ANCA ENDANGERED SPECIES PROGRAM

FINAL REPORT: PROJECT 22

Conservation of the Red-tailed Phascogale (*Phascogale calura)*

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SUMMARY

Like many other Australian mammals, the red-tailed phascogale (*Phascogale calura*) has undergone an enormous contraction in range since European colonization. Historically recorded from widely separated parts of the arid and semi-arid zones across Australia, it is now known only from the southern part of the major cereal growing area of south-western Australia (the wheatbelt), where it is found in vegetation remnants containing suitable habitat.

The preferred habitat of *P. calura* in the western part of its surviving range at least, is in long-unburnt tall and dense vegetation of the *Eucalyptus wandoo/Eucalyptus accedens* and *Allocasuarina huegeliana* alliances, with populations being most dense in the latter type. The impact of fire on the species and its habitat was assessed by monitoring the effects of a prescribed burn carried out in March 1990 as part of a wider research project on the effect of fire on small vertebrates and invertebrates.

The effect of the fire on the *P. calura* population and its habitat in the 100ha burnt block was assessed by trapping before and for over two years after the fire, by radio-tracking individuals before, during and after the fire, and by measurement of various physical attributes of the habitat in the burnt block as well as in an unburnt control block.

The fire killed about 70% of the *A. huegeliana* and 22-90% of the *Acacia acuminata* , but only a small proportion of the wandoo (*E. wandoo*) trees on the sampling grids. Although not of extreme intensity, it caused the death of one-third of the red-tailed phascogales in the burnt block. There were no longer-term changes in the population dynamics or condition of animals, however, as a result of the fire. This was no doubt partly due to the close proximity of intact populations in the surrounding woodland, allowing recolonization of the block soon after the fire. Surviving individuals continued to use the same general areas during their nightly activity, but home range size was smaller immediately after the fire. One year after the fire, however, home ranges of resident phascogales were larger than those used by animals radio-tracked before the fire. Radio-tracking prior to the fire had showed that red-tailed phascogales nest, sometimes communally, in hollows in trees and logs as well as under the skirts of living grasstrees (*Xanthorrhoea drummondii*) and in the remains of dead grasstrees. Selection of nest sites after the fire necessarily favoured the less flammable types of site such as wandoo trees, rather than the previously commonly used dead sheoaks (*Allocasuarina huegeliana*) and dead grasstrees that had been consumed in the fire. Fire prescriptions for land containing *P. calura* populations should ensure that significant adjacent areas of suitable habitat are left unburnt, to allow recolonization after the fire.

Red-tailed phascogales share with other small dasyurids life cycle that involves the death of all males in the population shortly after the mating period in July. During this period, male movement and nesting behaviour changes. A radio-tracking study was carried out to investigate this phenomenon with respect to habitat use, in order to determine whether it generates different habitat management requirements than does behaviour at other times of year. The area covered in nightly movement by males at this time of year increases significantly. Nest selection changes, and it is clear that less secure refuges are used by males at this time, perhaps as they venture into areas with which they are less familiar. In particular, underground nest

sites were used more frequently in June/July 1992. Survival of males at this time of year (until the natural die-off) would be enhanced by a greater availability of nest hollows, as are found in long-unburnt vegetation.

A survey of nature reserves and other vegetation remnants in the southern part of the wheatbelt that contained suitable habitat was carried out to help define the conservation status of *P. calura*. It resulted in the discovery of 17 previously unknown populations of *P. calura,* most of which were in remnants of less than 500ha, the smallest being a 69ha nature reserve. The discovery of a population in VCL adjacent to Fitzgerald River National Park and evidence of populations in the vicinity of Newdegate and east of Hyden showed that the species is more widespread than recent records indicated. However, fruitless surveys in Bendering (1601ha) and North Karlgarin (5119ha) Nature Reserves, where *P. calura* was recorded in the 1970s, indicate that all populations are not necessarily secure, and that research may be necessary to determine suitable management regimes in various parts of the species' range.

CONTENTS

INTRODUCTION

At the time of European colonization of Australia the Red-tailed Phascogale (*Phascogale calura* Gould, 1844) had a wide but patchy distribution throughout arid and semi-arid areas of the Northern Territory, South Australia and Western Australia. The species is now confined to remnant patches of suitable habitat in the central and southern wheatbelt region of Western Australia. It is listed as rare, or likely to become extinct in Western Australia (Government Gazette, 1990) and is included in the 1990 IUCN Red List of Threatened Animals as `Indeterminate' (taxa known to be `Endangered', `Vulnerable' or `Rare' but there is not enough information to say which of the three categories is appropriate; IUCN 1990). In a recent review of the causes and conservation implications of the modern decline of Western Australia's vertebrate fauna, Burbidge and McKenzie (1989) listed *P. calura* as priority two, which species "require special protection, detailed research studies and the development of species management plans".

Apart from some work on breeding, diet and habitat preferences by Kitchener (1981), and field studies of the endocrinology of the annual male die-off (Bradley 1987) and water turnover (Green *et al.* 1989), there is virtually no information available on the species' ecology and requirements for effective long-term conservation and management (see above; IUCN 1990). Available information suggests that *P. calura* inhabits long-unburnt tall and dense vegetation of the *Eucalyptus wandoo/Eucalyptus accedens* and *Allocasuarina huegeliana* alliances, with populations being most dense in the latter type. In these habitats poison plants (*Gastrolobium* spp., toxic to introduced herbivores and predators) are very common and may bestow some protection to *P. calura* and other native vertebrates. Within its remaining range, much of the habitat of *P. calura* is now on nature reserves, where burning is infrequent. These two factors may have contributed to the persistence of populations in the south-west. Such information needs to be carefully assessed, and data on the species' distribution, habitat usage and response to fire gathered before effective management can be undertaken.

In February 1990 the Western Australian Department of Conservation and Land Management commenced a detailed program of research on the conservation status, habitat usage and fire ecology of *P. calura* aimed at ensuring the long-term conservation of the species. The research, funded by the Australian National Parks and Wildlife Service (now Australian Nature Conservation Agency) through the Endangered Species Program, was carried out in two phases between February 1990 and February 1991 (Phase 1), and the remaining (Phase 2) work until July 1992.

The scope for each phase was as follows:

Phase 1 (February 1990 - February 1991)

a) Review and assess current knowledge of the distribution and ecology of *P. calura*.

b) Based on the results of this review and predictions of species' distribution using the BIOCLIM software package, conduct surveys to assess these predictions and determine the conservation status of populations.

c) Assess the impact of fire on a population of *Phascogale calura* using an experimental approach combined with contemporaneous sampling of different-aged areas.

Phase 2 (March 1991 - July 1992)

a) Determine the home range and habitat usage of *P. calura* using radio tracking.

b) Assemble critical data on distribution, habitat preferences and the impact of fire on *P. calura*.

c) Continue the survey of predicted and reported occurrences of *P. calura* and determine the conservation status of populations.

The above aims of the project were formulated following a review of the literature, and were designed to remedy deficiencies in our knowledge regarding management of the species and the reserves in which its habitat occurs. The most important questions addressed by the project therefore concerned the current status and distribution of the species and its response to fire, living as it does in very flammable vegetation types. Part of these questions concerned the way in which *P. calura* uses its habitat, and the impact of fire on key elements of this habitat.

METHODS

IMPACT OF FIRE

Studies of the impact of fire on a population of *P. calura* were carried out at Tutanning Nature Reserve, 200 km south-east of Perth (37^{o} 31' S, 117^{o} 23' E), and complemented on-going fire ecology research on small vertebrates and invertebrates which began in 1986. The fire history of the Reserve and location of study sites are shown in Fig 1. Transect-based reconnaissance trapping commenced in September 1989 and indicated the presence of a population of *P. calura* in the block scheduled for burning in the following autumn. The externally-funded work began in February 1990, only six weeks before the prescribed burn which was carried out (as part of the longer-term research) on 20 March 1990. The fire impact work comprises three parts: regular live trapping on grids, radio tracking and habitat assessment.

Trapping

The Tutanning population was monitored regularly on three trap grids on a capture-mark-recapture system. Trap sessions were conducted monthly between February 1990 and March 1991, and every second month thereafter until July 1992 (except for an extra sample in December 1991). Each of the grids comprised 64 trap-stations at 20 m spacing in an 8 x 8 array. Each station was marked by a short metal stake, and the four corners of each grid were also marked with steel pickets. All grids were in Rock Sheoak *Allocasuarina huegeliana* habitat, two (Grids 1 and 2) being within the 100 ha block that was prescription burnt under low-moderate intensity on 20 March 1990. The other (Grid 3) was situated in similar habitat in a block which remained unburnt as a control (Fig 1). Vegetation on grids 1 and 2 had last been burnt in 1965, probably as a result of an escaped clearing burn. Prior to this, all of the southern area of the reserve (ie. all three study sites) had been burnt in a high intensity wildfire in 1940. The control Grid 3 was thus 50 years old with many large *A. huegeliana* and occasional old Wandoo *Eucalyptus wandoo* trees forming a relatively open habitat, while Grids 1 and 2 comprised quite dense 25-year-old *A. huegeliana* and some Jam Wattle *Acacia acuminata* with only the very occasional large sheoak or wandoo.

On each trapping session traps were baited with a mixture of peanut butter, rolled oats and sardines, and run for two or three nights depending on weather conditions. Animals are very susceptible to low temperatures and only short trap-runs, with each trap enclosed in a plastic bag, were carried out over the winter months (June-August). New animals were given individual identification numbers using a system of ear punching. Individuals were weighed and measured for head length, with scrotal width measured for males, and pouch condition and number and crown-rump length of young recorded for females.

For each grid, the minimum number of animals (males, females and total) known to be alive (KTBA) at each trap session was calculated as those caught at that time plus those previously marked individuals subsequently caught. These values were plotted against time to enable comparison of numbers and trends between grids. Mean weights of males and females were also plotted against time for the whole study, and over twelve months. The latter was also done for mean scrotal widths of males. To assess any changes in condition of the animals following the fire, and to compare animals on the three grids, the mean weights of males and females in the samples taken immediately before and immediately after the fire were compared using Tukey's multiple comparison test (Zar 1984).

Radio-tracking

The aims of the radio-tracking component of the study were

a) to monitor the survival of individual *P. calura* during the fire and the period immediately following it,

b) to compare home range size before and after fire, and

c) to determine the effect of fire on use of the type of nesting hollow used, as many of these are clearly extremely flammable.

Radio-tracking was carried out over three different periods, as follows:

i) Pre-fire: March 1990
ii) Post fire: March 1990
iii) One year post-fire: March 1991

Methods used for the radio-tracking component of this study changed during its course.

March 1990

In early March, a regular trapping session (as described in the previous section) was run. The first ten animals caught on Grid 2 in the area to be burnt, and all six caught on Grid 3 in the unburnt "control" area 2km away were fitted with radio transmitters. The transmitters (Model SM-1, AVM Instrument Company, California) were encapsulated in acrylic and mounted on a plastic cable-tie used as a collar. The whip antenna was 5cm of plastic-coated braided wire that passed around the collar inside heatshrink plastic to a point above the nape of the neck, before turning posteriorly and lying parallel to the animal's spine. The maximum weight of each collar was 6g, and the transmitter-battery combination gave an estimated life of 19 days.

Nocturnal movements of all 16 animals were monitored by two methods during the first ten days after collars were fitted. Three-element or four-element Yagi antennas were mounted on 4m masts positioned at two points near each trapping grid (Grids 2 and 3). Bearings to each animal were recorded simultaneously by the two operators each 15 minutes from 1900 to 2400 hrs. Problems encountered with this method necessitated the collection of further fixes by radio-tracking on foot using hand-held three-element Yagi antennas. One tracker worked on each grid collecting fixes by recording bearings in quick succession from two points so that the angle subtended by the animal was at least 45° and ideally 90°. Fifty to eighty acceptable fixes were collected for most animals during the nights of pre-fire radio-tracking.

By day, each animal was located and its nest location recorded and mapped. Nest position and hollow type were recorded. If visible, nest structure and nesting material were also noted. During the fire, the animals on Grid 2 were located by radio-tracking on foot as opportunity permitted.

After the fire, nocturnal radio-tracking was carried out for two nights only on Grid 2 in the burnt block. To improve data collection, all four masts were sited around the grid and mast height increased to 6m. This ensured that at least two operators received signals from each animal at almost all appointed times.

Home ranges were plotted using the NUMTRACK program (Paul Gioia and Norm Hall) and RANGES IVm (Kenward 1987,1990). Harmonic mean distance isopleths (Dixon and Chapman 1980) were plotted to include 50% and 95% of fixes for each animal. The area of each home range estimate at 50% and 95% was calculated by a subroutine of RANGES. The reliability of each home range estimate was tested by plotting cumulative home range estimate against number of fixes. Comparisons of home range size between groups of animals (e.g. males vs. females, before fire vs. after fire) were made by paired and unpaired t-tests.

March 1991

For this and subsequent radio-tracking of *P. calura* (including the sessions monitoring the male die-off), several improvements were made to equipment and methodology used.

Firstly, transmitter aerial whip length was increased from 5cm to 10cm, resulting a range increase of 50-100%. Transmitters were repotted using less acrylic, with the result that mean weight was reduced to 2-3g.

Secondly, a null-peak receiving antenna system (Telonics, Mesa, Arizona) incorporating paired 12-element Yagi antennas mounted on the 6-metre mast at each of three tracking stations was employed, replacing the three-element single antennas previously used. This antenna system gave much more accurate fixes and a substantially greater range than the old system. The overall effect of these two changes was to increase average range from 400 to 1500 metres.

Thirdly, the software package LOCATE (Pacer, Truro, Nova Scotia, 1990) was used to calculate animal locations from two or more bearings, to map fixes and to generate input files for the RANGES IVm program (Kenward, 1987, 1990) that was again used to generate home range maps.

In March 1991, a radio-tracking session was conducted to allow a comparison of movements of the animals resident in the burnt block in the vicinity of Grids 1 and 2 before the fire and one year after the fire. The initial trapping was carried out from 13-15 March, and 13 animals (6 males and 7 females) were fitted with radio-collars. Each animal was located in its nest during daylight hours on most days from 14 March to 25 March. The type of nest site and its location were recorded. Intensive radio-tracking using the mast-mounted aerials was carried out on the nights of March 18-21. After 25 March, the phascogales were captured when possible in order to remove their transmitters.

Habitat assessment

Structural attributes of the habitat within each trap grid were recorded in an attempt to identify those attributes which influence habitat preferences and distribution of *P. calura*. Unfortunately, due to the timing of the funding for the project, no habitat data were able to be obtained prior to the prescribed burn. However a considerable amount of information on the impact of fire on habitat attributes could be gleaned from *a posteriori* measurement. The main attributes assessed were tree stem density and overstorey species composition, leaf litter and shrub density, canopy cover and potential nesting site density.

Estimates/measurements of habitat were made at each trap-station and over each 20 x 20m area enclosed by the trap stations (recorded on a plan of the grid) in June and August 1990, as detailed below.

<u>Trap point data</u>

(a) At each trap point on the grid (64 points per grid) the triangular tessellation method of estimating stem density (Ward 1990) was carried out. The three trees forming the shortest perimeter triangle enclosing the sample point were chosen, and the length of the three sides was recorded as triangle sides A, B and C. These data were then converted to a measure of stem density (stems/ha; Ward 1990).

(b) The species and condition of the three trees was recorded as:

species

c	=	*Allocasuarina huegeliana* (sheoak)
w	=	*Eucalyptus wandoo* (wandoo)
j	=	*Acacia acuminata* (jam wattle)
y	=	*Eucalyptus loxophleba* (York gum)
b	=	*Xanthorrhoea drummondii* (blackboy)

condition

a	=	alive (after fire)
k	=	killed by fire
d	=	dead before fire

(c) Leaf-litter cover in a one metre square around each trap point was assessed as one of five categories:

0 = 0 - 1% cover
1 = 2 - 25% cover
2 = 26 - 50% cover
3 = 51 - 99% cover
4 = 100% cover, <3cm thick
5 = 100% cover, >3cm thick

The pre-fire litter cover was also able to be estimated from burnt duff and scorch.

(d) Presence or absence (±) of shrubs within 1m of each trap point was recorded, and any evidence of shrubs being consumed by the fire (e.g. stems) was noted in the comments column.

(e) Canopy cover (mostly of *Allocasuarina*) was assessed using a spherical densiometer. While the operator was facing south the densiometer was held level at chest height and the number of squares out of 25 with any foliage visible was recorded (e.g. a value of 23 means that 23 of the 25 squares have foliage (a cover of 92%) and that there are 2 squares without foliage, which correspond to two 1m gaps in the canopy 7-8m above).

(f) On the two burnt grids the average height of scorch on several of the *Allocasuarina* trees nearest to each trap point also was estimated.

(g) Comments could be added if necessary.

Quadrat data

A scale plan of the grid was drawn showing the trap positions and the 20 x 20m quadrats thus enclosed. The north point was drawn in, the four corners of the grids labelled, and creek lines and other significant features were indicated.

In each 20 x 20m quadrat the numbers of trees were counted and coded as:

w	=	young wandoo (no hollows)
h	=	old wandoo (with possible hollows)
b	=	blackboys
j	=	young live jam trees
old	=	large live jam trees
d	=	dead jam trees
y	=	York gum
ml	=	melaleuca
mld	=	dead melaleuca
cas	=	*Allocasuarina huegeliana*
ldc	=	large dead *Allocasuarina huegeliana*

The numbers of hollow or partially hollow logs were counted in four diameter classes: 10 - 20cm, 21 - 50cm, 51 - 100cm and > 100cm. For the two grids that were burnt the number of logs >10cm diameter consumed by the fire was able to be estimated by ash beds and coals.

Pre-fire densities (stems/ha) of the three main tree species (*A. huegeliana, E. wandoo* and *A. acuminata*) were calculated for the three grids using triangular tessellation (Ward 1990) and plotted as schematic 3D diagrams. The densities of live and dead *A. huegeliana* trees before and after the fire and the percentage killed were also tabulated for Grids 1 and 2. Total abundance of the co-dominant species in the various condition categories and the number of hollow logs and burnt logs over each grid area (1.96 ha) were also calculated and tabulated. The frequency of litter cover classes were calculated before and after the fire and plotted as histograms. Mean canopy cover and mean scorch heights (for the burnt grids) were also calculated for the grids. Scorch height was plotted in schematic 3D to indicate variation in fire intensity over each grid area, and allow some comparison with the stem density diagrams.

HABITAT USE DURING THE MATING PERIOD

The life cycle of *P. calura* involves the die-off of all males in the population during July. During the mating period in the weeks prior to die-off, males apparently move more widely than usual (Bradley 1987). Two periods of radio-tracking were carried out at Tutanning, during July 1991 and June-July 1992. Home range size and nest hollow use were recorded, to compare these with measurements made in March 1990 and 1991 before the mating period during the fire study.

In 1991, traps were set on grids 1 and 2 on 8 July. As only four animals were caught, a further 55 traps were set at wider spacing in the surrounding habitat, so that a total area of approximately 25 ha was covered. Trapping was carried out for two more nights. In total, five phascogales were captured (three males, two females) and fitted with radio-transmitters. Phascogales were located during daylight hours on most days while collars were fitted. Intensive tracking was carried out on the nights of 16-18 July. Another trapping session was run on the nights of 22 and 23 July. One further female was caught and collared, and another tracking session was conducted on the nights of 24 and 25 July. A search for the males' transmitters using a light aircraft fitted with wing-mounted aerials was carried out on 27 July. Trapping to retrieve collars fitted to females was carried out on the nights of 31 July and 13 August.

In 1992, traps were laid out on the enlarged grid described above and set on the nights of 16 and 17 June. A total of eight males and one female were caught and fitted with transmitters, although one of the males was found dead six days after capture. Each animal was located on most days while the transmitters were operating, until the animal was either found dead or disappeared from the study area. Intensive nocturnal tracking was carried out on the nights of June 22-25, June 30-July 2 and July 7-10. The four surviving males had disappeared from the study area by July 10, and a flight to locate their transmitters was carried out on 15 July. The female's collar was removed at a subsequent trapping period.

PREDICTED DISTRIBUTION USING BIOCLIM

BIOCLIM is a computer program developed by Henry Nix to predict the distribution of a biological taxon by matching its "bioclimate envelope", defined by the upper and lower values of 16 variables at the recorded localities of the taxon with the known climate across Australia. Points are then displayed, on a 0.5° grid, according to the degree to which the climate matches that calculated for the taxon, in terms of selected threshold values of each of the 16 variables.

The original intention of this study was to use BIOCLIM to identify areas in which *P. calura* was likely to occur, but in which it had not yet been located. Difficulties in accessing and using BIOCLIM during the first 18 months of the project, however, resulted in the surveys being planned and executed prior to this analysis being completed. Consequently survey sites were chosen in relation to the known distribution and to information received from the public. The BIOCLIM analysis was completed in 1992 once a copy of a PC-based version was obtained.

Data used to write BIOCLIM input files included all specimen-based museum records of *P. calura*, as well as localities recorded by Burbidge *et al.* (1987) in interviews with older Aboriginal people in central Australia. Sub-fossil records were not used. Latitude and longitude of the recorded localities of *P. calura* were entered into a dBXL file as input for MAPINFO and plotted on a map of Australia. The plot file generated by BIOCLIM for the predicted distribution was treated similarly and a map of the predicted distribution at different probabilities was generated.

DISTRIBUTION AND CONSERVATION STATUS

Locality records associated with museum specimens were collated and a map of recorded distribution constructed. Based on recent locality records, a survey program was drawn up to examine the boundary of the known distribution as well as to survey smaller reserves in order to determine the lower bounds to the size of reserves where *P. calura* might be expected to occur.

During surveys of large areas, traplines of 20-25 medium-sized Elliott traps (set as in section (a)) or grids of four lines of ten traps were set. Three to four nights trapping was carried out, so that with over 200 traps, trap effort generally exceeded 600 trap-nights. Approximately half of the trapping effort was expended in *Allocasuarina* associations (if present) and half in other vegetation associations.

Use of grids allowed some estimation of phascogale population density, given sufficient captures.

To carry out surveys of small reserves, two or three traplines were set in likely habitat on each of a number of reserves and all were operated over the same period. Vegetation associations on traplines were described using the vegetation classification of Muir (1977).

In July 1991, an appeal was made through the television stations for reports of sightings of red-tailed phascogales. This time of year was chosen as it just preceded the time of male die-off. Museum records indicate that at this time of year, a high number of *P. calura* specimens are handed in, either found dead on the ground or brought in by cats.

RESULTS

IMPACT OF FIRE

The burn carried out at Tutanning was of much lower intensity than anticipated. An attempt to carry out the burn earlier (on the 17 March) was abandoned due to very strong winds which were well above those specified in the burn prescription. On the 20 March weather conditions were quite mild (wind strength below that prescribed), but because of the lateness in the season and the very uncertain nature of future weather it was decided to go ahead with the burn. The majority of Grid 2 (where the radio-tracking was carried out) was not burnt by the headfire, but rather, as a mild intensity backburn. The headfire through the *A. huegeliana* also was of relatively low intensity, with crowning occurring in only a few places (not on the grids), but the very low soil dryness (about 7%) and dry condition of the vegetation led to fairly long flame residence times and a significant impact on much of the habitat in the aftermath of the main fire front.

Trapping

The numbers of male and female *P. calura* known to be alive (KTBA) on the three grids are shown in Figs 2 and 3 respectively, while totals are shown in Fig 4. These data suggest that abundance trends were quite similar on all three grids. Numbers of males and females peaked during the February-April period in all three years as young, recently independent animals entered the trappable population. Numbers then declined markedly over the late autumn-early winter period (May-June) as animals established territories and the population stabilised prior to the June-July breeding season. Following this, adult males underwent the die-off characteristic of this group of dasyurids (Bradley 1987), so that KTBA numbers were low on all grids during August-December each year as young were raised and weaned. New adult males and females entered the trappable population during December-February and the population cycle began again (Figs 2 and 3). Thus in the period August to April the population comprised three distinct classes of animals: juvenile/subadult males, juvenile/subadult females and adult parous females. For the remainder of the year all animals were adult, but both parous and nulliparous females were present.

The only differences in population trends between the unburnt control grid (Grid 3) and the two burnt grids were:

- population peaks were later in 1990 and 1991 on the control grid (April-May, Grid 3; February-March, Grids 1 and 2; Fig 4).

- males disappeared slightly earlier on the unburnt grid (before July) than on the two burnt grids (after July but before August-September; Figs 2 and 3).

- numbers were generally lower on the unburnt grid (Fig 4).

These trends may reflect some qualitative differences in habitat between the burnt area and the 50-year-old unburnt area.

Although peak KTBA numbers (and recruitment) were lower on both burnt grids in 1991, this trend was also evident on the unburnt grid (Fig 4), indicating considerable year-to-year seasonal variation rather than any effect of the fire.

A plot of mean male body weight against time of year (ie. over 12 months) showed that young males entered the trappable population in December and grew rapidly to peak in May at about 48g, then lost weight (and condition) even more rapidly over the next three months prior to death in July-August (Fig 5). Scrotal widths (Fig 6) followed a similar pattern with maximum sizes of about 15mm reached in May before the onset of breeding, then declined rapidly in size as the animals lost condition prior to death. This timing corresponds to the sharp increase in plasma testosterone during May recorded by Bradley (i987) Females, on the other hand, did not gain weight as rapidly as males during the January-May period, but remained relatively stable at about 30g (Fig 7). Then, following a slight decline in June (probably associated with high activity levels during the breeding season), mean weights rose over the July-November period as females became pregnant, carried pouch young and later put on condition to feed young in the nest. Mean weights then fell in December (but variability markedly increased), reflecting the new cohort of young trappable animals which joined the parous adults in the population (Fig 7).

A plot of male and female mean body weights over the whole study for the burnt and unburnt grids (Figs 8 and 9) does not indicate any marked difference in age structure of populations between the treatment and control. There was, however, a tendency for animals on the burnt grids to be generally heavier than those on the unburnt grid at most times of the year. Furthermore, there was no marked decline in mean weights in November/December 1991 on any of the grids, indicating a low level of juvenile recruitment that year. Mean weights of males and females immediately before and after the fire were not significantly different for any of the grids, but females on Grid 3 were significantly lower in weight than those on Grid 2 before the fire ($p < 0.01$), and those on both burnt grids after the fire ($p < 0.05$; Table 1). These results again indicate that between-grid differences in weight and year-to-year seasonal variations in recruitment outweigh those effects due to fire.

