A COMPARISON OF MANAGEMENT STRATEGIES FOR THE WOYLIE (Bettongia penicillata) IN SOUTHERN JARRAH FORESTS

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Abstract: We compared the probability of woylie (*Bettongia penicillata*) population persistence, predicted time to extinction, average population size, and average genetic loss caused by inbreeding among 4 management strategies using a spatially explicit population viability model. In the southern jarrah (*Eucalyptus marginata*) forest, either poisoning of foxes (*Vulpes vulpes*) that caused a 20% increase in survival rates of juvenile woylies, or a 20-year prescribed burn cycle was predicted to result in higher probability of persistence, longer time until extinction, higher average populations, and less genetic loss than a 10-year burn cycle without fox poisoning. Additional improvements in the probability of persistence, population size, and genetic retention were predicted if survival rates of juvenile woylies increased by 40% after fox poisoning, or with a combination of a 20-year burn cycle and fox poisoning that increased survival rates of juvenile woylies by 20%. We recommend that foxes be poisoned in suitable habitat for woylies in the southern jarrah forest to increase the probability of woylie recovery in the region, but that juvenile survival rates be monitored. If juvenile survival rates do not increase by 40% or more after poisoning, then less frequent burning in woylie habitat may be necessary to increase the probability of woylie persistence in the region.

INTRODUCTION

The woylie (*Bettongia penicillata*) or brush-tailed bettong now occupies < 1% of its former range and is considered a threatened species in Western Australia (Hall et al. 1991). It occurs in 4 isolated populations in Western Australia (Hall et al. 1991). A fifth population in the Fitzgerald River National Park has not been confirmed (Hall et al. 1991). The largest occupied block of habitat in Western Australia seems to be in and around the Perup Forest (Hall et al. 1991). This population has persisted despite lack of fox (*Vulpes vulpes*) control primarily because of the occurrence of heartleaf shrubs (*Gastrolobium bilobum* and *Melaleuca viminea*) that contain natural poisons not toxic to woylies but toxic to exotic predators such as foxes (Christensen 1980, King et al. 1981). Woylies seem particularly vulnerable to predation by foxes during the first 3-4 years following a fire, though the young animals are capable of reoccupying burned areas once shrub cover has recovered (Christensen 1980). Populations in the area remain low and isolated, however, so Christensen and Maisey (1987) designed a management strategy for woylies and tammar wallabies (*Macropus eugenii*) that was based on an extended fire frequency and a burn pattern that minimised adjacency between recently burned patches. Additionally, baits have been distributed to poison foxes in various locations elsewhere in the jarrah forest in an effort to increase populations of medium-sized marsupials (G. Friend, pers. commun.).

The relative contribution of fox poisoning and altered fire frequencies to the long-term persistence of woylie populations in the region is not clear. Where foxes have been baited in the presence of woylies, populations seem to have increased dramatically (G. Friend, pers. commun., P. Christensen, pers. obs., Hall et al. 1991: figure 3). Also, woylies have persisted in the Perup Forest, portions of which have been managed on prolonged fire frequencies for the past 15-20 years and, which until recently, had not been baited for foxes (Christensen and Maisey 1987). The woylie recovery plan establishes as goals, control of exotic predators where woylie populations currently occur and establishment of 8 mainland populations consisting of a total of > 5,000 adults (Hall et al. 1991). Preparation and distribution of fox baits to continually maintain low fox populations over large areas is relatively inexpensive ($11,000 per year for woylies in Western Australia, Hall et al. 1991), compared to continuation of the prescribed burning program in the forests of Western Australia (~ $8 million per year). Further, alteration of fire regimes has implications for other resources, including human safety (Christensen and Maisey 1987).

Within the forests of southwestern Western Australia, the conservation objective of the Department of Conservation and Land Management is to "...maintain biological diversity at the genetic, species and ecosystem level in the forest, with special emphasis on the protection and conservation of threatened, rare and uncommon taxa and communities."(Department of Conservation and Land Management 1992). Maintenance of biological diversity by focusing conservation efforts on rare, threatened, and endangered species can be facilitated by use of population viability analyses (PVA, Possingham et al. 1993). Several PVA models also consider the implications for genetic loss caused by inbreeding depression in small populations, a concern raised in the woylie recovery plan (Hall et al. 1991). We used a spatially explicit population viability model (McKelvey et al. 1994) to compare the relative likelihood of woylie population persistence in the southern jarrah (Eucalyptus marginata) forest among 4 management strategies.

METHODS

We adapted a spatially explicit population viability model, originally developed for the North American northern spotted owl (Strix occidentalis caurina, McKelvey et al., 1994), to predict woylie population response to 4 management strategies. Details of the model are provided by McKelvey et al. (1994). Briefly, this model considers each animal's home range as a spatially explicit location over an area encompassing up to 150,000 home ranges (McKelvey et al. 1994). Further, the model allows simulation of population responses on dynamic landscapes, such as those altered by fire and/or logging disturbance and habitat recovery following the disturbance (McKelvey et al. 1994). We focus on the relative gains or losses of persistence, population sizes, and genetic loss from inbreeding after imposing each of 4 management strategies rather than the actual predicted values because of the uncertainty in estimating several demographic parameters.

We followed a 5-step process to predict the responses of woylies to management over the area: 1. map habitat availability over the southern jarrah forest; 2. produce one map for each year during a 10- or 20-year prescribed burn cycle, with corresponding estimates of habitat suitability based on time since the burn; 3. regrid the map into cells that correspond to woylie home ranges (approximately 30 ha, Christensen 1980), 4. estimate the woylie demographic and movement parameters corresponding to each stage in recovery of the post-burn habitat; and 5. predict the probability of extinction, time until extinction, population trends for woylies, and genetic loss over 100 years over the region. Each of these are described in more detail below.

Mapping Available Habitat

The Forest Management Information System (FMIS) Geographic Information System (GIS) was used to map habitat over a 332,200-ha portion FO the southern jarrah forest bounded by the 1000 mm rainfall isohyet in the west, developed agricultural farmland to the east, the karri forests (Eucalyptus diversicolor) to the south, and the Blackwood River to the north. FMIS is a raster-based system with 2-ha pixel size and covers forested areas of the southwest of Western Australia. A range of themes describing administrative, physical and biological characteristics, together with details of completed forest operations are stored in the system.

Woylie use of habitat seems to be associated with the area of bare ground between shrubs (Christensen 1980). Ground cover of 50-80 percent with 20-40 percent bare ground allows woylies free movement through scrub while providing sufficient cover for protection from predators (Christensen 1980). Shrub cover is not a theme available within FMIS, so a correlate with shrub cover was used to map suitable woylie habitat. In the study area, based on personal observations of P. Christensen and F. J. Bradshaw, shrub conditions suitable for use by woylies seemed to be most highly associated with the height class of jarrah and wandoo (Eucalyptus wandoo) forest, dependent on rainfall zone. Shrub density is generally too high for woylies to move freely in areas with rainfall > 1000 mm, so these areas were considered unsuitable habitat. Where rainfall is 900-1000 mm, suitable habitat was considered jarrah and wandoo stands that averaged 15 - 24 m tall because they generally provided adequate shrub cover; taller and shorter stands supported shrub cover that was too dense. The exception to this rule is that stands with a total tree cover of < 10% also were considered unsuitable habitat, again because of the associated understorey characteristics. In southern jarrah forest areas receiving < 900 mm of rainfall, jarrah and wandoo stands averaging < 30 m in height were considered suitable habitat, except those stands with < 10% total tree cover which were considered unsuitable. We visually checked 12 stands throughout the region to assess this association and these rules seemed to reasonably estimate habitat suitable for woylies.

Mapping Burn Cycles

Survival rates of woylies are effected by burning, with survival and reproduction stabilising once stands have recovered > 4 years following a burn (Christensen 1980). Consequently it was necessary to impose a fire mosaic over the suitable habitat on the map for each year of a burn cycle. Nearly all patches are prescribed burned in the region for protection from wildfires. Based on burn records and burning themes in FMIS, and consultation with the Fire Protection Branch, CALM, most stands in the southern jarrah forest are currently burned on a 10-year cycle and that cycle is likely to persist into the future. Using burn records, we assigned each stand in the region a time of burning based on the timing of burns that occurred in the past 10 years. Consequently 10 maps of the area were produced, one for each year in the burn cycle reflecting the disturbances caused by burning and the stage of recovery (<1, 1-2, 2-3, 3-4, or > 4 years after the burn) (e.g., figure 1). These maps were cycled 10 times for each 100-year simulation of woylie population change based on a 10-year burn cycle. Similar maps were used to test effects of a 20-year burn cycle.

