Spotlight surveys to investigate the impacts of timber harvesting and associated activities within the jarrah forest of Kingston State Forest, with particular reference to the koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*).

Progress Report
April 2001

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KINGSTON PROJECT PROGRESS REPORT
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REPORT SUMMARY

Between November 1995 and January 2001 a total of 189 spotlight surveys were conducted along three transects through Kingston State Forest. Interim results for the koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*) are reported here. The number of koomal and/or ngwayir detected was significantly correlated with environmental factors such as moon phase, cloud cover, season and hours of darkness. Different observers and the timing of the surveys during the evening were also significant determining factors for possum detections.

The refuge value of the unharvested forest within Kingston, including the TEAS (temporary exclusion area system) and riparian zones, was demonstrated by the maintenance of the numbers of koomal spotlighted at the forest block scale despite significant declines of populations from trap grids within the more intensely harvested cells. The detection abundance of ngwayir throughout Kingston has recently declined significantly and up to 85% (adjusted for significant observer and environmental variables). The reasons for these declines have not yet been satisfactorily explained, but timber-harvesting disturbance cannot, at this stage, be eliminated as a potential cause. Differences in habitat use between the two possum species in relation to timber harvesting are also described. Implications for forest and conservation management are discussed and potential future research is briefly described.

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INTRODUCTION

Mammal sampling for the Kingston study commenced in March 1994 and was undertaken using various trapping techniques (Morris *et al.* 2001). To supplement the data gained from trapping, standardised spotlight transects were used to monitor nocturnal bird and mammal populations at the forest block scale. The spotlight survey technique was also a useful means of collecting data on the arboreal possums, particularly the ngwayir (western ringtail possum, *Pseudocheirus occidentalis*) that is not readily trapped. These spotlight surveys are therefore directly associated with the Kingston Project studies into the impacts of timber harvesting on terrestrial vertebrates (CALMScience SPP 93/0115, formerly 98/0109) and the ngwayir (CALMScience SPP 97/0007).

METHODS

The Transects

Preliminary spotlight surveys began in November 1995 and were refined during 1996. At this time, two transects were established within the greater Kingston forest area. The 'Northern' transect is 10.91 kilometres long and runs along the northern boundary and through the centre of Kingston State Forest block (Figure 1). The 'Southern' transect bisects parts of Warrup and Kingston State Forest and is 10.65 kilometres long. From March 1997 a third standardised spotlight transect was established within Kingston 4 logging coupe as part of the species specific study on the impacts of logging on the ngwayir (Wayne *et al.*, 2000). The 'Kingston 4' transect travels along various logging coupe roads and shunts and is a total length of 10.33 kilometres (Figure 1).

The Survey Protocol

Prior to March 1997 the 'Northern' and 'Southern' spotlight surveys were conducted infrequently, with either one or two spotlights and generally on different nights to each other. With the commencement of the 'Kingston 4' spotlight transect all three surveys were performed simultaneously, with two spotlighters per transect, and were done twice monthly. This survey effort was reduced to once a month from April 1998 to January 2001.

Data collected during these surveys included distance along the transect, time of sighting, species and the number of individuals, treatment (unlogged, gap or shelterwood), animal activity and general comments. Beginning in April 1997 additional data collected included, closest reference point (marker pegs spaced 200m along transects, or 100m along the Kingston 4 transect), animal location (tree species, logs or ground, etc), and tree maturity (sapling, pole, mature, over-mature). To estimate animal densities, approximations of the distance of sighted individuals from the road were recorded from February 1999.

The spotlight surveys were conducted from vehicles and began approximately ½ to 1 hour after sunset and were travelled at an average of four to five kilometres per hour. Two spotlights were used per vehicle, each spotlight concentrating on one side of the road only. The spotlighters were either positioned on the back of 'utility' vehicles or on a specially adapted double seat fitted to the roof rack of a 4x4 station wagon.

Each of the three spotlighting teams had at least one experienced spotlight operator from the CALMScience Forest Ecology Research Team (FERT) to maintain consistency of technique. These operators and their vehicles were rotated through the three transects to measure and minimise observer bias. Volunteers provided the second spotlighter and driver for each spotlight team.

Logging History
The majority of logging within Kingston (K1, K2, K3, and K5) was conducted between February 1995 and April 1996. The post-silvicultural burn for these areas was conducted in late November 1996. Logging within Kingston 4 occurred between March 1997 and January 1998. The post-silvicultural burn in Kingston 4 was conducted in November 1998. Timber harvesting within Warrup 2, adjacent to part of the Southern transect, occurred between January and May 1997. The associated silvicultural burn was proceeded by a prescribed burn (M45) that was completed in December 1997 and was adjacent to much of the Southern transect. The relative extent and type of timber harvesting disturbance along the three spotlight transects is described in Table1.

Table 1. The proportion of forest along the Kingston spotlight transects subjected to timber harvesting disturbance.

Transect	Unlogged (%)	Buffers (%)	Shelterwood (%)	Gap Release (%)	Transect Length (km)
Northern	59	7	24	10	10.9
Southern	87	3	7	3	10.6
Kingston 4	3	39	31	27	10.3

Data Analysis
Detection abundance data that was collected using two spotlighters was involved in the analyses in this report. Those surveys that were conducted with only one spotlighter were excluded. These involved eight surveys on the Northern transect, and five surveys on the Southern transect, all of which were conducted during 1995 and 1996.

The step-wise methodology for statistical analysis of the spotlighting data for the two possums is illustrated in a flow chart (Appendix 1). To investigate the relationship between the number of possums detected and a selection of environmental and survey variables, Poisson regression analysis was applied. Poisson regression is analogous to the common linear regression model, but is appropriate where the dependent variable has characteristics of the Poisson random variables.

To estimate the relationship between categorical factors such as observer, moon phase and season, each categorical variable was coded as a design (dummy) variable. As shown in the flow chart (Appendix 1), univariate Poisson regression was applied to each factor. If the significance level of a variable, or all the design variables of a factor, was greater than 0.25 then this factor was eliminated from further analysis, except for key factors such as 'Year and Transect', 'Observer', 'During and After harvest activity', 'Survey duration', and 'Individual survey length'. Therefore, all the factors with p-value less than 0.25 are considered as potentially important and included initially in multivariate Poisson regression analysis. The analysis was estimated using the stepwise model-building strategy of Hosmer and Lemeshow (1989). This strategy uses backward elimination of variables deemed non-significant at alpha = 0.05. The Poisson regression model was applied using the SAS software package (SAS Institute, 1990).

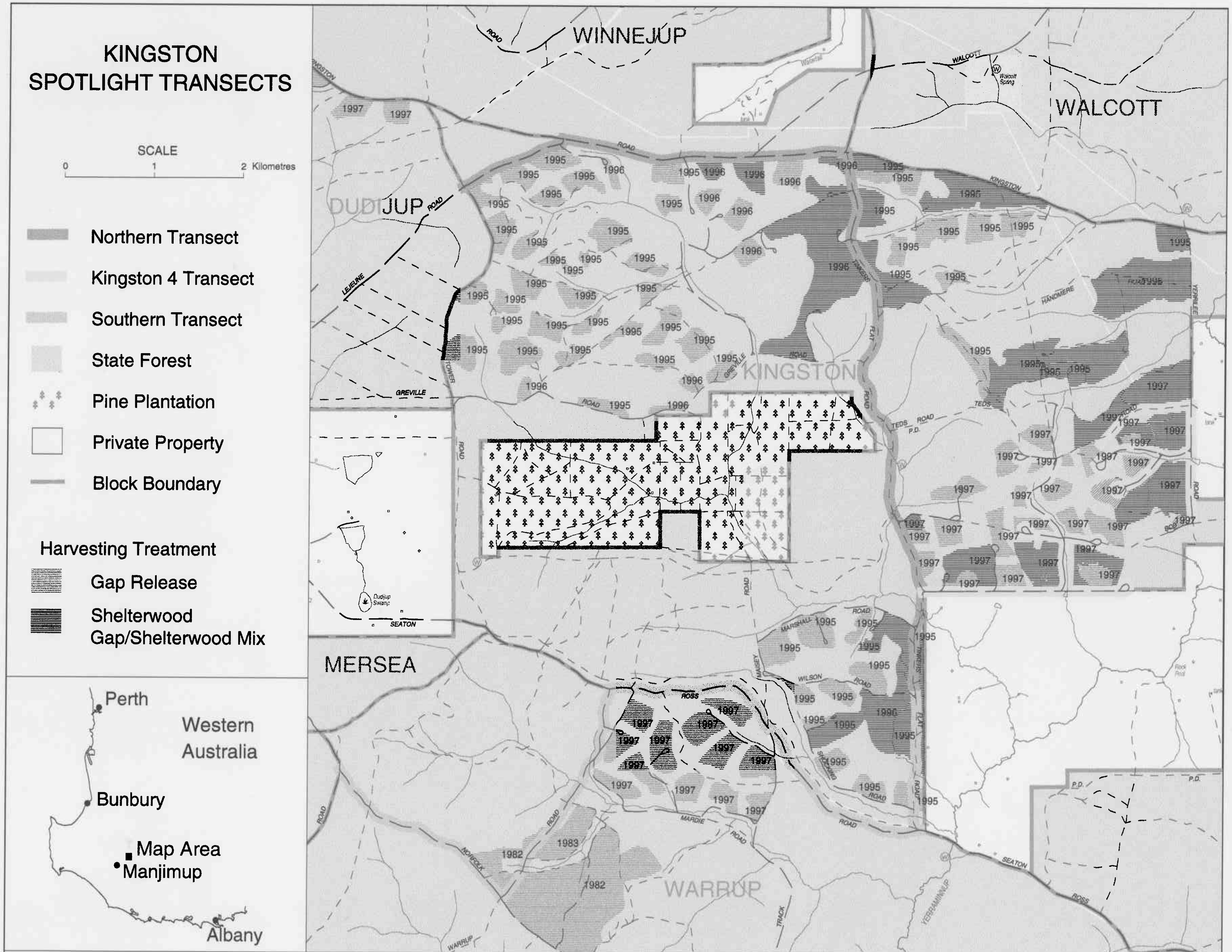

Figure 1 . Spotlight survey transects for the Kingston Study

RESULTS

Between November 1995 and January 2001, 70 spotlight surveys (16 pre March 1997) were conducted along the Northern spotlight transect and 65 surveys (14 pre March 1997) on the Southern spotlight transect. Since March 1997, 54 surveys were conducted on the Kingston 4 spotlight transect. Table 2 lists the species tally totals for nocturnal birds and mammals detected along these transects during these surveys. The recording of nocturnal birds on all transects and mammals other than possums on Kingston 4 transect were inconsistent until late 1998. Therefore data for these species needs to be regarded accordingly. Appendix 2 provides the species tallies for each survey conducted on the three transects.

Table 2. Species tally for nocturnal birds and mammals detected along the three Kingston study spotlight transects during surveys conducted between November 1995 and January 2001 for the Northern and Southern transects and between March 1997 and January 2001 for the Kingston 4 transect.