Radio tracking

Pre-fire and post-fire studies in 1990

(a) Home Range Analysis

(i) Reliability of estimates

The adequacy of the radio-tracking data to describe the home ranges of the phascogales tracked may be assessed using the graphs in Figs 10-13. These show the increase in the home range area estimate with the increase in the number of fixes. This curve should flatten out as the true value of the home range area is approached. Generally speaking, the pre-fire home ranges of males were estimated well with the amount of radio-tracking carried out, but some of the females were still using new parts of their home ranges at the end of the radio-tracking period. The post-fire radio-tracking period was too short, due to the postponement of the fire for several days, with the result that some of the post-fire home range estimates are probably small. It appears that more than 60 fixes are necessary to adequately describe *P. calura* home ranges.

(ii) Comparison between male and female home range size

Table 3 shows the areas of home ranges estimated for each animal tracked in 1990, and the number of fixes on which each estimate is based.

Home range sizes are given as the area in hectares enclosed by the harmonic mean distance isopleth (Dixon and Chapman, 1980) which includes 50% and 95% of fixes ("50%" or "95% home range"). The 50% home range may be regarded as the area in which the animal carries out most feeding ("core" home range), whereas the 95% home range includes the area of interaction with neighbouring animals ("social" home range). The mean 95% home range size for animals (both blocks) tracked before the fire was 3.7ha ($n=16$). Female and male 95% home ranges were 2.8ha ($n=10$) and 5.3ha ($n=6$) respectively, and these were significantly different ($t=2.5$, $df=14$; $p<0.05$).

(iii) Home range size before and after fire

Notwithstanding the possibility that insufficient fixes were accumulated in the post-fire period, 50% and 95% home ranges for each surviving animal before and after the fire were compared by a paired t-test. This showed a significant difference in the estimated home ranges (50% home ranges, $t=3.52$, $df=6$, $p<0.05$; 95% home ranges, $t=3.31$, $df=6$; $p<0.05$).

Mean home range size was smaller after the fire. In our sample of four females and three males, 50% home range decreased from 0.8ha to 0.4ha, 95% home range decreased from 5.1 ha to 2.6 ha;. There appears to have been some decrease in the range of movement after the fire, which may have been accentuated by insufficient sampling.

(b) Spatial relationships

(i) Male and female home ranges

The relative locations of phascogale home ranges before the fire in the vicinity of each trapping grid are shown in Figs 14 and 15 (burn block) and Figs 16 and 17 (unburnt block). Adult animal numbers are prefixed AM and AF for males and females respectively. Female 95% home ranges show a greater tendency to overlap each other than do male 95% home ranges, and there is considerable overlap between male and female 95% home ranges. When 50% ("core") home ranges are examined, there is no overlap between males, but females still share some common areas. Two females in the burn block, AF24 and AF66, coincide almost totally.

(ii) Impact of fire on spatial relationships

Figs 14 & 15 and 18 & 19 show 50% and 95% home ranges in the burn block before and after the fire. It is clear that the post-fire estimated home ranges were smaller than the pre-fire home ranges, but as stated previously, this is partly due to insufficient sampling.

Figs 20-33 show the pre-fire (green lines) and post-fire (red lines) 50% and 95% home ranges for each of the seven animal that survived the fire. Clearly there was very little shift in home range by the animals in the first nights of activity after the fire.

(c) Nest selection and impact of fire on nest hollows

(i) Hollow types

All ten phascogales with collars on Grid 2 were located each day on six days in March before the fire. During this time they occupied a total of 22 nest hollows. Many hollows were occupied on several successive days by the same animal, and sharing of nests was frequently observed.

Nests were found in a variety of types of hollow, and, in descending order of occurrence were in:

Dead *Allocasuarina huegeliana*	6
Dead *Eucalyptus wandoo*	4
Live *E wandoo* (much dead wood)	3
Xanthorrhoea drummondii stump	3
E. wandoo log on ground	3
Live *A. huegeliana*	2
A. huegeliana log on ground	1

All six phascogales with collars on Grid 3 were also located on the same days.

Seventeen nest hollows were used on Grid 3 during this period. They were as follows:

Live *E. wandoo* (much dead wood)	7
Dead *E. wandoo*	4
E. wandoo log on ground	3
E. wandoo fallen branch suspended	2
Xanthorrhoea drummondii stump	1

Eucalyptus wandoo trees are much more abundant in the vicinity of Grid 3 than Grid 2. Such trees offer many hollows, as the living trees are attacked and hollowed out by termites. Their predominant use as nest sites by phascogales on Grid 3 probably reflects this greater availability of hollows, whilst dead *A. huegeliana* were apparently not used on this grid to any significant degree.

On the day after the fire, AF24 was found in a burrow-like hole in the ground in her home range. Next day she was in another hole in the ground nearby. This was the first recorded use of burrows by the phascogales, and may have been a response to loss of nest hollows, although a number of hollows in her area survived the fire.

(ii) Nest sharing

The recorded instances of nest sharing on Grids 2 and 3 are shown in Table 6. As there were uncollared animals on the grids this may not give the full picture. However it is clear that nest-sharing is prevalent at this time of year, at least. No males were found sharing nests, although females frequently aggregated in a nest. Three of the four males on Grid 2 were recorded sharing nests with females: one female, AF95, shared nests with all three of these males during the monitoring period.

(iii) Impact of fire on nest sites

During the radio-tracking period before the fire 22 nest sites were recorded near Grid 2. Of these, four were outside the burn block. Eight nest sites were burnt in the fire, and one burnt away slowly over the nest three days. Of the remaining nine nest sites on the burn area, one was alight but the fire went out, one was broken by falling trees, and seven remained intact.

The survival of the various types of nest site is shown here, and shown graphically in Fig 34.

Type	**Original No.**	**No. surviving intact**
Dead *A. huegeliana*	6	0
Dead *E. wandoo*	4	3 (1 broken)
Live *E. wandoo*	1	1
X. drummondii stump	1	0
E. wandoo log	3	2
Live *A. huegeliana*	2	2
A. huegeliana log	1	0

Clearly, phascogales nesting in dead *A. huegeliana* are at risk even during low intensity fires, whereas animals using *E. wandoo* stand a much greater chance of surviving.

(d) Behaviour during and after the fire

On the morning of the prescribed burn on 20th March 1990, nine of the radio-tagged phascogales were in the burn block and one (AM22) was in a nest in an adjacent block.

Wind was from the opposite quarter of the block to the phascogale trapping grids, so the main fire was to be lit there. A backburn was started on the edge of the block near Grid 2 at about 1100. The main fire was started at 1330, and met the backburn at about 1600.

After the backburn was lit logs near the edge of the block caught fire quickly and by 1150 an *A. huegeliana* log in which AM83 was nesting had burnt and the radio signal had stopped. By 1250 the standing dead *A. huegeliana* in which AF21 was nesting had burnt, and that signal also had stopped. The *E. wandoo* log in which AM24 was nesting caught fire at 1250, and was alight inside by 1320. At 1530 AF24 was seen in the *A. huegeliana* foliage above the burning log; she had left the log at some stage after it caught fire. The live *A. huegeliana* in which AM70 was nesting caught fire, but went out before the entrance, at which the animal was seen on one occasion, was affected by heat. AF95 was nesting in a dead *A. huegeliana* which caught fire, and she also left the tree at some time before 1715, but stayed nearby. She was still within 15m of the burning remnants of the tree at 2150, and at 0940 the next day was found unharmed on the ground, cowering between the roots of another *A. huegeliana* within 10m of the burnt nest tree.

The dead *A. huegeliana* in which AF83 and AF23 spent the day of the fire was alight at the base by 1740. At 2200, AF83 was still in the smouldering tree, but AF23 was found dead on the ground about 20m away, its fur quite scorched. This nest tree burnt through at the base and fell, to lean against other trees as it continued to burn from the base. AF83 was still in the nest the next day at 0850 and 1630. She was caught in the next night's trapping session, and when released at 0730, returned to the nest in the burning tree. The next morning she was in another nest.

Between 2145 and 2230 on the night after the fire, only one of the seven survivors (AF66) was active in the burnt block, whilst two were active in an adjacent unburnt block. All the surviving animals were active within their old home ranges 36 hours after the fire.

(e) Mortality during the radio-tracking period

No deaths were recorded amongst the 16 radio-tagged animals during the period 9-19 March. During the fire on 20 March three phascogales died, amongst the nine that nested within the burn block that morning.

Between 23 and 29 March, AF24 was taken by a bird of prey, probably an owl, the animal's remains being found beyond the eastern extremity of her recorded home range. This female had been found on 22 and 23 March nesting in burrows in the burnt block.

On 21 March AF29's undamaged radio-collar was found on the ground in her home range in the unburnt control block. She was not caught subsequently, despite having been captured regularly in previous trapping sessions. On 24 April, traps were placed around this animal's two most frequently-used nest trees, with no success. It appears most likely that AF29 was also taken by a predator, but it is possible that the animal removed its own collar.

Post-fire studies in 1991

(a) Home range analysis and spatial relationships

Table 4 shows the areas of home ranges estimated for each animal tracked in March 1991, and the number of fixes on which each estimate is based.

(i) Comparison between male and female home range size

Female and male 95% home ranges were 8.5 ha (n=5) and 7.8 ha (n=5) respectively. These are not significantly different ($t=2.43$, $df=8$, $p=0.8$). Even if the rather anomalous home range size of 18 ha corresponding to female AF44 is discarded, the means are still not different (females' mean now 6.1 ha; $t=1.55$, $df=7$, $p=0.165$). This differs from the situation in March 1990 before the fire, when there was a significant difference between male and female home range size, using data from animals from both the unburnt and the burn block.

(ii) Comparison between home range size in March 1990 before fire and in March 1991, one year after fire.

Using 95% home range sizes from the burn block only, none of the four combinations of male versus female and pre-fire versus one year after fire produce a significant difference. If male and female data are pooled, however, mean home range size is found to be significantly larger one year after the fire than just before it (1990 mean 4.7 ha, 1991 mean 8.1 ha; $t=2.56$, $df=18$, $p=0.02$).

(iii) Spatial relationships

Home range plots for each animal tracked (males plotted in blue, females in red) are shown in Fig 35 (50% home ranges) and Fig 36 (95% home ranges). The 50% plots of males and females show that there is a high degree of overlap of core home range between females, but very little between males. In March 1990, males showed the same degree of avoidance of each other, but there was less overlap between females (Figs 14 and 15).

(b) Nest selection before and one year after the fire

The frequency of each type of nest hollow in which radio-collared phascogales were located during the day in the burn block in March 1991 is shown below, with the corresponding data from animals living in the burn block in 1990. Some of the pre-fire nests were outside the burn block. The comparison is also shown in Fig 37.

Hollow type	Pre-fire	1 year after fire
Dead *Allocasuarina huegeliana*	6	3
Dead *Eucalyptus wandoo*	4	11
Live *E. wandoo* (much dead wood)	3	3
Xanthorrhoea drummondii stump	3	2
E. wandoo log on ground	3	2
Live *A. huegeliana*	2	1
A. huegeliana log on ground	1	0
Live *X. drummondii*	0	1
Acacia acuminata log on ground	0	1
Total	22	24

The most obvious difference between the two periods is the greatly increased importance of dead wandoo trees as nests in the post-fire period. As shown in the March 1990 section, wandoo trees were the preferred nest site on Grid 3, where they were common. Before the fire, dead *A. huegeliana* trees were more commonly used on Grid 2, where *E. wandoo* trees are scarce. The fire reduced the number of dead *A. huegeliana*, which are extremely flammable, in the burnt area. The response of the phascogales has been to nest in *E. wandoo* trees (many of which were killed in the fire) far from their feeding areas, and to travel up to ~~40~~ metres /400 each way at night. Clearly the most flammable types of nest site such as dead *A. huegeliana* and logs were less available in the burn block after the fire. It appears that dead *E. wandoo* are much more widely used since the fire. The effect of this change in nesting behaviour is not known. It is likely that the increased movement each night results in a greater exposure to predation from avian predators, and if the animals move along the ground, to nocturnal mammals as well. Whether red-tailed phascogales move along the ground or in the canopy during these long movements is not known, but they appear to move rapidly, covering 200 metres in 10-15 minutes in several cases monitored at dusk.

Habitat assessment

Measurement of stem densities and other habitat components showed that the two grids in the burnt block differed considerably from that in the older unburnt area. Before the fire grids 1 and 2 had a high density of *A. huegeliana* stems (both alive and dead), while Grid 3 supported about half the mean stem densities of these two grids (Table 7). Grid 3, however, had more *E. wandoo* trees than the other two grids (Table 7), and a much higher proportion of large old hollow individuals (Table 9). *Acacia acuminata* was virtually absent from Grid 3 but was an important sub-dominant component of the vegetation on the two younger grids (Tables 2 and 4), while hollow logs and *Xanthorrhoea drummondii* were more abundant on the former grid (Table 9). Density was spatially very variable on all three grids (Figs 38-40), but particularly on Grid 2 and to a lesser extent Grid 1. Mean canopy cover values were quite similar on the three grids, being 95%, 95.2% and 92.7% for Grids 1, 2 and 3 respectively.

Although the fire was only of low intensity within the trap grids (crowning in only a few isolated patches off the grids), it killed about 70% of the *Allocasuarina* (Table 8) and between 22% and 91% of the *A. acuminata* on the two grids, but only a small proportion of the wandoo trees. Mean scorch heights were 0.55 ± 0.07m and 0.51 ± 0.04m on Grids 1 and 2 respectively, but fire intensity varied considerably over both grid areas, reaching maximum values in the upslope parts of Grid 1 (Figs 41 and 42). Comparison of scorch height and stem density diagrams (Figs 38, 39 and 41, 42) suggests that fire intensity was not greatly influenced by density of the overstorey vegetation.

Despite its low intensity, the fire destroyed many of the potential nesting sites of *P. calura*. Skirts of *Xanthorrhoea* burnt fiercely during the main fire, and some old *Allocasuarina* and hollow *E. wandoo* fell down and were consumed, along with other hollow logs, over the week following the fire. Surface leaf litter was considerably reduced, reflected in the marked increases in the frequency of the lower litter cover classes and a skewed frequency distribution after the fire (Figs 43-45). In many places, however, the duff layer adjacent to the mineral soil was not completely burnt, and it is likely that the fire had only a short-term impact on litter and soil-dwelling invertebrates.

HABITAT USE DURING THE MATING PERIOD

Home range analysis, spatial relationships and male disappearance

July 1991

As only two males and three females were captured in July 1991, and as the males both disappeared from the study area six and eight days respectively after radio-collars were fitted, only a small amount of tracking data was collected. Home range estimates may be found in Table 5. The tracking period to follow the movements of the two males, however, was immediately prior to disappearance, and they showed a pattern of moving very widely. Some of the positions recorded were discarded as they appeared to be beyond the accurate range of the tracking mast set-up, but there is no doubt that the animals were well outside their March home range, and the mean 95% home ranges were significantly larger ($t=13.65$, $df=5$, $p<0.001$). The male AM33 was tracked in both March and July 1991, and his 95% home range increased from 8.6ha to 88.8ha. Mean female home ranges are not significantly different from those measured in March ($t=0.142$, $df=6$, $p>0.1$). The broad movements of the male phascogales take the animals well outside the well-developed *Acacia huegeliana* stands as they move over a kilometre away from their usual feeding range.

The relative positions of the phascogales tracked are shown in Figs 46 and 47. In Fig 47, the 95% home ranges show how the females remained close to their capture points, while the two males moved up to a kilometre away. Both the 50% and the 95% home ranges of the males overlap each other greatly, and both overlap the three females' home ranges. This situation contrasts with that observed in March 1990 and March 1991 (Figs 14, 15, 35 and 36), when the males displayed much less overlap, especially in the 50% home range.

The male AM33 was last located on July 16, while the other male, AM50, was last located alive on July 18. The search by light aircraft on 26 July succeeded in locating AM50's signal on the edge of farmland approximately 5km from Grid 2. The radio-collar was found the next day on top of a broken wandoo trunk 5m off the ground. It was damaged, and had fur adhering to it. The top of the wandoo trunk was not hollow, but formed a platform that had apparently been used by a bird of prey.

June/July 1992

The study was commenced three weeks earlier in 1992 than in 1991 to allow a longer monitoring period before the males disappeared. Robust estimates of home range were made before the first of the radio-collared males disappeared between 3 and 7 July. Home ranges were calculated from fixes taken over two periods (22-25 June and 30 June - 2 July, 7-10 July combined), and the estimates are shown in Table 6. The 95% home ranges determined for males between 22 and 25 June 1992 (mean=30.4ha) were smaller than those measured in July 1991 (mean=102.18ha) ($t=5.17$, $df=6$, $p<0.01$), but significantly larger than the March 1990 male home range estimates ($t=2.78$, $df=8$, $p<0.05$). The 95% home range sizes measured between June 30 and July 10 are not significantly different from those measured earlier in June ($t=2.15$, $df=10$, $0.05<p<0.1$).

The differences in home range size discussed above are obvious from the plots in Figs 48-51. In June there is very little overlap between male 50% home ranges, but there is more evidence of overlap by the beginning of July.

Selection of nest hollows

July 1991

Radio-collared phascogales were located in 14 different nest sites during the monitoring period. These are as follows:

E. wandoo log	5
Dead *E. wandoo*	4
Live *E. wandoo*	1
Live *Xanthorrhoea drummondii*	1
Dead *X. drummondii*	1
Live *Allocasuarina huegeliana*	1
Live *A. acuminata*	1

This distribution of nest types is not unlike that observed in March 1991.

June/July 1992

During the radio-tracking period, radio-collared phascogales used a total of 33 different nest sites, as follows:

E. wandoo log	8
Underground	8
Live *E. wandoo*	5
Dead *E. wandoo*	4
Live *Xanthorrhoea drummondii*	2
X. drummondii stump	2
Dead *Allocasuarina huegeliana*	1
Under logs	1
Under bark	1
Under sedge clump	1

Apart from one female that used a burrow after the fire, there was no use of burrows recorded for *P. calura* in any of the four tracking periods in 1990 and 1991. It is remarkable then, that underground nest sites were used by six of the seven radio-collared animals during the 1992 tracking period. Many of these nest sites were not burrows as such, but access was through a crack in the soil surface that had been opened up by a dead tree falling or leaning over. Consequently, the nest sites were generally near the bases of dead trees. A possible increase in the rate of tree fall two years after the fire may explain the increased use of underground refuges. However, not all of the underground nests were in the burnt block. The types of nest used include a number of temporary shelters, such as under logs and bark. It is likely that the males, in extending their sphere of movement, are moving through areas in which they are not so familiar with the available nest hollows, and are forced to use anything that they come across. This would also tend to expose the animals to a greater threat of predation

PREDICTED DISTRIBUTION USING BIOCLIM

The recorded distribution of *Phascogale calura,* from museum specimens and interviews with aboriginal people, is shown in Fig 52. The predicted distribution derived by the BIOCLIM package using the recorded distribution, is given in Fig 53. BIOCLIM matches the climate, defined by mean values of 16 climate variables ("parameters") at 0.5° grid points across Australia, with the range of those parameters encompassed by the localities at which the species has been recorded (the "climate profile"). The size of dot plotted in Fig 53 represents the level of agreement between the climate profile of *Phascogale calura* and the climate at the particular 0.5° grid point. These levels are as follows:

Level 1 (smallest dot)	All 16 climate parameters match in total range
Level 2	All 16 parameters match within the 90-percentile (5-95%)
Level 3	13-15 parameters match within the interquartile (25-75%), the rest in the 90-percentile
Level 4 (largest dot)	All 16 parameters match within the interquartile (25-75%)

Agreement at Level 4 is achieved at only one 0.5° grid point, at 33°05'S 117°55'E, a point about 10km east of the main block of Dongolocking Nature Reserve.

DISTRIBUTION AND CONSERVATION STATUS

The recorded distribution of *P. calura* in the south-west of Western Australia is shown in Fig 54. The results of the survey are shown in Tables 10 and 11. Table 10 is a summary, listing the survey sites and showing whether there was a previous record, whether the survey located a population there, and the area of the reserve or the total vegetation remnant, even if these are of different tenures. The recent recorded distribution (1980-present) based on specimen records and trapping conducted under this program is shown in Fig 55.

The public appeal on television generated ten good sightings, some of which were backed up by specimens. Two were from outside the recent range of the species. These were at Dardadine to the south-west of recent records, and one to the east, near the rabbit-proof fence east of Hyden. Evidence of another eastern population was received in June 1993, when a specimen, found in the bushland surrounding the town of Newdegate was given to a local CALM officer.

DISCUSSION

IMPACT OF FIRE

The habitat and refuge requirements of *P. calura* suggest that this species is likely to be severely affected by fire. The Rock Sheoak (*A. huegeliana*) thickets in which *P. calura* feeds, and the old *E. wandoo* and dead *A. huegeliana* in which they shelter are extremely flammable. Even low intensity fire will kill *A. huegeliana* trees, and if a further fire affects the area before the even-aged regrowth stand has matured and set seed, the area will be converted to an entirely different habitat type. Fire is also likely to burn out many potential nest hollows in old *E. wandoo* trees, though it may also create new hollows.

The life history characteristics of *P. calura* also suggest high potential sensitivity to fire, particularly those in spring. With the semelparous Type 1 breeding strategy (Lee, Woolley and Braithwaite 1982) of *P. calura* and many *Antechinus* species, males die off following the winter breeding season (Bradley 1987). There is thus complete replacement of the male population each year, (although some females may breed in a second season), and a critical period (August - December) when there are only dependent young and adult parous females present in the population. A marked reduction in shelter and/or food, resulting from a disturbance such as fire, could lead to increased stress on animals resulting in pre-breeding mortality and failure to breed, or, in the case of a moderate to high intensity spring fire, high mortality rates of females and their dependent young. This could lead to local extinction of populations.

Our data indicate that the Tutanning fire, although of only low intensity around the two grids, caused significant injury and mortality in the *P. calura* population. Radio-tracking studies confirmed the death of a third of the collared animals during the fire. Regular trapping, however, indicated no marked longer-term changes in population dynamics or condition of animals as a result of the fire. Breeding in 1990 did not appear to be disrupted by the fire, and the poor breeding and recruitment recorded on all grids in the 1991 season was clearly a general phenomenon related to seasonal and year-to-year differences rather than to fire. Most disruption therefore seems to have been only short-term, occurring during and immediately after the fire as a result of direct death and destruction of nest sites. Such an outcome is no doubt related to the low intensity of the fire, but is also probably attributable to (a) the presence of *E. wandoo* trees near the grids which provided refuge to compensate for the loss of *A. huegeliana* trees in the fire, and (b) the small area affected by the fire (~100ha) which allowed rapid recovery of the population through recolonization from surrounding unburnt habitat, and/or enabled animals to live in unburnt areas but utilise the burnt stand for feeding.

The major differences in the phascogale populations monitored on the trap grids were between the 50-year-old unburnt area and the area that was burnt, but these differences were unrelated to the experimental fire *per se*, but rather, probably to attributes reflecting the age and fire history of the two areas. The older area appeared to be less favourable habitat for *P. calura*. Animals only occurred in numbers there during the period of maximal activity and movement prior to the breeding season, following which numbers rapidly declined again. These trends may be related to the more open stand structure of the older site which may not facilitate easy movement through the vegetation compared with the dense younger stand, or to differences pertaining to food or other resource availability which were not quantified in this study. Refuge availability is unlikely to be a factor contributing to these differences, however, since old hollow *E. wandoo* trees were more abundant in the 50-year-old area.

Although *P. calura* individuals continued to use the burnt *A. huegeliana* habitat after the fire, this area may become increasingly unsuitable for the species as the overstorey collapses. Furthermore, regenerating seedlings of *A. huegeliana* were selectively grazed and eliminated by a severe locust plague during the 1990/91 summer, and this may have dramatic long-term effects on the structure and composition of the habitat. With the elimination of the sheoak regeneration, the stand is likely to change to one with a very open canopy and a few old surviving trees, some younger *A. acuminata* and a sparse layer of shrubs. Since our data suggest that *P. calura* favour areas with a moderate to high density of *A. huegeliana* trees, it is likely that this area will become unsuited for phascogales in the longer term. This outcome shows the critical importance of the scale and timing of prescribed burns in relation to episodic (and partly predictable) events like locust plagues.

PREDICTED DISTRIBUTION USING BIOCLIM

The output from BIOCLIM, taken at the lowest level of correspondence in climate profiles, predicts a much wider distribution for *P. calura* than has been recorded. If the decline that reduced the species to its current relatively tiny distribution began to occur only with European settlement, then there are a number of predicted areas of occurrence in which red-tailed phascogales should have been recorded in the early days of settlement.

The predicted occurrence of *P. calura* in the northern wheatbelt warrants discussion, because if the species had survived there until the 1970s, it would presumably have been recorded during the Western Australian Museum's biological survey of the W.A. wheatbelt, as a number of reserves in that region were surveyed at that time. However, there are no records from the wheatbelt north of the level of Perth. This is particularly interesting with respect to the theory advanced by Kitchener (1981) that the survival of *P. calura* in its remnant populations has been dependent on the presence of fluoroacetate-bearing plants, and the protection that they afford by secondary poisoning of foxes and possibly cats through the food chain. It is certainly true that the highest concentrations of these plants occur in the Great Southern, the area which is the stronghold of *P. calura*.

DISTRIBUTION AND CONSERVATION STATUS

Collation of recent records of *P. calura* from the south-west of Western Australia indicates that up to the mid-1970s at least, the species still spanned its recorded range in the southern wheatbelt. In fact since 1980 several records to the west (Dwellingup) and south of this region (Bremer Bay) have considerably extended the recorded range of the species. Despite this, at the commencement of this project, there were only relatively few recent records of the species, and most of these were in the extensively cleared agricultural areas.

New records achieved through this project were largely from small nature reserves where no biological survey has previously been done. Kitchener (1983) stated that *P. calura* is found only in areas of the wheatbelt with an annual rainfall of 300-600mm, and that within that area it is confined to isolated reserves larger than 450ha. However, most of the previously unknown populations that we have located are in fact on much smaller reserves. Setting aside the Calyerup Creek area, which is contiguous with the 500 000ha Fitzgerald River National Park, these populations were found in 16 vegetation remnants varying in area from 67ha to 500ha, with a mean area of 251ha. Within these remnants, the phascogales appear to be predominantly in rock sheoak patches, so the effective habitat patches are much smaller than the reserve size would indicate.