Regridding Habitat Maps

The average home range size for woylies in the Perup Forest is about 30 ha (Christensen 1980). Consequently, habitat maps were regridded to 30-ha cells by assigning the cell to a stage in habitat recovery following a burn based on the stage present at the centre of the 30-ha grid cell. Such regridding has the potential to alter the habitat mosaic (Schulz and Joyce 1992), so we compared the area in each stage of recovery following fire between original maps and regridded maps using a paired _t_-test to determine if the average difference between maps over a burn cycle departed significantly from zero. Pattern of all original and regridded maps also was inspected visually to identify any gross errors made during regridding.

Estimates of Demographic and Movement Parameters

Estimates of the mean movement, and mean and variance of reproductive and survival rates in each of 5 woylie age classes in each of the post-burn recovery stages were made by P. Christensen based on past work (Christensen 1980), unpublished data, and experience (Table 1). Reproductive rate information was confirmed by G. Friend (CALM) who has worked with woylies in the Battaling population and recently in the southern forest region.

The estimates in table 1 were used to predict persistence, population trends, extinction time, and genetic loss in the absence of fox baiting and with a 10-year burn cycle. The same demographic and movement parameters were used with simulations of a 20-year burn cycle. Because P. Christensen and G. Friend (pers. commun., CALM) suggested that foxes probably have the greatest impact on juvenile survival rates, we assumed that fox baiting could decrease mortality in this age class and hence increase survival rates by 20-40% over those estimated by Christensen (1980). Because we did not know what the actual increase in survival rates of juveniles might be following fox baiting, we modelled 2 rates of increase in survival following fox baiting that encompassed this range (20% and 40% increase in juvenile survival) resulting in 5 scenarios for the 4 management strategies: 1. no fox baiting and a 10-year burn cycle; 2. fox baiting and a 10-year burn cycle [2 scenarios], 3. no fox baiting and a 20-year burn cycle, and 4. a combination of fox baiting [20% increase in juvenile survival] and a 20-year burn cycle. Estimated increases in juvenile survival following baiting were based on observations of population increases following baiting near the Battaling population (G. Friend, pers. commun.) and recently near the Perup Forest (N. Burrows, Pers. commun.). In addition, Hall et al. (1991) cited work conducted by J. Kinnear that resulted in a 9-fold increase in woylie capture rates 5 years after poisoning of exotic predators on the Tutanning Nature Reserve. We considered a 20-40% increase in survival rates of one age class likely to encompass the effects of fox baiting.

Simulating Population Responses

Each of the 4 management strategies was simulated 100 times for 100 years. To initiate each simulation, 510 adults were distributed on the map among 3 areas known to support woylies: the Perup Forest, a patch north of the Perup forest, and the Kingston block northwest of the Perup Forest. Based on recent trapping records (CALM, unpubl. data) this distribution and number of individuals simulated seemed reasonable. The number of juveniles predicted to be produced by these adults during the first year of the simulation did not differ among the 5 scenarios ($\underline{x}$ = 308; SE = 9.6; $\underline{F}$ = 1.31; 4,359 df; $\underline{P}$ = 0.27).

Five response variables were used to assess the relative value of each treatment toward recovery of woylie populations in the region: 1. the probability of extinction during 100 years, 2. the predicted time until extinction (based on the $\underline{x}$ intercept using a linear regression of populations over time), 3. the probability of the adult population achieving the recovery plan goal of > 5,000 adults, 4. average total populations over the region, and 5. the average percent genetic loss as a function of inbreeding. Analysis of variance was used to compare total populations over the region and average percent genetic loss among the 5 scenarios. Scheffe's multiple means comparison tests were used to identify differences in mean population sizes and percent genetic loss between all possible pairs of scenarios. Chi-square goodness-of-fit tests were used to determine if percent extinctions predicted in each management strategy differed from the percent predicted for the 10-year burn cycle with no fox baiting, the strategy used as the basis for expected values.

RESULTS

Approximately 139,800 ha of the 339,200-ha area represented potential woylie habitat in some stage of recovery following a burn. The area of habitat available in each stage of recovery since a burn varied over each burn cycle. Regridding did not significantly ($\underline{n}$ = 10, $\underline{P}$ > 0.32) change the area represented in each stage of recovery following burning. On average, regridding overestimated habitat area in areas burned < 3 years by 91 ha (SE = 96), overestimated areas burned 3-4 years by 73 ha (SE = 97) and underestimated areas burned > 4 years by 140 ha (SE = 134). Overestimates of habitat which have lower survival probabilities for the reproductively active portion of the population should have resulted in conservative estimates of persistence of the population.

Relative improvement in all response variables was greater with either baiting (20% increase in juvenile survival) or prolonged burning (table 2). Relative improvement was further increased by a baiting program that increased juvenile survival by 40%, or a combined baiting (20% increase in juvenile survival) and prolonged burning approach (table 2). We predicted that given the current management strategy for the region, in the absence of continued fox baiting, woylies would become extinct in the region in 94 years (table 2). During the 100-year simulation period, only 29% of the simulated populations persisted for 100 years (table 2) and populations were predicted to remain low throughout the 100 years (figure 2). The model predicted that either a decrease in the frequency of burning to once each 20 years (figure 3) or fox baiting that would increase juvenile survival rates by 20% (figure 4), would result in an increase of the probability of persistence from 29% to 43 and 55%, respectively. Either a 20-year burn cycle or baiting increased the predicted time to extinction to > 100 years, and average populations in the area were predicted to more than double (table 2). In 6% of the simulations, populations were predicted to exceed the population recovery goal of 5,000 adults. However, if baiting resulted in increasing the survival of juvenile woylies by 40%, then further increases in population persistence and average populations were predicted (table 2, figure 5). Predicted responses were similar between baiting that increased juvenile survival by 40% and a combined strategy of a prolonged burn cycle and baiting that increased juvenile survival by only 20% (table 2, figures 5 and 6). Of these, based on predicted probability of persistence and the probability of exceeding the 5,000-adult goal of the recovery plan, a fox baiting effort that increases juvenile survival by 40% or more would seem most effective.

DISCUSSION

The results of this exercise provide an example of use of an approach to developing a management and monitoring strategy for woylie recovery in the southern jarrah forest, as well as for identifying several avenues of research and additional inventory needs. Clearly, the effects of fox baiting on juvenile survival rates should be monitored to determine if our estimate of a 20-40% increase in juvenile survival following fox baiting is correct. If survival rates are increased by > 40% then alteration of burning regimes seems unnecessary. Secondly, monitoring of populations in areas identified as potential woylie habitat in the region following adoption of a woylie habitat management strategy for the southern jarrah forest would provide estimates of rates of dispersal of woylies into currently unoccupied habitat. Current estimates of dispersal rates and movement probabilities are based on few data (table 1).

We used height class of trees as a surrogate for shrub cover. An FMIS theme of shrub types, percent cover, and a model of shrub dynamics following fire would have provided more precise estimates of habitat availability for woylies. Opportunities for inventory foresters to include shrub species and cover during ground inventory operations in combination with use of a shrub dynamics model would allow wide-scale prediction of shrub cover. Also, we assumed that shrub conditions were consistently poor immediately after a burn and that the rate of recovery of habitat quality was consistent among all sites. Fire intensity and resulting patchiness of post-burn shrubs needs to be more carefully considered during mapping.

Despite the uncertainty associated with survival probabilities in the absence of exotic predators, with movement parameters (table 1), with actual changes in survival following baiting, and with the actual association between tree height classes and shrub cover, the simulations represent use of the best information available to predict woylie responses to habitat change and to poisoning of exotic predators over time. Once new information becomes available from inventory foresters and/or research results, these simulations can be easily rerun to more precisely estimate woylie responses to management strategies. In the meantime, relative gains resulting from proposed management strategies can be assessed using our approach. Until new simulations can be made with improved information, we suggest that fox baiting should be focused on habitat areas likely to be occupied by woylies (fig. 1) and juvenile survival rates should be monitored. If juvenile survival rates do not increase by 40% or more, then fire frequency in habitat patches likely to be occupied by woylies in the southern jarrah forest should be prolonged up to 20 years, where compatible with human safety considerations.

Expansion of populations into currently unoccupied habitat could be accelerated over what we simulated if animals were relocated into these patches following fox baiting and/or alteration of burning regimes. Over $30,000 per year is expected to be spent in Western Australia in woylie relocation attempts (Hall et al. 1991). We recommend that suitable habitat be mapped using a GIS to identify high priority relocation sites, followed by PVA modelling to estimate appropriate founder population sizes, thereby increasing the probability of relocation success.

