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Evaluation of reptile survey methodologies

Final report

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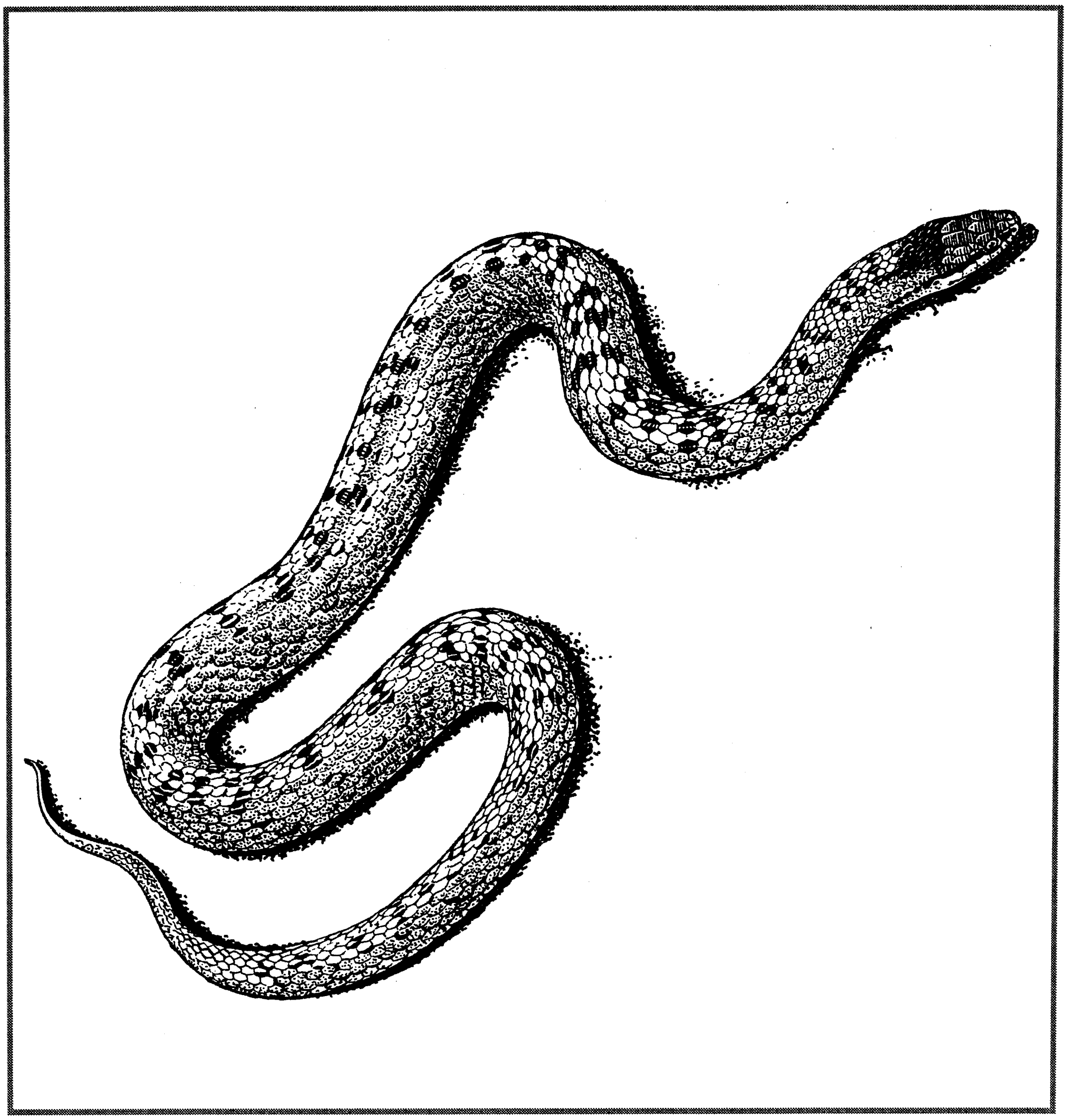

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Number 200

Evaluation of reptile survey methodologies: final report

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Preface

This three year study to evaluate the methods currently used by both professional and amateur herpetologists to survey sites for the presence of reptiles was initiated by ITE and funded by Species Conservation Branch of English Nature. The main aim of the study was to determine if a standard method could be found for surveying for reptiles that would allow reptile population size estimates to be made for different sites and enable comparisons to be made both between sites and, over time, within sites.

1. Summary

1.1 A three year study using arrays of artificial refuges to survey for reptiles was done on a 20 hectare area of mature *Calluna* heathland in Wareham Forest, south Dorset between 1993-1995.

1.2 During each of the 3 years different arrays were used, each duplicated, to investigate the relationships between reptile numbers and array size, refuge number and refuge density. A total of 18 arrays were therefore used with a range in array area of 0.335-0.597 hectares, a range in refuge number per array of 7-127 and a range of refuge densities of 14-378 per hectare.

1.3 Each year each refuge in each array was checked either 25 (1994 & 1995) or 28 (1993) times during the period March/April-October for the presence of reptiles by walking a pre-determined transect route visiting each refuge in turn.

1.4 The precise location of every capture or sighting of a reptile was recorded as was the air temperature (at 1m above the surface), vegetation temperature and temperature at the precise spot a reptile was found whether under a refuge or in the open.

1.5 A record was made, on each visit, of the prevailing weather conditions in terms of sunshine, wind, temperature and rain.

1.6 Individuals of all three snake species were individually marked using PIT (Passive Integrated Transponder) tags inserted subcutaneously on the side of the snake about 5cm anterior of the cloaca.

1.7 During the course of the study total reptile captures/sightings of 321 smooth snakes, 44 grass snakes, 6 adders, 96 sand lizards, 286 slow worms and 1 common lizard were made. The majority of smooth snakes (96%), grass snakes (86%) and slow worms (99%) were found beneath refuges whilst the majority of sand lizards (75%) and the single common lizard were found in the open between refuges (transect walk). Adders were found equally under refuges or in the open. For the three snake species the total number of captures represented 77 individual smooth snakes (71 pit-tagged, 6 juveniles), 25 individual grass snakes and 4 individual adders.

1.8 The total number of smooth snake and sand lizard captures showed logarithmic relationships with refuge number and refuge density such that at refuge numbers of 37 per array and refuge densities of 80-120 per hectare they levelled off indicating that these two species were resident within the study area.

1.9 The total number of grass snake and slow worm captures were also described by logarithmic relationships but in these two species no levelling off of the relationship occurred indicating, in the case of the grass snake, that it could not be considered a resident of the study area but was passing through it. The slow worm, on the other hand, although considered to be a resident was the least 'free ranging' of the reptile species present and was almost certainly not adequately 'sampled' by the range of refuge densities used in the study.

1.10 The relationships between the number of individual smooth snakes and grass snakes present in an area and the total number of snake captures further supported the hypothesis that smooth snakes can be considered residents of the study area (heathland) whilst grass snakes cannot and were passing through.

1.11 With the exception of the sand lizard, for which transect walks were more productive, the best method for surveying sites for reptiles was the use of artificial refuges laid out in a basic array of 37 refuges spaced 10m apart and visited 15-20 times throughout the year between April and October.

1.12 A standard method for the survey of reptiles is proposed and described.

2. Introduction

In the past, artificial refuges, usually in the form of pieces of corrugated sheet steel, have been extensively used as a tool to survey for the presence of reptiles at a given site. This has usually been done using a variable, but often small, number of refuges laid out either randomly or where reptiles are expected to be found and often over rather short periods of time and within relatively small patches of larger areas of possible reptile habitat. Similarly, random walks or transect walks have been done by both 'experienced' and 'inexperienced' observers searching for reptiles at sites of interest. As with the use of refuges, these walks have tended to be done in an unstructured manner with respect, particularly, to the length of the walk, the time spent searching and the expertise of the observer. In addition, they have often been done in selected areas where reptiles were expected/known to occur and thus the results obtained were biased.

The reptile captures/sightings resulting from the use of refuges or 'walks' in the ways described are of limited value as they can only reveal the presence of reptiles if animals are actually seen but not absence if animals are not seen. Information that cannot be gained using these methods is that relating to the number of reptiles at a particular site or that enabling comparisons to be made between sites, particularly when the methods used are not even standardised between them. Unfortunately, in the past, both these methods have all too frequently been used to make just such statements about the absolute and relative abundance of reptiles at specific sites.

If estimates of the abundance of reptiles at a particular site, or comparisons of relative abundance between sites, are required then there needs to be a standardisation of the methods used. To this end English Nature (EN) funded an ITE initiative to compare the two methods commonly used (refuges and transect walks) and determine, if possible, a standard method that could be adopted where ever a survey of reptiles was required.

3. Site description

The site chosen for the study was an area (approx. 20 hectares) of heathland surrounded by conifer plantation *Pinus sylvestris* and within the confines of Wareham Forest, Dorset. The site was approximately 750m long and 300m wide at its widest, reducing to 100m at its narrowest. It was orientated in an east-west direction and was bisected, longitudinally, by a ditch/small stream forming a slight valley which was dominated by Purple moor grass *Molinia caerulea*. Away from the 'valley' bottom the heath was dominated by mature heather *Calluna vulgaris* which formed a discontinuous sward with numerous small patches of open sandy ground sometimes covered in moss. Within the heath were numerous 'bushes' of gorse *Ulex minor* and the occasional small (<3m high) conifer *P. sylvestris*.

During February 1994 Forest Enterprise employed contractors to fell most of the small conifers within the study area. Although this resulted in considerable disturbance to the site during felling operations the trees were not removed, but left on site, so as to prevent further disturbance and heath damage.

4. Methods

During the field seasons of 1993-95 the reptile (and amphibian) species present within the study area were surveyed using hexagonal 'arrays' of artificial refuges (Fig 1) whose ground density varied both between arrays and years. Refuges were pieces of galvanised corrugated sheet steel measuring approximately 76cm x 65cm (2ft-6in. x 2ft-1in.) and painted black ('Hammerite') on the upper surface to aid heat absorption. Refuges within an array were placed in a hexagonal pattern so that each could be regarded as being at the centre of a circle (radius = half the distance between adjacent refuges) that only minimally overlapped with circles associated with adjacent refuges. In addition, refuges could be removed from, or added to, existing arrays to maintain the overall hexagonal pattern, thus varying the density of refuges used over what was essentially the same area of heath (eg. Fig. 1). Three different arrays were used each year, each being duplicated so that six areas of heath were covered in refuges (Map 1). The number of refuges used in individual arrays during the 3 year study ranged between 7 and 127 with inter-refuge distances (IRD) of 5.8m - 30m and individual array areas of 0.335-0.597 hectares (Table 1). A total of 174 refuges were used in 1993; 330 in 1994 and 270 in 1995. The total area covered by refuge 'arrays' in each of the 3 years of the study were 2.862, 2.536 and 2.274 hectares respectively.

Refuges within each array were checked either 25 or 28 times each year, between March and October (Glandt 1972), by walking a set route between refuges (transect walk) during which reptiles were also searched for by eye (Table 2). Most searches (64%) were made during the morning (Spellerberg & Phelps 1977), with the remainder occurring from mid morning to mid afternoon (24%) or during the afternoon (12%). The duration of searches varied between years, being dependent on the number of refuges used each year and the distance between them. Although site visits were spaced out as evenly as possible throughout the study period they were dependent on the occurrence of 'suitable' climatic conditions ie. not cold or wet. The monthly number of site visits was similar in all three years with a mean of 1.0-2.0 visits during the early spring (March/April) and late autumn (October) and 4.5-5.3 (range 3-8) during the late spring and summer (May-September).

The date and position of every reptile capture or sighting was recorded and every captured snake was weighed to the nearest gramme, measured (snout/vent length and tail length) to the nearest millimetre, sexed and previously unmarked animals marked by inserting a PIT (Passive Integrated Transponder) tag under the skin on the side of the snake 2-5cm anterior of the cloaca enabling individuals to be recognised if recaptured. PIT tags (model ID-100; length = 11mm; diameter = 2mm; weight = 101mgm) were obtained from UK ID Systems Ltd. (Collinsons) of Preston and supplied in sterile needles ready for implantation. The unique code emitted by each tag was decoded and displayed by a hand held 'wand' receiver. A detailed description of this method is provided in Reading & Davies (1996).

The climatic conditions prevailing (observer perception/feeling eg. yes/no) at the time of each site visit (humid, sunny, sun+cloud, cloudy, wind, breeze, still, hot, warm, cool) were noted and three temperatures (under a refuge, within vegetation and 1m air temperature) recorded at the time and precise location of most snake captures.

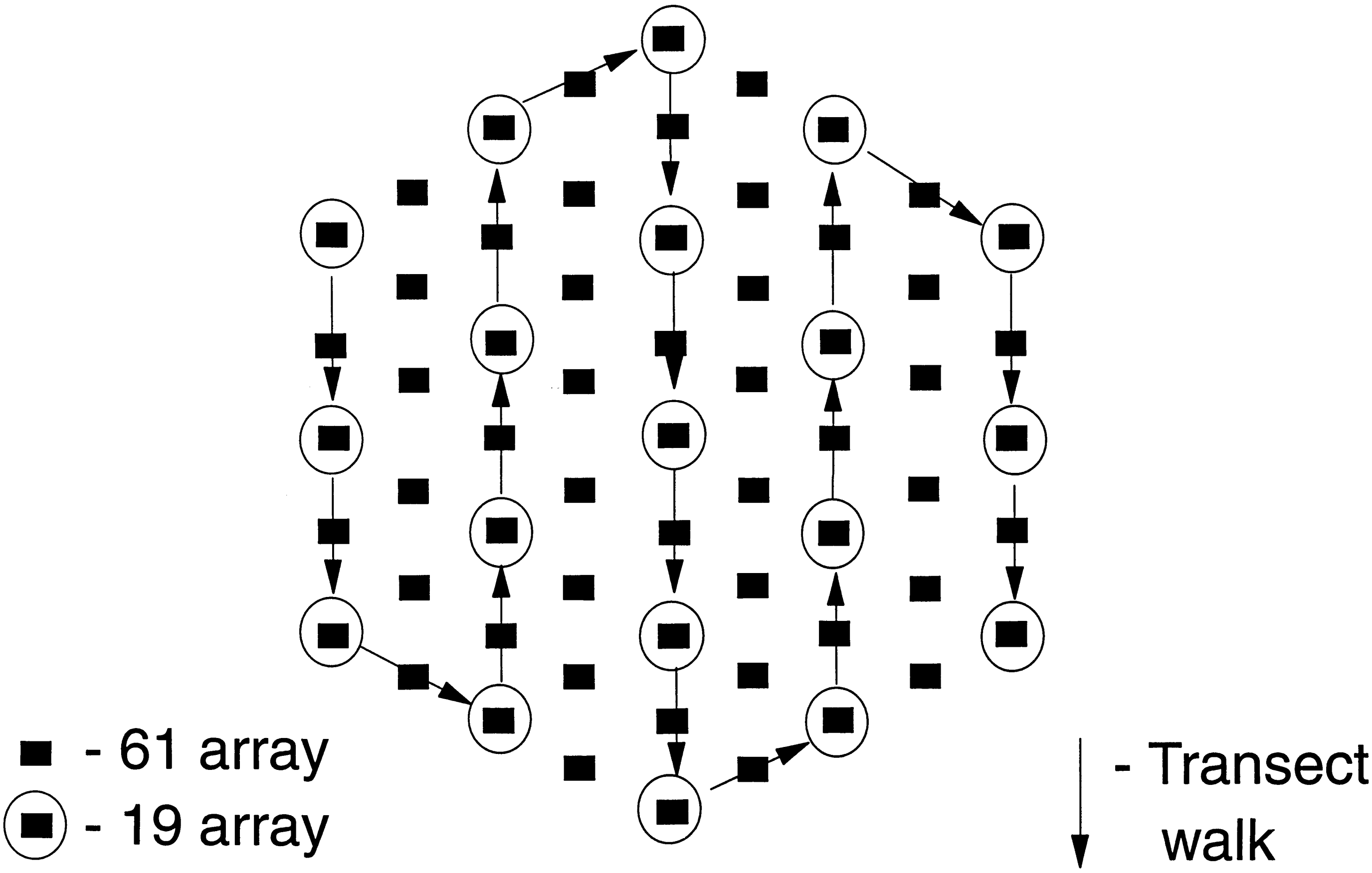
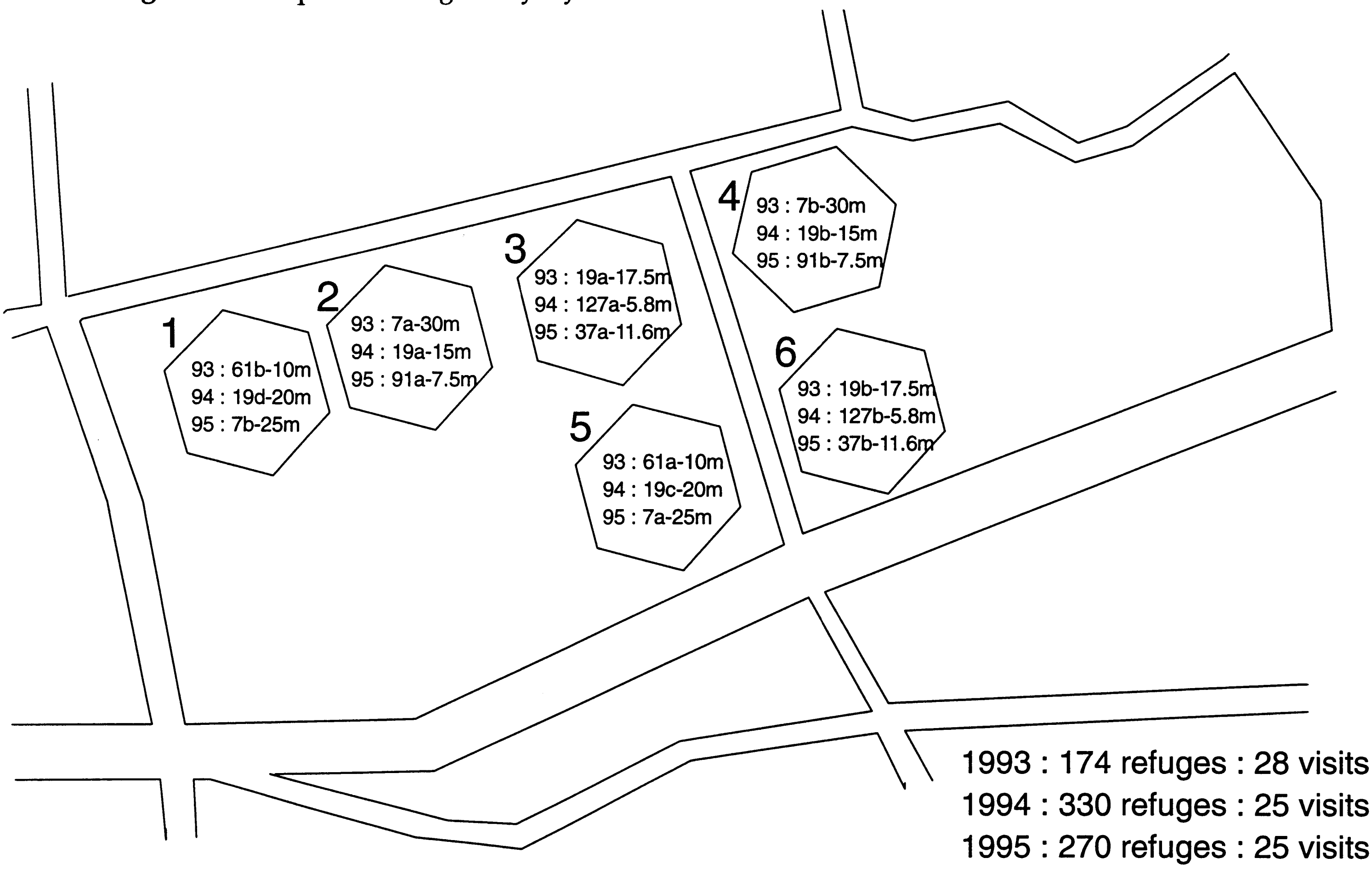


Figure 1: Example of a refuge array layout



Map 1: Diagrammatic map of the Wareham Forest study area

Table 1 : Array areas and transect lengths for the years 1993-1995

Year	Array (Refuge no.)	IRD (m)	Transect length (m)	Array area (hectares)
1993	61	10	600	0.479
	19	17.5	315	0.457
	7	30	180	0.495
1994	19	20	360	0.597
	127	5.8	731	0.335
	19	15	270	0.336
1995	7	25	150	0.344
	37	11.6	418	0.391
	91	7.5	675	0.402

Table 2 : Number of site visits per month to check refuges for reptiles

Year	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Total
1993	2	1	-	5	4	8	7	1	28
1994	-	-	4	5	5	5	5	1	25
1995	-	2	5	5	5	3	4	1	25
Mean	2.0	1.5	4.5	5.0	4.7	5.3	5.3	1.0	

5. Results

5.1 Total number of captures and/or sightings of each reptile species

During the three years of the study individuals of all six species of native British reptile were captured (Table 3). Of these, the most abundant were the smooth snake (321 captures) and slow worm (286 captures) with the least abundant being the common lizard (1 capture) and adder (6 captures). The number of captures/sightings for a given species was largely dependent on the method used to search for reptiles. Thus, the smooth snake, grass snake and slow worm were found almost exclusively (84-100%) under refuges whilst the sand lizard was encountered mainly (69-86%) on the open heath between refuges (Table 3).

Table 3 : Number of reptile and amphibian captures/sightings each year a) on/under refuges b) in the open (transect walk). Percentages for the proportion of reptile captures/sightings on/under refuges or in the open are given in parenthesis.

a. On/under refuges

Species	1993		1994		1995		Total	
Smooth snake *Coronella austriaca*	130	(97%)	124	(95%)	55	(96%)	309	(96%)
Grass snake *Natrix natrix*	14	(87%)	21	(84%)	3	(100%)	38	(86%)
Adder *Vipera berus*	1	(50%)	2	(50%)	0		3	(50%)
Sand lizard *Lacerta agilis*	12	(27%)	9	(31%)	3	(14%)	24	(25%)
Slow worm *Anguis fragilis*	135	(100%)	111	(99%)	37	(95%)	283	(99%)
Common lizard *Lacerta vivipara*	0		0	(0%)	0		0	(0%)

b. In the open (transect walk)

Species	1993		1994		1995		Total	
Smooth snake *Coronella austriaca*	4	(3%)	6	(5%)	2	(4%)	12	(4%)
Grass snake *Natrix natrix*	2	(13%)	4	(16%)	0	(0%)	6	(14%)
Adder *Vipera berus*	1	(50%)	2	(50%)	0		3	(50%)
Sand lizard *Lacerta agilis*	33	(73%)	20	(69%)	19	(86%)	72	(75%)
Slow worm *Anguis fragilis*	0	(0%)	1	(1%)	2	(5%)	3	(1%)
Common lizard *Lacerta vivipara*	0		1	(100%)	0		1	(100%)

Because the majority of reptiles were found associated with refuges (Table 3) and, in the case of those that were not (eg. sand lizard), the length of transect walks was highly correlated with both inter-refuge distance ($r=-0.903$; $n=18$; $p<0.001$) and the number of refuges per array ($r=0.949$; $n=18$; $p<0.001$), the capture/sightings data were analysed with respect to array variables (refuge number and inter-refuge distance) only.

Comparisons between the number of captures of each reptile species each year cannot be made before being standardised to allow for between year differences in the number of site visits during which a species was encountered, the number of refuges used and the area over which refuges were used (Table 4). The standardised Index of captures represent the estimated number of individuals encountered/site visit/refuge/hectare (a site visit for species 'x' is defined as one on which it was encountered and not one on which it was not as climatic conditions may not have been suitable for it to be found).

Table 4 : Standardisation of reptile capture numbers to allow for annual differences in the number of site visits during which a species was encountered, refuge number and the area sampled by refuges.