Species	Common Name	Northern (n=70)	Southern (n=65)	Kingston 4 (n=54)
Aegotheles cristatus	Australian Owlet-nightjar	4	0	0
Podargus strigoides	Tawny Frogmouth	18	16	22
Ninox novaeseelandiae	Southern Boobook	3	1	5
Tyto novaehollandiae	Masked Owl	1	3	0
Tyto alba	Barn Owl	0	0	1
Vulpes vulpes	Red Fox	1	2	2
Felis catus	Feral Cat	3	1	4
Mus domesticus	House Mouse	0	1	1
Oryctolagus cuniculus	European Rabbit	10	0	14
Dasyurus geoffroii	Chuditch	1	1	1
Phascogale tapoatafa	Brush-tailed phascogale	1	3	1
Macropus fuliginosus	Western Grey Kangaroo	294	150	146
Macropus irma	Western Brush Wallaby	88	105	35
Isoodon obesulus	Quenda	20	26	2
Bettongia pennicillata	Woylie	269	130	60
Trichosurus vulpecula	Koomal	1232	636	1079
Pseudocheirus occidentalis	Ngwayir	733	397	467

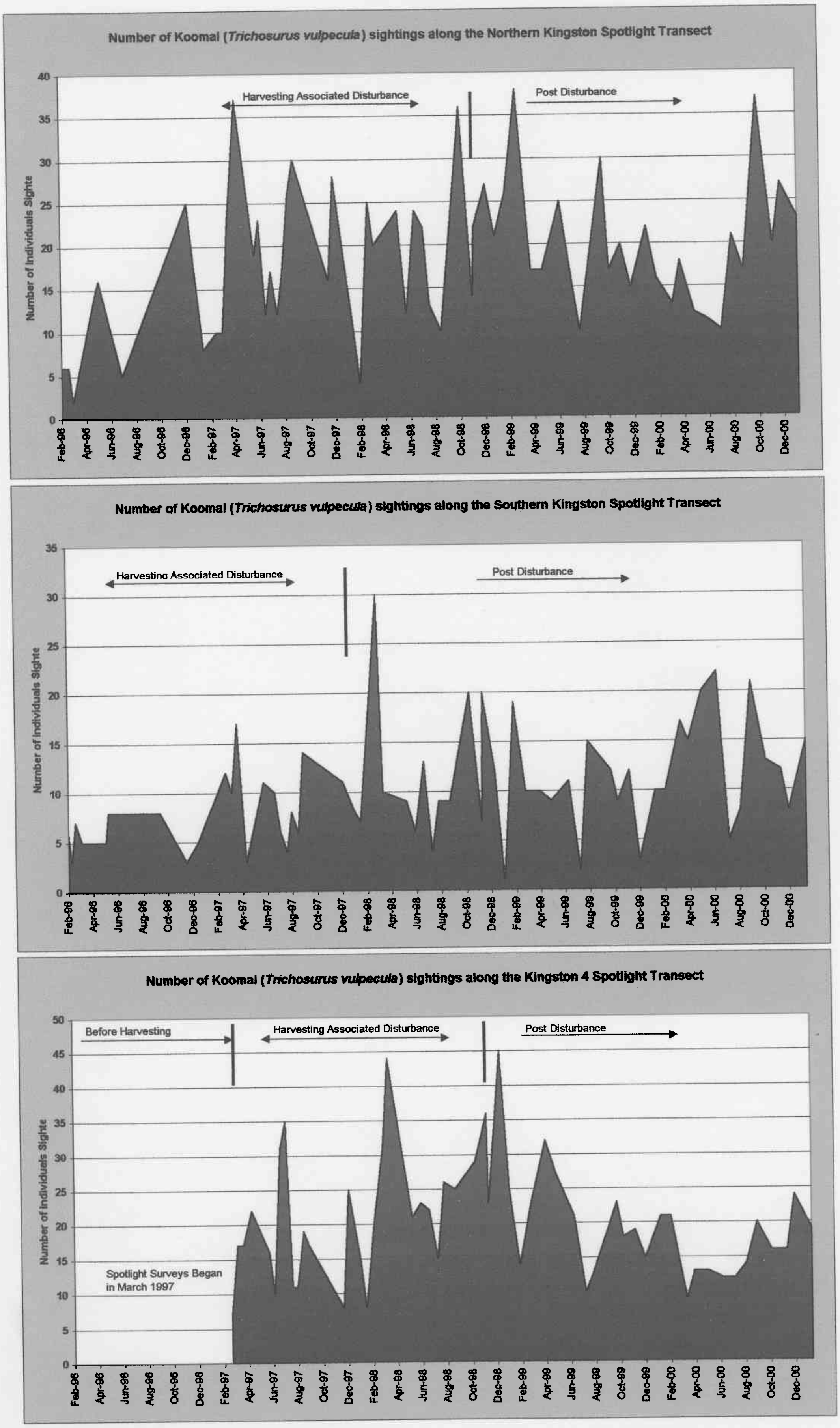

Figure 2. The number of koomal (*Trichosurus vulpecula*) sightings along the three Kingston spotlight transects

Koomal

Detection Abundance

Where two spotlighters were used, the average and range of the number of koomal (*Trichosurus vulpecula*) detected on any one survey was 18.4 (2-38), 10.2 (1-30) and 20.0 (7-45) individuals for the Northern, Southern and Kingston 4 transects respectively. Although the detection of koomal along each transect was highly variable between surveys, there appeared to be no gross positive or negative trends over the duration of the study (Figure 2).

Multivariate Poisson Regression Analysis

Table 3 summarises the results from the multivariate Poisson regression analysis examining the factors that affect koomal detection. Significantly fewer koomal were detected on the Southern transect (Figure 3) and there were significant differences between observers. Fewer koomal were detected during partial cloud cover (2/8 to 7/8) and during summer and winter. Generally more koomal were detected when the surveys finished later in the evening and significantly so when they finished between 22:31 hours and 23:15 hours. In addition, the longer the survey duration the more koomal that were sighted. After adjusting for all significant variables there was a marginally significant increase in the koomal detected by spotlighting throughout the Kingston area after harvesting, compared with during harvesting (18% increase, p value = 0.0827).

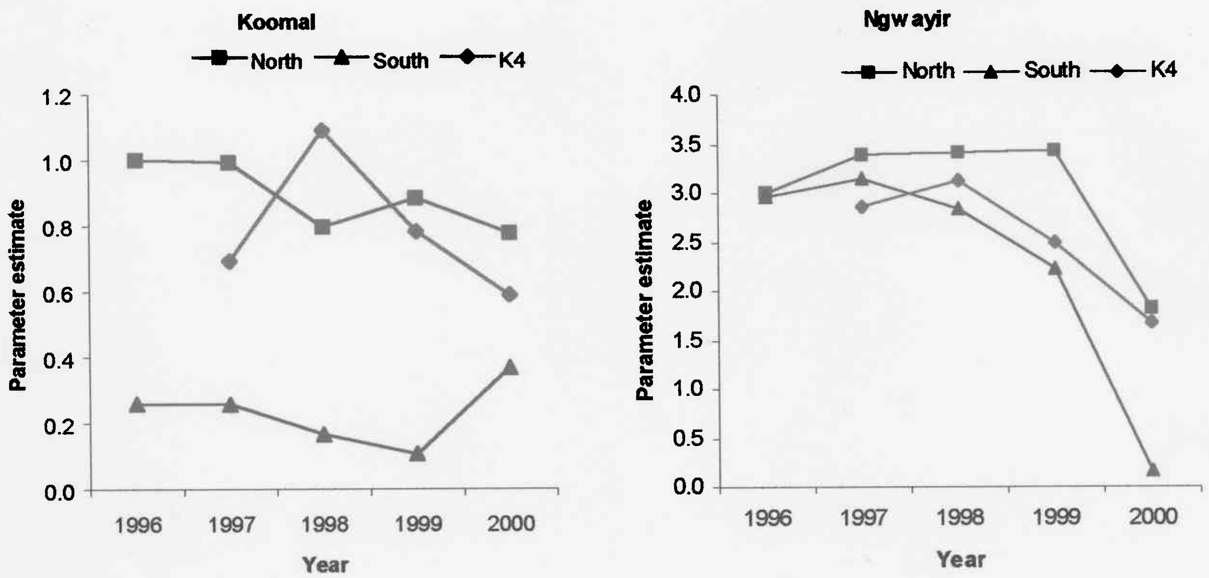

Figure 3. Relative detection abundances of koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*) from the Northern, Southern and Kingston 4 spotlight transects within the greater Kingston jarrah forest.

Table 3. Multivariate Poisson regression analysis results for factors affecting the detection of koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*) along the three Kingston spotlight transects.

Variable Descriptions	Sample Size (n)	Koomal		Ngwayir	
		Parameter Estimate	p-value	Parameter Estimate	p-value
Year & Transect					
1996 North	7	0.0000		0.0000	
1996 South	8	-0.7422	0.0001	-0.0443	0.8465
1997 North	15	-0.0087	0.9559	0.3802	0.0662
1997 South	13	-0.7430	0.0000	0.1445	0.5071
1997 Kingston 4	13	-0.3078	0.1232	-0.1385	0.5897
1998 North	15	-0.2045	0.2390	0.4122	0.0601
1998 South	14	-0.8351	0.0000	-0.1582	0.5420
1998 Kingston 4	15	0.0879	0.6206	0.1233	0.5963
1999 North	12	-0.1179	0.5458	0.4277	0.1025
1999 South	12	-0.8940	0.0000	-0.7708	0.0069
1999 Kingston 4	12	-0.2191	0.2828	-0.5155	0.0785
2000 North	12	-0.2246	0.2493	-1.1757	0.0001
2000 South	12	-0.6329	0.0016	-2.8358	0.0000
2000 Kingston 4	12	-0.4126	0.0626	-1.3226	0.0001
Observer					
Observer 1	37	0.0000		0.0000	
Observer 2	39	0.0296	0.6253	-0.1753	0.0435
Observer 3	42	-0.0300	0.6052	-0.0274	0.7435
Observer 4	27	-0.1835	0.0061	-0.2116	0.0310
Observer Not recorded	27	-0.3851	0.0013	-0.6545	0.0000
Before, During, or After harvest activity					
During timber harvest activity	79	0.0000		0.0000	
After timber harvest activity	93	0.1683	0.0827	-0.1955	0.1718
Moon Phase Class					
Nil (no moon)	72			0.0000	
1/4, 1/5, 1/6, 1/8	34			-0.2150	0.0067
1/2, 1/3, 2/3, 3/4	20			-0.0854	0.4290
7/8, Full	37			-0.1629	0.0454
Not recorded	9			-0.1206	0.3048
Cloud Cover Class					
Nil (no cloud cover)	120	0.0000		0.0000	
1/8	11	0.0811	0.2639	-0.0835	0.4701
From 2/8 to 7/8	21	-0.1929	0.0066	-0.1894	0.0356
Full (8/8)	20	-0.0383	0.5923	0.1045	0.2430
Season					
Spring	37	0.0000		0.0000	
Summer	41	-0.1919	0.0053	0.0041	0.9665
Autumn	46	-0.0047	0.9365	0.4461	0.0001
Winter	48	-0.2046	0.0009	0.3441	0.0163
Survey Finish Time					
20:15 - 21:45	34	0.0000			
21:46 - 22:30	51	0.1267	0.1199		
22:31 - 23:15	61	0.2150	0.0283		
23:16 +	26	0.1777	0.2104		
Survey duration in hours	172	0.0037	0.0017	0.0049	0.0000
Hours of darkness on survey night					
9:30 - 10:30	39			0.0000	
10:31 - 11:30	27			0.0988	0.3410
11:31 - 12:30	30			-0.2527	0.0715
12:31 - 13:30	27			-0.6569	0.0001
13:31 +	49			-0.8355	0.0000
Individual survey length (km)	172	-0.0046	0.8404	0.0074	0.8168

Important variables included in the analysis even if they were not significant.
Significant differences at the 95% confidence level.