Based on our simulations, it seems likely that woylie populations in the southern jarrah forest could be recovered following control of exotic predators perhaps in combination with prolonged burning cycles in some areas. However, populations should be monitored to determine if our simulations represent reasonable approximations of woylie responses to these management strategies. Over $12,000 per year is expected to be spent in monitoring woylie populations in Western Australia (Hall et al. 1991). This monitoring should include collection of information on survival and movement rates to further refine future PVA simulations to better predict when recovery will be achieved.

Scope and Limitations of the Study

The results of this study are based on the population characteristics and habitat patterns that have occurred and are likely to occur in the future in the southern jarrah forest. Populations in other areas, especially with different habitat mosaics and disturbance frequencies, intensities, sizes, and patterns may produce very different results. The approach that we have taken could be used in these other areas. The accuracy of the simulations are constrained by a number of assumptions and estimates for population demographics, movement patterns, and habitat dynamics. Research is needed to estimate habitat-specific survival and movement rates, and shrub dynamics. However, because we used the only available information for the southern jarrah forest, we feel that the relative differences in response variables should provide reasonable indications of appropriate management strategies.

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Table 1. Demographic and movement parameters used to model woylie population persistence based on a 10-year burn cycle without fox baiting and with fox baiting (x 120% and 140%), southern jarrah forest, Western Australia.

Parameter Age class	Unsuitable	Burn < 1 year ago	Burn 1-2 years ago	Burn 2-3 years ago	Burn 3-4 years ago	Burn > 4 years ago	Reference
Survival probabilities							
< 1 year	0.05 (0.00)[1]	0.40 (0.01)	0.35 (0.01)	0.30 (0.01)	0.30 (0.01)	0.25 (0.01)	Christensen (1980)
< 1 year (x 120%)	0.05(0.00)	0.48(0.01)	0.42(0.01)	0.36(0.01)	0.36(0.01)	0.30(0.01)	
< 1 year (x 140%)	0.05(0.00)	0.56(0.01)	0.49(0.01)	0.42(0.01)	0.35(0.01)		
1 - 5 years	0.05 (0.00)	0.25 (0.01)	0.40 (0.01)	0.50 (0.01)	0.60 (0.01)	0.75 (0.01)	Christensen (1980)
Reproduction probabilities							
< 1 year	0.00 (0.00)	0.50 (0.02)	0.50 (0.02)	0.50 (0.02)	0.50 (0.02)	0.50 (0.02)	Christensen (1980)
1 - 5 years	0.00 (0.00)	0.95 (0.01)	0.95 (0.01)	0.95 (0.01)	0.95 (0.01)	0.95 (0.01)	Christensen (1980)
Young/female/year	----	3.00	3.00	3.00	3.00	3.00	Christensen (1980)
Proportion of male young	----	0.58	0.58	0.58	0.58	0.58	Christensen (1980)
Probability of attempting reproduce	0.00	1.00	1.00	1.00	1.00	1.00	Christensen (1980)
Probability of a female breeding with an adjacent male	0.00	0.99	0.99	0.99	0.99	0.99	Christensen (1980)

Table 1. Continued.

Parameter	Unsuitable	Burn < 1 year ago	Burn 1-2 years ago	Burn 2-3 years ago	Burn 3-4 years ago	Burn > 4 years ago	Reference
Probability of settling	0.01	0.15	0.35	0.55	0.75	0.95	Christensen (pers. obs.)
Probability of continuing dispersal	0.90	0.50	0.40	0.30	0.20	0.10	Christensen (pers. obs.)
Probability of crossing an occupied home range	0.50	0.50	0.50	0.50	0.50	0.50	default value
Number of home range diameters moved per year	10	10	10	10	10	10	Christensen (pers. obs.)

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[1] Variances indicated parenthetically.

Table 2. Predicted population persistence and population sizes for woylies in the southern jarrah forest, Western Australia, based on 100 simulations for each scenario.

Response variable	10-year burn cycle, no fox baiting	20-year burn cycle, no fox baiting	10-year burn cycle, foxes baited (20%)[1]	10-year burn cycle, foxes baited (40%)[1]	20-year burn cycle, foxes baited (20%)[1]
Persistence (%)	29	43[2]	55[3]	96[4]	80[5]
Population > 5000 adults (%)	0	6	6	71	41
Time to extinction (years)	95	116	114	---[6]	---[6]
Average population size	291(5.3)C[7]	651(9.6)B	657(9.7)B	1247(27)A	1248(19)A
Genetic loss (%)	58.8(0.4)A	46.8(0.4)B	46.4(0.4)B	37.9(0.4)C	37.1(0.4)C

[1] Percent increase in juvenile survival that was simulated.

[2] Differs from 10-year burn cycle, no fox baiting, chi-square = 8.9, *P* = 0.0

[3] Differs from 10-year burn cycle, no fox baiting, chi-square = 31.6, *P* = 0.0

[4] Differs from 10-year burn cycle, no fox baiting, chi-square = 214.8, *P* = 0.0 ; differs from 20-year burn cycle, no fox baiting, chi-square = 112.5, *P* = 0.0 ; differs from 10-year burn cycle with fox baiting (20% increase in juvenile survival), chi-square = 66.3, *P* =

0.0 .

[5] Differs from 10-year burn cycle, no fox baiting, chi-square = 123.9, $P = 0.0$; differs from 20-year burn cycle, no fox baiting, chi-square = 54.4, $P = 0.0$; differs from 10-year burn cycle with fox baiting (20% increase in juvenile survival), chi-square = , $P = 0.0$; differs from 10-year burn cycle with fox baiting (40% increase in juvenile survival), chi-square = 15.0, $P = 0.0$.

[6] **Positive slope so no positive x intercept is predicted.**

[7] Standard error given parenthetically. Means with different letters differ, $P \leq 0.05$, Scheffe's multiple means comparison test.

Figure 1. An example of the habitat patch mosaic on a portion of the 339,200-ha area used to simulate woylie population responses to 4 management strategies in the southern jarrah forest. Each 100-year simulation consisted of 10 maps cycled 10 times, or 20 maps cycled 5 times, depending on the burn cycle.

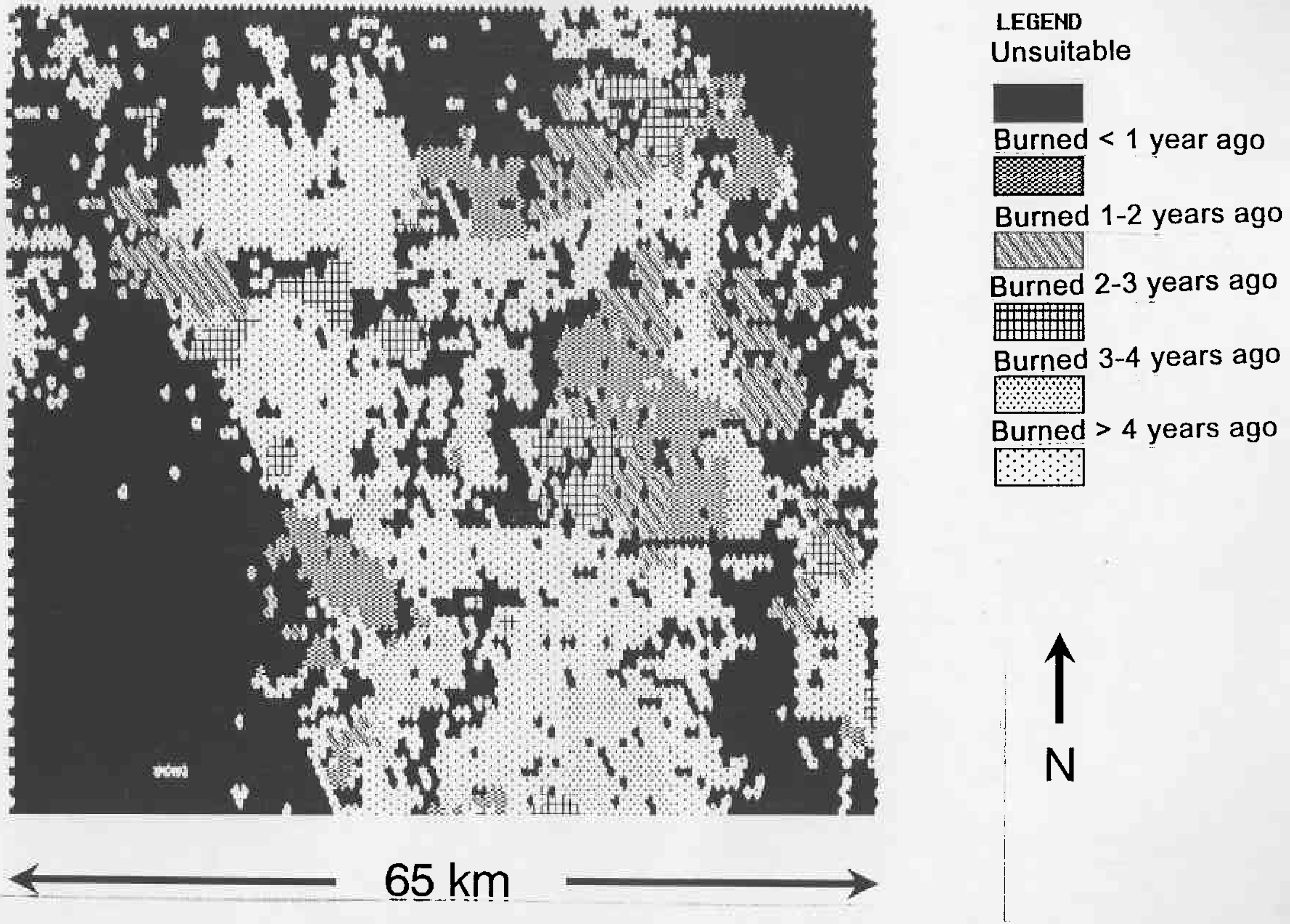
Figure 2. Predicted responses of populations of woylies in the southern forest region based on a 10-year burn cycle and no fox baiting.