	1993	1994	1995
Total no. of site visits	28	25	25
No. of visits with sightings of each species (a)	Ca : 28 Nh : 10 Vb : 2 La : 18 Af : 28 Lv : 0	Ca : 25 Nh : 15 Vb : 4 La : 14 Af : 23 Lv : 1	Ca : 15 Nh : 2 Vb : 0 La : 14 Af : 15 Lv : 0
No. refuges (b)	174	330	270
Total sampling area (hectares) (c)	2.862	2.536	2.274
Standardisation Factor : SF (1/a x b x c)	Ca: 7.172×10^{-5} Nh: 2.008×10^{-4} Vb: 1.004×10^{-3} La: 1.116×10^{-4} Af: 7.172×10^{-5} Lv: -	Ca: 4.780×10^{-5} Nh: 7.966×10^{-5} Vb: 2.987×10^{-4} La: 8.535×10^{-5} Af: 5.195×10^{-5} Lv: 1.195×10^{-3}	Ca: 1.086×10^{-4} Nh: 8.143×10^{-4} Vb: - La: 1.163×10^{-4} Af: 1.086×10^{-4} Lv: -
Standardised Index of Ca captures	134 x SF = 9.610×10^{-3}	130 x SF = 6.214×10^{-3}	57 x SF = 6.190×10^{-3}
Standardised Index of Nh captures	16 x SF = 3.213×10^{-3}	25 x SF = 1.991×10^{-3}	3 x SF = 2.443×10^{-3}
Standardised Index of Vb captures	2 x SF = 2.008×10^{-3}	4 x SF = 1.195×10^{-3}	-
Standardised Index of La captures	45 x SF = 5.022×10^{-3}	29 x SF = 2.475×10^{-3}	22 x SF = 2.559×10^{-3}
Standardised Index of Af captures	135 x SF = 9.682×10^{-3}	112 x SF = 5.818×10^{-3}	39 x SF = 4.235×10^{-3}
Standardised Index of Lv captures	-	1 x SF = 1.195×10^{-3}	-

Ca - Smooth snake *Coronella austriaca*
Nh - Grass snake *Natrix natrix*
Vb - Adder *Vipera berus*
La - Sand lizard *Lacerta agilis*
Af - Slow worm *Anguis fragilis*
Lv - Common lizard *Lacerta vivipara*

After standardisation the apparent decline in the number captures of all species between 1994 and 1995 (Table 4) can be seen to be an artefact. With the exception of the common lizard, for which too few data were obtained, the true pattern for the remaining five species was one of a decline between 1993 and 1994 of 35-51% and stabilisation between 1994 and 1995 (Table 5). Thus, despite the very reduced number of overall captures in 1995 compared with the previous two years, and when the effects of the very hot summer in 1995 which resulted in six non-productive site visits are allowed for, there was very little change in the estimated abundance of each reptile species.

Table 5 : Percentage change in standardised reptile capture numbers

Species	1993-1994	1994-1995
Smooth snake	-35%	-0.4%
Grass snake	-38%	+23%
Adder	-40%	-
Sand lizard	-51%	+3%
Slow worm	-40%	-27%

5.2 Total number of individual snakes captured each year

Although the total number individual smooth snakes, grass snakes and adders captured each year varied, more individuals were captured in 1994 than in 1993 or 1995 and fewer in 1995 than in the previous two years (Table 6).

Table 6 : Number of individuals captured each year. The percentage change from the previous year is shown in parenthesis

Species	1993	1994		1995	
Smooth snake *Coronella austriaca*	45	47	(+4%)	30	(-36%)
Grass snake *Natrix natrix*	9	13	(+44%)	3	(-77%)
Adder *Vipera berus*	2	3	(+50%)	0	(-100%)

The mean number of captures of individuals per year also varied (Table 7), with the between species variation, possibly indicating differences in behaviour. Thus the higher mean number of captures of individual smooth snakes compared with either the grass snake or adder may suggest that they are a less free ranging species (Gent & Spellerberg 1993) or that they have a higher thermal requirement causing them to seek out refuges, which tend to warm up even on cool days with little sunshine. Alternatively the differences may purely reflect the overall differences in abundance between the three species within the study area.

Table 7 : Mean number of captures per individual snake per year

Species	1993	1994	1995
Smooth snake (*Coronella austriaca*)	2.98	2.79	1.90
Grass snake (*Natrix natrix*)	1.78	1.92	1.0
Adder (*Vipera berus*)	1.0	1.33	-

The above argument, suggesting a difference in behaviour between the three species of British snake, is supported when the numbers of 'new', previously untagged, snakes found each year are investigated (Table 8).

Table 8 : Number of 'New' (previously untagged) individuals per year. Their numbers, in proportion (%) to the total number of individuals captured (see Table 6), are shown in parenthesis.

Species	1993		1994		1995	
Smooth snake *Coronella austriaca*	45	(100%)	19	(40%)	7	(23%)
Grass snake *Natrix natrix*	9	(100%)	13	(100%)	3	(100%)
Adder *Vipera berus*	2	(100%)	2	(67%)	0	

In the case of the smooth snake, the proportion of previously untagged individuals found each year steadily declined from 100% (all untagged) at the start of the study, in 1993, to just 23% by 1995 despite the number of captures, particularly in 1994, increasing. The 'new' snakes each year may have been new immigrants to the study area, juveniles growing to a size which could be tagged (hatchling smooth snakes are too small to implant a PIT tag) or animals that had been missed during the previous year. This was tested by determining the number of smooth snakes captured in 1995 that had been first captured and tagged in 1993 but not recaptured in 1994. Only two snakes fell into this category. Both were sub-adult, one being male and the other female. Thus, the very limited data available gives an estimate for the number of 'missed' snakes in a year as two (8.7%) out of 23.

In the case of the grass snake multiple captures only occurred within years and not between years. Most (72%) grass snakes were captured only once, five (20%) were captured twice and only two (8%) captured three times.

In the case of the adder one adult male was captured on three occasions, once in 1993 and twice in 1994. The remaining three snakes were only captured once.

These data suggest that the smooth snake is probably the most 'sedentary' of the three species of British snake followed closely by the adder with the grass snake being particularly far ranging.

5.3 Climatic conditions

Observer perceived weather conditions in terms of sunshine, air movement and temperature were recorded on 76 occasions during the three years of the study (Table 9). No significant differences were detected between years in any of the variables although more hot sunny days were recorded in 1995 than in either of the other two years. Also, most hot days were sunny but not vice versa and most sunny or sun+cloudy days were warm (χ^2=13.19; df=4; p=0.01).

Table 9 : Number of days each year on which each of the nine weather variables were recorded.

Year	Sun	Sun + Cloud	Cloud	Wind	Breeze	Still	Hot	Warm	Cool
1993	8	16	4	8	17	3	1	22	5
1994	8	12	3	5	15	3	0	19	4
1995	14	9	2	3	17	5	4	20	1
χ^2		4.48	(4df)		2.67	(4df)		7.67	(4df)
P		>0.05	(NS)		>0.05	(NS)		>0.05	(NS)

5.3.1 Total reptile captures in relation to climatic conditions

Analysis of variance of the total number ($\log_e$) of smooth snakes, grass snakes, sand lizards and slow worms against year, single and multiple climatic variables (sun, wind and temperature) revealed highly significant differences in the number of all species, except the sand lizard, between years (Table 10). When total reptile numbers were regressed against each of the climatic variables individually only temperature gave a significant correlation and then only in the case of the smooth snake and slow worm. Similarly, multiple regressions of all possible combinations of climatic variable against total reptile numbers revealed significant correlations with temperature even when sun, wind and sun+wind were allowed for and then only in the case of the smooth snake and slow worm. Total grass snake and sand lizard numbers were not significantly correlated with any single variable or combination of variables, probably due to the relatively low numbers of each of these species that were sighted/captured.

Table 10 : ANOVA probability values for Log_e of total numbers of each species captured in relation to single and multiple variables.

Variable	Smooth snake	Grass snake	Sand lizard	Slow worm
Years	<0.0001	0.002	NS	<0.0001
Sun	NS	NS	NS	NS
Wind	NS	NS	NS	NS
Temp	0.002	NS	NS	0.004
Sun+wind	NS	NS	NS	NS
Sun+temp	temp: 0.005	NS	NS	temp: 0.013
Wind+temp	temp: 0.008	NS	NS	temp: 0.002
Sun+wind+temp	temp: 0.024	NS	NS	temp: 0.005
Df	75	75	75	75

NS = not significant : p>0.05.

5.4 Reptile captures/sightings in relation to the time of year.

5.4.1 Smooth snake

Although smooth snakes were captured throughout the year from March to October (Figs. 2-4) they were encountered more frequently during the spring (May & June) and early autumn (September & October) than during the summer months (July & August). The number of captures per visit and the date of each visit varied between years with captures during 1993 peaking in June (no visits were able to be made in May) and then levelling off for the rest of the year with no secondary rise in capture numbers in the early autumn as occurred in both 1994 and 1995. When the data for all three years are combined and the number of captures plotted against the day of the year (Fig. 5) the importance of the months of May and June become more clear . Similarly the drop in the number of captures during the summer becomes apparent as does the increased interval between site visits during the summer compared with the spring. This was a reflection of the number of days which were deemed to be suitable for finding reptiles ie. predominantly warm but not hot (Spellerberg & Phelps 1977). A histogram of the mean number of smooth snakes captured per visit per month for each of the three years again reveals the relative importance of May, June, September and October for finding animals (Fig. 6).

The capture of 'new' snakes (ie not previously captured during the year) also occurred throughout the year from March to October but unlike the pattern of overall captures there was no suggestion of a secondary peak in captures of 'new' animals during the early autumn (Fig. 7). As with total captures the highest number of captures of 'new' individuals occurred during May and June.

5.4.2 Grass snake

Unlike the pattern of smooth snake captures during each year of the study, that of grass snakes was less clearly defined (Figs. 8-10). Nevertheless, there was a tendency for snakes to be encountered more frequently during early spring (May & June) and again during the early autumn (September). Too few animals (n=3) were captured during 1995 to enable realistic comparisons with the previous two years to be made. When the data for all three years are combined and the number of captures plotted against the day of the year (Fig. 11) the seasonal pattern of captures becomes a little clearer revealing the slight increase in the number of captures during the periods mid May to Mid June and again in early September compared with the summer months.

A histogram of the mean number of grass snakes captured per visit per month for each of the three years indicates, as suggested by Figs 8-10, that May, June and September/October are the best months for finding animals with July and August being slightly less productive in terms of encounters (Fig. 12).

The capture 'new' grass snakes each year occurred throughout the season (May-September) with most being encountered during the months of May, June and September thus broadly mirroring the overall pattern of captures (Fig. 13).

