UNIVERSITY OF SOUTHAMPTON

Faculty of Science

Department of Biology

THE ECOLOGY OF THE SAND LIZARD (LACERTA AGILIS L.) IN FORESTRY PLANTATIONS AND COMPARISONS WITH THE COMMON LIZARD (LACERTA VIVIPARA JACQUIN)

Submitted by

SUSAN DENT

for the degree of

DOCTOR OF PHILOSOPHY

1986

To my parents.

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ABSTRACT

FACULTY OF SCIENCE

BIOLOGY

Doctor of Philosophy

THE ECOLOGY OF THE SAND LIZARD (*LACERTA AGILIS* L.) IN FORESTRY PLANTATIONS AND COMPARISONS WITH THE COMMON LIZARD (*LACERTA VIVIPARA* JACQUIN)

The sand lizard, *Lacerta agilis* has a restricted habitat range and distribution in Great Britain. It is regarded as an endangered species in this country. The ecology of *L.agilis* on heathland habitats within forestry plantations in southern Britain has been studied. Where possible, comparisons have been made with the common lizard *Lacerta vivipara*.

The distribution of *L.agilis* within forest heathland habitats was affected by both the nature of the vegetational habitat and the shade produced by the surrounding trees. The distribution of *L.vivipara* was also influenced by these factors but to a lesser extent than *L.agilis*.

L.vivipara was able to thermoregulate under a greater range of weather conditions than *L.agilis*. Individuals of *L.vivipara* could therefore be active for longer than those of *L.agilis*, both on a seasonal and a daily basis.

The home ranges of *L.agilis* within forest heathland habitats were found to be in the same size range as those previously reported form open habitats. The density and age and sex structure of *L.agilis* populations within forest heathland habitats were studied.

Experiments conducted in the laboratory showed that *L.vivipara* were equally active within shaded and non-shaded areas of an artificial habitat. However, feeding occurred most frequently in non-shaded areas.

A strategy is suggested which could be used as a basis for the conservation of *L.agilis* within forestry plantations. The differences observed between *L.agilis* and *L.vivipara* are discussed.

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CHAPTER ONE
INTRODUCTION

The indigenous reptile fauna of Britain consists of six species; three lizards and three snakes. Of these the common lizard *Lacerta vivipara* Jacquin, the slow worm *Anguis fragilis* L., the adder *Vipera berus* L. and the grass snake *Natrix natrix* Lacepede are quite common and widespread whereas the sand lizard *Lacerta agilis* L. and the smooth snake *Coronella austriaca* Laurenti are uncommon and have a restricted distribution in Britain.

The basic habitat range of both *L.agilis* and *C.austriaca* in Britain is quite limited. The former is found associated with dry heathlands and sand dune systems (Prestt et al 1974, Corbett & Tamarind 1979, Jackson 1979, Frazer 1983, Wildlife Advisory Branch, Nature Conservancy Council 1983) whereas *C.austriaca* is associated with lowland heath communities (Prestt et al 1974, Frazer 1983, Goddard 1981, Wildlife Advisory Branch, Nature Conservancy Council 1983). Because of their restricted habitat range both *L.agilis* and *C.austriaca* have been badly affected by habitat loss in recent years and there has been concern about the survival of these species in Britain (Corbett 1969, Prestt et al 1974, House & Spellerberg 1983).

In 1975, *L.agilis* and *C.austriaca* were listed under Schedule I of the 'Conservation of Wild Creatures and Wild Plants Act, 1975', and both species are now listed under Schedule 5 of the 'Wildlife and Countryside Act, 1981. This recent legislation makes it illegal to catch, collect or kill either *L.agilis* or *C.austriaca* or to intentionally damage, destroy or obstruct any place which they are using for shelter or protection or to disturb them in such a place.

One of the major causes of the loss of heathland in recent years has been afforestation. It has been estimated that in 1962 forest plantations (mostly coniferous) covered approximately 20% (7700 hectares) of the original area of the Dorset heathlands (Moore 1962). However it has also been estimated that in Wareham Forest Dorset, 4% of the forest area surveyed remained as heathland and *L.agilis* was located on a number of sites within this forest. The potential of afforested areas as *L.agilis* habitat is illustrated by a recent estimate that 25% of *L.agilis* remaining in Britain were found within afforested areas. However, the same report also suggested that *L.agilis* probably would not survive in these areas without active management (Wildlife Advisory Branch, Nature Conservancy Council 1983).

The aim of this project was to investigate the potential of heathland areas within forestry plantations as a habitat for *L.agilis*, with a view to being able to suggest ways of maintaining viable *L.agilis* populations within forest areas. While this study was carried out using *L.agilis* only, *C.austriaca* was observed within the study areas used and because of the similar habitat requirements of *L.agilis* and *C.austriaca* it is envisaged that habitat management based on the requirements of *L.agilis* would also benefit *C.austriaca*.

The common lizard, *L.vivipara* was also found within the forest habitat being studied where it was generally more common and widespread than *L.agilis*. Although *L.agilis* and *L.vivipara* are superficially quite similar there are two major differences between them. Firstly, *L.vivipara* is slightly smaller than *L.agilis* both in terms of body weight and body size (Nicholson 1980) and secondly *L.vivipara* is viviparous whereas *L.agilis* is oviparous. In some of the studies described here, a comparison has been made between *L.vivipara* and *L.agilis*. An attempt was made to identify the biological/ecological differences between the two species which enable *L.vivipara* to apparently exploit the available habitat more successfully than *L.agilis* and thus to identify those characteristics of *L.agilis* biology which are important to its survival within a forest heathland habitat.

Both *L.agilis* and *L.vivipara* are members of the family Lacertidae which occurs throughout most of Europe and includes about 180 species (Arnold & Burton 1978). Both species are widely distributed in continental Europe although *L.vivipara* is found further north than *L.agilis*, its range extending from the northern regions of Spain and Italy, north beyond the artic circle and east through much of Asia as far as the Pacific coast (Fig. 1.1). The range of *L.agilis* is similar but extends north only as far as southern Scandinavia and east into central Asia (Fig. 1.2).

In Britain, *L.agilis* is at the north western limit of its range and has a very restricted and fragmented distribution (Figs 1.2 & 1.3), whereas *L.vivipara* appears to have no such limitations and is found scattered throughout the country (Fig. 1.1).

While *L.agilis* and *L.vivipara* are sympatric over much of their range and are frequently found in the same habitat, their habitat preferences have been shown to differ. In continental Europe *L.agilis* is found associated with several habitats including man-made landscapes of grasses and mixed shrubs and hedges and 'natural' habitats which tend to be mostly open coastal or mountainous areas where substratum instability and/or exposure to a harsh environment preclude the

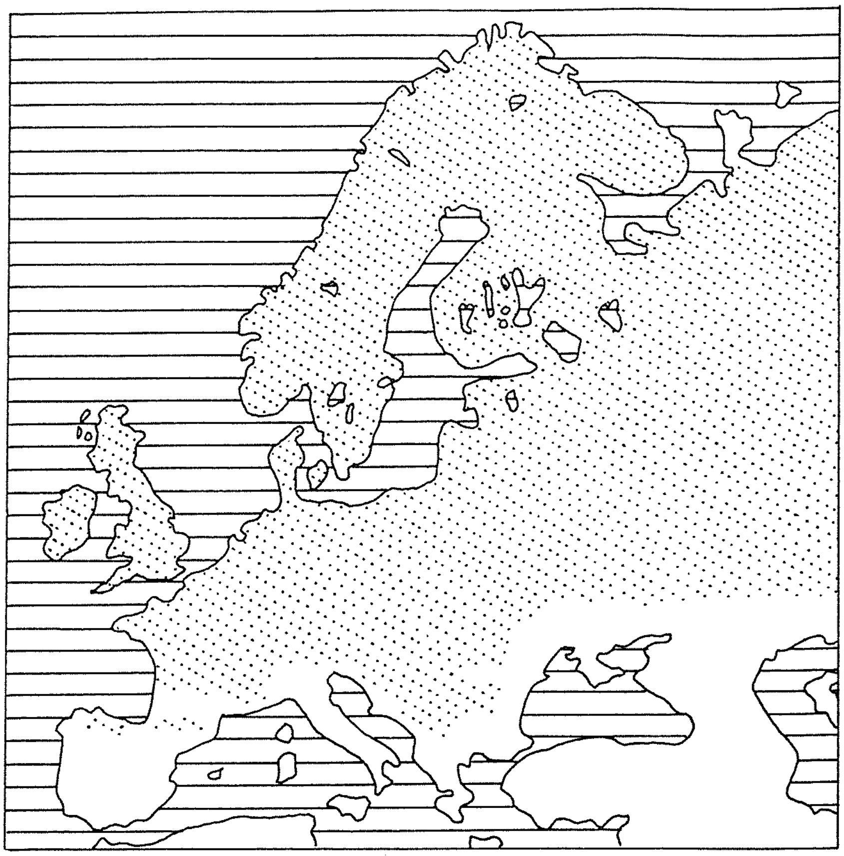


Fig. 1.1 Introduction.
The European distribution (:::::) of the common lizard, *Lacerta vivipara*.

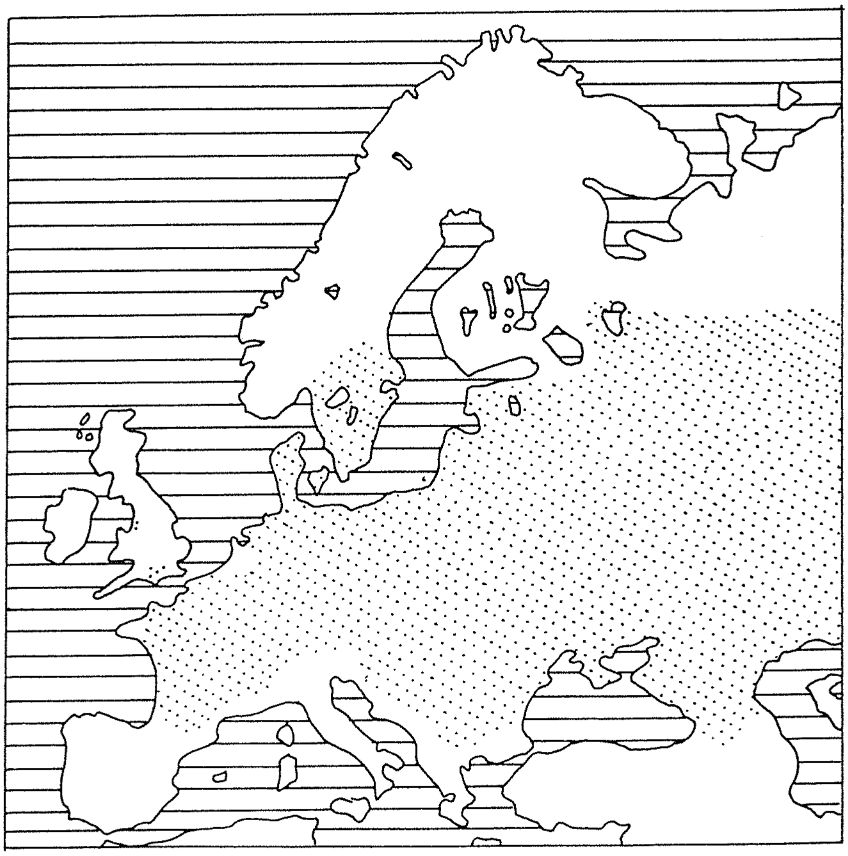
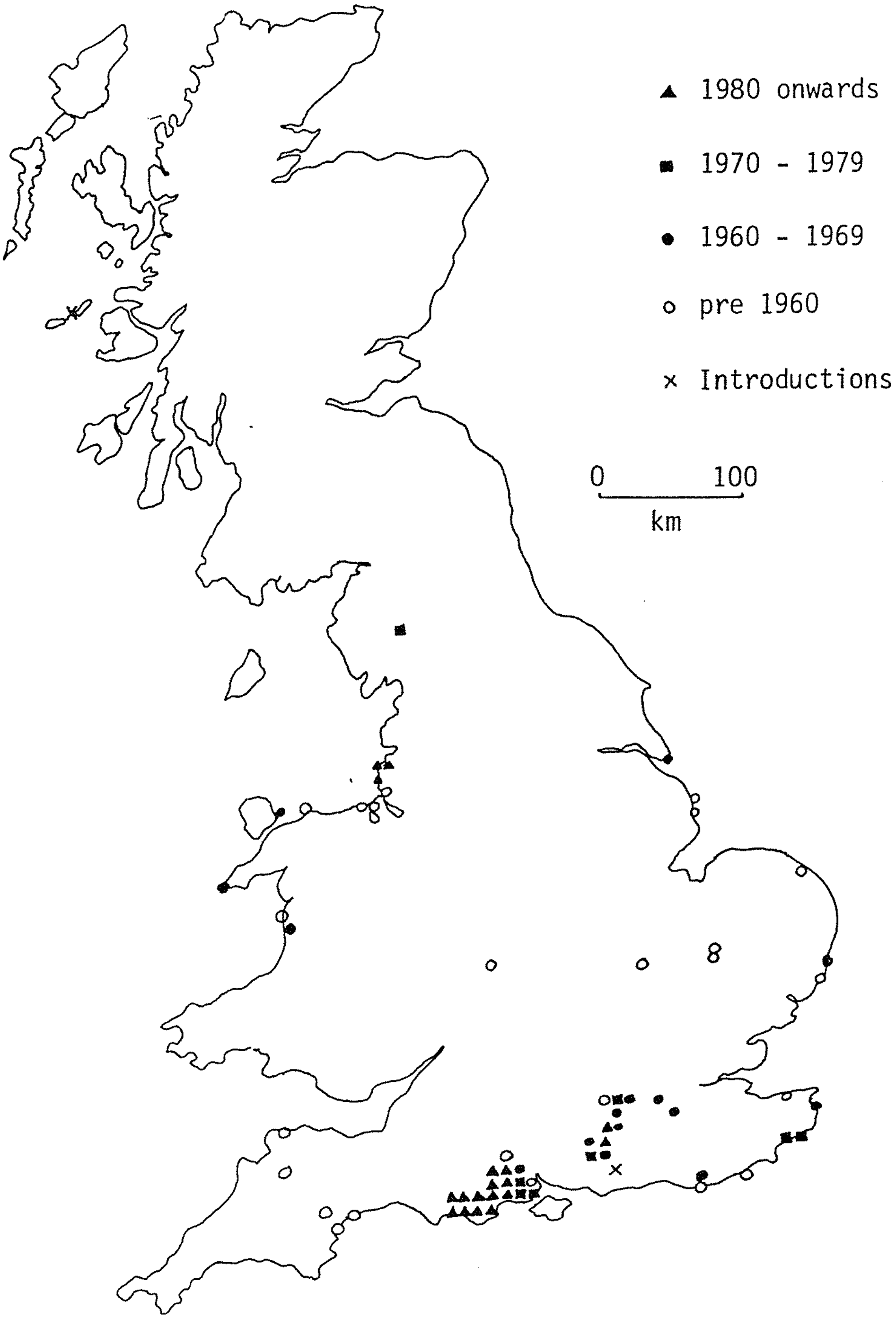


Fig. 1.2 Introduction.
The European distribution (:::::) of the sand lizard *Lacerta agilis*.

Fig. 1.3 Introduction.
The distribution of Lacerta agilis in Britain (L.agilis does not occur in Ireland which has been omitted).



Redrawn from Nature Conservancy
Council 1983

extensive growth of tall shrubs or trees (Spellerberg & House 1980). In comparison, L.vivipara is found in alpine meadows, moist ditches, marshes, edges of damp woods, rice fields, field edges, heaths and bogs (Arnold & Burton 1978).

In Britain, as previously mentioned, L.agilis is found associated with two habitat types, open dry heathlands and sand dune systems. Other habitat types may be used but usually only in conjunction with adjacent areas of heathland or sand dunes. In Britain L.vivipara is found in a range of habitats from dry heathlands to bogs and will use almost any habitat where there is cover for shelter and feeding and open areas for basking (Frazer 1983).

At present L.agilis is found in three main areas in Britain

1. the sand dune systems of south west Lancashire.
2. the heaths of Surrey, north east Hampshire, south east Berkshire and north west Sussex.
3. the south west Hampshire heaths and the heaths and coastal dunes of south-east Dorset.

These areas have been isolated from each other for perhaps 2,000 years, the third area having been further sub-divided by more recent urban development (Prestt et al 1974).

Evidence of recent reductions in distribution have been summarised by Prestt et al (1974) and include

1. the loss of all known major colonies from the sand dune systems of Lancashire and a ten or perhaps 100 fold reduction in numbers.
2. the loss of all known breeding populations from the north Surrey and north east Hampshire area, the loss was from 34 breeding colonies in 1950's to two in 1971.
3. all known breeding colonies in the New Forest lost since 1950's.
4. an estimated 80% reduction in the populations on some Dorset heathlands form 1965 to 1975.

These recent declines are probably due to habitat loss and fragmentation due to afforestation, urbanisation, agricultural reclamation, military activity and mineral extraction (Prestt et al 1974). The fragmentation of habitats produces small, isolated populations which may then be more vulnerable to extinction by fire, collection, predation by cats or by winter gassing of rabbit warrens rabbit control (Prestt et al 1974, Spellerberg 1974, Wildlife Advisory Branch, Nature Conservancy Council 1983).

Records show that probably 47% of the sand dune area existing in south west Lancashire in 1841 has been destroyed by building and afforestation and that a further 12% of the original area has been modified by the building of an airfield, golf-courses and mineral extraction, although these latter areas may still be used by L.agilis (Jackson 1979).

Similarly, of an estimated 30,400 hectares of heathland present in the Poole Basin area of Dorset in 1811, only 5,832 hectares remained in 1978 (i.e. 19.2% of the original area). The causes of this reduction were mainly agriculture, forestry, urban development and mineral extraction. Not only has the area been reduced dramatically but the heath remaining has been fragmented into many small areas. In 1750, the heathland of the Poole Basin consisted of 10 large blocks separated only by rivers. In 1978 there were 768 separate pieces, 160 of which were greater than four hectares (largest 476 hectares) in area, while of the remaining 608 pieces, 476 were less than one hectare (Webb & Haskins 1980).

Because of its restricted habitat range, attempts to conserve L.agilis have to be based on the conservation of specific areas of suitable habitat (Spellerberg 1975, Corbett and Tamarind 1979) and if necessary on the reintroduction of animals to managed areas. In the south of England work has mainly been carried out by voluntary organisations such as the British Herpetological Society (B.H.S.) and the Dorset Naturalists Trust (D.N.T.). These organisations have undertaken a programme to maintain particular areas of habitat in a condition suitable for use by L.agilis. This is done mainly by clearing encroaching shrub and pine and by the provision of open sandy areas for egg laying where these are scarce in the surrounding habitat (Corbett & Tamarind 1979). Such measures have changed the cries of "well on the way to extinction" (Corbett 1969) to ones of optimism for the survival of the species in Britain (Tamarind 1975).

As a result of continued concern for the survival of L.agilis in Britain, several studies have been undertaken in an attempt to assess the status of L.agilis and to suggest management plans for the conservation of L.agilis in Britain. The work includes that by Jackson (1978,1979) on the L.agilis populations in south west Lancashire, by Nicholson (1980) on feeding and general ecology in southern England and by House & Spellerberg on habitat requirements, daily behaviour and egg incubation in southern England (House,Taylor & Spellerberg 1979, House & Spellerberg 1980, Spellerberg & House 1980, House & Spellerberg 1983).

From this recent research and from conservation work in the field it is to be hoped that colonies of L.agilis can be maintained in suitable habitats. However, with the continued destruction of heathland in southern Britain it seems an appropriate time to explore the potential of afforested areas as a L.agilis habitat. Of all the developments on heathland there are only two which do not totally destroy the heath on which they exist. One is mineral extraction where disused pits or pit edges can provide a favourable habitat for L.agilis (Spellerberg 1975) and the other is afforestation.

THE FOREST HEATHLAND COMMUNITY

The heathland occurring within forestry plantations may be divided into three categories.

1. OPEN AREAS

Within many forest plantations there remain areas of open heath with no trees on them at all. These include areas which are unsuitable for forestry and have never been planted, areas where a crop has failed and died back or remained very sparse, areas which have been set aside for a specific reason such as National Nature Reserves (N.N.R.) and areas such as unploughed firebreaks or the open stretches of land under electricity pylon lines.

2. COMPARTMENTS

Forestry Commission plantations are set out in blocks or compartments of trees (Plate 1.1). Each compartment may contain a single species of crop tree or two or more species planted together. A compartment represents a unit of trees of a particular species or combination of species planted at a particular time. In this text the term Compartment is used in a less specific way to describe areas upon which there is a crop of trees.

For 10 to 15 years (depending on tree species and planting density etc.) enough light reaches the ground under a growing crop for a heathland-type of vegetation to grow. Because of the limited number of years for which this habitat will be available its usefulness will depend greatly on the nature of the surrounding area and on the availability of suitable areas for colonisation from.

3. RIDES

Rides from four to seven metres wide run throughout forestry plantations to allow access to crops (Plate 1.1). These may be of three types; hardcore, i.e. especially laid roads, usually in those areas most heavily used by forest traffic; sand, i.e. roads consisting of the local substratum and mown, where the vegetation has been left in situ but the ride is mown once a year to allow passage by tractors and to

Plate 1.1 Introduction.
An aerial view of part of Wareham Forest, Dorset. The network of rides dividing the forest block is clearly visible, as is the division of the forest into Compartments of tree crops of a particular age and species composition. The open area to the right of the picture is Morden Bog, a National Nature Reserve.

maintain the usefulness of the ride as a firebreak.

Between the rides and the adjacent Compartment there is usually an area (0.5 to 10m wide) of essentially (or potentially) undisturbed vegetation. Part of this width may be mown periodically to maintain the width of the firebreak but often the vegetation of this area can remain undisturbed for some years. These Ride verge areas may be used as a habitat in their own right, or in conjunction with an adjacent open area or Compartment vegetation. They may also provide an important corridor for the movement of resident L.agilis populations from one area of the forest to another, this may be important as forest habitats are generally only suitable for use by L.agilis for a limited period of time.

The use of Ride Verge and Compartment habitats only was looked at here. Open areas were not included in this research because it was assumed that the principles which apply to the conservation of open heathland habitats for L.agilis will also apply (at least for the larger areas) to open areas within forestry plantations.

The work carried out here was done in collaboration with the Forestry Commission, Forest Research Station at Alice Holt, Surrey. While the principal objective of the Forestry Commission is the efficient production of wood for industry, it nonetheless recognises the importance of its forest areas as wildlife habitats and is prepared to safeguard and improve wildlife habitats where possible. This is particularly the case for sites where nature conservation has been identified as being of particular importance (Forestry Commission 1980), hence the Commissions interest in and willingness to collaborate with attempts to improve the potential of their forests as L.agilis habitat.

The lizard L.agilis is a legally protected species and a licence was obtained from the Nature Conservancy Council (NCC) for the summer field seasons of 1981, 1982 and 1983. The NCC was also directly involved in parts of this work, in particular with the radiotracking studies carried out in 1982 and 1983.

All field work for this project was carried out in Wareham Forest, Dorset. This forest was surveyed in 1980 both for suitable L.agilis and C.austriaca habitat and for the presence of these species themselves (Rowe & Nicholson 1980). This earlier work provided a great deal of basic information on the whereabouts of L.agilis populations and therefore provided a good framework on which to start a more detailed study.

The basic aim of this project was to assist in the conservation and management of *L.agilis* within forestry plantations. However, the work done has also provided basic information on the ecology and biology of *L.agilis* which is relevant to the species as a whole and not just to its exploitation of forest habitats. The layout of the thesis is as described below.

Chapter Two incorporates the Materials and Methods for all the work carried out. This includes general information concerning the study sites used and the methods employed for population sampling, the measurement of microclimatic variables and for radiotracking of *L.agilis*. The methods relevant to each chapter are then detailed in the order in which the chapters appear in the text. The subsequent chapters do not include any further Materials and Methods but for each experiment the relevant section of Chapter Two is given so that it can be referred to if necessary.

In Chapter Three the habitat preferences of *L.agilis* within both Compartment and Ride Verge habitats have been investigated. This chapter deals with both the use of the heathland habitat by *L.agilis* and the influence of surrounding trees on *L.agilis* distribution within the available heathland habitats.

Chapter Four deals with the influence of weather and season on the activity and behaviour of *L.agilis*. This includes the timing of seasonal activities such as emergence from winter dormancy or egg laying and also patterns of daily activity in relation to weather and season. An attempt is also made to identify the optimal weather conditions for the sighting/capture of *L.agilis*.

In Chapter Five, the home range size of *L.agilis* was compared within Compartment and Ride Verge habitats. Radio transmitters were used to provide data within Compartments together with information from repeated observations of animals throughout the season. Only the latter type of data was available for ride verge habitats on which radio tracking was unsuccessful.

Chapter Six incorporates general information on the population biology and growth of *L.agilis*. This includes population density, age structure and sex ratio and the growth patterns of various age classes and of males and females within a population.

Chapter Seven describes the results of a series of experiments investigating the affects of shading within an artificial habitat on the behaviour and feeding of patterns of *L.vivipara*. For mainly practical reasons *L.vivipara* was used instead of *L.agilis* in these experiments. However, it was felt that the same overall principles could be applied to both species.

In Chapter Eight, the information on the habitat preferences of L.agilis detailed in Chapter Three, has been used and somewhat extended to produce an overall picture of how L.agilis could be conserved within forest plantations.

Chapter Nine is a general discussion of the results of the work as a whole.

CHAPTER TWO
MATERIALS AND METHODS

I GENERAL METHODS

2.1 STUDY AREAS

All the work described here was carried out within the Main Block area of Wareham Forest, Dorset (9050,8970) which is situated on the Bagshot Beds, the most extensive geological formation in the Poole Basin. The Bagshot Beds consist of current-bedded yellow and white sands with seams of pipe clays which are mainly overlaid by podsols (Haskings 1978).

The habitat in Wareham Forest varied from the dry heathland communities which have developed on well drained, nutrient poor soils, to the wet heathlands which are characteristic of soils with continually wet organic strata as a result of impeded drainage (Gimingham 1979). A dry heathland vegetation is characterised by the predomince of C.vulgaris* other species often present include E.cinerea and U.minor. C.vulgaris is found together with E.tetralix and M.caerulea in a damp heathland. On a very wet heathland C.vulgaris may be absent and its place taken by E.tetralix and M.caerulea.

The sites used in this research were chosen because each represented a different type of plant community used by L.agilis as habitat within the forest. The Morden Site was an area of heathland under a young crop, Morden Rides an area of verge habitat on either side of forest rides and East Gore was a small site consisting of heathland under a failed crop adjacent to an area of damp heathland and bog.

East Gore and Morden Rides both had a very rich reptile fauna and were inhabited by all six British reptile species. Four species, L.agilis, L.vivipara, C.austriaca and V.berus were found on the Morden Site.

2.1.1. MORDEN SITE

This site was a small area of about 1 hectare (ha) of Corsican Pine (Pinus nigra var maritima) which was planted in 1970. Prior to this the area was a block of open heathland within the forest (Fig.2.1). The growth of the crop was variable and the extent of the canopy varied from trees which are blocking out sufficient light to cause the ground covering vegetation to die back, to areas where the

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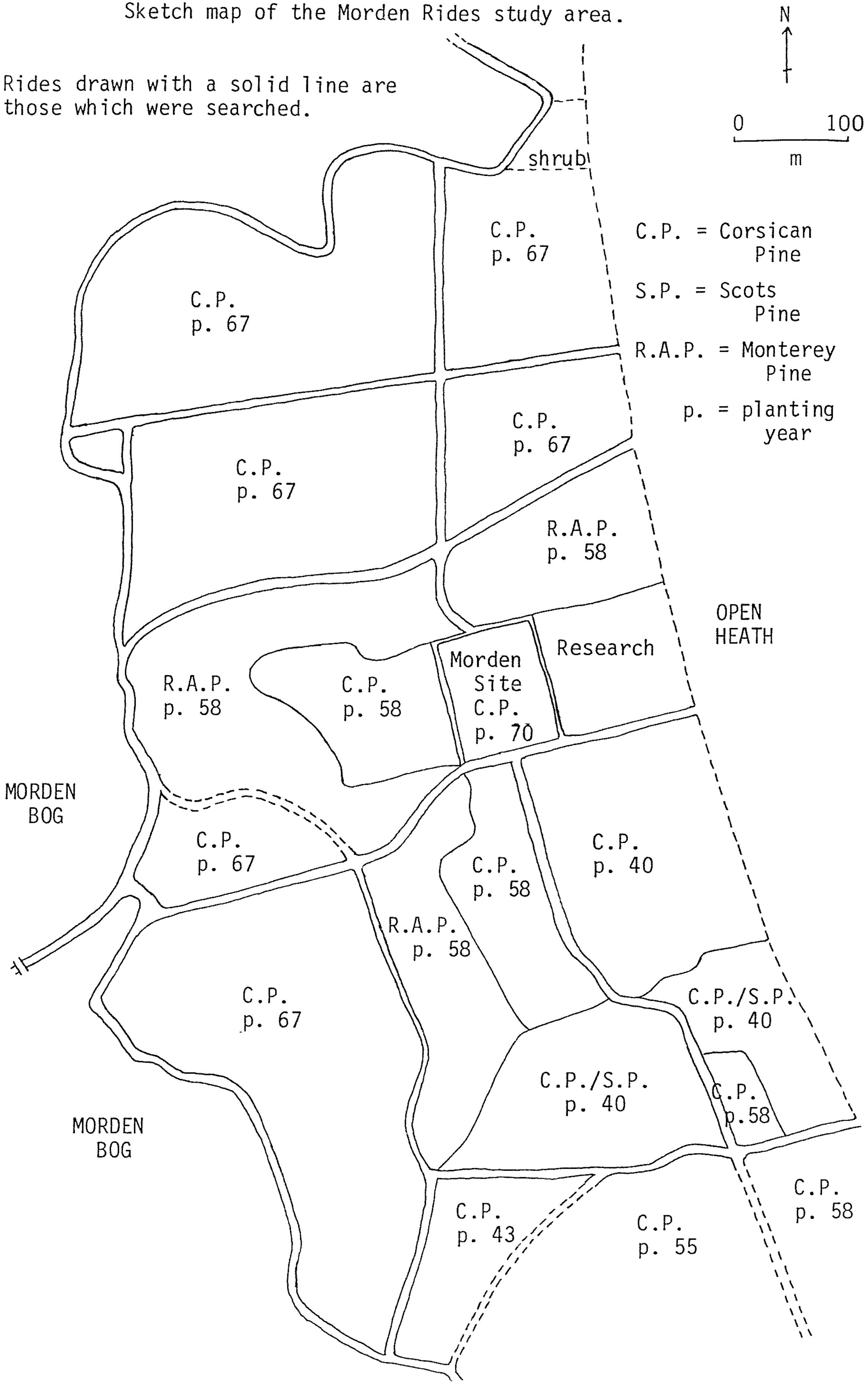
*Nomenclature according to Clapham, Tutin & Warburg (1962)

Fig. 2.1 General methods, study areas.
Sketch map of the Morden Rides study area.



Rides drawn with a solid line are those which were searched.

C.P. = Corsican Pine

S.P. = Scots Pine

R.A.P. = Monterey Pine

p. = planting year

trees were only one to two metres high and the ground vegetation had hardly been affected. In general, the vegetation was dry heathland, dominated by Calluna vulgaris with some E.cinerea, E.tetralix, M.caerulea and U.minor, the south-eastern corner tends towards M.caerulea dominated wet heath. The site was surrounded to the east, west and north by old, established plantations with little or no ground vegetation and to the south by a hardcore ride about five metres wide. On the other three sides of the area there were mown rides about two metres wide, the ride to the west having a verge approximately three metres wide.

2.1.2 EAST GORE

This was a small site of approximately 1.5 ha. It was surrounded on two sides (north and west) by old plantations which were completely devoid of any ground vegetation. On the east side there were fields and to the south was a burnt area which was dominated by M.caerulea. Although the area was small it divided into four basic regions (Fig.2.2).

2.1.2.1 Main Slope

This was an area of failed crop which occupied the northern half of East Gore. It was on a south facing slope and had a dry heathland vegetation of C.vulgaris and E.cinerea with some U.minor, Pteridium aquilinum and M.caerulea. The planted crop was a mixture of Scots Pine (Pinus sylvestris), Corsican Pine and Montery Pine (Pinus radiata) but most of the trees standing were probably self-seeded. The extent of the canopy cover of the trees varied from slight to almost total, so that in some areas the ground vegetation had died back completely, whereas in others it was still apparently uneffected.

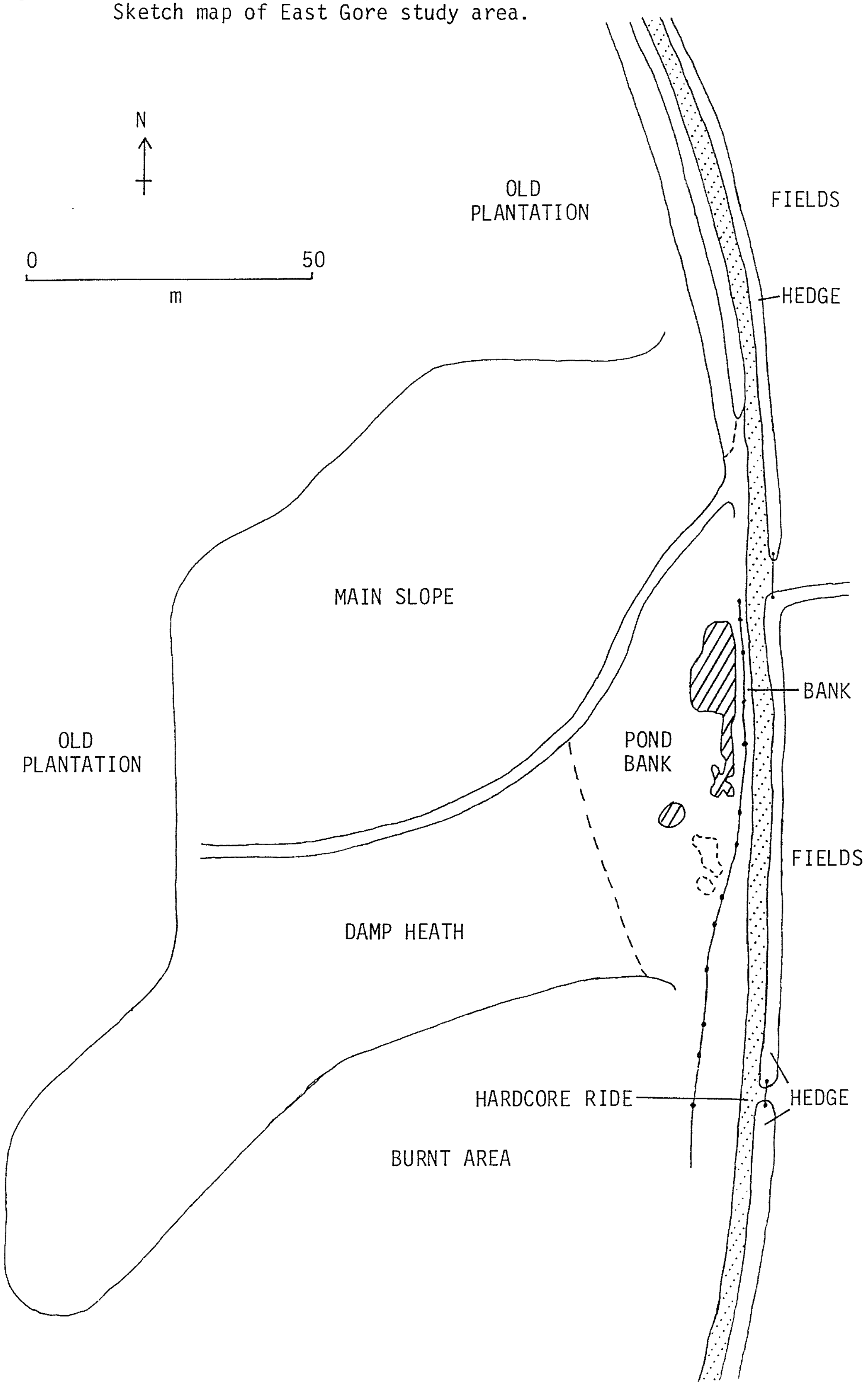
2.1.2.2 Damp Heath

To the south of the Main Slope was an area of damp heath on which the crop of Scots Pine planted in 1943 had failed leaving a scattering of pines two to three metres high. The vegetation consisted of a mixture of C.vulgaris, E.tetralix, M.caerulea and E.cinerea.