The results of our survey give cause for concern. While 17 previously unknown populations have been discovered, most of these are on small isolated patches of vegetation. In addition, there seems to have been a decline in the eastern part of the species' recent range, evident from our inability to locate populations in 1386 trapnights at Bendering Nature Reserve (1601 ha) or 1173 trapnights at North Karlgarin Nature Reserve (5119 ha). The WA Museum survey obtained 6 captures of *P. calura* in 1470 trapnights (Elliott traps) at Bendering, and 6 in 966 trapnights at North Karlgarin (Kitchener and Chapman 1977).

The continued persistence of *Phascogale calura* in such a highly modified environment requires appropriate management of the remnants of habitat on which it depends. This includes management of fire regime, so that a sufficient quantity of a suitable seral stage is found on each discrete vegetation remnant (e.g. nature reserve) where a population exists. Perhaps the most important requirement is that if fire is necessary, sufficient of the *Allocasuarina huegeliana* woodland on the remnant should remain unburnt to support a population while the area being burnt returns to a suitable state. Feral predator control may also be necessary. A new project, implemented by CALM under contract to the Feral Pests Program of ANCA, commenced in April 1993 to assess the effect of fox control on populations of *P. calura*.

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TABLES

TABLE 1

Weights of male and female *Phascogale calura* immediately before and after fire (mean ± s.e.)

		BEFORE	AFTER
MALES	Grid 1	39.1 ± 0.9	43.9 ± 0.6
	Grid 2	40.0 ± 0.9	42.1 ± 1.2
	Grid 3	39.3 ± 1.8	40.4 ± 1.3
FEMALES	Grid 1	29.5 ± 1.1	30.4 ± 0.6[b]
	Grid 2	31.1 ± 0.5[a]	30.7 ± 0.4 [c]
	Grid 3	27.2 ± 0.8[a]	27.9 ± 0.6[b,c]

Significant differences (Tukey multiple comparison test); a, p = 0.005; b, p = 0.040 ;c, p = 0.018.

TABLE 2

Home range areas (ha) of radio-collared *Phascogale calura* at Tutanning in March 1990 before and after fire calculated as area enclosed in isopleths of harmonic mean distance including 50% and 95% of fixes.

	BEFORE FIRE		AFTER FIRE		NUMBER OF FIXES	
	50%	95%	50%	95%	BEFORE FIRE	AFTER FIRE
BURN BLOCK						
Females						
AF21	0.34	1.93	-		53	-
AF23	0.78	3.35	-		58	-
AF24	0.56	4.56	0.33	2.03	49	28
AF66	1.06	6.49	0.36	1.50	54	46
AF83	0.67	2.49	0.38	0.96	50	35
AF95	0.55	3.08	0.15	1.25	80	38
Mean ± SD	0.66±0.24	3.65±1.65	0.31±0.11	1.44±0.45		
Males						
AM22	0.74	4.27	0.78	5.23	63	40
AM19	1.20	8.83	0.26	4.10	51	29
AM70	0.93	6.27	0.47	2.97	52	31
AM83	0.53	5.20	-	-	82	-
Mean ± SD	0.53±0.28	6.14±1.97	0.50±0.21	4.10±1.13		
UNBURNT BLOCK						
Females	50%	95%				
AF1	0.23	0.93			44	
AF19	0.47	2.10			76	
AF28	0.37	2.21			32	
AF29	0.19	0.50			32	
Mean ± SD	0.32±0.13	1.44±0.85				
Males						
AM4	0.38	1.85			50	
AM23	0.73	5.37			65	
Mean ± SD	0.56±0.25	3.61±2.49				

TABLE 3

Nest-sharing by *P. calura* at Tutanning sudy site in March 1990. Each letter refers to a particular nest site shared by two or more animals on any one day.

ANIMAL NO	DATES					
Grid 2 (before fire)						
	11/3	14/3	15/3	16/3	17/3	20/3
AF21	B	C	E	G		
AF23		D			D	D
AF24	B	C	C	E	E	
AF66	B	C	C	E		
AF83		D			D	D
AF95	A		F	G	E	
AM19						
AM22		C	E	E	E	
AM70	A					
AM83			F			
Grid 3 (unburnt "control")						
	11/3	14/3	15/3	16/3	17/3	21/3
AF1						
AF19						
AF28						
AF29	X			X		
AM4	X			X		
AM23						

TABLE 4

Home range areas (ha) of radio-collared *Phascogale calura* radio-tracked in March 1991, calculated as area enclosed in isopleths of harmonic mean distance including 50% and 95% of fixes.

	50%	95%	NO. OF FIXES
FEMALES			
AF44	3.03	17.86	84
AF46	1.30	6.46	79
AF49	1.30	5.53	78
AF50	1.22	5.25	78
AF92	0.97	7.22	89
Mean ±SD	1.56 ±0.83	8.46 ±5.31	
MALES			
AM32	2.02	8.62	83
AM33	1.29	8.62	86
AM35	1.69	9.43	82
AM38	1.56	4.93	85
AM39	0.92	6.54	84
Mean ±SD	1.50 ±0.42	7.80 ±1.79	

TABLE 5

Home range areas (ha) of radio-collared *Phascogale calura* radio-tracked in July 1991, calculated as area enclosed in isopleths of harmonic mean distance including 50% and 95% of fixes.

	50%	95%	NO. OF FIXES
FEMALES			
AF36	1.49	9.27	50
AF55	0.30	12.29	47
AF56	0.95	4.57	112
Mean ±SD	0.91 ±0.60	8.71 ±3.89	
MALES			
AM33	13.22	88.79	20
AM50	26.93	117.18	33
Mean ±SD	20.08±9.70	102.99 ±20.07	

TABLE 6

Home range areas (ha) of radio-collared *Phascogale calura* radio-tracked in June and July 1992, calculated as area enclosed in isopleths of harmonic mean distance including 50% and 95% of fixes.

	JUNE			JULY		
	50	95%	NO. OF FIXES	50%	95%	NO. OF FIXES
FEMALE						
AF61	1.83	7.99	98	1.28	8.05	45
MALES						
AM52	6.71	34.08	74	2.80	23.27	22
AM53	4.85	20.37	51	1.88	12.55	45
AM54	0.90	5.20	41	0.08	0.55	12
AM64	7.80	41.44	67	3.97	23.43	19
AM65	5.36	24.19	76	1.50	12.85	35
AM88	8.56	57.13	41	2.10	9.23	13
Mean ±SD	5.70 ±2.74	30.40 ±18.02		2.06 ±1.30	13.67 ±8.75	

TABLE 7

Pre-fire densities (stems/ha) of main tree species on grids estimated by triangular tessellation

SPECIES		GRID 1	GRID 2	GRID 3
Allocasuarina huegeliana	alive	2923	2870	1631
	dead	2030	516	362
Eucalyptus wandoo	alive	308	83	336
	dead	31	0	39
Acacia acuminata	alive	61	206	0
	dead	277	289	0
MEAN ± S.E.# (stems/ha)		5908 ± 1017	3965 ± 509	2485 ± 476

mean includes stems of other species

TABLE 8

Densities (stems/ha) of live and dead *Allocasuarina huegeliana* before and after fire estimated by triangular tessellation

		GRID 1	GRID 2
PRE-FIRE	alive	2923	2870
	dead	2030	516
POST-FIRE	alive	707	908
	dead	4246	2478
% KILLED		76	68

TABLE 9

Total abundance and condition of co-dominant species (excluding *Allocasuarina huegeliana*) and hollow logs and burnt logs over each grid area (1.96ha).

COMPONENT	GRID 1 (burnt)	GRID 2 (burnt)	GRID 3 (unburnt)
Young *Eucalyptus wandoo*	267	98	179
Old hollow *Eucalyptus wandoo*	2	0	110
Xanthorrhoea drummondii	25	146	357
Young *Acacia acuminata*	55	54	2
Old *Acacia acuminata* (alive)	16	16	0
Dead *Acacia acuminata*	255	428	1
No. of hollow logs	25	20	73
No. of logs burnt	46	17	-

TABLE 10

Sites and success of surveys for *Phascogale calura* during this project, according to CALM region and district and local authority. New records are denoted by an asterisk: survey sites where previously known populations were not relocated are shown in italics.

Location	Previous record?	Population located?		Size (ha)
SWAN REGION				
<u>Dwellingup District</u>				
Shire of Wandering				
Wandering Block SF (Mooramockining Hill)	No	No		~1200
WHEATBELT REGION				
<u>Narrogin District</u>				
Shires of Cuballing & Williams				
Dryandra SF (main block)	Yes	Yes		~13000
Shires of Brookton & Pingelly				
Boyagin NR (east block)	Yes	Yes		2000
Shire of Brookton				
Weam NR	No	Yes	*	250
Pingeculling NR	No	Yes	*	400
Shire of Narrogin				
Yilliminning NRs	No	Yes	*	323
Highbury SF (Borgey Block)	No	Yes	*	962
Shire of Kondinin				
Bendering NR	*Yes*	*No*		1601
North Karlgarin NR	*Yes*	*No*		5119
Shire of Wickepin				
East Yornaning NR	Yes	Yes		248
NR 19122	No	Yes	*	144
NR 19118	No	Yes	*	207

Location	Previous record?	Population located?		Size (ha)
Shire of Pingelly				
Tutanning NR	Yes	Yes		2089
PP S of Landscape H. NR39174	No	Yes	*	140 total
Noombling NR 26150	No	No		64
Hotham River NR 8291	No	Yes	*	139
Pumphreys Bridge NR 21286	No	No		61
Boonagin NR 21287	No	Yes	*	202
Petercarring NR 20095	No	Yes	*	100
Mourambine NR 6798	No	No		19
<u>Katanning District</u>				
Shire of Kent				
Lake Magenta NR	No	No		94170
Shire of Dumbleyung				
Dongolocking NRs	Yes	Yes		1232
Tarin Rock NR 25711	No	No		2010
North Tarin Rock NR 29857	No	No		1416
Shire of Woodanilling				
Wingedyne NR 28471	No	No		253
PP near 28471	No	No		60
Gravel Reserve 15801	No	No		23
King Rock NR 9377 & Gravel Reserve 27923	No	Yes	*	67
NR 5339	No	No		40
Shire of Katanning				
"Old Airstrip" Reserve	No	No		308
Johns Well NR 24599	No	No		385
NR24282	No	No		308
Shire of Wagin				
Mt Latham PWD 27580	No	Yes	*	500
North Wagin NR 30443	No	Yes	*	90
Parkeyerring Lake NR 24792	No	Yes	*	306
Timber Reserve 14459	No	Yes	*	453
Shire of West Arthur				
PP at Dardadine Siding (Williams loc 9981)	No	Yes	*	200
Hillman NR 16904	No	No		247

Location	Previous record?	Population located?		Size (ha)
SOUTH COAST REGION				
<u>Albany District</u>				
Shire of Gnowangerup				
"Calyerup Creek" (VCL adj. Fitzgerald R NP)	No	Yes	*	500000+
PP Kent locn 1408	No	No		1448
PP cnr Stock & Chittowurup Rds	No	No		564
PP Kent locn 1460	No	No		1355
PP Kent locn 1419	No	No		2409

TABLE 11

Trapping effort, *Phascogale calura* capture rate and captures of other vertebrates in Elliott traps at each survey site.

LOCATION	EFFORT (TRAP-NIGHTS)	*P. CALURA* CAPTURE RATE x 100	OTHER CAPTURES
East Yornaning NR	40	32.5	-
Lake Magenta NR	1530	0	1 *Sminthopsis granulipes* 5 *Pseudomys albocinerus* 1 *Notomys mitchelli* 3 *Mus domesticus*
Dryandra SF	150	4.7	1 *Antechinus flavipes* 1 *Sminthopsis gilberti* 1 *Mus domesticus*
Parkeyerring Lake NR	40	2.5	-
Dongolocking NRs	754	0.5	2 *Mus domesticus*
Highbury Block SF	738	0.3	1 *Mus domesticus*
Wandering Block SF (Mooramockining Hill)	200	0	2 *Mus domesticus*
Pingeculling NR	140	12.1	2 *Mus domesticus*
Yilliminning NRs	150	3.3	
Highbury SF (Borgey Block)	672	0.29	1 *Mus domesticus*
Bendering NR	1386	0	1.*Mus domesticus* 5 *Tiliqua rugosa*
North Karlgarin NR	1173	0	21 *Mus domesticus* 11 *Notomys mitchelli* *4 Tiliqua rugosa*
NR 19122	150	0.66	
NR 19118	120	2.5	
PP S of Landscape H. NR39174	140	1.4	1 *Mus domesticus*
Noombling NR 26150	82	0	5 *Mus domesticus*
Hotham River NR 8291	40	7.5	1 *Tiliqua rugosa*
Pumphreys Bridge NR 21286	51	0	1 *Mus domesticus*

TABLE 11 continued

Boonagin NR 21287	60	1.66	
Petercarring NR 20095	30	10	
Mourambine NR 6798	40	0	5 *Mus domesticus*
Tarin Rock NR 25711	850	0	1 *Pseudomys occidentalis* 1 *Trichosurus vulpecula* 5 *Mus domesticus* 1 *Tiliqua rugosa*
North Tarin Rock NR 29857	460	0	6 *Mus domesticus* 1 *Tiliqua rugosa*
Wingedyne NR 28471	25	0	
PP near 28471	25	0	
Gravel Reserve 15801	25	0	1 *Mus domesticus*
King Rock NR 9377 & Gravel Reserve 27923	30	3.33	
NR 5339	120	0	11 *Mus domesticus* 2 *Rattus rattus*
"Old Airstrip" Reserve	45	0	3 *Mus domesticus*
Johns Well NR 24599	198	0	6 *Mus domesticus* 1 *Tiliqua rugosa*
NR24282	75	0	1 *Mus domesticus*
Mt Latham PWD 27580	90	10	
North Wagin NR 30443	40	0	
Parkeyerring Lake NR 24792	40	2.5	
Timber Reserve 14459	120	4.2	2 *Mus domesticus* 1 *Tiliqua rugosa*
PP at Dardadine Siding (Williams loc 9981)	50	24	
Hillman NR 16904	75		1 *Mus domesticus*
"Calyerup Creek" (VCL adj. Fitzgerald R NP)	160	4	1 *Mus domesticus* 3 *Rattus fuscipes*
PP Kent locn 1408PP cnr Stock & Chittowurup Rds	100	0	
PP Kent locns 1460 & 1419	60	0	

LIST OF FIGURES

Figure 17. "Social" home ranges shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for male (blue) and female (red) *Phascogale calura* near Grid 3 in the control (unburnt) block at Tutanning NR in March 1990, before the fire.

Figure 18. "Core" home ranges shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for surviving male (blue) and female (red) *Phascogale calura* near Grid 2 in the burn block at Tutanning NR in March 1990, after the fire.

Figure 19. "Social" home ranges shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for surviving male (blue) and female (red) *Phascogale calura* near Grid 2 in the burn block at Tutanning NR in March 1990, after the fire.

Figure 20. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for female 24 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 21. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for female 24 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 22. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for female 66 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 23. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for female 66 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 24. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for female 83 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 25. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for female 83 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 26. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for female 95 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 27. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for female 95 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 28. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for male 19 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 29. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for male 19 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 30. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for male 22 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 31. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for male 22 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 32. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for male 70 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 33. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for male 70 near Grid 2 in the burn block at Tutanning NR in March 1990, before the fire (green) and after the fire (red).

Figure 34. Survival of *Phascogale calura* nests in the fire at Tutanning NR, according to the type of hollow. The 18 nests recorded in use by radio-collared animals before and during the fire were checked after the fire and their survival or destruction noted.

Figure 35. "Core" home range shown as isopleths of harmonic mean distance enclosing 50% of acceptable fixes for male (blue) and female (red) *Phascogale calura* near Grid 2 in the burn block at Tutanning NR in March 1991, 1 year after the fire.

Figure 36. "Social" home range shown as isopleths of harmonic mean distance enclosing 95% of acceptable fixes for male (blue) and female (red) *Phascogale calura* near Grid 2 in the burn block at Tutanning NR in March 1991, 1 year after the fire.

Figure 37. Percentage frequency of use of different types of nest hollow used in March 1990 before the fire compared with that to one year after the fire, in March 1991.

Figure 38. Three dimensional representation of density of *Allocasuarina huegeliana* stems on Grid 1.

Figure 39. Three dimensional representation of density of *Allocasuarina huegeliana* stems on Grid 2.

Figure 40. Three dimensional representation of density of *Allocasuarina huegeliana* stems on Grid 3.

Figure 41. Three dimensional representation of scorch heights on Grid 1.

Figure 42. Three dimensional representation of scorch heights on Grid 2.

Tutanning Nature Reserve - Fire History

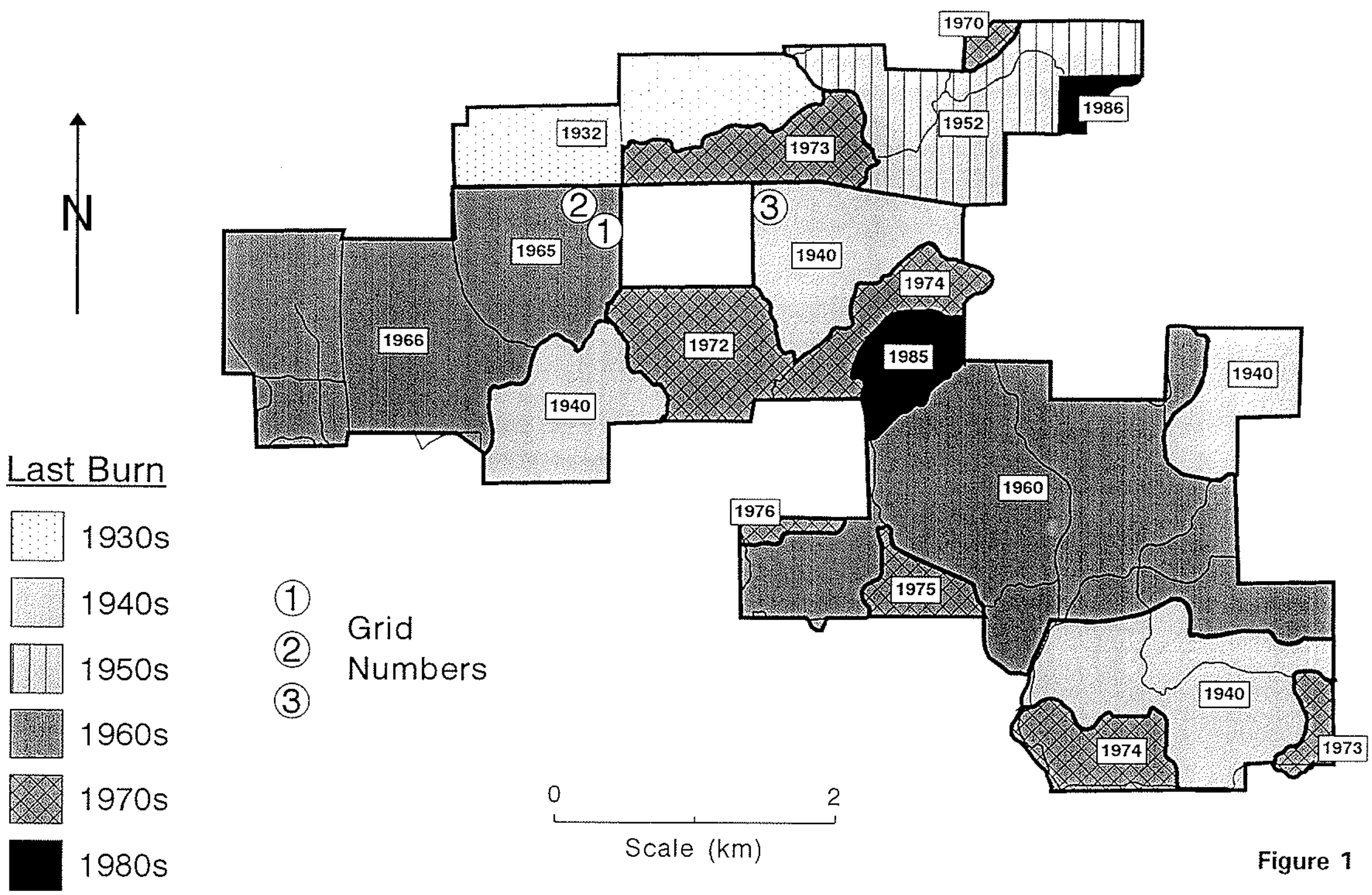


Figure 1

NUMBERS KNOWN TO BE ALIVE (KTBA)

MALE PHASCOGALE CALURA

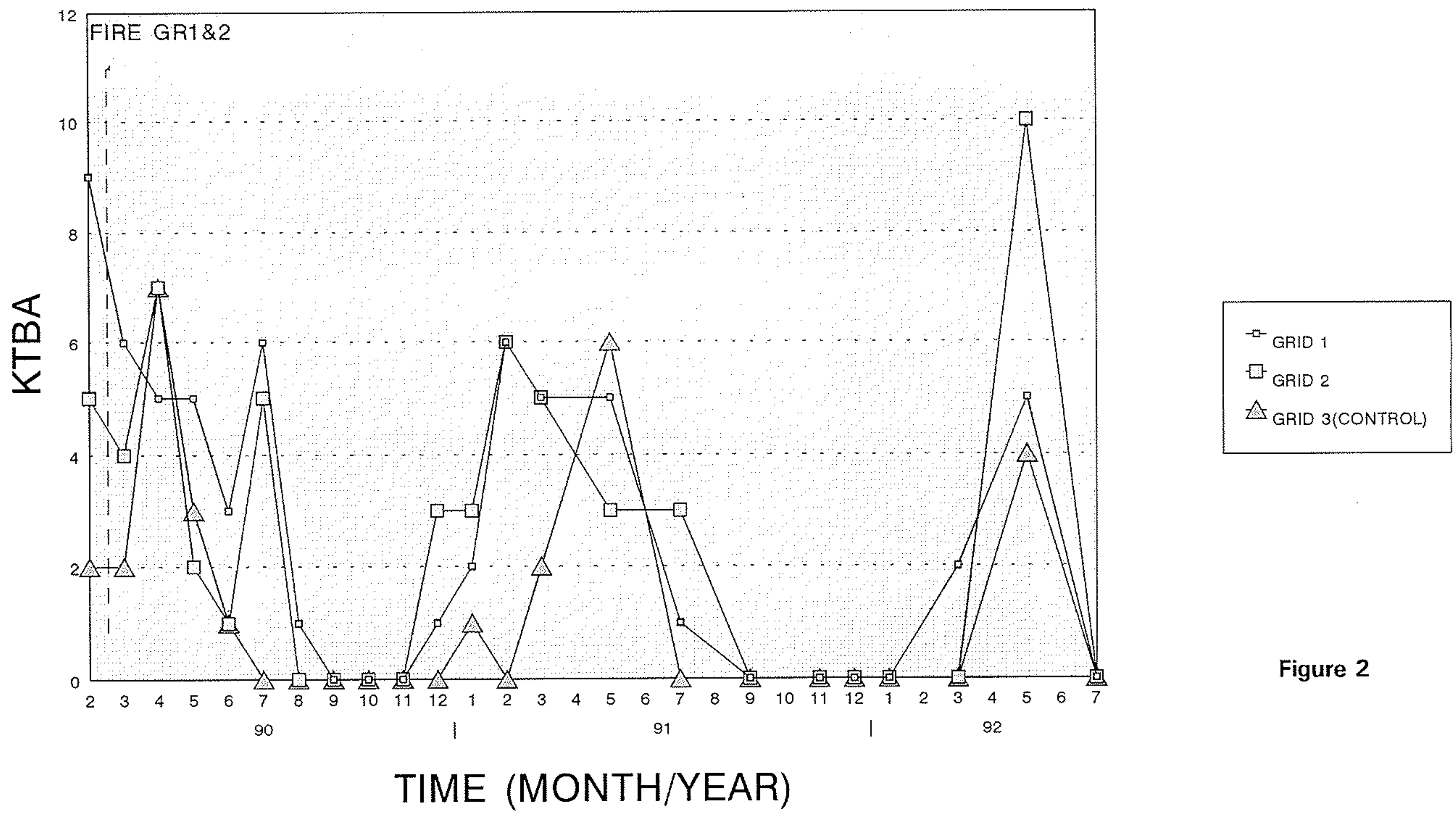


Figure 2

NUMBERS KNOWN TO BE ALIVE (KTBA)