Habitat Use

A greater proportion of koomal were sighted in unharvested forest after disturbance than during disturbance on both the Northern and Southern spotlight transects (Chi square = 4.12, p value = 0.0424; and Chi square = 20.87, p value = 4.922×10^{-6}, respectively). Conversely, relatively fewer koomal were sighted in unharvested forest after harvesting along the Kingston 4 transect than during harvesting (Chi square = 8.69, p value = 0.0032). Relative to the proportions of the three transects adjacent to harvested and unharvested forest, there were significantly more koomal sighted in harvested forest both during and after disturbance (Chi square = 191.34, p value = 2.8173×10^{-42}, and Chi square = 96.01, p value = 1.420×10^{-21} for during and post disturbance surveys respectively; Table 4).

Table 4. The proportion of koomal (*Trichosurus vulpecula*) sightings along the three Kingston transects within unharvested and harvested forest during and after timber harvesting and associated disturbance.

			During Harvest Disturbance		After Harvest Disturbance	
Spotlight Transect	% Transect Unharvested	% Transect Harvested	% Koomal Sightings in Unharvested	% Koomal Sightings in Harvested	% Koomal Sightings in Unharvested	% Koomal Sightings in Harvested
Northern	66.3	33.7	52.8	47.2	58.7	41.3
Southern	90.3	9.7	60.4	39.6	79.5	20.5
Kingston 4	42.2	57.8	41.7	58.3	33.0	67.0

Overall, just over half of the koomal sighted were recorded in either jarrah (27%) or marri (26%) trees, whilst the majority of other koomal were sighted on terrestrial habitat such as the ground, logs or other forest debris. The sightings of koomal on 'Other' habitat included *Eucalyptus rudis, Hakea oleifolia,* and *Melaleuca incana* (Appendix 3). Within harvested forest there were relatively more sightings in jarrah (21% to 40%) and fewer sightings in marri (30% to 18%) compared with unharvested forest (Figure 4). The sightings of koomal in *Banksia grandis*, *Gastrolobium bilobum* were substantially less in harvested areas (90% and 74% less respectively). There were also relatively more sightings of koomal in 'Other' habitats in unharvested sections of the transects. Sightings on terrestrial habitat were roughly the same in harvested and unharvested forest (Figure 4).

Generally koomal were sighted predominantly in mature (diameter at breast height over bark (dbhob) greater than 40cm) jarrah trees (46%), whilst saplings (dbhob less than 15cm) and poles (between 15 and 40 cm dbhob) were used about the same (24% and 26% respectively). For both jarrah and marri, the number of sightings in saplings were greater in harvested forest whilst the relative number of sightings in mature trees were less (Figure 5). Koomal in over-mature jarrah and marri trees (mature tree with signs of advanced senescence) were rarely sighted.

Some seasonal changes in habitat use were observed. An increased use of marri trees between December and March occurred in most years. Almost all sightings of koomal in *B. grandis* (up to 35% of koomal per transect per night), were between November and December when the banksia were in flower. Similarly, *G. bilobum* is an important food source (up to 54% of koomal per transect per night), between October and December. There was some increased use of jarrah between April and June 1997 and March to July 1998, however similar pulses were not observed in subsequent years (Appendix 4).

Ngwayir

Detection Abundance

The mean number of ngwayir (*Pseudocheirus occidentalis*) detected along the Northern, Southern and Kingston 4 transects when two spotlighters were used was 12.0 (range 1-33), 7.0 (range 1-19) and 9.2 (range 1-30) respectively. The detection of ngwayir along all three transects has substantially declined since 1999 (Figure 6).

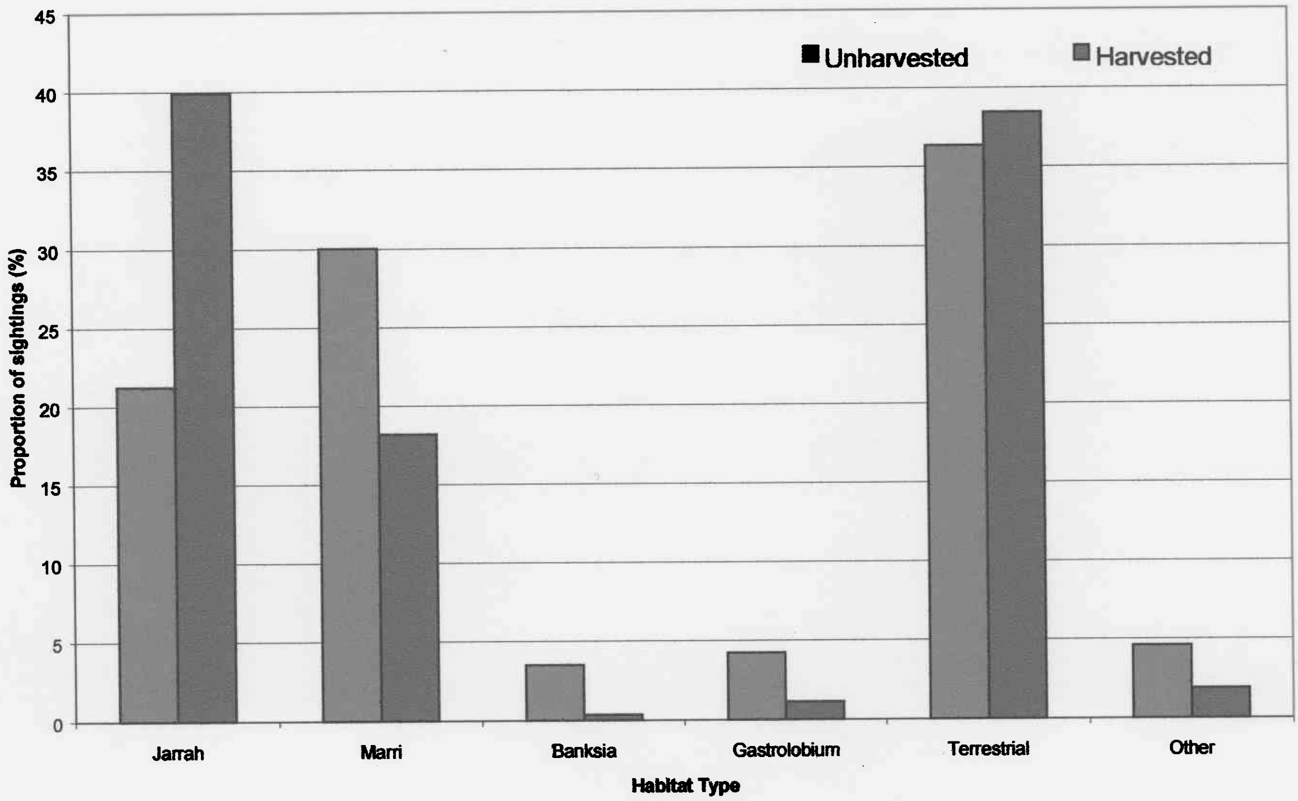

Figure 4. Habitat types in which koomal (*Trichosurus vulpecula*) were sighted within harvested and unharvested forest along the three Kingston spotlight transects.

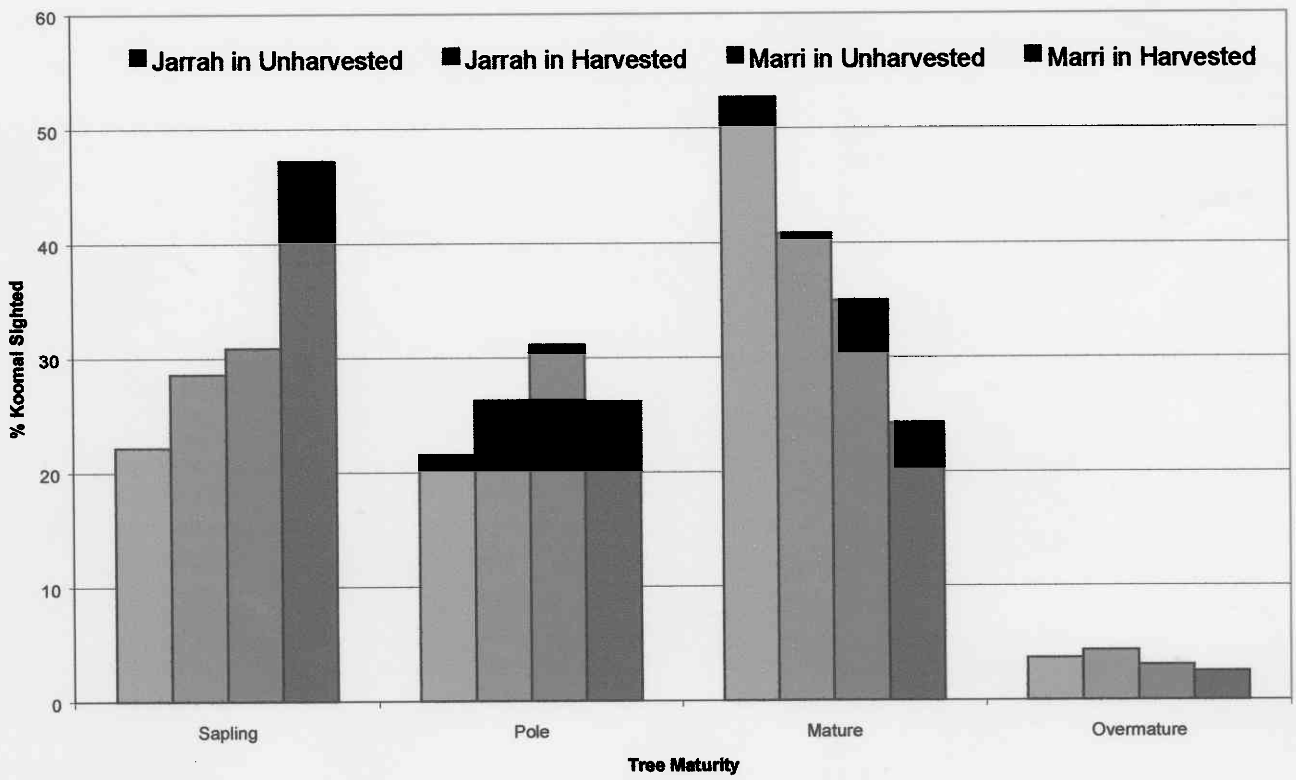

Figure 5. Habitat use of jarrah and marri trees by koomal (*Trichosurus vulpecula*) spotlighted within greater Kingston during and after timber harvesting and associated disturbance.