2.1.2.3 Pond Bank

To the east of the damp heath the vegetation changed to a M.caerulea dominated area with Juncus effusus and Vaccinium myrtillus, surrounding a small pond. This area was flooded each winter and dried out only in late spring. To the east of this area and separating it

Fig. 2.2 General methods, study areas.
Sketch map of East Gore study area.



from a north south ride was a grassy bank of Ulex europaeus, Rubus spp., V.myrtillus and P.aquilinum with a ground layer of grasses and herbaceous plants (annuals).

2.1.2.4 Hedge

The study area was bordered to the east by a hardcore ride which was in turn separated from the adjacent fields by a one to two metre wide hedge. The vegetation of this area was mainly U.europaeus and Rubus spp with a ground layer of grasses and annuals.

2.1.3 MORDEN RIDES

This 'site' consisted of the verge habitat available on either side of an approximately 5000m long stretch of forest rides (Fig.2.1). The habitat was varied in terms of its vegetation, the nature of the adjacent crop and the aspect, width and height of the verge itself. The verges were from one to ten metres wide. Occasionally there was a bank, some being four metres high above the level of the ride, whilst others sloped down away from the ride. The vegetation ranged from wet to dry heathland. The age of the adjacent plantations also varied greatly, from 42 year old Corsican Pine approximately 14m high to the 13 year old, 4m high Corsican Pine of the Morden Site. Several areas of the ride were adjacent to plantations on one side only. To the west of the forest block was Morden Bog and to the east was an area of open dry heathland. Only the western of the two edges of the area was studied, the eastern edge abutting straight onto open heath was not used.

2.2 POPULATION SAMPLING

2.2.1 SEARCHING

Lizards were located by visual observation, i.e. walking slowly through the vegetation searching the ground on either side. Searching efficiency varied with the conditions on a given day but on average a strip of ground 1.5-2.0m wide was covered. The methods used were different on each site although the same basic techniques were used in each case.

2.2.1.1 Morden Site

Twenty three fixed transects were used running north to south across the site. These ran between alternate rows of trees and were 2.5 to 3.0m apart. Transects were walked in a set pattern such that no two adjacent transects were walked consecutively. This decreased the problability of disturbing animals on one transect whilst walking an adjacent one. Fixed transects were used in preference to random ones because of the susceptibility of heathland vegetation to trampling (Harrison 1980), and also on a small site of this kind the whole area was effectively covered by the use of fixed transects. The data from transects was supplemented by searching the areas where *L.agilis* was known to occur. This was thought to be necessary because of the scarcity of the species and the low numbers of animals found on transects.

Morden Site was visited approximately once a week from June to September 1981. Only sightings of *L.agilis* were recorded.

2.2.1.2 East Gore

Sixteen fixed north-south transects spaced five metres apart were used from May to October 1981 and March to October 1982. The area searched was extended to the south west in 1983 giving 28 transects walked from March to October 1983. Areas where lizards were known to occur were searched in addition to transects.

2.2.1.3 Morden Rides

A limited area of this site was first used in September and October 1981. A larger area was used in March to October 1982 and 1983. Verges were normally searched from the ride but where there was a particularly high bank or wide verge, the transect was made along the verge itself. During 1982 and 1983 each ride was walked approximately once a month with additional searches of rides where *L.agilis* was frequently found.

The presence of both *L.agilis* and *L.vivipara* were recorded.

2.2.2 LOCATION OF ANIMALS

The position of each observed animal was recorded.

2.2.2.1 Morden Site

Small labelled canes were used to mark the postions of *L.agilis* sightings, the position of these relative to the edges of the site was then measured.

2.2.2.2 East Gore

In 1981, labelled canes were used to mark the postions of any lizards seen and the positions of these were later measured relative to the markers which indicated the beginning and end of transects.

In 1982, lizard positions were recorded relative to obvious landmarks or labelled trees on the site.

In 1983, a 5m x 5m grid was marked out across the area. Trees labelled in 1982 were positioned relative to this, enabling the sightings of animals seen in 1982 to be accurately located. Animals seen in 1983 were located relative to the grid.

2.2.2.3 Morden Rides

In 1981 and 1982 lizard postions were recorded relative to obvious landmarks (such as single trees or posts) along each ride.

In 1983 a tree approximately every 25m along each ride was painted with a characteristic symbol (in white tree paint). Landmarks used in 1981 and 1982 were located relative to these marked trees to identify the position of animals seen in 1981 and 1982. Animals seen in 1983 were located relative to the labelled trees.

2.2.3 CLASSIFICATION OF AGE AND SEX CLASSES

2.2.3.1 Age groupings

The following scheme was used for indicating the age of animals:

JUVENILE = animal prior to first winter dormancy
SUB-ADULT = animal between its first and second winter dormancy
ADULT = animal that has passed two or more winters.

2.2.3.2 Sex

During the spring male L.agilis could be readily separated from females by the vivid green colour on their flanks. At other times of the year , males often retained a slight green colouring to their sides and they could also be separated from females by the greater width of their heads relative to their body size.

It was not possible to sex juveniles and sub-adults early in the year.

For L.vivipara males and females could not usually be separated without capture.

2.2.4. DESCRIPTION OF BEHAVIOUR, POSITION AND WEATHER

The behaviour of each observed L.agilis and L.vivipara was noted The following categories were used:

BASKING - O = sitting in the sun
- F = using flattened basking posture
ACTIVE = moving through the vegetation
RESTING = visible in the vegetation but not active
DISTURBED = animal disturbed or flushed by observer

The weather conditons at the time of sighting were noted. The following code was used:

S = sunny
C = clear
CL = cloudy
D = dull

W = warm
H = hot
C = cool

ST = still
StrW = strong wind
Sl.B = slight breeze

e.g. S/C = sunny and clear
W/H warm to hot
ST still

2.2.5 CAPTURE OF ANIMALS

Individuals of *L.agilis* were caught whenever it was possible. This was done either by hand or using a noose of thin nylon (3lb. breaking strength) on the end of a bamboo pole. This method worked well particularly when animals were quite active and hence would have been difficult to catch by hand.

Juveniles were caught in 1982 and 1983 but not in 1981.

2.2.6 MARKING AND IDENTIFICATION

2.2.6.1 Marking by Toe Clipping

All animals caught were permanently marked by removing the last digit of a toe using a pair of sharp sissors. Each animal was given a unique mark by the clipping of up to three toes, not using more than one toe per foot.

2.2.6.2 Identification by using Back Patterns

Each *L.agilis* was found to have a unique pattern of markings on its dorsal surface. This had been used for identification previously by Nicholson (1980) who drew the back patterns of individual animals and used them for subsequent identification. The method was particularly useful because it enabled animals to be identified without being caught, this not only decreased the amount of disturbance to the population but also considerably increased the number of animals successfully identified.

During 1981 the back pattern of any animal caught was drawn and this was then used as an aid to the identification of animals in the field. Attempts were made to draw back patterns from uncaptured animals but it was difficult to obtain an accurate result in this way.

During 1982 and 1983 a 200mm zoom lens and close-up adaptor were used to take a photo of each animal seen. This provided a means of identifying the animals without unduly disturbing them so that an attempt could still be made to catch them if required.

The use of drawings of the back pattern made a small contribution to the number of animals which were identified in 1981, 35% of the animals seen were identified but only 20% were caught (Table 2.1), the difference between these two figures being a measure of the usefulness of the drawing of back patterns.

The use of photographs greatly increased the number of animals identified in a season. In 1982 and 1983, 73% and 71% of the animals seen respectively were identified, whereas only 20% and 26% respectively were caught (Table 2.1).

In adult animals the back patterns were clearly defined (Plate 2.1) and from a clear photograph of the entire pattern an animal could be identified. Once such a photograph had been obtained animals could often be identified on subsequent occasions from a photograph which included only a part of the whole pattern (Plate 2.2). The method was less successful for juveniles and some subadults because their back pattern was much less clearly defined at this age.

2.2.7 MEASUREMENT

The following measurements were made of each animal that was caught:

(i) weight; measured using a 10g or 30g Pesola balance, animals were weighed in a plastic bag of known weight, to an accuracy of 0.2g.

(ii) length; measured using a clear plastic ruler. Care was taken to ensure that the animal was at full stretch before any measurements were taken. The total length from snout to the tip of the tail and the snout to vent length were recorded (to an accuracy of 1mm).

2.2.8 SUMMARY

Table 2.2 gives a summary of the number of L.agilis and L.vivipara observed in each field season on each study area. Captures have been sub-divided into sex and age group. The number of observations on transects only has been given as well as the total number observed in each season.

2.3 MICROCLIMATE MEASUREMENTS

A small weather station was set up in an clearing in which no trees were present adjacent to the Forest Offices at Coldharbour. This

Table 2.1 General methods; Marking and identification.

The number of L.agilis identified and caught in 1981, 1982 and 1983.

	1981		1982		1983	
	No.	%	No.	%	No.	%
Caught	23	19.3	56	20.5	39	26.2
Identified	42	35.3	198	72.5	106	71.1
Total No. seen	119		273		149	

Plate 2.1 General methods, marking and identification. Photographs of the back patterns of four <u>L.agilis</u> individuals to demonstrate the variety of back patterns found, a. female, (EG 20) from East Gore, 2.9.81 b. female (EG 19) from East Gore, 2.9.81 c. female, (EG 18) from East Gore, 8.9.81 and d. male, (MR 4) from Morden Rides, 8.9.81.

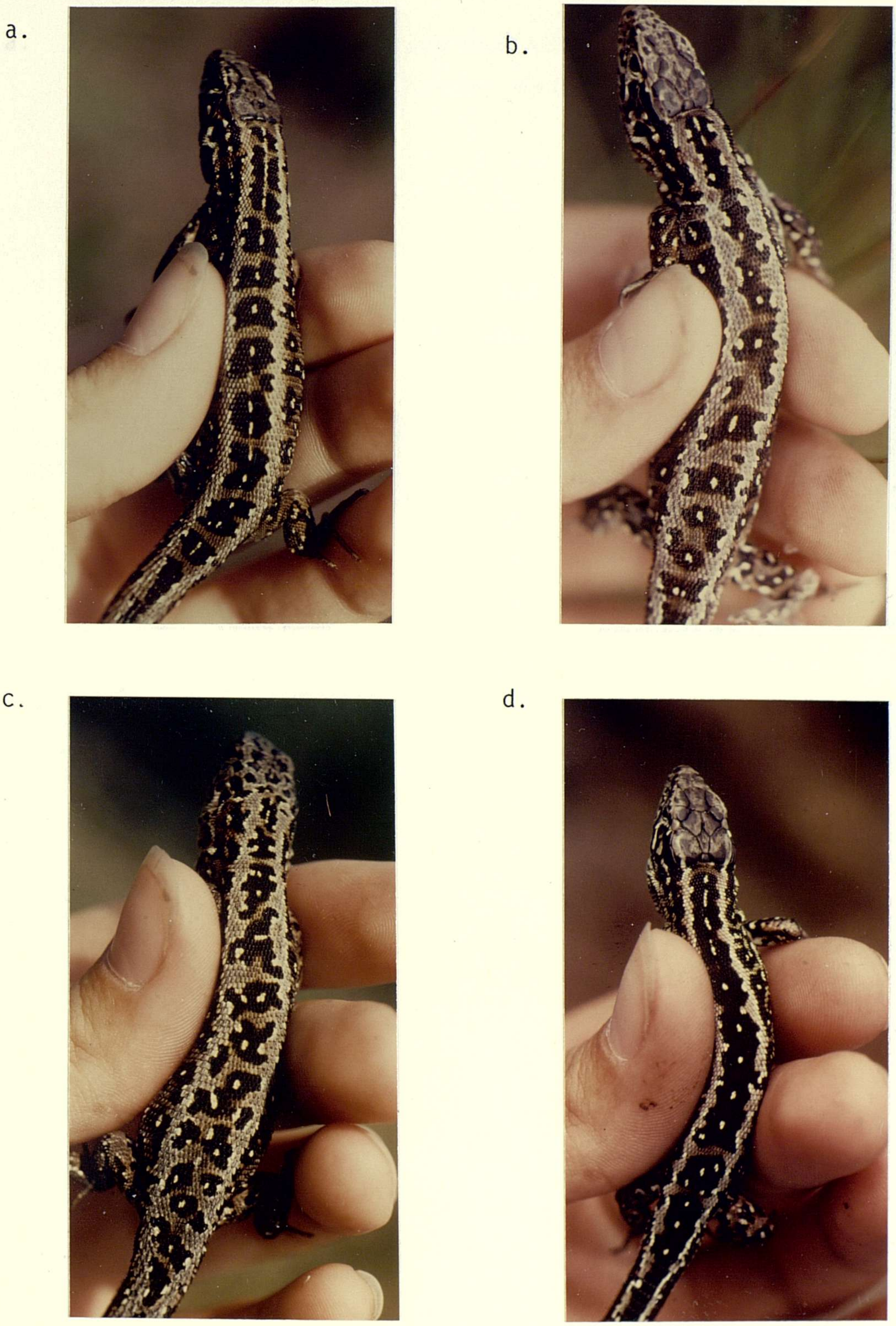


Plate 2.2 General methods, marking and identification.

Four photographs of a male *L.agilis* (liz. No. 10, East Gore) taken on a. 4.8.81 b. 16.4.82 c. 3.6.82 and d. 18.5.83. This series demonstrates the distinctiveness and consistency of the back pattern of an individual of *L.agilis*.

Table 2.2 General methods; marking and identification.

A summary of a. the L.agilis and L.vivipara observations on Morden Rides, and of the L.agilis observations on b. East Gore and c. Morden Site. Observations have been divided into adult, sub-adult and juvenile age groups. Male and female adults have been separated for L.agilis only. The number of hours spent searching each study area is also shown (effort).

OT = observations made while walking transects.
TOTAL = all observations made.

A. MORDEN RIDES, L.AGILIS

	ADULT		SUB-ADULT	JUVENILE	TOTAL	EFFORT (HOURS)
	MALE	FEMALE				
1981 - OT	0	3	0	61	64	27.4
- TOTAL	0	5	1	68	74	32.2
1982 - OT	39	22	42	23	126	119.7
- TOTAL	72	37	54	36	199	147.9
1983 - OT	49	24	54	20	147	104.5
- TOTAL	62	39	70	20	191	141.9

MORDEN RIDES, L.VIVIPARA

1981 - OT	17	2	136	155	27.4
- TOTAL	27	2	139	168	32.2
1982 - OT	149	66	74	289	119.7
- TOTAL	191	71	84	346	147.9
1983 - OT	215	85	136	436	104.5
- TOTAL	243	95	145	486	141.9

Table 2.2 (cont.)

B. EAST GORE, L.AGILIS

	ADULT		SUB-ADULT	JUVENILE	TOTAL	EFFORT (HOURS)
	MALE	FEMALE				
1981 - OT	7	15	4	5	31	33.2
- TOTAL	29	61	18	11	119	112.1
1982 - OT	5	26	4	10	45	33.3
- TOTAL	68	140	25	39	272	209.3
1983 - OT	18	16	17	9	60	37.9
- TOTAL	24	55	42	26	147	85.7

C. MORDEN SITE, L.AGILIS

	ADULT		SUB-ADULT	JUVENILE	TOTAL	EFFORT (HOURS)
	MALE	FEMALE				
1981 - OT	7	9	2	0	18	48.9
- TOTAL	12	15	5	2	34	60.9

site was approximately two kilometres from the Morden Rides and Morden Site area and four kilometres from East Gore. The variables recorded and their methods of measurement varied in each year and are summarised in Table 2.3.

2.3.1 TEMPERATURE

Temperature was measured in two ways.

a. using a thermograph inside a Stevenson's screen at 1.5m above the ground.

b. using a Grants temperature recorder which had probes recording:

(i) the temperature inside a Stevenson's screen on the ground
(ii) the shade air temperature
(iii) the temperature of the air at the base of the *C.vulgaris* bush
(iv) the subsurface temperature at 3cm.

Readings were made every 15 minutes.

2.3.2 NET RADIATION

The net radiation was measured using a circular net radiometer positioned one metre above the ground and two tube net radiometers at 30 cm above the ground. Data was recorded by a Delta-t Devices chart recorder which made readings every 15 minutes.

2.3.3 OTHER SOURCES OF MEASUREMENTS OF WEATHER VARIABLES

Weather data was also available from two other sources:

(i) The Institute of Hydrology weather station, Hartland Moor.

This automatic recording weather station was situated about 10 kilometres away from the study sites, data from this source was therefore only used to give an overall indication of weather conditions.

(ii) Forestry Commission weather station, Coldharbour, Wareham.

The Forestry Commission ran a small weather station at the Forest Offices, at Codlharbour, adjacent to the station described above (2.3.1 & 2.3.2).

2.4 RADIOTRACKING

The increasing miniaturisation of the electronic components necessary to make radiotransmitters and the decrease in the size and weight of the batteries needed to run them, has meant that radiotransmitters are now available which can be used on smaller

Table 2.3 General methods; Microclimate measurements.

Summary of the measurement of microclimate variables in 1981, 1982 and 1983.

	Air Temperature 1.5m	Air Temperature 0.3m	Net Radiation	Wind	Humidity
1981	*		*	*	
1982		*	*		
1983	*	*	*		*

animals than has been previously possible. In attempting to use radiotransmitters on a small lizard such as L.agilis the problems encountered were essentially the same as in any other radio-telemetry study, that is:

(i) the weight of the package relative to the weight of the animal
(ii) the length of life of the batteries
(iii) the method of attachment of the package
(iv) the period for which the radio can be left attached
(v) the range of the transmitter signal

The weight of a radio-transmitter package is usually assessed as a percentage of the body weight of the animal carrying it. Radio transmitters weighing 2.5-3.0g have been used on meadow voles, Microtus pennsylvanicus (Ord.; Webster & Brooks 1980) and Bufo bufo L. (Van Nuland & Claus 1981). In the former case the radios were never used on animals where they would have constituted more than 10% of the body weight. In the latter, the radios weighed from 6 to 13% of the body weight of the toads. A radio transmitter weighing 0.75g has been developed for the measurement of the deep body temperature of small birds but this had a range of only one metre (Reinertsen 1982).

The most commonly used methods for the external attachment of radiotransmitters have been a collar around the animal's neck or some form of harness. In some cases the radio may simply be glued onto the fur or feathers of the animal. Collar attachments have been frequently used for small mammals such as the deer mouse Peromyscus leucopus (Ratinsque; Mineau & Madison 1977) or the vole M.pennsylvanicus (Hamley & Falls 1975, Webster & Brooks 1980). A shoulder harness system has been used for the iguana Iguana iguana (Linne; Montgomery 1973) and the desert iguana Dipsosaurus dorsalis (Baird & Girard; Muth et al 1978).

2.4.1 RADIO TRANSMITTERS

The radio transmitters used were supplied by Biotrack (Huntingdon, Cambs.) and each consisted of a package approximately 15mm x 7mm x 5mm, the components being surrounded by Araldite. The basic transmitter without harness weighed 1.5g. The radio had a 5cm whip antenna, initially this was made of a stiff wire but this was later replaced by a flexible plastic coated wire.

2.4.2 BATTERIES

Two types of battery were used. Initially 1.5V Gould Activair hearing aid batteries were used. These were zinc-air batteries which had the advantage that they could be switched on immediately prior to use by removing a piece of tape and letting air into the battery. The batteries subsequently used were Duracell 1.5V hearing aid batteries, These were less convenient as they could only be made up into the radio package immediately before they were required for use. The mercury batteries only lasted about three weeks compared to approximately six for the zinc-air ones, however, this was adequate for the purposes of this work.

Batteries were replaced by chipping off the Araldite and removing the old battery and then soldering a new one in place and replacing the Araldite.

2.4.3 ATTACHMENT

Because of the small size of L.agilis it was not possible to design a harness which would remain in position without constricting the animal. Instead, an elastoplast ('Sleek') was used to stick the radio in place. This proved to be strong enough to hold the radio in position but the package would come away if the animal became entangled in the vegetation and struggled hard enough. The radio was positioned just in front of the hind legs (Plate 2.3). The harness did not form a complete ring around the animal which could have prevented the passing of faeces etc.. The radio was attached to a basal piece of Sleek using superglue, a second piece was then placed over the top of this to help hold the radio in position. The top piece included a tab which ran down onto the lizards back (Fig.2.3). If this tab came away from the lizards back and vegetation became lodged under the radio the animal could be recaught and the tab replaced.

2.4.4 LENGTH OF ATTACHMENT OF RADIOTRANSMITTERS

The length of time for which the radios could be used was limited to three weeks by the length of battery life. The completed radio package weighed 1.8g and was, on average, 17.9% of the body weight of the animals to which it was attached (Table 2.4). Because of their considerable weight the radios were left on for a period of seven days, which was long enough to produce some useful information without causing undue distress to the animal. At the end of seven days the animal was recaught and the radio removed. If the Sleek was still well stuck to the animal it was left in place when the radio itself was removed, to be lost when the animal sloughed.

Plate 2.3 General methods, radio-tracking.
An adult male L.agilis fitted with a radio-transmitter.

Fig. 2.3 General methods, radio-tracking.
Diagram of the completed radio-transmitter package, ready to be fitted to the animal.

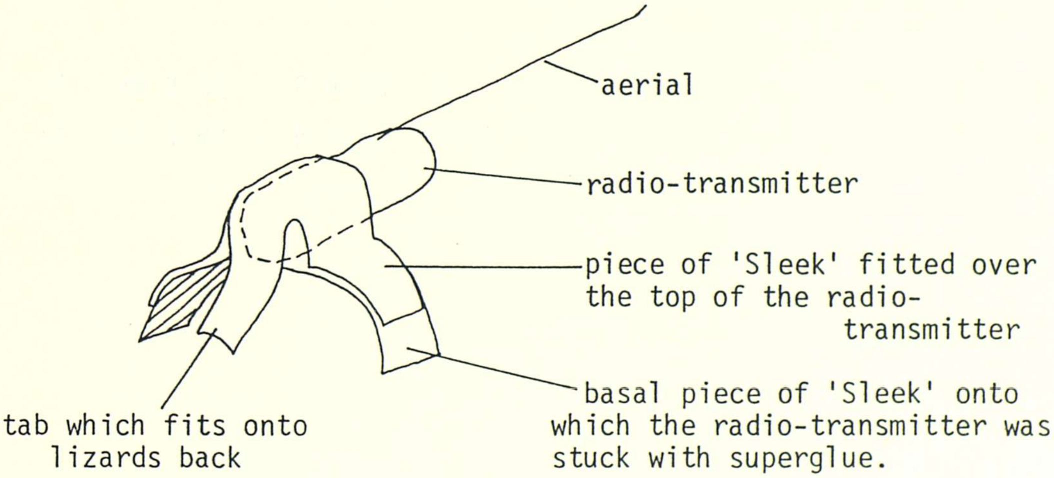


Table 2.4 General methods; Radiotracking.

Details of lizards used for radio tracking on East Gore in 1982 and 1983.

B.W. = radio weight expressed as a percentage of the body weight of the animal being used.

No.	Start	Finish	Sex	Liz. No.	Weight (g) Start	Finish	Days Total	Work	% B.W.
1	23.3.82	30.3.82	M	11	11.7	-	8	6	15.4
2	24.3.82	1.4.82	M	22	10.2	11.2	8	6	17.6
3	24.5.82	24.5.82	M	10	9.7	-	1	0	18.6
4	1.6.82	12.6.82	M	8	9.7	-	12	10	18.6
5	5.6.82	12.6.82	M	10	9.7	9.7	8	6	18.6
6	28.6.82	1.7.82	F	18	9.7	9.2	5	3	18.6
7	28.6.82	1.7.82	M	8	9.7	8.6	5	3	18.6
8	28.6.82	28.6.82	F	3	12.2	-	1	0	14.8
9	8.7.82	16.7.82	F	31	9.8	8.2	9	7	18.4
10	9.7.82	14.7.82	F	19	10.8	-	6	4	16.7
11	10.7.82	15.7.82	M	8	9.4	-	6	4	19.1
12	14.7.82	15.7.82	M	37	9.7	-	2	0	18.6
13	27.7.82	4.8.82	F	31	9.7	9.0	9	7	18.6
14	29.7.82	30.7.82	M	10	10.4	-	2	0	17.3
15	1.8.82	8.8.82	M	22	9.8	9.8	9	7	18.4
16	28.3.83	2.4.83	M	8	11.2	-	6	4	16.1
17	31.3.83	8.4.83	M	10	10.9	10.6	9	7	16.5

2.4.5 RANGE OF TRANSMISSIONS

The radios used had a range of approximately 25 metres.

2.4.6 LOCATION OF ANIMALS

The location of the animals was determined every 1.5 hours after their release. Their behaviour at the time was noted using the method described earlier (2.2.3). For analytical purposes data from the day of release was not used in order to allow a short time for the animal to become accustomed to carrying the radio-transmitter. Similarly any days when attempts were being made to recapture an animal were not used for analysis because of the disturbance caused.

2.4.7 CHOICE OF ANIMALS FOR USE WITH RADIOTRANSMITTERS

All animals used were adult L.agilis weighing over 9.0g but animals weighing over 10g were preferred if they could be found. Radio tracking was carried out during the early spring using recently emerged males. During the mating season no radio-tracking was done but after this males were used again. Immediately after egg laying females were very thin and obviously in poor condition, however they gain weight rapidly and were not used for radio tracking until they had regained weight and conditon. Radio tracking was carried out on East Gore during 1982 and the spring of 1983. Attempts were made to use the radios on Morden Rides in the summer of 1983 but failed partly because of the difficulties encountered in catching animals, and partly because of the four animals which were caught three of the radios fell off after one day and only one remained in place for a useful time.

When a suitable animal was caught the radio was fitted immediately and the animal released . Some animals were kept in the shade for half an hour in a suitable container after the radio had been fitted. This appeared to give the Sleek time to stick and to increase the chances of the radio staying in postion when the animal was released.

2.4.9 DISCUSSION OF METHODS OF RADIOTRACKING

The radio transmitters proved to be satisfactory for their purpose. The signal range was quite short but since animals were being located at regular intervals this did not present a problem. Inconsistencies in radio performance were due to the use of zinc air batteries which were unreliable and prone to fail particularly under damp conditions. Mercury batteries were found to be more reliable and in this kind of research their short life was not a disadvantage. Batteries were replaced at regular intervals and the radios were robust to this operation. The whip antenna on one radio did rust through and break but this problem was solved by using plastic coated, flexible wire.

The harness system was rather prone to being dislodged. Four out of seventeen were lost before a day's data could be obtained and only five remained in place for a full seven days (Table 2.4). However, thirteen did produce sufficient data to warrant their use. Seven out of the 17 radios used on East Gore were lost before they could be removed. Of the four radios fitted on Morden Rides, one animal sloughed on the same day, one animal lost the radio on the same day, one animal sloughed after two days and one animal sloughed after four days. All but one of the radios lost before the animal was recaught were successfully recovered.

This highlights one of the problems of using radios on <u>L.agilis</u> for short periods of time. On some occasions a lot of effort was necessary in order to catch an animal and there was a 23% chance (33% if the animals from Morden Rides are taken into account) that the radio would fall off, or that the animal would slough. A harness system would reduce the chance of this happening but it seems unlikely that one suitable for a lizard as small as <u>L.agilis</u> could be developed, unless the radio itself was smaller.

Apart from some minor damage to the scales beneath the radio itself no injury could be detected in any of the animals caught after radio-tracking. Lizards appeared undisturbed by the process of radio attachment and gave every appearance of behaving normally upon release.

Of the animals recaught after radiotracking in the spring, one had gained one gram in weight and one had lost 0.3g (Table 2.4). During the summer, males lost on average 0.4g (N=3) and females 0.9g (N=3). The sample sizes were small but it is apparent that during the summer when the animals were more active their weight loss was greater. As animals would not be expected to loose weight during the summer, this weight loss must be considered to be a consequence of the presence of the radio. However, it may indicate that the lizards were behaving normally despite the increased energy required, and that the animals were not responding to the presence of the radios by remaining inactive. On emergence in the spring males are inactive (Frazer 1983) and the radios did not appear to affect the condition of the animals to the same extent as in the summer.

The presence of the radios does not appear to inhibit the movement of the animals through the loose heathland vegetation, and at least some radios did remain in place. However, two attempts (Lizard No. 9, 1982 and No.3 1982, Table 2.3) were made to use them in the grass dominated Hedge habitat of East Gore. One of these radios was lost within a day, the second animal was observed after release and it was so apparent that she could not move underneath the closely matted grass that she was recaptured immediately and the radio removed.

2.5 STATISTICAL ANALYSIS

Several well known techniques of statistical analysis were used to help interpret the data reported here. The techniques used include chi square (Siegel 1956 & Meddis 1975), t-test (Meddis 1975), analysis of variance (Snedecore & Cochran 1978) and regression analysis (Snedecore & Cochran 1978, Meddis 1975). Where more specialised techniques have been used a brief explanation of the method and its output has been reported at an appropriate point in the data chapters. All computerised analysis was carried out using Genstat (Alvey 1982) or Basic (Alcock 1981).

A probability level (P) of 0.05 (5%) has been used throughout the analysis as the borderline for decidng whether to accept or reject the null hypothesis in a statistical test. That is, if $P<0.05$ for any statistical test then the result has been taken as being significant. For P below 0.05 the exact probability of a result occurring has been reported.

Table 2.5 summarises the abbreviations which have been used throughout the text in connection with statistical tests and for the presentation of data tables.

II CHAPTER METHODS

2.6 HABITAT

The type of habitat used by *L.agilis* has been studied on all three study areas; that of *L.vivipara* was only investigated for the Morden Rides study area.

2.6.1 HABITAT USE WITHIN COMPARTMENTS AND SIMILAR AREAS, LIZARD VS. RANDOM QUADRATS

Quadrats around the position of lizard (*L.agilis*) sightings and random points were used to describe the habitat use of *L.agilis* on the Morden Site and East Gore study areas. For this work East Gore was subdivided into three main areas; Main slope, Pond bank and Hedge.

Table 2.5 General methods; Statistical analysis.

A summary of the abbreviations used in connection with statistical tests or for the presentation of data. These abbreviations have been used throughout the remainder of the text and tables.

Abbreviation

N = Sample size
S.E. = Standard error of the mean
C.V. (%) = Coefficient of variation ([S.E./mean]x100)

r = Correlation coefficient
P.V. = Percentage of the variance in a data set accounted for by regression analysis

F = Variance ratio (ANOVA)
D.F. = Degrees of freedom (t-test, chi square)
DF1, DF2 = Degrees of freedom (ANOVA)

P = Probability of the observed result in a statistical test occurring by chance
$P<0.05$ = Minimum level of P at which the result of a statistical test were considered significant.

2.6.1.1 Morden Site, lizard vs. random quadrats

From June to September 1981 a quadrat was placed around the position of each lizard sighting. A set of random quadrats were also placed over points chosen using pairs of random co-ordinates. 34 lizard and 25 random quadrats were done. The following is a summary of the characteristics of each quadrat recorded.

2.6.1.1.1 In a 2m x 2m quadrat around each point

The following characteristics were recorded:

(i) the plant species present

(ii) a visual assessment was made of the percentage cover of Pine overhanging the quadrat.

(iii) a visual assessment was made of the percentage cover of *P.aquilinum* in the quadrat.

2.6.1.1.2 In a 5m x 5m quadrat around each point

The following characteristics were recorded:

(i) the number of trees

(ii) the height of all trees

(iii) the diameter at breast height (DBH, 1.3m off the ground) for all trees.