FEMALE PHASCOGALE CALURA

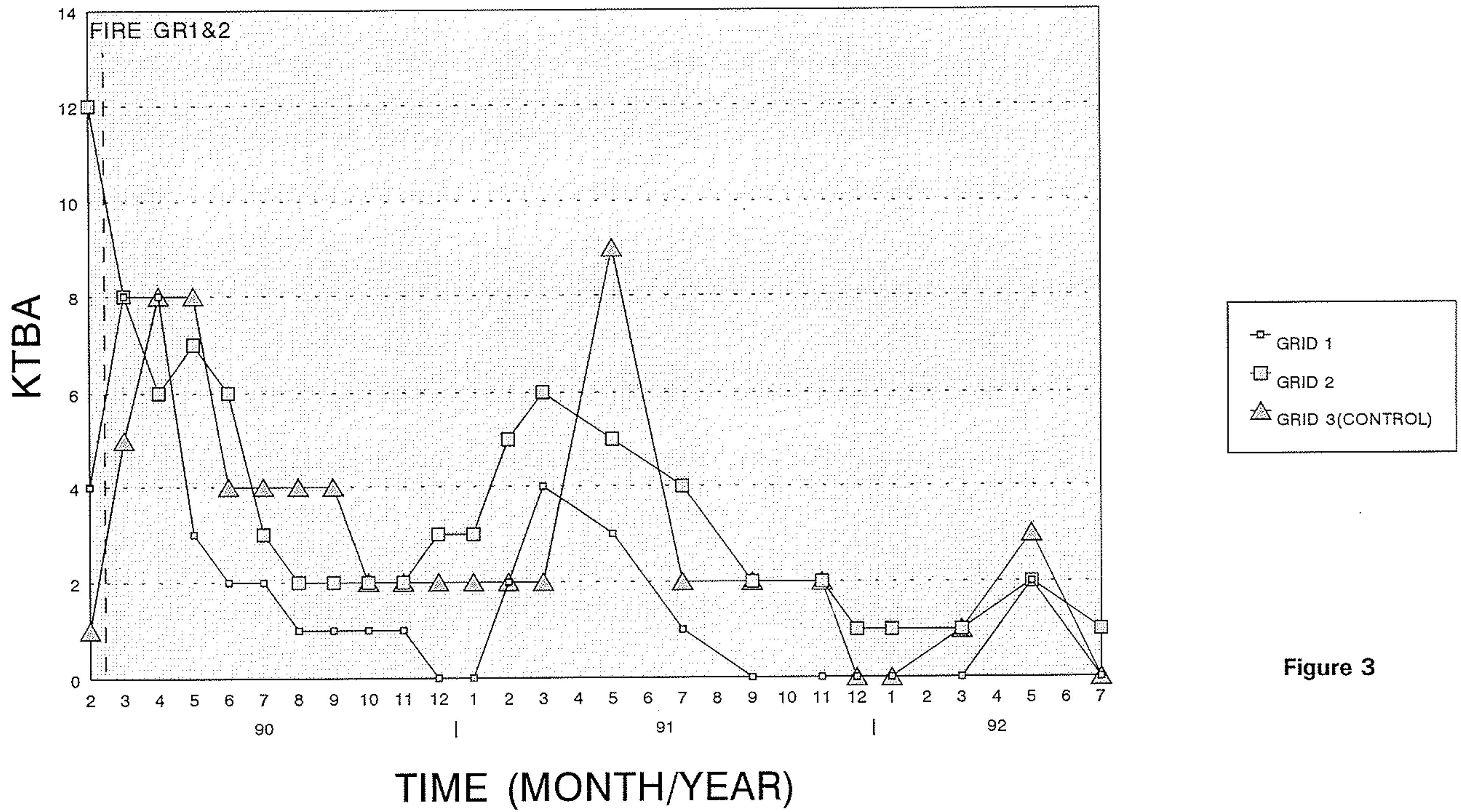


Figure 3

NUMBERS KNOWN TO BE ALIVE (KTBA)

TOTAL PHASCOGALE CALURA

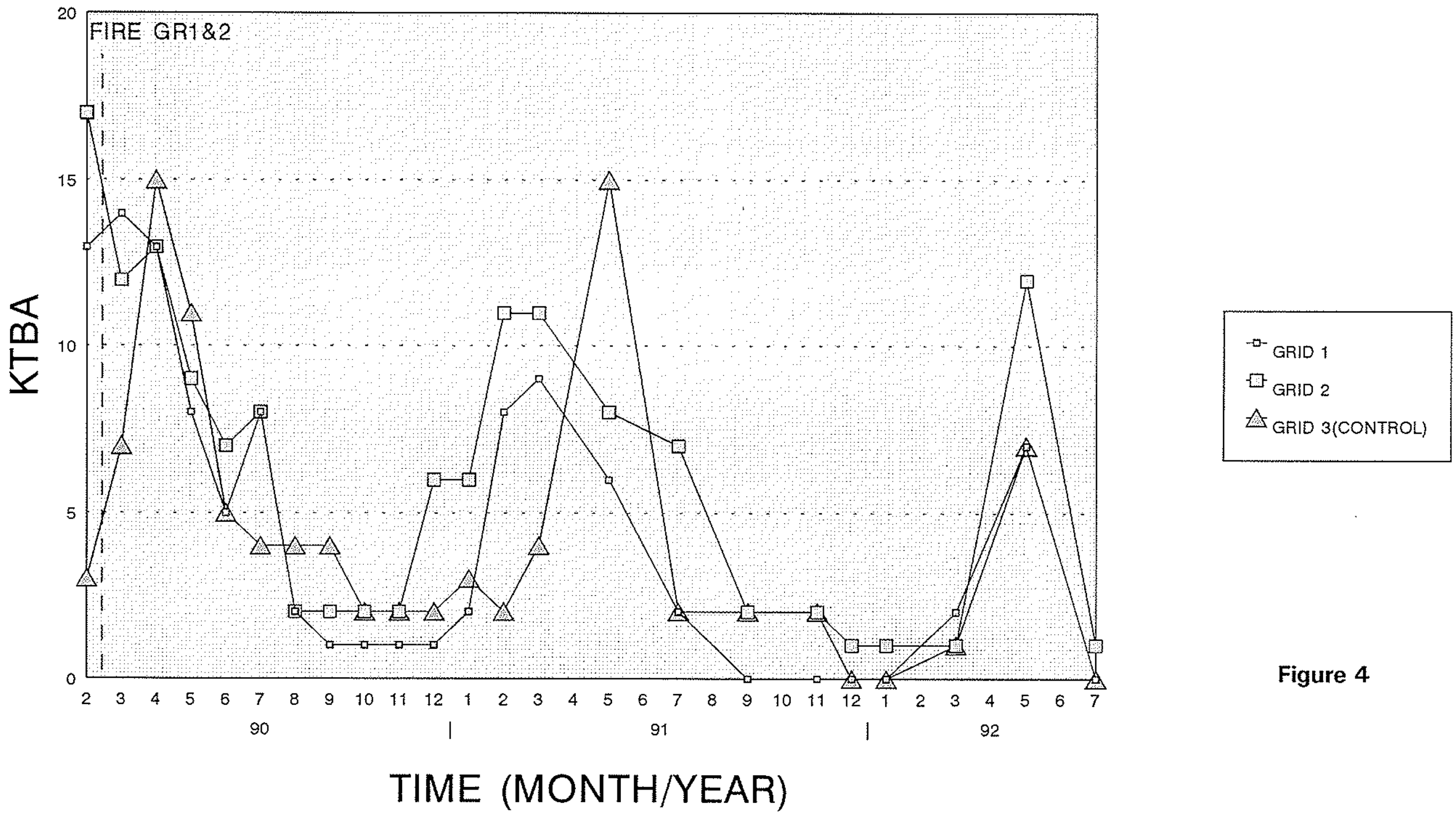


Figure 4

MEAN WEIGHT V TIME OF YEAR

MALE PHASCOGALE CALURA

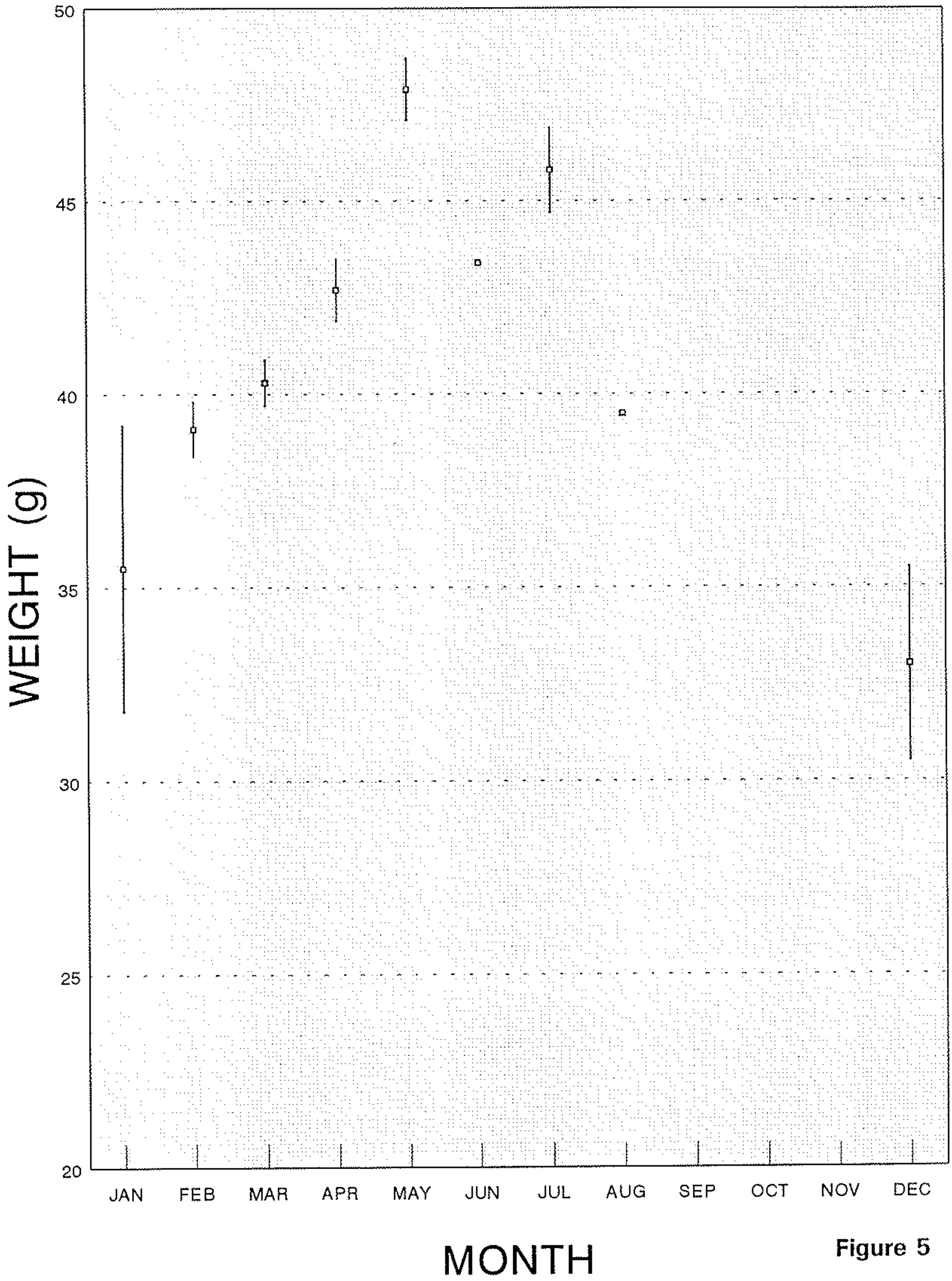


Figure 5

SCROTAL WIDTH V TIME OF YEAR

PHASCOGALE CALURA

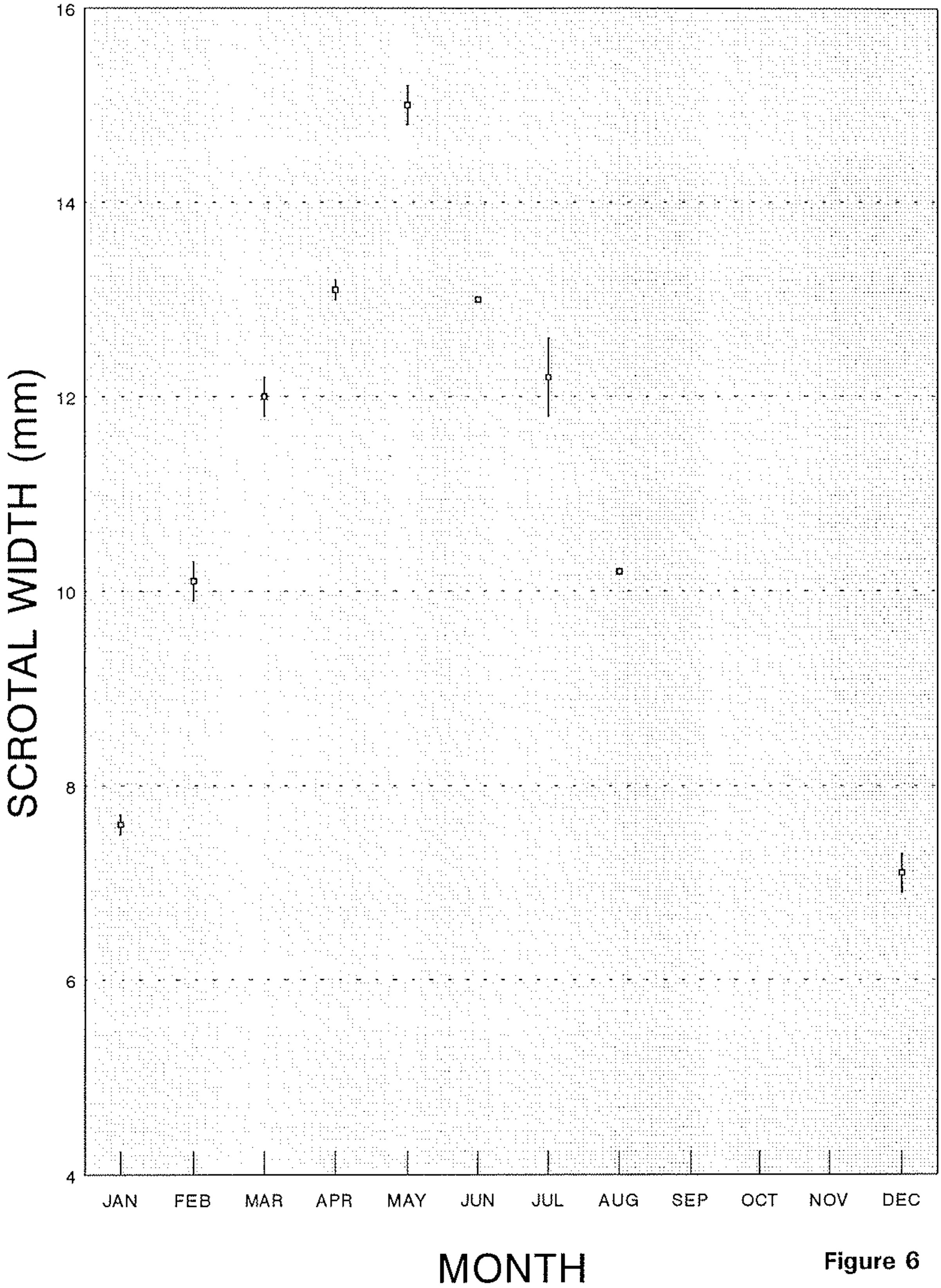


Figure 6

MEAN WEIGHT V TIME OF YEAR

FEMALE PHASCOGALE CALURA

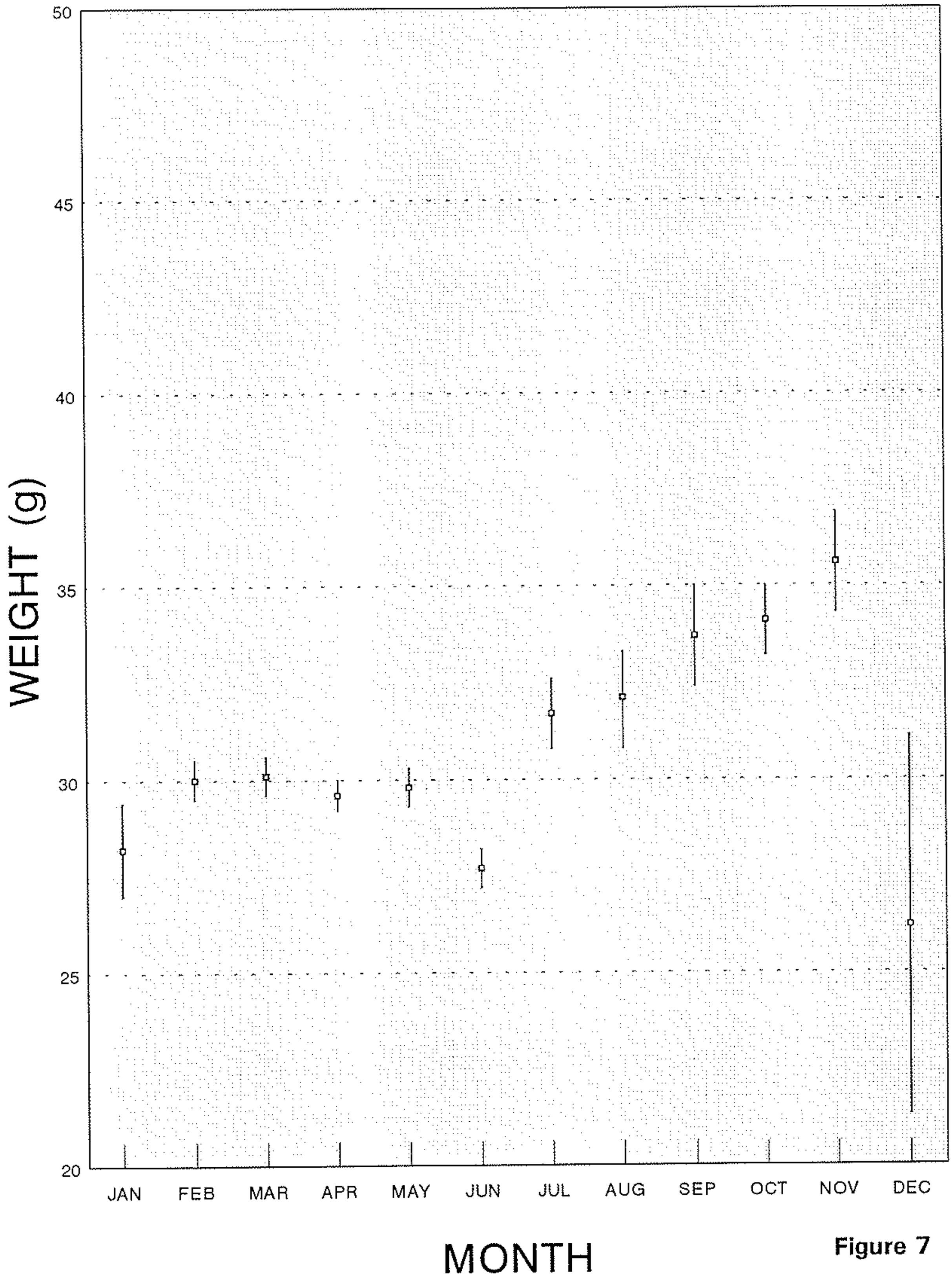


Figure 7

MEAN WEIGHTS OVER TIME

MALE PHASCOGALE CALURA

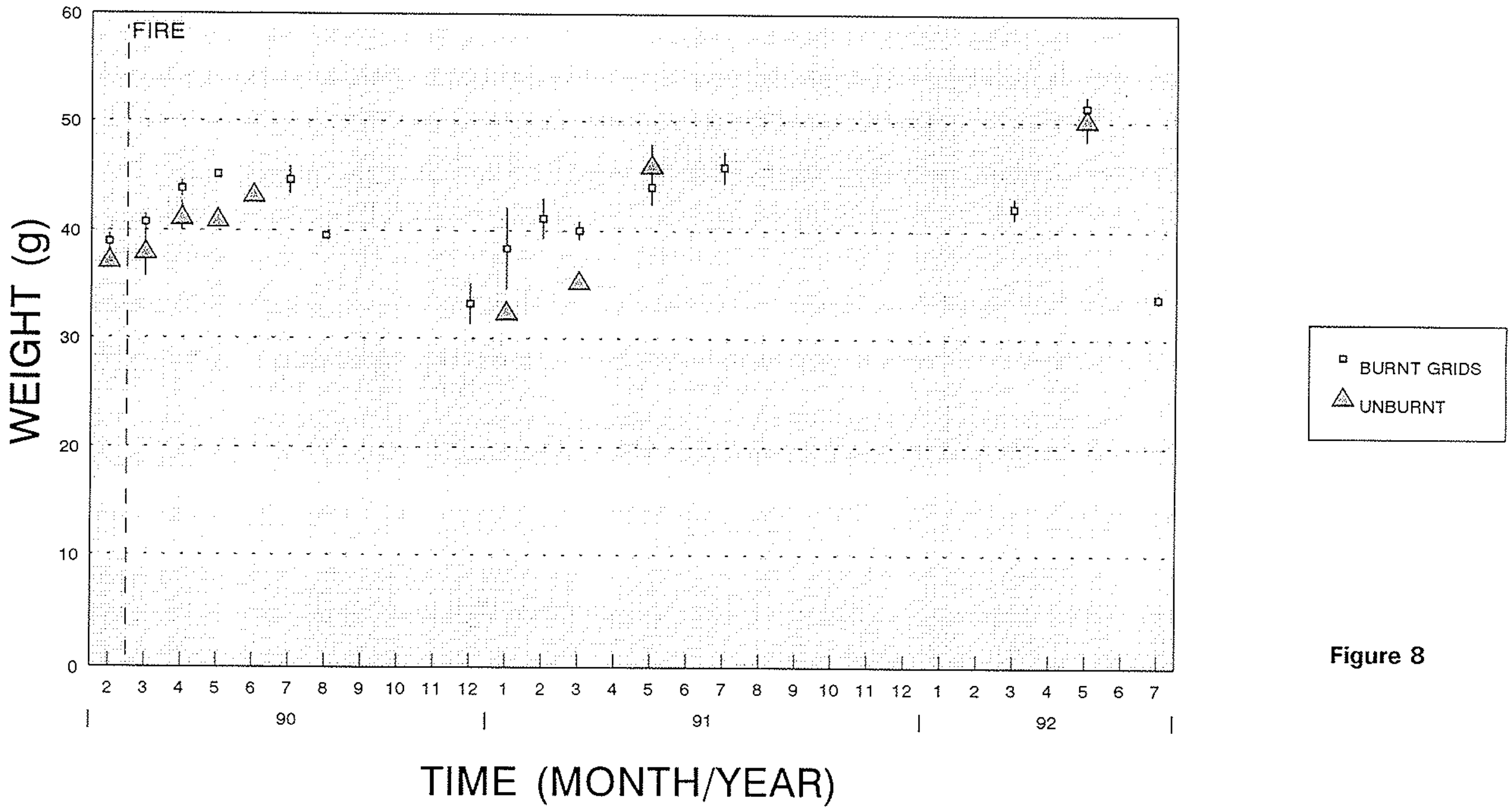


Figure 8

MEAN WEIGHTS OVER TIME

FEMALE PHASCOGALE CALURA

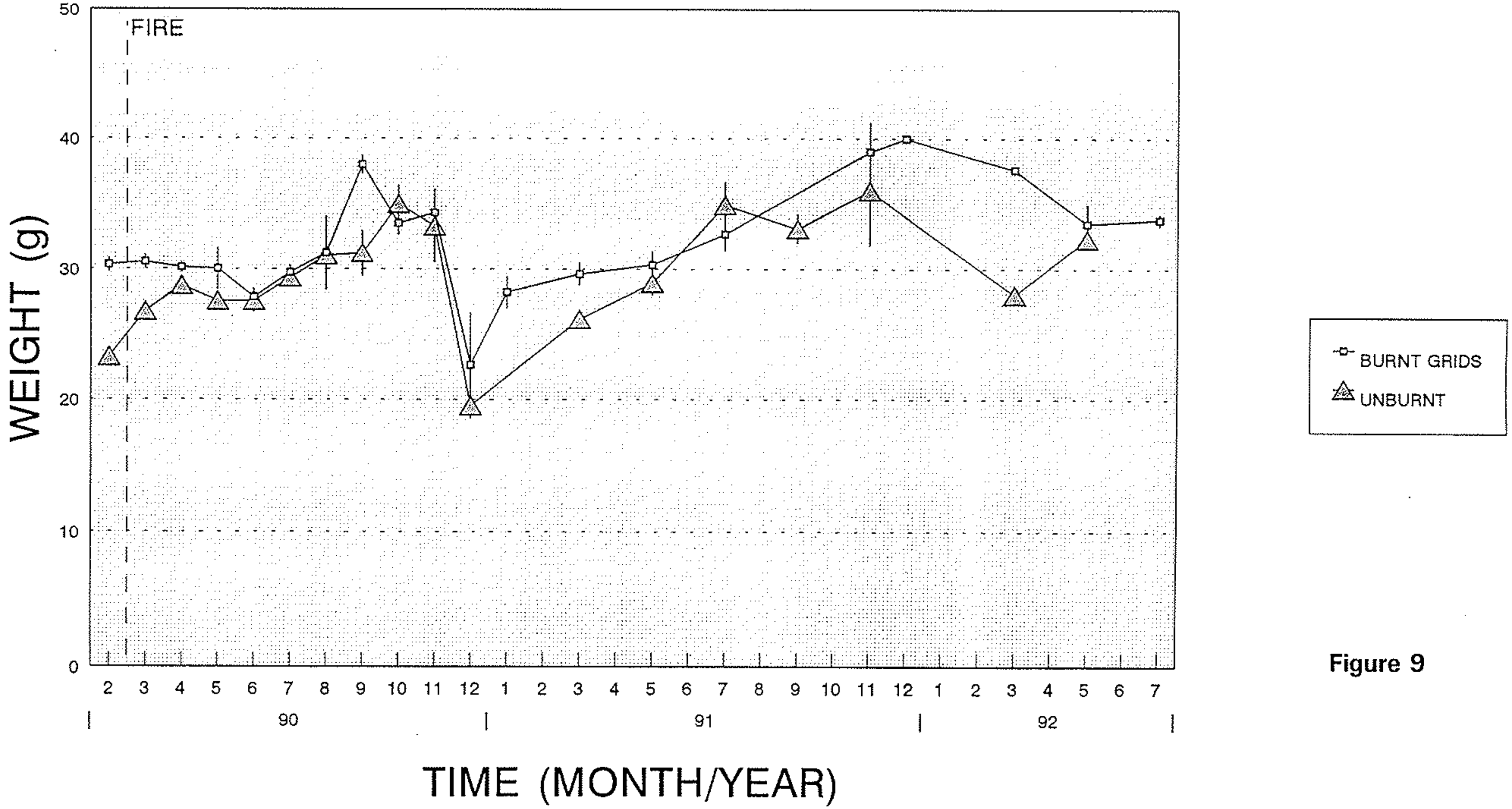


Figure 9

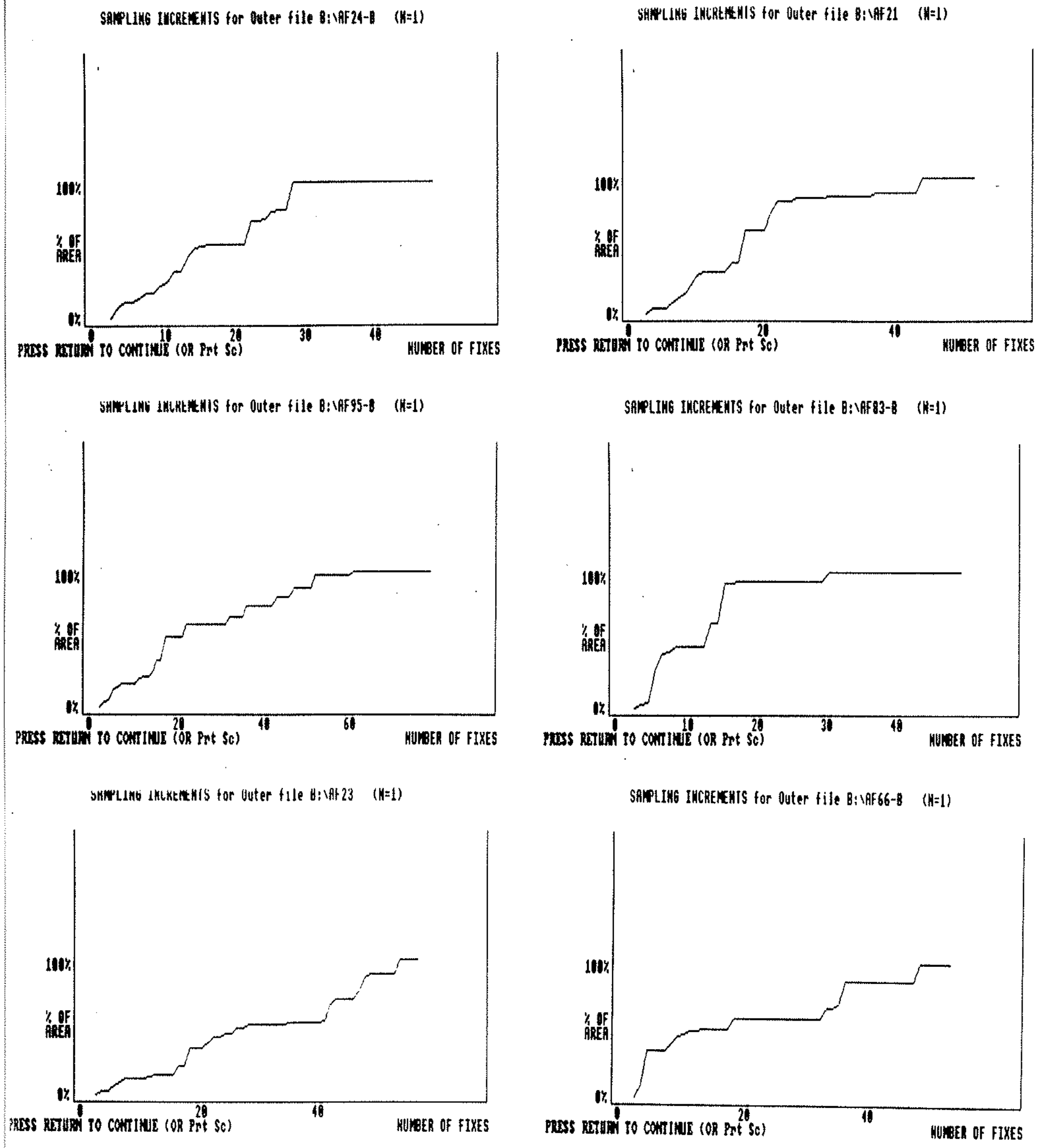


Figure 10.
Females on Grid 2 before fire.