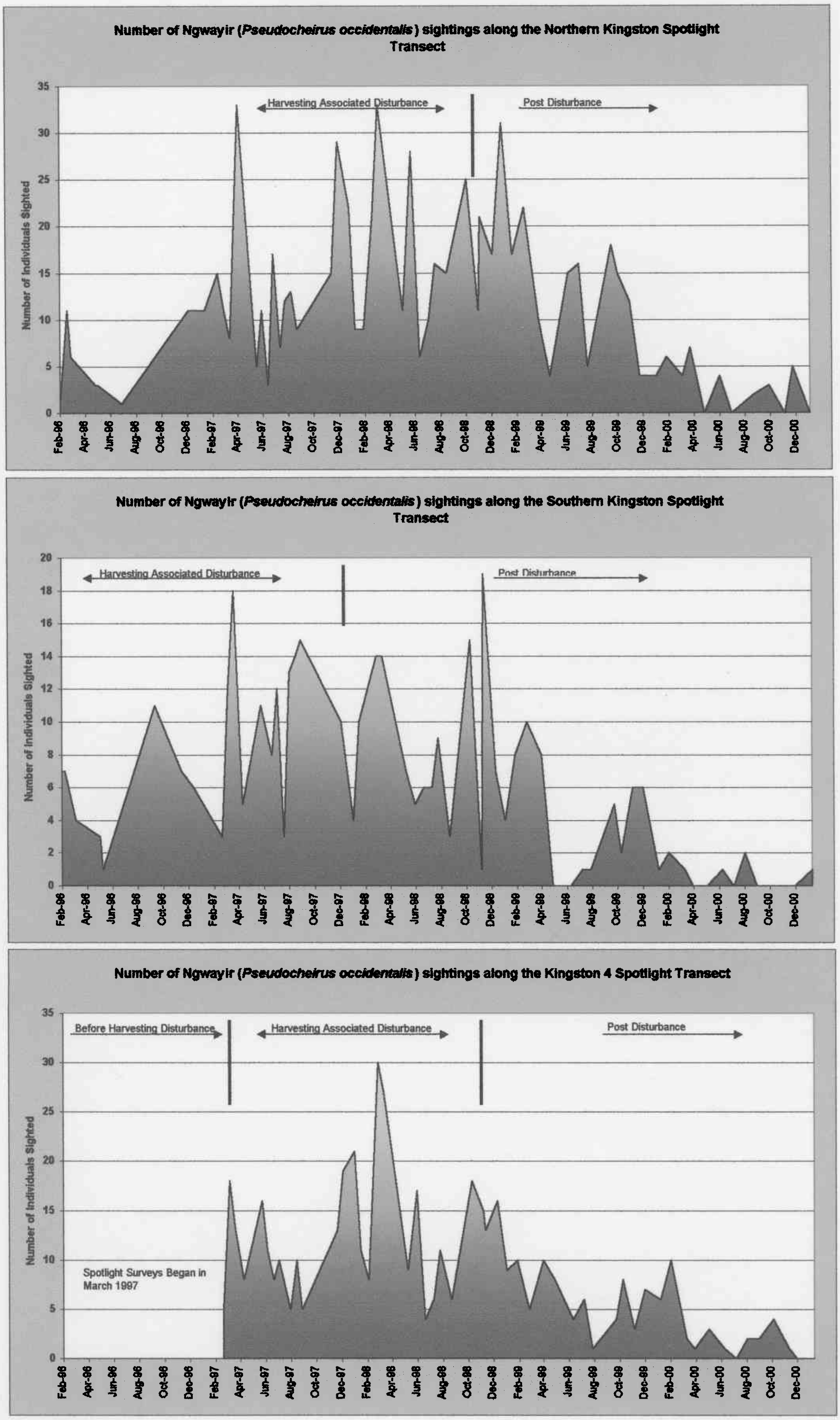

Figure 6. The number of ngwayir (*Pseudocheirus occidentalis*) sightings along the three Kingston spotlight transects

Multivariate Poisson Regression Analysis
Compared with the spotlight detection abundances on the Northern transect in 1996, ngwayir were substantially and significantly less on the Southern transect in 1999 and on all transects in 2000 (Table 3, Figure 3). There was, however, no significant difference (p=0.1718) detected in the number of ngwayir during and after logging for all three transects combined. There were significant observer differences in the detection of ngwayir, and more ngwayir were observed during relatively longer survey sessions. Environmental variables such as moon phase, cloud cover, season and hours of darkness were also significantly related to the number of ngwayir observed. After adjusting for all significant variables, the overall mean annual detection abundance of ngwayir along a Kingston transect was 7.15, 8.46, 7.90, 5.20, and 1.27 individuals for the years 1996 to 2000, inclusive and respectively. Therefore, the decline since the 1997 peak, has been up to 85% in 2000.

Habitat Use
The proportions of ngwayir detected within unharvested and harvested forest along each of the three transects did not differ significantly between surveys during and after disturbance (Northern transect p value = 0.4426, Southern transect p value = 0.9616, Kingston 4 transect p value = 0.7879). Significantly more ngwayir were detected within harvested compared with unharvested forest relative to their extent along the three spotlight transects (All survey data; Chi square = 155.73, p value = 1.5222×10^{-34}; Table 5).

Table 5. The proportion of ngwayir (*Pseudocheirus occidentalis*) sightings along the three Kingston transects within unharvested and harvested forest during and after timber harvesting and associated disturbance.

			During Harvest Disturbance		After Harvest Disturbance	
Spotlight Transect	% Transect Unharvested	% Transect Harvested	% Ngwayir Sightings in Unharvested	% Ngwayir Sightings in Harvested	% Ngwayir Sightings in Unharvested	% Ngwayir Sightings in Harvested
Northern	66.3	33.7	56.9	43.1	53.9	46.1
Southern	90.3	9.7	72.9	27.1	72.8	27.2
Kingston 4	42.2	57.8	42.6	57.4	43.0	57.0

Overall, about half (49%) of the ngwayir were sighted in jarrah trees and another 35% were in marri trees. Ngwayir were seldomly sighted on the ground or other terrestrial habitats (5%) and rarely in *Banksia grandis* or *Gastrolobium bilobum*. The majority of the 'Other' habitat used by ngwayir (6%) were *Hakea oleifolia, Eucalyptus rudis* and *Melaleuca incana* (Appendix 3). The relative number of sightings in jarrah and on terrestrial habitats was greater (41% and 136% respectively) in harvested forest. Sightings in marri, *B. grandis, G. bilobum* and 'Other' habitats were relatively less in harvested forest (31%, 60%, 47% and 91% respectively; Figure 7).

Ngwayir were predominantly sighted in marri and jarrah saplings (57% on marri sightings and 49% of jarrah sightings). The relative frequency of sightings within poles and mature trees were relatively similar to each other and between tree species (24% each for jarrah poles and mature trees, 22% for marri poles and 18% for mature marri trees). There were slightly more sightings of ngwayir in marri saplings and correspondingly fewer sightings in mature marri trees in harvested areas (Figure 8).

Seasonal changes in habitat use were not easily recognised within ngwayir spotlighting records since most patterns were very weak or not apparent. However, most sightings in *B. grandis* (up to 33% of ngwayir per transect per night), tended to be for a brief period between October and March each year. There were December to February pulses of sightings in *G. bilobum* (up to 40% of ngwayir per transect per night), in only some years. There was a tendency to see some ngwayir on the ground during summer and there was a weak pattern of increased sightings in jarrah between May and August.

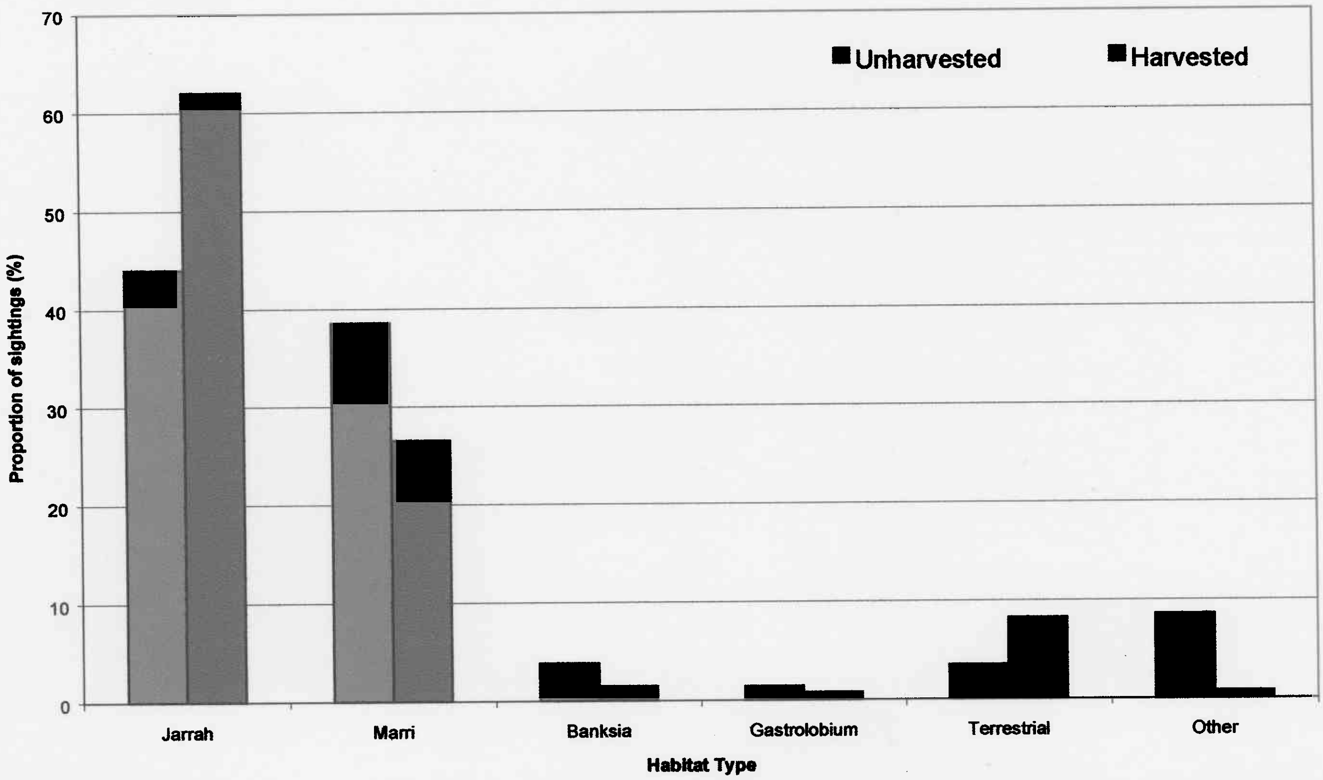

Figure 7. Habitat types in which ngwayir (*Pseudocheirus occidentalis*) were sighted within harvested and unharvested forest along the three Kingston spotlight transects.