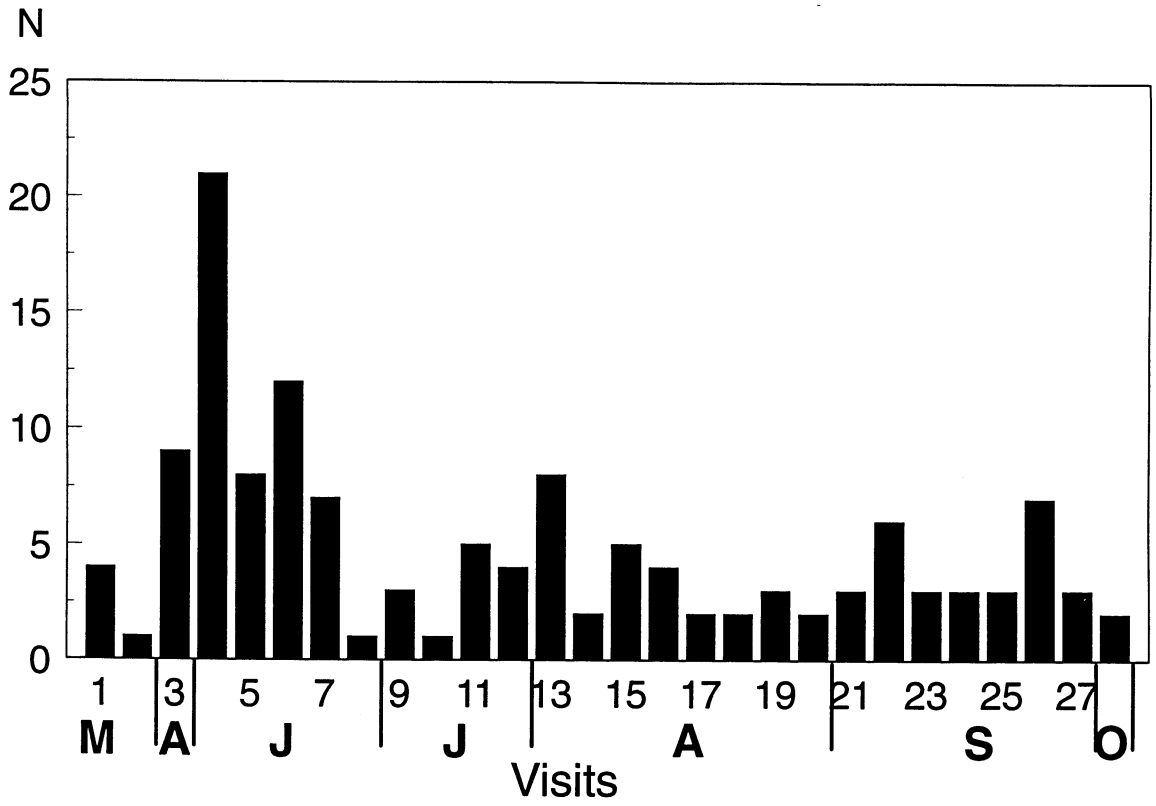


Figure 2: Total number of smooth snake captures per visit: 1993

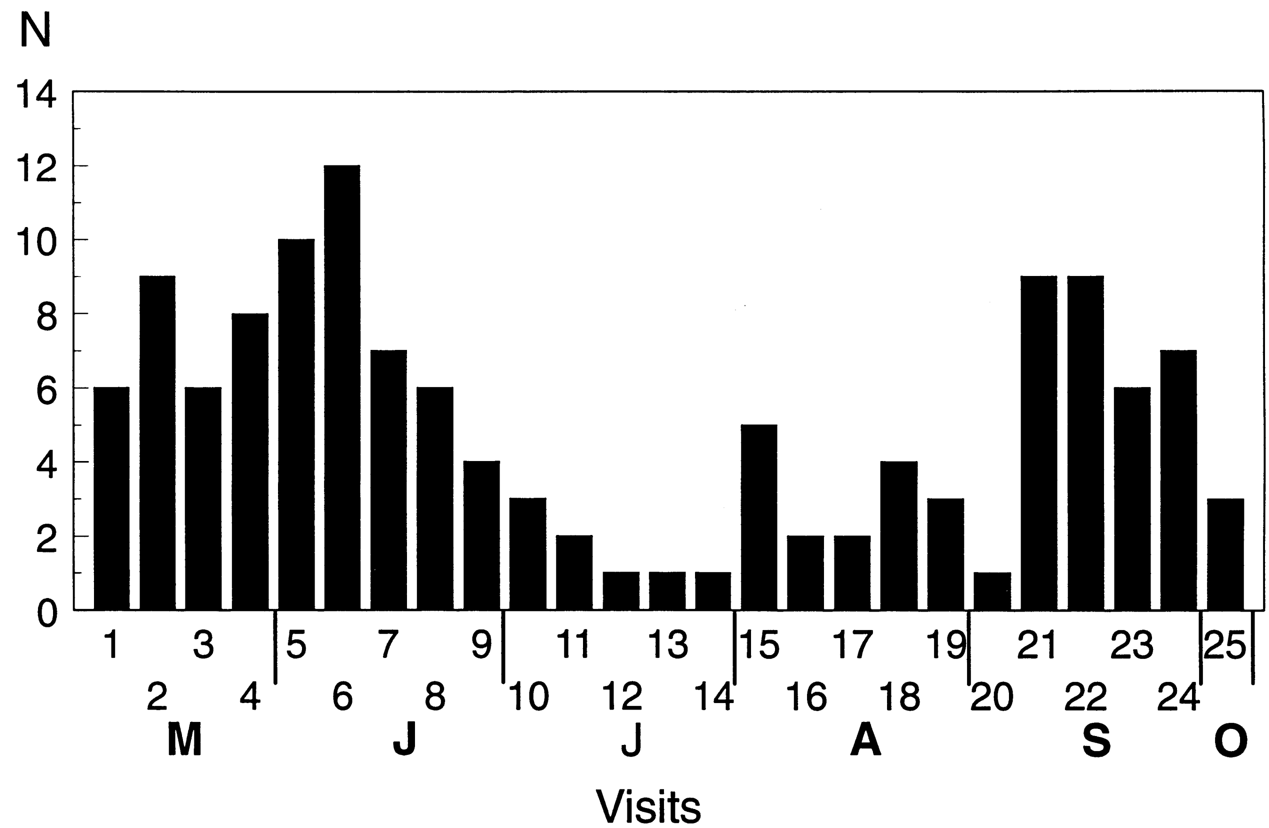


Figure 3: Total number of smooth snake captures per visit: 1994

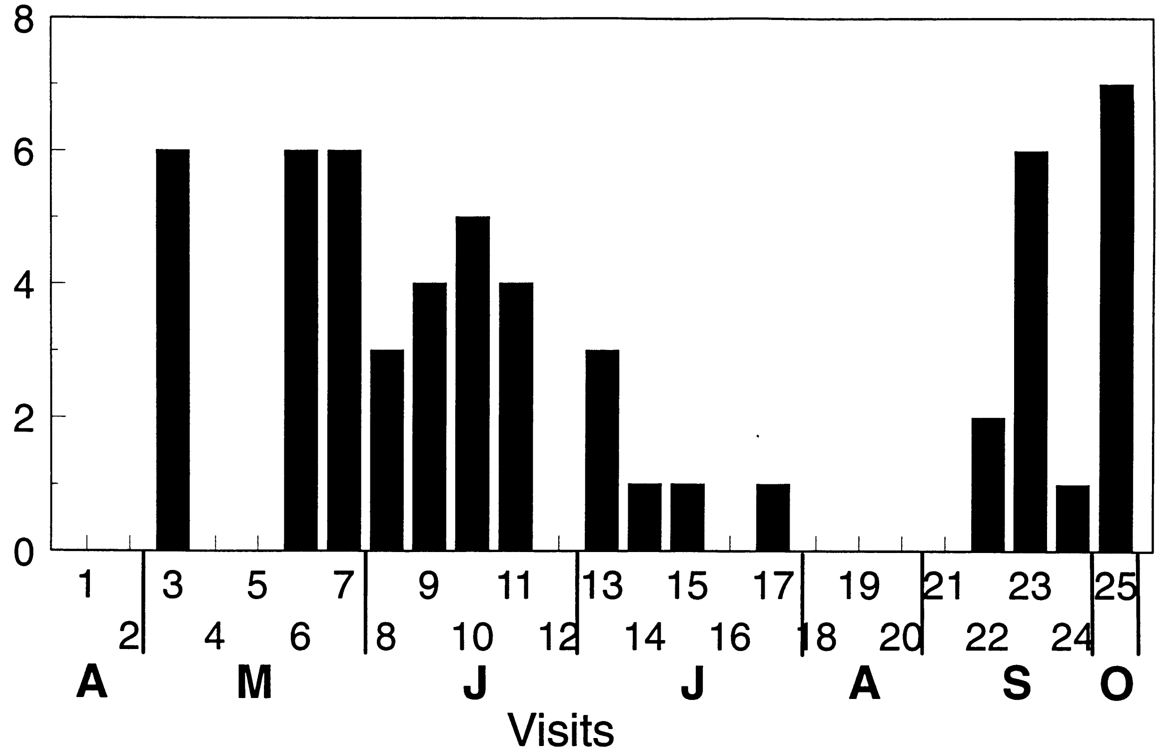


Figure 4: Total number of smooth snake captures per visit: 1995

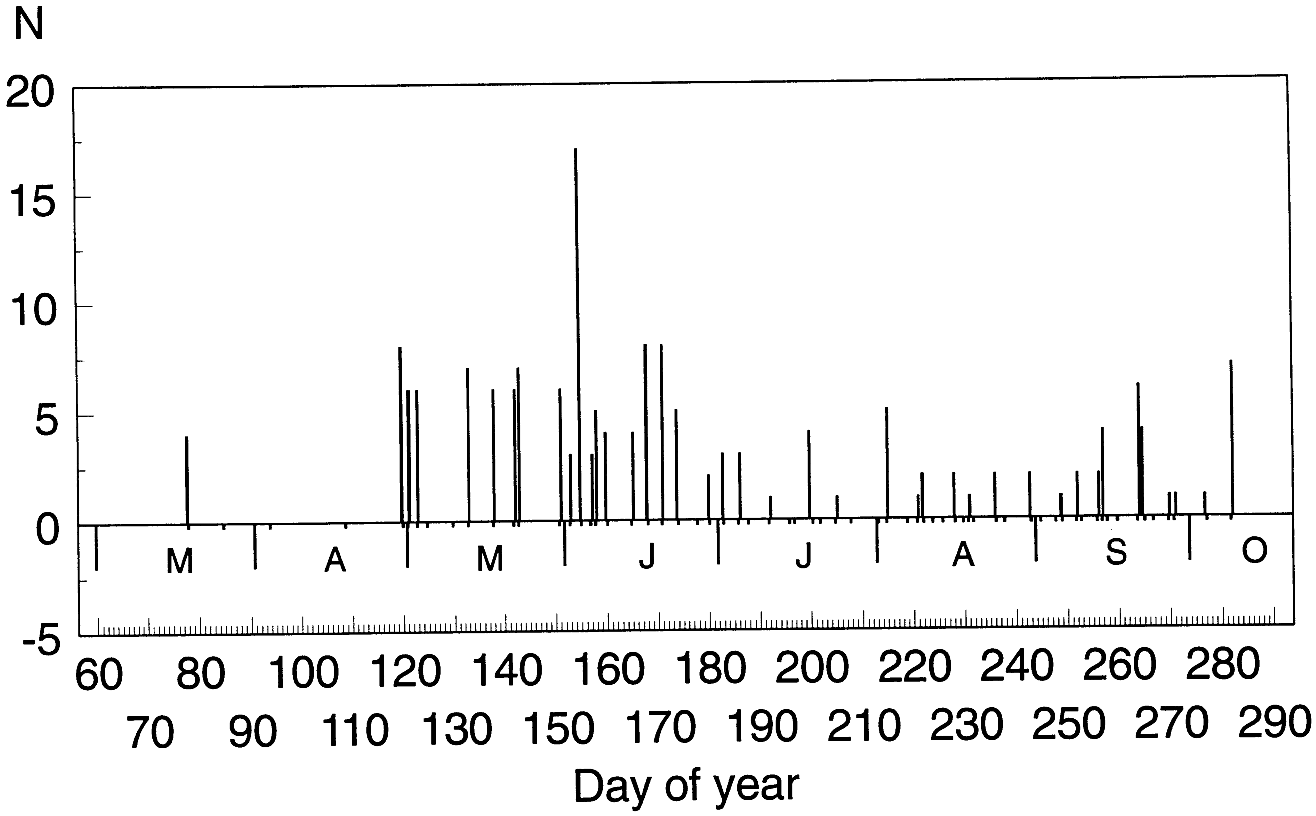


Figure 5: Total number of smooth snake captures/day of year

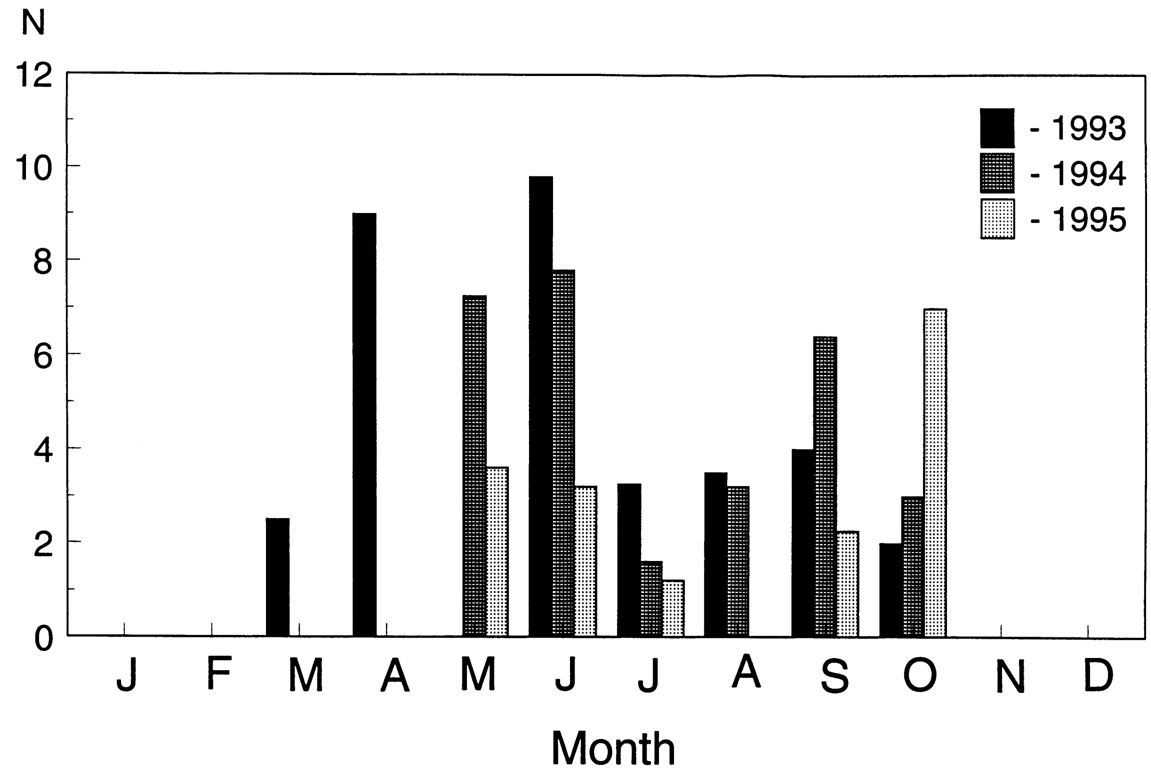


Figure 6: Mean number of smooth snake captures/visit/month: 1993-1995

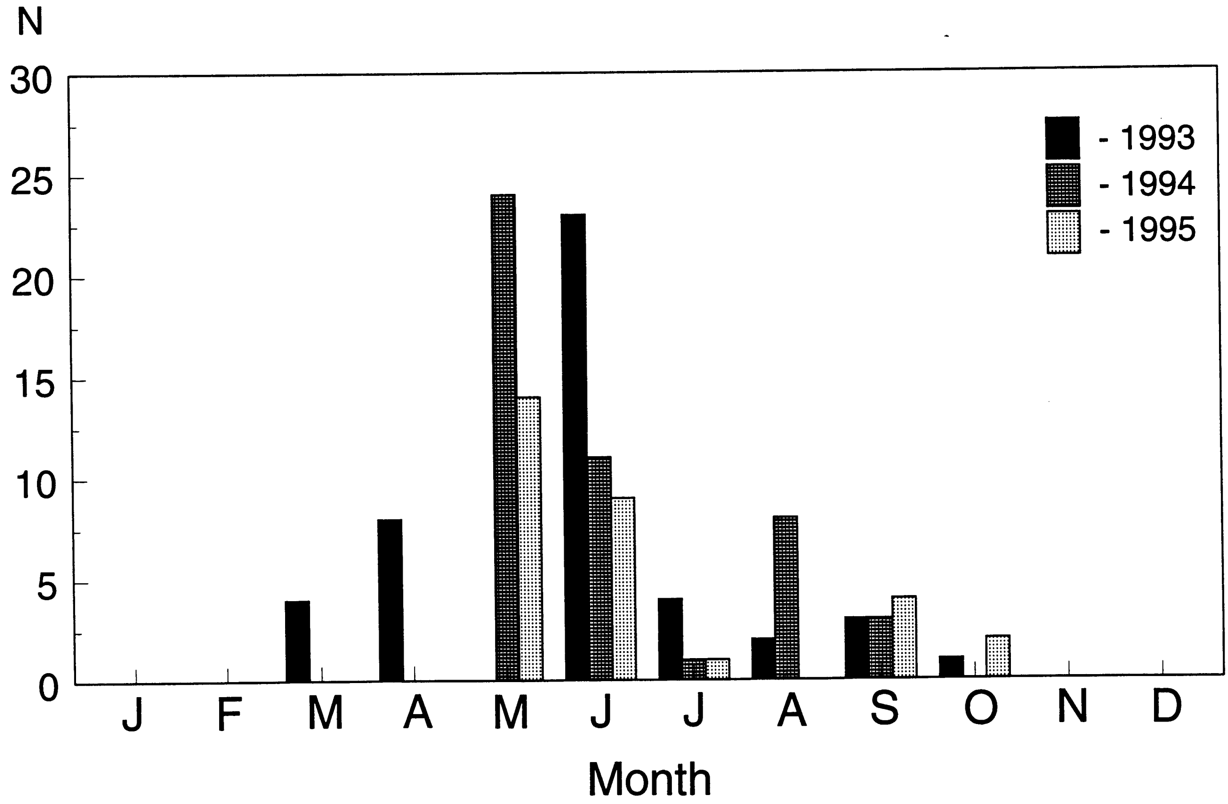


Figure 7: Monthly number of new smooth snakes (individuals): 1993-1995

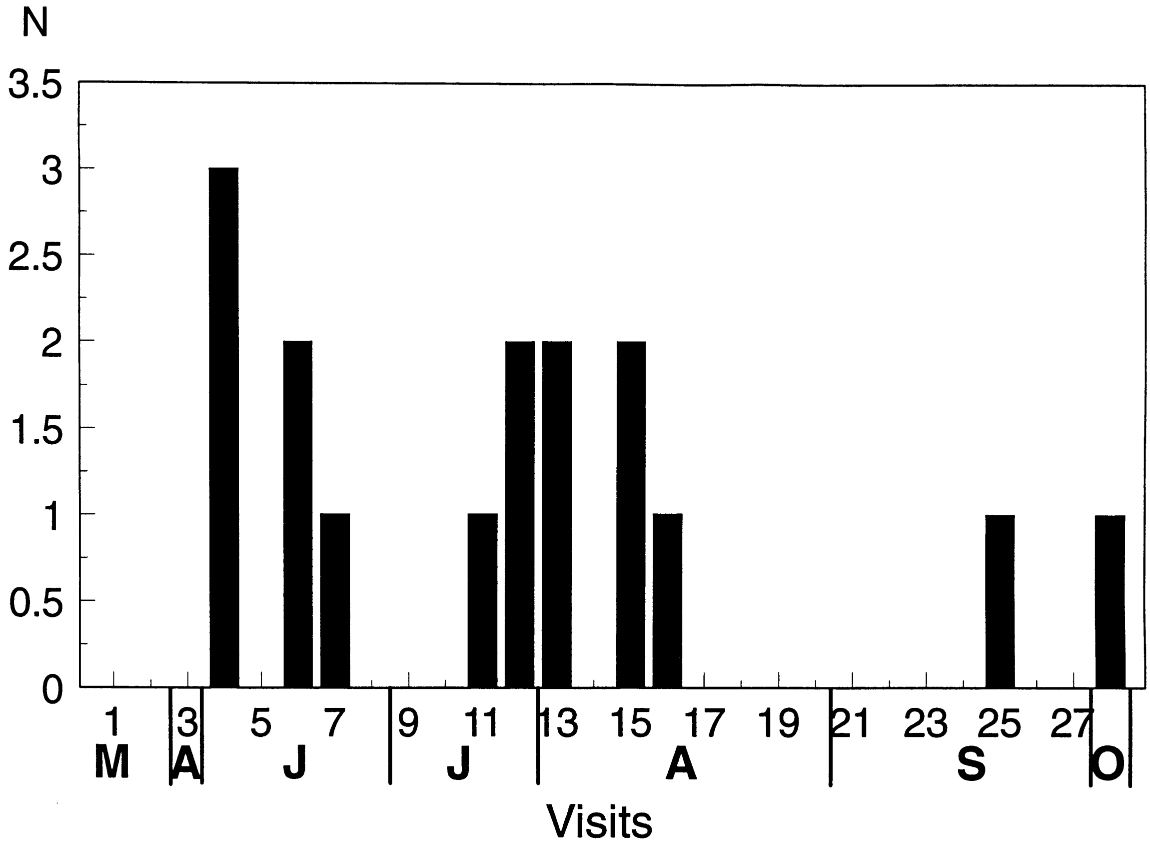


Figure 8: Total number of grass snake captures per visit: 1993

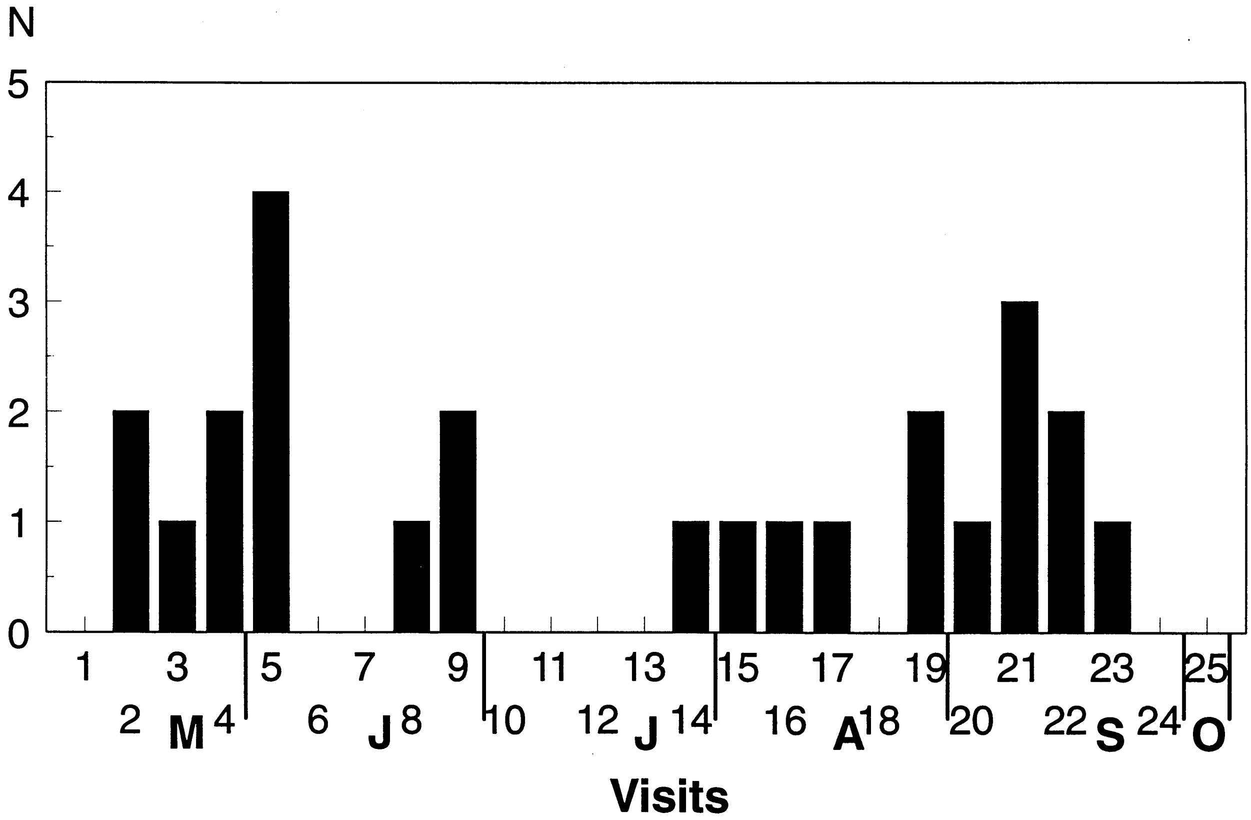


Figure 9: Total number of grass snake captures per visit: 1994

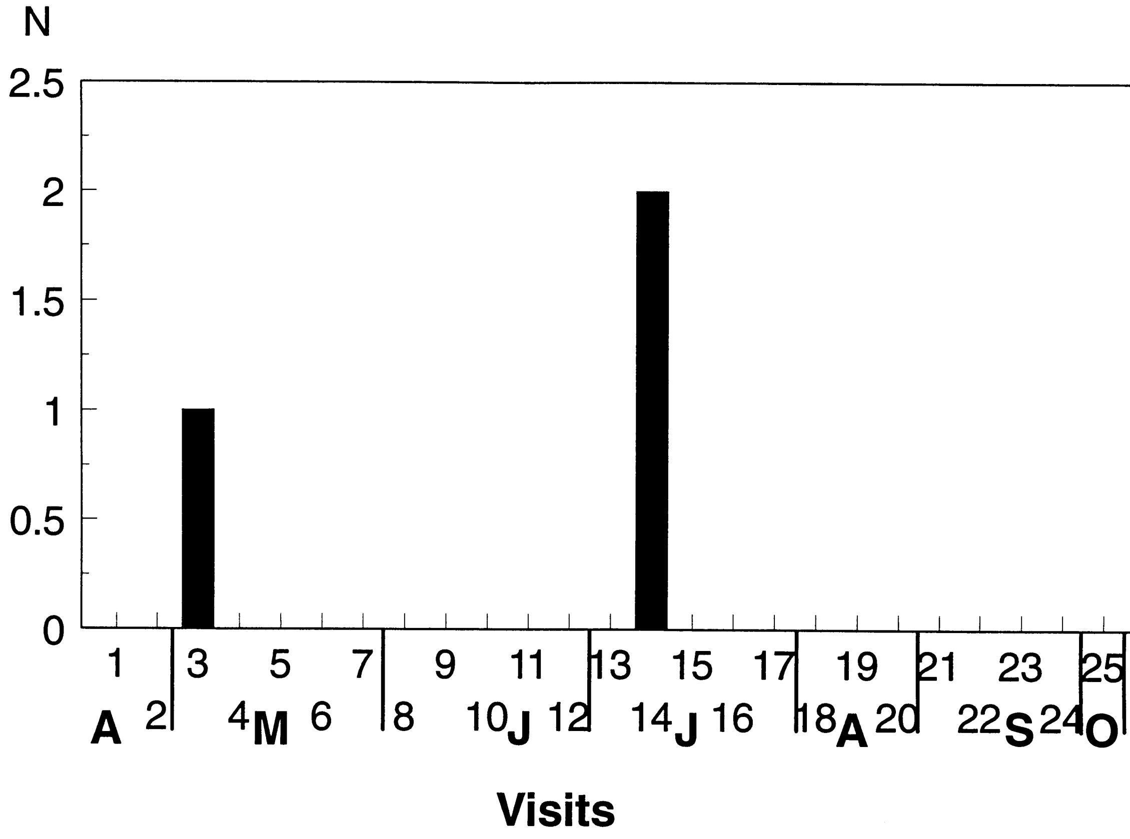


Figure 10: Total number of grass snake captures per visit: 1995

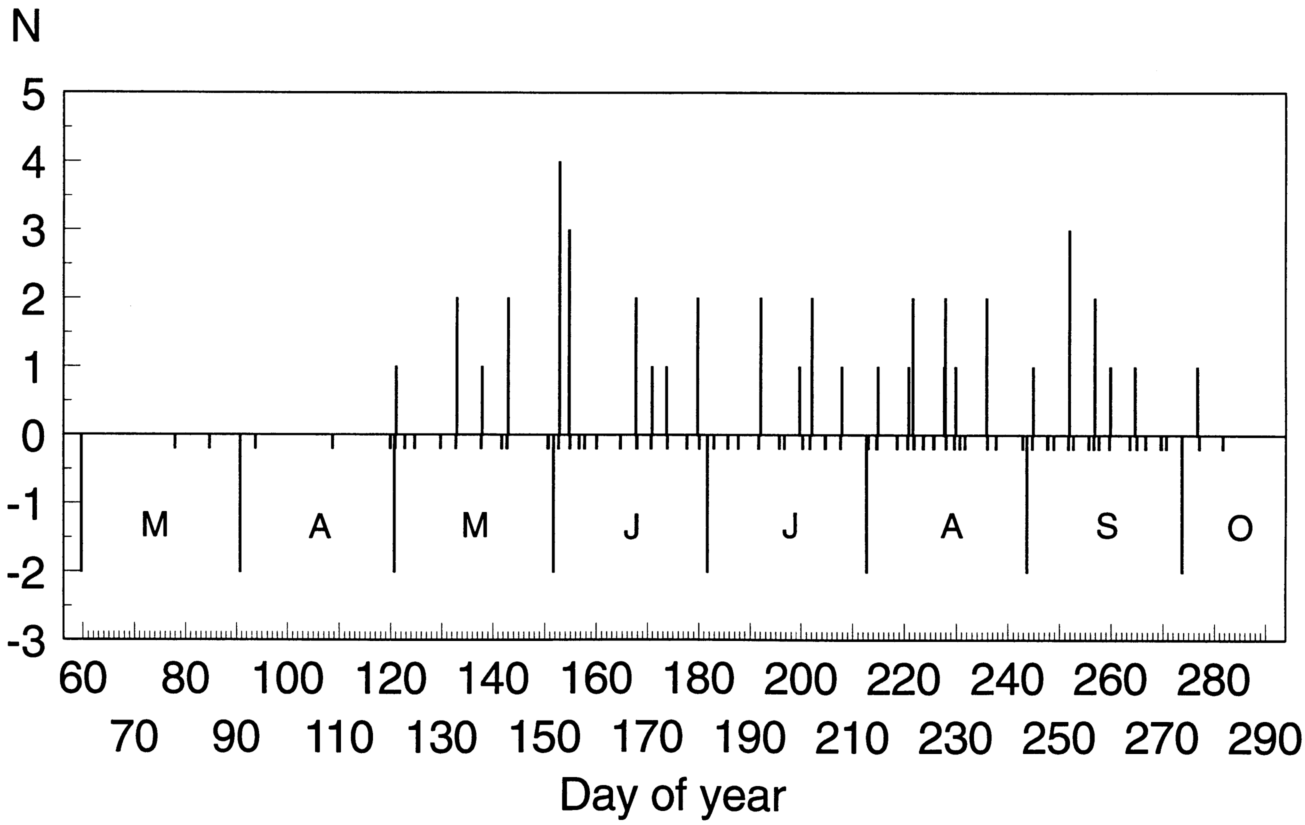


Figure 11: Total number of grass snake captures/day of year

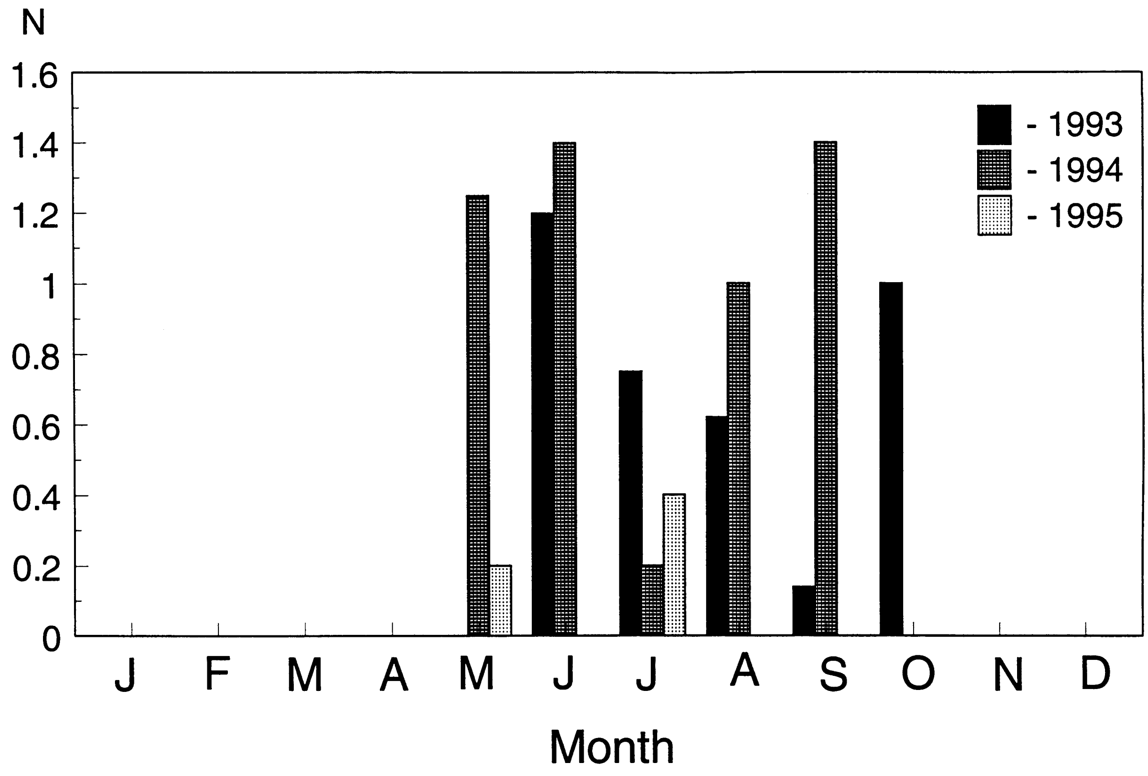


Figure 12: Mean number of grass snake captures/visit/month: 1993-1995

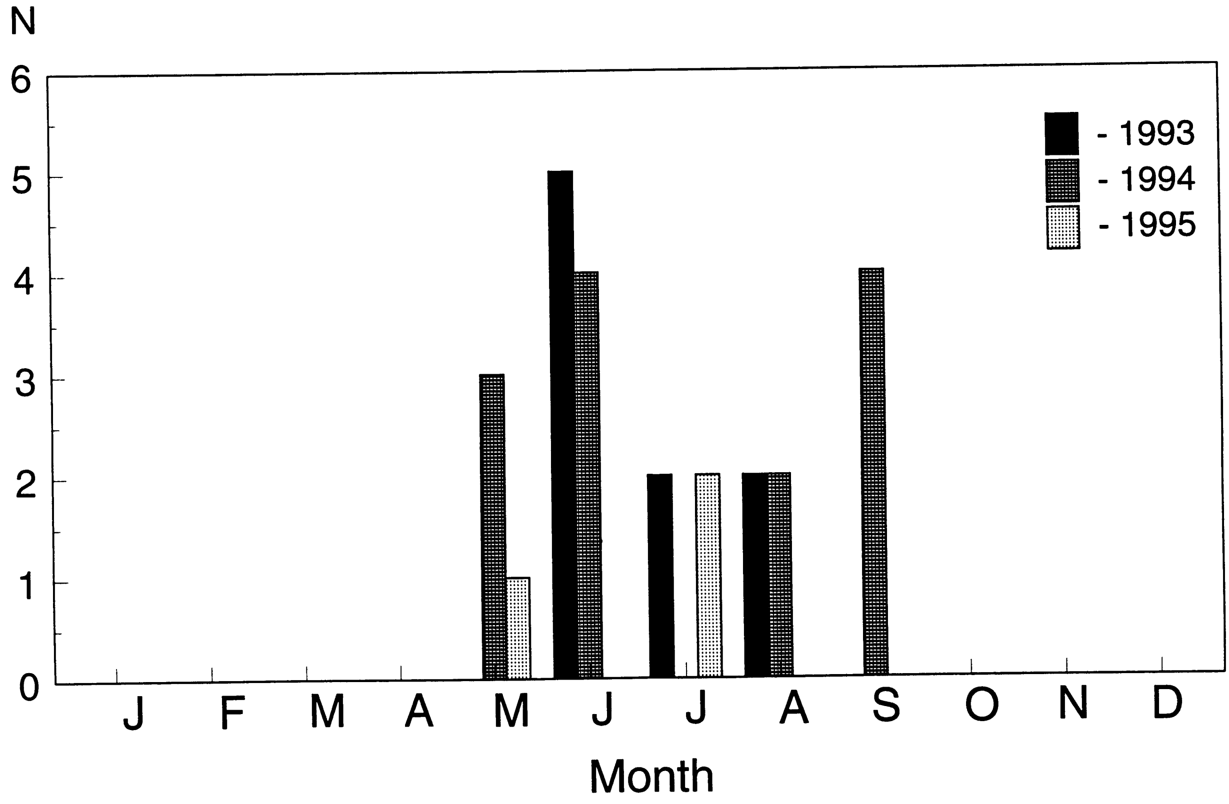


Figure 13: Monthly number of new grass snakes (individuals): 1993-1995

5.4.3 Adder

Too few adders were found to enable any definitive statements to be made about which months of the year are best for finding them. In 1993 adders were captured on 16 August and 22 September whilst in 1994 they were captured on 23 May, 3, 9 & 16 August suggesting that the best months for encountering them might be spring and late summer/early autumn. At these times of the year night temperatures tend to be rather low and adders may therefore need to bask in sunshine to attain the required body temperature for activity and food digestion. It is also possible that adders were only encountered within the study area at these times because this was where they hibernated and that during the late spring and summer months they migrated out of the area to more suitable feeding areas.

