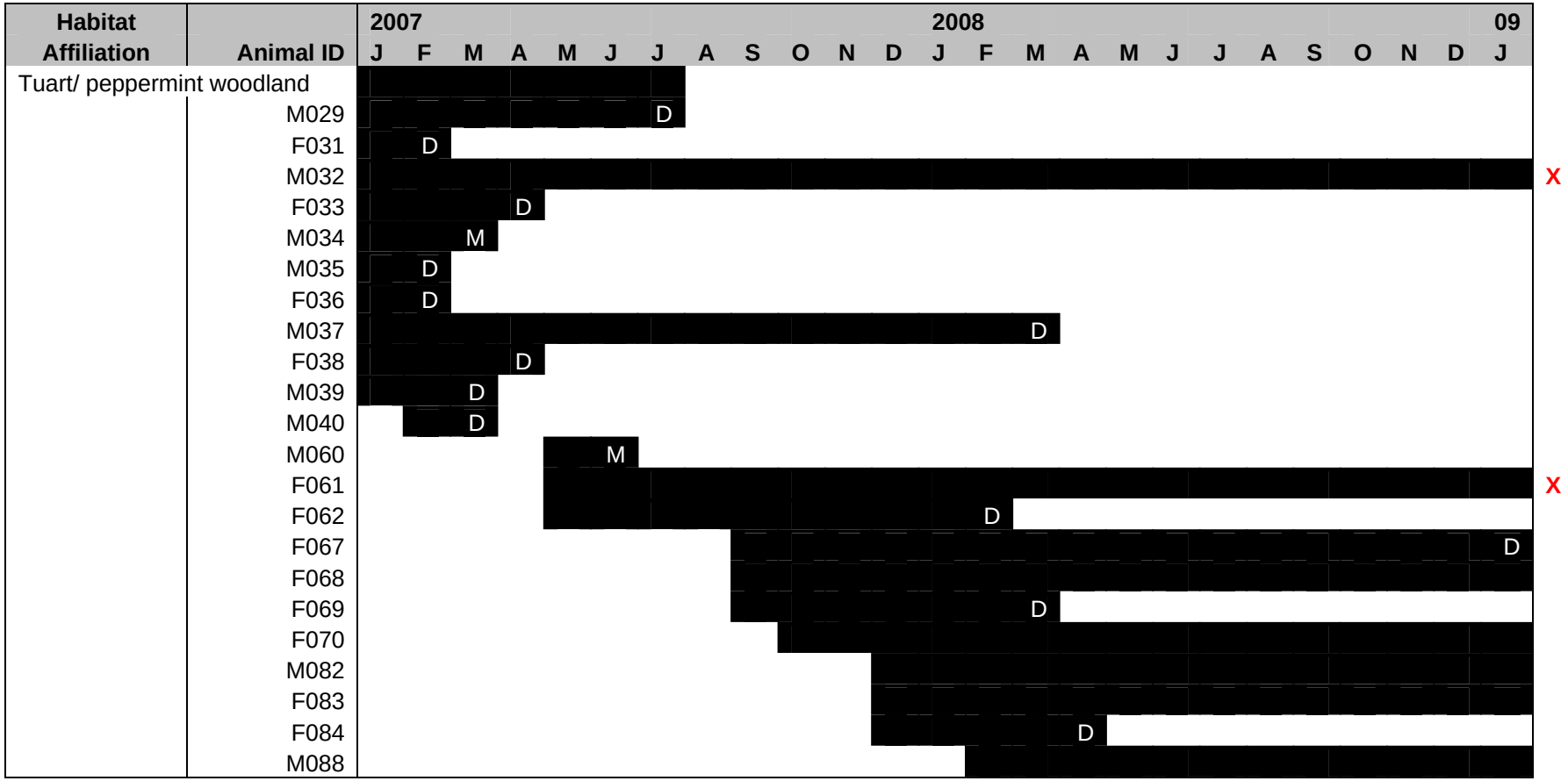


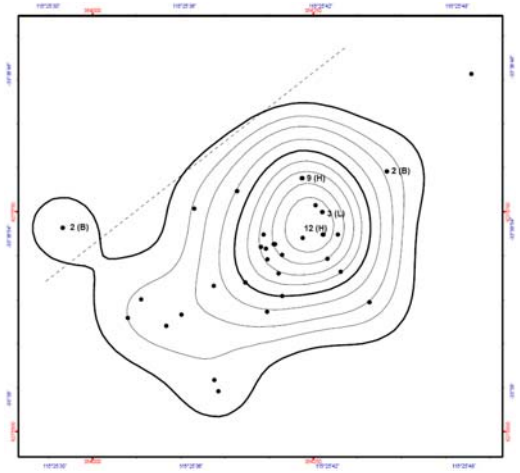

Figure 10: Survival histories for radio collared ringtail possums
Survival history recorded only from the point of first capture. D: died; M: missing (lost signal); U: unknown (not collared)