Figure 3. Predicted responses of populations of woylies in the southern forest region based on a 20-year burn cycle and no fox baiting.

Figure 4. Predicted responses of populations of woylies in the southern forest region based on a 10-year burn cycle with fox baiting (20% increase in juvenile survival).

Figure 5. Predicted responses of populations of woylies in the southern forest region based on a 10-year burn cycle with fox baiting (40% increase in juvenile survival).

Figure 6. Predicted responses of populations of woylies in the southern forest region based on a 20-year burn cycle with fox baiting (20% increase in juvenile survival).


LEGEND
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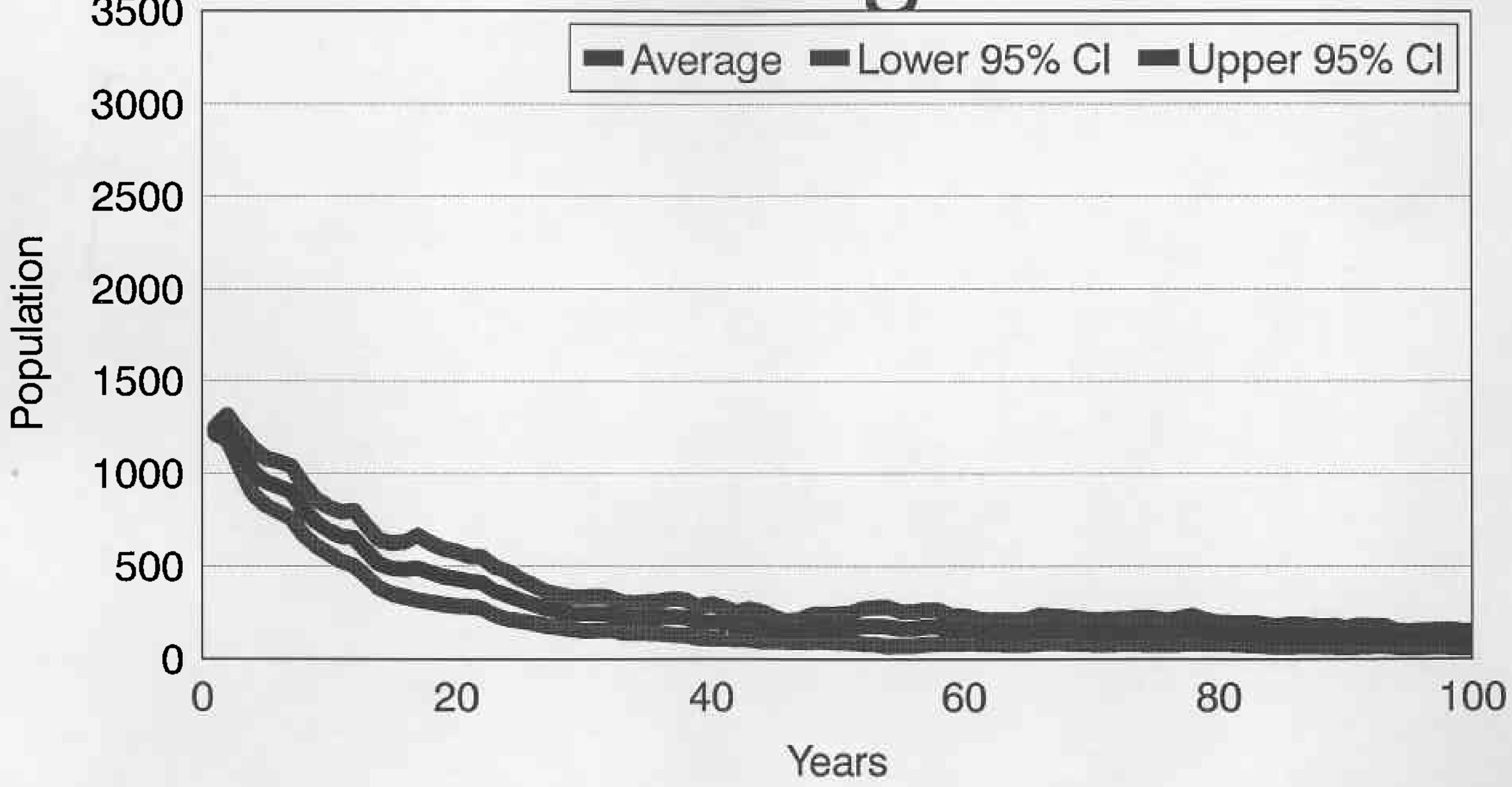
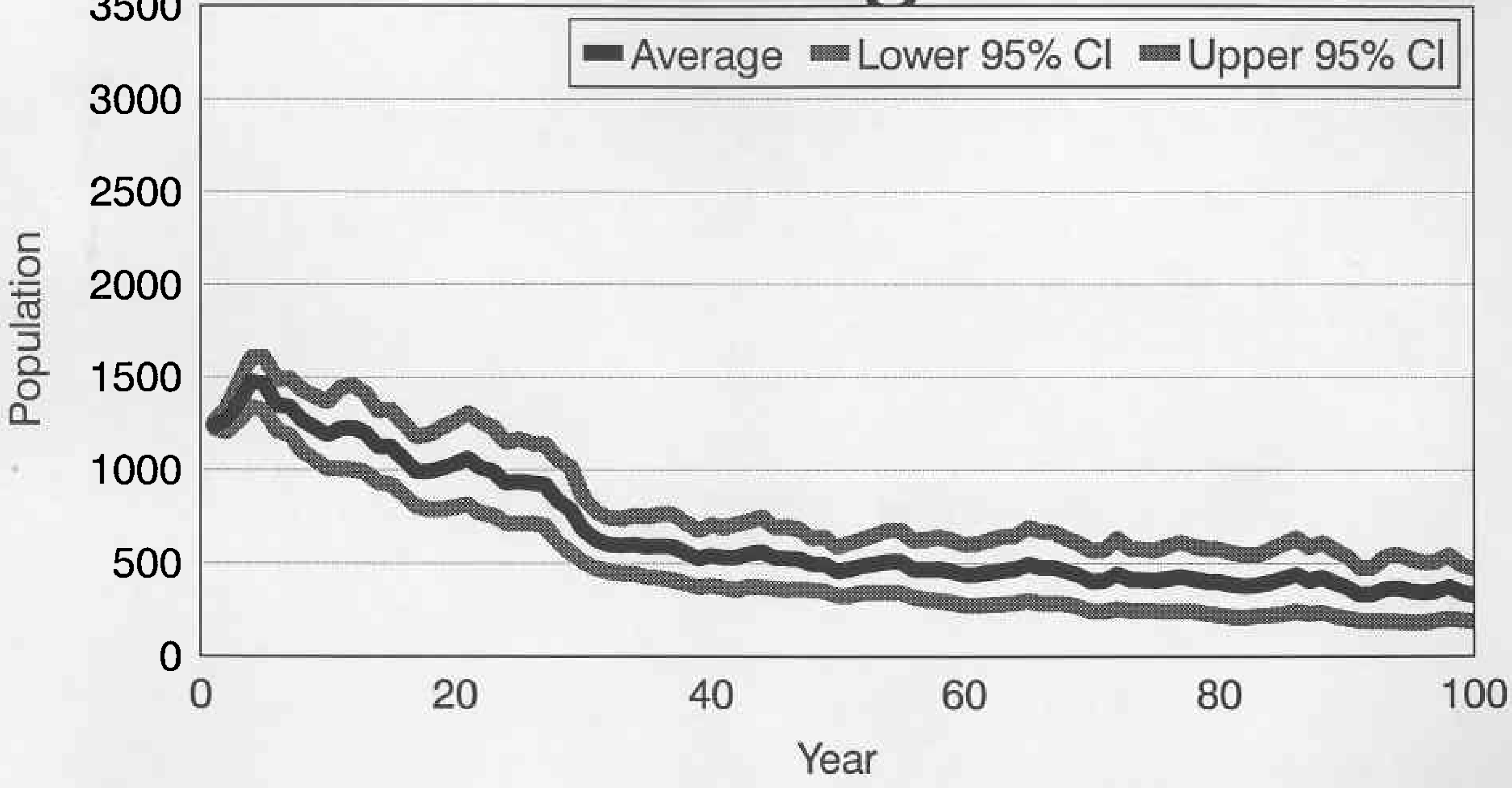
10-year fire cycle and no fox baiting