2.6.1.1.3 100 point quadrats around each point

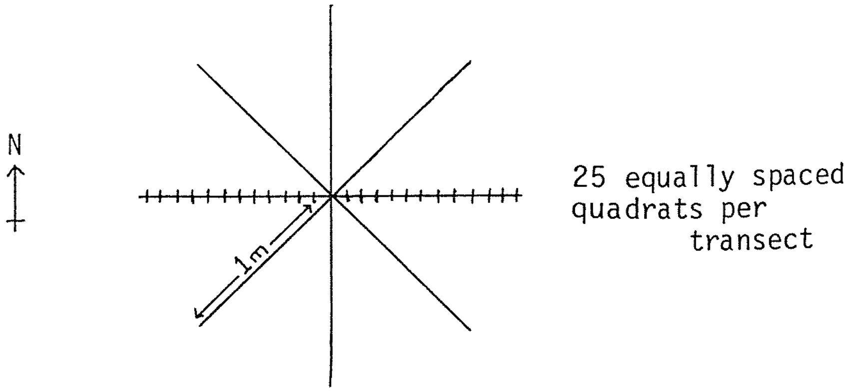
2.6.1.1.3.1 Structure of quadrats

A grid of 100 point quadrats over each point was used. This took the form of four, two metre transects each running through the central point. One transect ran from north to south, one from east to west, one from north-east to south-west and one from north-west to south-east (Fig. 2.4a). A point quadrat was done at 25 equally spaced positions along each transect, one point on each transect being at the centre so that each arm was one metre long with 12 recording points. The entire structure had 97 points. Each transect was marked out by a 2m length of nylon string with the point quadrat positions marked on it. Two, two metre lengths of string were attached at their centres to a bamboo pole, four other poles were attached to the ends of the strings. In this way the central pole was positioned at the random point or lizard sighting and the two transects could be stretched out in an appropriate compass direction using the bamboo poles at their ends (Fig. 2.4b). The string was positioned horizontally using a spirit level and ran at a convenient height above tthe vegetation. Two transects were assessed in this way (e.g. north-south and east-west) then the outer poles were

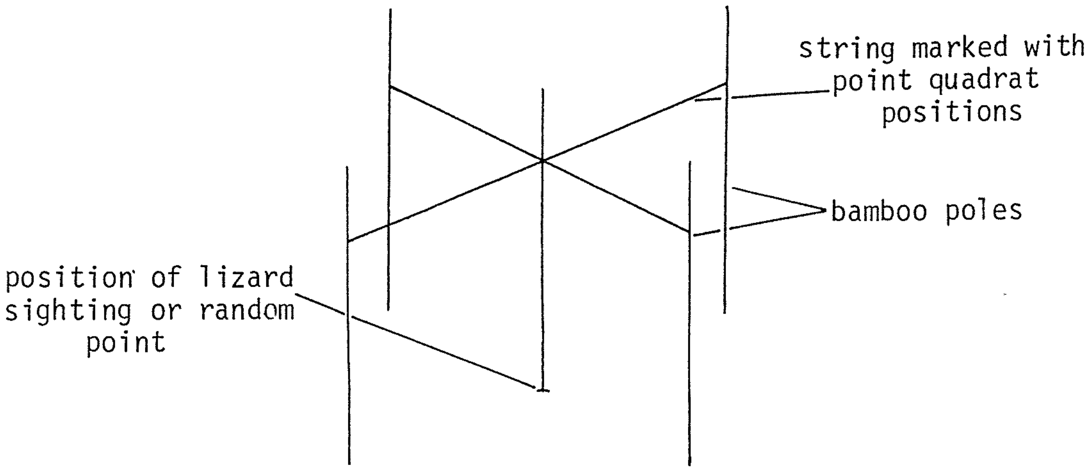
Fig. 2.4 Chapter methods, Habitat.
Habitat use within Compartments and similar areas.

Point quadrats used in the analysis of habitat use by L.agilis on the East Gore and Morden Site study areas.

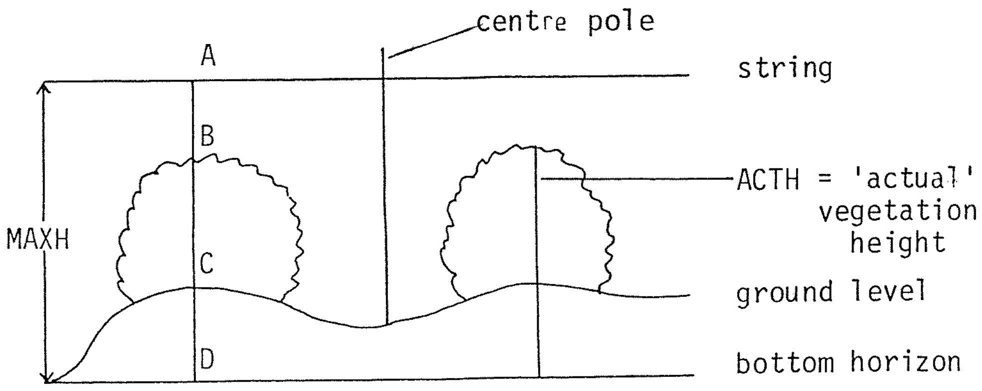
a. overhead view of point quadrat transects.



b. framework used for two point quadrat transects



c. height measurements made using point quadrats



moved to do the second two transects (e.g. north-east to south-west and north-west to south-east).

2.6.1.1.3.2 Characteristics of the vegetation recorded

At each point quadrat position a 1.5m length of 3mm diameter metal rod, graduated every two cm was placed vertically into the vegetation and the following characteristics were recorded:

(i) the plant species contacting the point quadrat at the highest point.

(ii) the type of ground cover, i.e litter and/or bare ground etc.

(iii) the distance from the ground to the tallest plant hitting the point quadrat (to nearest cm.).

(iv) the distance from the string to the ground (to nearest cm.).

2.6.1.1.3.3 Characteristics of vegetation assessed from point quadrats

From the measurements described above the following characteristics of the vegetation could be assessed.

a. The percentage cover of each plant species

The number of quadrat touches for each plant species was converted from a figure out of 97 to a percentage. If P.aquilinum was present it was recorded but it was not counted as a ground level species, i.e. the highest touch of grass or C.vulgaris etc. below it was used.

b. The percentage cover of litter and bare ground

Ground cover was classed as being one of the following.

(i) OPEN/LITTER = dead plant material from vegetation
(ii) OPEN/BG = bare ground
(iii) OPEN/MLI = moss or lichen covered ground

In the absence of a clear dominance by one litter type or by bare ground, joint categories such as LITTER/BG were used. In this case both classes would be credited with one point such that the ground cover values are not additive in the same way as the the plant cover values, where only one species was recorded per point quadrat. Values were converted to percentages.

c. Vegetation height

Fig. 2.4c shows the height measurements obtained from the point quadrats, using the nomenclature of the figure, these are

(i) BC = measured vegetation height
(ii) AC = measured distance from string to ground

The vegetation height was calculated as follows:

$$\text{Measured vegetation height} = \frac{\Sigma BC}{N} \qquad \text{where } N = 97. \tag{2.1}$$

d. Vegetation structure

The required measurement was the 'actual' profile of changes in the vegetation height between adjacent point quadrat positions i.e. taking into account irregularities in the ground level which would be disregarded if the calculations utilised the measured vegetation height. Using the terminology of Fig. 2.4c the 'actual' vegetation height and structure was calculated as follows.

(i) MAXH = maximum measured distance from the string to ground (AD)

(ii) MAXH - AC = difference between the bottom horizon (defined by MAXH) and that at a given point.

(iii) ACTH = the height of the vegetation relative to the fixed bottom horizon, i.e. the 'actual' vegetation height.

$$ACTH = (MAXH - AC) + BC \tag{2.2}$$

ACTH was then used to assess the structure of the vegetation, i.e. the amount of change in vegetation height around the lizard or random point, in two ways.

Firstly, the standard deviation of ACTH was used as a measure of the amount of variation in the actual vegetation height.

Secondly, the following formula was used to assess the changes between adjacent ACTH measurements.

$$\text{'STRUCTURE'} = \frac{1}{n-1} \sum_{t=1}^{t=n-1} \frac{2\left|(x_{t+1} - x_t)\right|}{(x_{t+1} + x_t)} \tag{2.3}$$

n = no. of points
x_t = height at point t
x_{t+1} = height at point next to t

This formula has been used to provide a measure of the variation between adjacent pairs of tree rings (Douglass 1928), to assess the sensitivity of tree growth to climatic changes. Since the interest here is in the vegetation structure, i.e. the degree of change in relative vegetation height in an area the above formula appears to provide the type of index required.

Because of the way in which the heights were measured the formula was applied to each transect in turn and a mean was taken for all four transects.

2.6.1.1.4 Hemispherical photographs

Hemispherical photographs were taken using a fisheye, wide angle lens on a tripod 35cm high. The lens was leveled so that it was horizontal using a circular spirit level on the camera body itself. A surveyor's pole was positioned due north of the camera and 5 to 10 metres away and marked the position of north on the photograph. The fisheye lens takes a phototgraph of a full hemispherical area above the camera. By using transparent overlays designed to take into account the non-linearity of the photographs it is possible to provide two measures of the light climate above a point.

2.6.1.1.4.1 Diffuse light factor

This is the proportion of the sky unobscured by trees. The overlay for this was divided into 1,000 units each of which represents 1/1000th of the sky illuminance. If more than 50% of the area of a square was obstructed by trees then it was counted as obscured. The total number of unobscured squares were counted and expressed as a percentage of the total area available.

2.6.1.1.4.2 Direct light factor

The overlay used for this measure has solar tracks marked on it equivalent to:

		Track
(i)	21st June/July	VI
(ii)	21st May/August	V
(iii)	21st April/September	IV
(iv)	21st March/October	III
(v)	21st February/November	II
(vi)	21st January/December	I

Each track was divided into sections of one hour. The Direct Light Factor was the percentage of the solar track unobscured by vegetation. This was calculated for tracks III and VI for each lizard sighting or random point.

2.6.1.1.5 Summary of characters assessed for random vs. lizard quadrats

The measurements made for each lizard and random point can be summarised as follows:

a. from a 2m x 2m quadrat
  - (i) the plant species composition
  - (ii) the percentage cover of pine over the quadrat
  - (iii) the percentage cover of *P.aquilinum* over quadrat

b. from a 5m x 5m quadrat
  - (i) the tree density
  - (ii) the mean tree height
  - (iii) the mean tree diameter at breast height

c. from 100 point quadrats
  - (i) the percentage top cover of species present
  - (ii) the mean vegetation height
  - (iii) the vegetation structure
  - (iv) the standard deviation of the actual vegetation height
  - (v) the percentage cover of litter/bare ground

d. from hemispherical photographs
  - (i) the diffuse light factor
  - (ii) the direct light factor

2.6.1.2 East Gore, lizard vs. random quadrats

Quadrats were completed around all lizard sightings on East Gore between May and September 1981. Random quadrats were carried out in three groups, one on each of the main habitat types i.e. Main slope, Pond bank and Hedge. No quadrats were completed in the damp heath area because only one lizard was seen there in 1981 (Table 2.6).

2.6.1.2.1 Main Slope

35 lizard and 25 random quadrats were completed. Random quadrats were chosen using pairs of randomly selected co-ordinates. The quadrats were assessed in the same way as for Morden Site and the same characters were recorded, except that no hemispherical photographs were taken.

2.6.1.2.2 Pond Bank and Hedge

36 lizard and 25 random quadrats were carried out in the Pond bank area and 19 lizard and 25 random quadrats in the Hedge area. Pond bank random quadrats were chosen in the same way as for the main slope, whilst those for the Hedge were chosen by first selecting a random

Table 2.6 Chapter methods; Habitat.

Habitat use within Compartments and similar areas, lizard vs. random quadrats.
Details of lizard sightings on East Gore 1981, and the number of lizard quadrats done in each area.

OT = Observed while walking a transect
XT = Observed during general searching of the habitat

Quadrats	Main Slope	Pond Bank	Hedge	Total
OT	13	9	6	28
XT	22	27	13	62
Total	35	36	19	90

point along the length of the Hedge (units = paces) and then taking a second random point across it's width (units = 50cm).

The measurements made were the same as for the Morden Site with two exceptions.

(i) no hemispherical photographs were taken

(ii) where *U.europaeus* or *Rubus spp* were present the point quadrat recorded the highest position of a ground level species (i.e. grasses, annual herbaceous plants, *M.caerulea* etc.). The perecentage cover of *U.europaeus* and *Rubus spp* were estimated visually in a 2m x 2m quadrat at the point.

2.6.1.3 Analysis of lizard vs. random quadrats

A Canonical Variate Analysis (CVA) was carried out to assess the contribution of each character towards the separation of the lizard and random groups.

2.6.2 HABITAT USE WITHIN COMPARTMENTS AND SIMILAR AREAS, HABITAT SURVEY

The habitat use of *L.agilis* on the East Gore study area was also assessed using a large scale survey of the habitat available. Again the habitat use of *L.agilis* was investigated by comparing the habitat occurring around *L.agilis* sightings with that around random points.

2.6.2.1 Assessment of vegetation types

2.6.2.1.1 The survey

In 1983, a 5m x 5m grid was marked out on East Gore using a series of small canes. Every third cane was labelled with an appropriate number and letter. Within each square the number of trees present was recorded, along with their height and DBH.

Also, within each square, the vegetation was assessed by dividing the area into regions of similar vegetation, which were then recorded on sketch maps of each square. Plant species associations were defined by using the following scale to describe the relationships between species present.

(i) ++ = DOMINANT SPECIES, other species present but in low numbers

(ii) ± = 2 OR MORE SPECIES CO-DOMINANT

(iii) + = SPECIES PRESENT IN SIGNIFICANT AMOUNTS, but not dominant

(iv) - = SPECIES PRESENT, but not in significant numbers

For example, H±EC+Mo, is *C.vulgaris* co-dominant with *E.cinerea* with M.caerulea present in significant amounts but not dominant, each such description of vegetation type is referred to as a plant species association in the remainder of the text.

Table 2.7 summarises the abbreviations used for plant species names for this survey and throughout the remainder of the text, figures and tables.

2.6.2.1.2 Quantitative assessment of vegetation types

In order to quantify the qualitative assessments made above, the major plant species associations found in the above survey were re-assessed by taking random quadrats within each area that had been described as being of one particular type.

Ten random quadrats were taken within each of 26 major species groups which were defined. The quadrats were then used to assess how consistent the dominance scale was in terms of percentage cover when using different species etc.

2.6.2.1.3 Habitat types

Each species association was put into one of seven habitat types

(i) M.caerulea dominant
(ii) Damp heath
(iii) Dry heath
(iv) Open
(v) Hardcore/Ride
(vi) Grass
(vii) U.europaeus/Rubus spp dominant

2.6.2.2 Assessment of lizard distribution in relation to vegetation type and to tree height and density

Each lizard sighting for 1981, 1982 and 1983 could be allocated to the particular square in which it was found. One point was given to a habitat type every time it occurrred in a lizard square. In this way frequency histograms of the occurrence of each habitat type were drawn.

100 squares were chosen using randomly selected co-ordinates within the area and the above process was repeated to give a standard against which to compare the lizard results. Separate sets of random points were used for 1981/1982 and 1983, as the area searched in 1983 was different to that used in 1981 and 1982.

The mean height and the density of the trees in each lizard and random square were calculated and used to construct frequency histograms of the occurrence of tree height and density in lizard and

Table 2.7 Chapter methods, Habitat.

Habitat use within Compartments and similar areas, Habitat Survey.
Abbreviations used for plant species names and habitat characteristics in tables and text.

Abbreviation	Name
H	*Calluna vulgaris*
EC	*Erica cinerea*
ET	*Erica tetralix*
UM	*Ulex minor*
UE	*Ulex europaeus*
R	*Rubus spp*
MO	*Molinia caerulea*
BR	*Pteridium aquilinum*
GRA	Grass species
JUNC	*Juncus effusus*
VAC	*Vaccinium myrtillus*
A	Annual herbaceous species
DEAD	Dead ericaceous species
OPEN	Open area
/MLI	open covered by mosses & lichens
/BG	open covered by bare ground
/LI	open covered by plant litter
/DP	open covered by dead pine needles
Brp	Cut branches of pine or brashings

random categories.

2.6.2.3 Statistical analysis

A chi square analysis was used to see if lizard and random distributions were significantly different from each other.

2.6.3 HABITAT USE ALONG PLANTATION RIDE VERGES, RIDE HABITAT SURVEY

The habitat use of both *L.agilis* and *L.vivipara* along plantation Ride verges was assessed by comparing the habitat associated with *L.agilis* and *L.vivipara* sightings with that randomly available within the Ride verge habitat. The habitat was described by means of a large scale survey of the area searched.

2.6.3.1 Survey of habitat

Each ride searched in 1982 and 1983 was surveyed in early 1983 and assessed for a variety of characters.

2.6.3.1.1 Vegetation features

The vegetation of each verge was assessed using essentially the same system as that used for the East Gore survey. The habitat was described for the entire verge width, changes along the length of the ride being noted. Each species present was given a score according to the dominance scheme described earlier.

(i) DOMINANT = ++ = 4
(ii) CODOMINANT = ± = 3
(iii) PRESENT in significant amounts = + = 2
(iv) PRESENT not in significant amounts = − = 1
(v) ABSENT = = 0

The vegetation assessed in each case was that of the verge proper i.e. not including any marginal areas or bank faces present between the ride and the main verge itself.

Open areas were assessed on a presence/absence basis for litter and bare ground.

The percentage cover of dead pine needles lying on the ground or on the vegetation was visually assessed for each area of ride.

2.6.3.1.2 Trees

The trees of each plantation were divided into areas of similar height and density. The number of front row trees in each area was counted. Where the rows of a plantation ran at an angle to the ride the number of trees within three metres of the start of the plantation, which were not obscured by trees infront of them were counted. The density of the trees was then expressed as the number of trees per 10m of ride edge. Ten trees were selected at random from each area and their height measured.

2.6.3.1.3 Ride and verge characteristics

The following were measured every five metres along the rides.

(i) the width of the ride

(ii) the width of the verge

(iii) the width of the area of disturbed ground between the ride and the undisturbed verge.

(iv) the height of the bank if present. This could be positive, i.e. a bank above the level of the ride, or negative, i.e. a bank sloping down away from the ride.

2.6.3.2 Assessment of lizard use of ride verge habitats

2.6.3.2.1 Lizard sightings

Data were recorded for both L.agilis and L.vivipara for autumn 1981 and for the full seasons of 1982 and 1983. Lizards observed while searching casually as opposed to walking entire rides or complete ride sections were not used in this analysis.

2.6.3.2.2 Random points

Because different rides were walked a different numbers of times in each year, three sets of random points were chosen, one for each year. Random points were chosen by taking the length of each ride walked and the number of occasions on which it was searched and producing a total, cumulative length of rides walked for a season. Random points were then chosen along this entire length, each section of which corresponded to a ride and a particular occasion on which it was walked, in this way each random point was allocated to an appropriate ride, in proportion with the number of occasions on which it was walked.

2.6.3.2.3 Habitat characteristics

For each lizard and random point the following characteristics were assessed.

a. Vegetation of the verge

(i) the dominance class of plant species present (0 to 4)

(ii) the presence/absence of litter and/or bare ground

(iii) the percentage cover of pine needles in the area as a whole

b. Characteristics of the ride and verge

(i) the width of the ride (WR)

(ii) the width of the adjacent verge - total (VAT)

- undisturbed (VAU)

(iii) the total width of the opposite verge (VO)

(iv) the height of the adjacent bank (BA)

(v) the height of the opposite bank (BO)

c. Trees

(i) the mean height of the trees of the adjacent area (THA)

(ii) the mean height of the trees of the opposite area (THO)

(iii) the density of the trees of the adjacent area (TDA)

(iv) the density of the trees of the opposite area (TDO)

2.6.3.3 Aspect

Compass bearings were taken parallel to the line of each verge so that the aspect of the verge (i.e. that direction facing perpendicularly away from the adjacent plantation) could be obtained by adding or sutracting 90^{0} (depending on the side of the ride being examined).

2.6.3.4 The use of hemispherical photographs to determine the number of sunshine hours received by an area

If the following three factors are known it should be possible to determine the number of sunshine hours received by an area.

(i) the angle between a point on the verge (here, arbitrarily chosen as half way across its undisturbed width) and the tops (expressed as the mean height) of the area opposite (ANGO).

(ii) the angle between a point on the verge and the tops of the adjacent trees (ANGA).

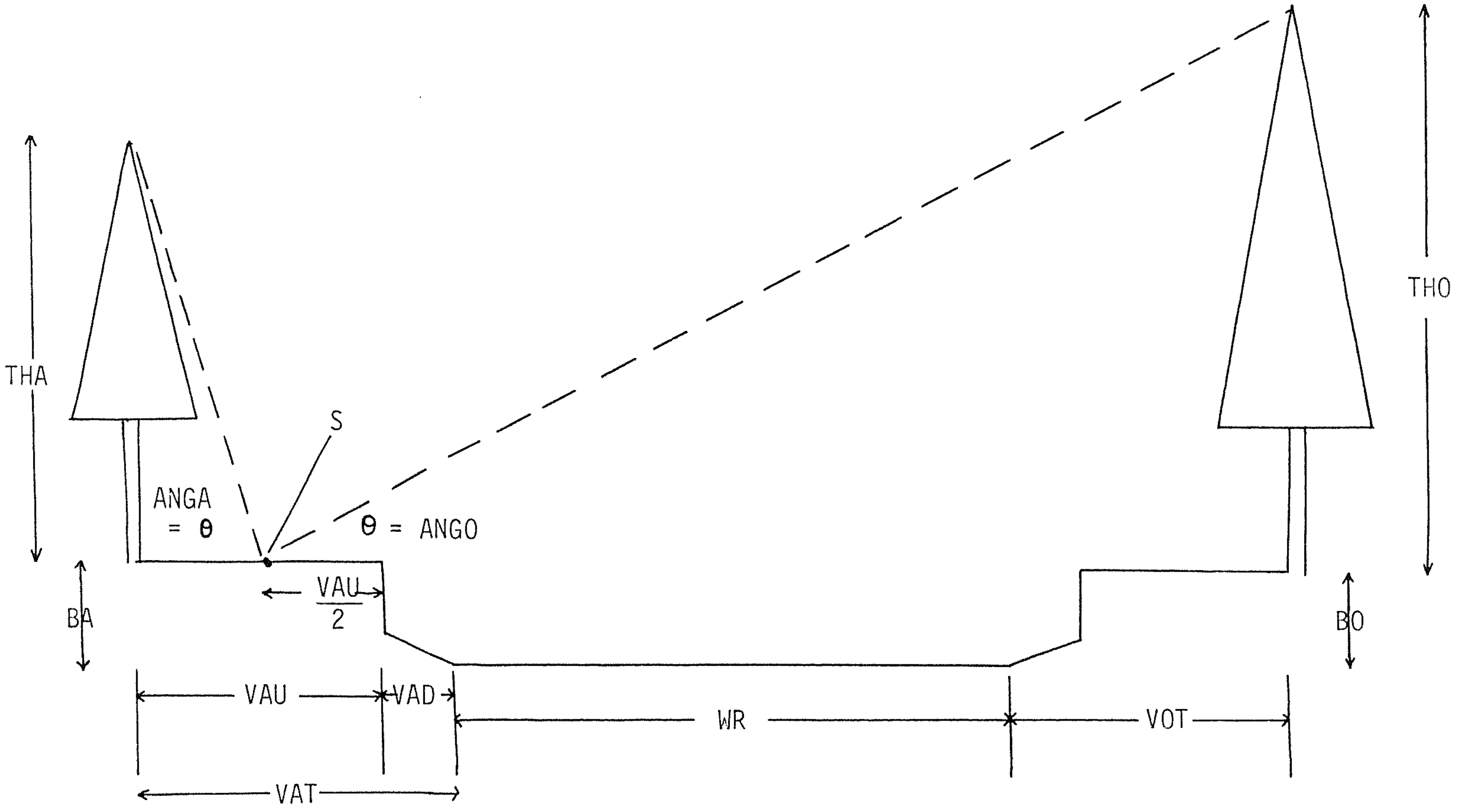
(iii) the relationship between this angle and the number of sunshine hours received for a given aspect of ride.

2.6.3.4.1 The angle between a point on the verge and the tops of the opposite and adjacent trees

The angle between a point half way across the undisturbed verge habitat and the mean height of the trees opposite can be calculated as below using the terminology of Fig. 2.5.

Fig. 2.5 Chapter methods, Habitat. Habitat use along plantation Ride verges.

The calculation of the angle from the Ride verge to the tops of the opposite and adjacent trees. All measurements are relative to a hypothetical lizard sighting or random point shown here as S. For abbreviations see Section 2.6.3.3.



a. opposite trees

$$\tan ANGO = \frac{OPP}{ADJ} \qquad (2.4)$$

$$OPP = THO + BO - BA$$

$$ADJ = \frac{VAU + VAD + WR + VOT}{2}$$

b. adjacent trees

$$\tan ANGA = \frac{OPP}{ADJ} \qquad (2.5)$$

$$OPP = THA$$

$$ADJ = \frac{VAU}{2}$$

2.6.3.4.2 Relationship between the aspect, ANGO, ANGA and the number of sunshine hours received by an area

A series of hemispherical photographs were taken from the ground at varying distances from the base of a vertical, straight brick wall at Chilworth Manor, Southampton. Knowing the height of the wall (2m) and the distance of the camera from it's base it was possible to calculate the angle between the camera and the top of the wall for each photograph.

By using overlays of solar tracks, the number of sunshine hours received by a point at each angle relative to the wall was calculated. By rotating the overlay relative to the photograph it was possible to estimate the relationship between angle and the number of sunshine hours received for aspects at 10^o intervals. The aspects 180^o - 360^o are a mirror image of those from 180^o to 0^o.

In each case the number of potential sunshine hours was determined for the solar tracks III to VI, i.e. those appropriate for the 21st of March/October, April/September, May/August and June/July. The sum of these four values was then used to give an overall seasonal evaluation of the number of sunshine hours received (SSH). See Table 2.8 for an example.

Regression analysis was then carried out between the angle (in radians) and the SSH for each aspect.

The aspects of lizard sightings and random points were grouped into classes around 10^o intervals, i.e. $10^o = 6 - 15^o$, $20^o = 16 - 25^o$ etc.. The calculated values of ANGO were then used to determine the SSH from the regression equation appropriate to the aspect of each point.

Table 2.8 Chapter methods, Habitat.
Habitat use along plantation Ride verges.

Example of the calculation of the number of sunshine hours received by an area of Ride verge of a given aspect (40^0 in this example).

Aspect = 40^0

Angle (degrees)	Solar Track III	IV	V	VI	SUM
0	10.0	12.0	14.0	16.0	52.0
8.0	10.0	12.0	14.0	16.0	52.0
26.6	7.1	11.7	12.6	15.1	46.6
33.7	5.7	8.6	12.6	15.1	42.1
43.0	4.2	6.8	9.5	12.2	32.7
53.1	3.4	5.6	8.1	10.4	27.5
63.4	2.6	4.6	6.7	8.6	22.5
76.0	2.1	3.7	5.4	6.9	18.1
82.9	2.1	3.7	5.3	6.8	17.9
87.1	2.0	3.4	5.0	6.4	16.8
90.0	1.8	3.2	4.7	6.0	15.7

To calculate the SSHA for the adjacent trees the same procedure was used but the reading of SSHA was taken from the regression of Aspect + 180^o.

The calculation for the overall SSH was as follows.

Maximium Number of Sunshine Hours Possible = 52

Number of sunshine hours lost due to shading of opposite trees = 52 - SSHO = LSSHO (2.6)

Number of sunshine hours lost due to shading of adjacent trees = 52 - SSHA = LSSHA (2.7)

Overall number of sunshine hours recevied (SSH) = 52 - LSSHO - LSSHA = SSH (2.8)

2.6.3.3 Statistical analysis

A canonical variance analysis of vegetation and tree canopy characteristics was used to discriminate between L.agilis and L.vivipara and random quadrats. The characters used are listed below.

(i) the dominance classes of species present
(ii) the presence/absence of litter and bare ground
(iii) the percentage cover of pine needles
(iv) the ride width
(v) the total verge width - adjacent (VAT)
 - opposite (VOT)
(vi) the width of undisturbed verge - adjacent (VAU)
 - opposite (VOU)
(vii) the bank height - adjacent (BA)
 - opposite (BO)
(viii) the mean height of the trees - adjacent (THA)
 - opposite (THO)
(ix) the mean density of the trees - adjacent (TDA)
 - opposite (THO)
(x) the SSH

Frequency histograms were used to compare L.agilis, L.vivipara and random distributions of aspect in eight classes, north, north east, east, south east, south, south west, west and north west. A chi squared analysis was used to compare lizard and random distributions.

An ANOVA was used to compare the seasonal number of sunshine hours received by the L.agilis, L.vivipara and random groups.

2.7 ACTIVITY AND BEHAVIOUR IN RELATION TO WEATHER AND SEASON

The seasonal and daily activity and behaviour of L.agilis and L.vivipara was investigated by relating the time of observation of individuals of *L.agilis* or *L.vivipara* to the weather conditions prevalent at that time. Measurements of weather conditions and microclimate were available as described in Section 2.3.

2.7.1 SEASONAL ACTIVITY

Sightings of *L.agilis* and *L.vivipara* on Morden Rides and of *L.agilis* on East Gore were used to construct an overall picture of the seasonal activity patterns of both species. For convenience in dealing with seasonal patterns of behaviour, each month has been divided into four quarters each of seven or eight days. For *L.agilis* males, females and subadults were considered separately, for *L.vivipara* males and females could not be identified without capture so the classes used were adults and subadults.

Weather data was obtained from the following sources:

(i) Hartland Moor Weather Station
- Maximum daily solar radiation per quarter of the month (Wm^{-2})

(ii) Forestry Commission Weather Station Coldharbour
- Maximum temperature per quarter of the month (^{o}C)

2.7.1.1 Emergence from Winter Dormancy

The time of emergence from winter dormancy was defined as that quarter of the month in which the fifth specimen was observed. For *L.vivipara* values are only available for 1982 as Morden Rides were not searched in March 1983.

2.7.1.2 Mating, egg laying and emergence of juveniles

The number of month quarters when male and female *L.agilis* were observed in pairs, mating or laying eggs was recorded in 1982 and 1983. In 1981 only data on egg laying was recorded.

Juvenile emergence was defined as the quarter of the month in which the fifth juvenile was seen, this was recorded for all three seasons for both species.

2.7.1.3 Disappearance into Winter Dormancy

The time of disappearance into winter dormancy was recorded as that quarter of the month after which no more than four individuals were seen. Data was available for males, females and juveniles of *L.agilis* and for adults and juveniles of *L.vivipara*.

2.7.2 DAILY ACTIVITY PATTERNS

2.7.2.1 Morning Emergence

Using the basic weather descriptions recorded whenever an animal was sighted (2.2.3), all the clear sunny mornings on which lizards were searched for were selected. For each day the earliest seen *L.agilis* and the earliest seen *L.vivipara* were noted. For *L.agilis* data from both East Gore and Morden Rides was used but for *L.vivipara* data was obtained only from Morden Rides.

These sightings of time of emergence were plotted against the month and the graphs were then replotted by taking the earliest sighting from each week. A curve was fitted by eye through the points.

Separate graphs were drawn for adults only and for subadults and juveniles together.

2.7.2.2 Activity in Relation to weather and season

2.7.2.2.1 Summer and autumn activity in relation to weather

2.7.2.2.1.1 Summer activity of *L.agilis*

For animals radiotracked on East Gore in the summer of 1982 all days for which weather data was available were used to construct a graph of lizard activity relative to net radiation and temperature at ground level (data available is summarised in Table 2.9). Climate data was collected by taking the nearest available 15 minute reading of net radiation and temperature available for each lizard sighting. The behaviour of each lizard was noted each time its position was recorded.

Data on net radiation and temperature were available for 25 days of radio tracking on East Gore, between June and early August 1982.

2.7.2.2.2 Summer and autumn activity

2.7.2.2.2.1 Repeat walks, Morden Rides 1983

Five rides were used, three of which received the sun in the morning and two in the afternoon/evening. All five rides were known to have populations of both *L.agilis* and *L.vivipara*. Each ride was walked at hourly intervals during the period for which the sun was on it, all *L.agilis* and *L.vivipara* seen were noted.

This process was carried out on two days in July and three in September (Table 2.10).

For each walk the following information was obtained.

(i) the net radiation at 1.5m above the ground (Wm^{-2})

(ii) the air temperature at 1.5m above the ground (^{o}C)

For the net radiation, as many 15 minute readings as were available for each searching period were used to calculate a mean for

Table 2.9 Chapter methods, Activity and behaviour in relation to weather and season.

Summer activity of L.agilis and L.vivipara.

The availability of temperature and net radiation records for times when lizards were radio tracked on East Gore in 1982 and 1983.

Lizard	Temperature	Net Radiation	No. Days
1			5
2			7
4	*		7
5	*		6
6	*	*	2
7	*	*	2
9	*	*	6
10	*	*	3
11	*	*	4
13	*	*	6
15	*	*	4
16	*		5
17	*		7

Table 2.10 Chapter methods, Activity and behaviour in relation to weather and season.

Summer and autumn activity of L.agilis and L.vivipara.

Repeat walks of Ride verge areas. The number of occasions on which each of the Ride verges used was walked in the summer (July) and Autumn (September) of 1983.

	Date				
	July		September		
Ride	26.7.83	27.7.83	7.9.83	8.9.83	9.9.83
3D, north	0	8	7	1	2
8F/G, west	8	6	6	1	2
8D, east	0	4	0	0	0
8Biii, east	6	4	3	0	0
9Bi, east	0	0	4	0	0

that period. Temperature was available on thermograph charts and a value for each period was read directly from these.

The number of L.agilis and L.vivipara observed during each walk was used to calculate a rate of capture.

Graphs were drawn of the net radiation against the temperature for July and September. In each case the areas enclosing all L.agilis, L.vivipara and searching points were drawn and visual comparisons of the areas of each were made.

2.7.2.2.2 Morden Rides, 1982

For the summer (June, July and August) and the autumn (September) of 1982, data was collected on the climatic conditions encountered in the following three circumstances:

a. while searching for lizards, all available weather readings within the time spent searching were noted.

b. for L.agilis sightings, this was done by taking the nearest 15 minute weather record available.

c. for L.vivipara sightings, the methods used were the same as those above (b).

Data on the net radiation (Wm^{-2}) and air temperature at ground level were available.

Separate graphs were drawn of the distribution of the members of each of the classes above relative to net radiation and air temperature at ground level, this enabled a comparison to be made of the climatic conditions ecountered in each case.

2.7.2.2.3 Seasonal Activity in relation to temperature

For each L.agilis sighting on East Gore in 1983 the nearest 15 minute recording of the air temperature at ground level was noted. All temperature readings available within the period spent searching were noted. The distribution of lizard sightings and time spent searching relative to temperature were compared for three seasons, spring (March, April and May), summer (June, July and August) and autumn (September and October).

2.7.3 BEHAVIOUR IN RELATION TO WEATHER AND SEASON

The behaviour of radio tracked lizards (2.4.5) was used to compare

(i) behaviour in relation to net radiation and temperature (at ground level) for spring and summer.

(ii) behaviour in relation to temperature and time of day in spring.

(iii) the frequency of use of a flattened basking posture in relation to time of day in spring and autumn.

2.7.4. THE RELATIONSHIP BETWEEN RATE OF SIGHTING AND WEATHER

For each searching period on East Gore for which weather data were available, the following were calculated:

(i) the rate of sighting of L.agilis (number of sightings per hour)
(ii) the mean air temperature (ground level)
(iii) the mean net radiation

The latter two values were calculated by taking a mean of the temperature and net radiation values available for each searching period.

Regression analysis was used to relate rate of sighting with net radiation and temperature.