5.4.4 Slow worm

The total number of slow worms seen during each site visit varied between years with fewest being seen during 1995 (Figs 14-16). Slow worms were found during every month of the season (March and October) in 1993 and 1994 but not during the hottest period (mid July-early September) of the 1995 summer. In all three years slow worms were found relatively early in the year (April and May) compared to the other reptile species and also showed an increase in sightings during the late autumn (mid September-early October) perhaps suggesting a better tolerance of lower temperatures than the smooth snake, grass snake and sand lizard. When these data are combined and sightings plotted against the day of the year when they occurred (Fig. 17), a pattern of relatively constant observations throughout the season, up to mid September, is found followed by an increase in the number of sightings from mid September to early October.

A histogram of the mean number of slow worm sightings per visit per month for each of the three years (Fig. 18) confirms the pattern of early spring and late summer observations and also reveals a slight decrease in the number of observations during the hottest months of the year (July & August).

5.4.5 Sand lizard

The total number of sand lizard sightings during each site visit for each of the three years are shown in Figs 19-21 and reveal that although, overall, they were encountered in every month between March and October they were most frequently seen during the period May to September. There was a tendency for more animals to be seen during the summer and autumn (July-September) than during the spring and early summer (May & June). Combining the data for all three years (Fig. 22) and plotting sightings against the day of the year shows an increase in the occurrence of sand lizards during August and September compared with May to July.

A histogram of the mean number of sand lizard sightings per visit per month for each of the three years not only confirms the relative importance of August and September for seeing animals (Fig. 23) but also shows an increased level of sightings during the early spring, particularly in 1993 and 1994, and a decrease in sightings during June and July. The overall pattern is therefore similar to that found for the smooth snake except that it is approximately one month earlier.