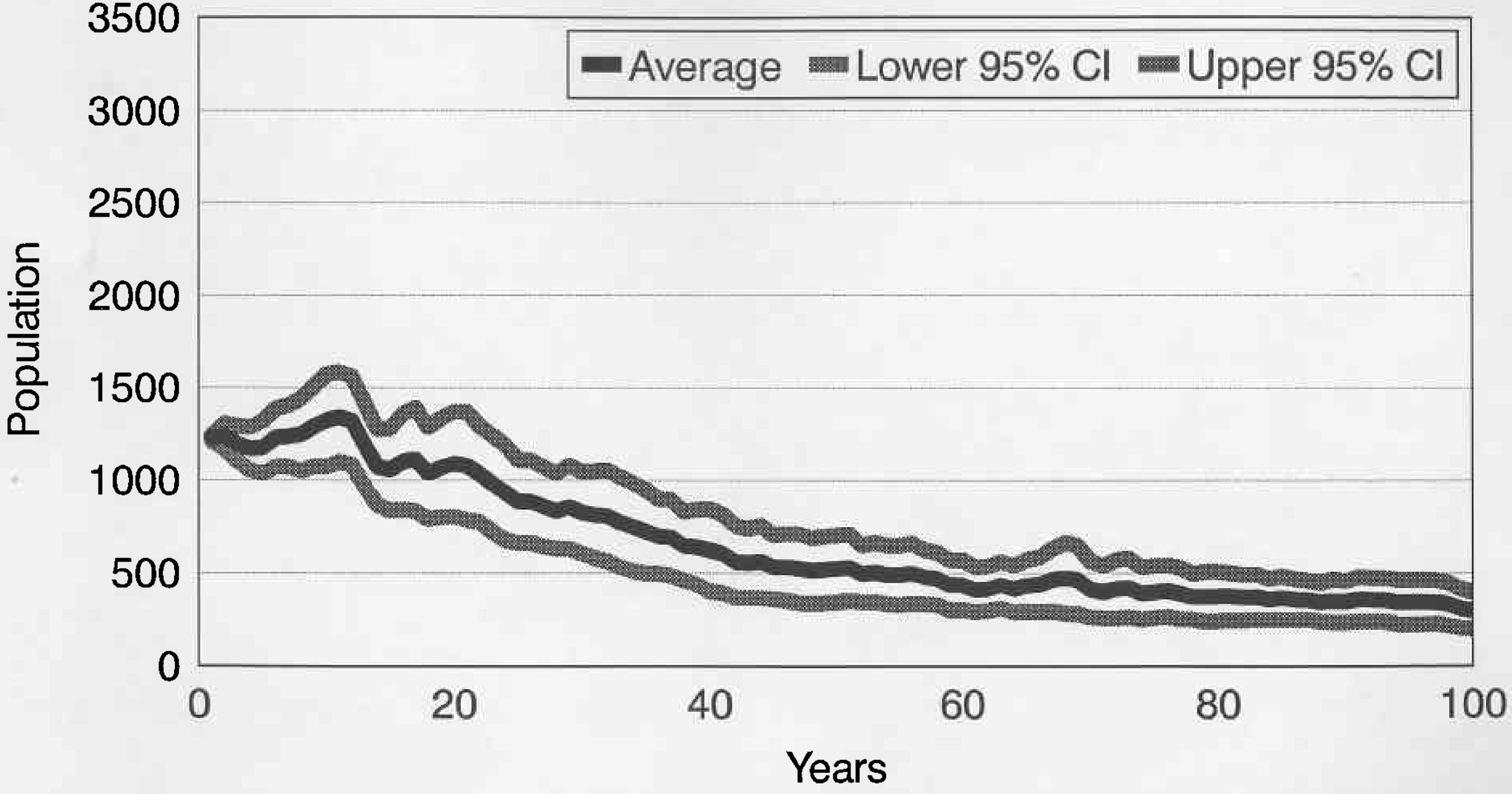


20-year fire cycle and no fox baiting



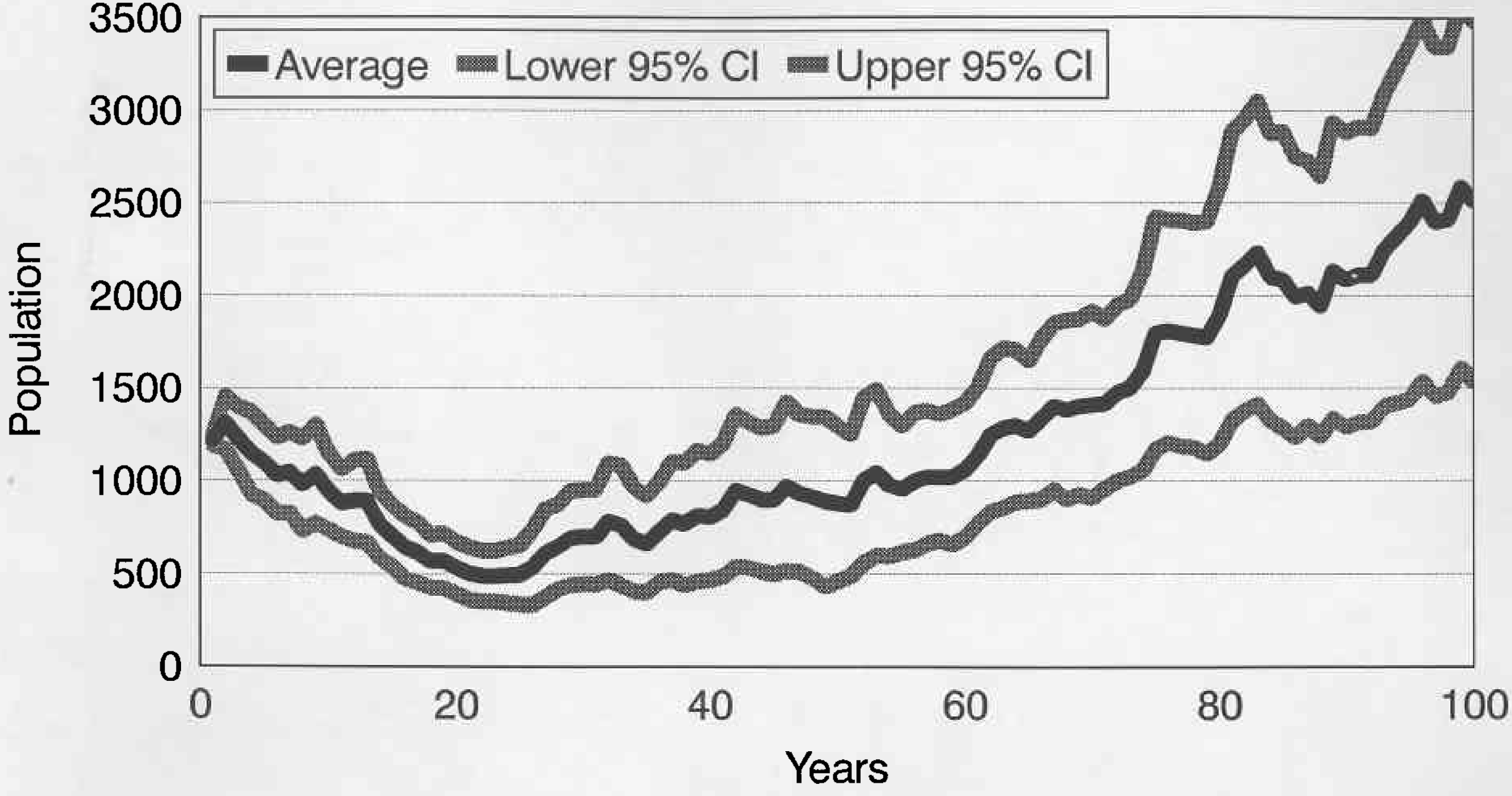
10-year fire cycle with fox baiting

(20% increase in juvenile survival)