**X** Indicates the mortality event identified after completion of the study period.

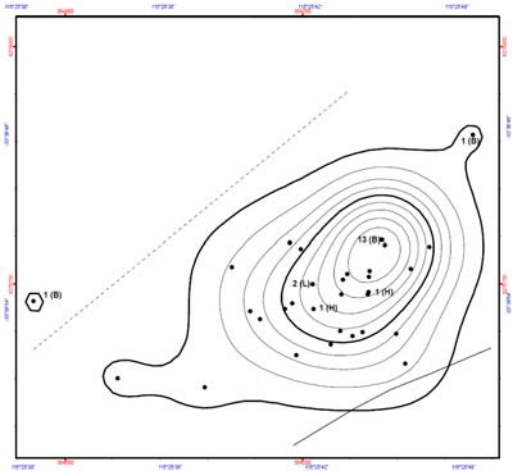
## 4.4 Radio-telemetry – utilisation distributions (home range) and home range overlap

Details of the radio-tracking period and kernel home range areas (where these were obtained) for brushtail possums categorised as affiliated with the pine plantation only, those affiliated with both habitat types and those affiliated primarily with the tuart/ peppermint woodland are given in Table 2. The results suggest brushtail possum home range areas *may* be larger for animals found only in the pine plantation. Ringtail possum home ranges were generally smaller than those of brushtails. Sufficient fixes were obtained from 5 male and 6 female western ringtail possums. The areas of the 50% cores were 0.37-0.83 ha (males) and 0.27-0.59 ha (females). The areas of the 90% cores were 1.22-3.09 ha (males) and 0.76-1.90 ha (females).

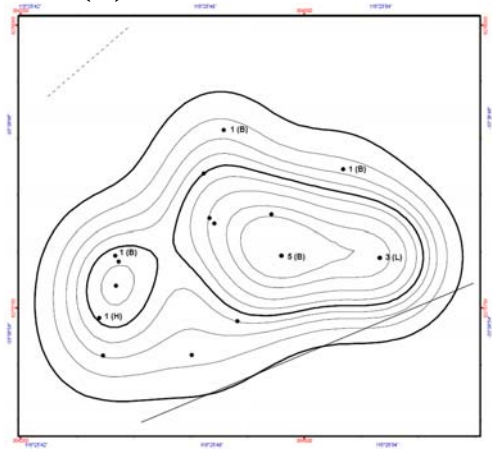
Utilisation distributions obtained for brushtail possums using only the pine plantation were generally unimodal (Fig. 11A - 11C). In contrast, the utilisation distributions obtained for brushtail possums using both the pine plantation and tuart/ peppermint woodland were largely bimodal, or bimodal to some extent (Fig. 11D - 11F). A unimodal distribution indicates an animal has a single centre of activity surrounded by a peripheral, usually nocturnal area of use. This pattern may be expected in a homogenous habitat such as the pine plantation. However the bimodal distributions obtained for brushtail possums recorded in both habitat types indicate selective use of the available area. The animals did not roam randomly across the habitat interface. The partial or complete "pinching in" of the distribution at this point (the track, indicated by the dashed line in Figure 11) reflects this area was not part of the core or nocturnal foraging area.