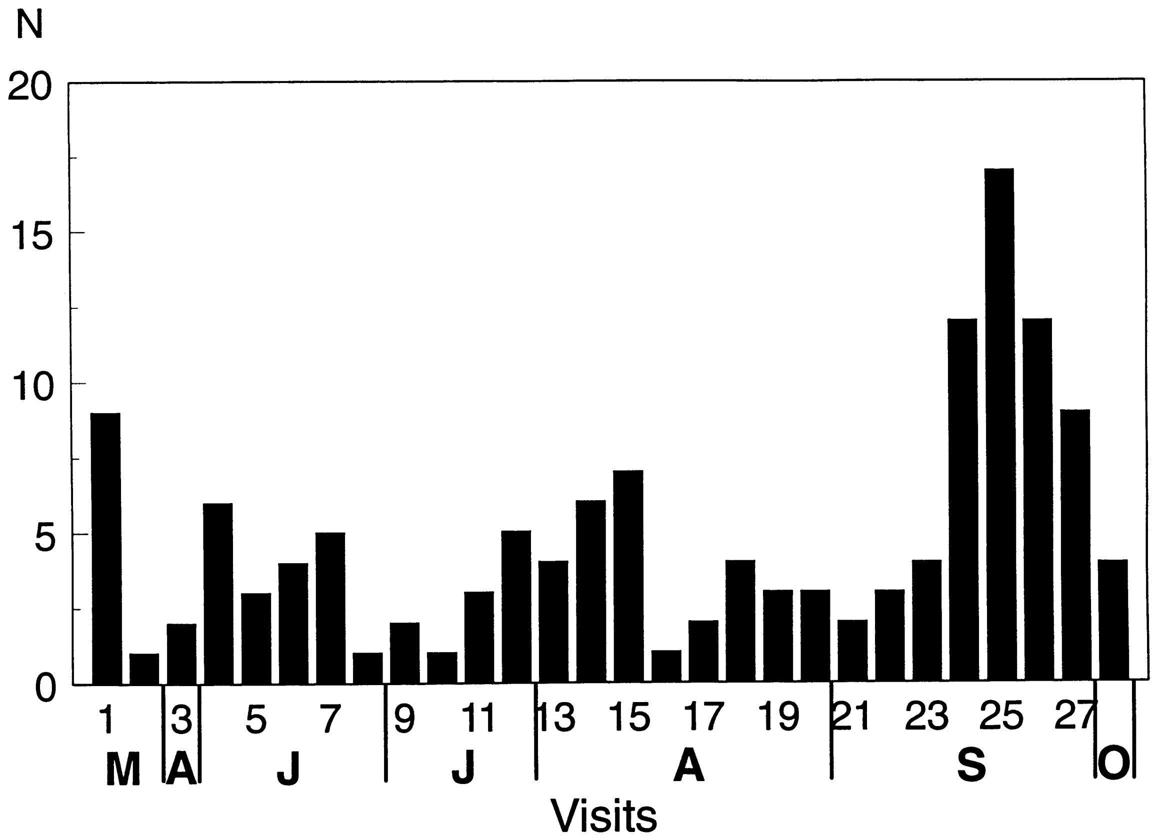


Figure 14: Total number of slow worm captures per visit: 1993

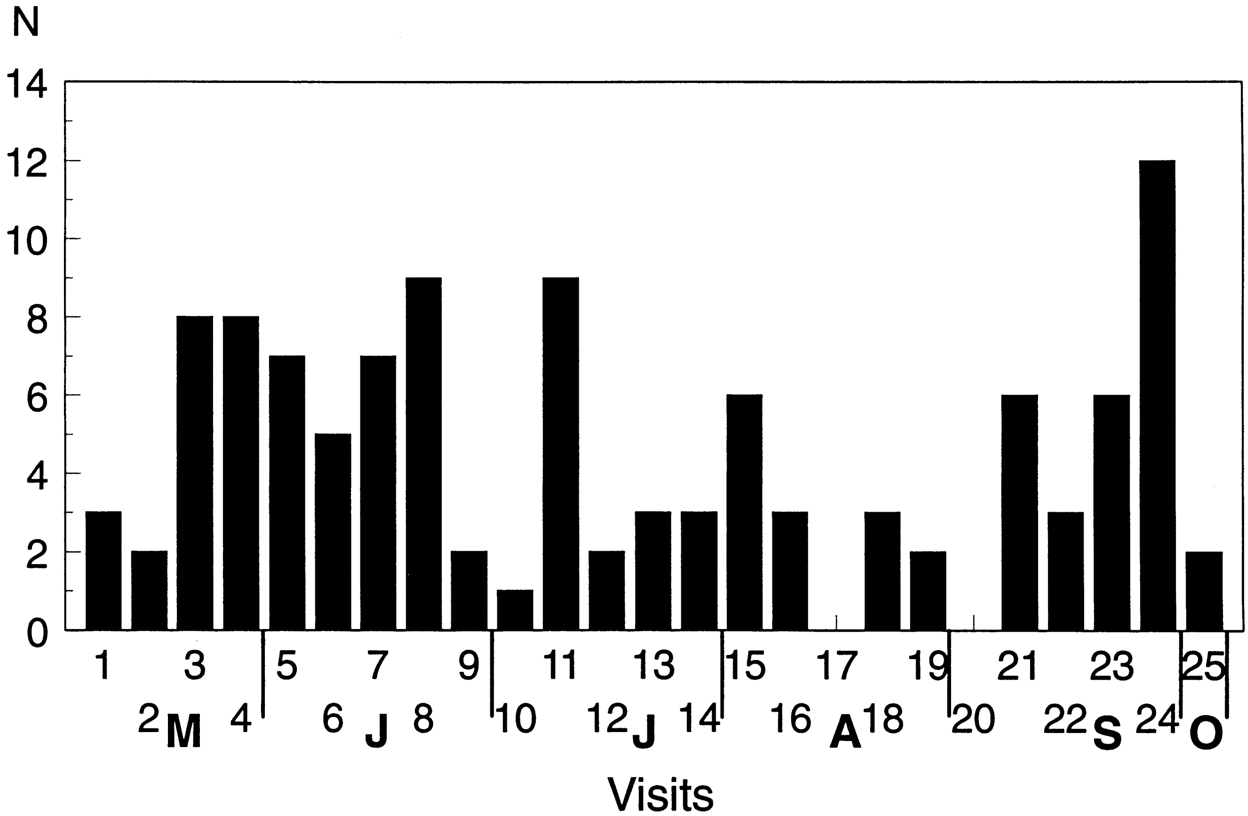


Figure 15: Total number of slow worm captures per visit: 1994

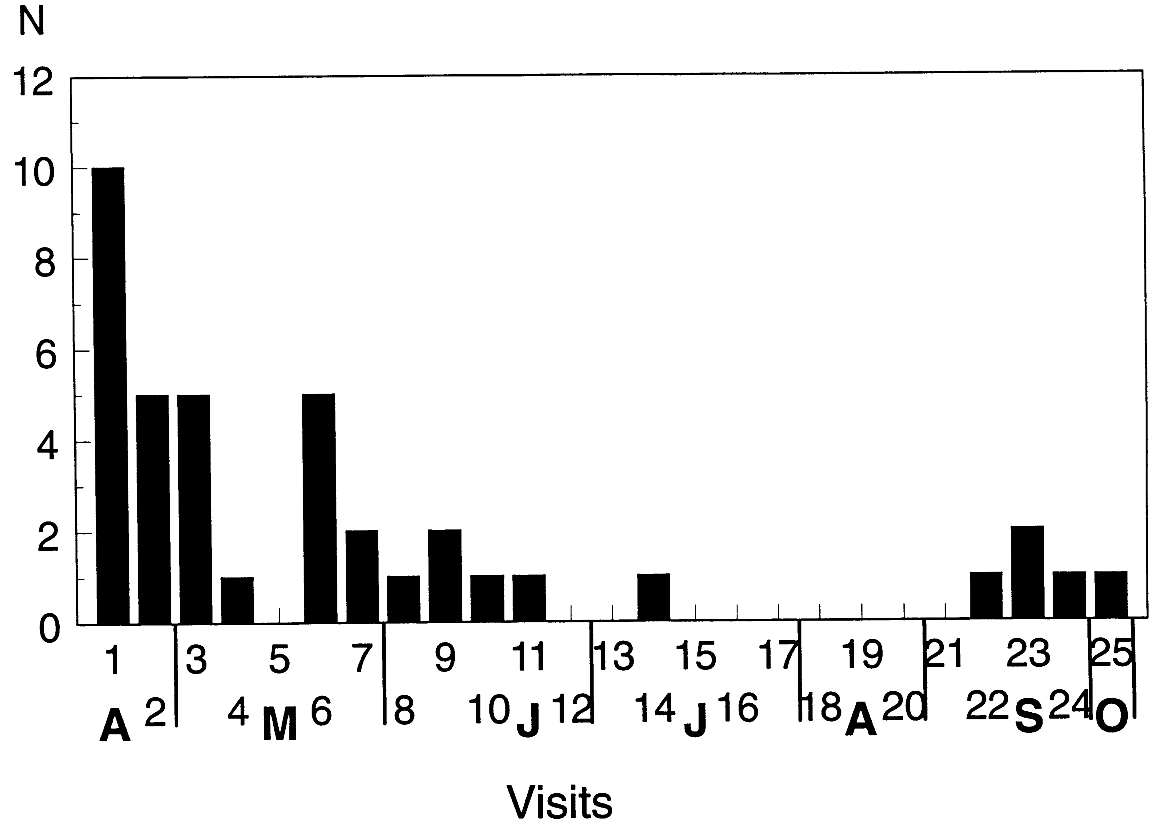


Figure 16: Total number of slow worm captures per visit: 1995

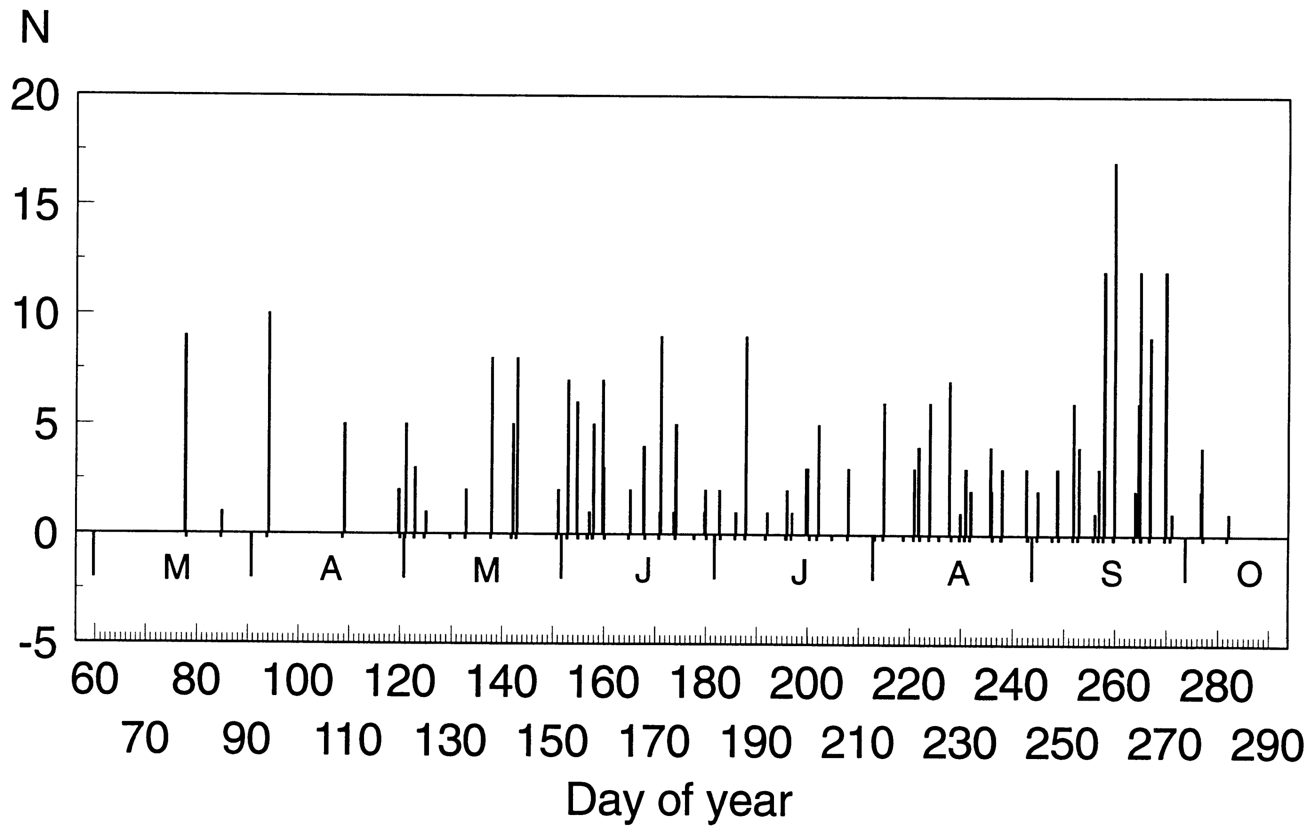


Figure 17: Total number of slow worm captures/day of year

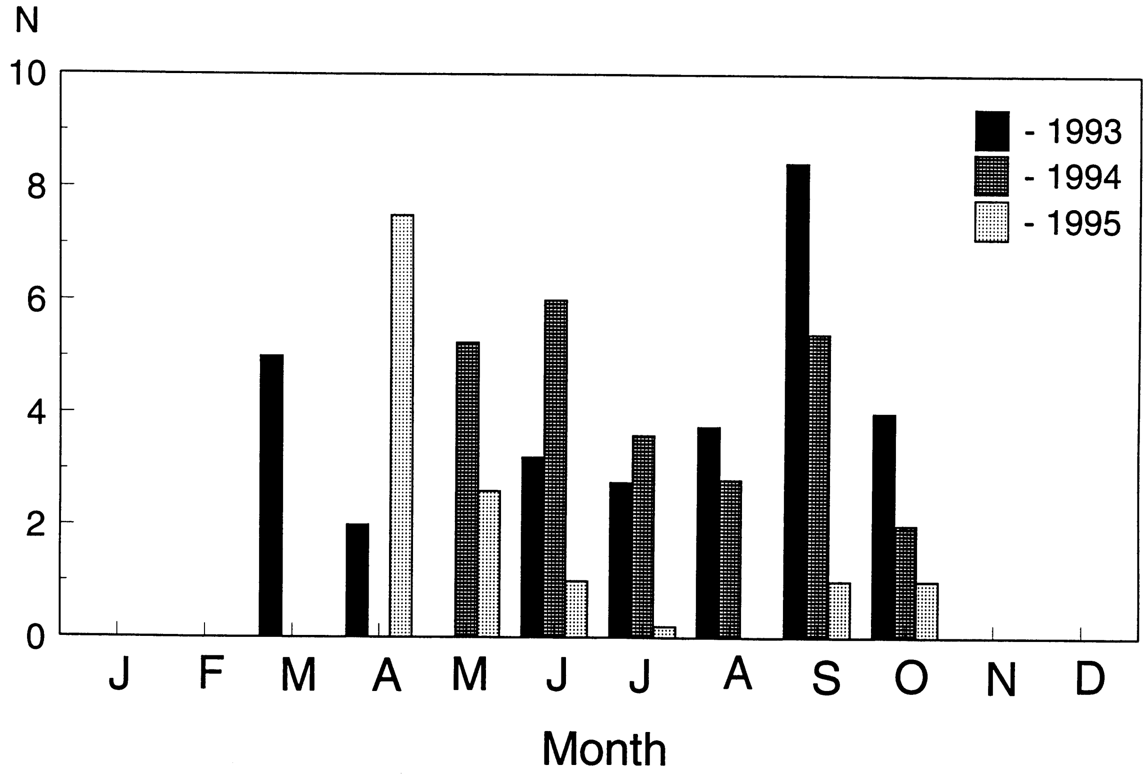


Figure 18: Mean number of slow worm captures/visit/month: 1993-95

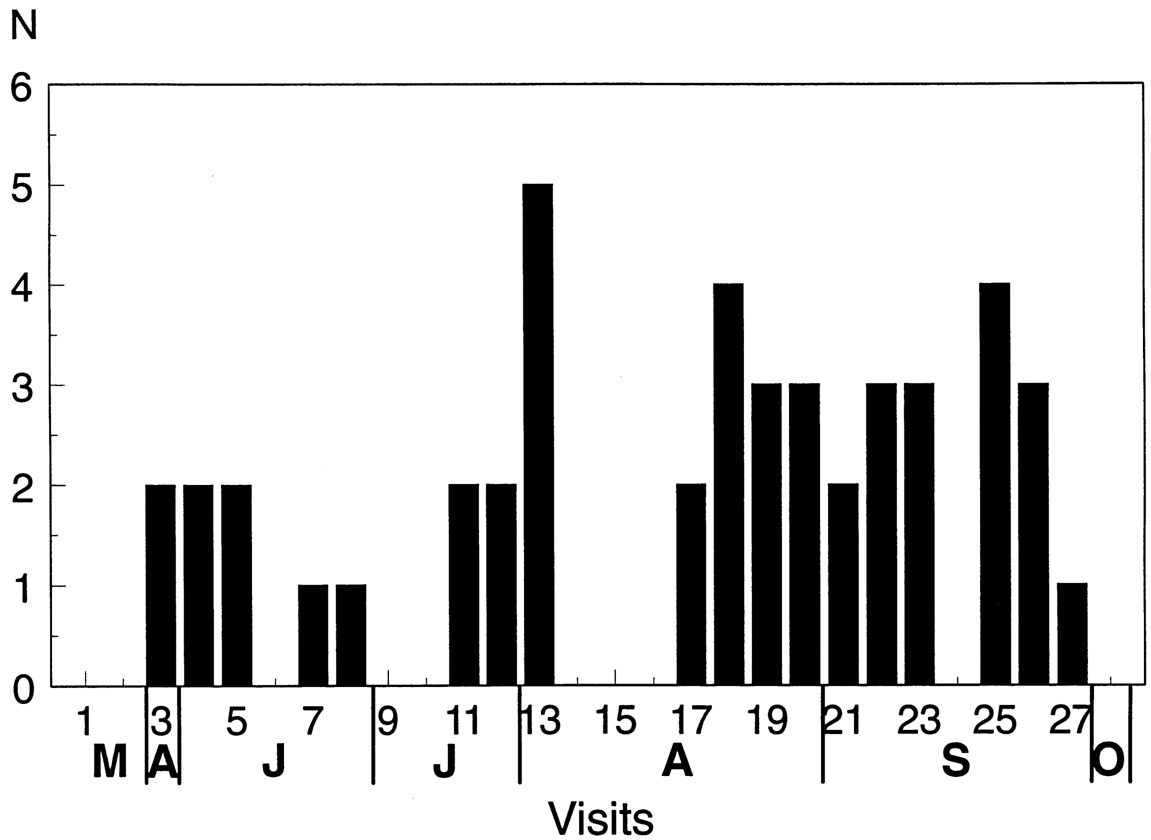


Figure 19: Total number of sand lizard sightings per visit: 1993

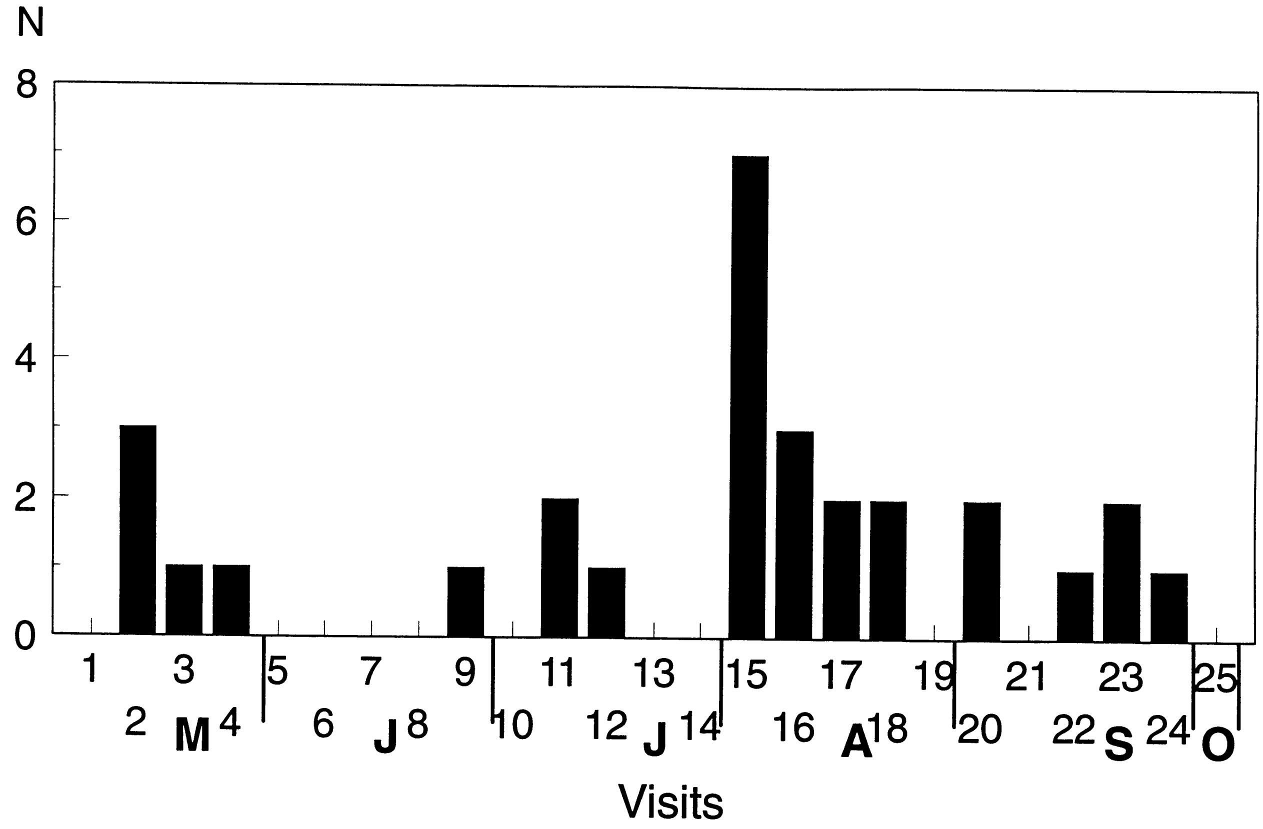


Figure 20: Total number of sand lizard sightings per visit: 1994

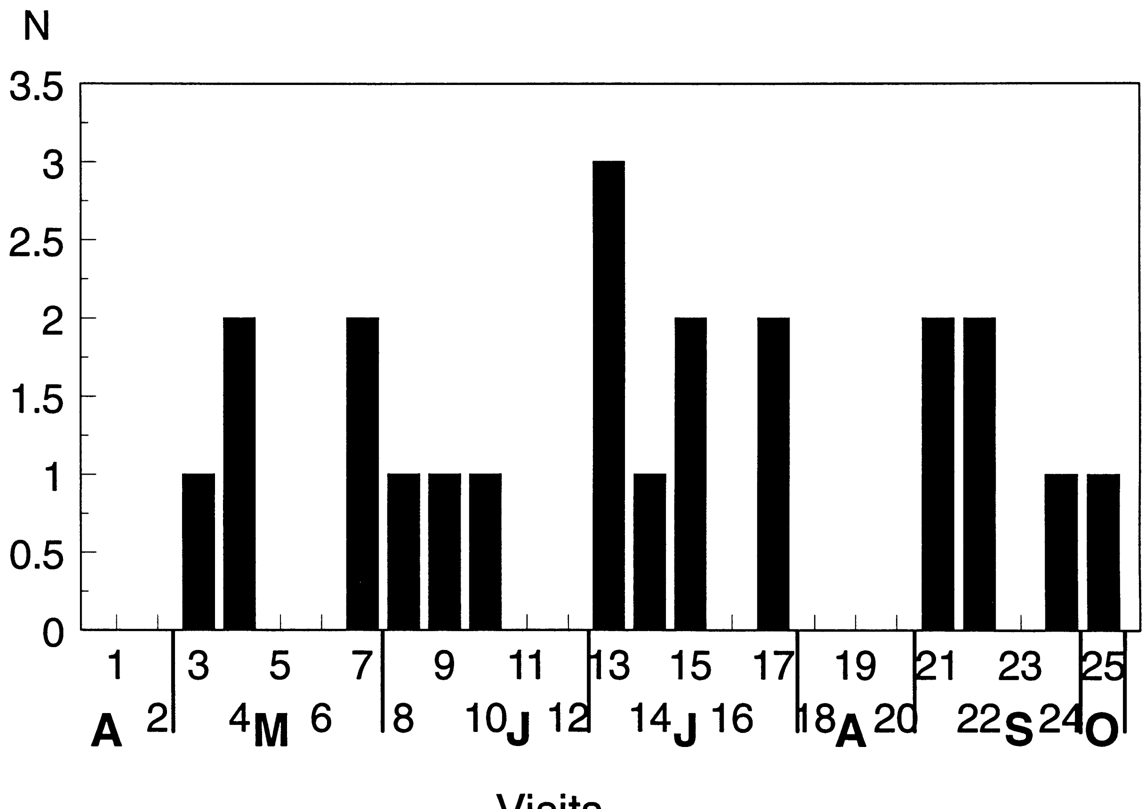


Figure 21: Total number of sand lizard sightings per visit: 1995

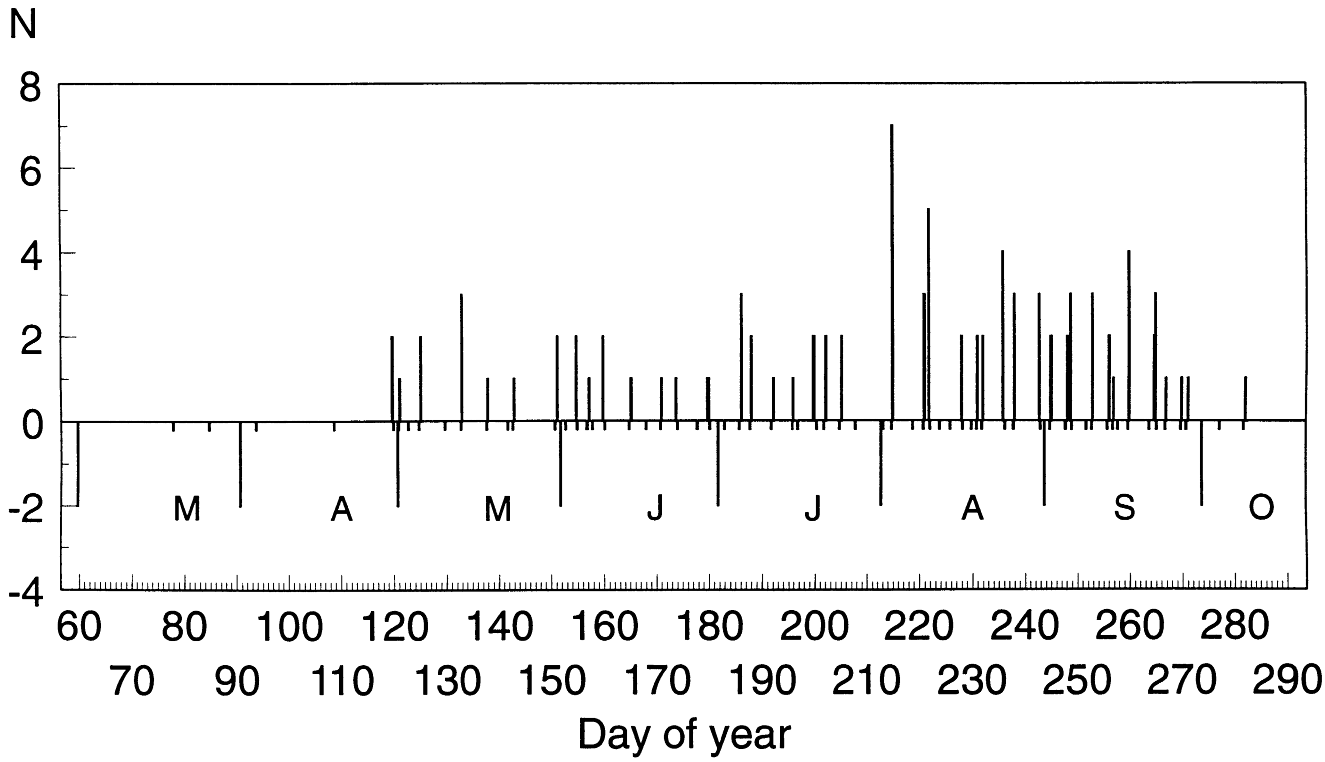


Figure 22: Total number of sand lizard captures/day of year

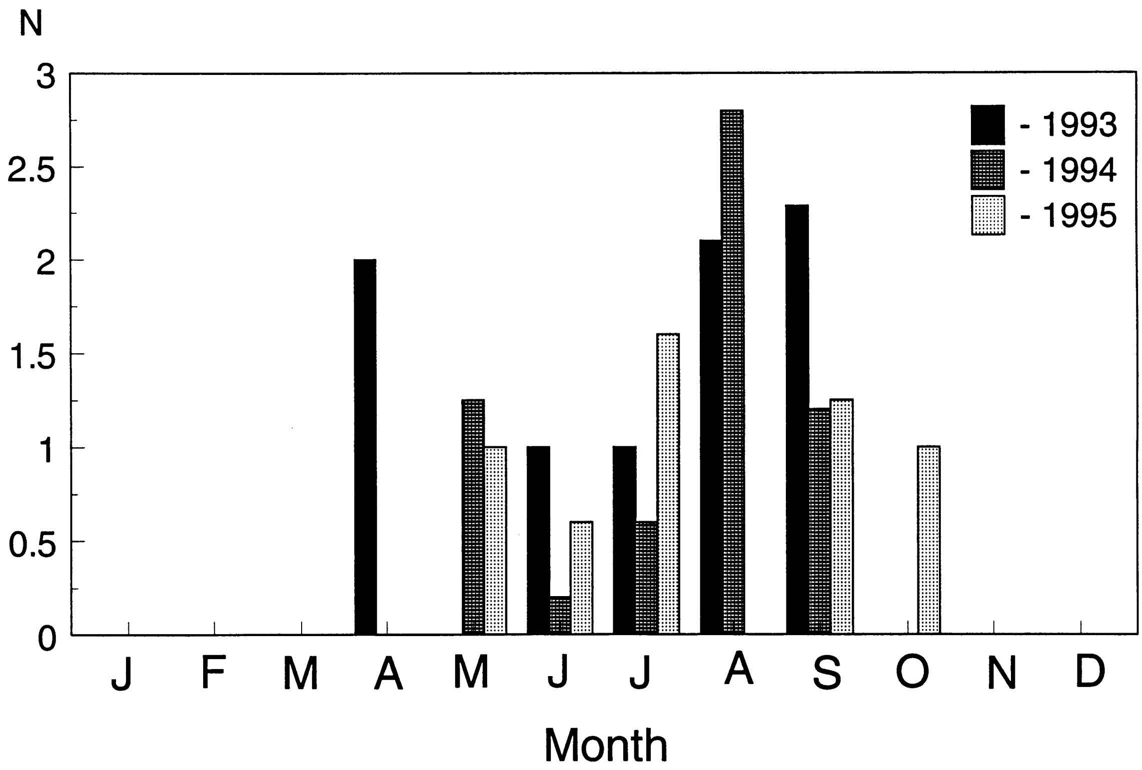


Figure 23: Mean number of sand lizard sightings/visit/month: 1993-95

5.4.6 Discussion

In each of the three snake species animals were more likely to be observed during the spring/early summer (May & June) and late summer/early autumn (September & October) than during the height of the summer (Spellerberg & Phelps 1977). The reason for this is almost certainly different for each of the species and a reflection of their utilisation of heathland. Thus, of the three species, the smooth snake is the one that is the least free ranging and the most dependent on heathland. It can therefore be considered to be a 'resident' of dry heathland whereas both the grass snake and adder can be considered to utilise, in addition to dry heathland, other habitat types and therefore they may be regarded as 'non-resident'.

Although grass snakes were captured within the study area individuals were rarely caught more than once suggesting that they were passing through the study area. This idea is further supported by the fact that grass snakes feed predominantly on amphibians (frogs, *Rana temporaria,* and toads, *Bufo bufo*) both of which are relatively uncommon on dry heathland. Similarly, adult adders prey predominantly on small mammals which are more abundant in wet heathland and grassland than on dry heathland. Furthermore adders are known to select relatively dry areas for hibernation sites (eg. dry heathland) and then migrate soon after emergence in the spring to their preferred summer feeding areas (wet heath, marsh and grassland) where small mammals are more abundant (Prestt 1971).

Thus in both the adder and grass snake dry heathland is not a habitat that is utilised during the summer months as it is relatively poor in prey species. It is, however, suitable for hibernation and thus the increased number of captures/sightings of both these species during the early spring (emergence from hibernation) and late summer/early autumn (preparation for hibernation) can be explained in terms of seasonal habitat requirements.

Although the smooth snake can be considered to be a resident of dry heathland and therefore present within the study area throughout the year, the decreased number of captures (the vast majority of which were made by finding animals under refuges) during the hot summer months (July & August) is probably a reflection of their thermal requirements being met by ambient ground temperatures rather than animals needing to make use of the increased temperatures found under refuges. In addition, the temperatures occurring under refuges during the hot summer months are, almost certainly, too high and therefore smooth snakes will avoid them rather than use them. During the cool spring and autumn months refuges warm up quickly, even in diffuse sunshine, and are therefore likely to be attractive to smooth snakes at these times of year.

Both the sand lizard and slow worm can be regarded as resident within the study area. The differences between the two species in the times of year when they were found appear to be a reflection of their respective temperature tolerances. The slow worm was found both earlier (March) and later (October) in the year than the sand lizard when ambient temperatures were low. Unlike the sand lizard which, in Britain, is at the northern edge of its geographical range the slow worm is not (its distribution includes Scotland) and therefore it is likely to be more tolerant of cool temperatures than the sand lizard. The majority of sand lizard sightings were between May and September with peak numbers being seen in the warmest summer months of July to September rather than in May and June. The pattern of sand lizard sightings differs from that of the smooth snake (which is also at the northern edge of its geographical range in Britain) because it was much less frequently observed associated with refuges and more often seen basking on or between heather bushes. The high mid-summer temperatures generated under/on refuges was not therefore reducing their likelihood of being found as was the case with smooth snakes.

Slow worms, on the other hand, were similar to smooth snakes in that they were less frequently found during the hottest summer months because the temperatures generated under refuges were too high.

The best time to find reptiles were the late spring/early summer months of (April) May-June and the late summer/early autumn months of September-October, the exception being the adder and sand lizard which were also found in mid summer (August).

5.5 Individual reptile captures in relation to search effort

The three lizard species occurring within the study area are not included in this analysis as it was not possible to individually PIT tag them. Also, too few adders were found to enable a meaningful analysis to be done.

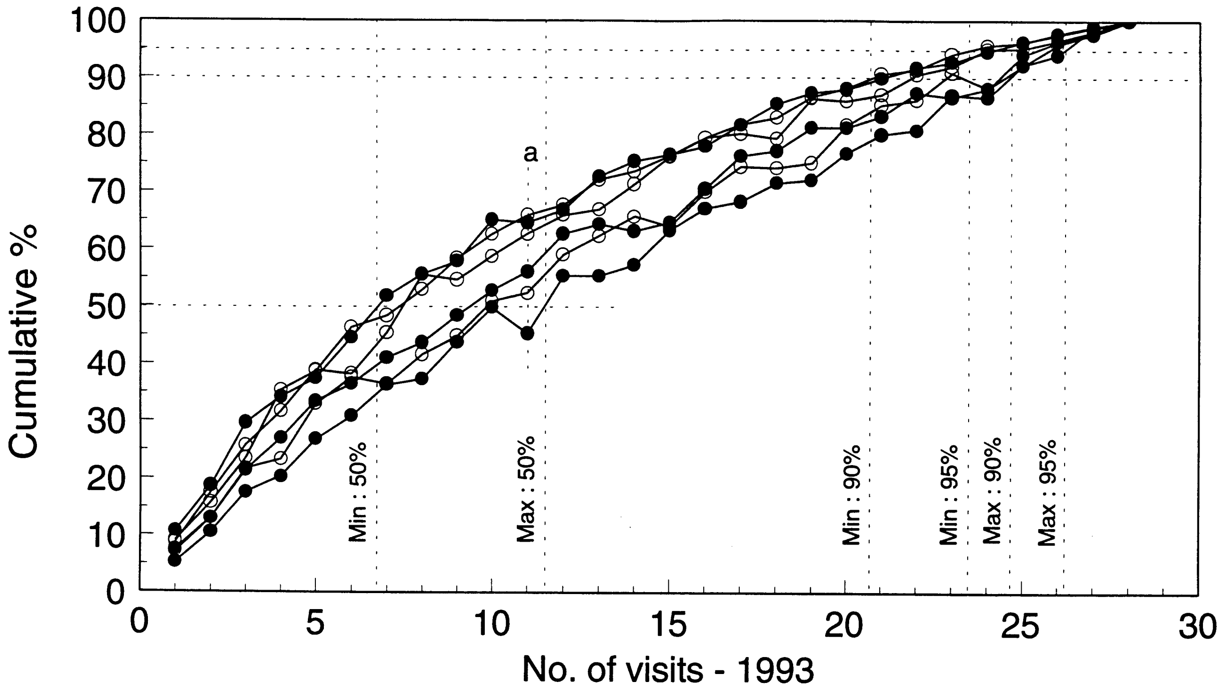
5.5.1 Smooth snake

The capture data for individual smooth snakes found on each array during each of the three years of the study were analysed separately and estimates made of the cumulative mean (based on 100 iterations of the data for each array) number of snakes found as a result of making between 1 and 25 (1994, 1995) or 28 (1993) searches (Figs 24-26). The plots reveal that with low numbers of refuges within an array the relationship between the number of visits and the cumulative number of individuals found tends to be linear whilst with increasing refuge number the relationships become increasingly curvi-linear. Using all these curves the number of searches required to be made in order to find 50%, 90% and 95% of the individuals present at a site can be estimated (Table 11). Depending on the density of refuges within an array (see Table 1 for IRD values) the number of visits required in order to find 50% of smooth snake individuals is between 7 and 12 whilst in order to find 95% of individuals the number of searches required rises to between 22 and 26.

5.5.2 Grass snake

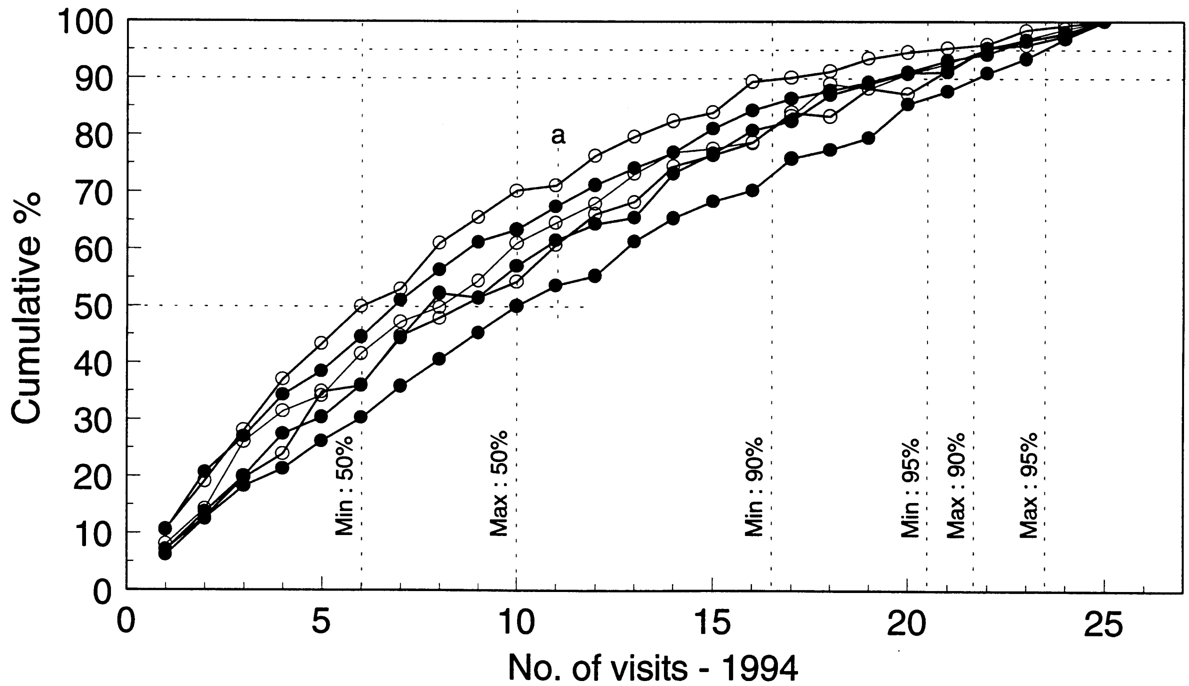
As for the smooth snake the capture data for individual grass snakes found on each array during each of the three years of the study were analysed separately and estimates made of the cumulative mean (based on 100 iterations of the data for each array) number of snakes found as a result of making between 1 and 25 (1994, 1995) or 28 (1993) searches (Figs 27-29). With the exception of array 61a in 1993 the plots may be described as linear although the data for 1994 does reveal a slight curvi-linear tendency. The absence of clear curvi-linear relationships between search effort and the number of individuals found, in all except one array, is almost certainly a result of the relatively low numbers of individuals found and their low recapture rates.

These plots may, nevertheless, reflect the true likelihood of finding individual grass snakes on heathland and thus they can be used to estimate the number of searches required to find 50%, 90% and 95% of the individuals present (Table 12). Thus, in order to find 50% of the individual grass snakes present within an area between 11 and 15 searches need to be made compared with between 23 and 26 searches if 90% of individuals are to be encountered.



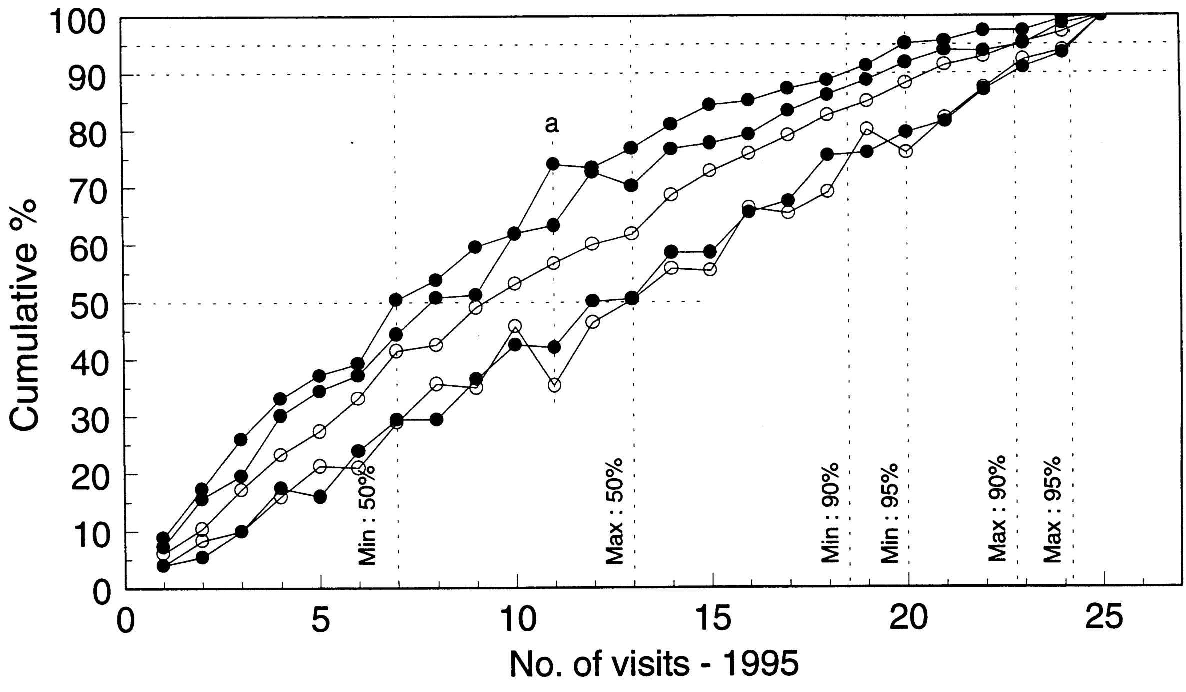
Array order at point 'a' (top-bottom) : 61a; 61b; 19a; 19b; 7a; 7b.