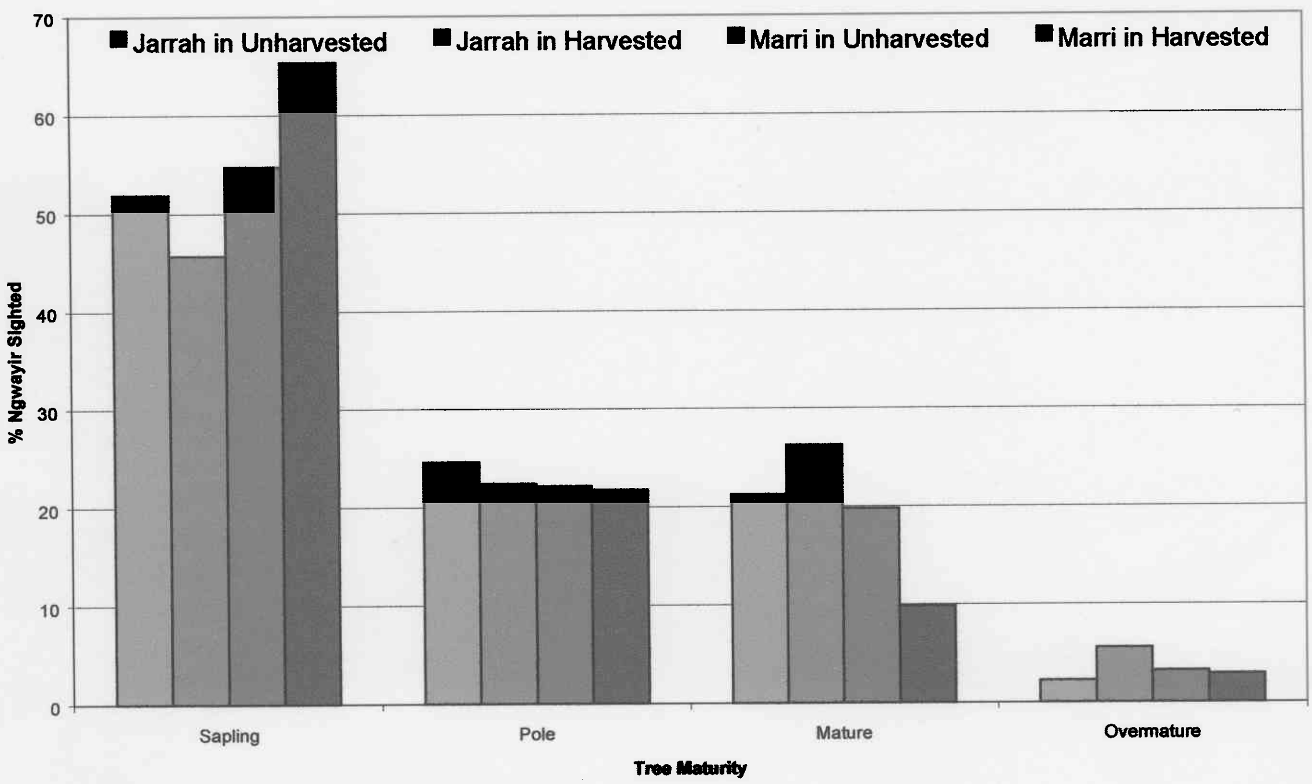

Figure 8. Habitat use of jarrah and marri trees by ngwayir (*Pseudocheirus occidentalis*) spotlighted within greater Kingston during and after timber harvesting and associated disturbance.

DISCUSSION

Nocturnal Birds and Mammals

The two possum species, koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*), were the most abundantly detected species during the spotlight surveys. In comparison, the woylie (*Bettongia pennicillata*) was the most abundantly trapped species within wire cages during the grid and road transect surveys of the same area (Morris *et al.* 2001, Wayne *unpublished*). The spotlight surveys were also able to collect data on some species, such as the larger macropods (*Macropus fuliginosus* and *Macropus irma*) and rabbit (*Oryctolagus cuniculus*), which were not targeted or trapped as part of the Kingston trapping program. The spotlight surveys also provide some data on nocturnal birds, although their sightings during early surveys were inconsistently recorded until 1998. These birds were rarely detected during the diurnal area plot surveys associated with the Kingston project (Craig *et al.* 1999; Liddelow *unpublished*). This clearly demonstrates that different survey techniques have their own strengths and biases. Used in conjunction with each other they help to develop a better understanding than might otherwise be realised had only one technique been used.

To date only the data for the two possum species has been analysed. Although the sample sizes for most other species are too small for analysis, the data for the large macropods may merit further enquiry.

Koomal and Ngwayir

Population Estimates
Despite ngwayir being rarely captured during the Kingston study trapping programs, the results from spotlight surveys suggest the species was generally in abundance throughout the greater Kingston area. Population estimates of ngwayir in Kingston would be valuable given that according to de Tores (2000), this information is very limited and the need for such information has been identified as a high priority. If monitoring was maintained at Kingston, this study may further assist future reviews of the conservation status of this IUCN (2000) listed species. To date there have been no estimates of the population size of ngwayir in and around Kingston. It is possible, however, to indirectly estimate ngwayir Kingston populations. By using the detection ratio of ngwayir to koomal during spotlighting (ie. 1:1.8 ngwayir to koomal ratio), it is possible to estimate the ngwayir population via koomal population abundance estimations from Kingston grid trapping (Wayne *unpublished.*). This approach, however, would rely on the assumption that the detection efficiency for ngwayir and koomal is the same. Given the more cryptic nature of the ngwayir, this assumption is probably invalid (ie. ngwayir populations would be underestimated to some unknown extent).

Alternatively, possum population sizes could be more directly derived by density estimates using the spotlight distance estimates from the transect (e.g. Buckland *et al.* 1993, Johnson 1980; using Kingston spotlight data since February 1999). This method is however compromised by the changing structural complexity of the forest. In particular, habitat modification through harvesting and burning and the subsequent regeneration is expected to dramatically affect the efficiency of detection of possums within these areas over time. To date there have been no data collected to measure and account for these changes accordingly. Furthermore, without determining the efficiency of the spotlight technique to detect possums, it is not possible to accurately relate the spotlight data (sample population, n) to the actual population (N).

The Kingston spotlight surveys lack pre-harvest data that would have monitored population responses to the broadscale Western Shield fox control program. These responses were, however, well studied as part of the Kingston trapping program for medium sized mammals (Morris *et al* 2001, Wayne *unpublished*). Nonetheless, the value of comparative pre-disturbance spotlight data would have been minimal in determining the impacts of the timber harvesting without a fundamental shift in the spotlight study design from one of monitoring to an adequately controlled and replicated experimental study. This alternative was considered unviable at the time given the resources available and the associated practical and logistical constraints. Although there was no corresponding control transects established at the forest block scale, spotlight data from the Perup Nature Reserve and some Western Shield transects (e.g. Tone River) may be suitable alternatives. The value of these datasets remains to be fully explored.

The strengths of the greater Kingston spotlight data include the ability to determine factors affecting the detectability of possums. Furthermore, the data provides some useful information in relation to possum habitat use within the jarrah forest in general and in the presence of harvesting associated disturbance.

Survey Methods

It is important to recognise that there are significant observer differences in the number of both possum species detected during the spotlight surveys. The different vehicles used may explain some of these differences. For instance, a specially adapted seat attached to the roof rack of a large four wheel drive station wagon provides a different perspective to standing on the back of a utility (approximately 1 metre height difference). Diesel vehicles were also found to have better control at speeds less than five kilometres an hour compared with petrol vehicles. Although monitoring differences can be an important mechanism for monitoring quality control, there will always be differences between observers. Therefore it is more important to measure these differences so that account of the data can be made accordingly so as to reduce the variance between surveys.

Later survey finishes tended to detect more koomal, significantly so when they ended between 22:31 and 23:15 hours. Therefore it is important to be aware of the timing of the surveys to maximise the efficiency of effort. That more possums are detected when more time has been taken to complete a transect makes common sense. This is in part at least, due to the extra time taken to record more observations during more active nights. Although a slower speed may improve detection it may not necessarily be so if there is any avoidance by possums. Given that many of the koomal (e.g. running up off the ground onto the blind side of tree trunks) and ngwayir (e.g. looking away and motionless amongst dense foliage) demonstrated apparent evidence of avoidance during spotlighting, this seems likely. In which case the optimum travelling speed would also be a compromise with a faster speed to improve the element of surprise. This study, however, did not investigate the optimum speed at which a transect should be travelled to maximise detection efficiency.

Some environmental factors were demonstrated to have a significant relationship with possum detection. These factors included moon phase, cloud cover, season, and hours of darkness. Other environmental variables that were examined and were not found to be significantly correlated with possum detection included, wind, time of moonrise, prior rain, the temperature at the time of the survey, the maximum and minimum temperatures of the preceding three days, and time after sunset at the start of the survey. It is important to note that the surveys were not conducted within the full range of environmental conditions experienced at Kingston. In particular, evenings that had a high likelihood of being exceptionally stormy or inclement were deliberately avoided because of personnel safety and/or the increased difficulty of detecting animals due to the excessive light reflection off falling rain drops. In addition surveys were always conducted shortly after dark rather than later during the evenings.

The results of the multiple Poisson regression analysis suggest that more koomal are likely to be detected during Spring and Autumn, and when there is either 1/8 or less cloud cover or during full cloud cover. Ngwayir on the other hand are more likely to be detected in greater numbers when it is Autumn, when there is either no moon or somewhere between 1/3 and ¾ moon, and when there is either full or 1/8 or less cloud cover.

For reasons that remain to be explained, the Southern transect had fewer ngwayir and significantly fewer koomal than the other transects. Topography is perhaps the greatest difference between the

Southern transect and the other two transects, with the former tending to be lower in the profile. Although superficially there appear to be no other striking differences, it would be interesting to examine whether vegetation, soils, moisture and available vegetative nutrition can better explain the apparent differences in possum abundance. Other factors worth considering would also include the logging, fire, and fox baiting histories.