(A) F001




(B) M056

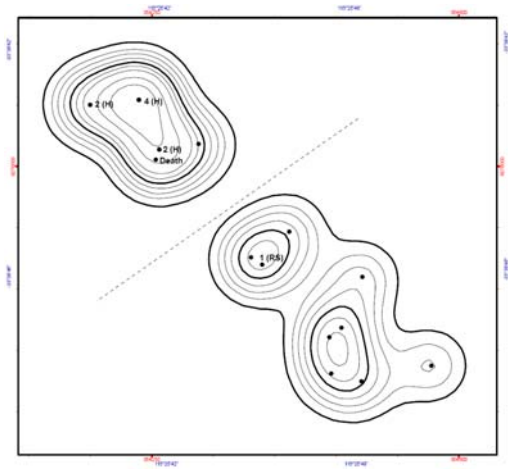



(C) M071

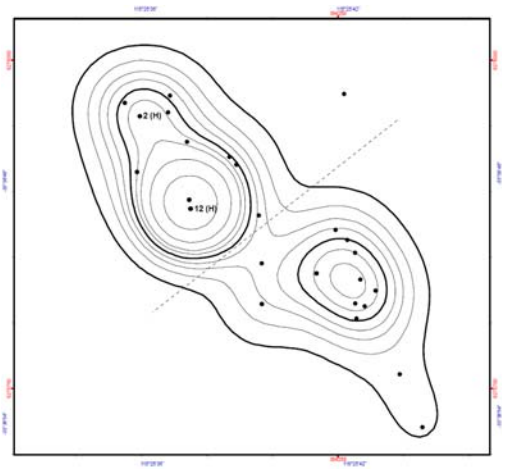
Figure 11: Representative utilisation distributions for brushtail possums recorded in the pine plantation. The X and Y axes represent longitude and latitude respectively. Datum is GDA 1994, Projection is MGA Zone 50.

A to C: Brushtail possums using only the pine plantation.

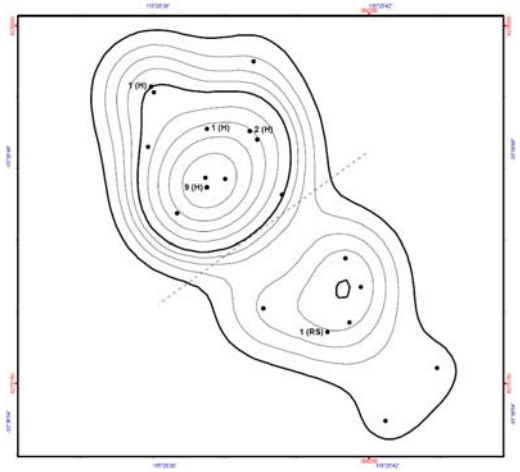
The dotted line indicates the track separating the tuart woodland (upper left hand side) from the pine plantation (lower right hand side).




(D) F005




(E) M027




(F) F066

Figure 11 (... cont.): Representative utilisation distributions for brushtail possums recorded in the pine plantation. The X and Y axes represent longitude and latitude respectively. Datum is GDA 1994, Projection is MGA Zone 50.

D to F: Brushtail possums using both the pine plantation and tuart woodland

The dotted line indicates the track separating the tuart woodland (upper left hand side) from the pine plantation (lower right hand side).

Brushtail possums recorded using both habitat types generally denned within the tuart/ peppermint woodland and used both the pine plantation and the tuart/ peppermint as a nocturnal foraging resource.

There was substantial spatial and temporal overlap in ringtail and brushtail possum home range at the 50% (core home range) and 90% (overall home range) utilisation distribution (Fig. 12A and Fig. 12B). Similarly, the proportion of each individual ringtail possum core and overall home range overlapped by each individual brushtail possums demonstrated spatial and temporal overlap (Fig. 13).

Table 2: Summary of brushtail possum monitoring during the study period

| | | Animal ID | Tracking Commenced | Tracking Ceased | Fate | No. Fixes | 50% (Core) (ha) | 90% (Overall) (ha) |
|---|---|---|---|---|---|---|---|---|
| Pine | Male | M009 | 7/12/06 | 8/04/08 | Dead | 38 | 1.91 | 7.87 |
| | | M011 | 5/08/07 | 5/12/07 | Missing | 11 | | |
| | | M012 | 7/12/06 | 5/04/07 | Missing | 12 | | |
| | | M056 | 17/04/07 | 21/01/09 | Alive | 45 | 1.75 | 7.42 |
| | | M071 | 19/11/07 | 21/01/09 | Alive | 23 | 2.49 | 7.14 |
| | Female | F001 | 30/11/06 | 21/01/09 | Alive | 60 | 2.01 | 9.20 |
| | | F064 | 5/08/07 | 18/04/08 | Dead | 18 | | |
| | | F074 | 12/07/08 | 21/01/09 | Alive | 7 | | |
| Both | Male | M007 | 6/12/06 | 22/03/07 | Dead | 16 | | |
| | | M008 | | | Uncollared | 4 | | |
| | | M014 | 11/12/06 | 12/02/07 | Dead | 10 | | |
| | | M016 | 11/12/06 | 12/02/07 | Dead | 9 | | |
| | | M018 | | | Uncollared | 14 | | |
| | | M022 | 3/08/07 | 29/04/08 | Dead | 19 | 1.14 | 3.50 |
| | | M024 | 10/07/08 | 9/12/08 | Alive | 14 | | |
| | | M027 | 17/04/07 | 9/12/08 | Alive | 47 | 1.18 | 4.04 |
| | | M078 | 9/07/08 | 9/12/08 | Alive | 13 | | |
| | | M097 | 10/07/08 | 21/01/09 | Alive | 5 | | |
| | | M098 | 10/07/08 | 21/01/09 | Alive | 10 | | |
| | Female | F005 | 5/12/06 | 24/05/07 | Dead | 19 | 1.07 | 3.56 |
| | | F017 | 11/12/06 | 12/03/07 | Dead | 12 | | |
| | | F020 | 12/12/06 | 28/03/07 | Dead | 11 | | |
| | | F026 | 3/08/07 | 9/12/08 | Alive | 33 | 0.38 | 1.84 |
| | | F066 | 3/08/07 | 9/12/08 | Alive | 33 | 1.03 | 3.92 |
| | | F077 | 9/07/08 | 9/12/08 | Alive | 14 | | |
| | | F080 | 10/07/08 | 11/12/08 | Alive | 9 | | |
| Tuart | Male | M003 | 3/12/06 | 22/01/07 | Missing | 6 | | |
| | | M028 | | | Uncollared | 7 | | |
| | | M041 | 14/03/07 | 21/08/08 | Alive | 34 | 1.64 | 7.04 |
| | | M042 | 14/03/07 | 10/04/07 | Dead | 4 | | |
| | Female | F023 | 3/08/07 | 9/12/08 | Alive | 24 | 1.48 | 4.69 |
| | | F025 | 3/08/07 | 9/12/08 | Alive | 30 | 0.69 | 3.10 |
| | | F065 | 3/08/07 | 30/10/07 | Missing | 6 | | |