Figure 24: Estimated mean cumulative % of individual smooth snakes captured with increasing effort (visits) at each array during 1993 based on 100 random iterations of the capture data for each array



Array order at point 'a' (top-bottom) : 127a; 127b; 19a; 19b; 19c; 19d.

Figure 25: Estimated mean cumulative % of individual smooth snakes captured with increasing effort (visits) at each array during 1994 based on 100 random iterations of the capture data for each array

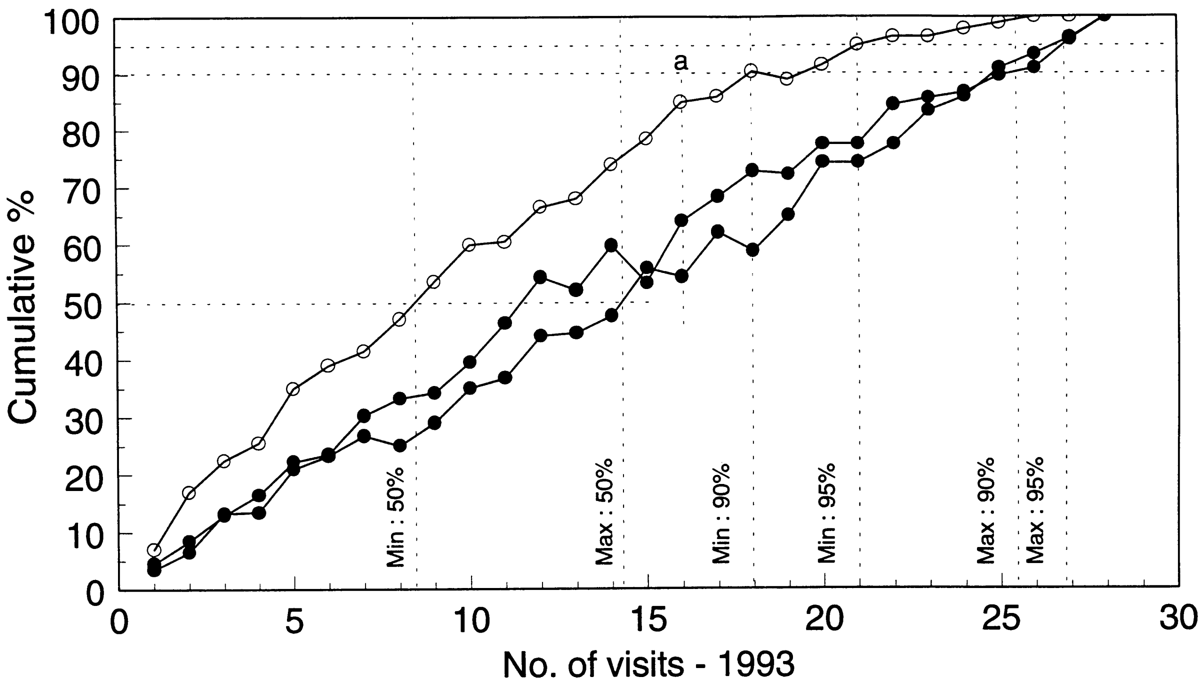


Array order at point 'a' (top-bottom) : 91a; 37b; 91a; 7a; 37a.
(No snakes were captured in array 7b)

Figure 26: Estimated mean cumulative % of individual smooth snakes captured with increasing effort (visits) at each array during 1995 based on 100 random iterations of the capture data for each array

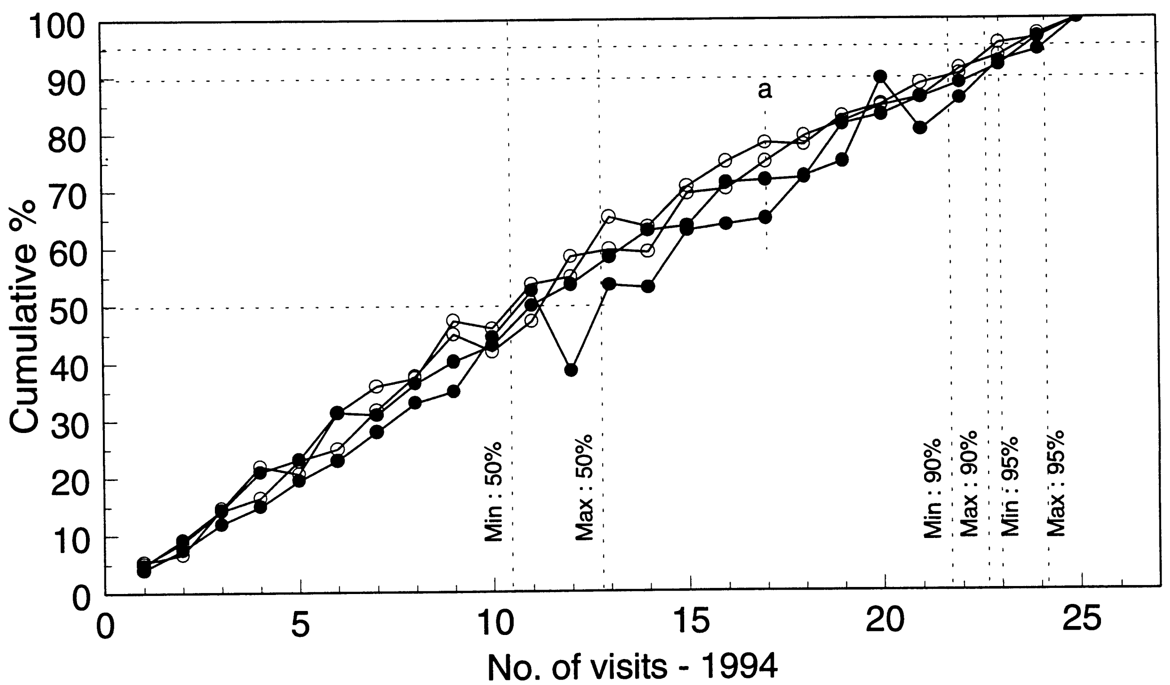
Table 11 : The estimated minimum and maximum number (derived from figs 24-26) of site visits (made at random throughout the period April-October) required to find 50%, 90% and 95% of the individual smooth snakes present within an area being sampled using hexagonal arrays of refuges. The means have been rounded up.

	1993	1994	1995	Mean
50% (Min)	7	6	7	7
50% (Max)	12	10	13	12
90% (Min)	21	17	19	19
90% (Max)	25	22	23	24
95% (Min)	24	21	20	22
95% (Max)	27	24	25	26



Array order at point 'a' (top-bottom) : 61a; 61b; 19b.
(No snakes were captured in arrays 7a; 7b; 19a)

Figure 27: Estimated mean cumulative % of individual grass snakes captured with increasing effort (visits) at each array during 1993 based on 100 random iterations of the capture data for each array



Array order at point 'a' (top-bottom) : 19d; 127b; 127a; 19c.
(No snakes were captured in arrays 19a; 19b)

Figure 28: Estimated mean cumulative % of individual grass snakes captured with increasing effort (visits) at each array during 1994 based on 100 random iterations of the capture data for each array

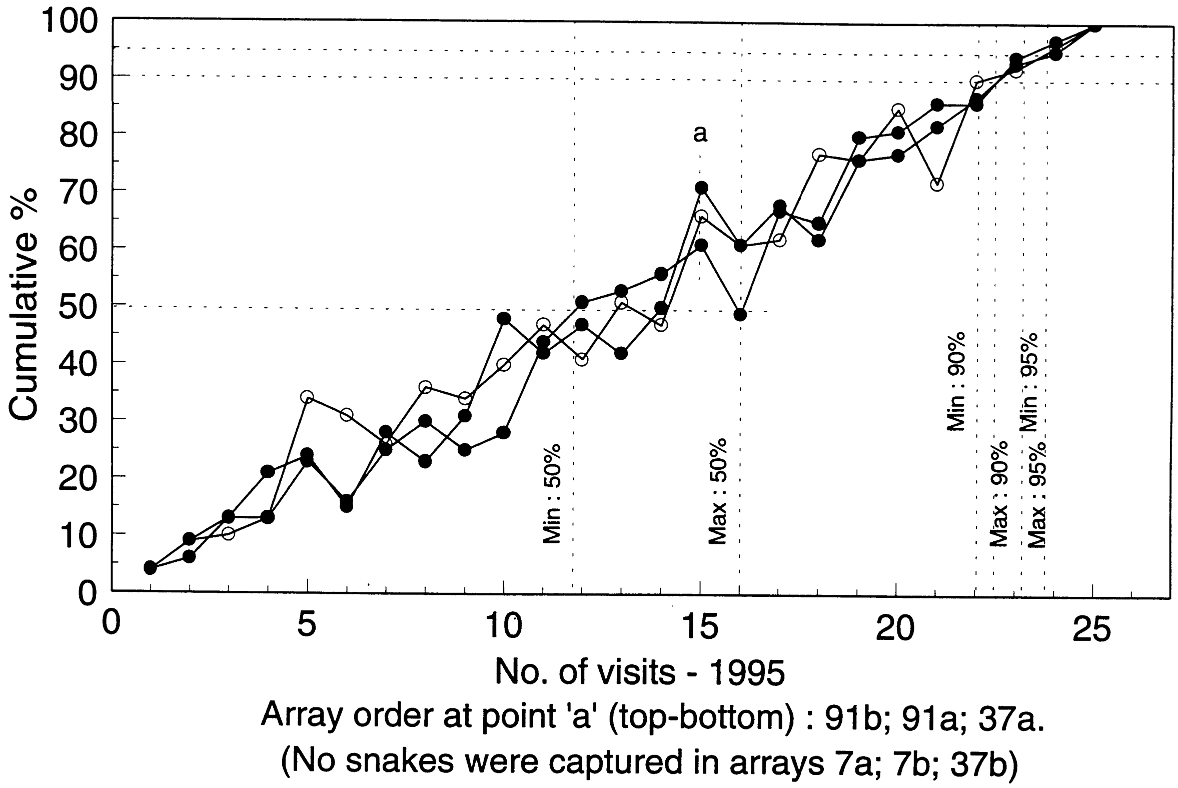


Figure 29: Estimated mean cumulative % of individual grass snakes captured with increasing effort (visits) at each array during 1995 based on 100 random iterations of the capture data for each array

Table 12 : The estimated minimum and maximum number (derived from figs 27-29) of site visits (made at random throughout the period April-October) required to find 50%, 90% and 95% of the individual grass snakes present within an area being sampled using hexagonal arrays of refuges. The means have been rounded up.

	1993	1994	1995	Mean
50% (Min)	9	11	12	11
50% (Max)	15	13	16	15
90% (Min)	18	22	22	21
90% (Max)	26	23	23	24
95% (Min)	21	23	24	23
95% (Max)	27	25	24	26

5.5.3 Discussion

The estimates for the number of searches required to be made to find specific proportions of the known number of individuals present within each refuge array are based on an analysis that selected capture data for search dates selected at random from the 25/28 available for each of the three years. These estimates are too high because they are based on randomly selected data that includes many dates when reptiles would not, in reality, have been expected to be found, particularly with the knowledge that reptiles are more likely to be found during some months (May, June, September & October) rather than others (July & August). The number of visits required will be less if more searches are done during the best months and fewer (but not no searches) during the worst months. It is, nevertheless, probable that if 90-95 % of individuals are to be encountered then at least 15-20 searches, spread throughout the 'active' period (April-October), will need to be made, irrespective of whether they are spread evenly, at random or concentrated more at certain times of year than at others.

5.6 Total reptile captures/sightings and individuals in relation to refuge density

5.6.1 Smooth snake

The relationship between the total number of smooth snake captures/year for a given refuge array (converted into captures per hectare) and the density of refuges per hectare (for a given array) is shown in Fig 30. The fitted line is described by the equation :

Ln. Captures/ha = 1.47 + 0.497 Ln. Refuges/ha. P=0.005. r=0.652. n=18

After an initial steep rise in the number of smooth snake captures as refuge density per hectare increases the slope then becomes relatively constant once a refuge density of 80-120/ha is reached. This is equivalent to a distance between refuges (IRD) of approximately 10-12m.

The relationship between the density of smooth snake individuals per hectare and the density of refuges per hectare (Fig. 31) is similar to that for captures/ha except that the fitted line, described by the equation :

Ln. Individuals/ha = 1.53 + 0.336 Ln. Refuges/ha. P=0.002. r=0.698. n=18.

has a greater tendency to level off after a refuge density of 80-120/ha is reached (IRD = 10-12m).

5.6.2 Grass snake

The relationship between the total number of grass snake captures/year for a given refuge array (converted into captures per hectare) and the density of refuges per hectare (for a given array) is shown in Fig. 32. The fitted line is described by the equation :

Ln. Captures/ha = -1.73 + 0.679 Ln. Refuges/ha. P=0.004. r=0.645. n=18

The graph shows that the number of grass snake captures per unit area increases with the number of refuges used.

The relationship between the density of grass snake individuals per hectare and the density of refuges per hectare (Fig 33) is similar to that for captures/ha except that the fitted line, described by the equation :

Ln. Individuals/ha = -1.59 + 0.626 Ln. Refuges/ha. P=0.004. r=0.646. n=18.

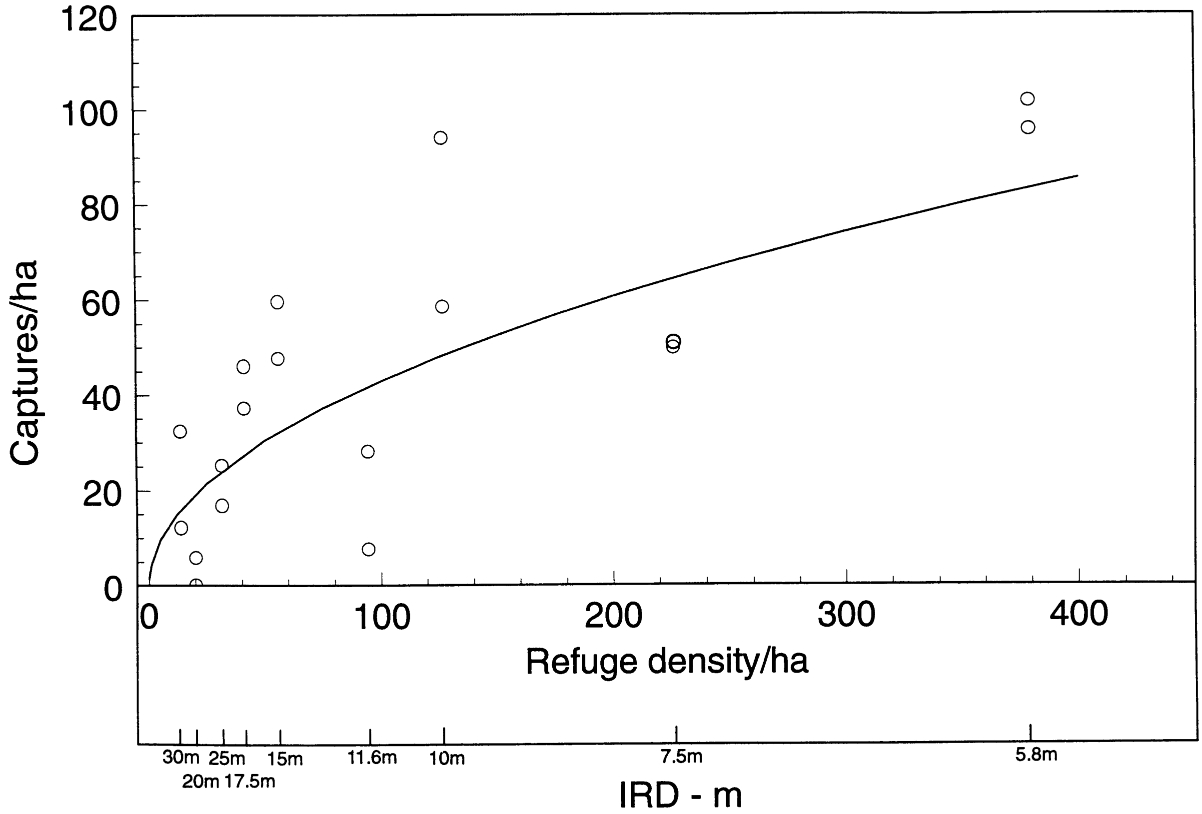


Figure 30: The number of smooth snake captures per hectare in relation to refuge density

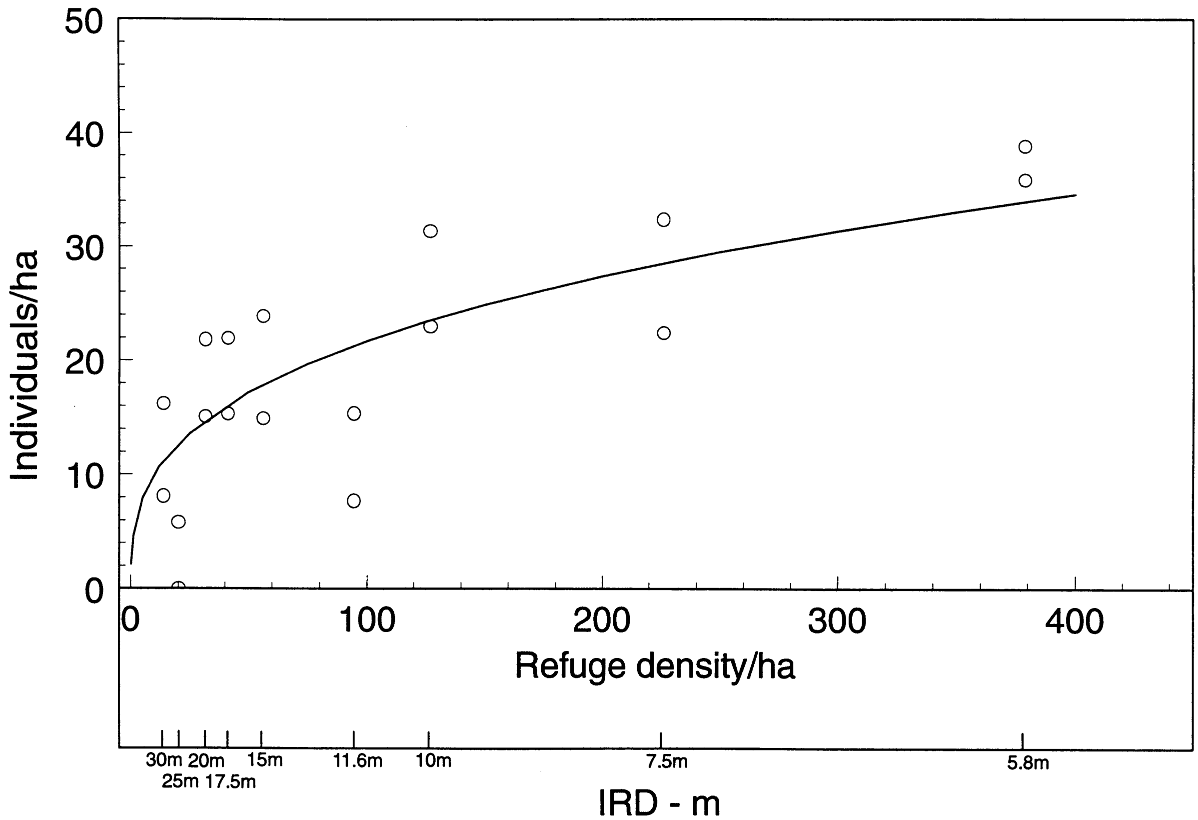


Figure 31: The number of individual smooth snakes captured per hectare in relation to refuge density

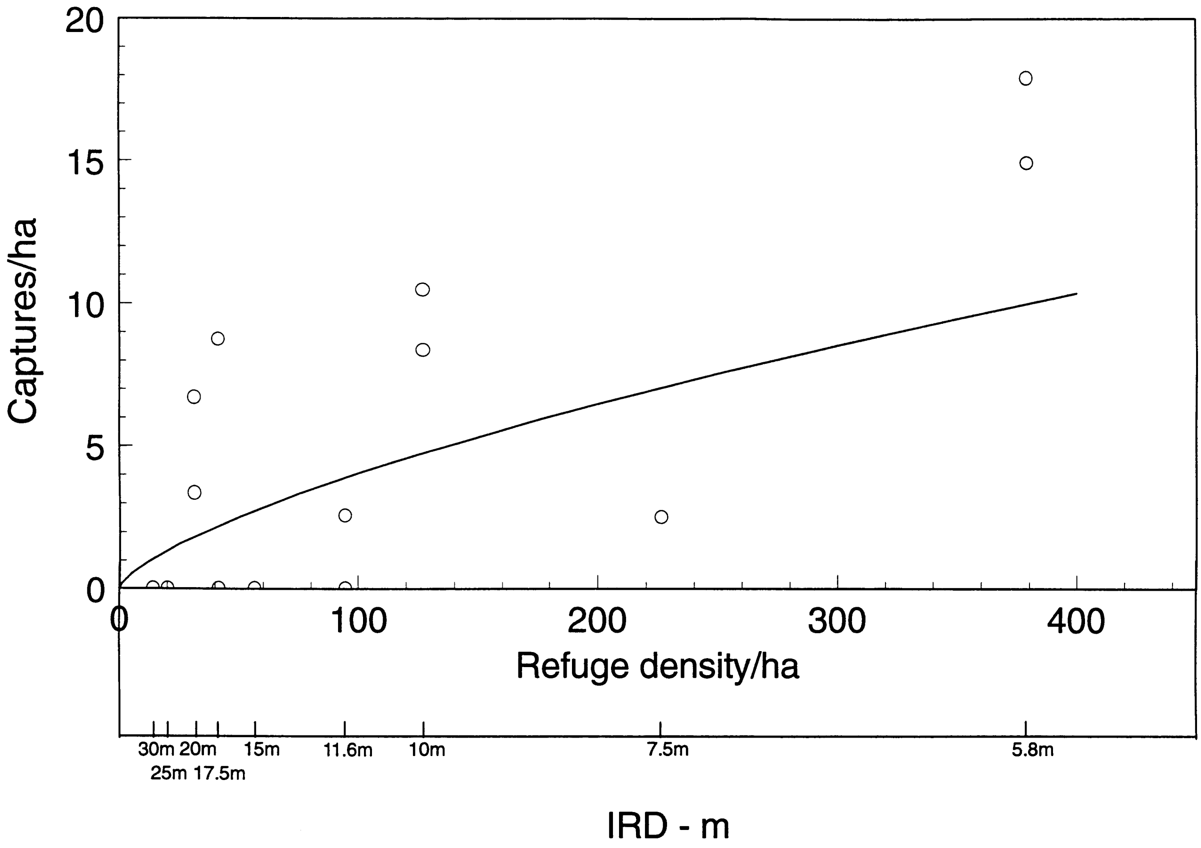


Figure 32: The number of grass snake captures per hectare in relation to refuge density

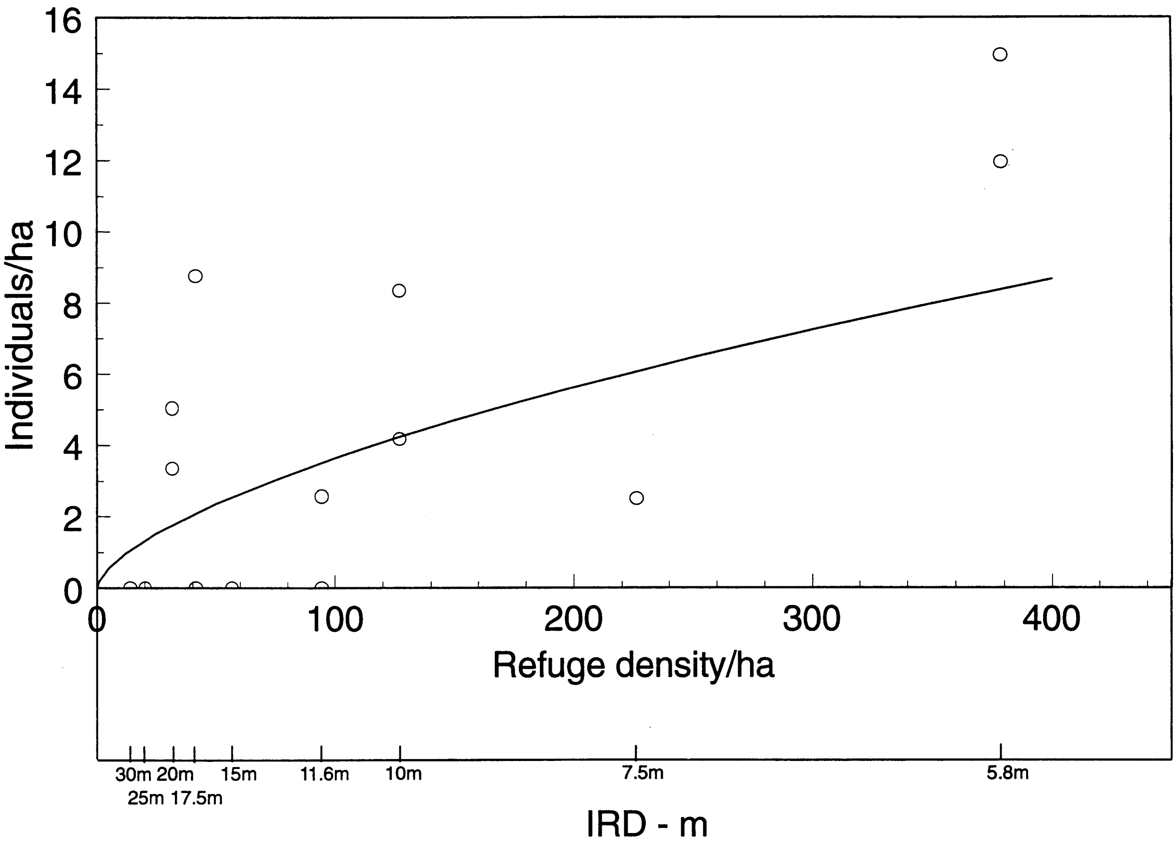


Figure 33: The number of individual grass snakes captured per hectare in relation to refuge density

5.6.3 Slow worm

The relationship between the total number of slow worm captures/year for a given refuge array (converted into captures per hectare) and the density of refuges per hectare (for a given array) is shown in Fig. 34. The fitted line is described by the equation :

Ln. Captures/ha = -0.418 + 0.839 Ln. Refuges/ha. P<0.0001. r=0.787. n=18

The graph shows that the number of slow worm captures per unit area increases with the number of refuges used. There is no real indication of a decline in captures per hectare within the range of refuge densities used in this study.