The grid trapping data demonstrated that there was a significant decline in the abundance of koomal within the more intensely harvested gap cells. For example, there was a 21% decline (p=0.0028), within gap release cells with prescribed habitat trees removed compared between the koomal population abundance estimates, during harvesting and after disturbance. There was also a 50% difference (p=0.0001) in population size between gap release cells with prescribed habitat trees removed and the external control areas (Wayne *unpublished.*). There was, however, a marginally significant increase in the koomal detected by spotlighting throughout the Kingston area after harvesting, compared with during harvesting (18% increase, p value = 0.0827). At this stage it has not been identified to what extent this increase may be as a result of increased detection ability of koomal within logged areas and to what extent the increase is as a result of a continued positive population response to fox control. If these results are reliable, then it provides evidence for the value of the unharvested forest network that remains within a harvested area. According to the 'Silrec' data for Kingston (CALM Forest Management Branch, Manjimup), 67% of the area (Coupes K1 – K5, 3606 ha) remained unharvested in the 1995- 1997 harvest cycle (17% was gap release and 16% was shelterwood creation). In particular, the unlogged riparian reserves and TEAS buffers constituted up to 39% of the spotlight transects. Therefore, the spotlight data may provide clear evidence for the important role that riparian reserves and TEAS play in sustaining koomal numbers at the forest block scale despite declines in some harvested cells.

The recent substantial and significant decline of up to 85% of the ngwayir detected (adjusted for significant observer and environmental variables) throughout the Kingston area is a concern. That the decline has been essentially simultaneous on all three transects suggests that the decline has been widespread. At this stage timber harvesting cannot be eliminated as a possible contributing causal factor. Given that ngwayir have a four to five year life expectancy and that timber harvesting and associated disturbance within Kingston was between February 1995 and November 1998, the apparent latency in the decline after timber harvesting disturbance may be as a result of a compromise to successful breeding and recruitment by the survivors of the logging. There may equally be other reasons for the sharp decline. These may include other environmental or ecological factors such as, disease, drought and/or heat stress, competition and/or increased predation. Although any of these factors, either in isolation or in conjunction, may have been directly responsible for the decline none of them have yet been rigorously tested. That these direct causes may have been related to logging disturbance cannot be eliminated. It should also be a matter of priority to determine whether similar trends have been observed elsewhere.

That the multivariate Poisson regression analysis did not detect a significant correlation between possum numbers and harvesting is not surprising. Firstly, all three transects lacked before disturbance data (except one survey of Kingston 4 transect). Secondly the different timings of harvest disturbance along the transects means that the analysis may be confounded with other factors affecting the level of possum detections. These particular results, therefore, need to be regarded cautiously and perhaps a more reliable means of testing possible impacts of timber harvesting and associated activities be investigated.

Habitat Use

Along two transects, proportionally fewer koomal were sighted in harvested forest after disturbance than during, whilst the opposite was true for Kingston 4. The significant proportional decline of koomal along the Northern and Southern transects within impacted sites post disturbance concurs with the findings from the Kingston grid trapping data (Wayne *et al.* 2001) for the same area. Despite significant overall declines in the number of ngwayir sighted over time, for all three transects there was no significant difference in the proportion of ngwayir detected in harvested and unharvested forest, during and after disturbance. Therefore ngwayir declines were extensive rather than confined to impacted sites only.

The observed differences in the relative proportions of sightings within harvested forest over time between the two possum species may be as a result of differences in their ecology and/or their behaviour and/or their detectability in different habitat. For example, the proportional decrease in detection of koomal and not ngwayir within harvested areas may be explained by the koomal's relative preference toward larger trees and foods associated with more mature plants. Preferential recruitment by koomal to unharvested forest could also explain the reduction in harvest areas whilst the population size is maintained at the landscape scale (assuming the population has not reached carrying capacity, for example, in response to fox baiting). These hypotheses, however, remain to be more rigorously tested. Similarly, it remains to be satisfactorily explained as to why in contrast to the Northern and Southern transects there were relatively more koomal observed in Kingston 4 harvested areas after disturbance than during.

Significantly more ngwayir and koomal were recorded within harvested than unharvested forest relative to the proportions of the transects subjected to these treatments both during and after disturbance. This is despite the significant proportional decline along two transects of koomal in harvest areas post disturbance. It is most likely that the greater number of sightings in harvested areas is as a result of the overall structural simplification of impacted areas making it easier to detect possums. Testing the detection efficiency with logging history and habitat structure is required to verify this.

To determine habitat selection preferences by koomal and ngwayir, the habitat use data needs to be related to the habitat resources available. For example, without this data it is not possible to determine to what extent changes in habitat use are as a result of changes in habitat availability or actual shifts in habitat use. Similarly, the efficiency of detection in different habitat types may also differ and/or change with habitat modification. For example, the shift in the relative ability to detect animals on the ground may not be the same as for the shift in the detection ability for animals in trees. The habitat surveys and experiments to account for these factors have not yet been conducted.

Despite these shortcomings the current data provides some useful comparative differences in habitat use between the two possums within the same habitat and therefore evidence for resource partitioning. Ngwayir are clearly more arboreal than koomal. Ngwayir also appear to use jarrah more frequently than marri, and saplings more so than larger trees, when compared with koomal. The koomal appeared to be more strongly seasonal in its habitat use of marri during the flowering months. The buds and flowers of *Banksia grandis* and *Gastrolobium bilobum* appear to be seasonally important food resources of both possum species. *Hakea oleifolia, Eucalyptus rudis* and *Melaleuca incana* were also occasionally used by both species. The importance of protecting seasonally important food sources is discussed in the following section, 'Implications for Management.'

In the absence of rigorous experimental validation, the data implies that there may well be an increase in the use of terrestrial habitats by ngwayir in harvested areas. Habitat modification as a result of harvesting would necessitate ngwayir to spend more time travelling along the ground rather than by their preferred means through the canopy. This would increase their vulnerability to predation, particularly given their seemingly high level of predator naivety. The decreased survivorship expectation of ngwayir within harvest areas as a result of increased predation is evidence for this (Wayne *et al.* 2000).

IMPLICATIONS FOR MANAGEMENT

The declines of ngwayir throughout the greater Kingston area are of potential threat to the viability of the populations. As a matter of priority, further research is required to determine the cause, magnitude and extent of the threat so that management action can be as efficient and as effective as possible.

In the interim, the results from the spotlight monitoring add support for the need for management to adopt the recommendations detailed in the timber harvesting impacts on ngwayir report (Wayne *et al.* 2000). Although the specific details of the recommendations are available within the Wayne *et al.* (2000) report, the main themes briefly include;

1. The need for clear conservation goals and objectives.
2. Increased control of introduced predators immediately prior to, during and after disturbance.
3. Maintaining habitat diversity at all spatial scales.
4. Improvements to the habitat refuge retention rates within harvested areas.
5. Refinements to the characteristics and selection criteria for retained habitat refuges within harvest areas.

Provided the koomal spotlight data is sensitive enough to avoid a Type II error, these results, in conjunction with the grid trapping data (Wayne *unpublished.*), provide compelling evidence for the important role that unlogged forest, such as riparian zones and TEAS, has within a harvest coupe. In particular these logged areas appear to maintain koomal numbers at the forest block level despite significant local declines within some of the more intensely harvested cells. This clearly has implications if/when the TEAS are harvested at a later date and will therefore need to be considered carefully before these activities are undertaken.

There is a need to consider potentially important possum food sources that may also be impacted by logging. For example, although less than 5% of all koomal sightings throughout the survey period were in either *Banksia grandis* or *Gastrolobium bilobum,* during the summer up to 35% and 54% of all koomal were sighted (usually feeding) per transect per night in these plant species respectively. Compared with unharvested areas of the transects, the use of *B. grandis* and *G. bilobum* in harvest areas was reduced 90% and 74% respectively. This has important implications when regarding that the carrying capacity of possums in an area will be largely determined by the number of animals that can be sustained when food resources available are at their seasonal low. Therefore the substantial loss of seasonally important food species such as *B. grandis* and *G. bilobum* may limit population numbers and recovery. As a consequence the protection of such species in adjacent unharvested and logged areas is important to maintain and/or allow a rapid recovery of fauna such as the koomal and ngwayir.

FUTURE RESEARCH

Both the data from the spotlight monitoring in greater Kingston and the ngwayir impact study in Kingston 4 (Wayne *et al.* 2000) indicate that there is a real potential threat to the viability of at least some ngwayir populations within jarrah forest. Given their current listing as Vulnerable (IUCN 2000), the cause, magnitude and extent of the threat to ngwayir needs to be determined as a matter of priority. Irrespective of current or future forest policies, some ngwayir populations may be at risk within both past and future harvest areas. There is therefore an imperative under the ecologically sustainable forest management principle to further investigate the impacts of native forest timber harvesting on the possums of the southwest. Adrian Wayne is currently refining a research proposal for this purpose.

Some analyses and power testing remains to be done on the existing spotlight data and analyses on the other species besides the possums need to be explored. To maximise the value of the existing Kingston data and to assist with future research, several key datasets would also be useful to collect and examine. These include;

- Measurement and experimentation of spotlight efficiency in various habitats (part of the future research proposal mentioned above) to improve understanding of the existing and future data.
- Measurements of the spotlight detection efficiency over distance in the various habitats present along the Kingston transects would enable population estimates through density estimates.
- Comparisons of the results from Kingston with other existing spotlight datasets to explore whether the significant declines of ngwayir in Kingston are also being observed elsewhere and to what extent timber harvesting is implicated in these declines.
- Habitat surveys along the spotlight transects to determine nocturnal habitat selection and preferences by koomal and ngwayir.

Whether or not the existing spotlight surveys should be continued also remains to be determined.

Factors to consider for the future of the existing spotlight surveys include the value that this data may contribute to improving the understanding of the conservation status of ngwayir and the legal constraints of spotlighting on the back or on top of moving vehicles.

In relation to the legal constraints associated with spotlighting, amendments to the Road Traffic Code 1975 (enforceable as of 1 January 2001) prohibit persons riding in the goods section of open load space vehicles unless the vehicle is equipped with an approved "Rollover Protection Device"(RPD). Therefore, current practices of spotlighting from the rear of utilities and from adapted seats on rooftops are now prohibited. Exemption from the amendment, specifically for spotlighting, is being sought from the Department of Transport. If an exemption is granted, it is likely to incur modification of current practices. These conditions would be applicable throughout CALM.