2.8 HOME RANGE AND MOVEMENT

2.8.1 HOME RANGE SIZE, COMPARTMENTS

2.8.1.1 Home range size, using all observations

The home range area of all lizards which had been sighted more than five times on East Gore during 1981, 1982 and 1983 was calculated. Sightings were plotted and home ranges were constructed by drawing the minimum convex polygon which enclosed all points. The home range area was calculated by drawing a rectangle which enclosed all the points, calculating the area of the rectangle and the area outside the home range and the deriving the home range by subtraction.

A regression analysis was used to investigate the relationship between the home range area and the number of sightings made of a given individual.

A one way analysis of variance was used to test for differences in area between male and female home ranges.

2.8.1.2 Seasonal shifts in home range area

For two male and two female L.agilis recaptured regularly on East Gore during 1982, graphs were drawn of the cumulative home range size against the number of recaptures. The number of recaptures were plotted relative to the date of the sighting rather than a uniform recapture unit.

2.8.1.3 Short term observations of home range size

The area used by each radio tracked animal was calculated as above (2.8.1.1).

The distance moved between adjacent sightings was also calculated. Since the interval between sightings was not always exactly 90 minutes these values were transformed to distances per hour.

A one way analysis of variance was used to test for significant differences between males and females for home range and the distance moved per hour. A comparison was also made between males radio tracked in the spring with those in the summer.

Mean values of temperature and net radiation were calculated for each period between sightings of radio tracked lizards. Temperature values were available for 11 animals and temperature and net radiation values for seven, followed during the summer of 1982 (Table 2.9).

Regression analyses were used to investigate the relationship between temperature and net radiation and the rate of movement.

2.8.2 HOME RANGE LENGTH, RIDE VERGES

Because of the linear nature of the ride verge habitat, or at least of that part of it searched, home ranges of lizards on rides have been expressed in terms of the greatest distance between all sightings in 1981, 1982 and 1983.

2.9 POPULATION BIOLOGY AND LIZARD GROWTH

2.9.1 POPULATION DENSITY

2.9.1.1 The frequency of sightings of known individuals

The recapture frequency of marked individuals on East Gore and Morden Rides was calculated for all three years data per site. A truncated Poisson distribution was fitted to the data using the formula:

$$E(n_x) = \frac{N\, e^{-\hat{\lambda}}\, \hat{\lambda}^{x}}{(1 - e^{-\hat{\lambda}})\, x!} \qquad x = 1,2\ldots \qquad (2.9)$$

Where:

$\hat{\lambda}$ = estimated mean of the Poisson distribution

N = total population size

n_x = number of individuals caught x times

$\hat{\lambda}$ was estimated from the sample mean of the data;

$$\bar{x} = \sum \frac{fx}{n} \qquad (2.10)$$

Where:

f = frequency of observation of x recaptures

$\hat{\lambda}$ was then read from tables in Cohen (1960) using x.

A chi-squared test was used to compare the observed recapture frequencies with the Poisson dsitribution.

The total population size (N) was estimated from

$$\hat{N} = \frac{\sum x\, n_x}{\hat{\lambda}} \qquad (2.11)$$

2.9.1.2 Estimation of population size from mark-recapture data

Schumacher & Eschmeyer (1943) developed the technique used here in order to estimate the population size of fish in ponds and lakes from a series of repeated mark-recapture samples of that population. A sampling occasion has ben defined here as the time taken to complete one round of all transects (East Gore) or of all rides (Morden Rides). The estimate of population size can be calculated from the following formula:

$$N = \frac{\sum [n^2(m+u)]}{\sum (nm)} \qquad (2.12)$$

Where N = calculated estimate of true population size (N')
n = number of previously marked animals in population for a given sample
m = number of marked animals caught in a given sample
u = number of unmarked animals caught in a given sample

The variance of N (s^2) can be calculated from:

$$s^2 = \frac{1}{k-1} \sum\left(\frac{m^2}{m+u}\right) - \frac{1}{N} \sum (nm) \qquad (2.13)$$

Where k = the number of samples.

The standard error of the population estimate N can then be calculated from:

$$S.E. = N^2 \left(\frac{Ns^2}{\sum (nm)}\right) \qquad (2.14)$$

2.9.2 POPULATION AGE STRUCTURE AND SEX RATIO

2.9.2.1 Population age structure

For both East Gore and Morden Rides the proportion of the population belonging to the adult, sub adult and juvenile age classes was calculated. Comparisons were made between years on each site and between sites. Data from sightings made on transects only was used for both sites, in order to prevent bias as a result of repeated sightings of particular individuals on consecutive days etc..

2.9.3 Population sex ratio

The proportion of males to females in the adult populations of both East Gore and Morden Rides were computed and compared. To prevent bias ratios were compiled using only data from the period after the spring when both sexes were active. Sightings on transects only were used for both sites.

2.9.3 LIZARD GROWTH

2.9.3.1 Growth of juveniles and sub-adults

The rate of growth of juveniles and sub-adults was investigated by drawing a graph of the weight of all juvenile L.agilis captured in 1982 and of sub-adults caught in 1983 against time. Time was divided into weekly units. A similar graph of snout-vent length (SVL) against time was also drawn. A regression analysis was carried out for sub-adult sightings only (i.e. 1983), for this data from East Gore and Morden Rides were combined.

The relative rates of increase of weight and SVL in sub-adults L.agilis were looked at by plotting weight against SVL for all sub-adults seen on East Gore in all years.

2.9.3.2 Adult growth

The weight and SVL of all adult L.agilis captured was known. A regression analysis of weight against SVL was carried out for male and female L.agilis separately. Data from East Gore and Morden Rdies were treated separately.

2.9.3.3 Changes in growth rate with age

Two animals were captured regularly throughout their sub-adult and first adult years. The data from these captures was used to trace the rate of increase in weight and SVL during these two years.

2.9.3.4 Distribution of size classes in the adult population

The frequency distribution of the adult population (males and females separately) between SVL classes was compared for East Gore and Morden Rides.

2.10 BEHAVIOUR AND FEEDING IN RELATION TO SHADE

These laboratory experiments were carried out between January and April 1983.

2.10.1 ANIMALS

Adult L.vivipara were used for all experiments. The animals were caught during the autumn of 1982 and were kept in glass vivaria. Animals were fed ad lib on a mixture of crickets, mealworms and maggots with water always available. No more than three animals were kept in a tank.

Experiments were carried out using groups of six animals (three males and three females) in the arena of which four were used for any one experiment (two males and two females).

2.10.2 ARENA

Experiments were carried out in an arena 2.5m by 2.5m, marked out into 25 identical 50cm x 50cm squares.

Each square contained the following materials, the lay out of which is illustrated in Fig. 2.6 and Plate 2.4a & b.

(i) 2X cardboard shelters, 10cm x 5cm x 1.5cm
(ii) 2X food dishes
(iii) 2X water dishes
(iv) 4X wooden blocks of assorted sizes
(v) hay

The floor of the arena was covered by a layer of sand.

2.10.3 FOOD AND WATER

Mealworm larve (Tenebrio spp) were provided in the arena and all food dishes were kept stocked with the same number of mealworms (four or five per dish). Each day after an experiment the number of mealworms eaten was recorded and the position of the dishes from which they had been eaten noted. Any mealworms eaten were replaced at the end of each day. The mealworms in all dishes were replaced every seven days. Water dishes were refilled every day.

2.10.4 LIGHT

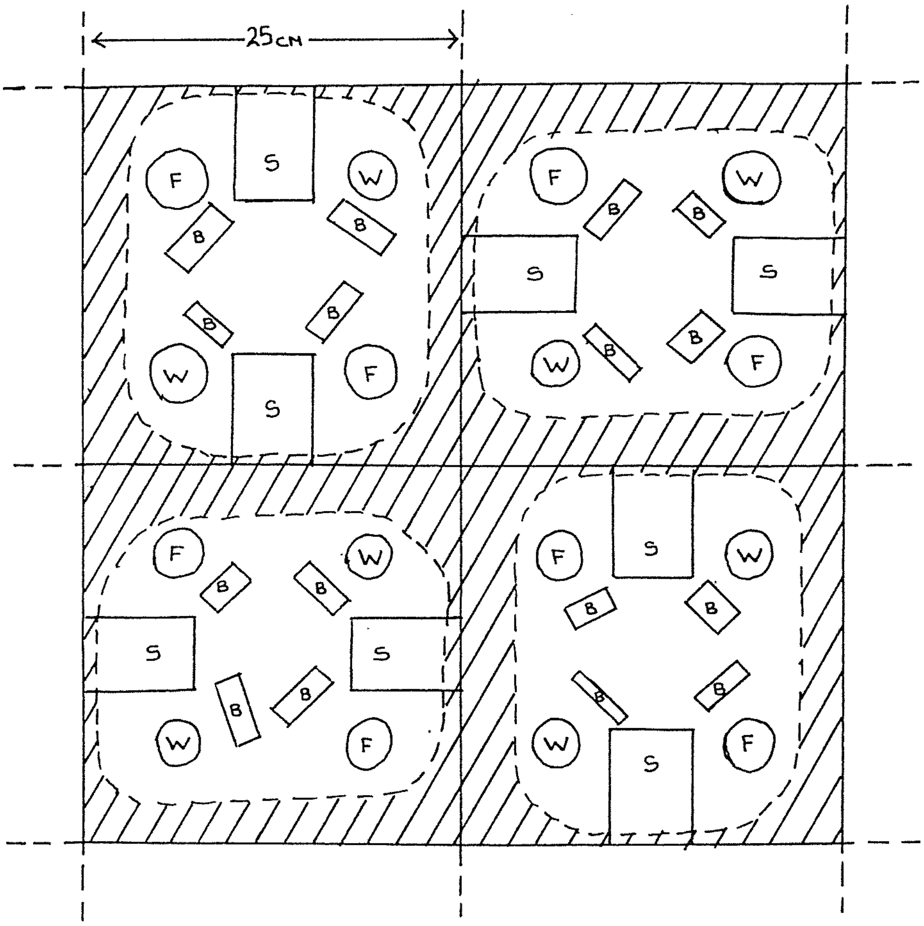
Light was provided via the fluorescent room lights which were on a 15:9, D:L cycle and a series of ten 275W heat lamps which were on a 16:8, D:L cycle, coming on 30 minutes after and going off 30 minutes before the room lights. The heat lamps had satin, diffused light, clear glass fronts and were arranged over the arena as shown in Fig. 2.7. The lamps were suspended from a Dexion frame and were 1.25m above the ground. Each lamp produced a pool of light approximately 90 cm in diameter and ten provided a reasonably even coverage of the arena (Fig. 2.7).

2.10.5 ROOM TEMPERATURE

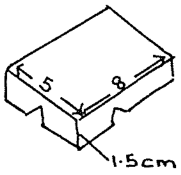
The experimental room was thermostatically heated by a fan heater which was used to keep its temperature above 10^{o}C at night. During the

Fig. 2.6 Chapter methods, Behaviour and feeding in relation to shade.

The arrangement of materials within four of the 25 squares of the arena used in the investigation of the behaviour of *L.vivipara* in relation to the presence of shade in the habitat.



B = wooden blocks
S = cardboard shelter



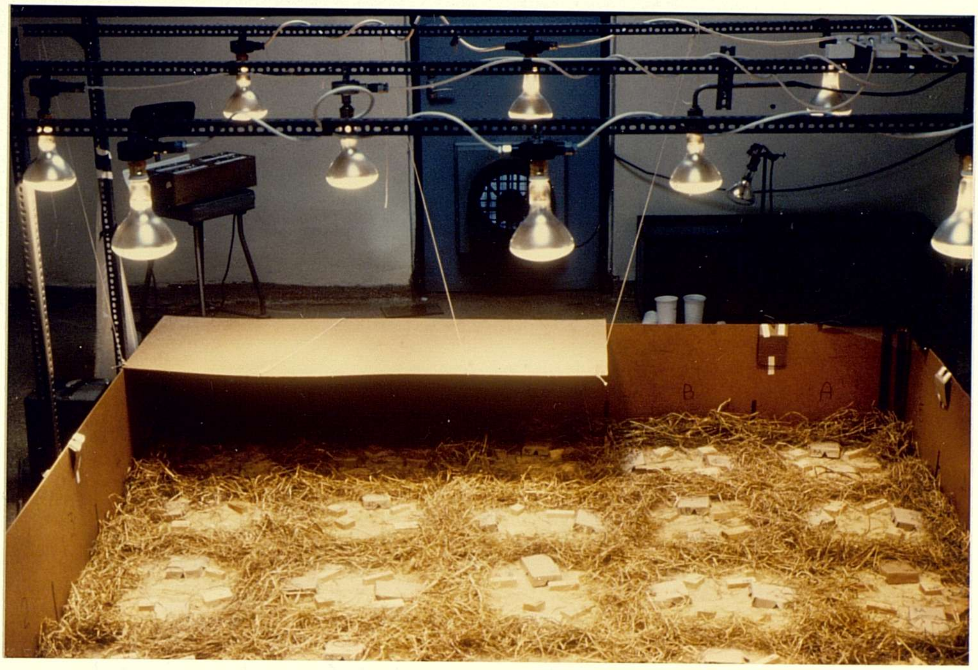
▨ = hay

W = water dishes
F = food dishes

Plate 2.4 Chapter methods, Behaviour and feeding in relation to shade.

The arena used in experiments on the behaviour and feeding of L.vivipara in relation to shade, a. an overall view of the arena and b. a closeup of four squares showing the arrangement of materials in the squares and the presence of shade areas.

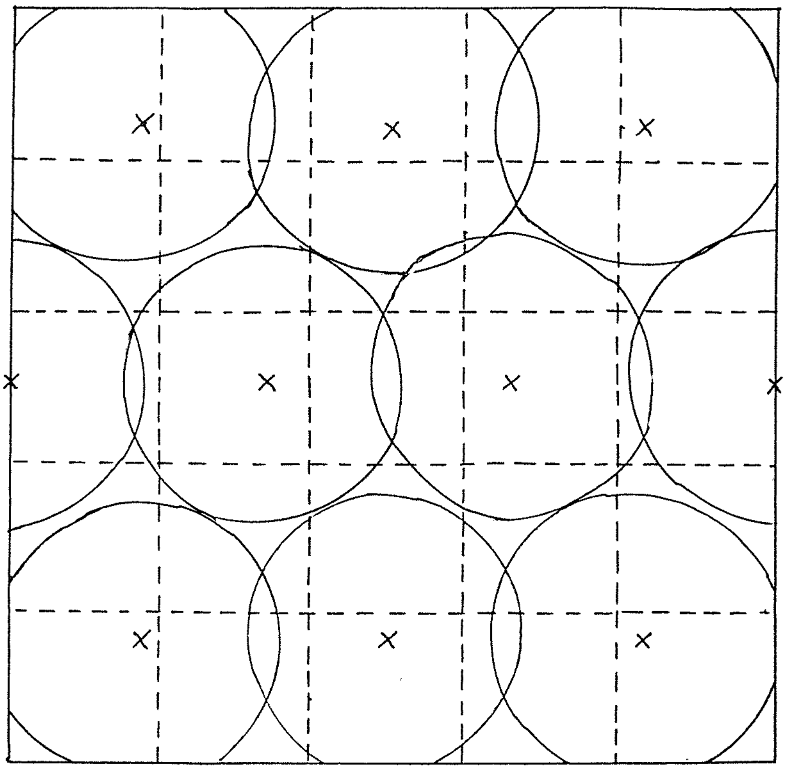
a.



b.

Fig. 2.7 Chapter methods, Behaviour and feeding in relation to shade.

The arrangement of heat lamps over the experimental arean, showing the area covered by the light/heat from each lamp.



× = position of lamp

○ = approximate area covered by the light/heat from each lamp.

day the heater was used only as a fan to help circulate the air above the arena.

2.10.6 SHADING

Pieces of hardboard suspended above the arena were used to produce shade areas within it (Plate 2.4a & b).

2.10.7 EXPERIMENTS

The experiments investigated the effects of varying the amount of shade over the arena on lizard behaviour and feeding.

Three sets of conditions were used, each with two replications:

(i) no shaded squares
(ii) 10 shaded squares
(iii) 15 shaded squares

The position of the shaded squares within the arena was chosen by the random selection of an appropriate number of squares. For the shade treatments the same shading pattern of the squares was used for each of the experimental runs but it was rotated through 180°C for the second run.

Each experiment consisted of three days of data recording preceded by at least two days of the same conditions to allow the animals to become accustomed to them.

2.10.8 DATA RECORDED

On each experimental day the first two males and two females to be active after the start of observations were followed for the rest of the day.

Animals were observed from behind a muslin screen from one hour after the heat lamps came on until one hour before they went off. During this time a 20 channel event recorder was used to record the behaviour of the animals which was divided into the following categories.

(i)	BASKING	-	sitting in the heat of the lamps
(ii)	ACTIVE	-	moving around the arena
(iii)	RESTING	-	not active, under hay or shelters
(iv)	FEEDING	-	from the time first started to feed to time moved on after had eaten mealworm
(v)	DRINKING		

For basking and resting the position of the animal on each occasion was recorded. While lizards were active the route taken was noted. The position of any feeding a drinking was also noted. The event recorder charts enabled the length of each activity period to be calculated.

2.10.9 ANALYSIS OF BEHAVIOUR AND FEEDING

Factorial analysis of variance was used to investigate the differences in Basking, Active and Resting behaviour under the three treatments.

A chi squared analysis was used to investigate differences in the effect of shade on the distribution of dishes used for feeding and drinking.

CHAPTER THREE
HABITAT

3.1 INTRODUCTION

The habitat of an organism or species is the 'range of environments in which a species occurs' (Krebs 1978) or the 'physical part of the community structure in which an organism finds it's home' (De Santo 1978). While a discussion of the habitat of a species deals with only a part of it's total niche or role within the community (Krebs 1978), it is only by reducing the discussion of a niche to one or two dimensions that it is possible to simplify an otherwise hugely complicated concept (MacArthur 1968).

The particular type of habitat within which a species is found must be one that supplies all the basic requirements of life for that species. In the case of a reptile species such as L.agilis, the major requirements can be summarised as being thermoregulation, reproduction, food and shelter. Previous studies have already indicated how these requirements may affect the habitat preferences of L.agilis in open heathland habitats (Corbett & Tamarind 1979, Prestt et al 1979, House & Spellerberg 1983).

Perhaps the central point in the habitat requirements of L.agilis is its need for a substratum suitable for the incubation of its eggs. In both Britain and Europe, L.agilis is restricted to areas with dry, loose and most frequently sandy soils (Liberman & Pokrovskaja 1943, Smith 1951, Simms 1970, Corbett & Tamarind 1979, House & Spellerberg 1980). Sand has a number of properties which would appear to make it an ideal substratum for egg incubation. Sand has a low specific heat and therefore warms more quickly than other soils, also its large particle size allows for both the free drainage of excess water and the movement of water via capillary action when the surface begins to dry out. Thus sand provides a constant microclimate over a wide range of environmental conditions (House & Spellerberg 1980). The frequent association of L.agilis with areas of topographical variation such as banks, ridges or tumuli (Corbett 1980) may also be due to the need for a well drained substratum in which to lay and incubate the eggs. This preference may also be related to the temperature requirements for egg incubation. Work by House & Spellerberg (1980) suggested that female L.agilis chose slope positions for their clutches which potentially received a maximum period of direct solar radiation during the summer. The presence of topographical variation, particularly of banks might provide a greater range of available slopes and therefore a greater number of suitable (or potentially successful) egg laying sites.

In Britain, L.agilis is most frequently found associated with dry heathland communities or their derivatives, except where the vegetation of other communities has a similar structural complexity or morphology to a heathland (Spellerberg & House 1980). It appears that the 'structure' rather than the precise species composition of the vegetation is important for L.agilis. Spellerberg & House (1983) showed that L.agilis was most frequently found associated with vegetation between 3cm and 50 cm high, which included a mosaic type of structure with frequent interfaces between vegetation types and between vegetation and open ground. It has been suggested that this type of vegetation provides areas of open ground suitable for basking closely adjacent to dense vegetation suitable for escape from predators, shelter and foraging, and therefore fulfils the requirements of L.agilis for thermoregulation, food and shelter. A varied topography may contribute to this 'structural' diversity, which in turn may have added advantages such as the presence of an abundant insect fauna and food supply.

These conclusions which have been based on the ecology of L.agilis in open habitats presumably also apply to the species in an afforested habitat. However, within a forest area the presence and close proximity of a large number of trees must also be affecting the suitability of any area as a potential L.agilis habitat. The effect of the surrounding trees is probably different in a Compartment or a Ride verge habitat.

(i) Compartments

In a Compartment where trees are spread fairly uniformly throughout an area, the trees produce a pattern of shade areas throughout the habitat. The density and size of these shade areas being in relation to the density, age and species of the crop itself. This shading may affect the habitat of L.agilis directly by reducing the area of habitat in the sun at any one time. There may also be an indirect affect as the presence of a canopy cover reduces the light intensity at ground level and this reduction eventually causes the deterioration of the vegetation on the ground (Hill 1979). The presence of trees may also produce changes in the microclimate of an area (Hocker 1979).

(ii) Ride verges

In a Ride verge habitat the trees are present as stands adjacent to or opposite to the L.agilis habitat (i.e. the Ride verge) which is itself largely clear of trees. The shade produced by these surrounding trees does not produce a pattern of shade throughout the habitat as in Compartments. Rather the trees block the sun out completely and so reduce the total number of sunshine hours received by an area per day. Depending on the height of the surrounding trees, and on the aspect and width of the ride, an area of Ride verge may be shaded for a period during the morning and/or the afternoon. In an extreme case of two very tall stands of trees with a narrow ride between them the number of sunshine hours received per day at ground level may be very low indeed.

Hence it is possible that by reducing the area of the ground receiving solar radiation at any one time, or by reducing the number of hours per day for which solar radiation is available at ground level, the surrounding trees may be capable of having a significant effect on the habitat use of L.agilis. This effect might act directly on the thermoregulatory capacity of the species or indirectly via the accelerated deterioration of the vegetation at ground level. Whichever is the case it is clear that the forest heathland community is a more complex habitat than an area of open heathland.

The aim of the work described in this chapter was to investigate the relative importance of as many characteristics of the forest heathland habitat as possible, in relation to the suitability of that habitat for use by L.agilis. Because of the obvious differences in the shading produced by trees in Compartment and Ride verge habitats, these have been dealt with separately and hence the chapter divides into two main parts. Section I deals with 'Compartments and similar areas' and Section II deals with 'Plantation Ride verges'.

(i) HABITAT USE WITHIN COMPARTMENTS AND SIMILAR AREAS

The study areas used have been described in Chapter Two, Section 2.1. The Compartment study areas used were Morden Site and East Gore. Morden Site was a small area of young, healthy plantation which represented the epitomie of the habitat to be assessed (Section 2.1.1). East Gore was a less uniform site including some open areas. However, the Main Slope of East Gore (see Section 2.1.2.1) was covered by a failed crop which produced a mixture of degrees of canopy cover and of ground level vegetation type and deterioration, therefore the response of L.agilis to these factors could be assessed although the area was not a typical Compartment.

Two methods were used to assess the habitat preferences of

L.agilis within Compartments, they can be viewed as assessing habitat use on two different scales.

a. LIZARD VERSUS RANDOM QUADRATS

Methods : 2.6.1
Results : 3.2

These experiments could be said to look at the 'small scale' habitat use of L.agilis. That is, they looked at the habitat preferences of L.agilis within a habitat, such as a dry heathland, which was itself known to be suitable as a whole for use by L.agilis. The aim was to identify specific characteristics within a generally favourable habitat which were associated with the presence of L.agilis. The method was also well suited to assessing the distribution of L.agilis relative to canopy cover and to the presence of trees.

The East Gore study area was easily divided into areas of similar vegetation types (i.e. wet/dry heathland etc., see Section 2.1.2). As the aim of these experiments was to look at the habitat preferences of L.agilis within a vegetation type, East Gore was sub-divided into vegetation types and a separate set of samples was taken in each of these areas (Main Slope, Pond Bank and Hedge).

b. HABITAT SURVEY

Methods : 2.6.2
Results : 3.3

A survey was done of vegetation type, tree height and tree density across the whole of East Gore. The distribution of L.agilis relative to these 'large scale' characteristics such as wet or dry heathland was investigated.

These experiments also gave an opportunity to compare the seasonal distribution of L.agilis relative to vegetation types and tree density or height.

(ii) HABITAT USE ALONG PLANTATION RIDE VERGES

Methods : 2.6.3
Results : 3.4

The Morden Rides study area (Section 2.1.3) was used to assess the habitat use of L.agilis and L.vivipara along plantation Ride verges. The Morden Rides area included various types of Ride verge, in terms of ride width, bank height, verge width and vegetation type etc., and also in terms of the age, density and height of the adjacent and opposite tree stands. A survey was carried out in 1982/83 (Section 2.6.3.1) in which as many ride/Ride verge/plantation characteristics as possible were assessed. A canonical variate analysis was then used to compare the distribution of lizard and random points relative to the measured ride characteristics. Each year of data (1981/1982 & 1983) was analysed separately.

The effect of two ride characteristics on habitat use by L.agilis were analysed separately, these were the aspect of the ride and the seasonal number of sunshine hours received by a ride.

For the Ride Verge habitat a comparison was made between the habitat preferences of L.agilis and those of L.vivipara. It was hoped that a comparison between the two species might help to shed some light on the ecological/biological mechanisms responsible for any differences observed between the two species.

I HABITAT USE WITHIN COMPARTMENTS AND SIMILAR AREAS

3.2 LIZARD VS. RANDOM QUADRATS

ANALYTICAL METHODS

3.2.1 INTRODUCTION

In these experiments a comparison was made between points associated with sightings of L.agilis (Lizard points) and points randomly distributed throughout the study area (Random points). For each lizard or random point as many characteristics of the vegetation, topography and canopy cover of the surrounding area as were thought to be potentially relevant were assessed. The methods used to collect this data are detailed in Chapter Two, Section 2.6.1.

Four study areas were used in these experiments, Morden Site (Section 2.1.1) and three sub-divisions of the East Gore study area, namely Main Slope (2.1.2.1), Pond Bank (2.1.2.3) and Hedge (2.1.2.4). A summary of the variables measured for Morden Site can be found in Section 2.6.1.1.5, and for the East Gore areas in Section 2.6.1.2.

A comparison was made between the distribution of the lizard and random points relative to the variables measured on each study area. A Canonical variate analysis (CVA) was used to make this comparison (see Section 3.2.2). The CVA produces a summary of those variables which most strongly discriminate between the two groups. These results are not directly comparable between study areas, but must be interpreted in relation to the habitat available in each particular area. The data from all sites may be combined to describe overall trends in the habitat use of L.agilis but the results per se cannot simply be combined and interpreted en masse.

Data from the set of random quadrats have been used to give an indication of the overall nature of the vegetation of each study area. The CVA provides a table of the within group correlations between the measured variables which was also used to characterise the state of the vegetation on each study area ($r>0.50$ was used as an indication of a significant correlation between two variables). The sub-divisions of the open ground category (i.e. Open/litter, Open/moss&lichen and Open/bare ground) were omitted from this part of the analysis as they served only to confuse the issue.

3.2.2 CANONICAL VARIATE ANALYSIS (CVA)

The purpose of canonical variate analysis is to examine how far it is possible to separate the members of two or more groups on the basis of a number of observations made on each group. Canonical variate analysis is an extension of ordinary analysis of variance for multivariate observations.

(i) CVA for two groups

e.g. Morden Site or East Gore

The analysis produces a Latent Vector or Loading for each variable, variables with the highest positive and negative values of the latent vector contributing most to the separation between the two groups. These loadings are then used to produce a canonical variate score for each quadrat or unit. These scores relate to the position of the quadrat along a single axis, a high positive or negative value denoting a particular affinity to the lizard or random groups. The two groups can then be illustrated as a histogram plot of the distribution of quadrats along a horizontal axis, thus demonstrating the degree of overlap between the two groups.

The canonical variate scores can be used to 're-allocate' each quadrat to one of the groups. Estimates of the probability of correct re-allocation (i.e. to the original group), can be expressed as the percentage of cases correctly classified.

The analysis also produces a canonical variate mean for each group and the significance of the difference between these can be tested using an F-test. A probability level of 5% has been used as the limit for indications of significance.

(ii) CVA for three groups

e.g. Morden Rides

When there are three groups to be separated, canonical variate analysis produces two sets of loadings for each variable, and from this two canonical variate scores can be derived for each quadrat or unit.

By plotting the canonical variate scores for each group relative to the First and Second canonical axes it is possible to illustrate graphically how well the three groups are separated, and on which axis the separation is greatest. Because of the large number of samples used on Morden Rides (and therefore the large number of canonical variate scores) only the maximum areas enclosed by each group have been drawn here.

As with two groups the analysis provides canonical variate means for each group which can be used with an F-test to test for the significance of the differences between the groups.

RESULTS

3.2.3 MORDEN SITE

Methods : 2.6.1.1

The canonical variate means of the L.agilis and random groups were significantly different (Table 3.1a), 87% of cases were correctly classified (Fig. 3.1).

Variables strongly associated with L.agilis quadrats were the cover of open ground covered by litter and by moss&lichens (Table 3.2a). Variables associated with the random group were the cover of Open ground (of any type) and the Diameter at Breast Height of the trees (Table 3.2a).

From the random survey the vegetation of Morden Site was very much dominated by C.vulgaris with a scattering of E.cinerea, U.minor, M.caerulea and P.aquilinum. Overall, 16% of the area was under an aerial cover of Pine (Table 3.4) and the mean vegetation height was 36 cm (Table 3.3). Some of the within group correlations found (Table 3.5) might be 'expected', such as the negative correlation between the cover of open ground and vegetation height, or the positive correlation between the height and the DBH of the trees. The only significant correlation between tree characteristics and plant growth was a negative correlation between tree density and the cover of P.aquilinum.

3.2.4 EAST GORE, MAIN SLOPE

Methods : 2.6.1.2.1

The canonical variate means of L.agilis and random quadrats were significantly different (Table 3.1) and 85% of cases were correctly classified (Fig. 3.2a).

The variables most strongly associated with L.agilis quadrats were the cover of Open ground and of M.caerulea and the tree height. Variables strongly associated with the random group were the cover of

Table 3.1 Habitat use in compartments and similar areas.
Lizard vs. Random quadrats.

Canonical variate means for <u>L.agilis</u> (lizard) and random groups and F-tests for significant differences between the two groups on each site.

	<u>L.agilis</u>	Random	F	DF1	DF2	P
a. Morden Site	0.9474	-1.3432	2.1172	22	36	<0.005
b. East Gore, Main Slope	0.9478	-1.2890	3.0500	17	41	<0.001
c. East Gore, Pond Bank	-1.2153	1.3611	2.7504	20	32	<0.001
d. East Gore, Hedge	-0.8487	0.7129	1.0419	17	28	>0.05

Fig. 3.1 Habitat use within Compartments and similar areas. Lizard vs. random quadrats, Morden Site.

The frequency distribution of canonical variate scores relative to the first Canonical Axis for the L.agilis (▨) and random (☐) groups.

▲ = canonical variate means.

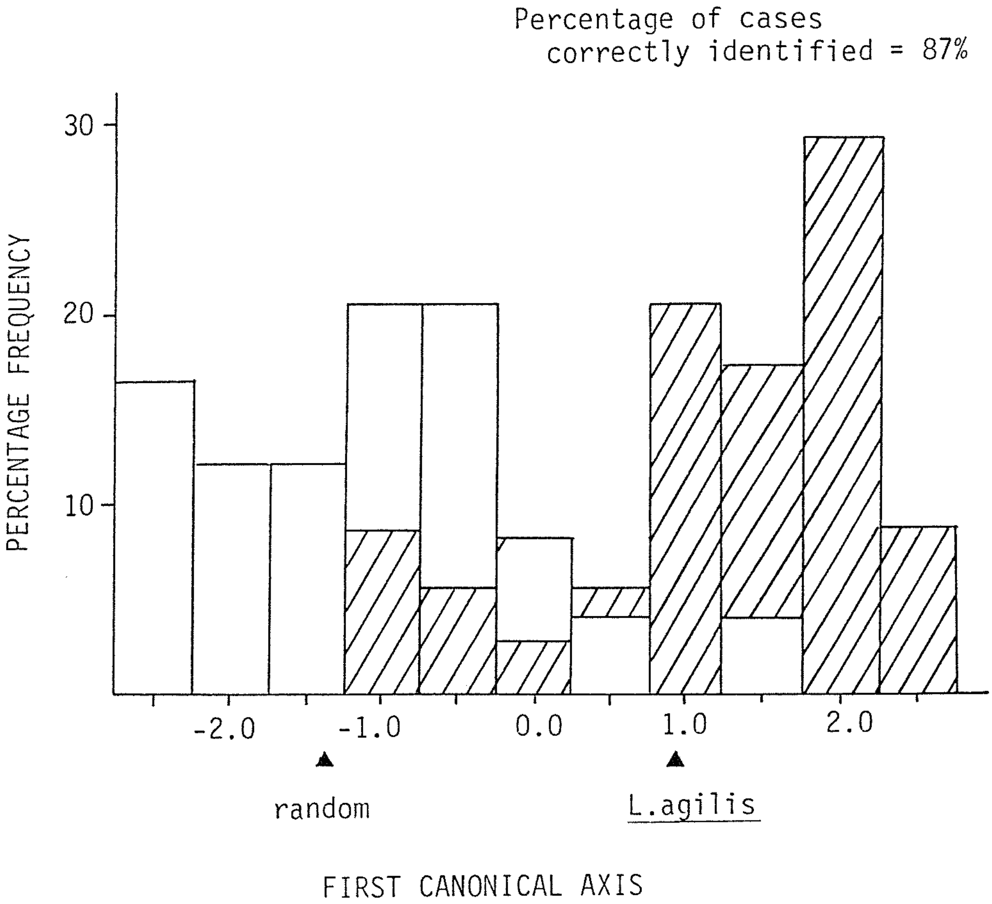


Table 3.2 Habitat use in compartments and similar areas.
Lizard vs. random quadrats.

Variables strongly associated with *L.agilis* (lizard) or random quadrats from Canonical variate analysis

	L.agilis	random
a. Morden Site	*E.cinerea* Open/litter Open/moss&lichen	Open ground Tree DBH
b. East Gore, Main Slope	Open ground Tree height *M.caerulea*	Open/litter Open/bare ground No. plant species
c. East Gore, Pond Bank	Tree height Open/bare ground No. plant species Tree height	Tree DBH Open ground Dead ericaceous species
d. East Gore, Hedge	No comparison can be made as the lizard and random groups are not significantly different.	

Table 3.3 Habitat use in compartments and similar areas. Lizard vs. random quadrats.