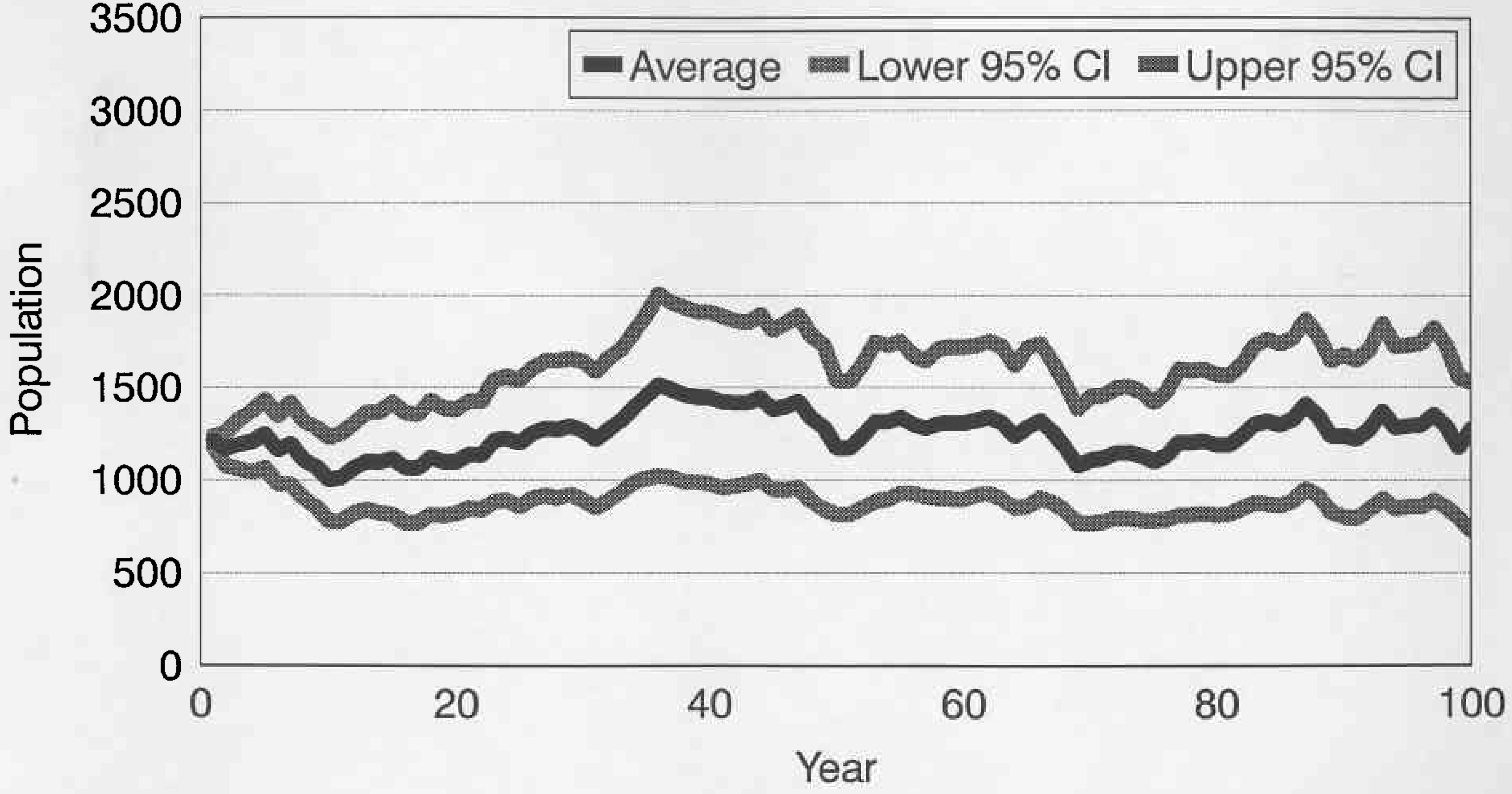
10-year fire cycle with fox baiting

(40% increase in juvenile survival)



20-year fire cycle with fox baiting

(20% increase in juvenile survival)



Contents of the OWLW.ZIP file

To use this program, copy OWLW.ZIP and PKUNZIP.EXE to a sub directory on your hard disk. From the DOS prompt in that sub directory (e.g., C:/OWLW>) type : PKUNZIP OWLW.ZIP. Pkunzip will extract the following files and place them on your hard disk in your sub directory:

BINDER.EXE -- Binds maps in a specified sequence for dynamic landscapes
CLASS.EXE -- establishes the look of maps to reflect patches of various habitat quality
GIS.EXE -- GIS interface
INCBETA.EXE -- population dynamics program
LAMBDA.EXE -- calculates lambda
MAP.EXE -- create/alter a map file
OWL.EXE -- adds/deletes animals from patches on the map
RULES.EXE -- create/alter survival, reproduction, movements, and time series parameters
SIM.EXE -- simulates population responses to landscapes
EGAVGA.BGI -- graphic interface
HERC.BGI -- graphic interface
SICORID.SIM -- ignore this one -- delete it.
WOYTEST.RUL -- rule file used for a single simulation for 5 years -- a demonstration rule set.
WOYFIRE.RUL -- rule file used as a baseline woylie response to landscapes
WOYBAIT.RUL -- rule file used to simulate woylie responses after fox baiting.
WOYLONG.RUL -- rule file used to simulate woylie responses under 20-year burn cycles.
BAITLONG.RUL -- rule file used to simulate woylie responses to baiting and long burn cycles.
WOYFIRE.BND -- bound maps to reflect a 10-year burn cycle.
WOYLONG.BND -- bound maps to reflect a 20-year burn cycle.
WOYFIRE.SIM -- initial simulation file for all simulations -- contains woylies in patches at time 0.
CLASS.DEF -- definitions of patch types and shading/colours. These can be changed easily.
0.MAP -- map of woylie habitat conditions at time 0, from FMIS.
1.MAP -- map of woylie habitat conditions at time 1, from FMIS.
2.MAP-- map of woylie habitat conditions at time 2, from FMIS.
3.MAP -- map of woylie habitat conditions at time 3, from FMIS.
4.MAP -- map of woylie habitat conditions at time 4, from FMIS.
5.MAP -- map of woylie habitat conditions at time 5, from FMIS.
6.MAP -- map of woylie habitat conditions at time 6, from FMIS.
7.MAP -- map of woylie habitat conditions at time 7, from FMIS.
8.MAP -- map of woylie habitat conditions at time 8, from FMIS.
9.MAP -- map of woylie habitat conditions at time 9, from FMIS.

Using the OWL program.

First, read the enclosed hard copy, "An introduction to the Landscape Model". To use the woylie files, here are a few tips. First, all rules files, except WOYTEST.RUL, are set to run 20 simulations, if you just want to run one simulation, use WOYTEST.RUL (see below).

Type: OWL <enter> to access the model. To run a simulation, select "Simulate" from the menu, and type in the file names requested. The firs will be WOYFIRE.SIM, the second will be WOYTEST.RUL (or a new rules file that you created), If you want to use dynamic landscapes, select "Y", and enter WOYFIRE.BND, then provide the name of an output file (if asked -- only asked when you request > 1 simulation). If you request only 1 simulation, it will ask you if you want graphics displayed. Select yes, then use the F2 key to zoom in on a part of the map if you wish. Again, refer to the hard copy guidelines for more detail about analysing output files, binding maps into dynamic landscapes, changing the look of the map. etc. When running many simulations, save each to an output file for later editing and concatenation into a master file for analysis in SAS. Should the program abort because of "Too Many Owls" (approximately 6,000), the output file will be created for all previous simulations (for instance if the program aborts on the 19th of the requested 20 simulations, the output for the first 19 will still be created). Save these output files as well. On large landscapes with the potential for many animals to accumulate, aborted runs because of too many animals are likely, but these runs can be informative as well.

Contents of WOYDAT.ZIP

ALLLONG.DAT -- 100 simulations of woylie population dynamics to a 20-year burn cycle without fox baiting.
ALLBAIT.DAT-- 100 simulations of woylie population dynamics to a 10-year burn cycle with fox baiting with a 20% increase in juveile survival..
ALLBASE.DAT-- 100 simulations of woylie population dynamics to a 10-year burn cycle without fox baiting.
ALLBOTH.DAT-- 100 simulations of woylie population dynamics to a 20-year burn cycle with fox baiting.
ALLB40.DAT -- 100 simulations of woylie population dynamics to a 10-year burn cycle with fox baiting with a 40% increase in juveile survival..
BAITTIME.DAT -- A subset of ALLBAIT.DAT listing year that the population went extinct for each simulation.
BASETIME.DAT -- A subset of ALLBASE.DAT listing year that the population went extinct for each simulation.
BOTHTIME.DAT -- A subset of ALLBOTH.DAT listing year that the population went extinct for each simulation.
LONGTIME.DAT -- A subset of ALLLONG.DAT listing year that the population went extinct for each simulation.
B40TIME.DAT -- A subset of ALLB40.DAT listing year that the population went extinct for each simulation.