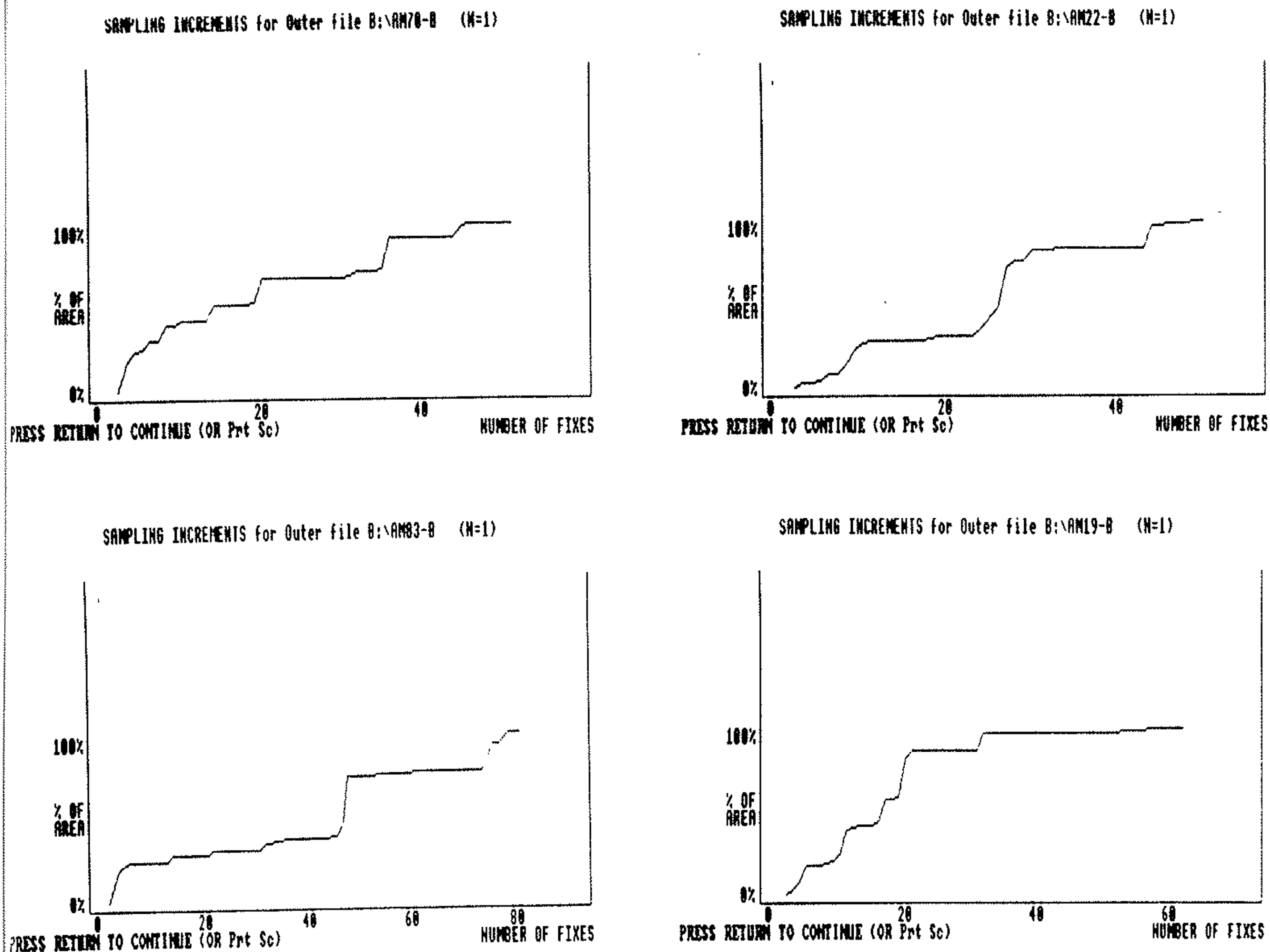


Figure 11.
Males on Grid 2 before fire.

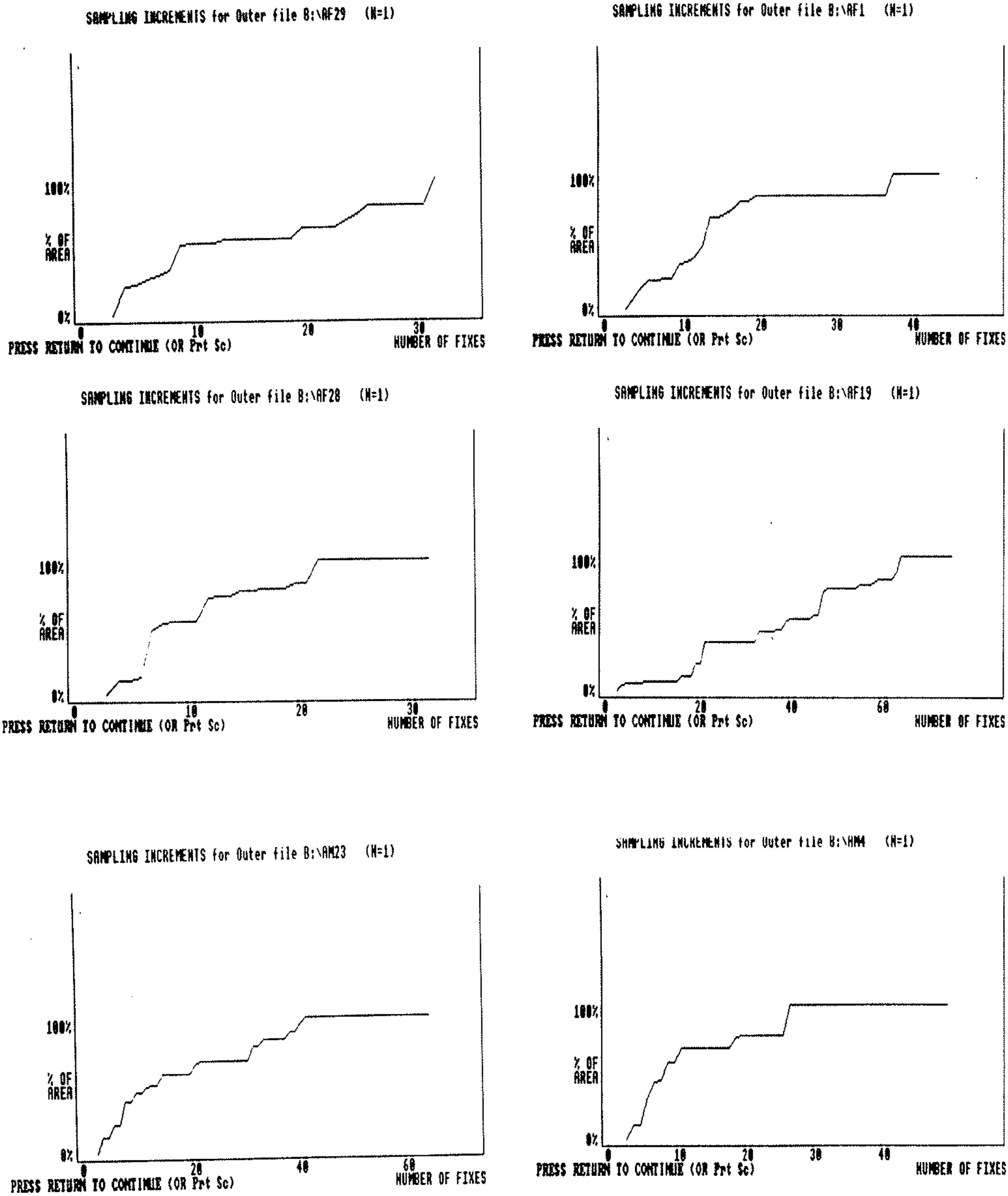
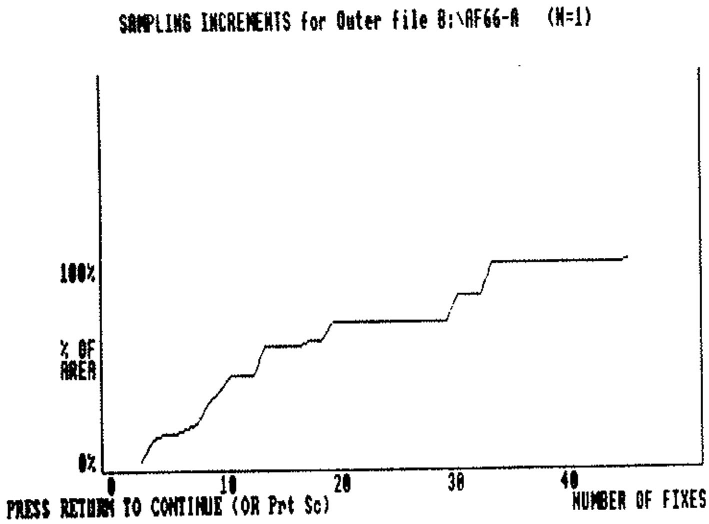
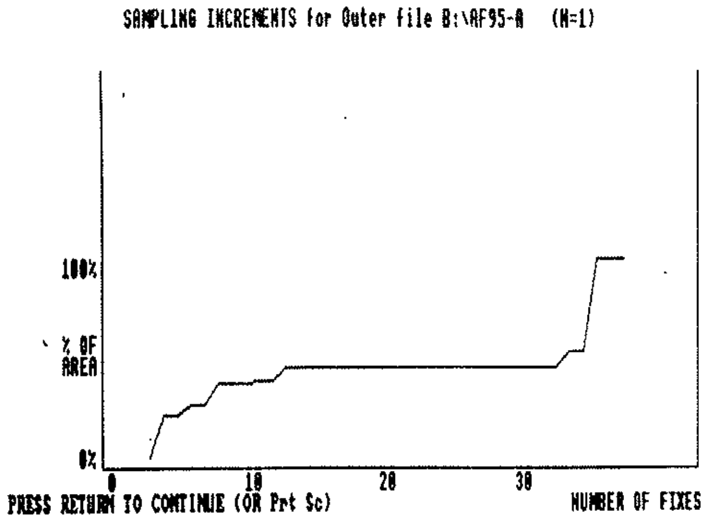
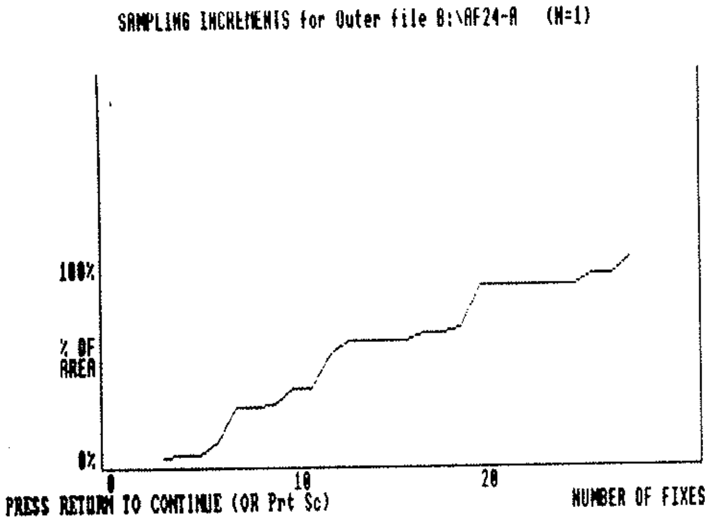
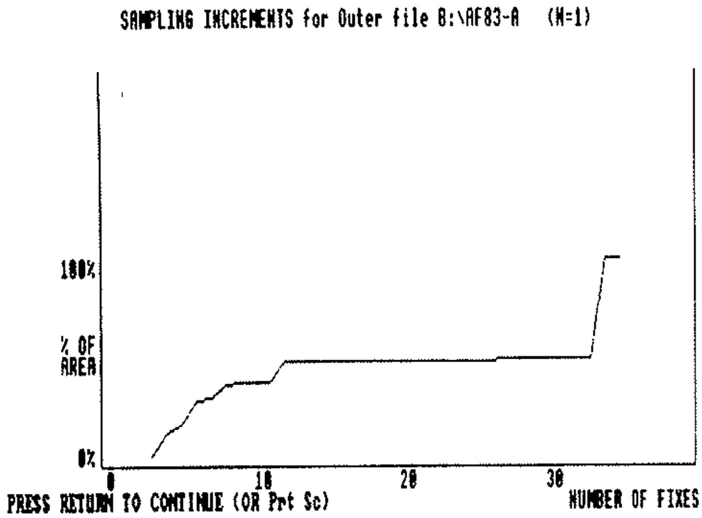


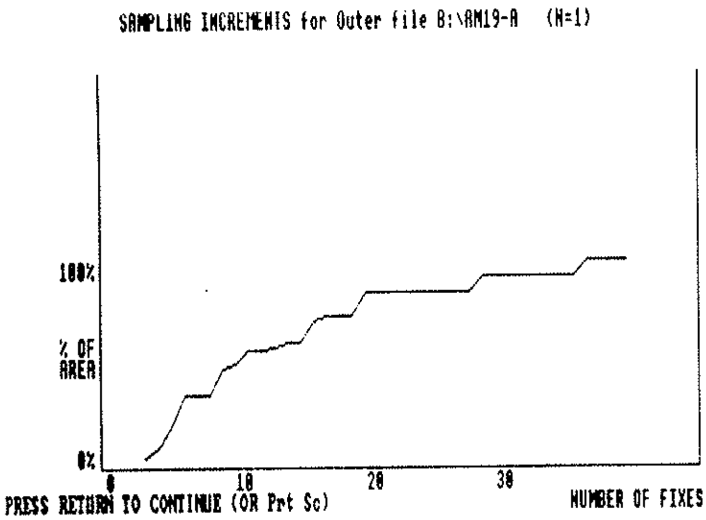
Figure 12.
Males and females on Grid 3.

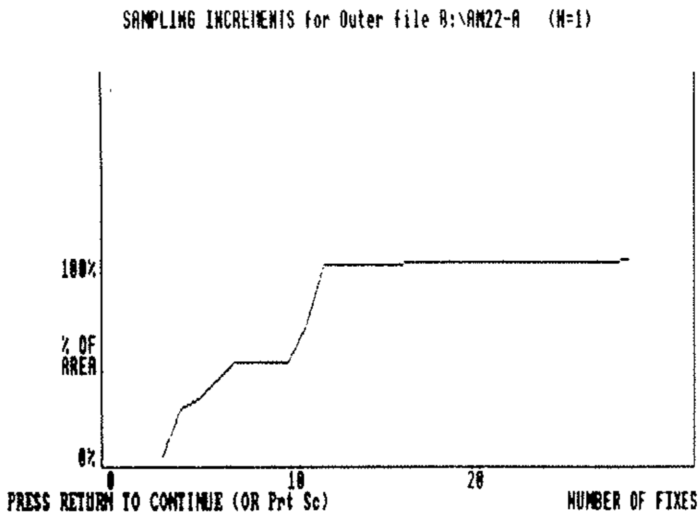












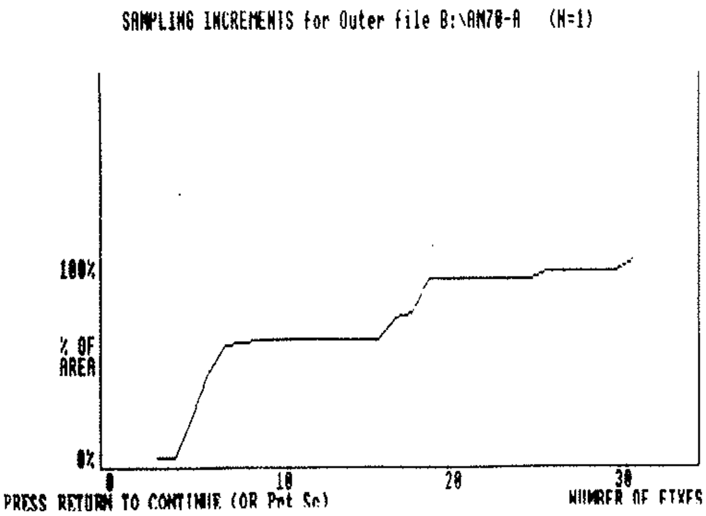


Figure 13.
Males and females on Grid 2 after fire.