The overall vegetation characteristics (% cover plant species, no. plant species and vegetation height, standard deviation and structure) for each study area. From random quadrats only.

% cover	Morden Site	Main Slope	Pond Bank	Hedge
H	70.9	55.3	8.3	0.4
EC	0.9	11.9	0.0	0.3
MO	0.3	0.1	69.3	0.3
GRA	0.0	0.0	7.1	68.9
BR	0.4	13.6	2.2	1.5
UM	6.4	0.0	0.0	0.0
OPEN	3.5	16.7	6.7	29.2
/litter	1.6	16.6	3.9	15.3
/moss&lichen	1.9	9.0	3.4	0.0
/bare ground	1.8	0.0	0.6	4.6
JUNC	0.0	0.0	2.4	0.0
UE	0.0	0.0	1.8	34.6
RUBUS	0.0	0.0	1.8	9.7
ET	0.0	0.0	2.8	0.0
ANNUALS	0.0	0.0	0.0	0.0
DEAD	13.9	15.2	1.4	0.2
NSP	3.7	4.0	3.7	9.1
VEG. HEIGHT	35.9	24.7	40.8	13.4
VEG. STANDARD DEVIATION	14.0	17.4	18.4	17.3
VEG. STRUCTURE	24.0	31.6	26.0	22.7

Table 3.4 Habitat use in compartments and similar areas. Lizard vs. random quadrats.

The overall tree characteristics (aerial cover of pine, tree height, density and DBH, tree canopy cover and number of sunshine hours from hemispherical photographs) for all study areas. From random quadrats only.

	Morden Site	Main Slope	Pond Bank	Hedge
Pine	16.4	42.4	0.0	0.0
Tree height (m)	2.6	3.1	1.4	0.0
Tree DBH (cm)	4.4	4.4	2.4	0.0
Tree density (/100 m^2)	35.7	33.4	3.8	0.0
Diffuse light factor	72.2	-	-	-
Direct light factor - July	52.9	-	-	-
Direct light factor - March	39.8	-	-	-

Table 3.5 Habitat use in compartments and similar areas.
Lizard vs. random quadrats.

Strong within groups correlations between measured variables (from Canonical variate analysis).
See Table 2.5 for plant species name abbreviations.

a. Morden Site

Variables			Correlation
H	:	DEAD	-0.576
	:	OPEN GROUND	-0.682
	:	VEG. HEIGHT	0.514
BR	:	GRA	0.535
	:	TREE DENSITY	-0.563
OPEN	:	VEG. HEIGHT	-0.664
TREE HEIGHT	:	TREE DBH	0.802

b. East Gore, Main Slope

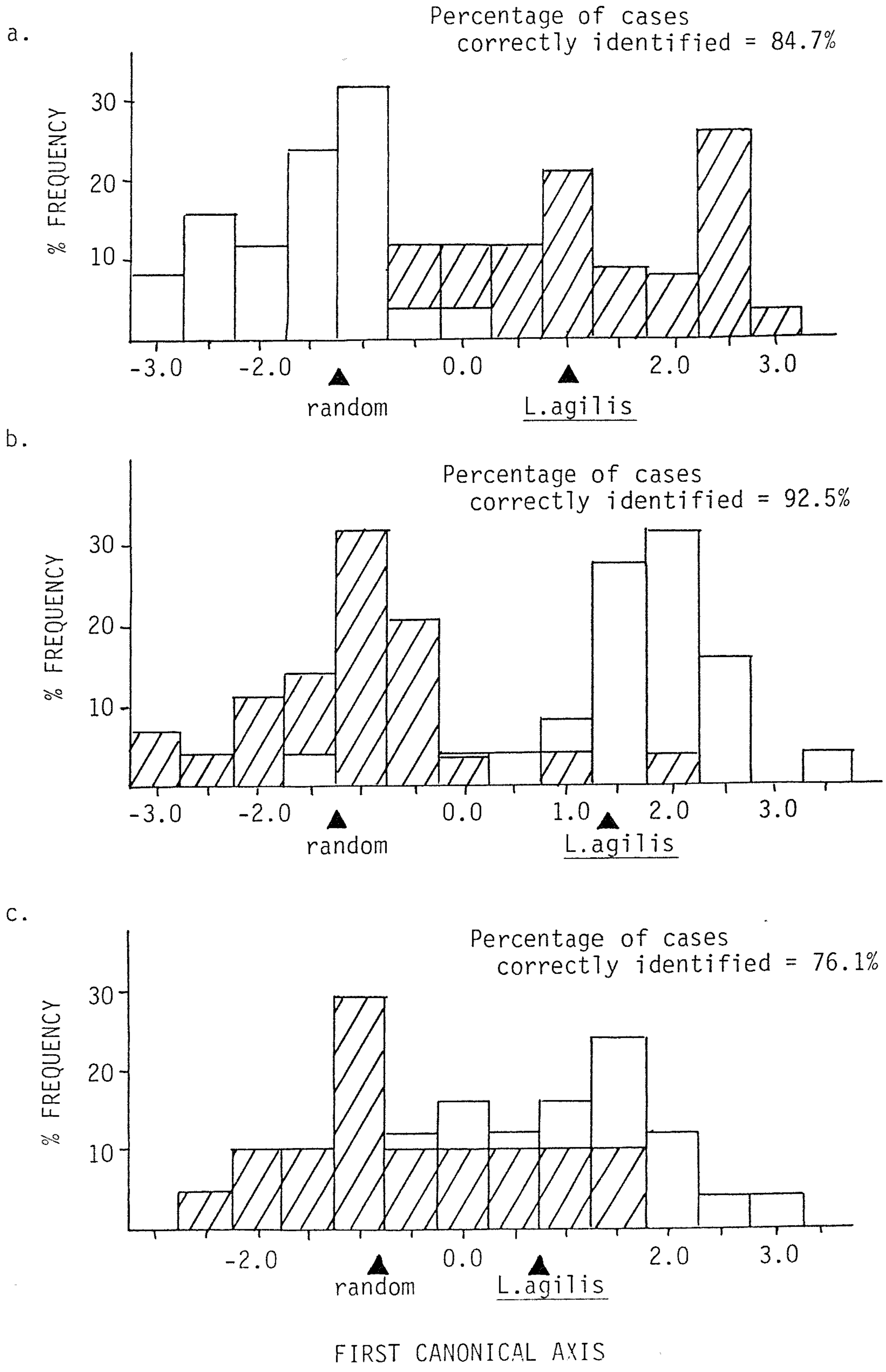
H	:	OPEN	-0.782
	:	VEG. HEIGHT	0.637
	:	VEG. STRUCTURE	-0.546
OPEN	:	VEG. HEIGHT	-0.738
(TREE DENSITY	:	DEAD	0.485)

c. East Gore, Pond Bank

MO	:	GRA	-0.676
	:	NSP	-0.670
GRA	:	NSP	0.615
JUNC	:	VEG. ST. DEV.	0.512
TREE DENSITY	:	DEAD	0.782
	:	PINE	0.566
	:	TREE HEIGHT	0.695
	:	TREE DBH	0.553
	:	VEG. STRUCTURE	0.504
PINE	:	DEAD	0.596
UE	:	VEG. STRUCTURE	0.536
VEG. HEIGHT	:	VEG. STRUCTURE	-0.551
TREE HEIGHT	:	TREE DBH	0.951

Fig. 3.2 Habitat use within Compartments and similar areas. Lizard vs. random quadrats, East Gore.

The frequency distribution of canonical variate scores relative to the First Canonical Axis for a. Main slope b. Pond bank and c. Hedge. Notation as for Fig. 3.1.



Open/litter and of Open/bare ground and the number of plant species present (Table 3.2b).

As for Morden Site, the Main Slope area was predominately covered by C.vulgaris but included a considerably larger area of open ground and E.cinerea than was found at Morden Site. There was also a considerable cover of P.aquilinum (Table 3.3). The mean vegetation height for Main Slope was 25cm. As for Morden Site, the cover of C.vulgaris was negatively correlated with the vegetation height and the cover of C.vulgaris was also negatively correlated with vegetation structure (Table 3.5). The cover of dead ericaceous species was positively correlated with the tree density (Table 3.5).

3.2.5 EAST GORE, POND BANK

Methods : 2.6.1.2.2

The random and L.agilis group canonical variate means were significantly different (Table 3.1c) and 92.5% of cases were correctly classified (Fig. 3.2b).

The variables strongly associated with L.agilis quadrats were the cover of Open/bare ground, the number of plant species and the tree height. Tree DBH and the cover of Open ground and of dead ericaceous species were associated with random quadrats (Table 3.2c).

The vegetation of the Pond Bank was entirely different to that of the Morden Site or the Main Slope of East Gore. The predominant plant species was M.caerulea with C.vulgaris, P.aquilinum, Juncus effusus, U.europaeus, Rubus spp, E.tetralix and grass species also present (Table 3.3). The vegetation height was somewhat greater than that on Morden Site or Main Slope (41cm, Table 3.3c). The tree density on the Pond Bank was approximately one tenth of that on either Morden Site or Main Slope (Table 3.4).

A number of significant within group correlations were found on the Pond Bank study area (Table 3.5). The cover of M.caerulea was negatively correlated with both the cover of grass species and the number of plant species present, the cover of grass species however was positively correlated with the number of plant species present. The density of the trees was positively correlated with both tree height and tree DBH and also with the ground cover of dead ericaceous plant species and the cover of aerial pine. The cover of U.europaeus was positively correlated with the structure of the vegetation.

3.2.6 EAST GORE, HEDGE

Methods : 2.6.1.2.2

The canonical variate means for the L.agilis and the random groups were not significantly different (Table 3.1d) and the two groups were not clearly separated relative to the first canonical axis (Fig. 3.2c).

Since the two groups were not clearly distinguishable relative to the variables measured it is not possible to draw any conclusions concerning the habitat preferences of L.agilis in the Hedge habitat.

3.3 COMPARTMENT HABITAT SURVEY

ANALYTICAL METHODS

3.3.1 INTRODUCTION

The habitat survey of East Gore was based on a comparison between the distribution of lizard (L.agilis) sightings with that of a number of randomly allocated points, within the area which was searched for L.agilis. The comparison was made relative to 'large scale' changes in vegetation type at ground level and to tree canopy cover.

A survey of the habitat available on East Gore was made in 1983 (see Section 2.6.2). For the vegetation at ground level this was carried out in two stages. Firstly the entire area was divided into regions of similar vegetation (termed plant species associations, see Section 2.6.2.1). The accuracy of this visual assessment of plant species associations was then checked by taking quadrats within each of the main plant species associations previously defined. This was done in order to see if an area described as belonging to one plant species association actually consisted of a reasonably homogeneous vegetation in terms of plant species cover (see Section 3.3.2).

Once the accuracy of the visual assessment was established, each plant species association was assigned to a Habitat type, this produced seven classes of habitat within East Gore (see Section 3.3.2; Table 3.9).

For the purposes of carrying out this survey the East Gore study area was divided up by a 5m x 5m grid (Section 2.6.2.1). As this survey was looking at 'large scale' habitat use by L.agilis, each L.agilis sighting was assigned to the grid square in which it occurred and the square was used as a unit of habitat measurement. For the random points a number of squares were randomly selected from those searched (Section 2.6.2.2).

The frequency with which each Habitat type occurred in L.agilis and random squares was calculated and frequency histograms and chi squared distributions were used to make comparisons between lizard and random distributions.

For each square the density and mean height of the trees present was known and a comparison was also made between lizard and random distributions with respect to tree height and density (see Section 2.6.2.2).

3.3.2 ASSESSMENT OF PLANT SPECIES ASSOCIATIONS AND HABITAT TYPES

Methods : 2.6.2.1

The major plant species associations found during the survey of East Gore could be divided into ten 'dominance classes' (Table 3.6). The 27 plant species associations which covered the greatest area were selected and 10 2m x 2m random quadrats were carried out within the area covered by each. The area covered by each plant species association was drawn out onto a grid map of the area and 10 sets of random co-ordinates within the area were chosen. In some cases two plant species associations were combined when they were considered to be sufficiently similar in growth pattern and morphology e.g. H+ET and H+EC and where only after combination was their area large enough to enable sub-sampling (Table 3.6).

The percentage cover of each plant species was visually assessed for each quadrat. A total of 287 quadrats were completed. On a species association level the percentage cover values are variable, with the coefficient of variation exceeding 10% for 38 out of the 62 cover estimates (Table 3.7). However, for dominance classes taken as a whole the estimates are less variable, with only one having a coefficient of variation greater than 10% (Table 3.8), so that on a gross level the dominance scale was providing a realistic view of the abundance of the principal species present.

The plant species associations were grouped according to habitat types, producing seven major groups. The allocation of species association to the habitat types is shown in Table 3.9.

3.3.2 ASSESSMENT OF LIZARD AND RANDOM DISTRIBUTIONS IN RELATION TO VEGETATION TYPES AND TREE HEIGHT AND DENSITY

The number of occasions on which each habitat type was associated with lizard and random squares was assessed as described in 2.6.2.2.

The frequency distributions of lizard sightings were compared with the random distribution for each year. The lizard sightings were divided into the following categories.

Table 3.6 Habitat use within compartments and similar areas.
Habitat Survey, East Gore.
Summary of major plant associations in the survey of East Gore. The associations listed are those within which quadrats were assessed.
Brackets indicate that associations have been grouped.
See Table 2.5 for plant species name abbreviations.

						No. Quadrats
1. One species dominant	OPEN	GRA	H	MO		70
2. One species dominant plus one other	MO+ET MO+H	H+EC H+ET H+DH	H+OPEN UE+GRA	GRA+OPEN OPEN+BR		60
3. One species dominant plus two others	H+EC+OPEN H+ET+OPEN	OPEN+BR+BP	H+EC+BR	MO+EC+OPEN		40
4. One species dominant plus three others						0
5. Two species co-dominant	H±ET H±EC	H±OPEN EC±OPEN	MO±EC	MO±ET	BR±OPEN	47
6. Two species co-dominant plus one other	MO±ET+H MO±H+ET H±DH+BR	OPEN±BR+H OPEN±BR+DH	H±OPEN+DH H±OEPN+EC	BR±EC+H BR±H+DH		40
7. Two species co-dominant plus two others						0
8. Three species co-dominant						0
	H±EC±OPEN H±DH±OPEN	H±ET±MO	H±BR±OPEN			30
9. Three species co-dominant plus one other						0
10. Four species co-dominant						0

Table 3.7 Habitat use within compartments and similar areas.
Habitat survey, East Gore.
Results of sub-sampling of plant species associations for the percentage cover of plant species present.
Results given per plant species association.

1. One species dominant

		Mean	SE	CV	N
	H	91.5	1.88	2.05	10
	MO	91.8	2.36	2.57	20
	OPEN	95.4	1.24	1.30	20
	GRA	93.3	1.71	1.83	20

2. One species dominant plus one other

		Mean	SE	CV	N
H+OPEN	H	55.1	5.64	10.23	10
	OPEN	36.5	5.38	14.74	
MO+H, MO+ET	MO	72.7	5.82	8.00	10
	H,ET	21.4	4.68	21.87	
UE+GRA	UE	83.3	4.64	5.57	10
	GRA	61.0	7.10	11.64	
OPEN+BR	OPEN	89.8	2.50	4.10	10
	BR	32.0	3.89	12.16	
GRA+OPEN	GRA	77.5	2.28	2.94	10
	OPEN	22.0	2.72	12.36	
H+EC, H+ET, H+DH	H	85.0	4.52	5.31	10
	EC,ET,DH	27.1	4.84	17.86	

3. One species dominant plus two others

		Mean	SE	CV	N
MO+OPEN+EC	MO	68.9	6.86	9.96	10
	OPEN	12.2	2.28	18.69	
	EC	16.4	3.38	20.61	
OPEN+BR+BRP	OPEN	91.9	1.83	2.00	10
	BR	13.5	2.59	19.19	
	BRP	21.7	3.64	16.77	
H+EC+OPEN, H+ET+OPEN	H	60.5	4.24	7.01	10
	OPEN	25.2	3.86	15.32	
	ET,EC	21.6	4.11	19.03	
H+EC+BR	H	76.1	3.16	4.15	10
	EC	15.2	4.40	28.95	
	BR	28.7	5.12	17.84	

Table 3.7 (cont. 1)

		Mean	SE	CV	N
4. <u>Two species co-dominant</u>					
H±ET, H±EC	H	73.8	4.24	5.74	10
	ET,EC	53.7	6.32	11.77	
OPEN±H, OPEN±EC	OPEN	41.7	3.51	8.40	10
	H,EC	43.9	5.69	12.96	
BR±OPEN	BR	59.5	5.28	8.87	10
	OPEN	68.0	7.30	10.74	
MO±EC	MO	42.8	8.06	18.84	10
	EC	39.7	7.56	19.04	
MO±ET	MO	46.5	6.73	14.48	9
	EC	25.5	6.63	26.00	
5. <u>Two species co-dominant plus one other</u>					
MO±ET+H, MO±H+ET	MO	47.0	4.46	9.50	10
	±ET,H	21.7	7.17	33.05	
	+H,ET	17.5	6.51	37.10	
OPEN±BR+H OPEN±BR+DH	OPEN	62.0	5.44	8.77	10
	BR	57.6	5.41	9.34	
	H,DH	19.0	4.09	21.54	
H±DH+BR	H	47.6	4.46	9.37	10
	DH	45.2	4.99	11.05	
	BR	14.9	3.76	25.30	
OPEN±H+EC OPEN±H+DH	OPEN	50.0	2.75	5.50	10
	H	39.0	2.91	7.46	
	EC,DH	13.2	2.34	17.73	
BR±EC+H BR±H+DH	BR	36.0	5.25	14.58	10
	EC,H	39.5	4.68	11.85	
	H,DH	18.7	2.81	15.05	
6. <u>Three species co-dominant</u>					
H±OPEN±EC H±OPEN±DH	H	45.0	6.61	14.69	10
	OPEN	31.4	5.15	16.42	
	EC,DH	31.2	3.86	12.37	
H±ET±MO	H	36.5	6.51	17.80	10
	ET	37.8	4.46	11.80	
	MO	41.7	3.89	9.33	
H±BR±OPEN	H	39.5	5.82	14.73	10
	BR	45.0	5.53	12.30	
	OPEN	36.0	4.08	11.33	

Table 3.8 Habitat use within compartments and similar areas. Habitat survey, East Gore.

Results of sub-sampling of plant species associations for the percentage cover of species present. Results are given as means for each of the major groups.

	Mean	S.E.	C.V.	N
1. <u>One species dominant on own</u>				
Dominant species	93.2	0.94	1.00	70
2. <u>One species dominant plus one other</u>				
Dominant species	77.9	2.39	3.07	60
Second species	34.2	2.59	7.57	60
3. <u>One species dominant plus two others</u>				
Dominant species	74.5	2.83	3.80	40
Second species	19.3	1.42	7.34	80
4. <u>Two species co-dominant</u>				
Co-dominant species	47.9	2.40	5.01	49
5. <u>Two species co-dominant plus one other</u>				
Co-dominant species	44.5	1.84	4.14	100
Second species	16.1	1.78	11.0	50
6. <u>Three species co-dominant</u>				
Co-dominant species	37.4	1.77	4.73	90

Table 3.9 Habitat use within Compartments and similar areas.
Habitat survey, East Gore.

Classification of plant species associations into habitat types.

1. MO dominant (MO)

MO
MO±J
MO+
MO±ET

2. DAMP HEATH (DAMP)

MO±GRA
MO±UE
MO±H
ET
ET+
ET±H
ET±H±MO
ET±H±OPEN
ET±H+OPEN
MO±H±OPEN

3. DRY HEATH (DRY)

H
H+
H±EC
H±DH
EC
EC+
EC±OPEN
EC±BR
H±OPEN
H±BR
H±EC±BR
H±OPEN±BR
H±EC±OPEN
H±DH±OPEN

4. OPEN/BR/BRP DOMINANT (OPEN)

OPEN±BR
OPEN±BRP
BR
BR+
BR±BRP
BRP
BRP+
BR±BRP±OPEN
OPEN
OPEN+

5. RIDE (RIDE)

RIDE
PLOUGH
FIELD

6. GRASS (GRA)

GRA
GRA+
GRA±OPEN
GRA± A ±BR
MO±GRA

7. UE/R DOMINANT (UE)

UE
UE+
R
R+
UE±R
UE±GRA
UE±BR
R±GRA
UE±OPEN
R± A ±GRA

(i) Spring (March, April and May)
(ii) Summer (June, July and August)
(iii) Autumn (September and October)
(iv) Juveniles only
(v) All observations

The mean height and density of trees in all lizard and random squares were calculated and used to produce frequency distributions for both groups relative to tree height and density classes. Chi-square distributions were used to test for the presence of significant differences between lizard and random distributions.

RESULTS

3.3.3 DISTRIBUTION IN RELATION TO HABITAT TYPE

Methods : 2.6.2

In 1981, the distribution of L.agilis sightings relative to habitat type was significantly different from the random distribution in the summer and autumn and for the season taken as a whole. There was no significant difference between the L.agilis and random distributions of juveniles relative to habitat type in 1981 (Table 3.10). In the Summer and Autumn (Fig. 3.3a & b) L.agilis was found associated with the Grass, UE/R and Ride habitat types more frequently and the Open habitat type less frequently than expected from the random distribution. This pattern was repeated for the year as a whole (Fig. 3.3d). For Juveniles only (Fig. 3.3c) the Dry vegetation type occurred more frequently in the L.agilis group than expected from the random distribution.

In 1982, the distribution of L.agilis relative to habitat type was significantly different from the random distribution in the spring and summer and for the year as a whole (Fig. 3.4; Table 3.10). In the spring, the distribution of L.agilis was significantly different from random if data from March and April only was used, if May was included in the analysis the distribution of L.agilis was not different from random (Fig. 3.4a, Table 3.10). In the spring of 1983, the distribution of L.agilis relative to habitat type (using data from March, April and May) was similar to that found in 1982 when using data from March and April only (Fig. 3.5).

In 1982 and 1983 the distribution of L.agilis relative to habitat type in the summer was significantly different from random. In particular, the Dry habitat type occurred more frequently and the Open

Table 3.10 Habitat use within compartments and similar areas.
Habitat survey, East Gore.

Significance tests on the difference between lizard and random distributions relative to habitat type.
Chi-square distributions.

	χ^2	DF	P
a. 1981			
Summer	60.2	6	<0.001
Autumn	13.0	6	<0.05
Juveniles	6.9	6	<0.50
Total	58.4	6	<0.001
b. 1982			
Spring	6.7	6	<0.50
- March&April	12.7	6	<0.05
Summer	22.2	6	<0.01
Autumn	6.9	6	<0.50
Juveniles	2.1	6	<0.95
Total	16.1	6	<0.02
c. 1983			
Spring	31.6	6	<0.001
Summer	16.4	6	<0.02
Autumn	22.6	6	<0.001
Juveniles	13.2	6	<0.05
Total	31.6	6	<0.001

Fig. 3.3 Habitat use within Compartments and similar areas. Habitat survey, East Gore 1981.

Frequency distributions of L.agilis sightings relative to Habitat type for a. summer only, b. autumn only, c. juveniles only and d. all observations, e. is the random distribution.

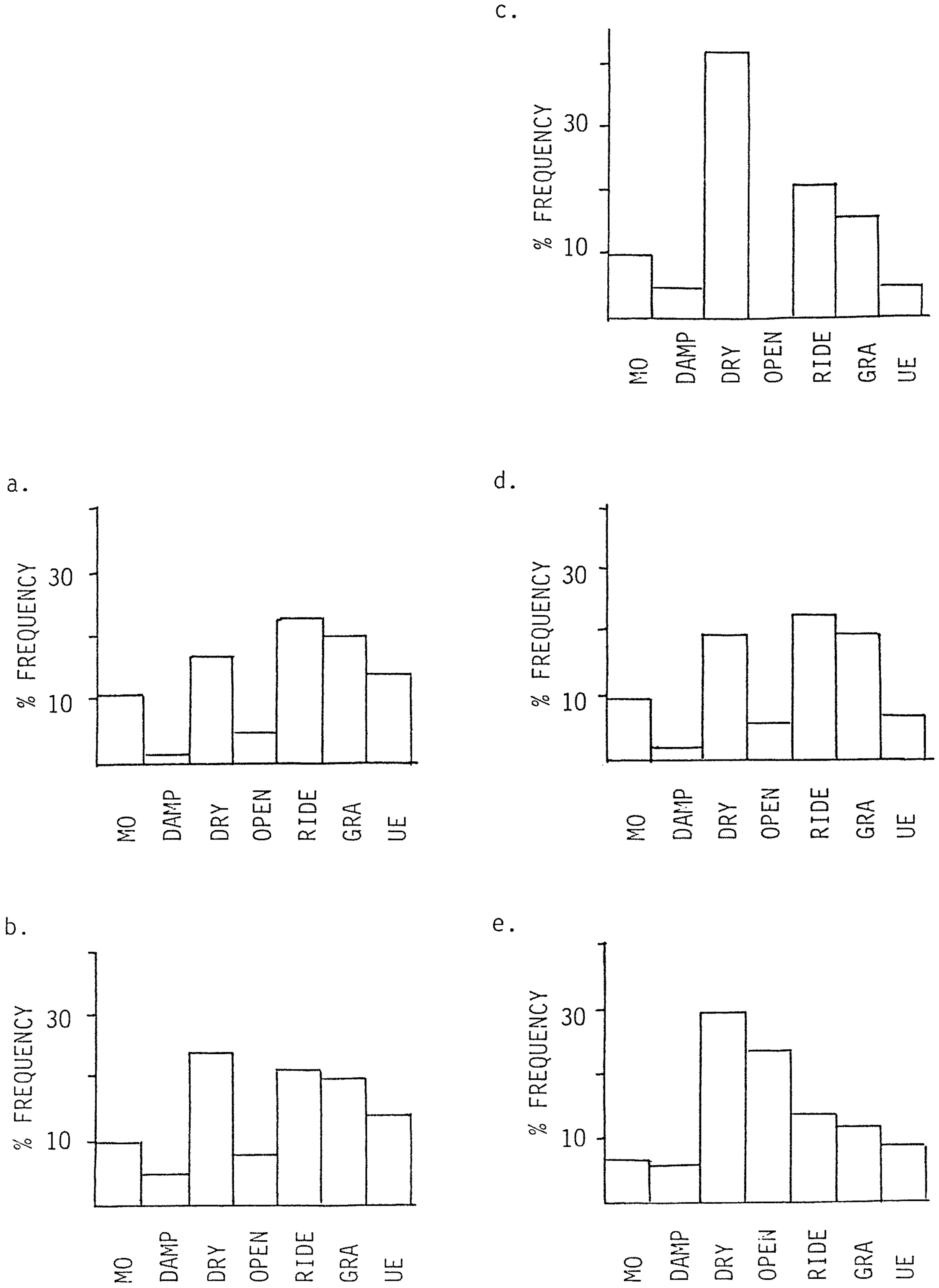


Fig. 3.4 Habitat use within Compartments and similar areas. Habitat survey, East Gore 1982.

Frequency distributions of L.agilis sightings relative to Habitat type for a. spring only, b. summer only, c. autumn only, d. juveniles only, e. all oberservations and f. random.

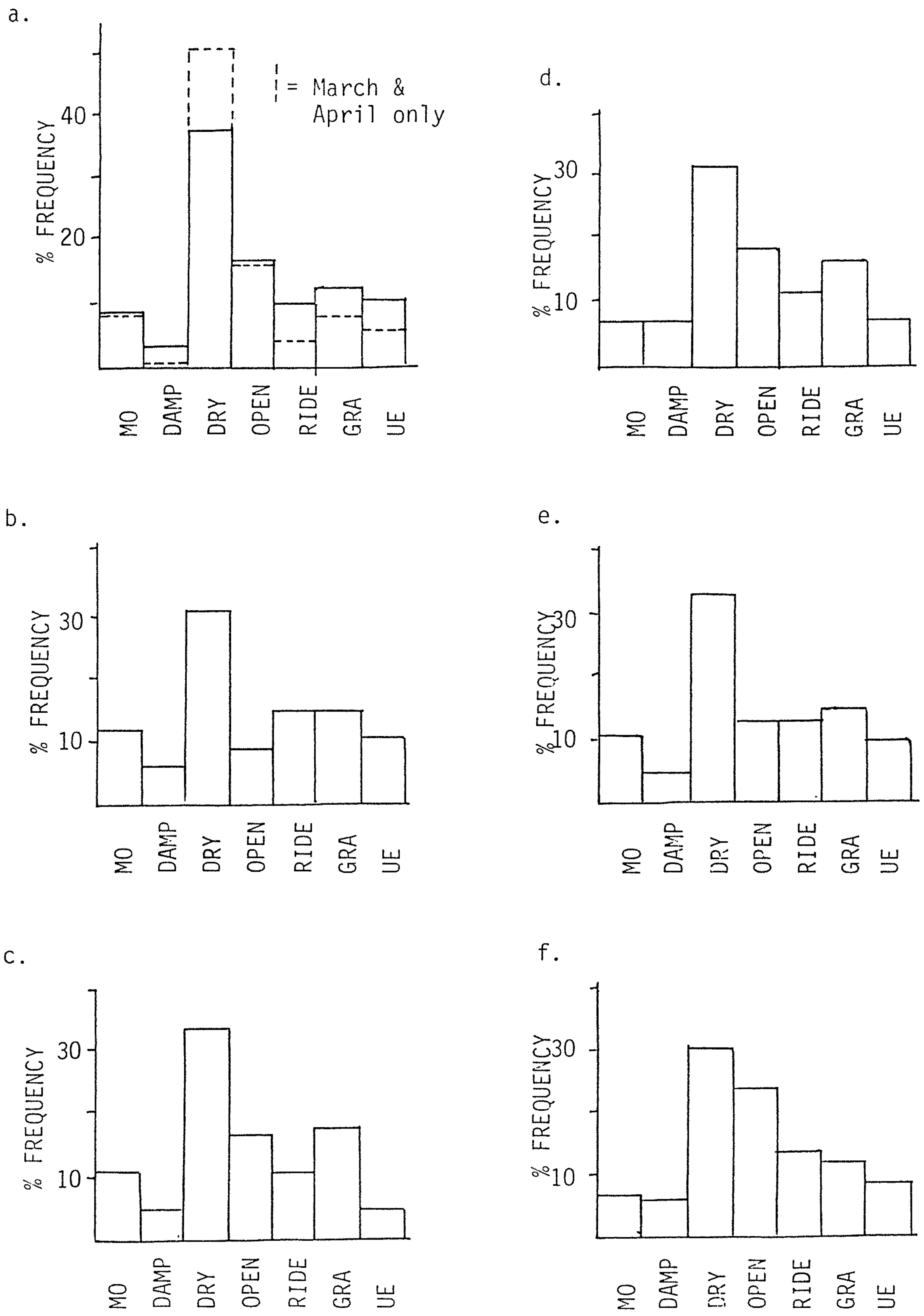
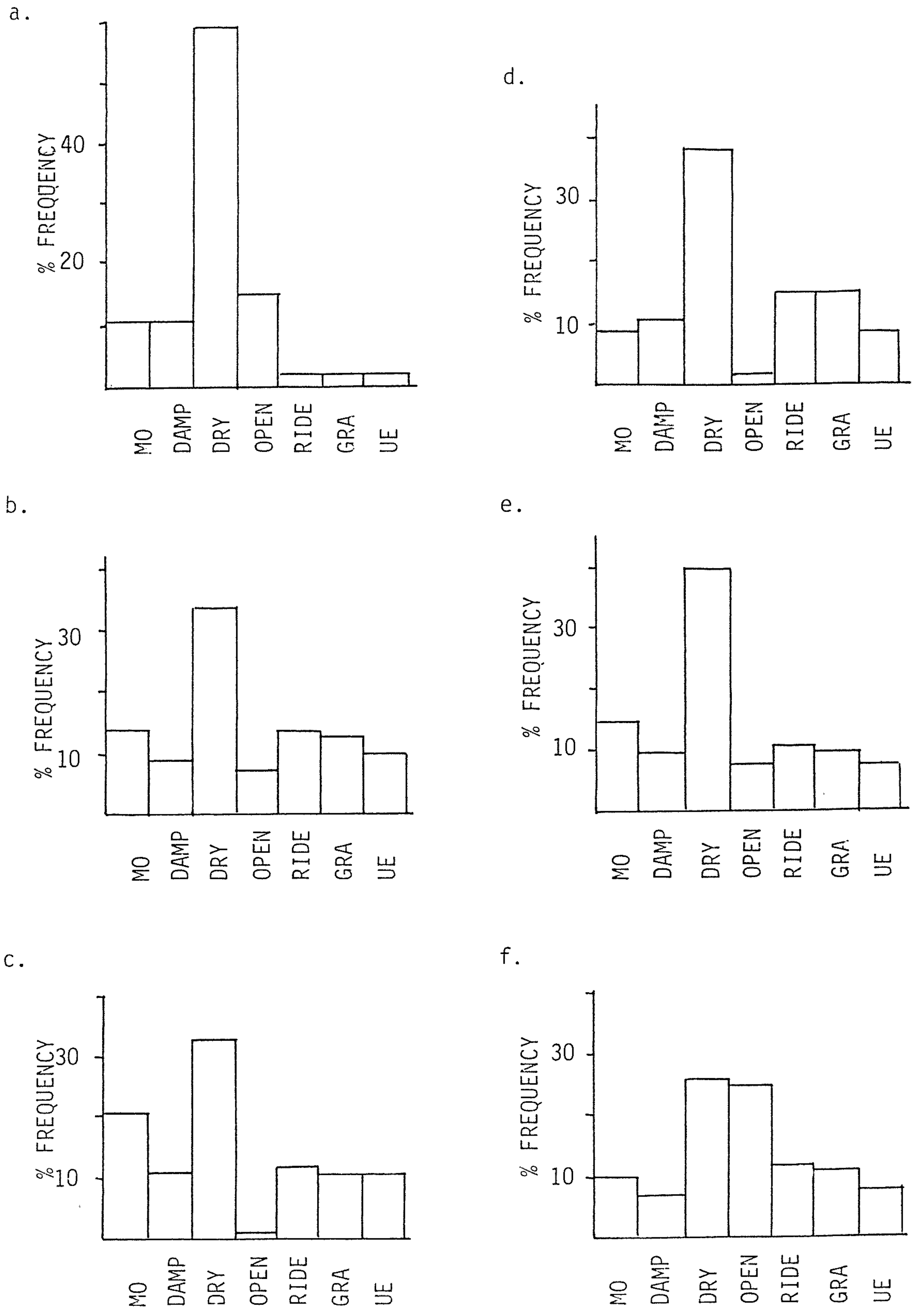


Fig. 3.5 Habitat use within Compartments and similar areas. Habitat survey, East Gore 1983.