Contents of WOYANA.ZIP

PVA.SSD -- Combined data from all 5 files above (ALL*.DAT) and saved as an SAS data set using WOYSSD.PRO
WOYSSD.PRO -- creates the SAS data set PVA.SSD
BAITPLOT.ASC -- average populations per year for plotting based on ALLBAIT.DAT.
BASEPLOT.ASC -- average populations per year for plotting based on ALLBASE.DAT.
LONGPLOT.ASC -- average populations per year for plotting based on ALLLONG.DAT.
BOTHPLOT.ASC -- average populations per year for plotting based on ALLBOTH.DAT.
B40PLOT.ASC -- average populations per year for plotting based on ALLB40.DAT.
TIME.SSD -- a concatenation of the *TIME.DAT data sets created by TIMESSD.PRO.
TIMESSD.PRO -- creates TIME.SSD
BURN1.DAT -- Area in habitat class 1 (< 1 year burned) for each year in the burn cycle (from FMIS).
BURN12.DAT -- Area in habitat class 2 (1-2 years since burned) for each year in the burn cycle (from FMIS).
BURN23.DAT -- Area in habitat class 3 (2-3 years since burned) for each year in the burn cycle (from FMIS).
BURN34.DAT -- Area in habitat class 4 (3-4 years since burned) for each year in the burn cycle (from FMIS).
BURN4.DAT -- Area in habitat class 5 (>4 years since burned) for each year in the burn cycle (from FMIS).
BURNAREA.PRN -- Area in each year of burn cycle for each habitat type at 2-ha pixel size and at 30-ha pixel size.
BURNAREA.PRO -- Compares estimates of areas based on different pixel sizes using a paired t-test for each habitat class type.
BURNTIME.PRO -- prints burn area by time step and habitat type for plotting.
EXTTIME.PRO -- Compares mean extinction time among the 4 management approaches using ANOVA.
PLOTBASE.PRO -- plots average populations over time for 10-year burn cycle and no fox baiting scenario.

TIMEPLOT.PRO -- Plots average populations over time for each scenario.
PVA.PRO -- compares average populations at 100 years among scenarios.
WOYREP.DOC -- MS WORD document containing an draft of the study.
WOYPOP.PRS -- Harvard Graphics for Windows file for figures.

Data definitions for PVA.SSD

trt -- The management strategy code.
yr -- year in the simulation.
c1 -- predicted number of individuals in year class 0-1.
c2 -- predicted number of individuals in year class 1-2.
c3 -- predicted number of individuals in year class 2-3.
c4 -- predicted number of individuals in year class 3-4.
c5 -- predicted number of individuals in year class 4-5.
p -- predicted number of reproductively active females.
tot -- total number of individuals.
gen -- rate of genetic loss.

Data definitions for ALL*.DAT

yr -- year in the simulation.
c1 -- predicted number of individuals in year class 0-1.
c2 -- predicted number of individuals in year class 1-2.
c3 -- predicted number of individuals in year class 2-3.
c4 -- predicted number of individuals in year class 3-4.
c5 -- predicted number of individuals in year class 4-5.
p -- predicted number of reproductively active females.
tot -- total number of individuals.
gen -- rate of genetic loss.

Data definitions for *TIME.DAT

yr -- year in the simulation that the population went extinct or the simulation ended.
c1 -- predicted number of individuals in year class 0-1 at the end of the simulation.
c2 -- predicted number of individuals in year class 1-2 at the end of the simulation.
c3 -- predicted number of individuals in year class 2-3 at the end of the simulation.
c4 -- predicted number of individuals in year class 3-4 at the end of the simulation.
c5 -- predicted number of individuals in year class 4-5 at the end of the simulation.
p -- predicted number of reproductively active females at the end of the simulation.
tot -- total number of individuals at the end of the simulation.
gen -- rate of genetic loss at the end of the simulation.

Data defintions for TIME.SSD

trt -- The management strategy code.
yr -- year in the simulation that the population went extinct or the simulation ended.
c1 -- predicted number of individuals in year class 0-1 at the end of the simulation.
c2 -- predicted number of individuals in year class 1-2 at the end of the simulation.
c3 -- predicted number of individuals in year class 2-3 at the end of the simulation.
c4 -- predicted number of individuals in year class 3-4 at the end of the simulation.
c5 -- predicted number of individuals in year class 4-5 at the end of the simulation.
p -- predicted number of reproductively active females at the end of the simulation.
tot -- total number of individuals at the end of the simulation.
gen -- rate of genetic loss at the end of the simulation.

Data definitions for BURNAREA.PRN

yr -- the year representing the burn pattern contained in the map (1984-1993).
hab -- the habitat patch type code (time since burning, < 1 = 32, 1-2 = 48, 2-3 = 64 , 3-4 = 80, > 4 = 96, unsuitable = 16).
orig -- the original area estimate for the habitat patch type based on 2-ha pixels.
regrid --- the estimate of area for the habitat patch type regridded to 30-ha pizels.
pct -- the percent difference between orig and regrid.
diff -- the difference in ha between orig and regrid.

Data definitions for *PLOT.ASC

yr -- the year in the simulation.
avpop -- teh average estimated popualtion after 100 simulations for that year.
lci -- the lower 95% CI after 100 simulations for that year.
uci -- th eupper 95% CI after 100 simulations for that year.

Transposing FMIS ASCII data into a *.MAP file for use with the OWL model.

FMIS pixels can be regridded into new sizes. These sizes should match as closely as possible the home range size of the species of interest. The best way to obtain these data from FMIS is from a regrid area that uses only one block. If cell information is obtained by block, then some resorting will be necessary to arrange the data in the correct order for the OWL program. When requesting regridded information, request that pixels be assigned a code that matches one of the 6 codes used to identify habitat patch types by the OWL program (e.g., 16, 32, 48, 64, 80, or 96). You can then assign the appropriate habitat patch type to each code using the CLASS option within OWL. When you receive the ASCII file from FMIS, you will need to delete the last series of columns that do not describe pixel information (they describe block information). I found it easiest to read the ascii file into LOTUS 1-2-3, parse the data, resort the data to be sure that the first row of numbers represents the first row of pixels in the owl map, second represents the second row, etc., delete the last few columns that have nothing to do with pixel information, then export the file as an ascii file (*.PRN file). Once you have this, simply add the following two lines to the top of the file in a text editor:

-9999
120 120 (or whatever your matrix size is -- in this case 120 pixels by 120 pixels)

Specifically:

1. regrid the FMIS map to the appropriate home range size and save as an ASCII file.

2. Delete the first line of the ASCII file containing non-pixel information.

3. Import into LOTUS 1-2-3 as a text file. Parse the data so each cell represents a code for a pixel.

4. Add a column to the worksheet that indicates the position of each block in a row of blocks from left to right.

5. Sort entire data set by block number (ascending and row number (descending).

6. Sort each ROW of blocks by line number (descending) and block number (ascending).

7. Add any codes as lines of columns to result in a square map)e.g., if you need more map at the bottom, add rows of codes at the bottom of the worksheet to accomplish this).

8. Extract the columns containing the pixel codes to a text file.

9. In a text editor, search and replace FMIS codes with codes used by OWL (16, 32, 48, 64, 80 or 96). Be careful which order you do this in so that you do not replace codes that you've just assigned.

10. Add -9999 to the first line

11. Enter the size of the matrix on the second line, be sure that it is square.

12. Save as a *.map file.

13. Read into OWL using the MAP option to see if the pattern is correct.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

To: Dr Bill McComb
Science and Information, Como

From: *Forest Management Branch.*

Our Ref: WP.11.7

Enquiries: *F.J.Bradshaw* **Phone:** *(097) 711988* **Fax:** *(097) 712855*

Subject: **WOYLIE TRAPPING IN CLEARFELLED JARRAH FOREST**

Attached is some data showing Woylie trappings in clearfelled jarrah coupes. The area was part of a paired catchment study cut in 1984. It was virtually clearfelled with only a few remaining small crop trees. Culling occurred after the cut and it was burnt (I'm not sure of the date but probably 1985 or 1986).