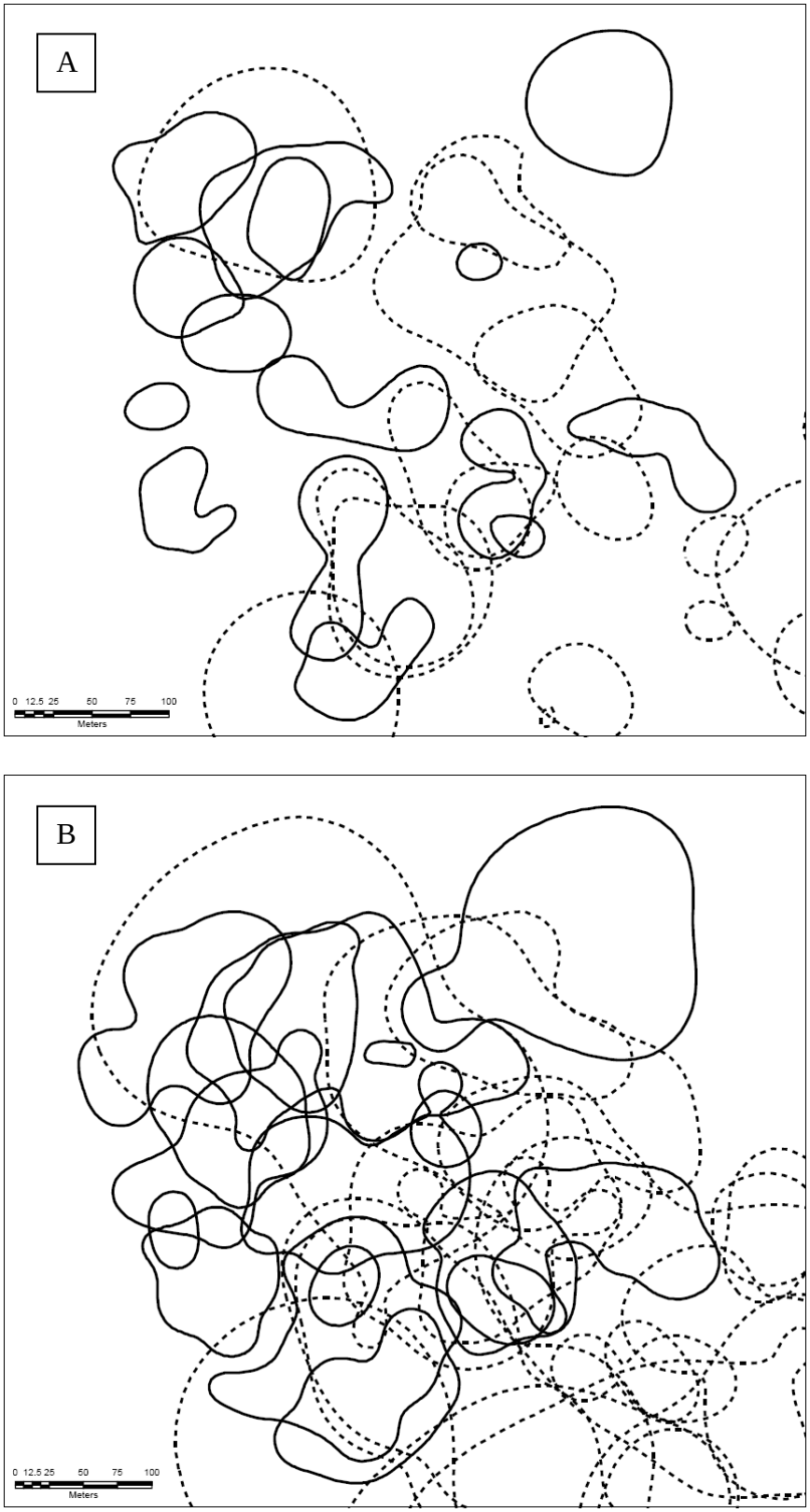



Figure 12: Relative arrangements of ringtail and brushtail possum home range in the tuart/ peppermint woodland
A: central area of activity (core home range); and
B: overall home range.