50% EDGES from Hc contour file a:\PRE-BURN.50

1 AF21
2 AF23
3 AF24
4 AF66
5 AF83
6 AF95
7 AM19
8 AM22
9 AM70
10 AM83

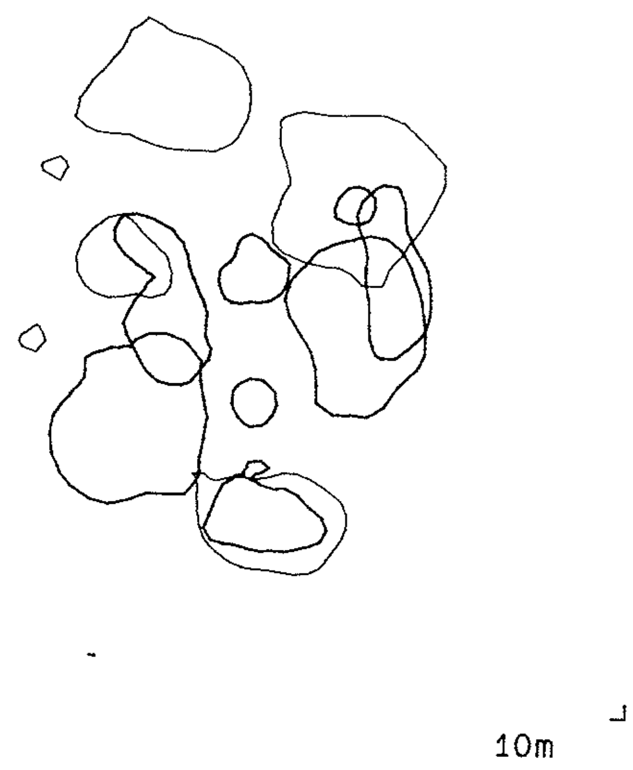


Figure 14

95% EDGES from Hc contour file a:\PRE-BURN.95

1 AF21
2 AF23
3 AF24
4 AF66
5 AF83
6 AF95
7 AM19
8 AM22
9 AM70
10 AM83

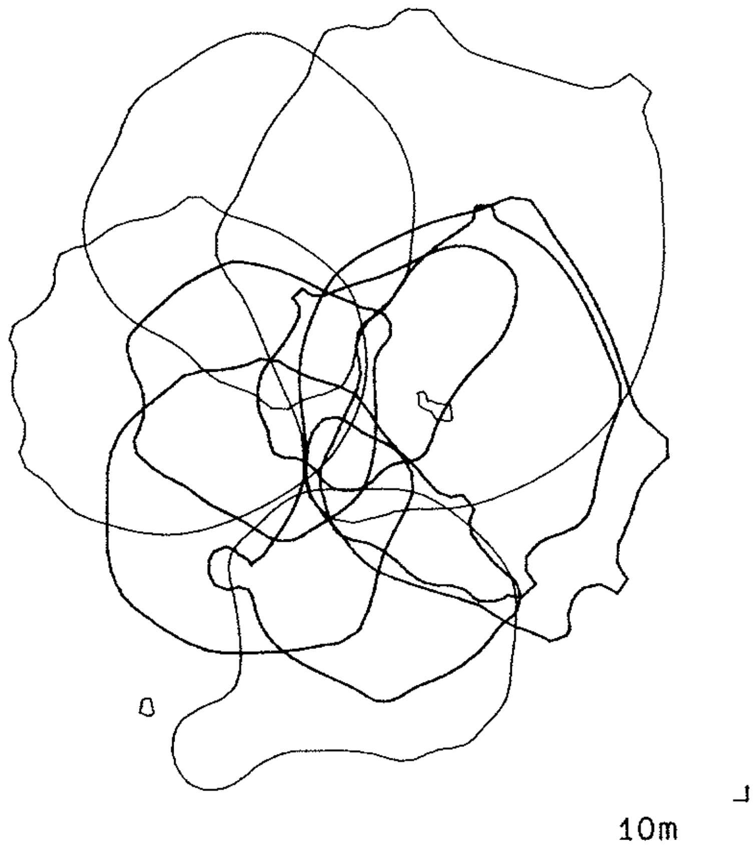


Figure 15

50% EDGES from Hc contour file a:\GR3T-50

1 AF1
2 AF19
3 AF28
4 AF29
5 AM4
6 AM23

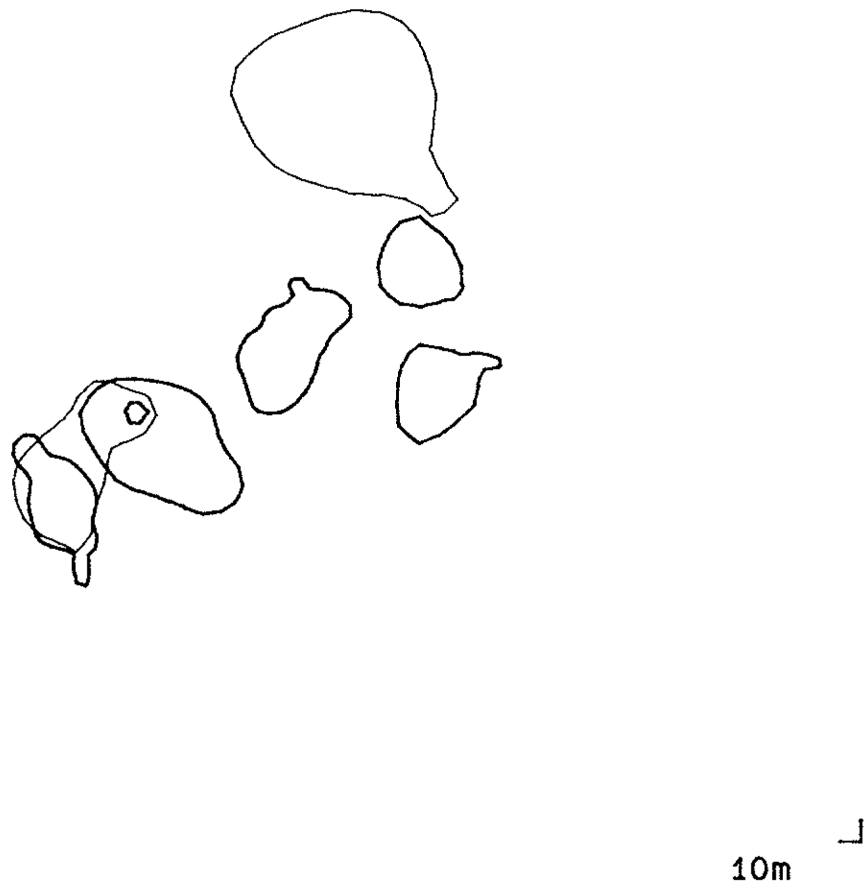


Figure 16

95% EDGES from Hc contour file a:\GR3T-95

1 AF1
2 AF19
3 AF28
4 AF29
5 AM4
6 AM23

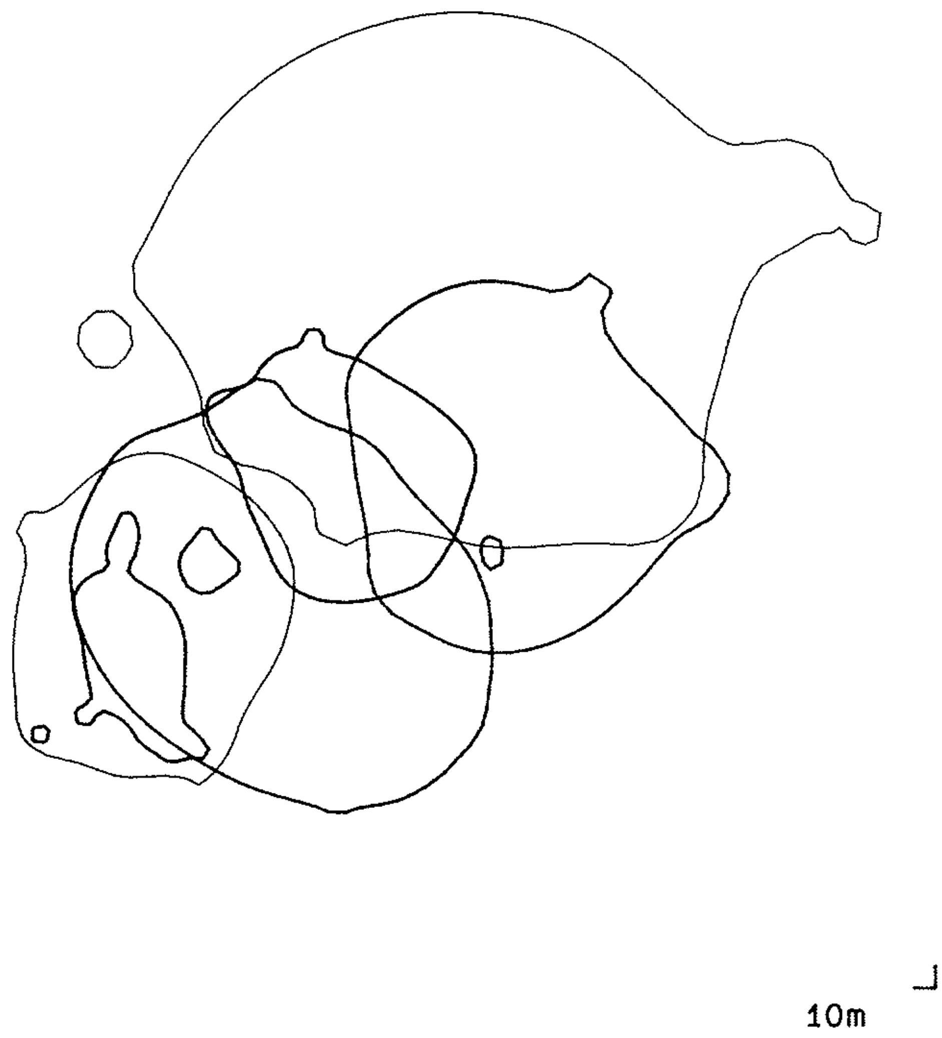


Figure 17

50% EDGES from Hc contour file a:\POS-BURN.50

1 AF24
2 AF66
3 AF83
4 AF95
5 AM19
6 AM22
7 AM70

Figure 18

95% EDGES from Hc contour file a:\POS-BURN.95

1 AF24
2 AF66
3 AF83
4 AF95
5 AM19
6 AM22
7 AM70

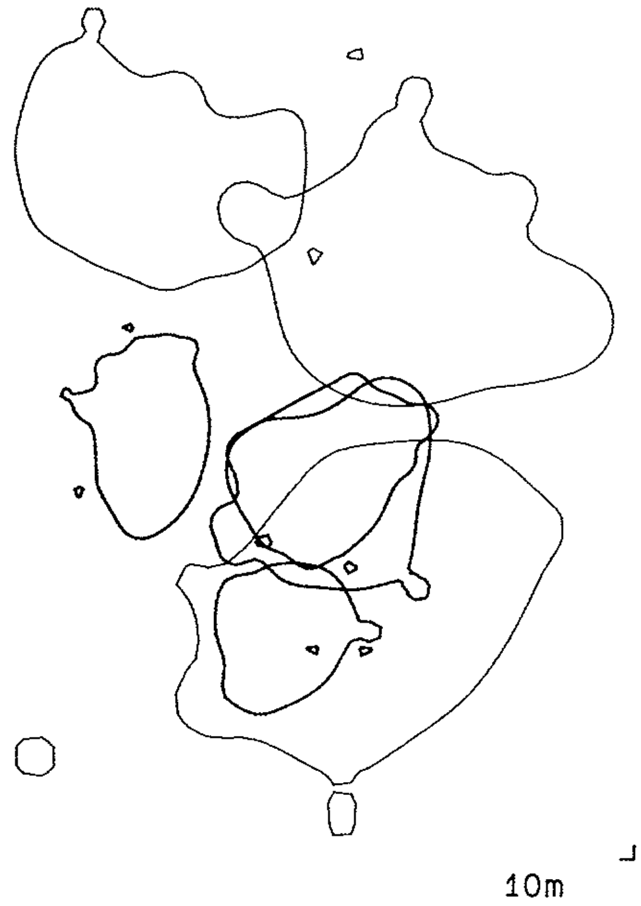


Figure 19

50% EDGES from Hc contour file a:\AF24'90.50

1 AF24
2 AF24

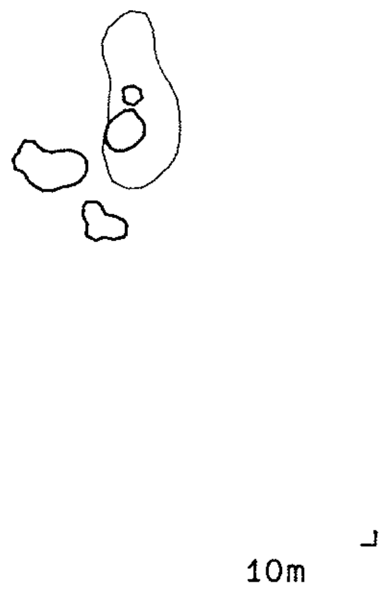


Figure 20

95% EDGES from Hc contour file a:\AF24'90.95

1 AF24
2 AF24

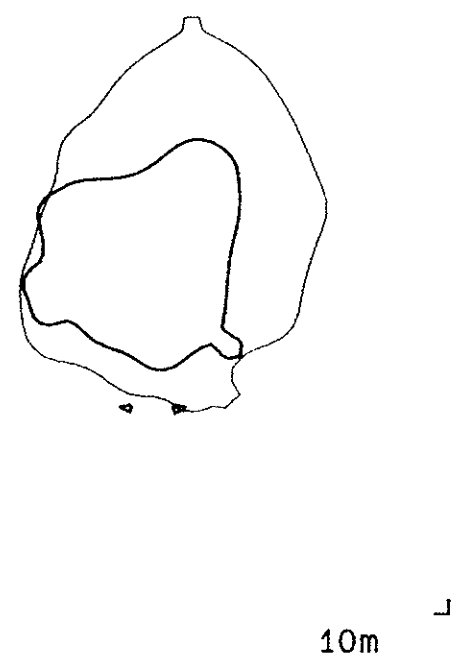


Figure 21

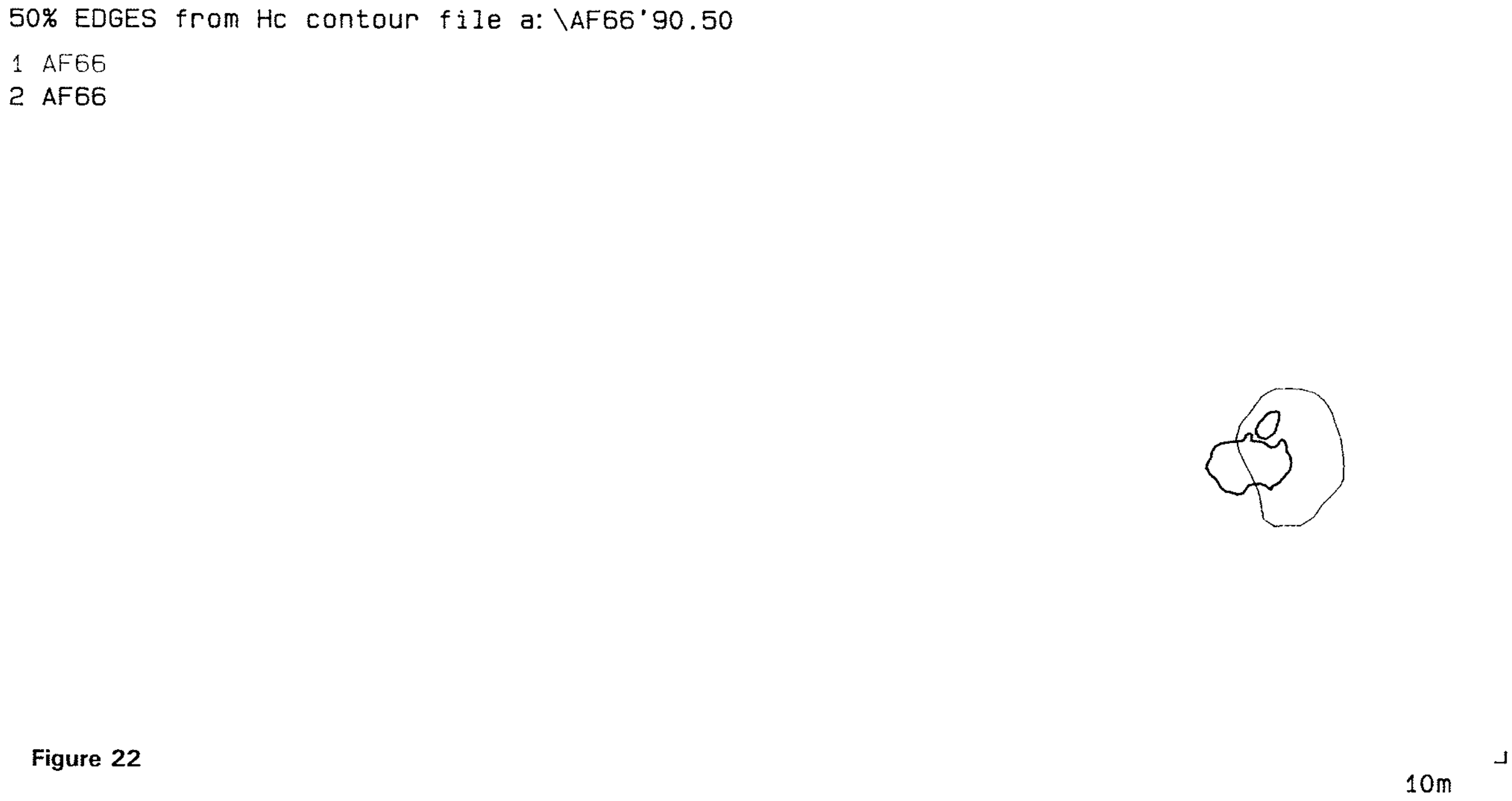


Figure 22

95% EDGES from Hc contour file a:\AF66'90.95

1 AF66
2 AF66

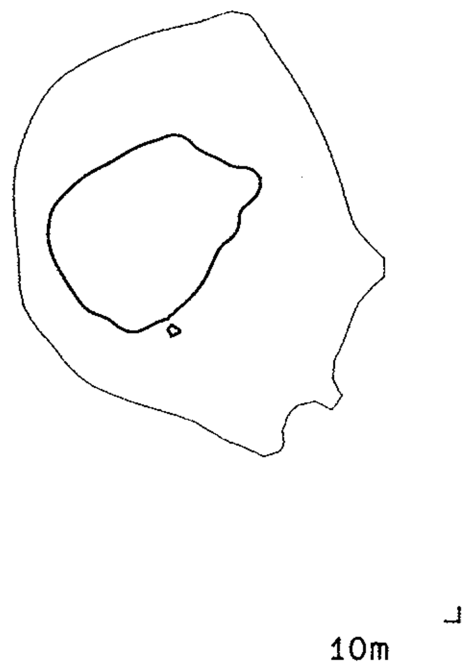


Figure 23

50% EDGES from Hc contour file a:\AF83'90.50

1 AF83
2 AF83

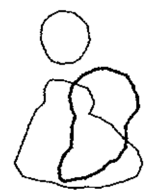


Figure 24

10m

95% EDGES from Hc contour file a:\AF83'90.95

1 AF83
2 AF83

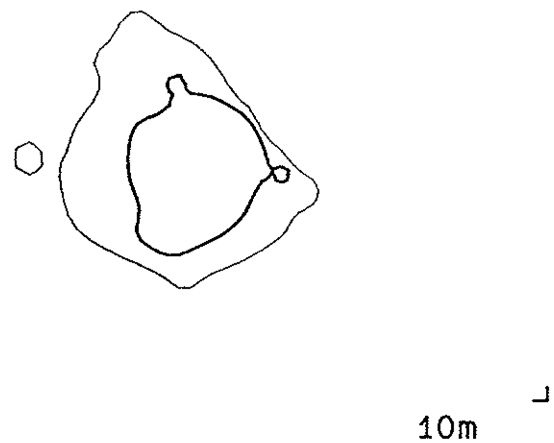


Figure 25

50% EDGES from Hc contour file a:\AF95'90.50

1 AF95
2 AF95

Figure 26

95% EDGES from Hc contour file a:\AF95'90.95

1 AF95
2 AF95

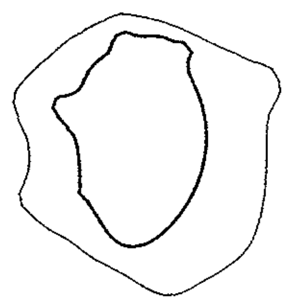


Figure 27

10m

50% EDGES from Hc contour file a:\AM19'90.50

1 AM19
2 AM19

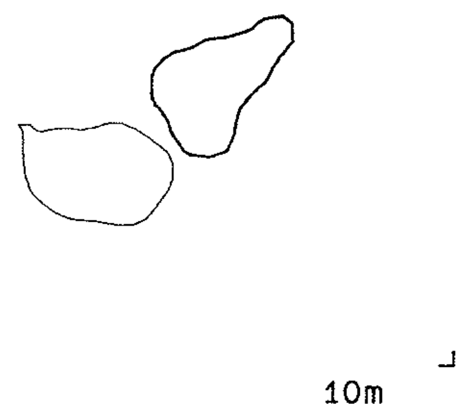


Figure 28

95% EDGES from Hc contour file a:\AM19'90.95

1 AM19
2 AM19

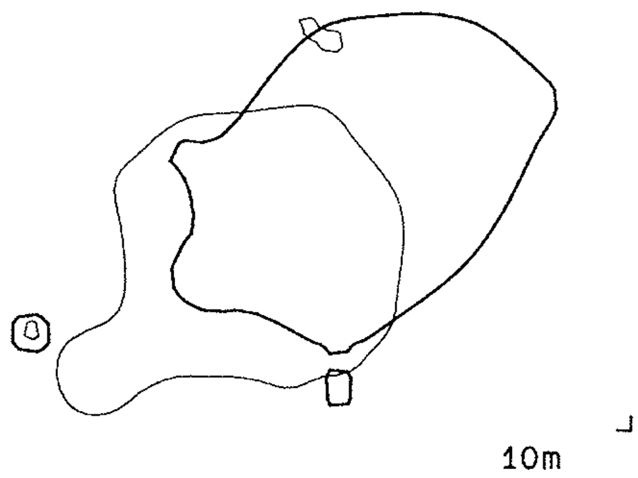


Figure 29

50% EDGES from Hc contour file a:\AM22'90.50

1 AM22
2 AM22

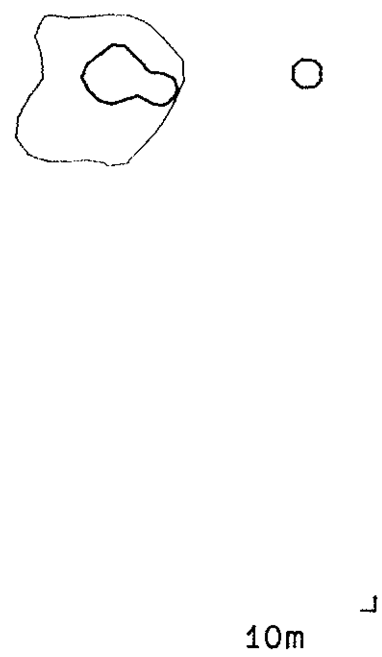


Figure 30

95% EDGES from Hc contour file a:\AM22'90.95

1 AM22
2 AM22

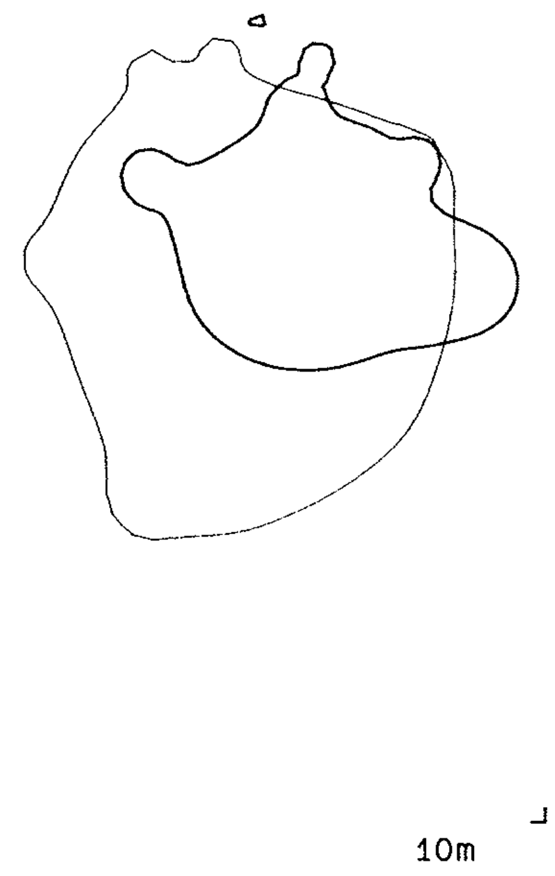
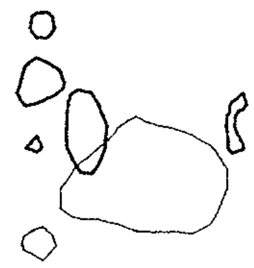


Figure 31

50% EDGES from Hc contour file a:\AM70'90.50

1 AM70
2 AM70



10m

Figure 32

95% EDGES from Hc contour file a:\AM70'90.95

1 AM70
2 AM70

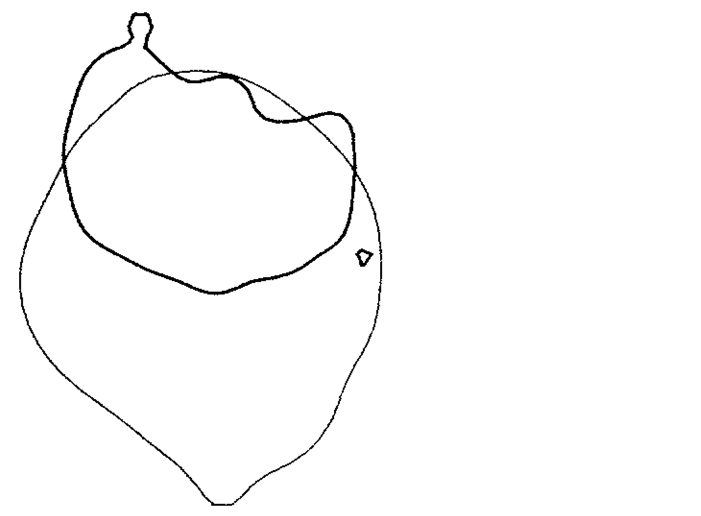


Figure 33

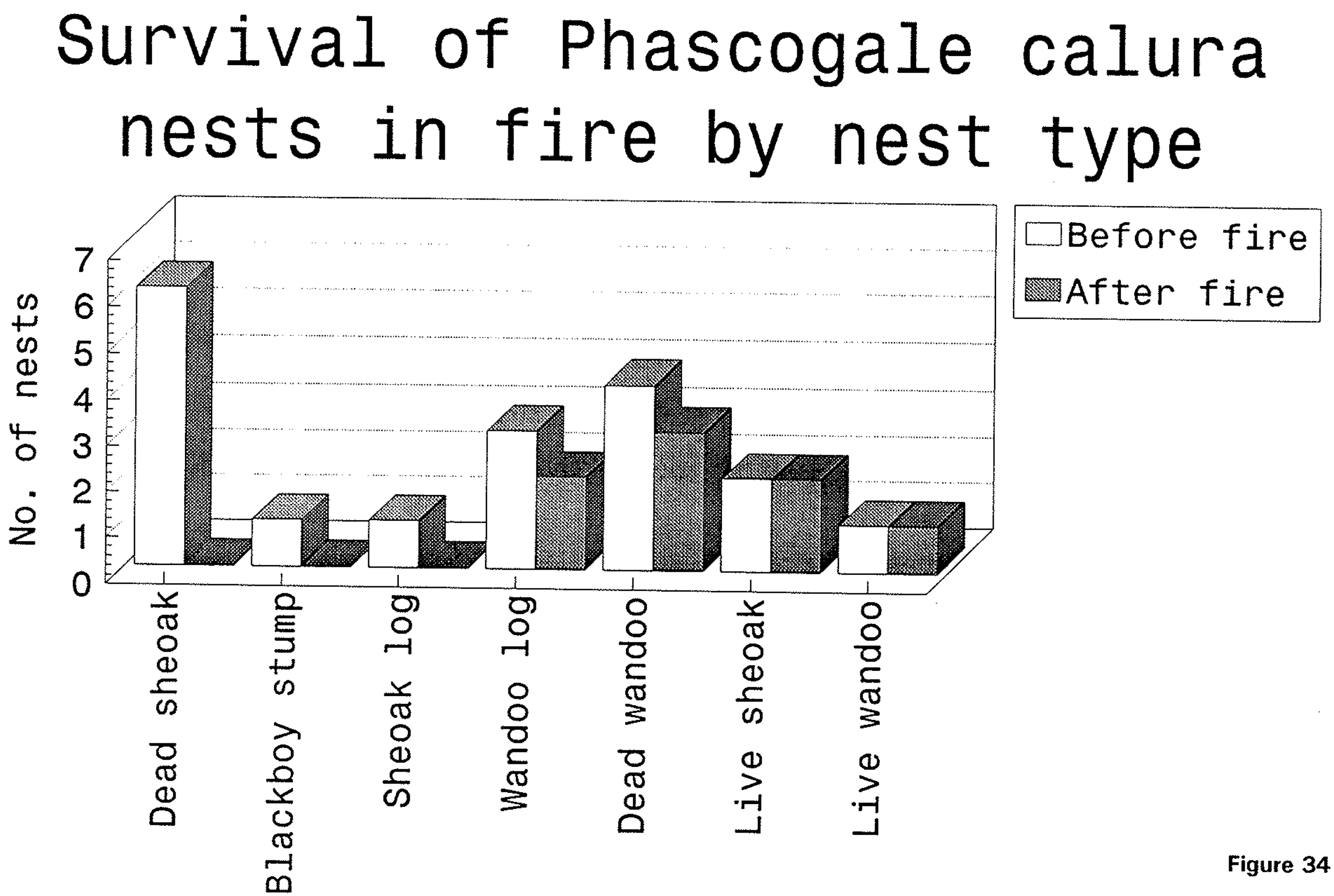
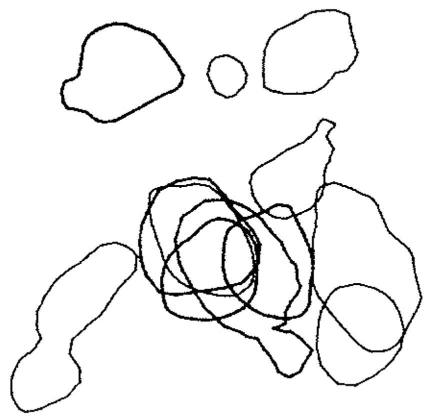

Survival of Phascogale calura
nests in fire by nest type
No. of nests
0
1
2
3
4
5
6
7
Dead sheoak
Blackboy stump
Sheoak log
Wandoo log
Dead wandoo
Live sheoak
Live wandoo
Before fire
After fire