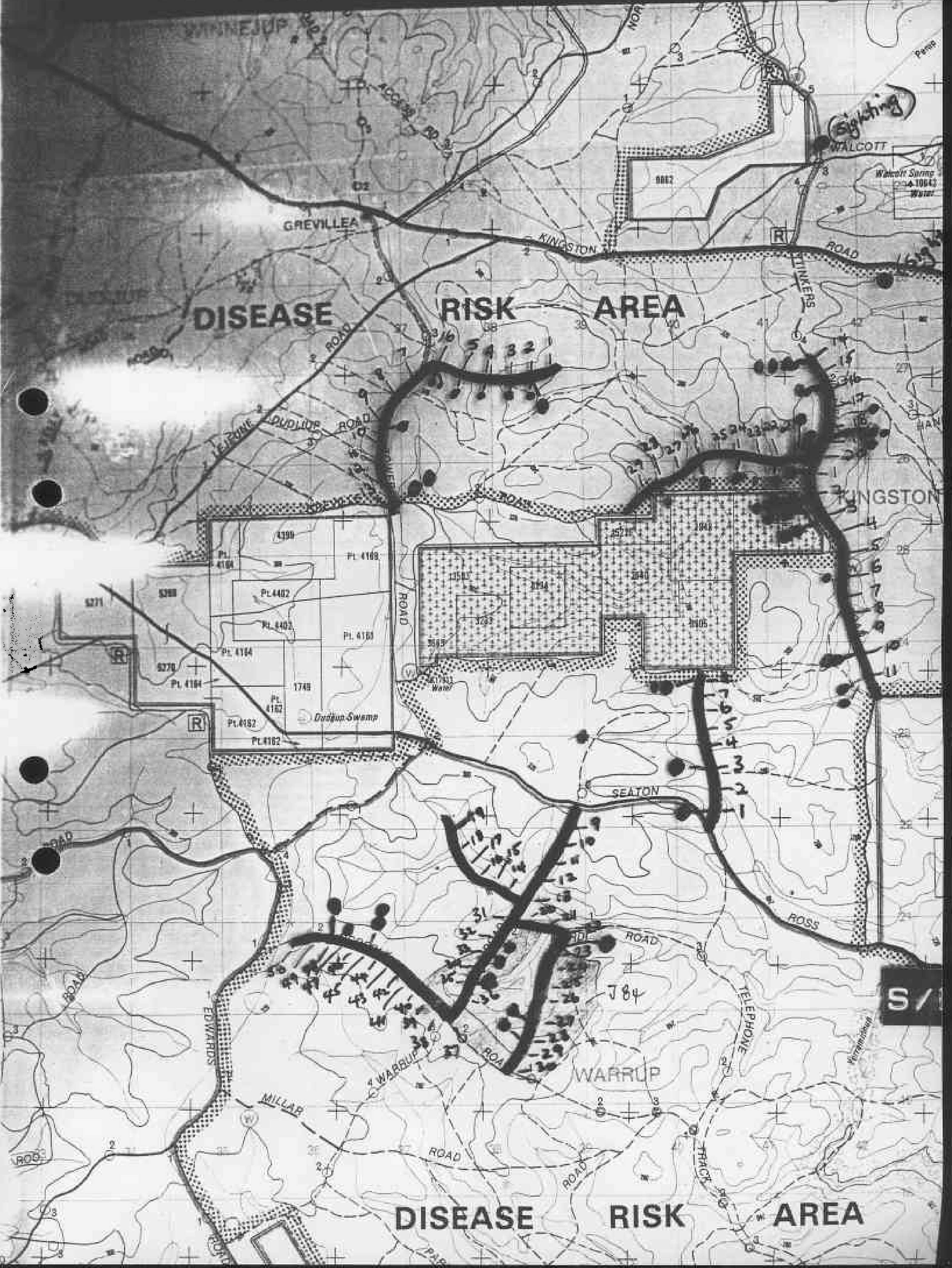
The first trapping in these sapling stands took place in 1992 and found Woylie, bandicoot, and chuditch. More recent limited trapping also found Woylie. I have requested Tim Foley of Manjimup District to look at the prospect of more intensive trapping within and outside the clearfelled area to give us more reliable data.

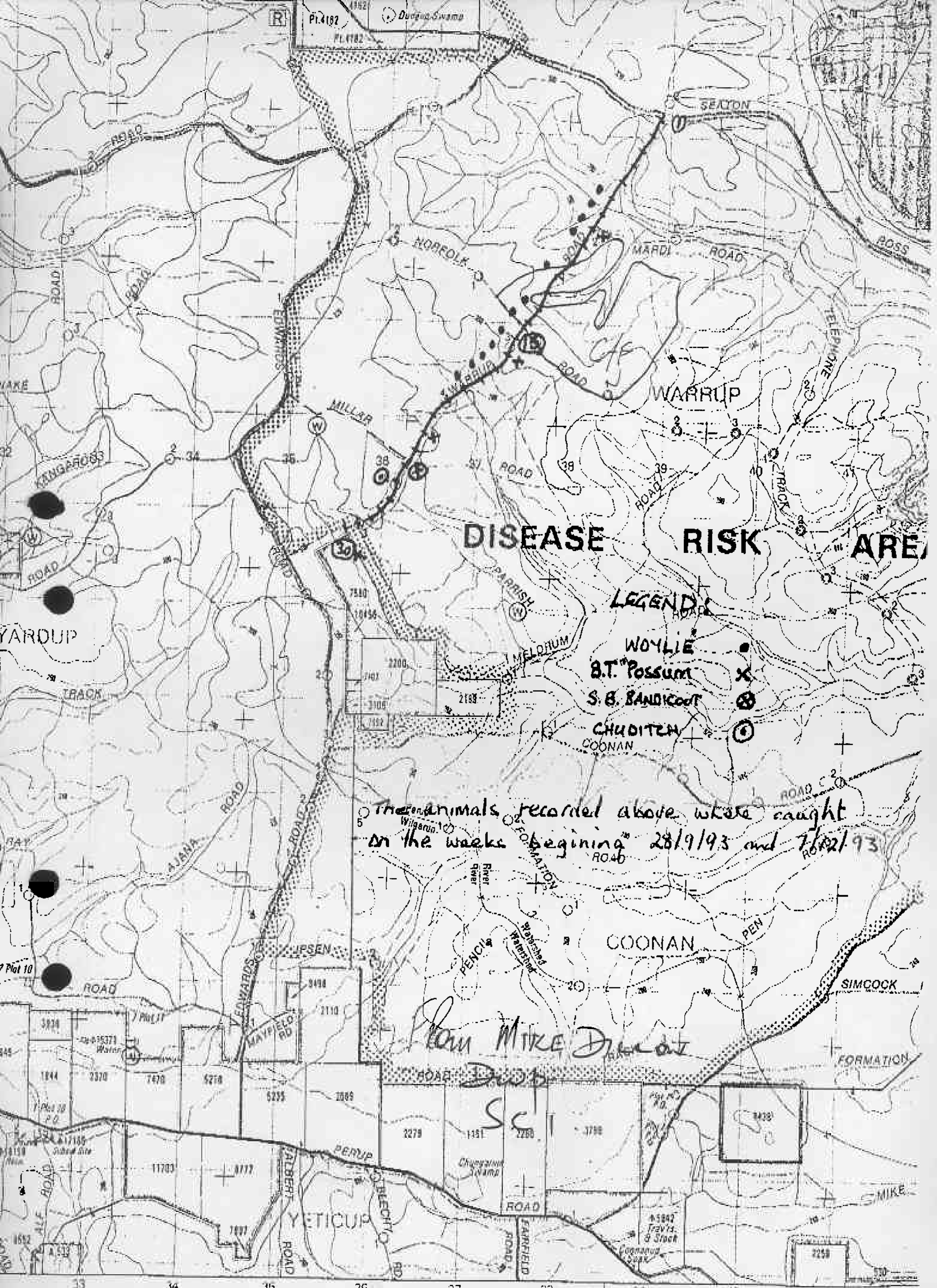
There is of course no data on what the animals were doing in these areas and therefore their real value as habitat. However the same can probably be said for areas outside the coupe.

Could you please return the main map and overlays when you have finished with it.

F.J.BRADSHAW
MANAGER, NATIVE FORESTS
7 January, 1994

MONITORING KINGSTON/DUDIJUP





LEGEND:
WOYLIE ●
B.T. Possum ×
S.B. BANDICOOT ⊗
CHUDITCH ⊙

The animals recorded above where caught on the weeks begining 28/9/93 and 7/12/93

From Mike [illegible]

MAPPING POTENTIAL HABITAT FOR VERTEBRATES IN FORESTS OF WESTERN AUSTRALIA

FINAL REPORT

For the Department of Conservation and Land Management, Western Australia

Bill McComb, Department of Forest Science, Oregon State University, Corvallis, OR 97331

10 August 1994