**Solid lines indicate ringtails and broken lines, brushtails**.

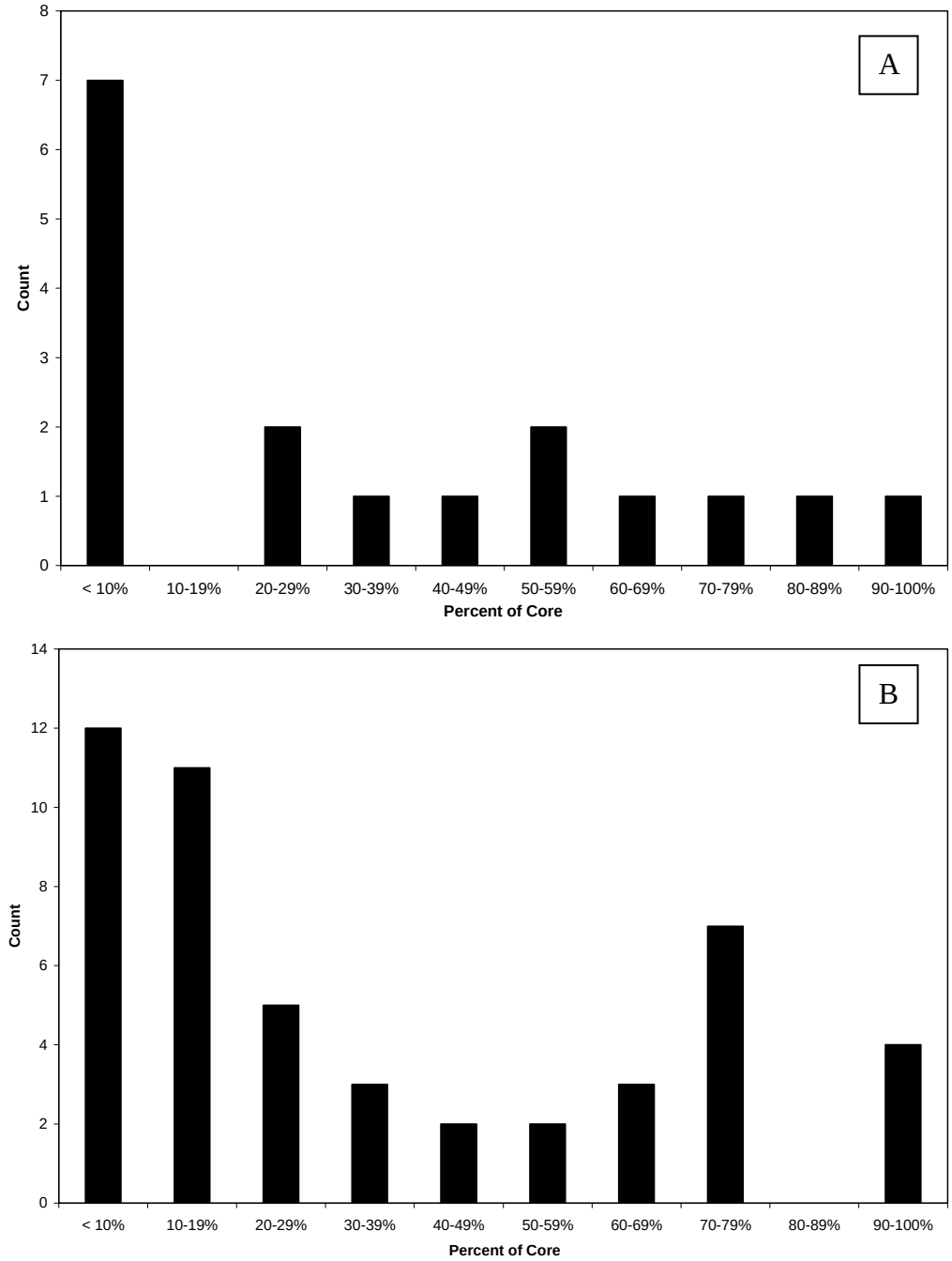



Figure 13: The degree of overlap of ringtail home range by brushtail home range in the tuart/ peppermint woodland
A: central area of activity (core home range) (50% isopleths)
B: overall home range (90% isopleths)

# 5 Discussion

The proposed harvesting operation within Ludlow State Forest was postponed, therefore the effect from pine harvesting on the resident population of common brushtail possums was therefore unable to be assessed. Any subsequent effect on the population of western ringtail possums in the adjacent tuart woodland within Tuart Forest National Park was also unable to be assessed. The stop/ start nature of the research, necessitated by the uncertainty associated with the timing of harvesting, also compromised the continuity of monitoring. However, some inference can be drawn from the information collected on brushtail and ringtail possum survivorship, population density, habitat use, home range and home range overlap.

***Survivorship***

Survivorship of monitored animals of both species was lower in late summer to autumn in 2007 and 2008 (Figs 9 and 10). Additional data (collected outside the study period) has shown this pattern again in 2009, at least for ringtail possums (Table 2, Fig 10).

Over the total period of the study, 50% (4/8) of the radio collared brushtails using the pine plantation only, and 41% (7/17) of brushtail possums inhabiting both habitat types, died or were lost from the monitored sample. Fox predation was implicated for every mortality event thought to be a result of predation and able to be attributed, by DNA techniques, to a predator species (Table 1).

There was no evidence to suggest predation was a result of land management practices and the high mortality rate was in spite of an existing fox baiting program.

Imposing an additional disturbance factor (*i.e.* harvesting) in the period of high mortality (late summer to autumn) may result in an unsustainable rate of mortality for one or both species. The seasonal effects of high mortality, if it occurred during harvesting, may be inadvertently and incorrectly attributed to harvesting alone.

Any effects on brushtail and ringtail possum mortality, either directly or indirectly resulting from harvesting, will need to be identifiable and not confounded with other factors influencing survivorship, *e.g.* seasonal effects. See recommendations (i), (ii), (iii) and (vii) below.