Figure 34

50% EDGES from Hc contour file a:\MARCH'91.50

1 AF44
2 AF46
3 AF49
4 AF50
5 AF92
6 AM32
7 AM33
8 AM35
9 AM38
10 AM39



10m

Figure 35

95% EDGES from Hc contour file a:\MARCH'91.95

1 AF44
2 AF46
3 AF49
4 AF50
5 AF92
6 AM32
7 AM33
8 AM35
9 AM38
10 AM39

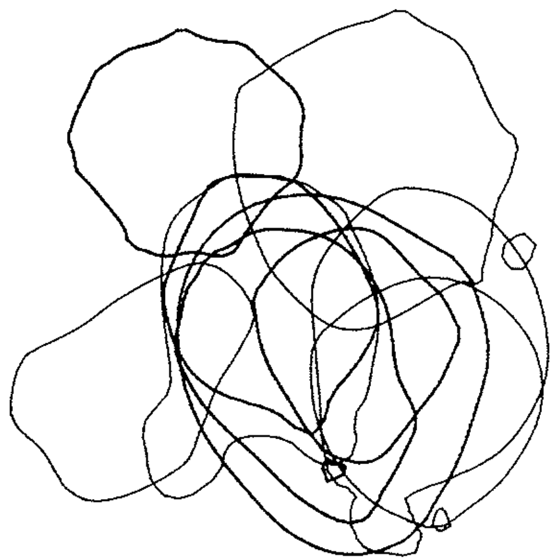


Figure 36

Percentage frequency of nest type used by Phascogale calura

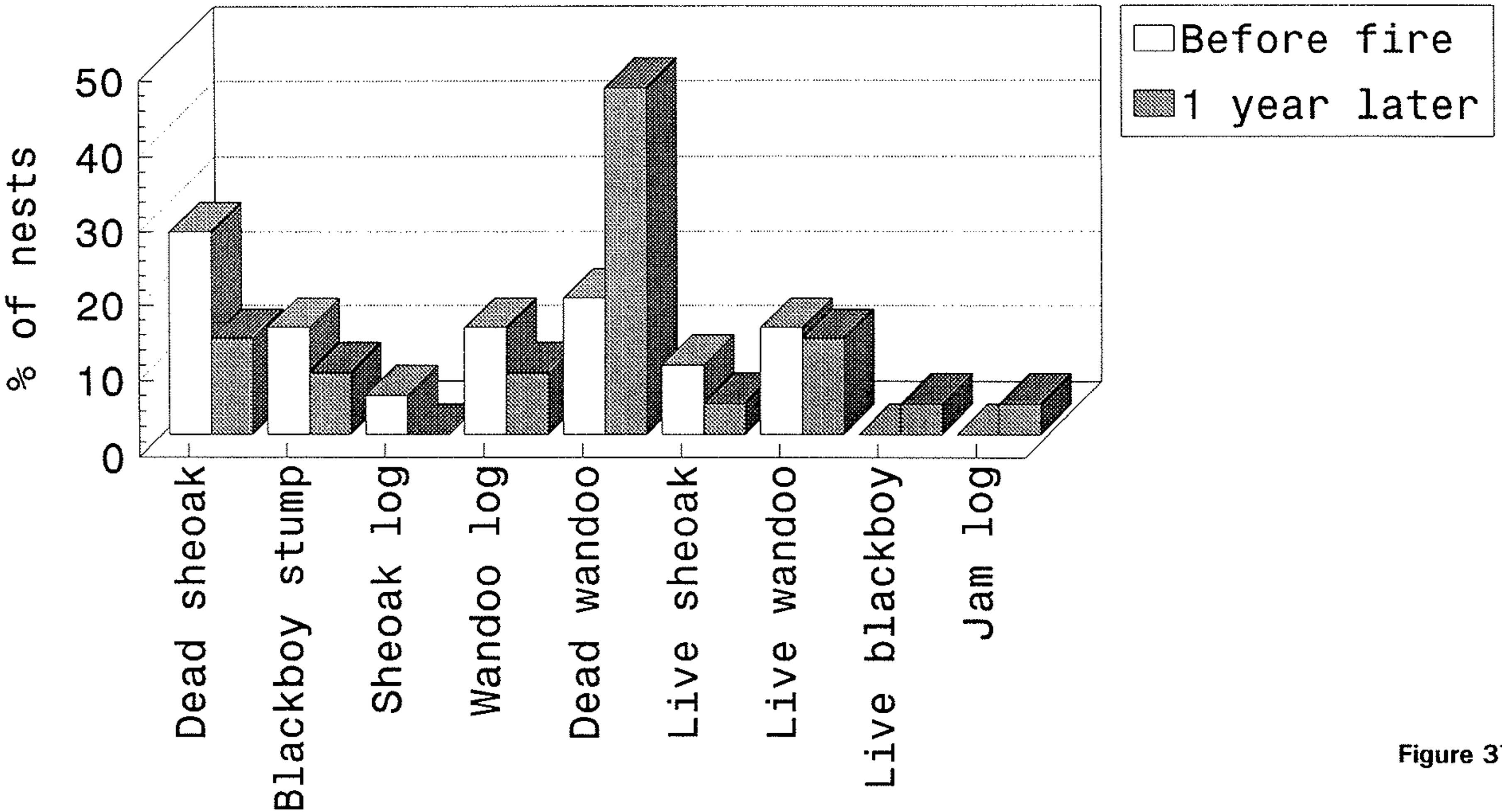


Figure 37

GRID 1 TREE DENSITY

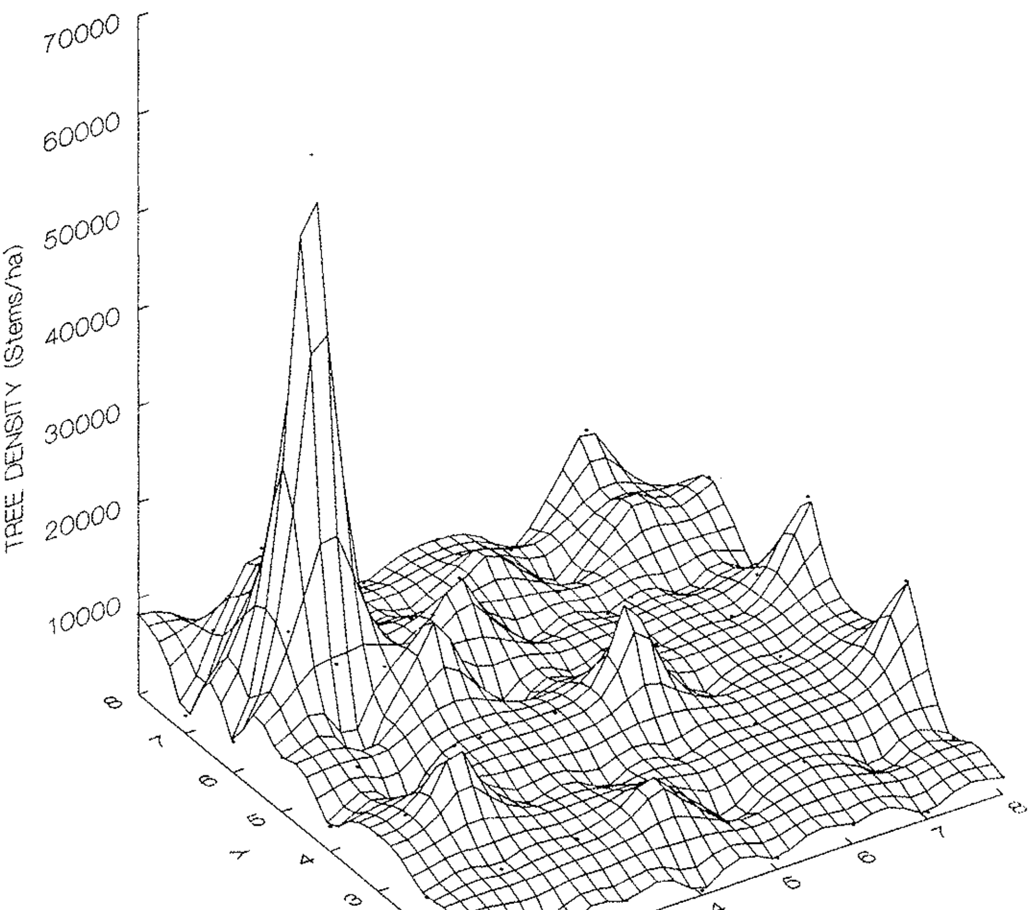


Figure 38.

GRID 2 TREE DENSITY

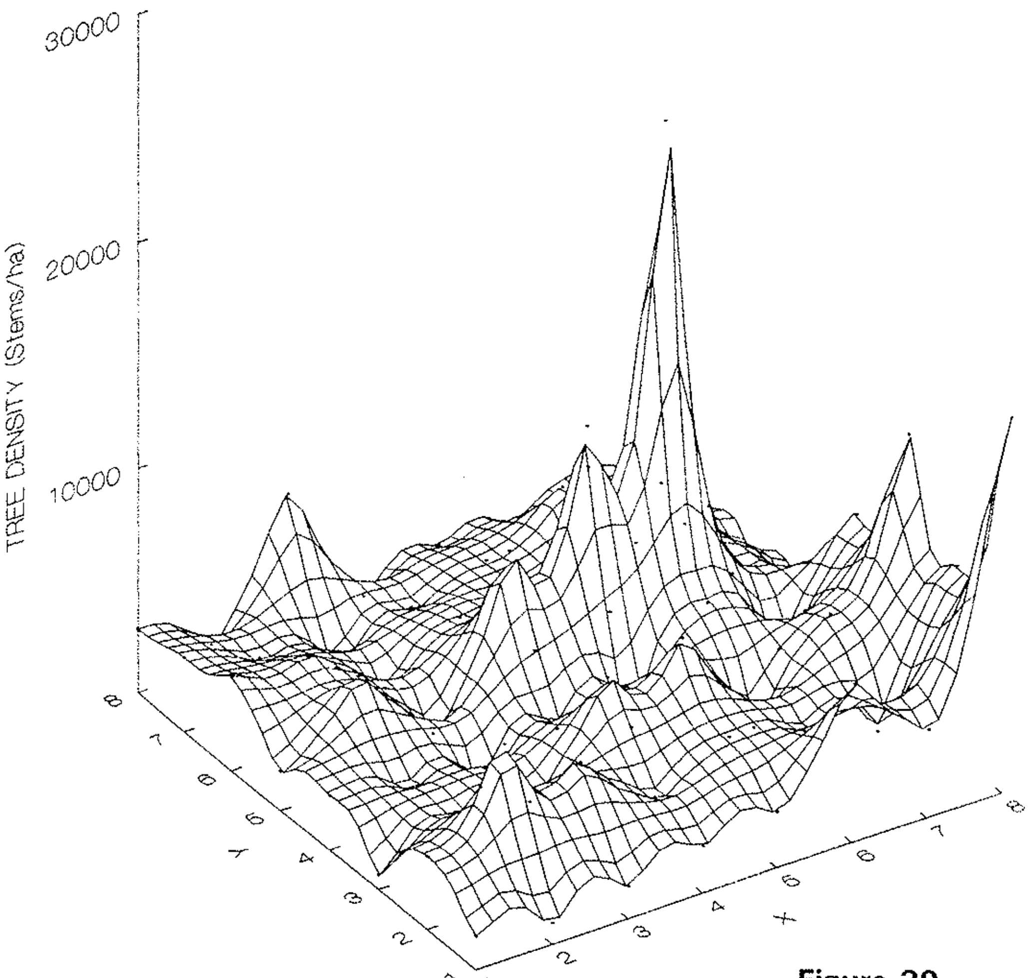


Figure 39.

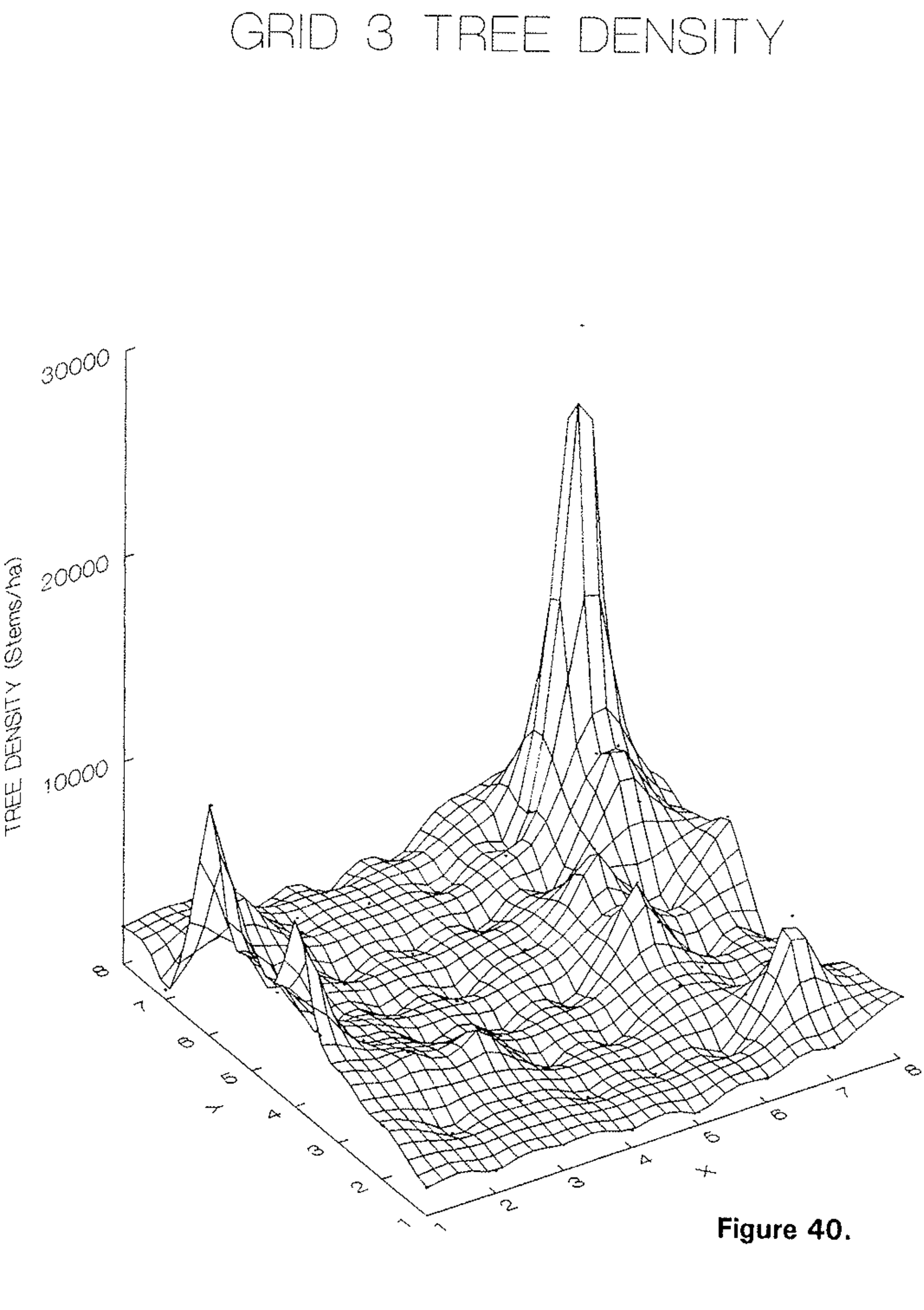

GRID 3 TREE DENSITY
TREE DENSITY (Stems/ha)
30000
20000
10000
Y
X
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8

Figure 40.

GRID 1 SCORCH HEIGHT

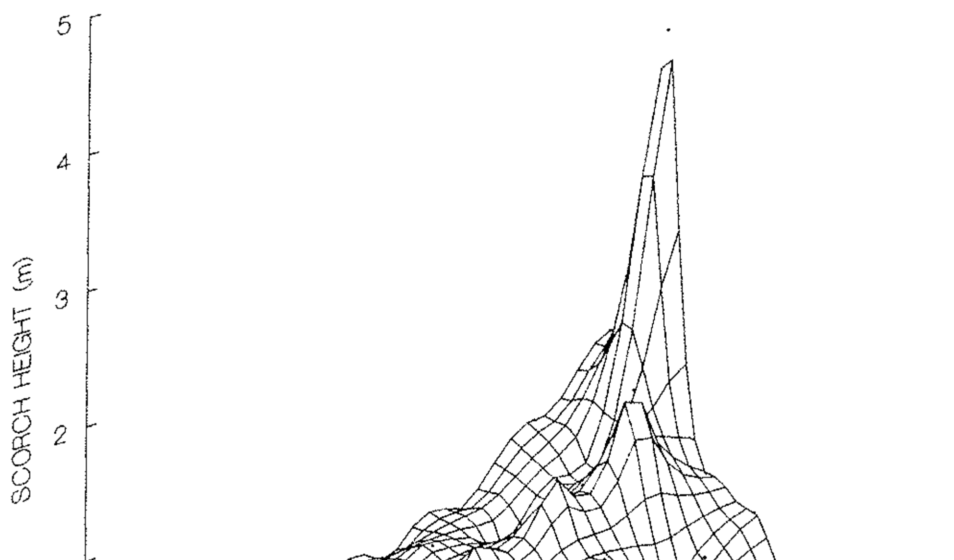


Figure 41.

GRID 2 SCORCH HEIGHT

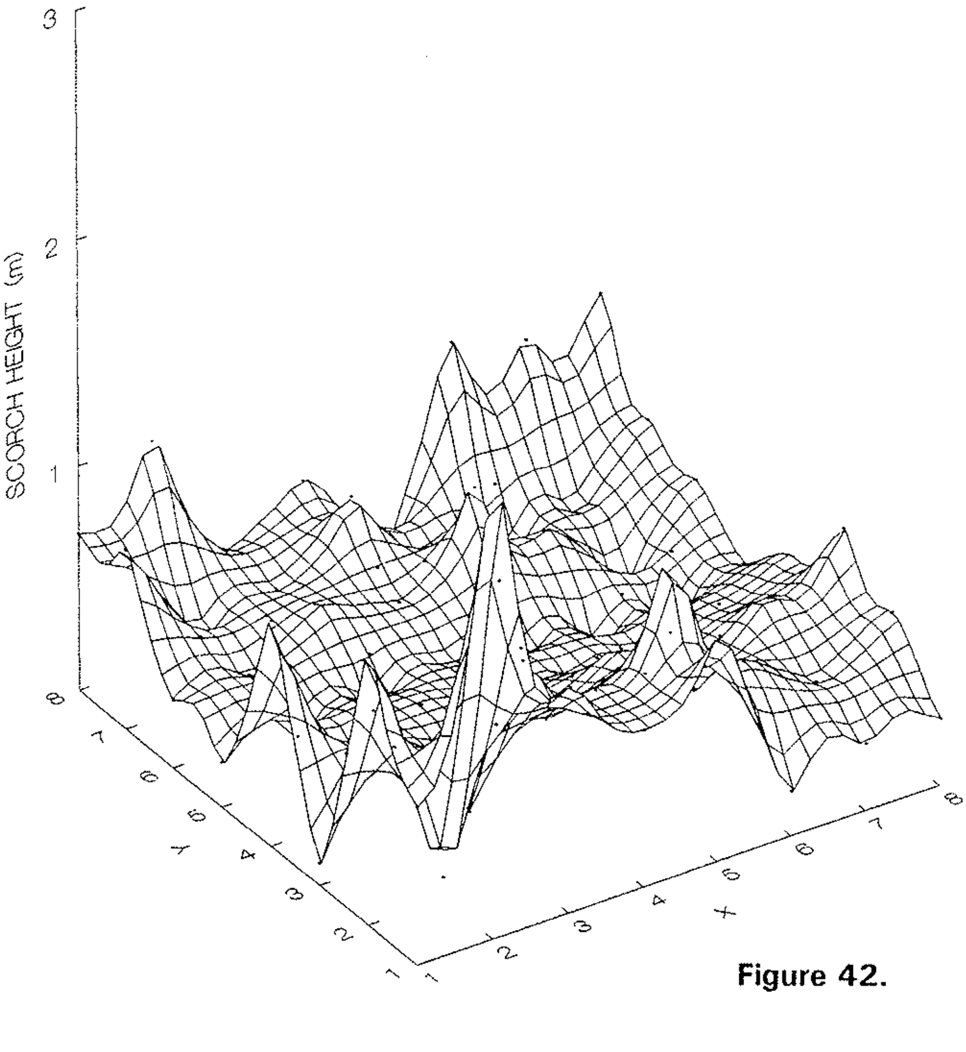


Figure 42.