Frequency distributions of *L.agilis* sightings relative to Habitat type, for a. spring only, b. summer only, c. autumn only, e. all observations and f. random distribution.



habitat type less frequently than expected from the random distribution. The remaining vegetation types had a similar frequency of occurrence in both the L.agilis and random distributions (Figs 3.4 and 3.5).

In 1983 the pattern found in the summer was repeated in the autumn. The distribution of L.agilis was significantly different from random (Table 3.10). The Dry habitat type occurred more and the Open habitat type less frequently than expected from the random distribution. There was also an increase in the frequency of occurrence of a Wet habitat type in the L.agilis as opposed to the random distribution. This was not a feature of the autumn L.agilis distribution in 1982 which was not significantly different from random (Table 3.10).

The distribution of juvenile L.agilis was significantly different from random in 1983 but not in 1981 or 1982 (Table 3.10). In 1981 the Open habitat type occurred less frequently than expected in the distribution of juvenile L.agilis. In 1982 the Open habitat type was relatively well represented in the distribution of juvenile L.agilis (Figs 3.3 and 3.4).

Taking all values together for each year, the Dry habitat type occurred in the L.agilis distribution more often than expected from the random distribution and the Open habitat type occurred less frequently than expected. This trend however was not noticeable in 1981 when the Dry habitat type was found less frequently in the L.agilis distribution than expected from the random distribution. The main trends in the 1981 distribution of L.agilis were that the Open habitat type occurred less frequently than expected and the Ride and Grass categories occurred more frequently than expected from the random distribution.

3.3.4 DISTRIBUTION IN RELATION TO TREE HEIGHT AND DENSITY

Methods : 2.6.2

The distribution of L.agilis sightings between tree height classes was significantly different from random for all years and for all seasons of each year with the exception of the spring of 1983 (Table 3.11a & b).

For the year taken as a whole the distribution of L.agilis between tree density classes was significantly different from random in all three years. However only in 1983 was the distribution of L.agilis relative to tree density significantly different from random for all three seasons. The distribution of L.agilis sightings between tree

Table 3.11 Habitat use within compartments and similar areas.
Habitat survey, East Gore.

Significance tests on the difference between lizard and random distributions relative to a. tree height and b. tree density.
Chi-squared distributions have been used.

a. Tree Height

	χ^2	DF	P
1981			
Summer	38.9	7	<0.001
Autumn	16.9	7	<0.02
Total	44.7	7	<0.001
1982			
Spring	21.5	8	<0.01
Summer	43.7	7	<0.001
Autumn	18.9	8	<0.02
Total	58.6	8	<0.001
1983			
Spring	14.1	8	<0.10
Summer	34.1	8	<0.001
Autumn	30.1	7	<0.001
Total	43.6	8	<0.001

b. Tree Density

	χ^2	DF	P
1981			
Summer	28.5	8	<0.001
Autumn	12.7	7	<0.10
Total	33.0	8	<0.001
1982			
Spring	11.2	8	<0.20
Summer	33.8	8	<0.001
Autumn	13.0	8	<0.20
Total	24.5	8	<0.01
1983			
Spring	16.4	8	<0.05
Summer	16.9	8	<0.05
Autumn	20.8	7	<0.01
Total	29.9	8	<0.001

density classes was significantly different from random for the summer but not for the autumn of 1981 or 1982 or for the spring of 1982. In all cases L.agilis distributions were more truncated than random ones, not including any of the extreme tree height or density classes (Figs 3.6, 3.7 & 3.8).

During both the summer and autumn of 1981 L.agilis squares were associated with a large number of the lowest tree height and smallest tree density classes (Fig. 3.6).

This pattern was repeated in 1982 and 1983 (Figs 3.7 & 3.8). A slight seasonal trend was visible as a reduction in the frequency of all but the smallest tree density and tree height categories in the summer and autumn in comparison to the spring.

II HABITAT USE ALONG PLANTATION RIDE VERGES

3.4 RIDE HABITAT SURVEY

ANALYTICAL METHODS

3.4.1 INTRODUCTION

Within the Ride verge habitat it was possible to study the habitat use of both L.agilis and L.vivipara. These experiments were carried out on Morden Rides, an area of approximately 5000m, of Ride verge.

The Morden Rides were searched for L.agilis and L.vivipara in the autumn of 1981 and for the full seasons of 1982 and 1983 (March to October). In 1981 the area searched was considerably smaller than that used in 1982 or 1983. The three years data were analysed separately because the pattern of time spent searching individual rides was different for each year and hence the random distribution of habitat searched was different for each year.

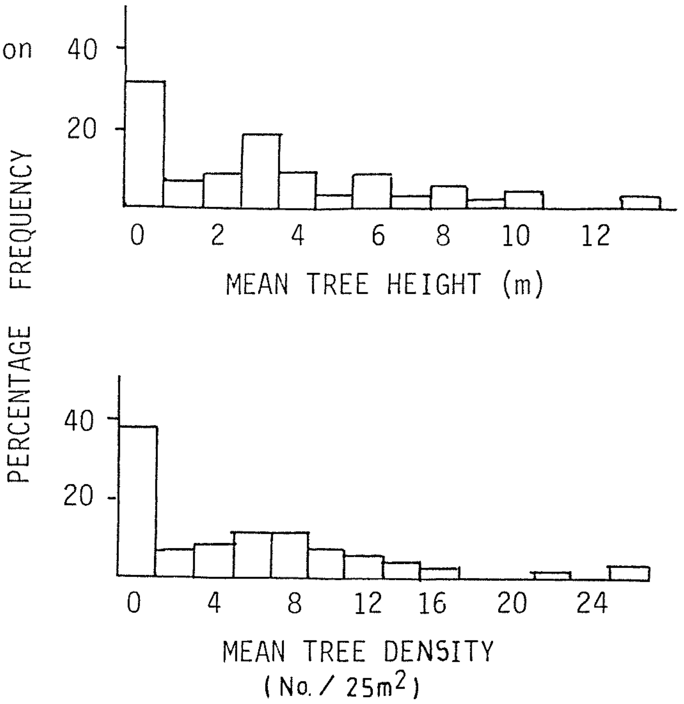
A survey of the entire ride area searched in all three seasons was carried out in 1983. A full list of the characteristics of the ride verge habitat recorded in the survey can be found in Section 2.6.3.2.3. The vegetation of the Ride verge was assessed using a dominance scale similar to that used in the survey of East Gore ground vegetation (see Section 2.6.3.1.1). The mean height and density of the trees adjacent to and opposite to the Ride verges being studied was also assessed. A number of features of the Ride verge and the ride itself were also recorded (such as ride width etc., see Section 2.6.3.1.3). The aspect of the ride verge was also recorded.

The habitat survey was used to describe the habitat of L.agilis and L.vivipara sightings for each year (the position of each of which

Fig. 3.6 Habitat use within Compartments and similar areas. Habitat survey, East Gore 1981.

The distribution of L.agilis on East Gore relative to tree height (a,b) and tree density (a,c).

a. random distribution



b. L.agilis - MEAN TREE HEIGHT

c. L.agilis - MEAN TREE DENSITY

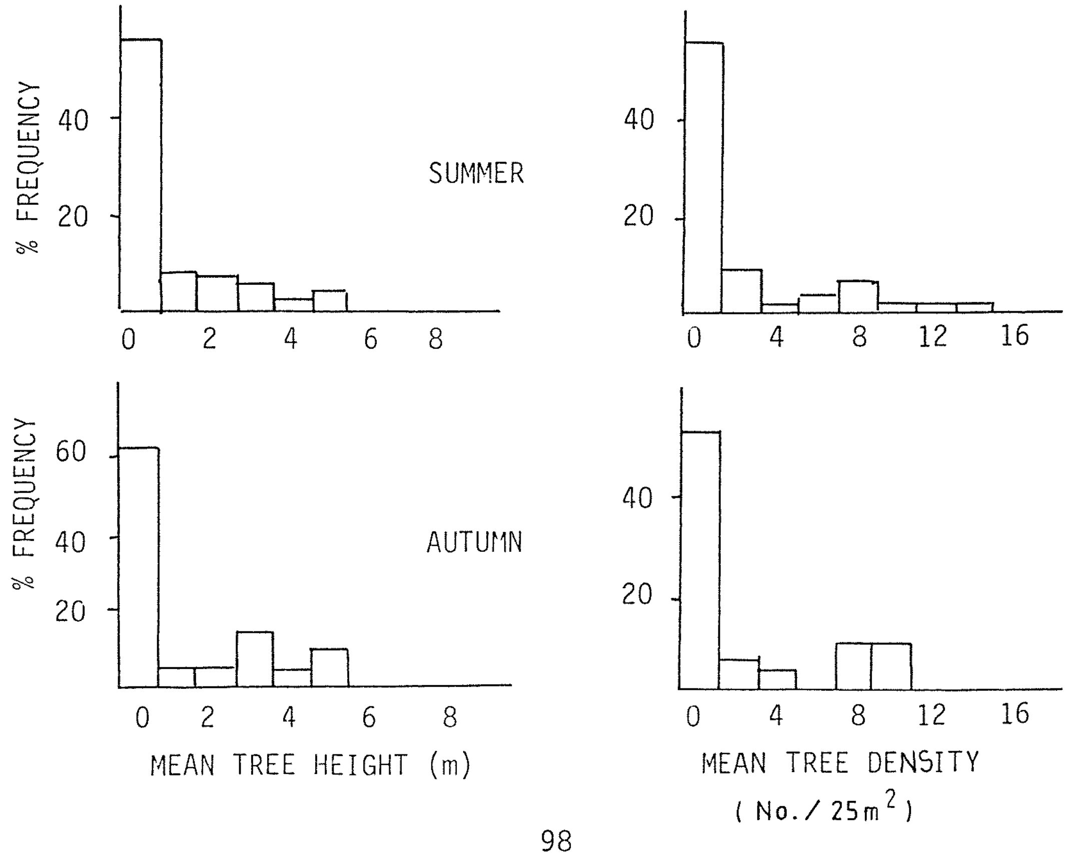
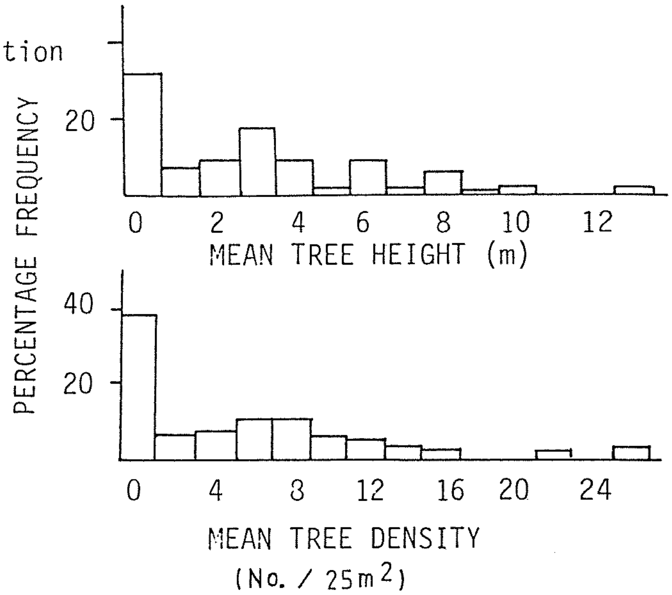


Fig. 3.7 Habitat use within Compartments and similar areas. Habitat survey, East Gore 1982.

The distribution of <u>L.agilis</u> on East Gore relative to tree height (a,b) and tree density (a,c).

a. random distribution



b. <u>L.agilis</u>

c. <u>L.agilis</u>

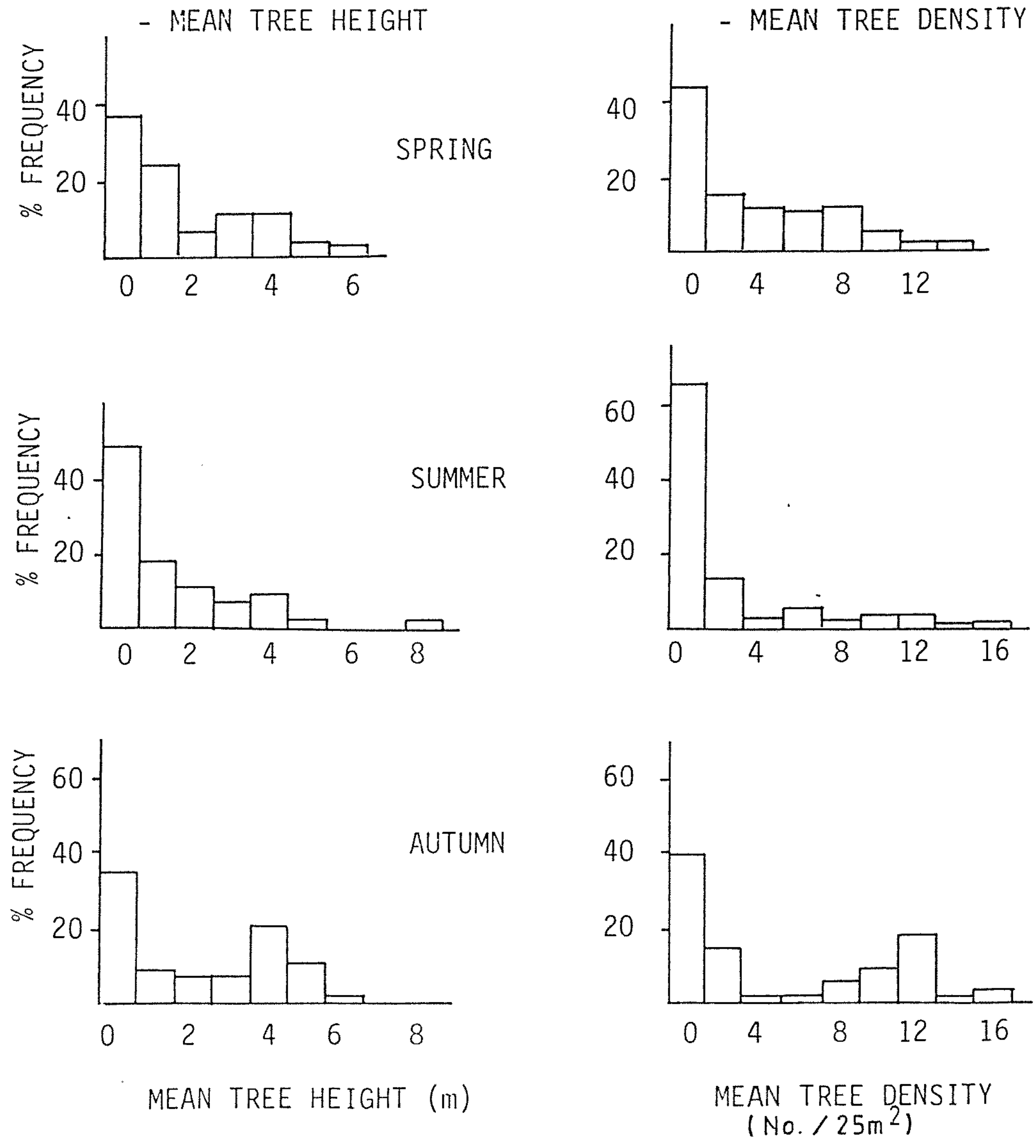
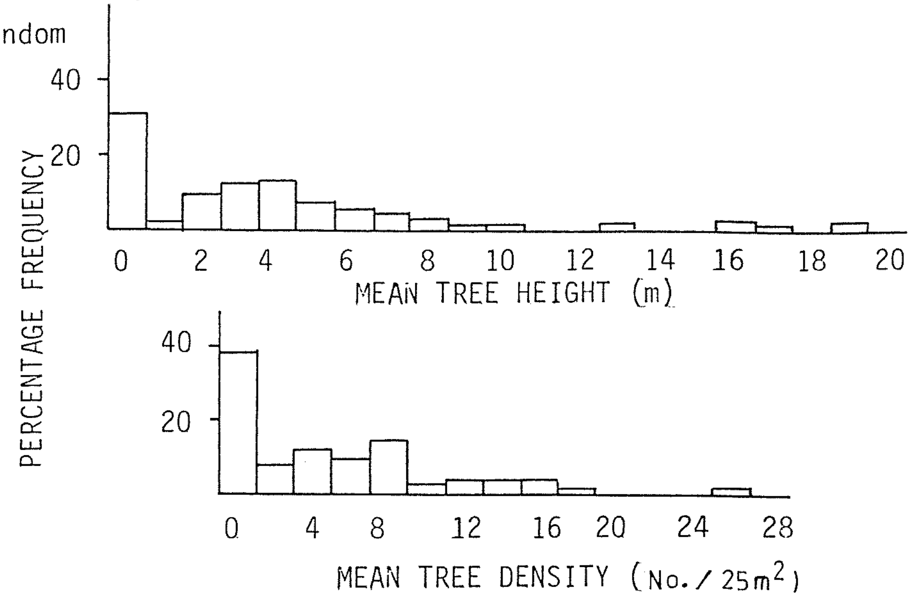


Fig. 3.8 Habitat use within Compartments and similar areas.
Habitat survey, East Gore 1983,

The distribution of <u>L.agilis</u> on East Gore relative to tree height (a,b) and tree density (a,c).

a. random

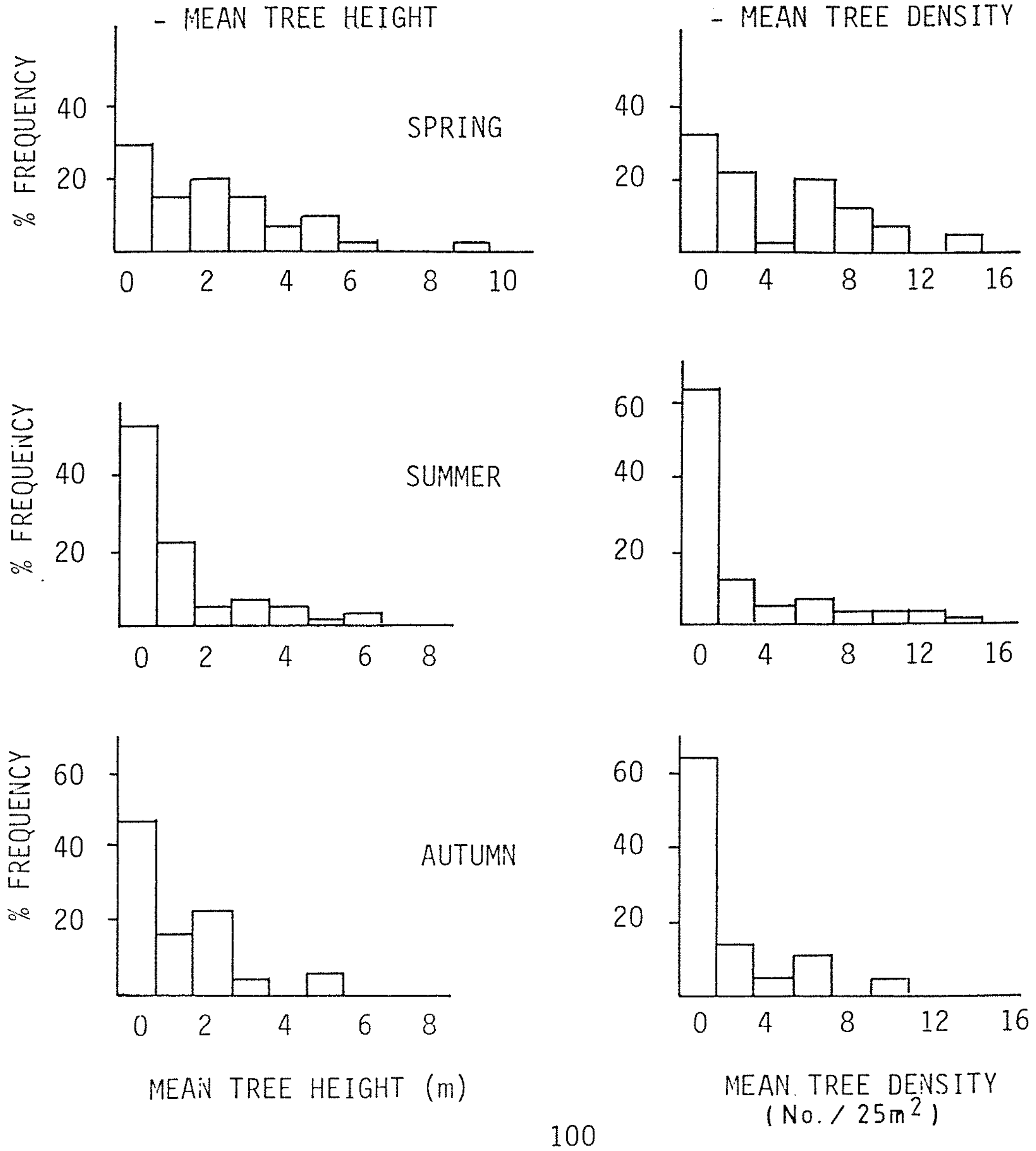


a. <u>L.agilis</u>

- MEAN TREE HEIGHT

c. <u>L.agilis</u>

- MEAN TREE DENSITY



was known). The habitat randomly available was quantified by selecting random points within the area searched each year and using the habitat survey to assess the overall habitat searched (Section 2.6.3.2.2).

3.4.2 STATISTICAL ANALYSIS

The results from the habitat survey of Ride verges were analysed in three main ways. Firstly, all the characteristics of the Ride verge habitat listed in Chapter Two, Section 2.6.3.2.3 were incorporated into a three group CVA (Section 3.2.2). As for the two group situation this analysis examines how far it is possible to distinguish between the three groups (L.agilis, L.vivipara and random) on the basis of the variables assessed for each group. The analysis also indicates which of the measured characteristics are most important in separating the groups.

The affect of aspect on the distribution of L.agilis and L.vivipara along ride verges was assessed by dividing the compass up into eight categories (north, north-east, east, south-east, south, south-west, west and north-west) and comparing the frequency distributions of the L.agilis, L.vivipara and random groups within these sub-divisions. This was done visually using histograms (Figs 3.12) and statistically using chi-square analysis. It was necessary to analyse the affect of aspect separately because aspect was a circular rather than a linear variable (i.e. 0 = 360), it was therefore not suitable to be included in a CVA. In assessing the distribution of L.agilis and L.vivipara relative to aspect only, an assumption must be made that all the other Ride verge characteristics which might be affecting the distribution of L.agilis and L.vivipara were randomly distributed relative to aspect. If this assumption is not correct then it cannot be shown that any differences between the L.agilis, L.vivipara and random distributions were a product of aspect and not of some other ride verge characteristic.

Unfortunately from a basic knowledge of the area of ride verges searched it was clear that this assumption could not be made. In particular the study area included one long north-south ride (Ride Eight, see Fig. 2.1.) which was adjacent to an open area. The open area on the east of this ride consisted of a bog vegetation and the Ride verge adjacent to this comprised of a largely wet heathland vegetation. In contrast the opposite verge which was adjacent to tree plantations included a high bank for much of its length and had a mostly dry heathland vegetation. Most of the other rides searched had similar tree cover and vegetation on both sides of the ride and for these areas the above assumption seemed reasonable. For this reason Ride Eight described above was left out of this analysis as it was felt that it would unduely bias the results obtained. Also, because some of the expected observations in the chi-square analysis were small (see Chapter 2, Section 2.5.2) it was necessary in some comparisons to combine the north-east, north and north-west facing aspects. These aspects were combined as they tended to be the classes which included the lowest numbers of observations. Comparisons where this was done can be seen in Table 3.21 as they have only five degrees of freedom as opposed to seven for those comparisons where no classes were combined.

Finally, a number of the ride verge characteristics used in the CVA were combined to produce an estimate of the seasonal number of sunshine hours received by a given area of ride verge (see Section 2.5.4.4 for calculations). For each year an ANOVA was used to compare the seasonal number of sunshine hours received by the L.agilis, L.vivipara and random groups.

RESULTS

3.4.3 MORDEN RIDES CVA, 1981

Methods : 2.6.3

The canonical variate means were significantly different for the comparisons between all three pairs of groups (Table 3.12), although there was considerable overlap between the groups, particularly between the L.vivipara and random groups (Fig. 3.9).

Relative to the first canonical axis the L.agilis group was clearly separated from the L.vivipara and random groups, the latter two groups being almost inseparable relative to this axis (Fig. 3.9; Table 3.12a). Variables strongly associated with the L.agilis groups were the dominance of C.vulgaris and of dead vegetation (ericaceous species) and the total width of the opposite verge. The L.vivipara and random groups were associated with the dominance of E.tetralix and of grass species, the ride width and the height of the bank of the opposite verge (Table 3.13).

Relative to the Second Canonical Axis there was a clear separation between the L.vivipara and random groups (Fig. 3.9; Table 3.12). Variables strongly associated with the random group were the dominance of E.tetralix and of dead ericaceous species, the width of the ride and the height of the bank of the adjacent verge. The dominance of

Table 3.12 Habitat use along plantation ride verges.
Morden Rides, Habitat survey, 1981.

Results of canonical variate analysis, a. canonical variate means for *L.agilis*, *L.vivipara* and random groups and b. F values for testing the differences between each pair of groups means.

a.

	Vector 1	Vector 2
L.agilis	1.3781	-0.0687
L.vivipara	-0.3442	-0.4544
Random	-0.2415	0.4993

b.

			F	D.F.		P
				1	2	
L.agilis	:	*L.vivipara*	6.4229	21	347	<0.001
	:	random	6.0148	21	347	<0.001
L.vivipara	:	random	3.1580	21	347	<0.001

Fig. 3.9 Habitat use along plantation Ride verges.
Morden Rides, Habitat survey CVA 1981.

The distribution of the canonical variate scores of the L.agilis (●), L.vivipara (o) and random (x) groups relative to the First and Second canonical axes. ▲= the canonical variate means for each group.

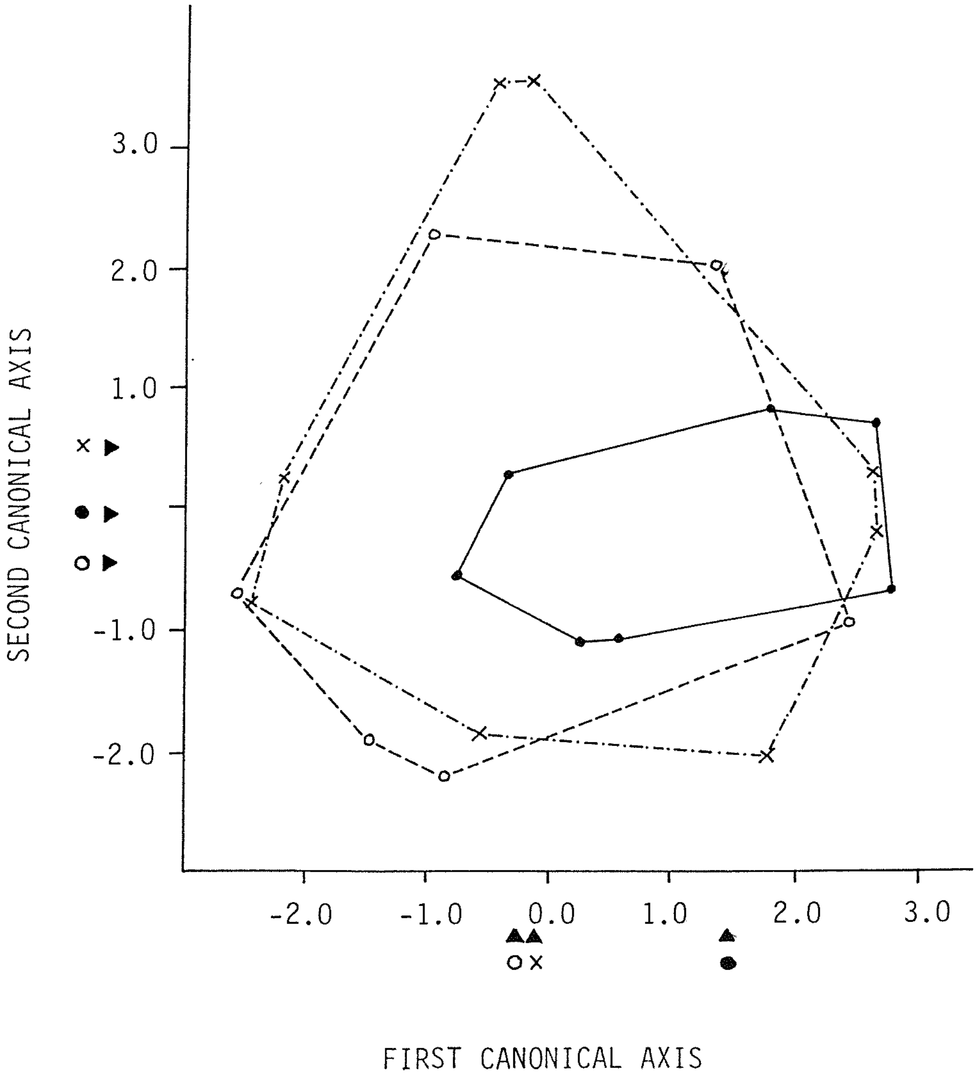


Table 3.13 Habitat use along plantation ride verges.
Morden Rides, Habitat survey 1981.

Results of canonical variate analysis. Variables strongly associated with the *L.agilis*, *L.vivipara* or random groups.

Vector 1	*L.agilis*	*L.vivipara*/random
	width of opposite verge	height of bank of opposite verge
	dominance of *C.vulgaris*	width of ride
	dominance of dead ericaceous species	dominance of *E.tetralix*
		dominance of grass species.
Vector 2	*L.vivipara*	random
	dominance of *M.caerulea*	dominance of dead ericaceous species
	dominance of *P.aquilinum*	width of ride
	dominance of *U.minor*	dominance of *E.tetralix*
	undisturbed width of adjacent verge	height of bank of opposite verge
	height of bank of adjacent verge	

M.caerulea, P.aquilinum and of U.minor were strongly associated with the L.vivipara group (Table 3.13).

Some of the variables measured showed strong within group correlations, these are summarised in Table 3.14. As with the habitat study within Compartments some of these correlations would be expected because of the nature of the variables measured. For instance there was a strong positive correlation between the width of the undisturbed adjacent verge and the total width of the adjacent verge. Both of these measures of the width of the verge also show a positive correlation with the height of the bank of the adjacent verge, indicating that wider verges were associated with the higher banks. In this way patterns of ride verge structure can be investigated using the within group correlations. Correlations between variables associated with the vegetation of the verge included a negative association between the dominance of C.vulgaris and that of open gound, and a positive association between the dominance of open ground and the percentage cover of dead pine needles. The latter suggests that open ground tended to be dominant in areas where there was a heavy needle fall.

3.4.2 MORDEN RIDES CVA, 1982

Methods : 2.6.3

The canonical variate means of the L.agilis group were significantly different from those of the L.vivipara and random groups, those of L.vivipara were also significantly different from the random group (Table 3.15b).

Relative to the First Canonical Axis the L.agilis group was clearly separated from the L.vivipara and random groups, the latter being close together (Fig. 3.10; Table 3.15a). Variables strongly associated with L.agilis included the dominance of C.vulgaris and of Vaccinium myrtillus, the width of the ride and the total width of the adjacent verge. Associated with L.vivipara and random groups were the dominance of E.tetralix and of grass species, the height of the trees opposite and the width of the adjacent undisturbed verge (Table 3.16).

The random group and L.vivipara were most widely separated relative to the Second canonical axis (Fig. 3.10; Table 3.15a). The variables associated with L.vivipara were the dominance of U.minor, the width of the adjacent undisturbed verge and the height of the bank of the opposite verge. The random and L.agilis groups were associated with the width of the ride and the total width of the adjacent verge and the dominance of V.myrtillus, C.vulgaris and of open ground (Table 3.16).

Table 3.14 Habitat use along plantation ride verges.
Morden Rides, Habitat survey.

From canonical variate analysis, strong within group correlations between variables, a. 1981, b. 1982 & c. 1983.

	Variables		Correlation
a.	height of adjacent trees	: density of adjacent trees	0.696
	dominance of *C.vulgaris*	: dominance of open ground	-0.588
	dominance of open ground	: cover of dead pine needles	0.636
	total width adjacent verge	: undist. width adjacent verge	0.912
		: bank height, adjacent verge	0.564
	undist. width adjacent verge	: bank height, adjacent verge	0.552
b.	height of opposite trees	: density of opposite trees	0.645
	height of adjacent trees	: density of adjacent trees	0.704
		: total width adjacent verge	-0.508
		: undist. width adjacent verge	-0.504
	density of adjacent trees	: total width adjacent verge	-0.533
	dominance of *C.vulgaris*	: dominance of *M.caerulea*	-0.527
	dominance of open ground	: cover of dead pine needles	0.595
	total width adjacent verge	: undist. width adjacent verge	0.965
c.	height of opposite trees	: density of opposite trees	0.774
	height of adjacent trees	: density of adjacent trees	0.756
		: total width adjacent verge	-0.582
		: undist. width adjacent verge	-0.582
	density of adjacent trees	: total width adjacent verge	-0.599
		: undist. width adjacent verge	-0.590
	dominance of *C.vulgaris*	: dominance of *M.caerulea*	-0.592
	dominance of open ground	: cover of dead pine needles	0.529
	total width adjacent verge	: undist. width adjacent verge	0.957

Table 3.15 Habitat use along plantation ride verges.
Morden rides, Habitrat survey 1982.

Results of canonical variate analysis a. canonical variate means for *L.agilis*, *L.vivipara* and random groups, b. F values for testing differences between each pair of groups.

a.

	Vector 1	Vector 2
L.agilis	0.9982	-0.1726
L.vivipara	-0.0708	0.3608
random	-0.3228	-0.2881

b.

			F	D.F.		P
				1	2	
L.agilis	:	*L.vivipara*	5.3118	22	690	<0.001
	:	random	6.5686	22	690	<0.001
L.vivipara	:	random	3.1844	22	690	<0.001

Fig. 3.10 Habitat use along plantation Ride verges.
Morden Rides, Habitat survey CVA 1982.

The distribution of the canonical variate scores of the <u>L.agilis</u> (●), <u>L.vivipara</u> (o) and random (x) groups. relative to the First and Second canonical axes.

▲ = the canonical variate means for each group.