***Population densities***

The pine plantation possesses different den and foraging resources from the tuart/ peppermint woodland. Therefore it is expected to support a different population density of brushtail possums. Spotlighting and trapping surveys were carried out in an attempt to obtain population densities for both possum species. Although the two habitat types were discrete and separated by a central track, final population estimates for the brushtail possum will be confounded by the lack of independence of the trapping grids within each habitat type. However, subject to confirmation from final mark-recapture analyses (Grimm, in prep), the trapping data suggest the brushtail possum population density in the pine plantation is approximately one third of that in the tuart/ peppermint woodland.

The absence of western ringtail possums from the pine plantation and the higher density of brushtail possums in the tuart/ peppermint woodland is consistent with the phenomenon of habitat partitioning, as reported from western ringtail possum translocation release sites (de Tores *et al.*, 2004). Further, the absence of western ringtail possums from the pine plantation does not support, but contradicts, the anecdotal claims whereby competition

between the two species results in western ringtail possums being forced into suboptimal habitat. Under such a scenario, western ringtail possums would be predicted to be present within the less optimal (in terms of diet and probably den site availability) pine plantation.

Harvesting will result in reduction or elimination of resources currently available in the pine plantation and will mean the surviving brushtail possums will seek these resources elsewhere. Brushtail possums denning in pines will seek alternative den sites and may displace resident brushtails or ringtails in the process. All animals previously foraging in the pine plantation will, if they survive the physical disturbance from harvesting, require food resources in the tuart/ peppermint woodland. Therefore, regardless of whether or not there is competition for den sites (tree hollows), there will be a greater density of brushtail possums (at least immediately post harvesting) seeking nocturnal foraging resources. This is highly likely to lead to competition for foraging resources.

Monitoring of population size and changes in population size pre, during and post harvesting is recommended. See recommendations (ii) to (iv) below.