FREQUENCY OF LITTER COVER CLASSES

GRID 1 PRE & POST FIRE

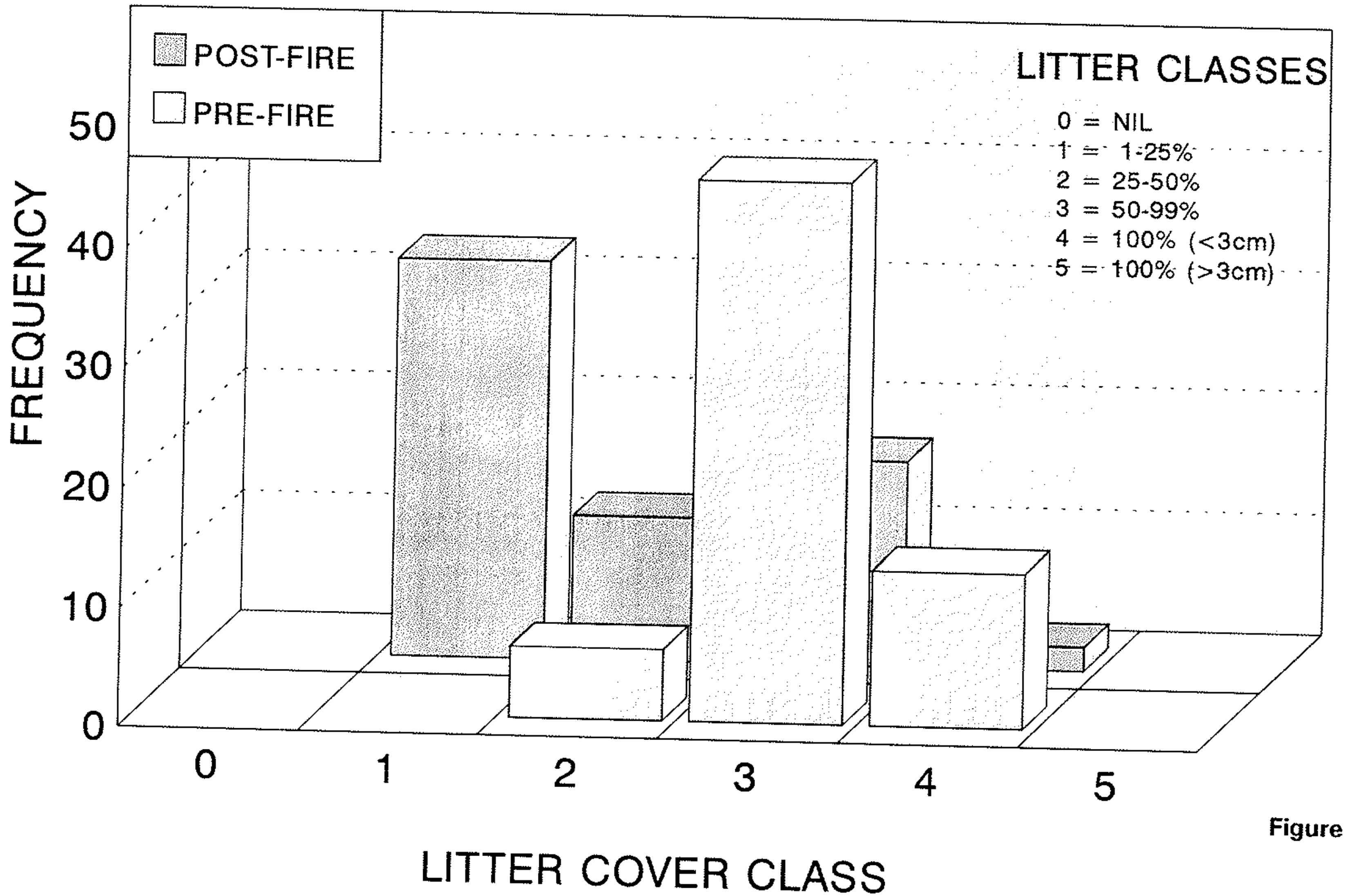


Figure 43

FREQUENCY OF LITTER COVER CLASSES

GRID 2 PRE & POST FIRE

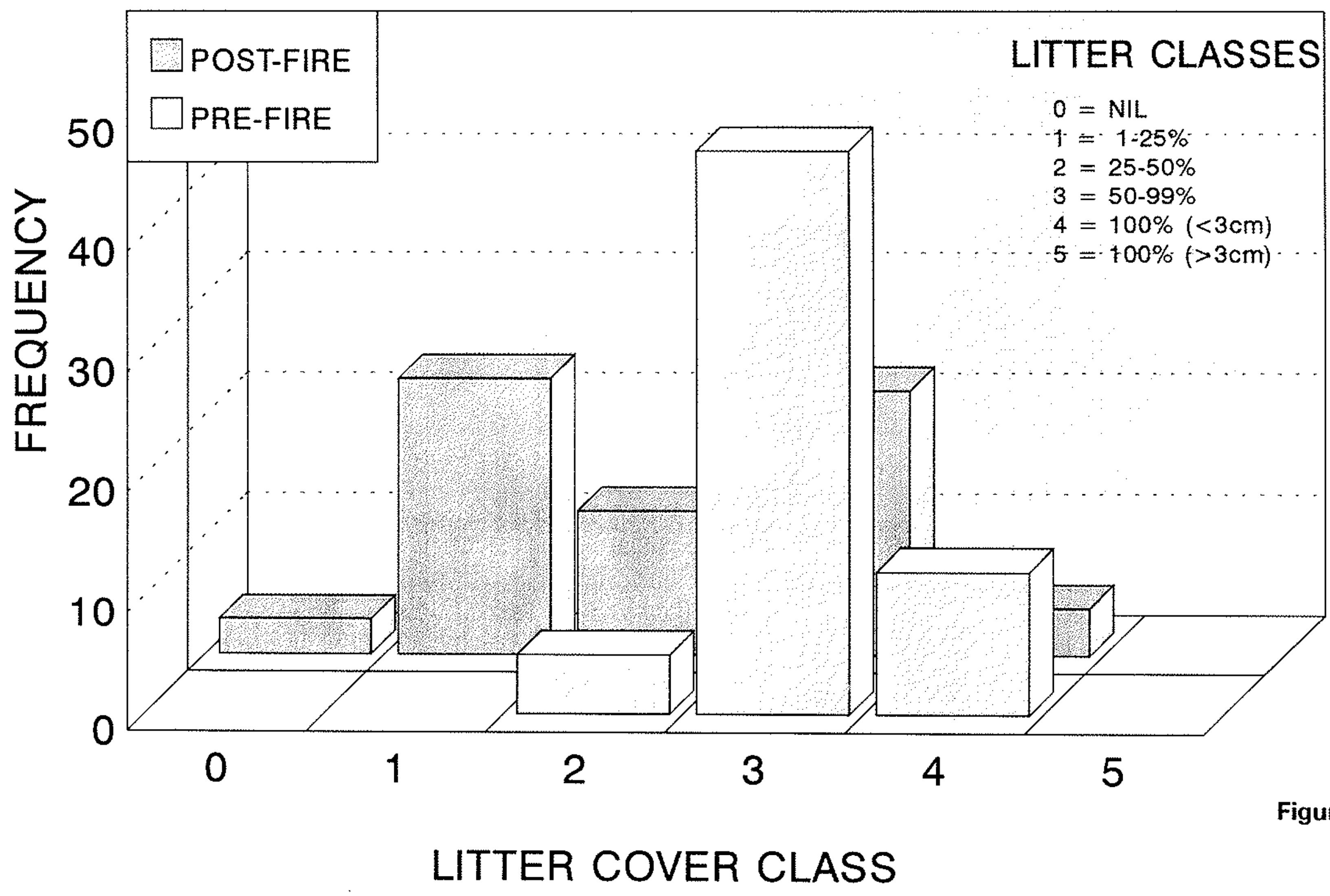


Figure 44

FREQUENCY OF LITTER COVER CLASSES

GRID 3 CONTROL

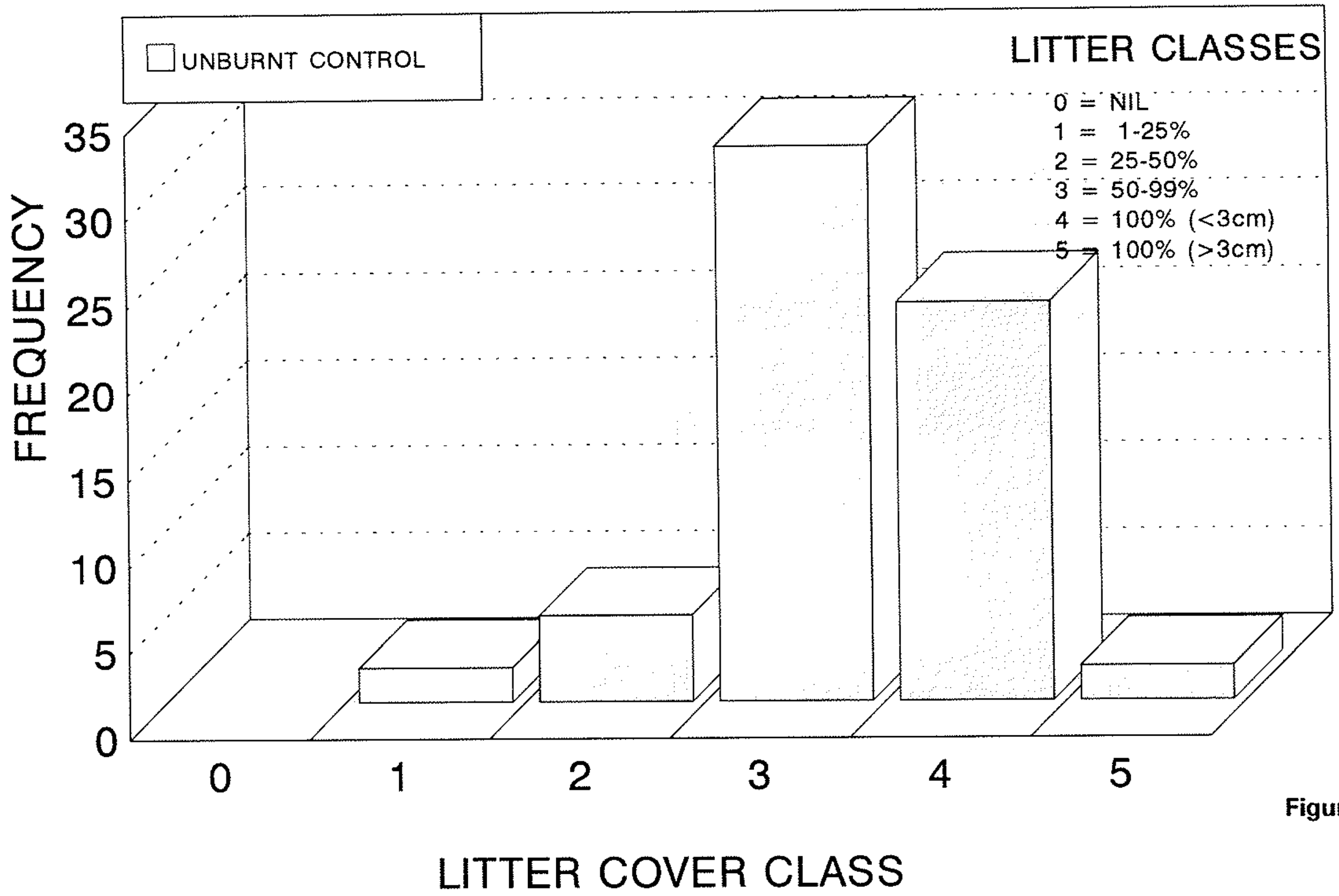


Figure 45

50% EDGES from Hc contour file A:\JMOD'91.50

1 AF36
2 AF55
3 AF56
4 AM33
5 AM50

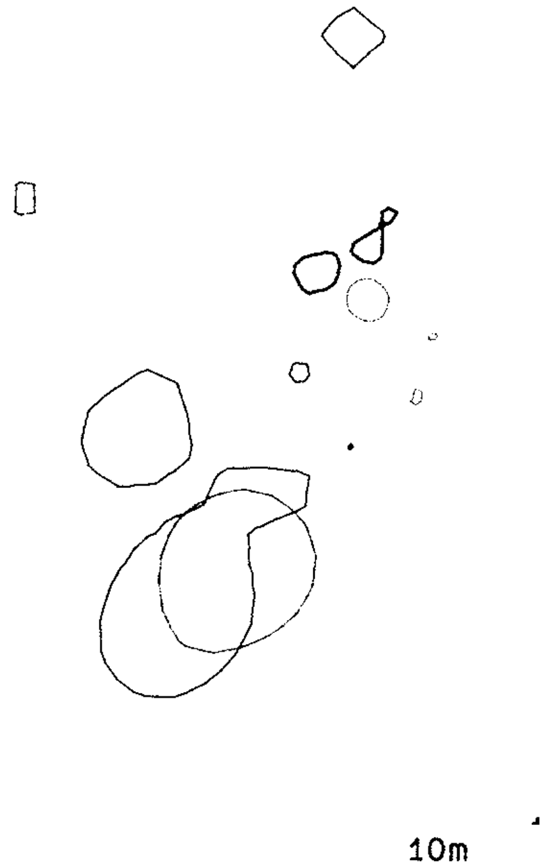


Figure 46

95% EDGES from Hc contour file A:\JMOD'91.95

1 AF36
2 AF55
3 AF56
4 AM33
5 AM50

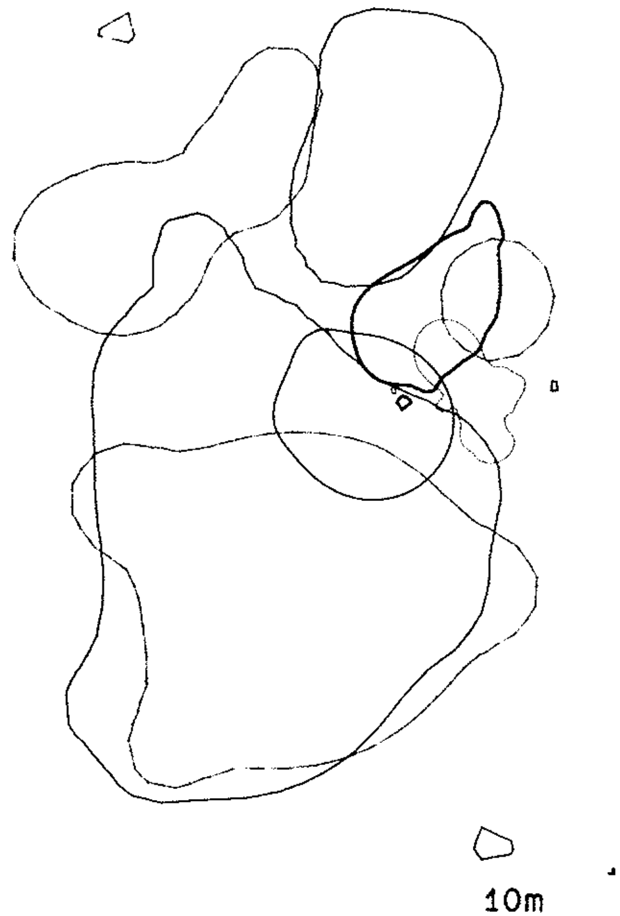
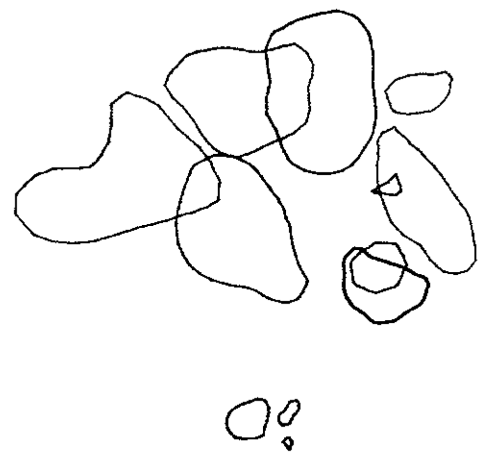


Figure 47

50% EDGES from Hc contour file a:\JUNE'92.50

1 AF61
2 AM52
3 AM53
4 AM54
5 AM64
6 AM65
7 AM88



10m

Figure 48

95% EDGES from Hc contour file a:\JUNE'92.95

1 AF61
2 AM52
3 AM53
4 AM54
5 AM64
6 AM65
7 AM88

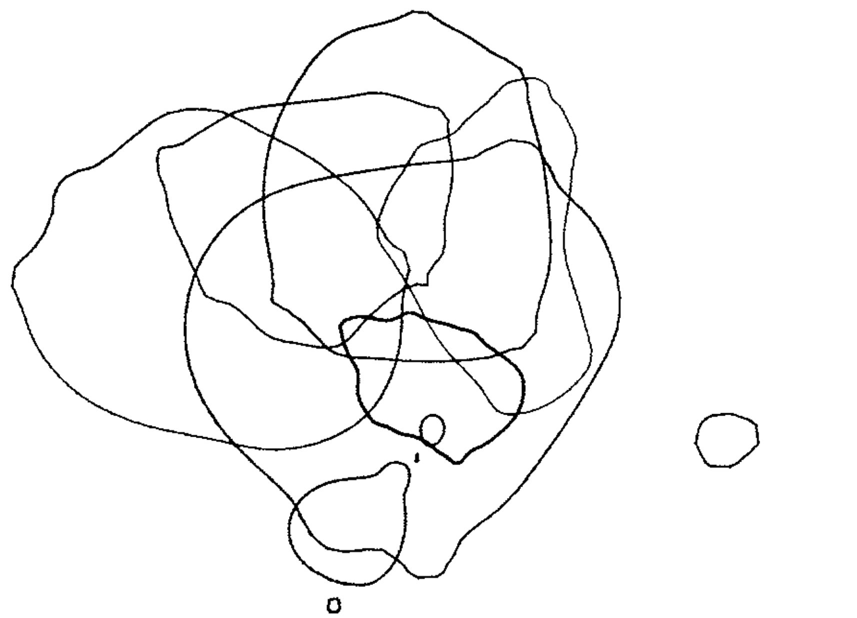


Figure 49

50% EDGES from Hc contour file a:\JULY'92.50

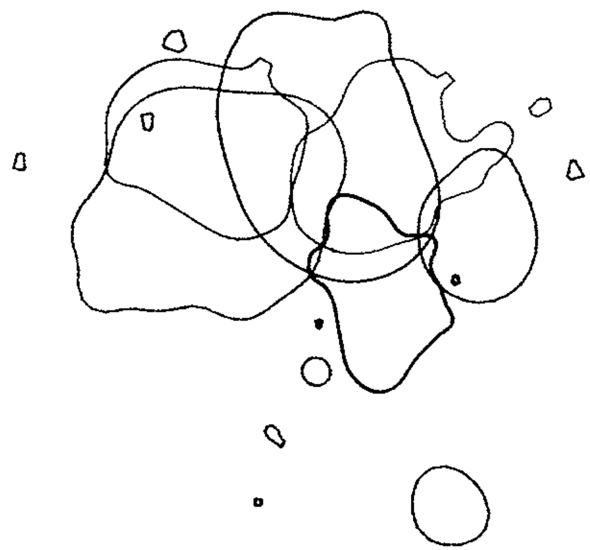
1 AF61
2 AM52
3 AM53
4 AM54
5 AM64
6 AM65
7 AM88

Figure 50

10m

95% EDGES from Hc contour file a:\JULY'92.95

1 AF61
2 AM52
3 AM53
4 AM54
5 AM64
6 AM65
7 AM88



10m

Figure 51

Locality records of *Phascogale calura*

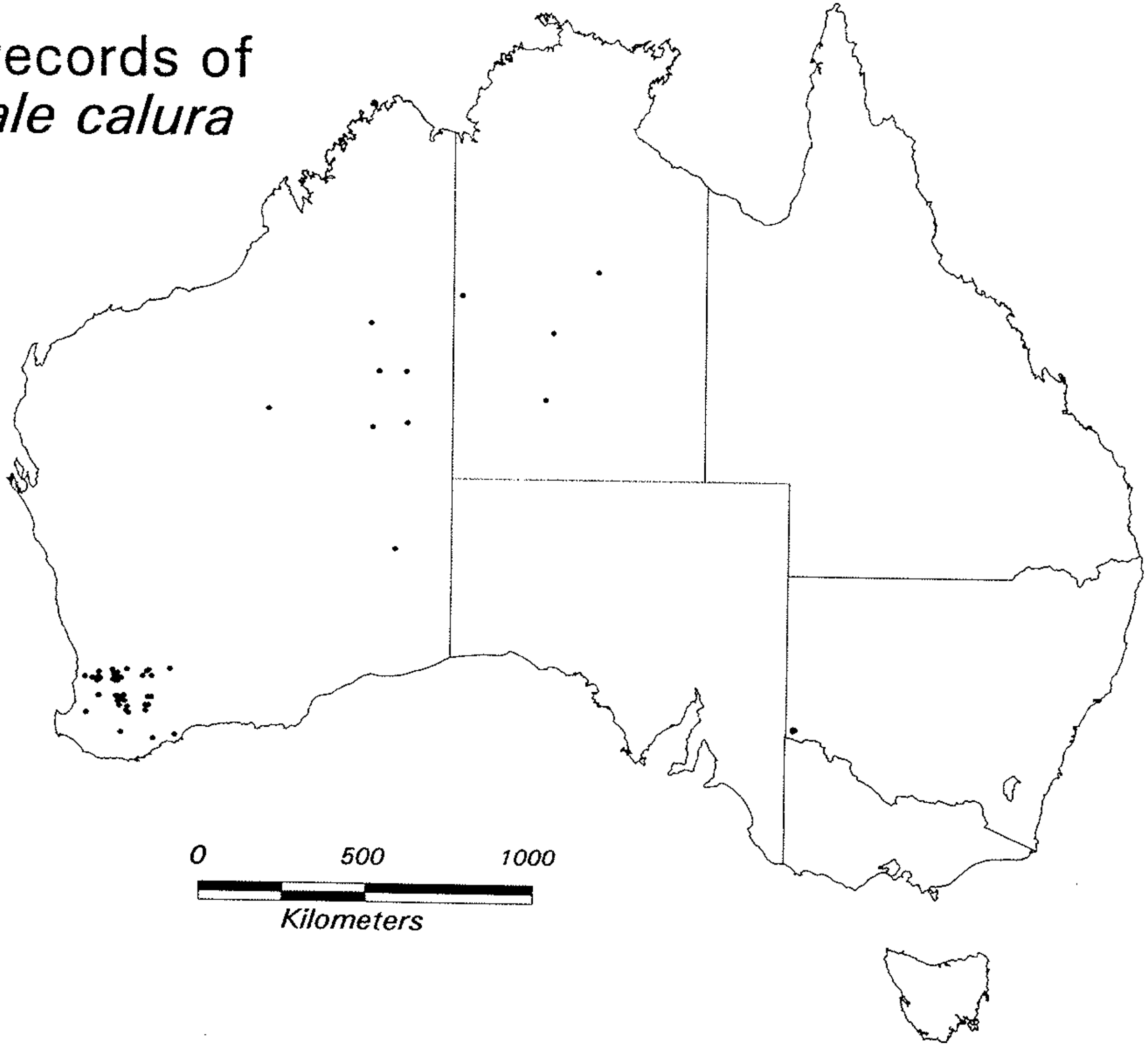


Figure 52

Predicted distribution of *Phascogale calura*

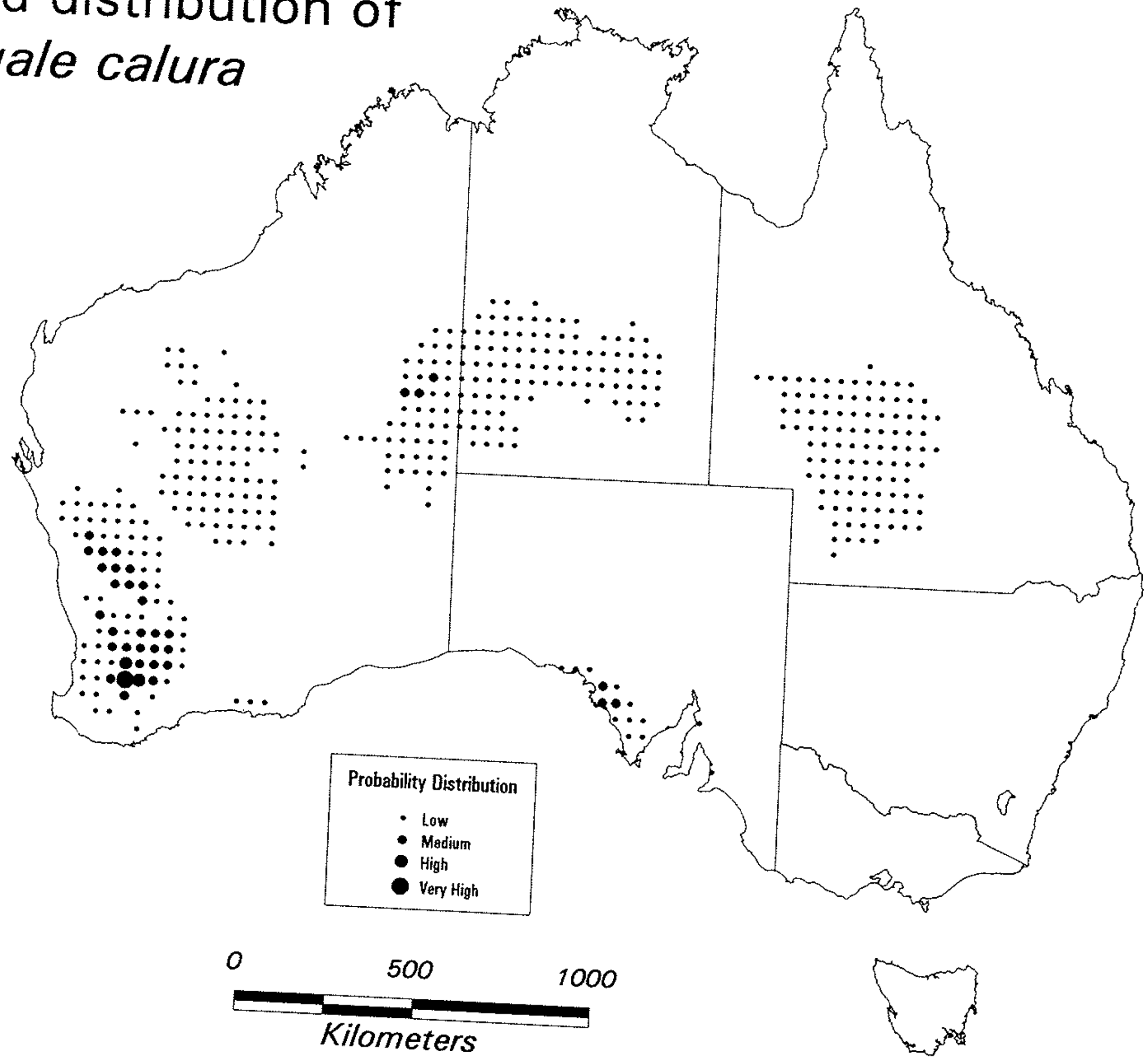


Figure 53

Figure 54

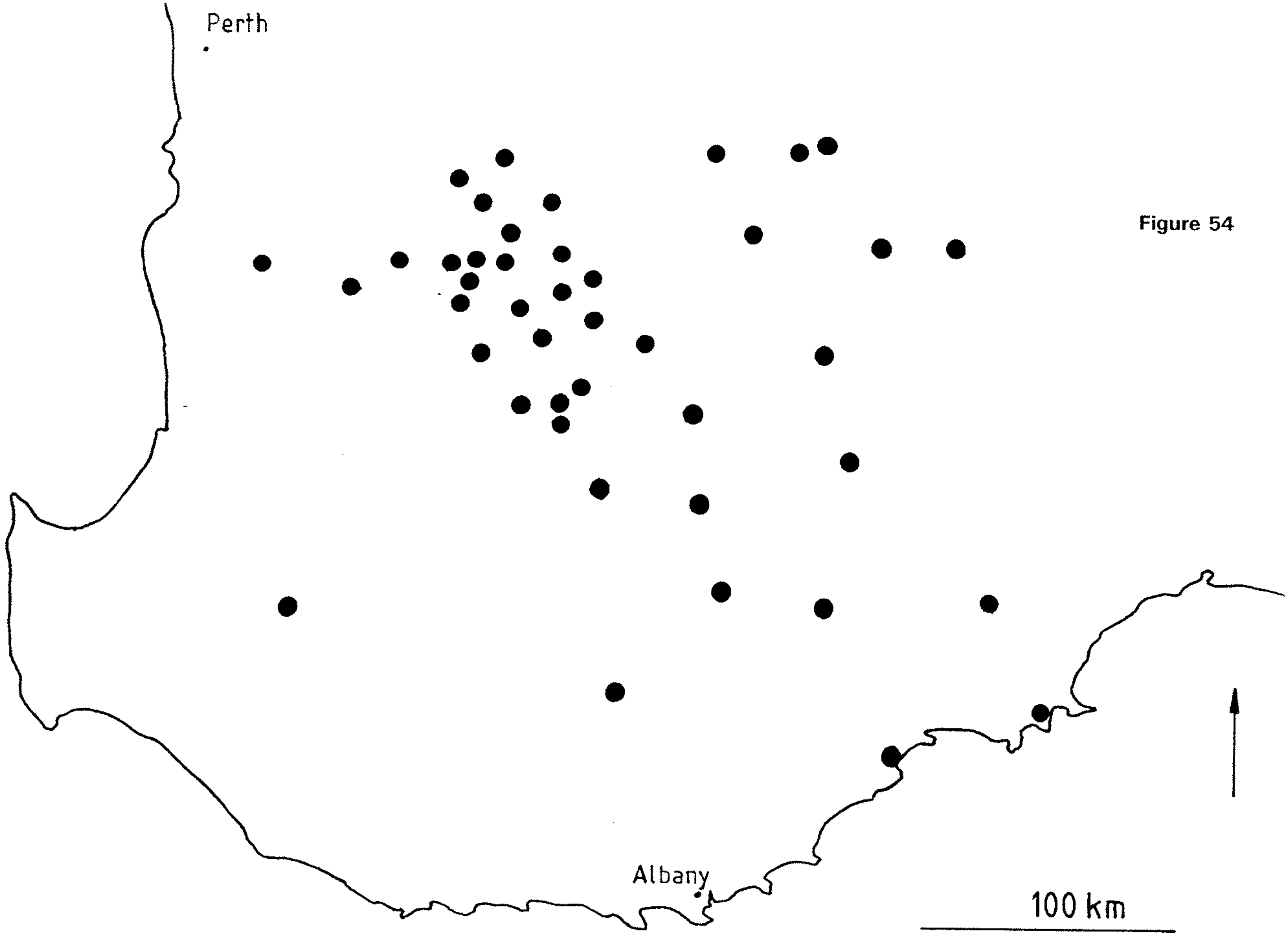
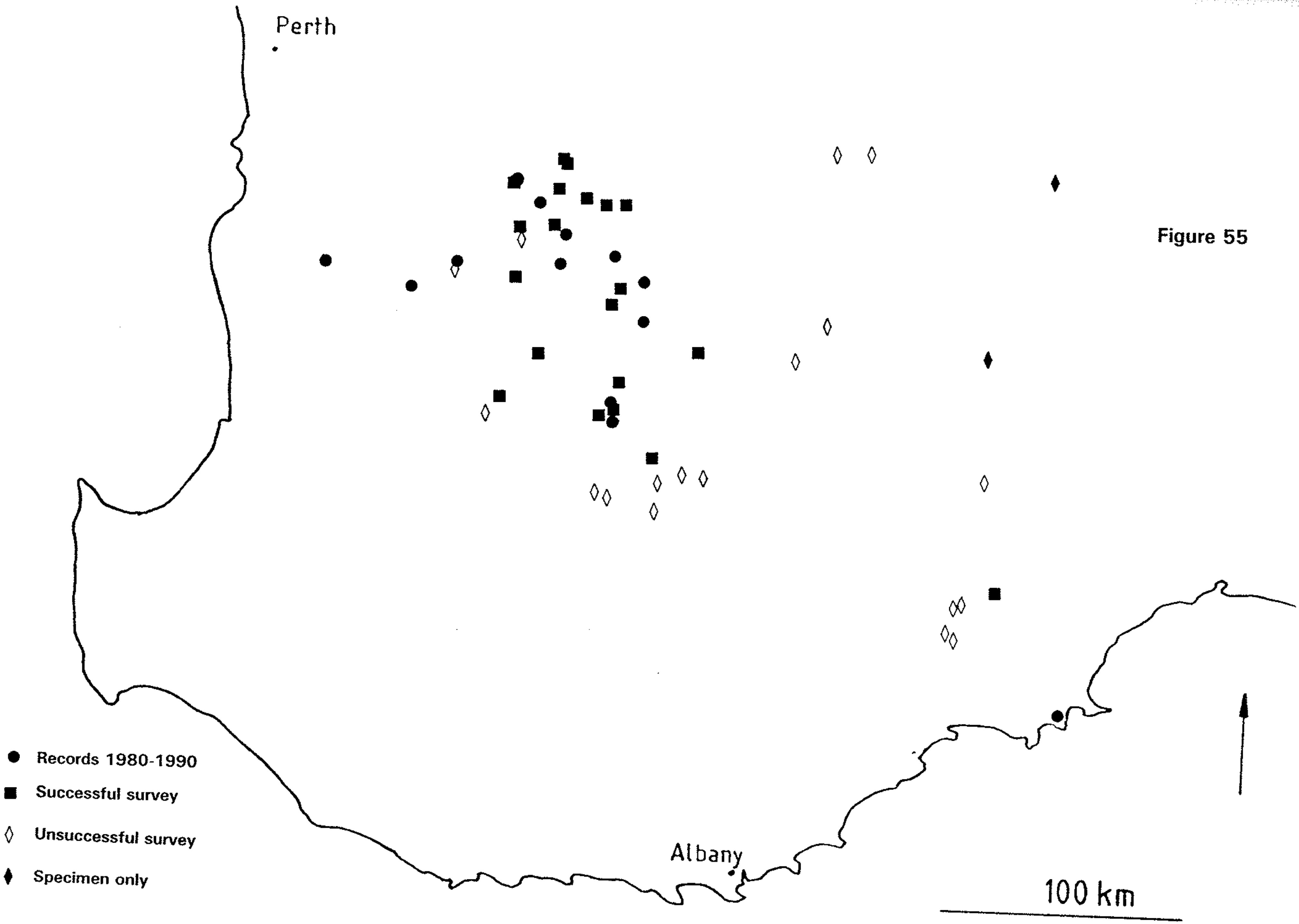


Figure 55


Perth
Albany
100 km
Records 1980-1990
Successful survey
Unsuccessful survey
Specimen only