5.6.4 Sand lizard

The relationship between the total number of sand lizard sightings per year for a given refuge array (shown as sightings per hectare) and the density of refuges per hectare (for a given array) is shown in Fig. 35. The fitted line is described by the equation :

Ln. Sightings/ha = 0.42 + 0.451 Ln. Refuges/ha. P=0.008. r=0.621. n=18

After an initial steep rise in the number of sand lizard sightings as refuge density per hectare increases the slope then becomes relatively constant once a refuge density of between 80-120/ha is reached. This is equivalent to a distance between refuges (IRD) of approximately 10-12m and is the same as that found for the smooth snake.

5.6.5 Discussion

The relationships between the total number of captures (sightings)/individuals per hectare and refuge density per hectare for the four species for which data are available fall into two categories. In the case of the smooth snake and sand lizard the relationships are curvi-linear whilst in the case of the grass snake and slow worm they are virtually linear. If the relationships are described using logarithmic scales then estimated slopes with a value of one show that the number of captures/sightings/individuals increases with refuge density whilst slopes with a value of less than one (<1) will result in a levelling off of the relationship with increasing refuge density. The lower the value for the slope the more the relationship will 'plateau'.

In the curvi-linear relationships the total number of captures (smooth snake)/sightings (sand lizard) and total number of individuals (smooth snake) found increased relatively steeply as the density of refuges increased and then levelled off at a refuge density of between 80-120 per hectare (slope values for captures/sightings and individuals: smooth snake = 0.497 and 0.336; sand lizard = 0.451). Thus, the use of refuge densities above 120/ha will result in relatively little increase in the number of captures/sightings or individuals within a particular area. Although sand lizards were not usually found on or under refuges but observed in/on heather between refuges, the density of refuges still remains relevant because it determines the length of transect walks and therefore the intensity of visual searching over a given area.

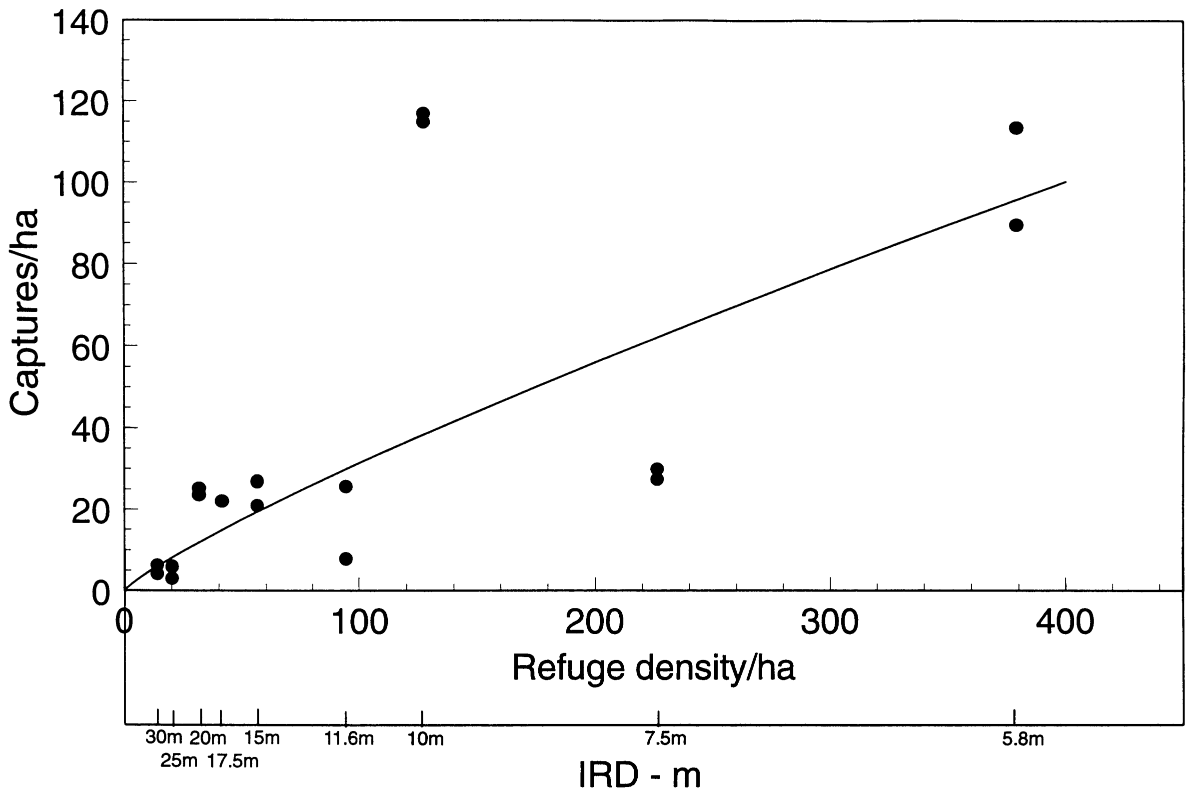


Figure 34: The number of slow worm captures per hectare in relation to refuge density

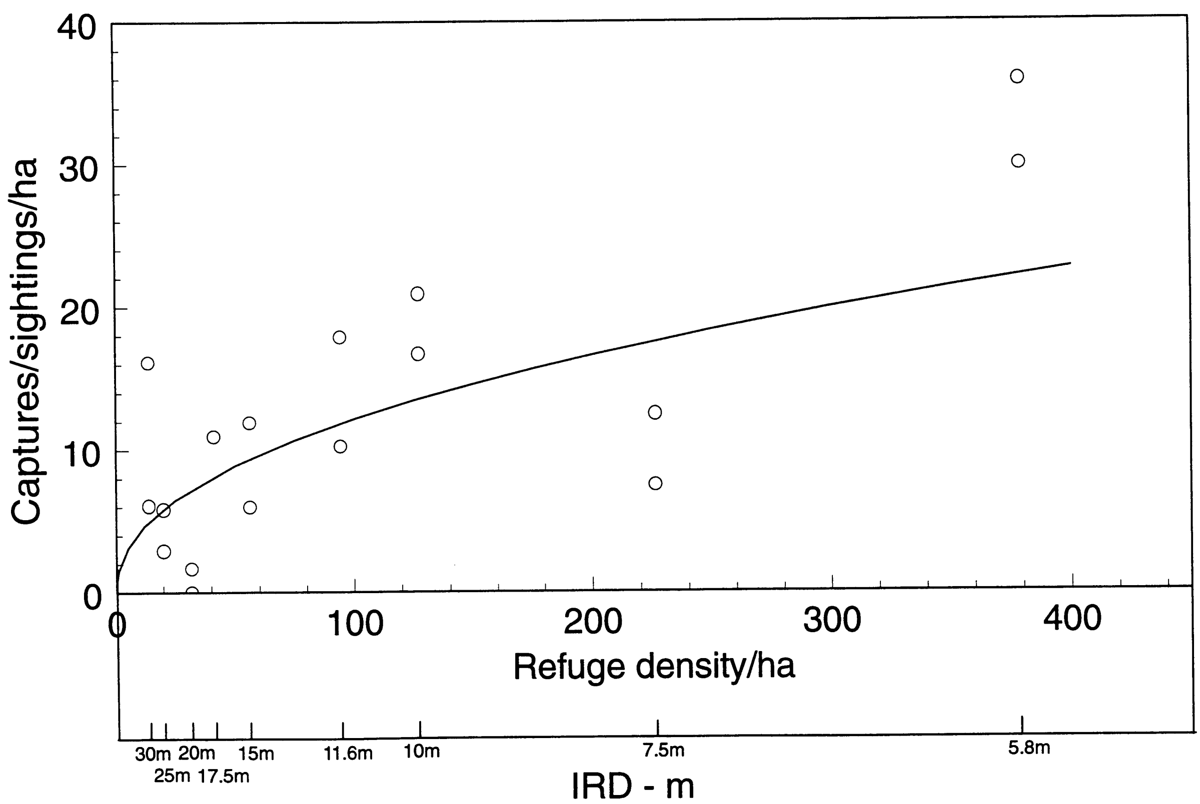


Figure 35: The number of sand lizard captures/sightings per hectare in relation to refuge density

In the linear relationships the total number of captures (grass snake and slow worm) and total number of individuals (grass snake) continued to increase as the density of refuges increased (slope values for captures/sightings and individuals: grass snake = 0.679 and 0.626; slow worm = 0.839). The reasons for the lack of a curvi-linear relationship in these two species are different and essentially the result of differences in scale. The grass snake is a very free ranging species whose main prey species (frogs and toads) are scarce on heathland. The capture data collected during this study suggest that individuals were probably passing through the study area when they were captured and thus one would expect the number of captures to increase as the density of refuges increased. On the other hand, the slow worm is an extremely sedentary species, individuals of which may remain within a very small area for relatively long periods if it is suitable in terms of food supply and cover. It is reasonable to suggest that a suitable area might be centred on a single ants nest (ie. perhaps no larger than 1-2 sq.m). In this case the density of refuges would need to be extremely high (eg. >3,200/ha) before the number of captures would be expected to level off. The maximum density of refuges used in this study was 379/ha (IRD = 5.8m).

The range of refuge densities used in this study (14-379/ha) were, therefore, adequate for allowing estimates of smooth snake and sand lizard (given that refuge density and number are both highly correlated with transect walk length : see section 5.1) numbers to be made but inadequate for similar estimates for the slow worm, all three species of which can be regarded as being resident within the study area. It is unlikely that any number of refuges would prove adequate for estimating grass snake numbers on heathland as this species cannot be regarded as being resident in these areas.

5.7 The relationship between reptile captures and individuals present

These relationships were only able to be determined for the smooth snake and grass snake as too few adders were found to allow meaningful data analysis. None of the three lizard species were individually marked and so no relationships could be determined.

5.7.1 Smooth snake

Fig. 36 reveals that the relationship between the density/ha of individual smooth snakes and the number of captures/ha is curvi-linear and positive, being described by the equation :

Ln. Individuals/ha = 0.855 + 0.588 Ln. Captures/ha. $P<0.0001$. $r=0.932$. $n=18$.

The data suggest that the number of individuals continues to rise with the number of captures. This is highly unlikely suggesting that more data are required in order to describe more accurately the relationship between snake captures and individuals present. Over the three years of the present study the maximum density of individual smooth snakes was determined as about 40/ha.

5.7.2 Grass snake

The relationship between the density/ha of individual grass snakes and the number of captures/ha is almost linear and positive (Fig. 37) being described by the equation :

Ln. Individuals/ha = 0.016 + 0.915 Ln. Captures/ha. $P<0.0001$. $r=0.993$. $n=18$

This very strong relationship is the result of fact that most grass snakes were captured only once and were therefore probably 'passing through' the study area rather than being resident in it.

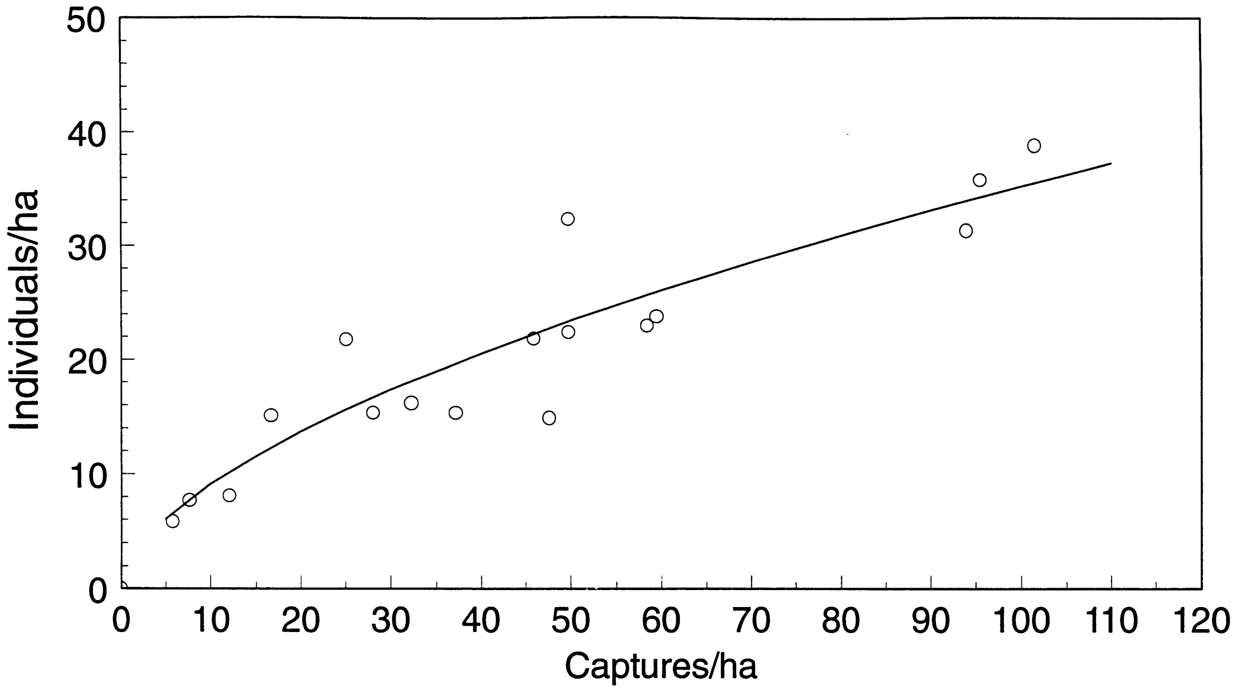


Figure 36: Relationship between the number of smooth snake captures per hectare and the number of individuals present

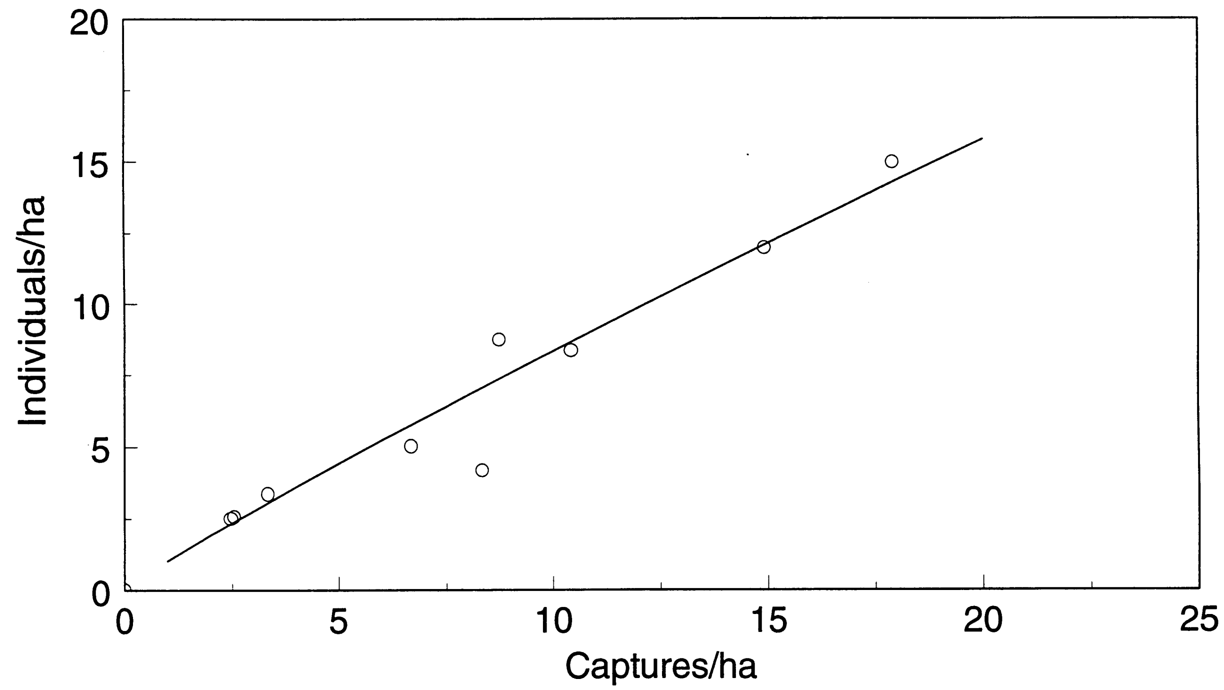


Figure 37: Relationship between the number of grass snake captures per hectare and the number of individuals present

5.7.3 Discussion

The type of relationships between the number of captures of a particular species and the number of individuals present are similar to those found in the previous section. The slope of the log x log graph for the smooth snake has a slope with a value considerably less than one (0.588) and thus the relationship levels off indicating that smooth snakes are resident within the study area with few, during the course of one season immigrating from other areas. Conversely, the slope for the grass snake is close to one (0.915) resulting in an almost linear relationship which indicates that they are not resident within the study area but are probably 'passing' through it.

5.8 Reptile captures/sightings and individuals in relation to refuge number per array

5.8.1 Smooth snake

The relationships between the number of smooth snake captures and individuals per hectare and the number of refuges in an array are shown in Figs. 38 & 39 respectively. The slopes of the fitted lines are described by the equations :

Ln. Captures/ha = 1.73 + 0.545 Ln. Refuge number. P=0.004. r=0.661. n=18.

Ln. Individuals/ha = 1.66 + 0.384 Ln. Refuge number. P=0.001. r=0.738. n=18

In both plots the slope begins to level off at a refuge number of between 20 and 40 which would indicate a hexagonal array of 37 refuges with a line pattern of 4,5,6,7,6,5,4 refuges.

5.8.2 Grass snake

The relationships between the number of grass snake captures and individuals per hectare and the number of refuges in an array are shown in Figs. 40 & 41 respectively. The slopes of the fitted lines are described by the equations :

Ln. Captures/ha = -1.52 + 0.794 Ln. Refuge number. P=0.001. r=0.714. n=18

Ln. Individuals/ha = -1.39 + 0.729 Ln. Refuge number. P=0.001. r=0.711. n=18

These strong curvi-linear relationships, which are not significantly different from a linear relationship, further emphasise the difference in heathland use by the two species with the grass snake probably being a 'visitor' and the smooth snake a 'resident'.

5.8.3 Slow worm

The relationship between the number of slow worm captures per hectare and the number of refuges per array are shown in Fig. 42. The fitted line is described by the equation :

Ln. Captures/ha = -0.014 + 0.937 Ln. Refuge number. P<0.0001. r=0.832. n=18

The highly significant relationship which is almost linear indicates that slow worm numbers will increase with the number of refuges used. However, unlike the case of the grass snake which is almost certainly not 'resident' on the study site the slow worm almost certainly is. In this case the graph suggests that refuges were not used at a high enough density for the number of captures to level off indicating that the slow worm is even less free ranging than the smooth snake.