***Habitat use***

The common brushtail possum and western ringtail possum occupy similar habitat niches in the forests of south-west Western Australia. Although there are recognised differences in food intake and behaviour they commonly interact, and may compete, in areas where they both occur. It is not known exactly how and to what extent one impacts upon the other. However, given the common brushtail possum is larger and more aggressive, it is likely the western ringtail possum is the more vulnerable of the two to changes in the interspecies balance and habitat disturbance from harvesting.

The pine plantation appears to provide sufficient habitat and food resources to support a brushtail possum population, albeit smaller than the brushtail possum population within the tuart/ peppermint woodland. The food resources within the pines were sufficient to attract brushtail possums known to den in the adjacent tuart/ peppermint woodland.

The absence of ringtail possums from the pine plantation may be related to:

- the lower nutrient content and/or lower palatability of pine needles and the scarcity of the ringtail's preferred food tree (peppermint); and/or
- the scarcity of suitable tree hollows; and/or
- the difference in vegetation structure and the resulting absence of predation refuges; and/or
- the difference in vegetation structure and the resulting increased difficulty for ringtail possums to forage without coming to ground.

The absence of ringtail possums from the pine confirms any effect from pine harvesting on ringtail possums will be indirect only. However, these potential indirect effects are not trivial and include competition (or increased competition) for den sites and food resources, eviction from tree hollows, increased stress levels and increased mortality rates. These potential effects also apply to the resident and the dispersing brushtail possums. Even in the absence of inter-species (brushtail/ringtail) competition, there will be increased intra-species (brushtail/brushtail) competition. The displaced brushtail possums may also display atypical habitat use and home range behaviours to survive and become established.

Ringtail and brushtail possums were recorded denning in different hollows in the same and adjacent trees. There was also recorded use of the same hollow by both species, although

no temporal overlap was recorded for this dual species use of the same hollow. The results suggest there is overlap in the characteristics of hollows used by both species and indicates a strong possibility that competition for tree hollows will occur if brushtails are displaced from the pine and disperse into the tuart/ peppermint woodland.

The nocturnal observation records (Fig. 8A and 8B) showed the height strata used by brushtail possums in the pine was different from that used in the tuart/ peppermint woodland.

Within the tuart/ peppermint woodland there appeared to be overlap and potential competition in ringtail and brushtail possum use of the lower canopy (up to 15m) (Fig. 8B and 8C). However, there were minimal records of ringtail possums foraging or using the canopy above 15m (Fig. 8B). This use of the lower canopy by ringtail possums and the upper canopy by brushtail possums suggests some degree of habitat partitioning.

This "possible" habitat partitioning within the tuart/ peppermint woodland does not necessarily reflect feeding preferences only. Possums of both species are known to feed in short bursts and spend much of the night either resting or travelling. The apparent habitat partitioning may reflect the different foraging preferences or may reflect different nocturnal rest site preferences, or both. Scat analysis and assessment of proportions of the different vegetation within scats is required to assess if this is a foraging and/or rest site preference. Scat analysis, combined with an assessment of the food resource availability, would also assist to determine if the observed patterns of nocturnal use of the habitat are a reflection of competition or habitat partitioning. However, removal experiments are required to unequivocally determine if there is competition for the foraging resource.

Removal experiments are not recommended. Clarification of the extent of dietary overlap in relation to availability is recommended. See recommendations (ii), (iii), (v) and (vi) below.

***Home range and home range overlap***

The use of spatial (*i.e.* home range) and habitat resources by animals is related to numerous instinctive and learned behaviours and multiple decision making processes (Krebs and Kacelnik, 1991). The patterns observed for brushtail possums (Fig. 11) and ringtail possums may be based on factors including, but not limited to den site availability, nutritional value and/or palatability of vegetation, presence of conspecifics and/or heterospecifics, weather conditions and season, and vegetation structure and its role as refugia from predators and its function in facilitating arboreal movement.

There was considerable inter-species home range overlap (Fig. 12). At the core home range level, not all radio collared ringtails were overlapped by brushtails (Fig. 12A). However, because of the homogeneity of habitat and the known presence of many other uncollared brushtails for which utilisation distributions were not obtained, it is likely the core home range of each ringtail in the tuart/ peppermint woodland was overlapped by one or more brushtail. Where home range overlap was recorded, most ringtails were overlapped by multiple brushtails of both sexes. Similarly, at the level of the overall home range most ringtails were overlapped by multiple brushtails of both sexes (Fig. 12B).

The proportion of ringtail core home range overlapped by brushtail core home range was calculated for each pair of animals. The ringtail core home range was completely enclosed by a brushtail home range for one ringtail only (Fig. 13A). At the level of the overall home range there were multiple ringtails with home range fully enclosed within the home range

of an individual brushtail (Fig. 13B). Combined, these results indicate substantial overlap in use of the habitat by brushtail and ringtail possums, confirming the potential for competition for resources between the species. See recommendations (ii), (iii) and (v) below.