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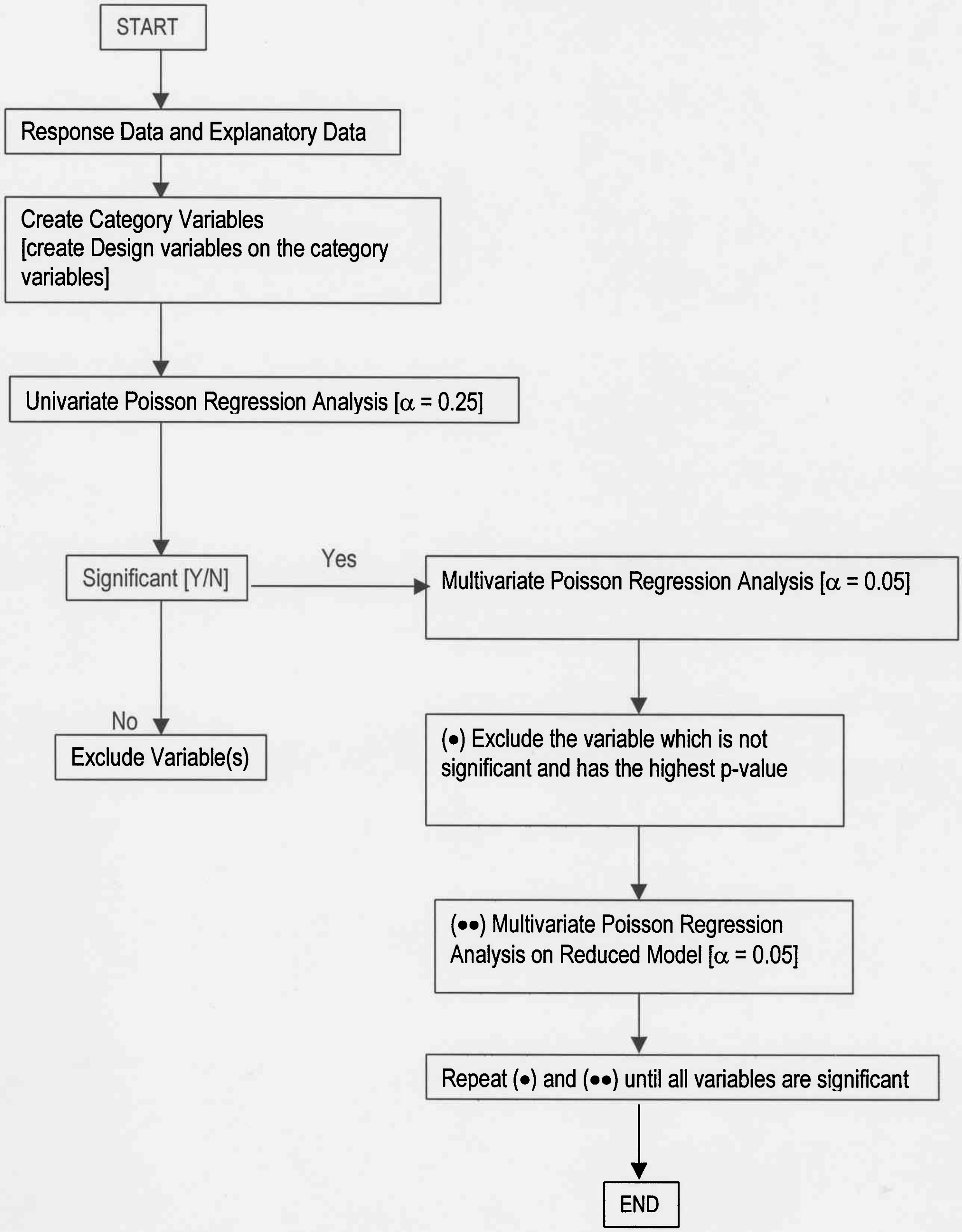
Appendix 1. Flow chart illustrating the step-wise methodology for statistical analysis of the spotlighting data for the koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*) relationships with environmental and survey variables.



Appendix 2a. Nocturnal bird and mammal species tally for Kingston spotlight surveys: Northern transect.

Genus	Aegotheles	Podargus	Ninox	Tyto	Tyto	Vulpes	Felis	Mus	Oryctolagus	Dasyurus	Phascogale	Macropus	Macropus	Isoodon	Bettongia	Trichosurus	Pseudocheirus
Species	cristatus	strigoides	novaeseelandiae	novaehollandiae	alba	Vulpes	catus	domesticus	Cuniculus	geoffroii	tapoatafa	fuliginosus	irma	obesulus	pennicillata	vulpecula	occidentalis
Common Name	Australian Owlet-nightjar	Tawny Frogmouth	Southern Boobook	Masked Owl	Barn Owl	Red Fox	Feral Cat	House Mouse	European Rabbit	Chuditch	Brush-tailed phascogale	Western Grey Kangaroo	Western Brush Wallaby	Quenda	Woylie	Brushtail Possum	Western Ringtail Possum
*21/11/1995												8	5			5	2
*22/11/1995												2	1			13	6
*12/12/1995												3		2	1	4	4
27/02/1996												3		1	3	6	1
15/03/1996												2		2		6	11
25/03/1996												1	1		1	2	6
22/05/1996										1		5	1	2	1	15	3
28/05/1996												7	1		1	16	3
*30/06/1996												1				3	4
23/07/1996												1				5	1
*30/09/1996									1			3	1		3	6	6
*5/11/1996		2										2	1	2	2	23	11
*28/11/1996	1											6	1		1	15	1
*4/12/1996												7	1	1	7	19	5
30/12/1996												2	7		2	25	11
7/02/1997												6			1	8	11
11/03/1997												8		1	1	10	15
25/03/1997		1										10			4	10	11
8/04/1997						1						5	3	1	3	23	8
29/04/1997												5	4	2	5	37	33
12/06/1997												7	1		3	19	5
24/06/1997												1			1	23	11
9/07/1997												9	1		2	12	3
22/07/1997												4	2		3	17	17
7/08/1997												4	2	1	7	12	7
19/08/1997												3	1	1	5	17	12
3/09/1997												8			8	26	13
16/09/1997												9	4		13	30	9
9/12/1997									1			3				16	15
23/12/1997									1			6	2		8	28	29
20/01/1998												10	3	1	3	17	22
3/02/1998												1	2		2	12	9
23/02/1998												3	4		2	4	9
17/03/1998												2			11	25	21
31/03/1998		1										5			2	20	33
28/05/1998												3	4		4	24	11
18/06/1998											1	4			4	12	28
8/07/1998												3		1	1	24	6
29/07/1998													1		3	22	10
13/08/1998												4		1	7	13	16
10/09/1998															5	10	15
29/10/1998												5			8	36	25
26/11/1998												5			3	14	11
30/11/1998		3	2									6	3		3	22	21
30/12/1998		2										7	1		15	27	17
21/01/1999		1										2			10	21	31
15/02/1999	1								1			12	5		7	26	17
16/03/1999												3		1	9	38	22
20/04/1999												4	2		1	17	10
17/05/1999	1						1					4	1		4	17	4
30/06/1999													2		10	25	15
27/07/1999									1			3	4		4	16	16
16/08/1999									1			3	2		4	10	5
12/10/1999									2			9			9	30	18
28/10/1999		1										2			4	17	15
25/11/1999		1										2	1		4	20	12
20/12/1999		2							2			6			14	15	4
27/01/2000												7	2		2	22	4
21/02/2000			1									4	2		1	16	6
30/03/2000		1		1								4	1		2	13	4
18/04/2000												1			4	18	7
22/05/2000	1												1		3	12	
28/06/2000							1					2			2	11	4
26/07/2000		1										1	1		2	10	
22/08/2000												4			4	21	1
19/09/2000												3	1		2	17	2
24/10/2000												5	1		4	37	3
30/11/2000		1										12	1		1	20	
19/12/2000							1						3		2	27	5
31/01/2001		1										2			1	23	
Species Total	**4**	**18**	**3**	**1**	**0**	**1**	**3**	**0**	**10**	**1**	**1**	**294**	**88**	**20**	**269**	**1232**	**733**

*One or no record of number of spotlighters. Therefore, not included in analysis.

Appendix 2b. Nocturnal bird and mammal species tally for Kingston spotlight surveys: Southern transect.

Genus	*Aegotheles*	*Podargus*	*Ninox*	*Tyto*	*Tyto*	*Vulpes*	*Felis*	*Mus*	*Oryctolagus*	*Dasyurus*	*Phascogale*	*Macropus*	*Macropus*	*Isoodon*	*Bettongia*	*Trichosurus*	*Pseudocheirus*
Species	*cristatus*	*strigoides*	*novaeseelandiae*	*novaehollandiae*	*alba*	*vulpes*	*catus*	*domesticus*	*cuniculus*	*geoffroii*	*tapoatafa*	*fuliginosus*	*irma*	*obesulus*	*penicillata*	*vulpecula*	*occidentalis*
Common Name	Australian Owlet-nightjar	Tawny Frogmouth	Southern Boobook	Masked Owl	Barn Owl	Red Fox	Feral Cat	House Mouse	European Rabbit	Chuditch	Brush-tailed phascogale	Western Grey Kangaroo	Western Brush Wallaby	Quenda	Woylie	Brushtail Possum	Western Ringtail Possum
*22/11/1995												5	2	1		5	3
*28/11/1995												3	1		1	9	25
20/02/1996				1								7		2	2	6	7
27/02/1996												5			3	3	7
8/03/1996													1	1	1	7	6
25/03/1996		1										1				5	4
22/05/1996												3	2		3	5	3
28/05/1996												5			1	8	1
*29/06/1996												2	1	1		1	6
*5/08/1996												1	1	1	1	5	5
1/10/1996		2										1	1		1	8	11
*26/10/1996												2	1		1	1	3
4/12/1996												2	2	1	1	3	7
2/01/1997												1	1			5	6
11/03/1997													1	2	1	12	3
25/03/1997												4		3		10	12
8/04/1997												7	1	3	4	17	18
29/04/1997													1		3	3	5
12/06/1997													2	1	1	11	11
9/07/1997													2			10	8
22/07/1997																6	12
7/08/1997													3		3	4	3
19/08/1997							1					3				8	13
3/09/1997												4	2		3	6	14
16/09/1997		1										5	4		5	14	15
23/12/1997										1					2	11	10
20/01/1998												7	3	1	1	8	4
3/02/1998												3			5	7	10
17/03/1998		1				1					1	1	1		4	30	14
31/03/1998												2	1	2	2	10	14
28/05/1998												2			1	9	7
18/06/1998		1										2			2	6	5
8/07/1998													2		1	13	6
29/07/1998												3			3	4	6
13/08/1998		1										3	3		5	9	9
10/09/1998												3	8		1	9	3
29/10/1998		1												1	2	20	15
26/11/1998												1			5	7	1
30/11/1998												7	2	1	9	20	19
30/12/1998		1										3	2		6	12	7
21/01/1999												1	1		1	1	4
15/02/1999			1									8	1	1	5	19	8
16/03/1999						1						3	3	1	4	10	10
20/04/1999		2						1					3	1	3	10	8
17/05/1999													3		1	9	
30/06/1999												1	1		4	11	
27/07/1999		1										1	3		2	2	1
16/08/1999												1	1		4	15	1
12/10/1999												2	1		1	12	5
28/10/1999												4	6	1	5	9	2
25/11/1999		1										1			4	12	6
20/12/1999		1										3	1		1	3	6
27/01/2000												2	1		2	10	1
21/02/2000												3	5		1	10	2
30/03/2000												3	2		2	17	1
18/04/2000													4		1	15	
22/05/2000		1											1			20	
28/06/2000												3	1		1	22	1
26/07/2000		1											4		3	5	
22/08/2000													4			8	2
19/09/2000											1					21	
24/10/2000												3	2			13	
30/11/2000											1	4	1			12	
19/12/2000												6	4			8	
31/01/2001				2								3	1	1	1	15	1
Species Total	0	16	1	3	0	2	1	1	0	1	3	150	105	26	130	636	397

* One or no record of number of spotlighters. Therefore, not included in analysis.