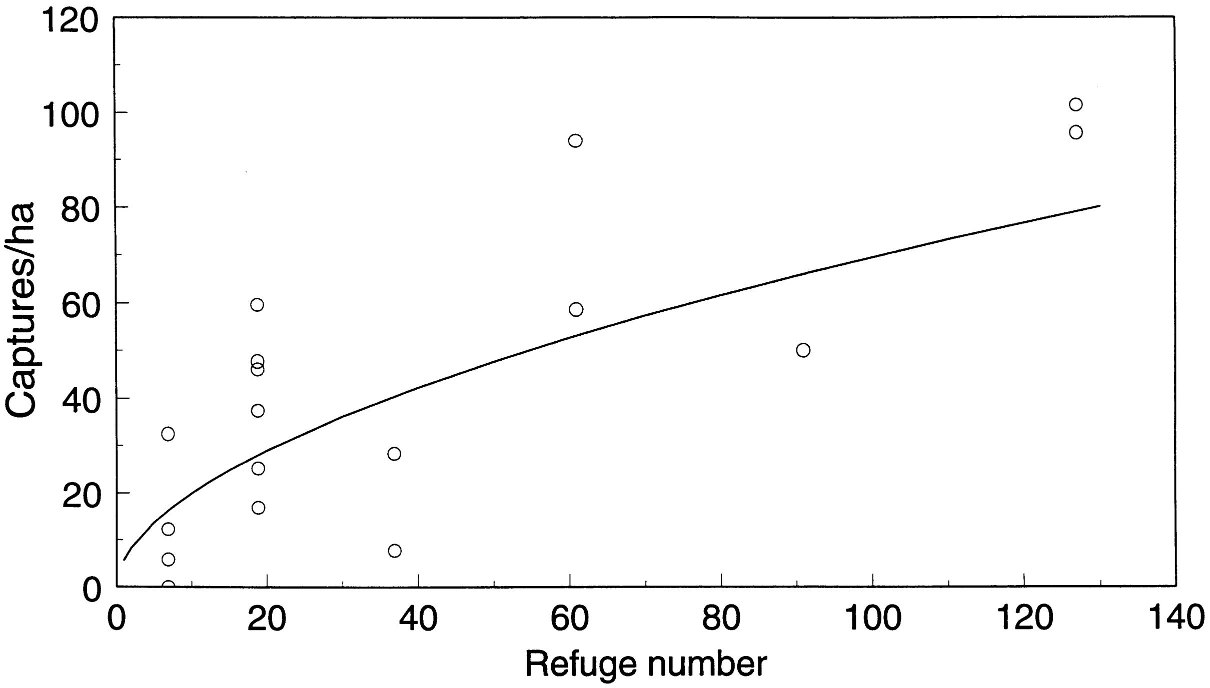


Figure 38: Number of smooth snake captures per hectare in relation to the number of refuges per array

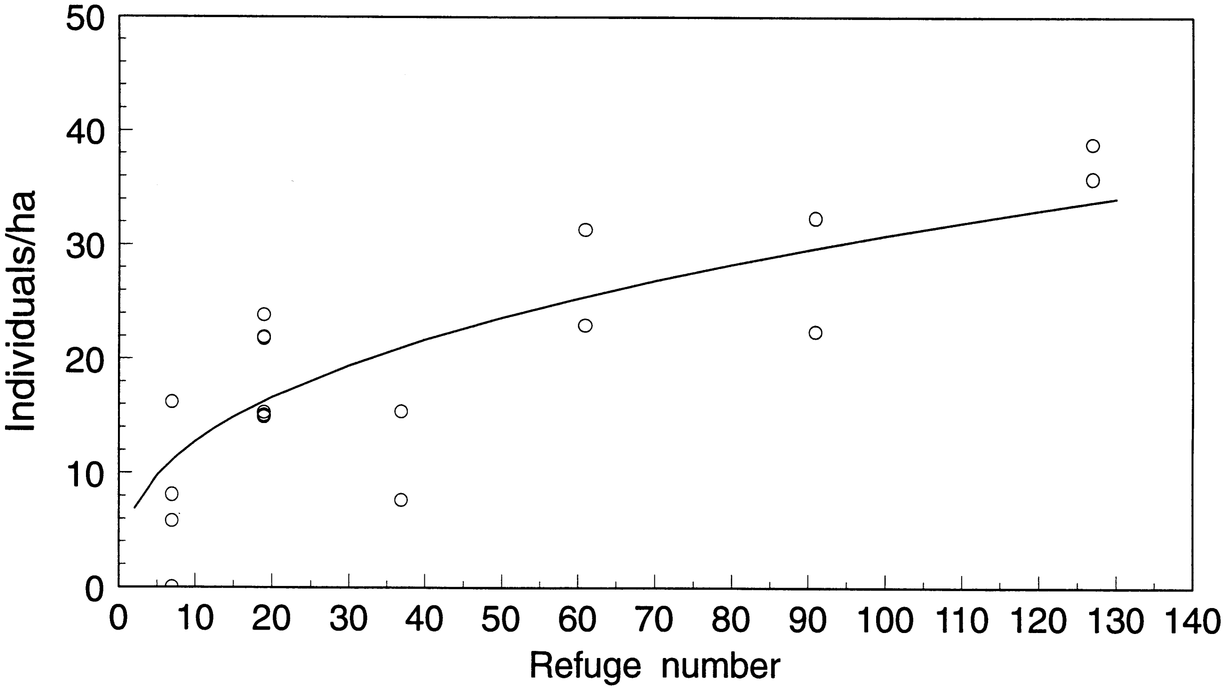


Figure 39: Number of smooth snake individuals captured per hectare in relation to the number of refuges per array

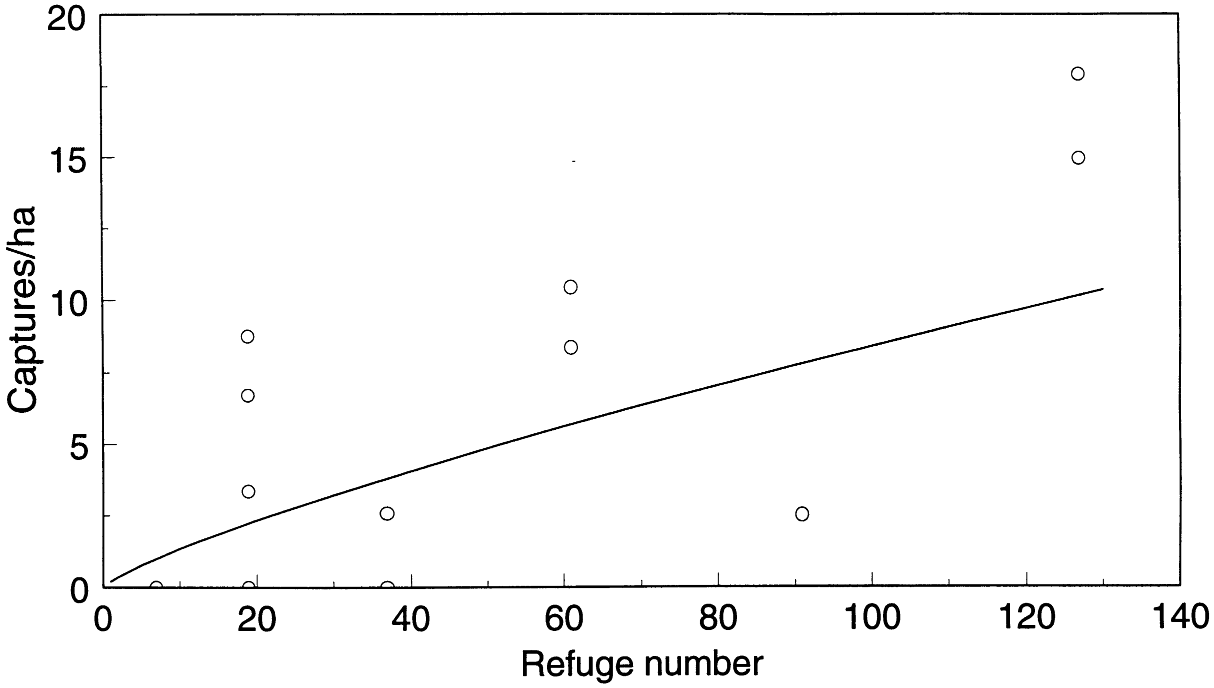


Figure 40: Number of grass snake captures per hectare in relation to the number of refuges per array

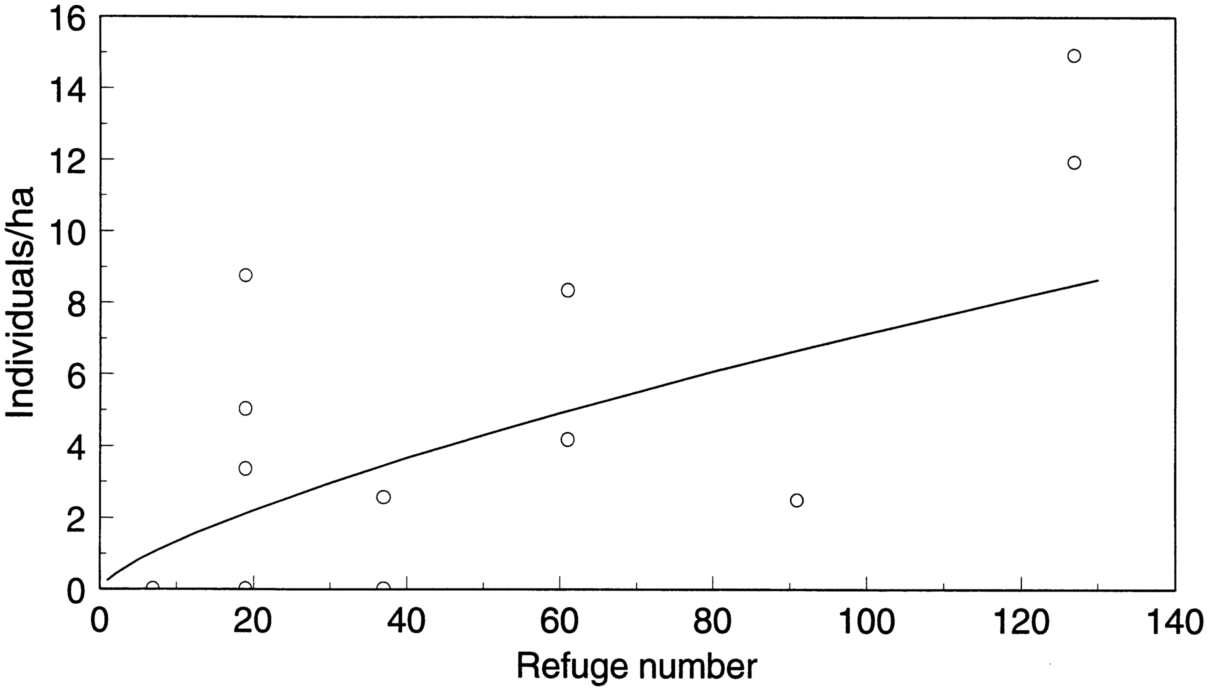


Figure 41: Number of grass snake individuals captured per hectare in relation to the number of refuges per array

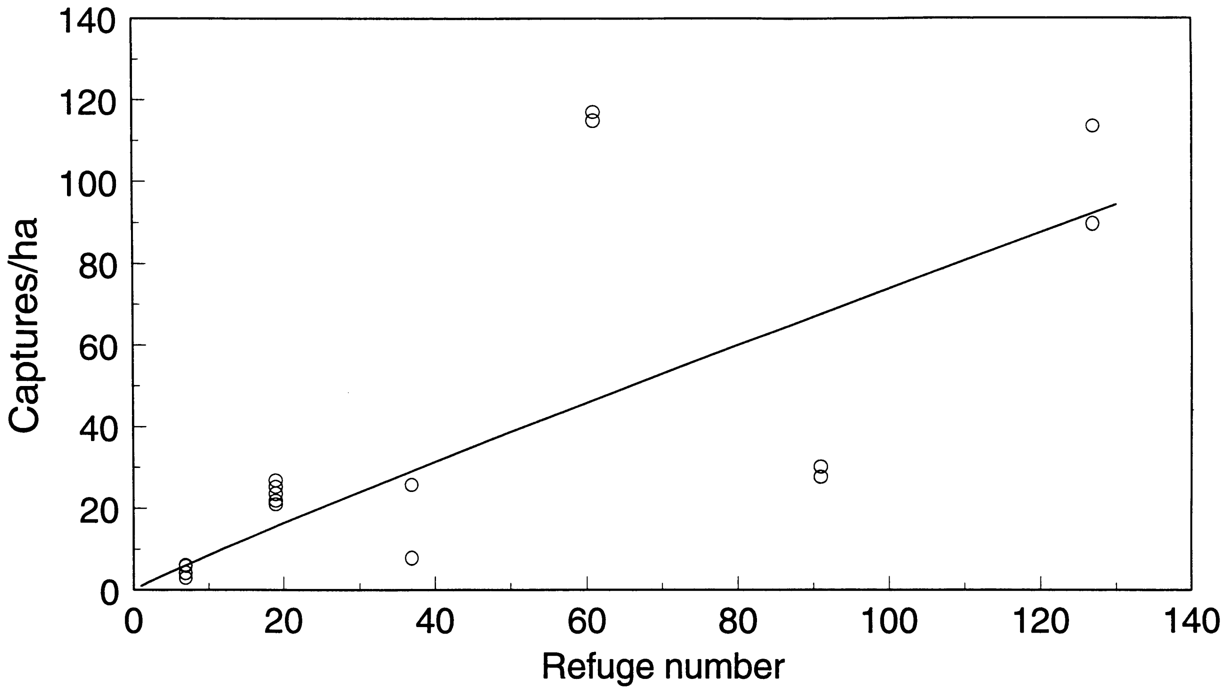


Figure 42: Number of slow worm captures per hectare in relation to the number of refuges per array

5.8.4 Sand lizard

The relationship between the number of sand lizard sightings per hectare and the number of refuges per array are shown in Fig. 43. The fitted line is described by the equation :

Ln. Sightings/ha = 0.794 + 0.46 Ln. Refuge number. P=0.01. r=0.605. n=18.

The slope begins to level off at a refuge number approaching 40 which would indicate a hexagonal array of 37 refuges (for refuge layout pattern see 5.8.1).

5.8.5 Discussion

As with the previous two sections the four species for which data are available divide into two distinct groups. The smooth snake and sand lizard are in one group characterised by curvi-linear relationships, between the number of captures (sightings)/individuals and number of refuges in an array, that increase steeply at first and then level off. These relationships have slopes significantly less than one (smooth snake : 0.545 & 0.384; sand lizard : 0.46) . The grass snake and slow worm form the second group in which the relationships are virtually linear with slopes approaching a value of one (grass snake : 0.794 & 0.729; slow worm : 0.937). The explanation for these differences between species and groups are largely behavioural and are given in section 5.6.5.

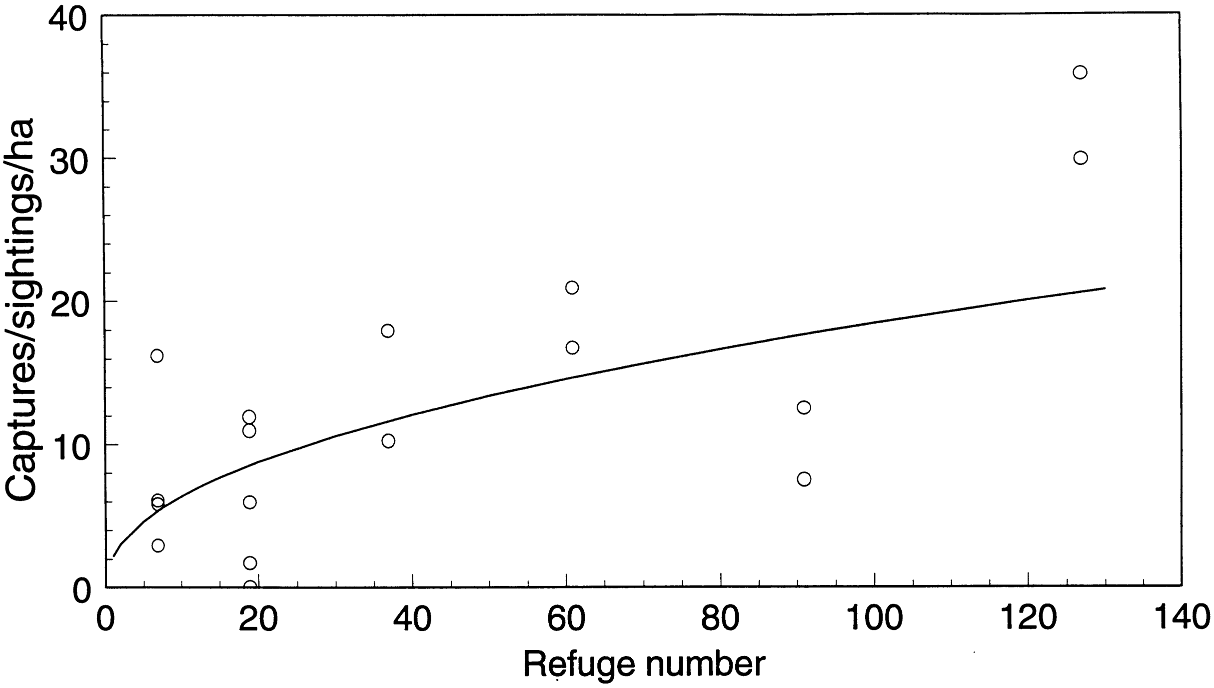


Figure 43: Number of sand lizard captures/sightings per hectare in relation to the number of refuges per array

6. Conclusions

The objectives of this study were to investigate, in depth, the two methods (artificial refuges and transect walks) commonly used by herpetologists (professional and amateur) to survey for reptiles, to evaluate them and determine a standardised method for future use that will enable comparisons between sites to be made.

To this end hexagonal arrays of artificial refuges were used comprising, over the three years, between 7 and 127 refuges at densities per hectare of between 14 (IRD = 30m) and 378 (IRD = 5.8m). Checking each refuge sequentially within an array involved walking a set route between refuges and this formed a transect walk. Because the length of transect walks were directly related to the number and density of refuges in an array all reptile observations were, for the purposes of data analysis, related to refuge number and density.

In order to determine a standardised reptile survey methodology a number of questions needed to be addressed : 1-What pattern of refuge layout should be used? 2-How many refuges should be used in a basic refuge pattern? 3-How close together should refuges be placed? 4-How large should refuges be and what should they be made from? 5-How many site visits should be made to determine reptile numbers within a particular site? 6-When are the most appropriate times of the year to search for reptiles? 7-Are the use of refuges and/or transect walks equally effective for finding all species or is one more effective than the other for some or all species of reptile?

The time and funding available for this project did not allow for an investigation of the effectiveness of refuges of different sizes or different materials. Therefore, a standard refuge made from galvanised corrugated sheet roofing steel was used that was painted black on the upper surface and measured 76cm x 65cm (corrugated roofing comes in standard widths and a variety of lengths). In this study standard 10ft (305 cm) lengths were cut transversely to make four refuges.

The most economic use of space, by 'cells', is that using a 'honeycomb' or hexagonal pattern. Thus, the area of each individual cell overlaps only minimally with that of an adjacent cell. Using other patterns (eg. squares or rectangles) of refuges results either in gaps in ground cover that are not directly attributable to any particular refuge or significant areas of overlap that may be attributable to more than one refuge. Hexagonal arrays of uniform refuges were used throughout this study. Arrays of this design can only comprise certain numbers of refuges if the basic hexagon is to be maintained : the smallest number is 7 in a pattern of 2, 3, 2 refuges followed by 19 (3, 4, 5, 4, 3); 37 (4, 5, 6, 7, 6, 5, 4); 61 (5, 6, 7, 8, 9, 8, 7, 6, 5); 91 (6, 7, 8, 9, 10, 11, 10, 9, 8, 7, 6); 127 (7, 8, 9, 10, 11, 12, 13, 12, 11, 10, 9, 8, 7) etc.

This study has demonstrated that, with the exception of the sand lizard for which only 25% of observations were on or under refuges, refuges are the most efficient way of finding smooth snakes, grass snakes and slow worms within an area to be surveyed. Too few common lizards and adders were found to enable a judgement to be made about the efficacy of transect walks vs. refuge arrays in finding these two species. An important point to recognise is that the use of refuge arrays automatically results in transect walks being completed as the observer moves from one refuge to the next and therefore the two methods should be viewed as complementary in this context. This is not the case if only a transect walk is completed.

Similarly the results of this study suggest that the standard array should comprise 37 refuges spaced 10m apart (transect walk length = 360m) and that in order to encounter the majority of animals present within the area covered by the array between 15 and 20 visits should be made during the course of a season and that some visits should be done during every month between April and October.

Refuges are the easiest and simplest way of trying to answer the question most frequently asked by/of field herpetologists about the presence or absence of reptiles at specific sites of interest. They can be used by relatively untrained people and do not require 'field craft' expertise in order to find animals. They are, however, not equally attractive to all species. In this study the species most likely to be found using refuges were smooth snakes, slow worms and grass snakes followed by sand lizards and adders.

The methods used in a survey for reptiles will depend on whether the aim of a survey is to determine reptile presence/absence, enable comparisons to be made between sites or to determine population size.

Presence/absence

For determining the presence or absence of reptiles at a site the number and layout pattern of refuges is not as important as the time of year when searching should be done. This study indicates that the best time to search for reptiles is during May, June or September. If searching is spread throughout the active period of March-October then a minimum of 7 site visits should be made to maximise the chance of detecting reptile presence. It is likely that fewer visits/searches would be necessary to detect reptile presence if they were done during May, June and September. It is important to realise, however, that the failure to find reptiles at a particular site does not automatically indicate that they are absent from it, merely that they have not been encountered, and this can be the result of insufficient searching time, observer inexperience, inappropriate search conditions or badly placed/too few refuges.

Comparing sites

In order to compare the reptile fauna occurring at different sites the over-riding consideration must be the standardisation of the methods used at the different sites in terms of the number, density and pattern of refuges used, the number of searches made and the timing of the searches. Standard hexagonal arrays should be used comprising 37 refuges laid out 10m apart (at a set density of 127/ha) and each array should be visited/searched 15-20 times throughout the period April to October. Data collected in this way would be comparable between both sites and years. Site visits made only during the best (May, June, September) or worst (March, July, August) months will result in biased data that will not be able to be used. Large sites should be surveyed using multiple standard arrays so that the data collected will be based on the 'standard' array and will, therefore, be comparable.

Population size

The methods required to determine the number of individuals within the population that are present at a particular site are similar to those used for presence/absence and population size, but more refined.

As large an area as possible (ideally all) of any suspected reptile habitat should be surveyed using arrays of artificial refuges. Individuals need to be identified and this is most efficiently done using PIT tags. However, these are relatively expensive and other less reliable and more time consuming methods may be used (eg. back, belly, head and chin scale patterns). Toe-clipping in lizards and scale-clipping in snakes have been used in the past but are now required, by law, to be done under a Home Office licence and should only be attempted (if at all) by experienced herpetologists.

The present study has demonstrated that, in the case of smooth snakes and grass snakes, sites need to be visited/searched during every month from (March) April to September (October) as new individuals may be encountered at any time. Most, however, are found during the months of May, June and September. If searches are not restricted to these key months, but are spread throughout the active period, then a minimum of about 15-20 visits need to be completed in order to maximise the chance to encountering most (95%) of the snakes present within the study area or using it at some time.

Finally, if a site is to be surveyed for reptiles then the most appropriate method is one employing refuge arrays as this combines the benefits of using refuges for some species, and transect walks for others, thus producing a more thorough, useful and comprehensive survey of the herpetofauna present.

7. Proposed standard method for reptile surveys

The single most important point about future surveys for reptiles must be that the same method is used at all sites so that the results from different sites can be compared. In order to do this I propose that the following method should be adopted as the standard for the UK.

1. **Refuge size and structure.** Refuges should be made from galvanised, corrugated sheet steel measuring approximately 2ft-6in x 2ft-1in. (76cm x 65cm). They should be painted black ('Hammerite') on the upper surface to promote heat absorption on dull, cool days. This material is available at most builders merchants.

2. **Refuge array layout and size.** A basic hexagonal array of 37 refuges 10m apart and laid out in a pattern of 4, 5, 6, 7, 6, 5, 4 on the area to be surveyed. An array of this size will have an area of 0.29 hectares and can be fitted into an area measuring 60m x 60m with the middle refuge at the centre of a 30m radius circle. The array is marked out on the ground using a 60m length of string knotted at 10m intervals, to indicate the position of refuges, and strung out between bamboo canes. With the central (longest) line of refuges in place the adjacent lines of refuges are positioned using the string and canes to mark points equi-distant from the refuges in the central line. When completed the array should have six sides, each measuring 30m and comprising 4 refuges. Refuges should be placed horizontally and as close to the ground as possible by manoeuvring them between clumps of vegetation if necessary.

   If the refuges in an array are checked systematically as shown in Fig.1 then a transect walk of 360m will also be completed.

   Large areas should be surveyed using multiples of the basic 37 refuge array.

3. **When to construct arrays.** The most appropriate time of the year to set up refuge arrays is during the winter so that they have time to 'settle' in before the reptiles emerge from hibernation in the spring. It should be recognised that placing arrays out once reptiles have emerged from hibernation may result in a period of time during which they may be 'unattractive' to reptiles.

4. **How often to check refuge arrays.** This will depend to some extent on which species are expected to occur within the study area. However, in order to encounter at least 90% of the reptiles present then the arrays should be visited and checked (transects between refuges walked in the case of sand lizards) on 15-20 times during the course of the season (April-October).

5. **When to check arrays.** The best months of the year for finding most reptiles are May, June, September and October. However, reptiles may be found during all months between April and October and therefore, although most effort could be put in to searching during the best months, some searches should be done at other times of year, particularly if it is important to know how many individuals are present at a site.

   The most suitable weather conditions for finding reptiles will vary depending on which species are present. However, as a general rule reptiles are not easily found during very hot, dry weather or during very cold wet weather. Warm days with intermittent sunshine following cool nights and or rain represent some of the best conditions during which to find most species.

8. Acknowledgements

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