# 6 Summary

On the basis of the observed patterns of habitat use, there appears to be little evidence of existing competition for den sites as, in the presence of strong competition for den sites and dominance by brushtail possums, ringtail possums would be expected to show greater use of dreys. However, the existing use of pines and tuart/ peppermint woodland by brushtail possums, combined with the observed movement of brushtails between habitat types and their minimal use of the interface between the habitat types (shown by the multimodal home ranges of brushtail possums using both habitat types) suggests, if pine harvesting occurs, brushtail possums can and will disperse from the pines to the tuart/ peppermint woodland.

The likely outcome from this dispersal is creation of competition for den sites within the tuart/ peppermint woodland, or if it already exists, an increase in the level of competition for den sites. This competition is likely to occur at the inter- and intra-species level.

The observed patterns of nocturnal foraging / nocturnal use of the canopy appear to reflect habitat partitioning based on foraging preferences and/or nocturnal rest site preferences. However, it is unclear if this apparent habitat partitioning reflects a real difference in preference for resources or reflects competition for resources. If the latter, the proposed pine harvesting will increase this level of competition and will potentially jeopardise the viability of the western ringtail possum population within the tuart/ peppermint woodland.

# 7 Recommendations

The following recommendations are based on the premise that harvesting of pines within Ludlow State Forest will proceed.

(i) It is recommended harvesting does not occur in late summer or autumn, when mortality rates for both species, western ringtail possums in particular, are at their highest. The additional disturbance from harvesting in this period may result in an unsustainable rate of mortality for one or both species.

(ii) A monitoring program is recommended to determine if pine harvesting results in dispersal of the resident population of brushtail possums and, if so, to determine if there is a subsequent effect on the population of western ringtail possums within the adjacent Tuart Forest National Park.

(iii) To achieve (ii) above, and determine the extent of any impact attributable to the harvesting operating, it is recommended a minimum of one control site is included in the monitoring program. The control site should ideally have the same vegetation/ habitat configuration as the treatment site (*i.e.* pines adjacent to tuart/ peppermint woodland) and would need to be monitored concurrently with the treatment site, pre, during and post harvesting. Opportunities to establish such a control may exist at the interface Ludlow State Forest and Tuart Forest National Park.

(iv) Monitoring of both possum species is recommended to determine pre and post harvesting estimates of population size. Conventional wire cage trapping of brushtail possums within both habitat types is recommended. Data from the trapping carried out in this study for the closed population estimate, plus the additional targeted trapping for individual brushtail possums could be pooled with any new trapping data and analysed using "Robust Design" models (White, 2001). This analysis allows for trapping at primary and secondary sampling periods and recognises births, deaths, immigration and emigration may occur between the primary sampling periods. Use of information-theoretic based techniques (e.g. Buckland *et al.*, 2005; Thomas *et al.*, 2005) is also recommended to derive estimates of population size for ringtail possums and to ensure estimates are sufficiently robust to draw meaningful inference.

(v) Radio telemetry monitoring of both possum species is recommended to assess habitat use pre, during and post harvesting. The pre harvest monitoring is recommended to commence a minimum of 6 months prior to harvesting. Post harvest monitoring is recommended to continue for at least 6 months post harvesting and include the seasons monitored in pre harvest monitoring period.

(vi) Scat analysis, combined with an assessment of the food resource availability, is recommended to clarify the extent of dietary overlap in relation to availability and to assist in differentiating between competition and habitat partitioning.

(vii) Use of movement sensitive (mortality) radio-telemetry combined with frequent survivorship monitoring is recommended to enable rapid detection of mortality events. Use of wildlife forensic techniques (DNA analysis) is also recommended to enable more accurate assessment of predators responsible for any mortality events and to determine whether there are any differences in the frequency and nature (*i.e.* different predator species) of predation events between the treatment and control sites. Information-theoretic based approaches (e.g. White, 2001) are recommended for analysis of radio-telemetry survivorship data.

(viii) Retention and protection of known brushtail possum den sites (e.g. disused rabbit warrens, fallen logs and remnant individual tuarts) within the harvesting area is recommended. These may serve as short and long term refuges from direct and indirect effects of pine harvesting. Monitoring the use of any retained den sites is recommended pre, during and post harvesting to determine the conservation value of retaining these den sites.

(ix) The feasibility of incorporating measures to routinely retain potential den sites in pine harvesting generally is also recommended.

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