Appendix 2c. Nocturnal bird and mammal species tally for Kingston spotlight surveys: Kingston 4 transect.

Genus	*Aegotheles*	*Podargus*	*Ninox*	*Tyto*	*Tyto*	*Vulpes*	*Felis*	*Mus*	*Oryctolagus*	*Dasyurus*	*Phascogale*	*Macropus*	*Macropus*	*Isoodon*	*Bettongia*	*Trichosurus*	*Pseudocheirus*
Species	*cristatus*	*strigoides*	*novaeseelandiae*	*novaehollandiae*	*alba*	*vulpes*	*Catus*	*domesticus*	*cuniculus*	*geoffroii*	*tapoatafa*	*fuliginosus*	*irma*	*obesulus*	*penicillata*	*vulpecula*	*occidentalis*
Common Name	Australian Owlet-nightjar	Tawny Frogmouth	Southern Boobook	Masked Owl	Barn Owl	Red Fox	Feral Cat	House Mouse	European Rabbit	Chuditch	Brush-tailed phascogale	Western Grey Kangaroo	Western Brush Wallaby	Quenda	Woylie	Brushtail Possum	Western Ringtail Possum
11/03/1997																7	5
25/03/1997																17	18
8/04/1997																17	13
29/04/1997																22	8
12/06/1997																16	16
24/06/1997																10	11
9/07/1997															1	31	8
22/07/1997																35	10
7/08/1997																11	7
19/08/1997												2			5	11	5
3/09/1997																19	10
16/09/1997																17	5
9/12/1997																8	13
23/12/1997																25	19
20/01/1998																15	21
3/02/1998						1				1	1	1		1	2	8	11
23/02/1998																20	8
17/03/1998																31	30
31/03/1998																44	27
28/05/1998																21	9
18/06/1998																23	17
8/07/1998																22	4
29/07/1998												2	2	1	1	15	6
13/08/1998																26	11
10/09/1998															1	25	6
29/10/1998		2			1							3	2		12	29	18
26/11/1998		3	1									10	7		4	36	15
30/11/1998												11	3		2	23	13
30/12/1998																45	16
21/01/1999			1						1							25	9
15/02/1999		1														14	10
16/03/1999		2					2		2			5	2		3	23	5
20/04/1999												6	4		3	32	10
17/05/1999		3														27	8
30/06/1999		2										6	2		5	21	4
27/07/1999																10	6
16/08/1999		6	1													13	1
12/10/1999			1						2			10			4	23	4
28/10/1999																18	8
25/11/1999												11	2		2	19	3
20/12/1999												1			5	15	7
27/01/2000									2			15			1	21	6
21/02/2000		1	1									13	1		2	21	10
30/03/2000																9	2
18/04/2000		1				1	1		2			10	2			13	1
22/05/2000												3	1			13	3
28/06/2000		1						1	3			1			2	12	1
26/07/2000												9			1	12	
22/08/2000																14	2
19/09/2000												3	1			20	2
24/10/2000												6	1		3	16	4
30/11/2000												3	1			16	1
19/12/2000							1		2			15	4			24	
31/01/2001															1	19	
Species Total	0	22	5	0	1	2	4	1	14	1	1	146	35	2	60	1079	467

* One or no record of number of spotlighters. Therefore, not included in analysis.

Appendix 3. Summary of "Other" habitat use by koomal (*Trichosurus vulpecula*; 56 records) and ngwayir (*Pseudocheirus occidentalis*; 73 records) along the Northern, Southern and Kingston 4 spotlight transects within the greater Kingston jarrah forest.

Species	Koomal %	Ngwayir %
Acacia alata	0.0	1.4
Acacia cyanophylla	0.0	1.4
Acacia pulchella	1.8	0.0
Acacia sp.	1.8	0.0
Banksia littoralis	0.0	1.4
Callistachys lanceolata	12.5	5.5
Eucalyptus patens	1.8	0.0
Eucalyptus rudis	21.4	16.4
Eucalyptus wandoo	3.6	0.0
Hakea amplexicaulis	0.0	1.4
Hakea oleifolia	14.3	41.1
Hakea sp.	3.6	0.0
Hibbertia cuneiformis	1.8	0.0
Melaleuca incana	12.5	16.4
Melaleuca viminalis	1.8	1.4
Myoporum tetrandrum	3.6	1.4
Paraserianthes lophantha	1.8	0.0
Persoonia longifolia	3.6	5.5
Stump coppice	3.6	0.0
Sucker advanced growth	1.8	0.0
Undescribed	5.4	5.5
Xanthorrhoea preissii	3.6	1.4

Appendix 4. Habitat use tally for koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*) for each spotlight survey along the three Kingston spotlight transects.

Koomal (*Trichosurus vulpecula*) sightings along the Kingston spotlight transects.

Date	Jarrah, *E. marginata*	Marri, *E. calophylla*	*Banksia grandis*	*Gastrolobium bilobum*	Terrestrial (ground, logs, etc)	Other
21/11/1995					4	
22/11/1995					7	
28/11/1995					7	
12/12/1995						
20/02/1996					4	
27/02/1996	1	1			5	
8/03/1996	2	5				
15/03/1996		4			2	
25/03/1996		3			3	
22/05/1996	3	3			9	
28/05/1996	7	1			15	
29/06/1996		1				
30/06/1996						
23/07/1996	1	4				
5/08/1996						
30/09/1996	2	3			1	
1/10/1996	1	4			1	
26/10/1996		1				
5/11/1996	2	8		4	5	4
28/11/1996	1				10	
4/12/1996	1	7	5	2	4	
30/12/1996	3	2	6	3	4	1
2/01/1997		1	1		3	
7/02/1997		6			2	
11/03/1997		20	2	1	4	2
25/03/1997	6	19	1		9	
8/04/1997	10	13	2		27	2
29/04/1997	24	12			14	1
12/06/1997	21	10		1	13	
24/06/1997	10	7			16	
9/07/1997	19	14			19	1
22/07/1997	13	29	1	1	14	
7/08/1997	6	9	1		9	1
19/08/1997	5	13			16	2
3/09/1997	13	11	1	3	20	1
16/09/1997	9	20		2	29	1
9/12/1997	3	3	4	4	8	2
23/12/1997	14	13	4	12	20	1
20/01/1998	12	9		3	15	1
3/02/1998	10	7			8	2
23/02/1998	10	7			6	1
17/03/1998	24	18	2	6	34	1
31/03/1998	39	10		1	22	1
28/05/1998	21	7	3		21	2
18/06/1998	28	8			3	2
8/07/1998	21	7		2	29	
29/07/1998	18	12		1	9	1
13/08/1998	14	6			26	1
10/09/1998	18	8			16	2
29/10/1998	16	16	1	12	39	1
26/11/1998	5	14	2		33	3
30/11/1998	13	11	3	7	31	
30/12/1998	14	11	1	4	52	2
21/01/1999	19	14		1	8	2
15/02/1999	8	38			13	
16/03/1999	14	41			15	1
20/04/1999	21	11			26	1
17/05/1999	11	10		1	28	3
30/06/1999	21	9		1	26	
27/07/1999	5	11		1	8	3
16/08/1999	12	5		1	18	2
12/10/1999	18	10		1	35	1
28/10/1999	10	13	1	2	13	5
25/11/1999	11	2	2	3	31	2
20/12/1999	3	15	4	3	3	5
27/01/2000	10	29			10	4
21/02/2000	7	19	1		17	3
30/03/2000	16	4			17	2
18/04/2000	14	6	1		25	
22/05/2000	11	7			22	5
28/06/2000	9	8	3		25	
26/07/2000	13	12			2	
22/08/2000	13	15			13	1
19/09/2000	26	10	1	3	17	1
24/10/2000	30	12		11	12	1
30/11/2000	4	14	11	1	11	4
19/12/2000	10	7	3	2	28	9
Habitat Totals	**756**	**720**	**67**	**100**	**1071**	**94**
% Habitat	26.92	25.64	2.39	3.56	38.14	3.35

Ngwayir (*Pseudocheirus occidentalis*) sightings along the Kingston spotlight transects.

Date	Jarrah, *E. marginata*	Marri, *E. calophylla*	*Banksia grandis*	*Gastrolobium bilobum*	Terrestrial (ground, logs, etc)	Other
21/11/1995					1	1
22/11/1995	2	1				3
28/11/1995	9	1				1
12/12/1995						
20/02/1996	1	2				2
27/02/1996	5	2				
8/03/1996	5	1				
15/03/1996	2	7			2	
25/03/1996	2	3			1	
22/05/1996		1			2	
28/05/1996		1			1	
29/06/1996	3	2				
30/06/1996						
23/07/1996	1					
5/08/1996	1					
30/09/1996	2	2			1	1
1/10/1996	7	3				
26/10/1996	2	1				
5/11/1996	1	6			1	3
28/11/1996						
4/12/1996	4	3				
30/12/1996		9				1
2/01/1997		3			2	
7/02/1997	5	3	1			2
11/03/1997	5	10	3		3	2
25/03/1997	18	18			2	2
8/04/1997	20	8	1	1		
29/04/1997	24	10	2	1		2
12/06/1997	26	5				1
24/06/1997	14	4		1	1	2
9/07/1997	7	12				
22/07/1997	16	18	1	2	1	1
7/08/1997	6	4			4	3
19/08/1997	13	13			1	3
3/09/1997	12	20		1	1	3
16/09/1997	14	11	1			3
9/12/1997	8	10	5		3	2
23/12/1997	31	18	3		4	2
20/01/1998	27	8			7	3
3/02/1998	12	9		1	4	4
23/02/1998	8	6			3	
17/03/1998	33	20	1		8	3
31/03/1998	44	23	1	2	3	1
28/05/1998	18	7				2
18/06/1998	29	15	1		1	3
8/07/1998	9	4			2	1
29/07/1998	12	9	1			
13/08/1998	15	11	2	1	6	1
10/09/1998	10	11	1			2
29/10/1998	30	18	2	1	4	2
26/11/1998	7	11	2		1	6
30/11/1998	26	19	2	2	2	
30/12/1998	15	13	1	4	2	5
21/01/1999	24	14	1	2		3
15/02/1999	10	18	1		3	3
16/03/1999	20	15				
20/04/1999	17	9				2
17/05/1999	11				1	
30/06/1999	9	7	1			2
27/07/1999	10	12				1
16/08/1999	7					
12/10/1999	12	5	3		2	5
28/10/1999	11	10	1		1	2
25/11/1999	7	7	2		1	4
20/12/1999	8	8	1			
27/01/2000	5	6				
21/02/2000	1	10		1		1
30/03/2000	4	2				
18/04/2000	6	2				
22/05/2000	1	2				
28/06/2000	2	4				
26/07/2000						
22/08/2000	2	3				
19/09/2000	1	1	2			
24/10/2000	6	1				
30/11/2000	1					
19/12/2000	2	1		2		
Habitat Totals	**738**	**533**	**43**	**22**	**82**	**96**
% Habitat	48.75	35.20	2.84	1.45	5.42	6.34