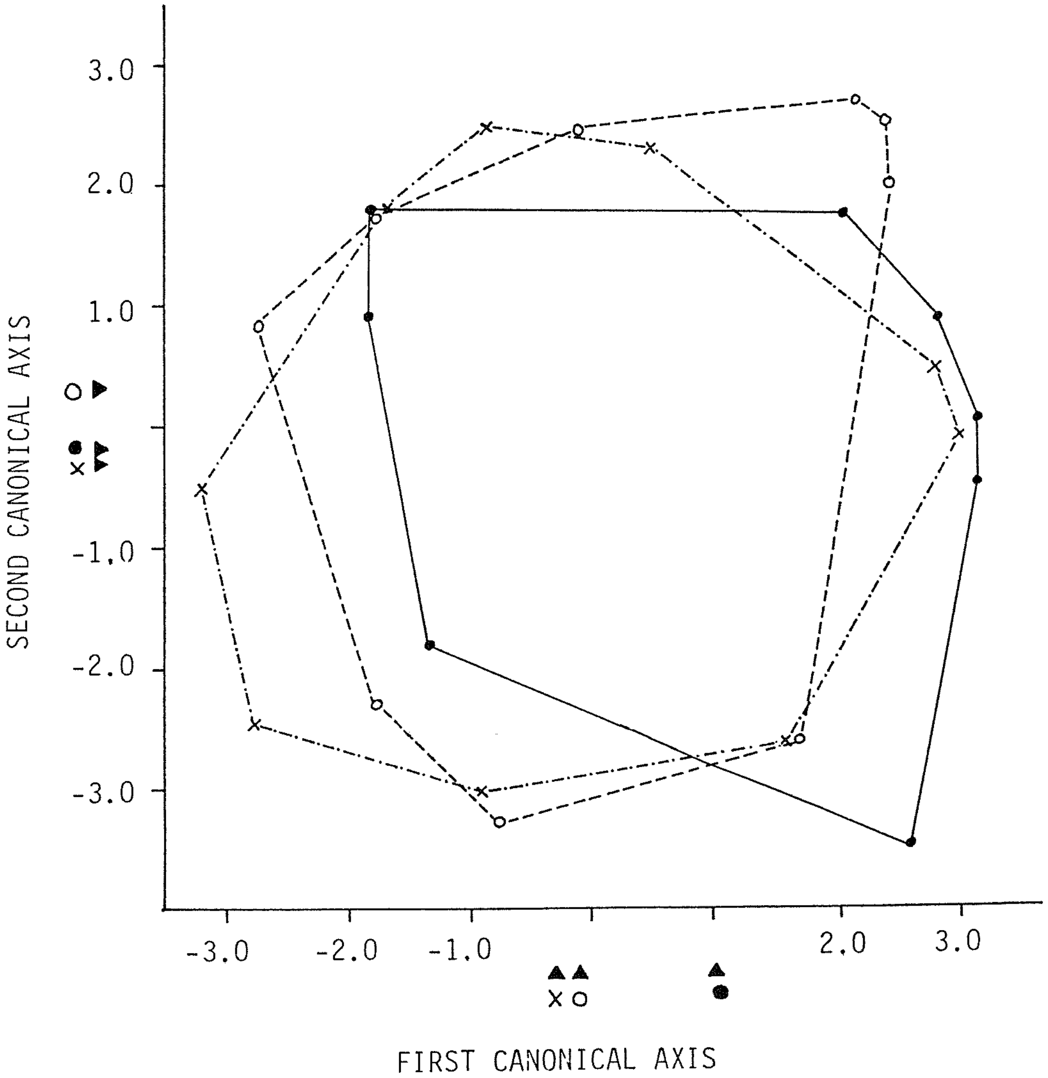


Table 3.16 Habitat use along plantation ride verges.
Morden Rides, Habitat survey 1982.

Results of canonical variate analysis, variables strongly associated with the *L.agilis*, *L.vivipara* or random groups.

Vector 1	*L.agilis*	*L.vivipara*/random
	dominance of *V.myrtillus*	dominance of *E.tetralix*
	width of ride	height of opposite trees
	dominance of *C.vulgaris*	undisturbed width of adjacent verge
	total width of adjacent verge	dominance of grass species

Vector 2	*L.agilis*/random	*L.vivipara*
	dominance of *V.myrtillus*	dominance of *U.minor*
	total width of adjacent verge	height of bank of opposite verge
	width of ride	undisturbed width of adjacent verge
	dominance of open ground	
	dominance of *C.vulgaris*	

As for 1981, the within group correlations show several associations between characteristics of the trees or of the ride and Ride verge. For both the trees of the opposite and adjacent plantations there was a positive correlation between tree height and tree density, indicating that the taller trees were closer together than the smaller ones. There was also a negative relationship between the height of the trees and the width of the adjacent verge (both total and undisturbed). In terms of vegetation characteristics there was a negative association between the dominance of *C.vulgaris* and that of *M.caerulea* (Table 3.14).

3.4.3 MORDEN RIDES CVA, 1983

Methods : 2.6.3

The canonical variate means were significantly different for comparisons between each pair of groups, that is, *L.agilis* : *L.vivipara*, *L.agilis* : random and *L.vivipara* : random (Table 3.17b).

The *L.agilis* group was most clearly separated from the *L.vivipara* and random groups relative to the First canonical axis (Fig. 3.11; Table 17a). The variables strongly associated with *L.agilis* included the dominance of *C.vulgaris*, *E.cinerea* and *P.aquilinum*. The *L.vivipara* and random groups were strongly associated with the dominance of *E.tetralix* and the undisturbed width of the adjacent verge (Table 3.18).

The *L.vivipara* and random groups were most clearly separated relative to the Second canonical axis (Fig. 3.11; Table 17a), on this axis the *L.agilis* and random groups were close together. The *L.vivipara* group was strongly associated with the dominance of *E.cinerea*, *M.caerulea* and of grass species and the width of the ride. The random and *L.agilis* groups were associated with the dominance of open ground, *P.aquilinum* and *V.myrtillus* (Table 3.18).

The within groups correlations between variables included the same associations as those found in 1982. Additional positive correlations were found between the density of the adjacent trees and the width of the undisturbed adjacent verge (Table 3.14).

3.4.4 THE INFLUENCE OF ASPECT ON LIZARD DISTRIBUTION

Methods : 2.6.3.1.4

The proportion of sightings of *L.agilis*, *L.vivipara* and of random points in each of eight aspect ranges were compared. As described in Section 3.4.2 one Ride verge area (Ride Eight) was omitted from this

Table 3.17 Habitat use along plantation ride verges.
Morden Rides, Habitat survey 1983.

Results of canonical variate analysis, a. canonical variate means for L.agilis, L.vivipara and random groups b. F values for testing differences between each pair of group means.

a.

	Vector 1	Vector 2
L.agilis	0.9756	0.2595
L.vivipara	-0.0308	-0.2926
random	-0.4022	0.3234

b.

			F	D.F.		P
				1	2	
L.agilis	:	L.vivipara	6.1879	22	868	<0.001
	:	random	7.9800	22	868	<0.001
L.vivipara	:	random	4.1474	22	868	<0.001

Fig. 3.11 Habitat use along plantation Ride verges.
Morden Rides, Habitat survey CVA 1983.

The distribution of the canonical variate scores of the L.agilis (●), L.vivipara (o) and random (x) groups, relative to the First and Second canonical axes.
▲ = the canonical variate means for each group.

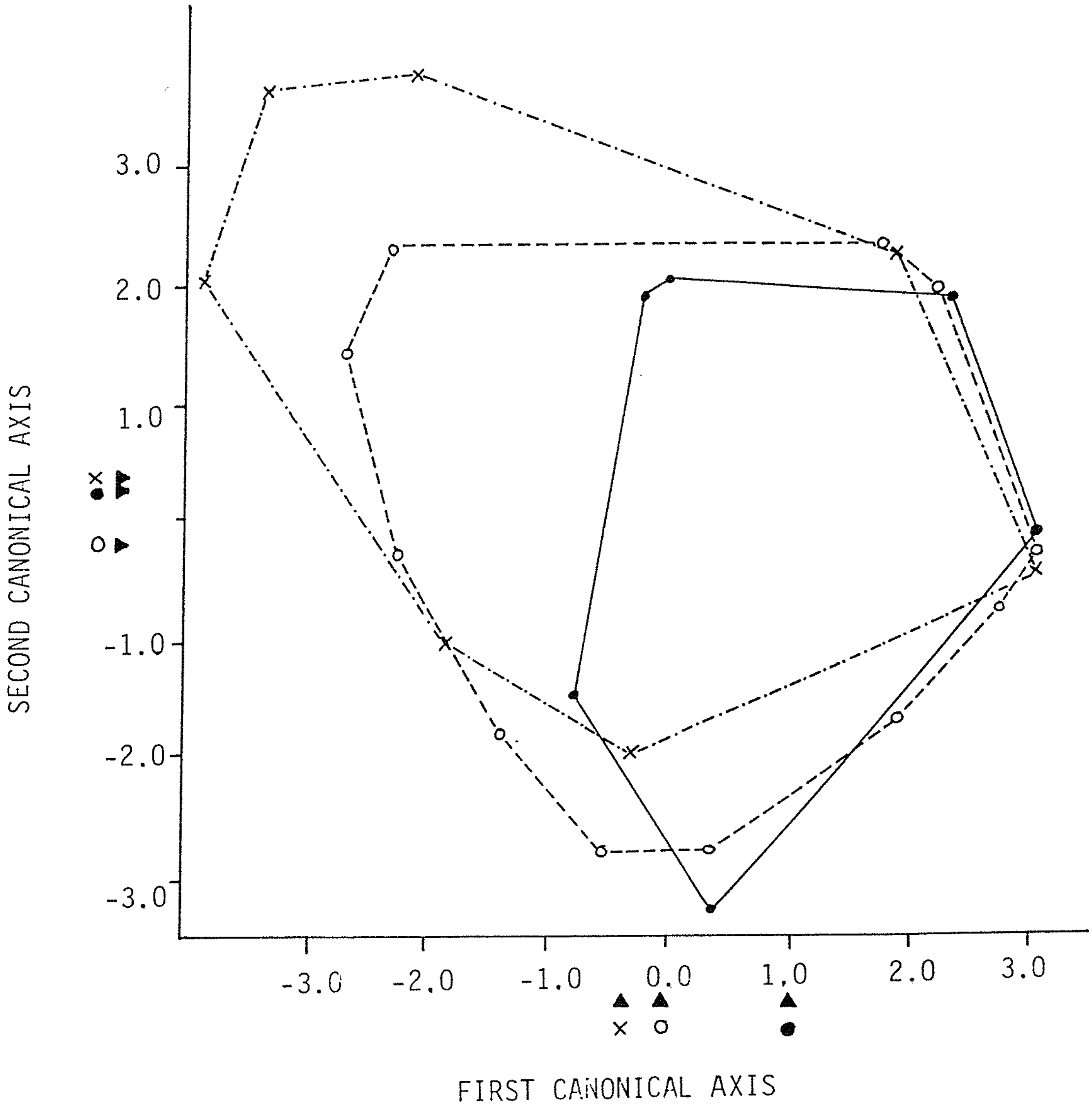


Table 3.18 Habitat use along plantation ride verges.
Morden Rides, Habitat survey 1983.

Results of canonical variate analysis, variables strongly associated with *L.agilis*, *L.vivipara* and random groups.

Vector 1	*L.agilis*	*L.vivipara*/random
	dominance of *C.vulgaris*	dominance of*E.tetralix*
	dominance of *E.cinerea*	undisturbed width of adjacent verge
	dominance of *P.aquilinum*	
Vector 2	*L.vivipara*	*L.agilis*/random
	dominance of *E.cinerea*	dominance of Open ground
	dominance of *M.caerulea*	dominance of *V.myrtillus*
	dominance of grass	dominance of *P.aquilinum* species

Table 3.19 Habitat use along plantation ride verges.
Morden Rides, Habitat survey.

Results from random survey of habitat for 1981, 1982 and 1983. a. Mean tree height and density, b. mean plant species dominance category (DP only percentage cover) and c. mean values of ride characteristics.

Variable	1981	1982	1983
a. THO (m)	6.77	5.95	5.49
THA (m)	5.06	5.00	5.39
TDO (/10m)	4.90	4.54	4.12
TDA (/10m)	3.88	3.51	3.91
b. H	2.64	2.62	2.72
DEAD	0.47	0.39	0.30
ET	0.38	0.60	0.75
EC	1.11	1.06	1.08
MO	1.71	1.82	1.93
GRA	0.47	0.43	0.46
UM	0.81	0.71	0.79
OPEN	1.25	1.22	1.20
VAC	0.01*	0.13	0.15
BR	0.83	0.84	0.68
DP	11.51	10.14	7.51
c. WR (m)	4.55	4.29	4.29
VAT (m)	3.36	4.11	3.95
VAU (m)	2.77	3.45	3.33
BA (m)	0.53	0.41	0.34
RIDE (m)	2.05	2.11	2.14
VO (m)	3.10	3.50	3.84
BO (m)	0.34	0.21	0.34

* not included in CVA for 1981.

analysis. The analysis was compiled twice, once using all sightings and once using sightings of juveniles only. However, the analysis could not be completed for L.agilis juveniles in 1982 or 1983 because the sample sizes were too small (Table 3.20).

(i) All sightings

The distribution of random points in 1981 indicated that the majority of rides searched were south, south east, east and west facing with relatively few facing north (Fig. 3.12a). The distribution of L.vivipara was significantly different from the random distribution but not from that of L.agilis. The distribution of L.agilis was not significantly different from random (Table 3.21). The aspect with which L.vivipara was most commonly found associated was a south-facing one. L.vivipara was more commonly associated with south facing slopes than L.agilis. Overall L.vivipara was found associated with seven out of the eight aspects (not found in north) whereas L.agilis was only found associated with four (not including south-west, west, north or north-east; Fig. 3.12).

In 1982 and 1983 the range of aspects walked was similar (Fig. 3.12). The distribution of L.vivipara was significantly different from random in 1982 but not in 1983. The distribution of L.agilis was significantly different from both that of L.vivipara and of random points in both years (Table 3.21). The distribution of L.agilis showed a clear tendency towards south, south-east or east facing ride verges. In both 1982 and 1983 the numbers found on west, south-west, north or north-east facing rides were very low (Fig. 3.12)

(ii) Juveniles only

In 1981 Morden Rides were only searched during the autumn so that the data set consisted of a high proportion of juveniles (Table 3.20). It was therefore not surprising that when sightings of juveniles only were used the distributions for 1981 did not substantially change for either L.agilis or L.vivipara (Fig. 3.12). The distribution of L.agilis juveniles was not significantly different from random or from that of L.vivipara, while the distribution of L.vivipara juveniles was significantly different from random (Table 3.21).

In 1982 the distribution of L.vivipara juveniles was not significantly different from random (Fig. 3.12; Table 3.21). However in 1983 the distribution of L.vivipara with respect to aspect was significantly different from random (Fig. 3.12; Table 3.21). Juvenile L.vivipara occurred more frequently than expected on west facing Ride verges and less frequently than expected on north-west, north or north-

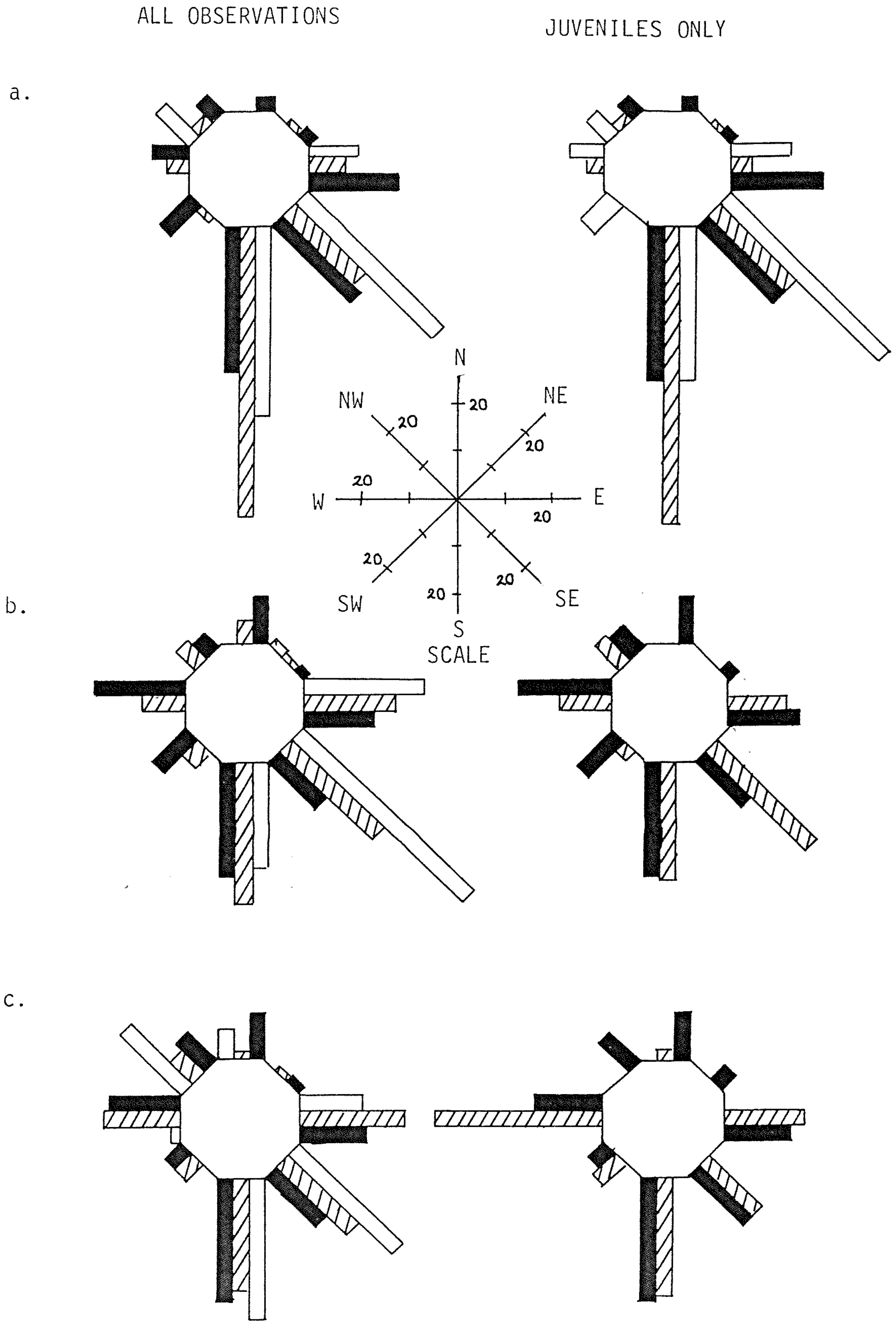
Table 3.20 Habitat use along plantation ride verges. Morden Rides Habitat Survey.

Sample sizes available for the analysis of the distribution of L.agilis and L.vivipara with regard to aspect.

		Year		
		1981	1982	1983
L.agilis	- all animals	28	32	43
	- juveniles	24	5	3
L.vivipara	- all animals	92	130	167
	- juveniles	77	32	49
Random		102	177	173

Fig. 3.12 Habitat use along plantation Ride verges.
Morden Rides, Habitat survey.

The distribtuion of L.agilis (□) and L.vivipara (▨) sightings and of random points (■) relative to aspect, for a. 1981, b. 1982 and c. 1983.



ALL AXIES ARE % FREQUENCY

Table 3.21 Habitat use along plantation ride verges.
Morden Rides, Habitat survey.

Comparisons of the distributions of *L.agilis*, *L.vivipara* and random points in relation to aspect for a. 1981, b. 1982 and c. 1983. (i) all observations (ii) juveniles only.

		Comparison		χ^2	D.F.	P
(i)	a.	*L.agilis*	: *L.vivipara*	10.0	5	<0.10
			: Random	8.2	5	<0.20
		L.vivipara	: Random	23.3	5	<0.001
	b.	*L.agilis*	: *L.vivipara*	12.7	5	<0.05
			: Random	30.7	5	<0.001
		L.vivipara	: Random	17.2	7	<0.02
	c.	*L.agilis*	: *L.vivipara*	15.7	5	<0.01
			: Random	17.7	7	<0.02
		L.vivipara	: Random	13.7	7	<0.10
(ii)	a.	*L.agilis*	: *L.vivipara*	9.9	5	<0.10
			: Random	8.8	5	<0.20
		L.vivipara	: Random	24.7	5	<0.001
	b.	*L.vivipara*	: Random	6.6	5	<0.30
	c.	*L.vivipara*	: Random	15.7	5	<0.01

east facing verges.

3.4.5 THE RELATIONSHIP BETWEEN LIZARD DISTRIBUTION AND THE NUMBER OF SUNSHINE HOURS RECEIVED BY AN AREA

Methods : 2.5.4.3

The mean number of sunshine hours received by the L.agilis and L.vivipara groups were not significantly different (Table 3.22). However, both the L.agilis and the L.vivipara groups received significantly more sunshine hours than the random group (Table 3.22).

3.5 DISCUSSION

While the precise analytical methods vary, all the experiments described in this chapter were based on the same principle. That is, that the habitat used by an animal species can be investigated by comparing the habitat within which the animal is found with that which is randomly available to it.

In these experiments where a number of variables have been measured on both the lizard and random groups (and a CVA used), a significant difference between the lizard and random groups in the analysis suggests that the measured variables include at least some which were important to the distribution of L.agilis within the habitat being studied. In each experiment or analysis the crucial factor was the comparison between what was used by the lizard and what was randomly available, therefore care must be taken when extrapolating the results obtained beyond the specific habitat which was being investigated.

It was not possible to say whether or not the measured variables included those characteristics of the habitat which were most important or vital to the habitat preferences of L.agilis or L.vivipara (if such specific characteristics exist). It can only be assumed that those variables which were found to be most important in discriminating between the lizard and random groups are in some way, directly or indirectly, affecting the habitat preferences of the L.agilis and L.vivipara. It may or may not be possible to deduce the importance of the results obtained to the biology or ecology of either L.agilis or L.vivipara.

3.5.1 HABITAT USE WITHIN COMPARTMENTS AND SIMILAR AREAS

3.5.1.1 Lizard vs. random quadrats

In three out of the four study areas used, the comparison of

Table 3.22 Habitat use along plantation ride verges.
Morden Rides, Habitat survey.

The mean number of sunshine hours (per season) received by rides associated with L.agilis, L.vivipara and random points.

a. Means.

	1981	1982	1983	Grand Mean
L.agilis	21.5	27.8	27.7	26.5
L.vivipara	18.5	25.4	27.2	25.1
Random	19.0	23.3	24.7	23.0
Grand Mean	19.3	23.0	26.4	

b. Intra-group differences

Comparison			t	D.F.	P
L.agilis	:	L.vivipara	1.80	1946	>0.05
	:	Random	4.40	1946	<0.001
L.vivipara	:	Random	5.95	1946	<0.001

c. Intra-year differences

Comparison			t	D.F.	P
1981	:	1982	7.59	1946	<0.001
	:	1983	9.68	1946	<0.001
1982	:	1983	2.29	1946	<0.025

quadrats based around lizard sightings with those around random points provided evidence that the distribution of L.agilis departed significantly from a random one. Characteristics of both the vegetation and the tree canopy cover appear to play a role in distinguishing between the L.agilis and random groups.

On all three sites where significant results were obtained the importance of the presence of open ground was difficult to interpret. In each case, different sub-divisions of the open ground category were associated with the L.agilis and the random groups. On both Morden Site and East Gore, Pond bank the Open ground category as a whole was associated with the random group whereas sub-divisions of the Open ground category (Open/litter and Open/moss&lichen on Morden Site and Open/bare ground on Pond bank) were associated with the L.agilis group. Although Morden Site was a dry heathland area and East Gore, Pond bank a wet bog one the two sites were similar in some respects. On both areas the vegetation was dense with only small areas of Open ground (Morden Site 3.5%; East Gore, Pond bank 6.7%; Table 3.3). Both sites also incorporated pockets of open and essentially unusable ground. On Morden Site these areas included adjacent rides and areas under particularly dense canopy cover. On East Gore, Pond bank there were also adjacent rides and the flat expanses left when the ponds within the area dried out each summer. The association between Open ground sub-divisions and L.agilis may indicate a preference for areas of open ground within the vegetation but not for the larger open areas described above.

On East Gore, Main slope the dry heathland vegetation included a considerably greater area of open ground (16.7%; Table 3.3) and the distribution of L.agilis was associated with the cover of Open ground as a whole. The association between Open/litter and Open/bare ground with the random group could indicate an avoidance of areas where the open ground resulted from a high level of tree canopy cover causing the vegetation to die back, these latter two categories of Open being characteristic of such areas.

The other features of the vegetation which were important in distinguishing between the L.agilis and random groups may all be interpreted in a similar manner. That is that within a habitat which tended to be dominated by a single species (such as C.vulgaris in a dry heathland) L.agilis was associated with areas of relatively high structural or plant species diversity. On Morden Site, L.agilis was associated with the cover of E.cinerea and on East Gore, Main slope with M.caerulea, both of which were found in only small amounts on the respective study areas (E.cinerea Morden Site 0.9%; M.caerulea East Gore Main slope 0.1%; Table 3.3). On East Gore, Pond bank where the dominant plant species was M.caerulea (69.3% cover; Table 3.3) L.agilis was associated with areas with a relatively high number of plant species present. As the number of plant species present was also itself highly positively correlated with the percentage cover of grass species (Table 3.5) this may also indicate a tendency to use areas with grass cover, rather than those where M.caerulea exists as a monoculture.

In terms of the influence of tree canopy cover on L.agilis distribution it is probably best to look first at the results from Morden Site, this being the study area with the most uniform cover of trees across the entire area. On Morden Site the DBH of the trees was strongly associated with the random group. It is interesting that of the six measurements of canopy cover taken (Table 3.4) on this study area, the tree DBH is the only one which appears to reflect the response of L.agilis to the presence of tree cover within a habitat. The particular relevance of the DBH of the trees may be that DBH is the most effective indication of the overall 'bushiness' of a tree and of the amount and density of foliage which it bears. A tree may be very tall but if it is thin and bears few branches its shading affect will be small. Another factor may be that a particularly bushy tree may very heavily shade the vegetation immediately below it and this together with a high level of needle fall over a small concentrated area may cause the rapid deterioration of the vegetation. On both East Gore, Main slope and Pond bank the picture with regard to the influence of tree canopy cover was much less clearly defined. The tree canopy cover on both these sites was much less uniform than on Morden Site and the nature of the plantations surrounding these two study areas may also be relevant. On East Gore, Main slope the distribution of L.agilis was strongly associated with tree height. The Main slope area was bordered to the north by an area of old, tall pine plantation which was immediately adjacent to the open south facing slope which constituted most of the L.agilis habitat. The association between L.agilis and tall trees may simply be a reflection of the layout of the site. This was such that much of the prime open area was adjacent to stands of tall trees whereas points randomly distributed throughout the area encountered mainly the somewhat smaller trees that covered the site as a whole. On East Gore, Pond bank a similar situation was found, the study area itself included only scattered trees but it was bordered to the north and south by tall pine plantation. Again a strong association was found between the distribution of L.agilis and tree height, there was also an association between tree DBH and the random group on this study area.

On each of the study areas there was some evidence of vegetation deterioration due to the presence of tree canopy cover. On Morden Site there was a negative correlation between tree density and the cover of P.aquilinum (Table 3.5). On East Gore, Main slope there was a low positive correlation between the percentage cover of dead ericaceous species and the tree density (Table 3.5). Finally on East Gore, Pond bank there was a positive correlation between the percentage cover of dead ericaceous plant species and both the tree density and the aerial cover of pine. However, for Morden Site and East Gore, Main slope these appear to be early signs of deterioration and on East Gore, Pond bank the cover of trees was so small that their effect however severe was probably not important to the site as a whole.

It appears that the distribution of L.agilis within compartments was being influenced by factors associated with both the vegetation and the tree canopy cover. The tree canopy cover was affecting the distribution of L.agilis before the stage was reached where it was severely affecting the growth of the ground vegetation.

3.5.1.1.1 Discussion of methods

When dealing with a rare and difficult-to-sample species such as L.agilis an experimental technique is needed which produces a large amount of information from relatively few observations of animals. The comparison of sets of lizard and random quadrats is one way of obtaining such data.

Overall these experiments have provided some useful observations on the habitat use of L.agilis within compartments. However, from the difficulties associated with interpreting the data from East Gore it is clear that the study areas used within this site were neither large enough nor uniform enough to produce clear results from this type of study. Morden Site was itself small (approximately one hectare) but because it was relatively uniform in terms of tree and vegetation cover it provided the most readily interpretable and useful data of all four study areas.

Of the variables measured in each experiment characteristics of both the vegetation and the tree cover appear to be useful in separating the lizard and random groups. The use of hemispherical photographs to measure canopy cover and the number of sunshine hours received (2.6.1.1.4) has shown no importance in separating the groups. Neither has the measure of vegetation 'structure' calculated from the vegetation in the immediate vicinity of the lizard or random point (2.6.1.1.3). In both these cases the measure used may simply have been too detailed and too refined for the situation it was applied to. It has previously been shown that L.agilis preferred a structurally diverse habitat (House & Spellerberg 1983) in terms of borders between vegetation types and between vegetation and open ground. However, with the point quadrat system used here, the important major changes in the vegetation height (i.e. from C.vulgaris bush to ground etc.) were probably being swamped by the many smaller changes which occurred between adjacent quadrat points within the vegetation itself.

For the Hedge area of East Gore the quadrats used show no discrimination between the lizard and random groups. This may mean that L.agilis was randomly distributed throughout the Hedge habitat. However, it is more likely that the variables assessed failed to pinpoint those characteristics which were relevant to the distribution of L.agilis within the Hedge habitat. The quadrats used in the Hedge study area were the same as those used on Morden Site and on East Gore Main Slope and Pond Bank. These quadrats were designed to assess the habitat of these latter compartment-like situations and not that of a linear habitat such as a hedge. For the Hedge habitat a simple measure of species cover and particularly of the height and % cover of the shrub species present, along with a measure of the width of the hedge may have provided more useful information.

3.5.1.2 Compartment habitat survey

The habitat survey of East Gore assessed the habitat available to L.agilis on a much larger scale than the lizard vs. random quadrats described above.

The results from the habitat survey of East Gore show that the available habitat types were not often used randomly. Overall the results show that for most years particular habitat types were used more frequently than would be expected from the random distribution. There was some evidence of seasonal changes in habitat type use within each year and also of considerable difference in the pattern of habitat type use between years.

The most striking overall trend found was the strong tendency for L.agilis to be associated with the Dry habitat type more frequently and the Open habitat type less frequently than expected from the random distribution. The latter may initially appear surprising, but it must be remembered that in this survey the Open habitat type consisted of open ground with P.aquilinum and brashing (discarded pine branches). That is, the type of ground cover found underneath pine trees with a closed canopy. This habitat type was well represented in the random quadrats because it occurred extensively around the periphery of the study area. However, as Open seldom incorporated any ground covering vegetation and therefore included no habitat it is not surprising that it was poorly represented in L.agilis squares.

The 1982 and 1983 seasons show some interesting differences in patterns of habitat type use through the seasons. The strong association between L.agilis and a Dry vegetation type was particularly noticeable in the spring (March/April/May) of 1983 when 60% of the L.agilis sightings were associated with a Dry vegetation type. In 1982 if data from March and April only were used, 50% of the lizard sightings were associated with a Dry habitat, if May was included in the analysis the figure was reduced to 36%. This difference between 1982 and 1983 may be explicable in terms of the different weather conditions in the spring of 1982 and 1983. In 1983 there was a particularly wet spring and the Pond Bank area and half the Damp Heath remained under water until early June. In 1982 only the Pond Bank area was flooded and this had dried by mid April. The particularly strong association with Dry vegetation types in the spring of 1983 may be a reflection of the inability of L.agilis to colonise the damp/wet areas, and may be an indication of a migration in the spring from dry winter hibernacular to a wider distribution encompassing damper habitats in the summer. Because of the drier spring in 1982, this migration may have started earlier and hence the reduction in the importance of the Dry vegetation type between the March/April and the March/April/May distributions in that year. In the spring of 1983, while the Dry habitat was the most frequently used habitat type, those which showed the greatest reduction in use compared to the summer distribution were UE/R, Grass and Ride. The topography of East Gore was such that the main route for colonisation of these ride edge habitats was via the Pond Bank region. The flooding of this area may have then prevented the colonisation of the ride edge area until the summer of 1983. The inference which may be drawn from this is that the ride verge and hedge habitats were not frequently used for winter dormancy but were mainly summer habitats. Also in 1982, the autumn and overall yearly distributions of L.agilis with reference to Habitat types were not significantly different from random ones, whereas in 1983 all L.agilis distributions were significantly different from random. This may be a further indication of the greater mobility of L.agilis across the site as a whole in 1982 as opposed to 1983. It also indicates a tendency to move from localised habitat types to a more general, and in this case random, distribution as the year progresses (and and the conditions available in alternative habitat types improve).

Although the degree of association of L.agilis with a Dry vegetation type was reduced in the summer it was still an important habitat. The autumn distribution of L.agilis does not appear to be related to that in the spring so that any movement to winter hibernacular, if this is what was reflected by the spring distribution does not appear to occur until late in the year.

In terms of tree cover, overall L.agilis was associated more frequently with the lower tree density and smaller tree height categories than the random squares. There was also some evidence of seasonal changes in the pattern of habitat use with regard to tree height and density. Particularly in terms of tree density there appears to be a movement towards the low density classes from spring to summer. The distributions of L.agilis in the spring and autumn of 1982 relative to tree density were not significantly different from random whereas that in the summer was. This may be because on East Gore the Dry habitat types (favoured by L.agilis in the spring) are associated with the failed crop area of Main Slope where most of the tree cover was located. A movement to the damp/wet habitat types in the summer would also entail a movement to areas of lower tree height and density. There is also some evidence of a return movement to the spring habitat in the autumn in relation to tree density. It cannot however be assumed that the causal relationship was functioning in this way, i.e. that movements in relation to habitat type were solely responsible for changes in the pattern of tree cover use, the reverse could also be the case. Lizards were infrequently found associated with trees higher than 5m or denser than 12 per square (25 m^2). Overall tree density appears to be a better measure for assessing lizard distribution in relation to tree canopy cover than tree height.

3.5.1.2.1 Discussion of Methods

For the purposes of a general survey such as this, the presence of a large number of different habitats within a small area, as found at

East Gore was an advantage rather than a disadvantage. The presence of a fairly dense population of L.agilis or of one that was at least 'apparent' to an observer, meant that East Gore was an ideal site for a General Survey such as that described here. In fact those characteristics which made East Gore unsuitable for a comparison using lizard vs. random quadrats made it a suitable area for a general survey of the type described here.

3.5.2 HABITAT USE ALONG PLANTATION RIDE VERGES

3.5.2.1 Ride habitat survey

The sources of variation within a ride verge habitat can be divided into three main categories:

(i) characteristics associated with the vegetation of the verge itself.

(ii) characteristics associated with the tree canopy cover above the verge.

(iii) physical characteristics of the verge itself (such as the verge width or bank height).

The last two categories are somewhat ambiguous. For instance, the width of the adjacent verge could be included in both classes, being of direct relevance to the area of habitat available (iii) and also contributing to the influence of tree canopy cover (i.e. the wider the verge the further away the trees of the opposite plantation).

Overall it was clear that the distribution of L.agilis within the ride verge habitat was significantly different both from a random distribution and from the distribution of L.vivipara. In the CVA in particular, the distribution of L.vivipara was significantly different from random for all three years but it was clear that the distribution of L.vivipara varied considerably less strongly from random than that of L.agilis. In general, characteristics from each of the three categories above were important in distinguishing between the distributions of L.agilis and L.vivipara in respect to the habitat randomly available.

From the CVA it is clear that the distribution of L.agilis was strongly associated with the dominance of C.vulgaris in the vegetation. Other features of the vegetation which were also associated with the L.agilis groups were the dominance of E.cinerea, P.aquilinum, V.myrtillus and of dead ericaceous plant species. In contrast L.vivipara was associated with the dominance of E.tetralix, M.caerulea, U.minor and of grass species. It appears that L.agilis was most frequently found associated with dry heathland vegetations and in particular with those dominated by C.vulgaris. On the other hand L.vivipara was associated with the damper ericaceous heathland vegetations and also with areas dominated by M.caerulea and by grass species.

The CVA included a number of variables which might have been influencing the distribution of L.agilis or L.vivipara because of their relevance to the effect of the tree canopy cover. These included all the plantation/ride/Ride verge measurements used to compute the seasonal number of sunshine hours received (see Section 2.6.3.4). In 1982, the height of the trees of the opposite plantation was associated with the L.vivipara/random group but this was the only clear pattern to emerge from the above measurements. In contrast there was a clear significant difference between the seasonal number of sunshine hours received by the L.agilis and L.vivipara groups in comparison with the random one. It does not appear that any one ride or tree canopy characteristic was especially important in determining the amount of shade received by a Ride verge. Hence it was only by looking at the net effect of all the measurements (i.e. the seasonal number of sunshine hours) that a meaningful relationship could be obtained.

There was no significant difference between the seasonal number of sunshine hours received by the L.agilis and L.vivipara groups. There were however significant differences between the L.agilis and L.vivipara groups with respect to the aspect of Ride verges used. In 1981, the distribution of L.agilis was not significantly different from random but that of L.vivipara was (with respect to aspect). The area searched in 1981 was small compared to that used in 1982 and 1983 and as these results may indicate, the area used was composed largely of aspects suitable for use by L.agilis. It may be that the strong association between L.vivipara and south facing rides was a result of experimental bias due to an association between available habitat for L.vivipara and south facing aspects within the area being searched. Overall, L.vivipara was found on rides with a greater range of aspects than L.agilis. Unfortunately little data was available for juvenile L.agilis, for L.vivipara there was little difference between the distribution of all lizards seen and that of juveniles.

It is noteworthy that there was a significant difference between L.agilis and L.vivipara with regard to the aspect of the ride verges used but not with regard to the seasonal number of sunshine hours received by the Ride verges used (although the seasonal number of sunshine hours received was greater for the L.agilis than the L.vivipara group). This may suggest that the time of the day at which the sun is hitting a Ride verge (and therefore the level of radiation received from the sun) may be more important to L.agilis than L.vivipara. A Ride verge which received the sun from 0600 to 1200 would receive overall less radiation than one which received the sun from 0900 to 1500, although both areas would receive the same number of sunshine hours in a day.

3.5.2.1.1 Discussion of methods

As for the habitat survey of East Gore, dealing with habitat on a large scale appears to be a more successful way of interpreting overall lizard habitat preferences than trying to assess the minute details of habitat use.

To some extent a clearer pattern may have emerged if more 'overall' categories had been used in the CVA rather than simply the individual measurements. For instance, the seasonal number of sunshine hours received could have been included in the CVA and all its constituent values removed. However the CVA and the survey were done as a general assessment of habitat to see if any single factors of the ride verge or surroundings in particular were influencing the distribution of L.agilis and L.vivipara. Also, using discrete measurements avoided the possibility of biasing the results obtained according to the expected outcome, which might be possible if the variables used in the CVA were only those values or estimates which were 'thought' to be important to the distribution of L.agilis and L.vivipara.

3.5.3 SUMMARY

Overall it was clear that the distribution of L.agilis within Compartment and Ride verge habitats was affected by characteristics of both the vegetation at ground level and the surrounding tree canopy cover.

Within both Compartments and Ride verges L.agilis was strongly associated with a C.vulgaris dominated, dry heathland vegetation. Within this vegetation type L.agilis was associated with the presence of open ground (within the vegetation) and the presence of other species such as E.cinerea (i.e. areas where C.vulgaris was not present as a monoculture).

Where other heathland vegetation types were available adjacent to a dry heathland area these were used by L.agilis. There was evidence of seasonal movements into such areas presumably when the microclimate within them was suitable. For instance an area of M.caerulea bog was used in the late spring and summer when it was quite dry, but not during the spring when it was flooded at ground level.

Within Compartments the distribution of L.agilis was affected by the presence of tree canopy cover, the best measurement of this apparently being the DBH of the trees, or on a larger scale the density of the surrounding trees.

Within the Morden Rides study area where large areas of different habitat types were available, L.agilis showed a strong association with C.vulgaris dominated areas. There appeared to be a strong separation between the habitat niches of L.agilis and L.vivipara particularly with regard to vegetation type. In particular, L.vivipara was associated with E.tetralix, M.caerulea, U.minor and grass dominated vegetations.

The differences between L.agilis and L.vivipara with regard to the affect of tree canopy cover on their distribution along ride verges were less clear cut. There was some evidence that overall L.vivipara was less restricted than L.agilis particularly with regard to the aspect of the rides used. This may be an indication that compared with L.vivipara, L.agilis occurs on rides which receive the sun during the hottest parts of the day - although the two species did not occur on rides which received significantly different numbers of sunshine hours per season.

CHAPTER FOUR

ACTIVITY AND BEHAVIOUR IN RELATION TO WEATHER AND SEASON

4.1 INTRODUCTION

Lizards are ectotherms, that is they use external sources of heat to maintain high and often very precise body temperatures. The most frequently used source of heat is solar radiation (these lizard species are termed heliothermic) but other source of heat used include that from hot rocks or substrata (thigmotherms) or from hot springs or geysers when they are available (Avery 1979). Thermal homeostasis in lizards was first demonstrated by Cowles & Bogert (1944) and has since been the subject of much interest (reviewed by Avery 1982 & Huey 1982). The degree of precision with which the body temperature is maintained varies, in some lizard species the body temperature of active lizards closely follows any changes in the ambient temperature (eurythermy or thermoconforming, Huey 1982) in others the precision of thermoregulation varies between habitat types (Lee 1980, Huey 1974).

Both L.agilis and L.vivipara are 'shuttling heliotherms'. That is they use solar radiation as their main source of heat for thermoregulation and they maintain their body temperature within the required limits by 'shuttling' between sun and shade areas, moving into the sun when the body temperature falls too low and into the shade when it is too high.

A number of parameters have been used to describe the thermal range and limits of lizard species These are summarised below and in each case the fist listed term is that used in the remainder of the text.

(i) Preferred or Eccritic (selected) body temperature.

This is the temperature which a lizard will select if placed in a cage with a range of temperatures from hot to cold. The preferred body temperature (PBT) usually differs between species and can differ within a species between seasons.

(ii) Activity Range (Avery 1979) or Thermal Performance Breadth (Huey 1982)

This is the range of body temperatures over which a lizard species may show active behaviour such as foraging.

(iii) Critical Minimum Temperature

The lower body temperature at which locomotory activity is disorganised or lost (Spellerberg 1976). This is usually quantified as the temperature at which a lizard is no longer able to right itself if placed on it's back.

(iv) Critical Maximum Temperature

When the body temperature of a lizard rises, a point is reached when the animal is torpid and no longer moves or breathes and appears to be dead. This state defines the critical maximum temperature and is reversible if the body temperature is lowered.

The values of each of the above mentioned parameters available for L.agilis and L.vivipara are listed in Table 4.1. There is a considerable spread of figures available for each species, however for those studies which included both L.agilis and L.vivipara, the former had a slightly higher PBT and Critical Minimum Temperature than the latter.

There is also some evidence of seasonal changes in the thermoregulatory needs of L.agilis and L.vivipara. In the laboratory the PBT of L.vivipara was greater in April than in the summer in males and greater in May than in the summer for females, the PBT of both males and females was also greater in the autumn than in the summer (Patterson & Davies 1978a). However the mean body temperature of animals caught in the field (in Denmark) was lower in May than July for both L.agilis and L.vivipara (Sveegaard & Hansen 1976).

The species richness of lizards is greater in tropical and desert areas than in temperate zones. Moving north or south of the tropics lizard abundance and species diversity decrease (Avery 1978). As lizards are dependent on external sources of heat it is possible that a temperate climate restricts lizard activity much more than a tropical one. On a daily basis, lizards in temperate climates are limited to diurnal activity and seasonally they must undergo a period of dormancy through the winter months when there is not enough heat available from external sources for them to maintain a body temperature at which they can be active.

L.vivipara has the most northerly distribution known for any lizard species (Avery 1976). Although L.agilis and L.vivipara are sympatric over much of their geographical range (Figs 1.1 & 1.2), L.agilis is less widespread than L.vivipara and has a more southerly distribution. In Britain L.agilis appears to be at the north western edge of its distribution, the limited and fragmented distribution of L.agilis in Britain (Fig. 1.3) may be due in part to thermoregulatory limitations.

If L.agilis and L.vivipara were found in the same habitat and microclimate, five variables could be used to summarise the relative

Table 4.1 Activity in relation to weather and season, Introduction.
A summary of important termoregulation parameters for L.agilis and L.vivipara.

		L.agilis	L.vivipara	Source
1. Mean Body Temperature	- May	33.7	32.3	Sveegaard & Hansen 1976
	- July	34.6	34.0	
2. Preferred Body Temperature		31.0	32.0	Spellerberg 1976
		33.3	32.1	Sveegaard & Hansen 1976
		33.4		Liberman & Pokrovskaja 1943
			30.2±2.5	Avery 1971
		29.8		Tertyshnikov 1976
	- Spring		32.4 (♂)	
			27.3 (♀)	
	- Summer		30.0 (♂)	
			28.2 (♀)	
	- Autumn		32.5 (♂)	
			32.1 (♀)	Patterson & Davies 1978a
3. Activity Range		23 - 38	22 - 38	Spellerberg 1976
		28 - 35		Liberman & Pokrovskaja 1943
		14 - 39		Tertyshnikov 1976
4. Critical Minimum	- May	3.6	1.6	
	- July	4.2	2.5	Sveegaard & Hansen 1976
		5.9	2.8	Spellerberg 1976
		7.5		Libermann & Pokrovskaja 1943
5. Critical Maximum		43.0		Grazhdankin 1973
		41.6		Libermann & Pokrovskaja 1943

thermoregulatory ability of the two species:

(i) metabolic rate

(ii) surface area

(iii) absorptivity of body surface

(iv) rate of heat transfer within the body (i.e. body diameter)

(v) rate of moisture loss (Porter & Gates 1969)

The known values of these variables for L.agilis and L.vivipara are given in Table 4.2.

Morphologically, L.agilis is a larger animal than L.vivipara, it therefore has a smaller surface area:volume ratio and a greater body diameter than L.vivipara. This means that relative to its bulk L.agilis has a smaller surface area over which to absorb heat and a greater volume through which the heat must transfer in order to heat the whole body. However, because of its larger volume, once heated L.agilis will cool more slowly than L.vivipara. The metabolic rate of L.agilis is slower than that of L.vivipara and may therefore contribute less to the body heat of L.agilis. However, L.agilis loses less moisture than L.vivipara through the skin, which not only reduces heat loss due to moisture evaporation but also enables L.agilis to inhabit drier and hotter microclimates than L.vivipara (Glandt 1979). Nothing is known about the ability of the skin of the two species to absorb thermal radiation.

Thus there is evidence of differences in the thermoregulatory capacities of L.agilis and L.vivipara, both in terms of their PBT and the thermoregulatory ability of the two species to achieve that PBT. The main points are summarised below:

(i) L.agilis has a more restricted and southerly geographical distribution than L.vivipara

(ii) L.agilis has a higher PBT than L.vivipara (measured in the laboratory)

(iii) L.agilis has a higher mean body temperature than L.vivipara (measured in field)

(iv) L.agilis has a greater surface area:volume ratio than L.vivipara and therefore heats more slowly than L.vivipara under the same conditions

(v) L.agilis has a lower metabolic rate than L.vivipara which probably contributes less heat to the body heat in L.agilis than L.vivipara

(vi) L.agilis has a greater body diameter and volume than L.vivipara and therefore once warm L.agilis looses heat more slowly

Table 4.2 Activity in relation to weather and season, Introduction.

A summary of the known measurement of variables important to the thermoregulatory ability of lizards, for *L.agilis* and *L.vivipara*.

1. *Metabolic rate* (cm^3/100g/hr)

		L.agilis	*L.vivipara*
at 35°C	- summer	53.3	68.5
	- winter	39.3	44.8

Sveegaard & Hansen 1976 (Denmark)

2. *Surface area*

	L.agilis	*L.vivipara*
Mean Adult Snout to vent length (cm)	7.5	5.0
Mean Adult Weight (g)	10.0	4.0

Arnold & Burton 1973, Nicholson 1980, Frazer 1983

3. *Absorptivity of skin surface*

no known measurements

4. *Rate of transfer of heat within the body*

Being a larger animal, *L.agilis* has a greater body diameter and therefore a slower rate of heat transfer within it.

5. *Rate of moisture loss*

L.agilis is better able to retain moisture in its body than *L.vivipara*

Glandt 1979

than L.vivipara

(vii) L.agilis looses less moisture through the skin than L.vivipara and therefore looses less heat due to evaporative cooling at the skin surface.

The aim of this chapter was to establish the degree to which L.agilis was restricted by its thermoregulatory requirements and ability when compared to L.vivipara. This was done by comparing the activity and behaviour patterns of L.agilis and L.vivipara relative to weather conditions and also relative to season.

Section 4.2 deals with the large-scale seasonal behaviour and activity patterns of L.agilis and L.vivipara. The time and weather conditions of emergence from and disappearance into winter dormancy were compared between the two species. A similar comparison was made of the timing of the emergence of juveniles of each species in the late summer. Data was available for L.agilis only on the time of mating and oviposition.

Section 4.3 looks at the daily activity patterns of L.agilis and L.vivipara in relation to weather conditions and season. Seasonal changes in the time of morning emergence have been looked at together with comparisons between the activity of the two species in relation to weather (expressed at air temperature and net radiation).

Section 4.4 uses data from the L.agilis radio-tracked on East Gore in 1982 and 1983 to investigate the relationship between behaviour and weather and to show how this relationship changes both on a daily and a seasonal basis. Particular attention was given to the conditions under which a 'flattened basking posture' was used.

Section 4.5 looks at the relationship between the rate at which L.agilis were sighted while searching and the weather conditions which were prevalent while searching. This was a measure of the 'apparency' of L.agilis to the searcher in relation to weather conditions rather than one of the level of activity of L.agilis.

4.2 SEASONAL ACTIVITY

4.2.1 INTRODUCTION

In this section data from the Morden Rides and East Gore study areas and from all three years of study (1981, 1982 & 1983) have been used. Data was available for both L.agilis and L.vivipara in most cases.

For convenience the timing of seasonal behaviour patterns was expressed per month quarter, each month was divided into four quarters of seven or eight days each (section 2.7.1). The timing of emergence from winter dormancy or of the birth or hatching of juveniles was defined as that quarter of the month when the fifth specimen was seen. Disappearance into winter dormancy was defined as that quarter of the month after which no more than four specimens were seen (see sections 2.7.1.1 & 2.7.1.2).

The weather data used was maximum air temperatures and maximum daily levels of solar radiation per quarter of the month (section 2.7.1). Data was available on the time and overall weather conditions under which both L.agilis and L.vivipara emerged from and disappeared into winter dormancy (sections 4.2.2 and 4.2.4 respectively).

For L.agilis data was also available on the time of occurrence of mating and oviposition (section 4.2.3). Data on the time of emergence of juveniles was available for both L.agilis and L.vivipara (4.2.3).

RESULTS

4.2.2 EMERGENCE FROM HIBERNATION

L.agilis : East Gore 1982 & 1983, Morden Rides 1982
L.vivipara : Morden Rides 1982

Methods : 2.6.1.1

Table 4.4 summarises the order and the weather conditions under which the various age and sex classes of L.agilis and L.vivipara emerged from winter dormancy.

In 1982, L.vivipara adults were the first to emerge (Table 4.3; Fig. 4.1), at maximum daily temperatures of 11.0 ^{o}C and at a maximum daily solar radiation of 140 Wm^{-2}. Male L.agilis appeared next (Table 4.4; Fig. 4.1) when maximum air temperatures reached 10-12 ^{o}C and maximum daily solar radiation 180 Wm^{-2}. In 1981, L.vivipara sub-adults emerged a week later than those of L.agilis but under similar weather conditions (Table 4.4). Females of L.agilis emerged latest, at maximum temperatures of 19^{o}C and daily maximum solar radiations of 220-250 Wm^{-2} (Table 4.4).

All age classes of L.agilis emerged from winter dormancy later in 1983 than in 1982 (Table 4.3; Fig. 4.1).

Table 4.3 Seasonal activity of L.agilis and L.vivipara, Emergence from winter dormancy.

The time of emergence from winter dormancy (month quarters) for males, females and sub-adults of L.agilis and for adults and sub-adults of L.vivipara.

		1982	1983
L.vivipara			
	- adult	I/3	
	- sub-adult	I/4	
L.agilis			
	- female	III/4	I/5
	- male	III/3	IV/3
	- sub-adult	IV/3	II/4

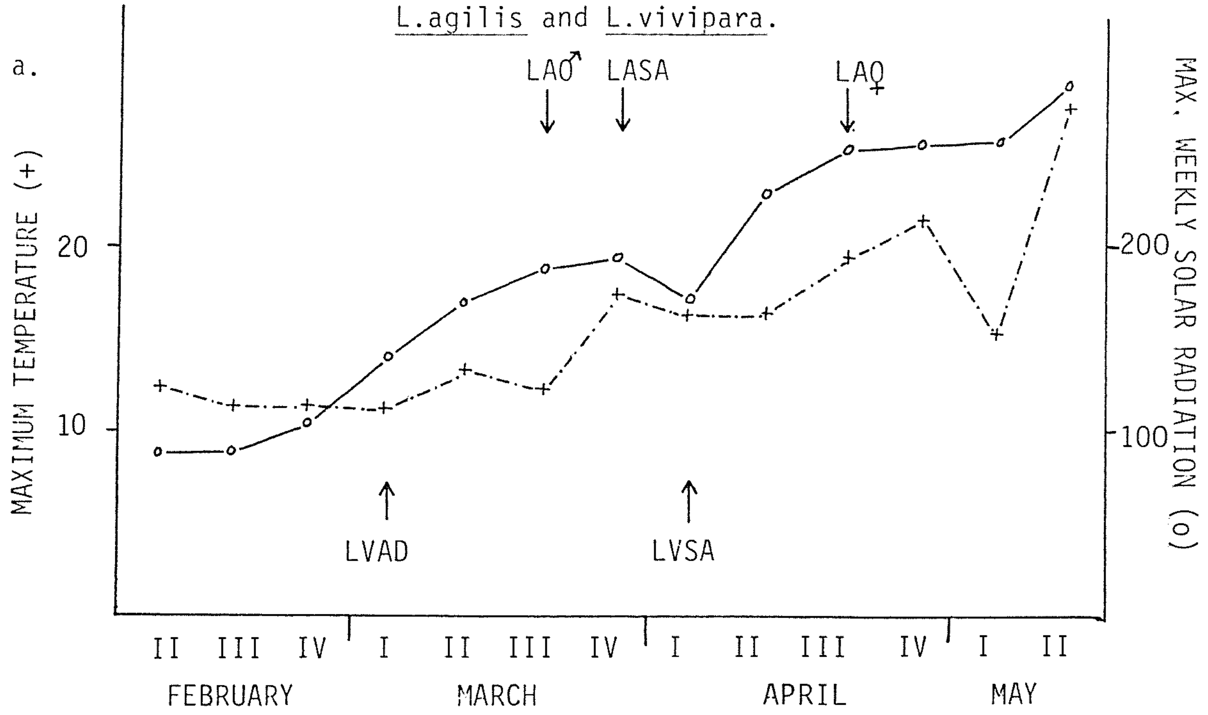
Table 4.4 Seasonal activity of L.agilis and L.vivipara, Emergence from winter dormancy.

Summary of weather conditions under which male (M), female (F) and sub-adult (SA) L.agilis and adult (AD) and sub-adult (SA) L.vivipara emerged from winter dormancy.

Order of Emergence	Maximum temperature (°C) (per month quarter)	Maximum daily solar radiation (Wm^{-2}) (per month quarter)
1. L.vivipara - AD	11.0	140
2. L.agilis - M	10.0 - 12.0	180
3. L.agilis - SA	15.0 - 17.0	190 - 230
4. L.vivipara - SA	17.0	190
5. L.agilis - F	19.0	220 - 250

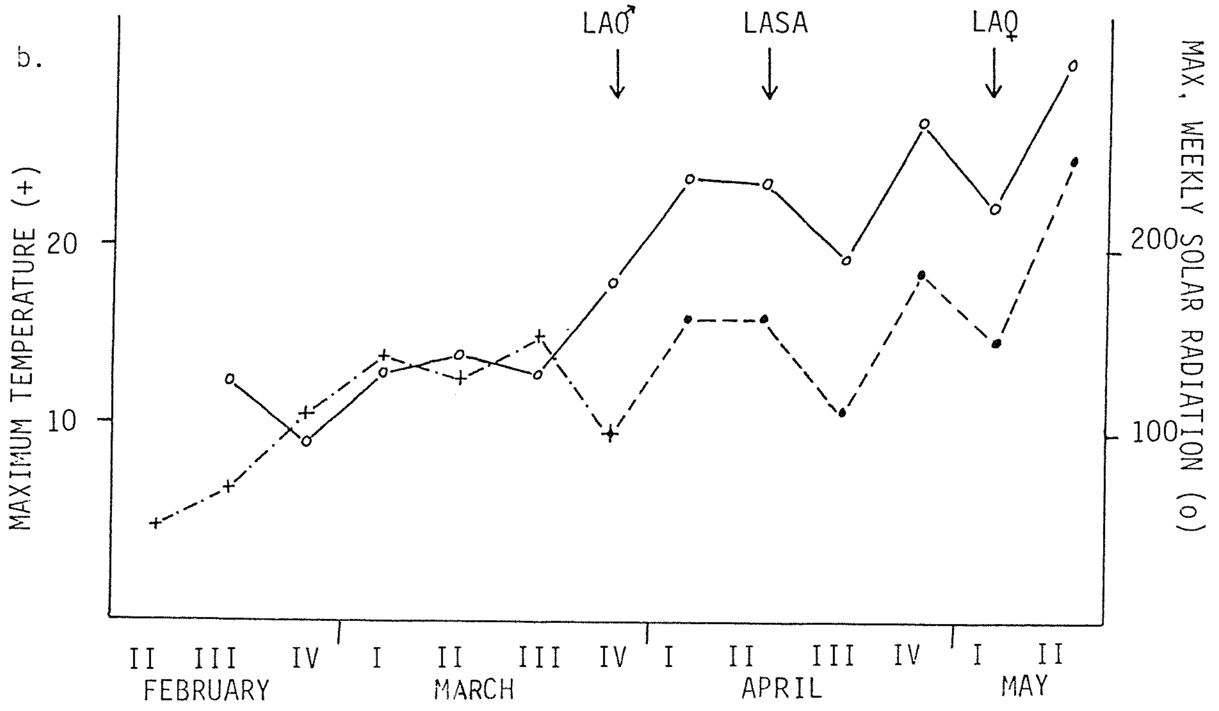
Fig. 4.1 Seasonal activity of L.agilis and L.vivipara.
Emergence from winter dormancy.

Graph of the maximum air temperature (+; ^{0}C) and maximum daily solar radiation (o; Wm^{-2}) per month quarter for the spring of a. 1982 and b. 1983. Arrows show the times of emergence from winter dormancy of L.agilis and L.vivipara.



LA♀ = L.agilis females
LA♂ = L.agilis males
LASA = L.agilis sub-adults

LVAD = L.vivipara adults
LVSA = L.vivipara sub-adults



4.2.3 MATING, EGG LAYING AND EMERGENCE OF JUVENILES

L.agilis : East Gore and Morden Rides 1981,1982 & 1983
L.vivipara : Morden Rides 1981, 1982 & 1983 (emergence of juveniles only)
Methods : 2.7.1.2

The formation of pairs of male and female L.agilis was recorded in the same quarter as that in which the females emerged in 1982 and two weeks later than emergence in 1983. Egg laying occurred in early to mid June in 1982 and mid to late June in 1983 and juveniles were observed three weeks earlier in 1982 than in 1983 (Table 4.5).

In 1981 juvenile L.vivipara were seen four weeks prior to juvenile L.agilis whilst in 1982 juveniles of both species appeared in the same quarter of August and in 1983 juvenile L.vivipara were observed six weeks before those of L.agilis (Table 4.5).

4.2.4 DISAPPEARANCE INTO WINTER DORMANCY

L.agilis & L.vivipara : East Gore and Morden Rides 1981,1982 and 1983
Methods : 2.7.1.3

Adult L.agilis were the first to go into winter dormancy in all years, during late August and early September. In 1981 and 1983 male L.agilis disappeared three month quarters before the females (Table 4.6). Male L.agilis disappeared at maximum air temperatures of 21^{o}C and daily maximum solar radiations of 250 to 290 Wm^{-2}. Female L.agilis remained until the daily solar radiation was 240 to 250 Wm^{-2} and the temperature 20 to 21 ^{o}C (Table 4.7, Fig. 4.2). Adult L.vivipara disappeared at maximum temperatures between 18 and 20 ^{o}C and net radiations between 110 and 130 Wm^{-2}. Juveniles of both species went into winter dormancy in late October at temperatures of 14 ^{o}C and daily solar radiations of 80 to 100 Wm^{-2} (Table 4.7).

4.3 DAILY ACTIVITY PATTERNS

4.3.1 INTRODUCTION

This section includes all information collected concerning the daily activity patterns of L.agilis and L.vivipara. Comparisons have been made both between the two species and within each species between seasons with respect to:

- the time of morning emergence (4.3.2)
- activity in relation to weather and season (4.3.3)

Section 4.3.2 is a comparison of the times of morning emergence of

Table 4.5 Seasonal activity of L.agilis and L.vivipara, Mating, egg laying and emergence of juveniles.

The time (month quarter) of mating and oviposition for L.agilis and of emergence of juveniles for L.agilis and L.vivipara

	1981	1982	1983
L.agilis			
Mating		III/4-IV/5	III/5-II/6
Egg laying	I/7	I/6-III/6	II/6-IV/6
Juveniles	II/9	II/8	I/9
L.vivipara			
Juveniles	II/8	II/8	IV/7

Table 4.6 Seasonal activity of L.agilis and L.vivipara, Disappearance into winter dormancy.

The time of disappearance into winter dormancy (in month quarters) of male, female and juvenile L.agilis and of adult and juvenile L.vivipara.

	1981	1982	1983
L.vivipara			
- juvenile	IV/10	IV/10	III/10
- adult	I/10	I/10	II/10
L.agilis			
- juvenile	III/10	IV/10	II/10
- male	IV/8	II/9	I/9
- female	II/9	II/9	III/9

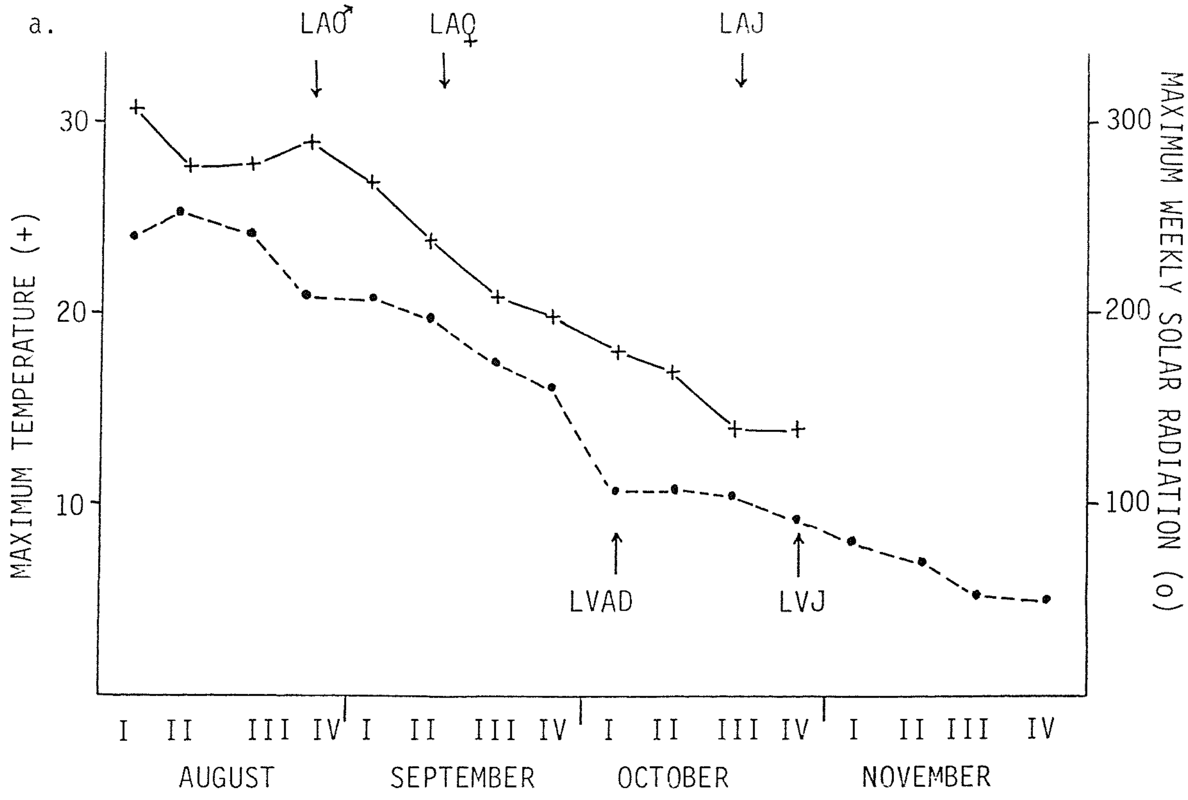
Table 4.7 Seasonal activity of L.agilis and L.vivipara, Disappearance into winter dormancy.

The order and weather conditions prevalent at the time of disappearance into winter dormancy for male (M), female (F) and juvenile (J) L.agilis and for adult (AD) and juvenile (J) L.vivipara.

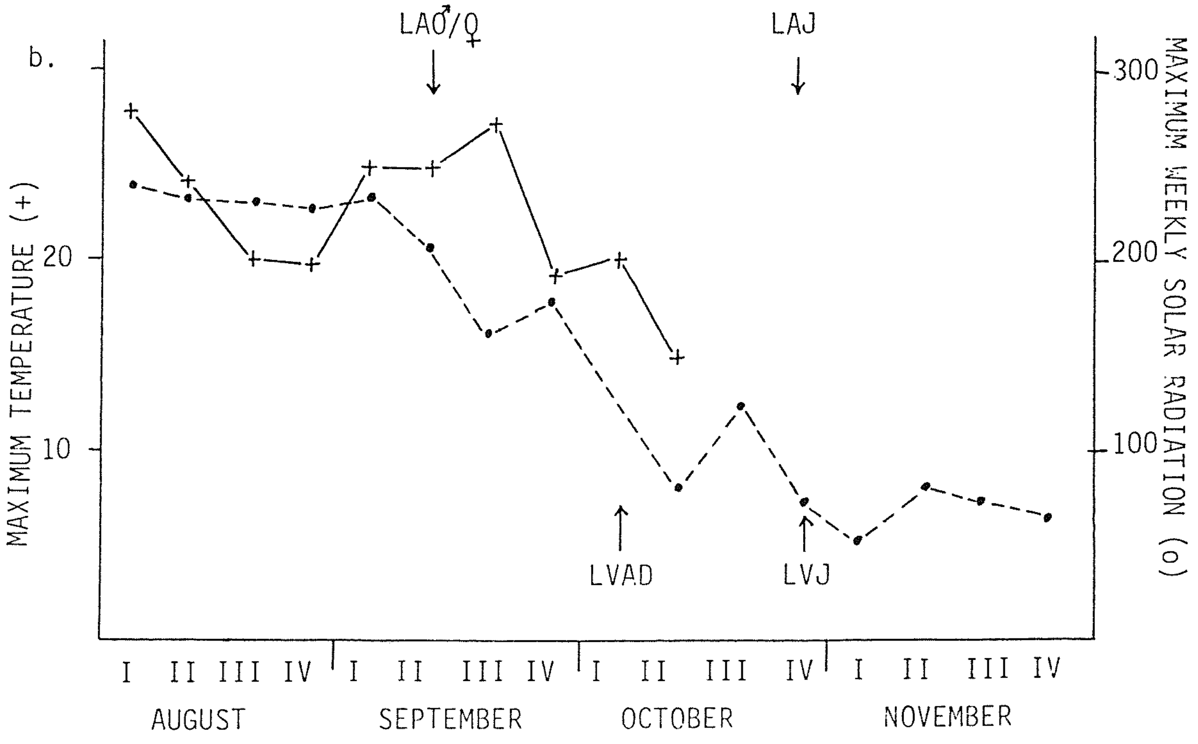
		Maximum temperature (°C)	Maximum solar radiation (Wm^{-2})
1. L.agilis	- M	21	250 - 290
2. L.agilis	- F	20 - 21	240 - 250
3. L.vivipara	- AD	18 - 20	110 - 130
4. L.agilis	- J	14	80 - 100
5. L.vivipara	- J	14	80 - 90

Fig. 4.2 Seasonal activity of _L.agilis_ and _L.vivipara_.
Disappearance into winter dormancy.

Graph of the maximum air temperature (+; °C) and maximum daily solar radiation (o; Wm^{-2}) per month quarter for the autumn of a. 1981 and b. 1982. Arrows show the times of disappearance into winter dormancy of _L.agilis_ and _L.vivipara_. For notation see Fig. 4.1.



LAJ = _L.agilis_ juveniles   LVJ = _L.vivipara_ juveniles



L.agilis and *L.vivipara* throughout their yearly active season. Data from days with clear, sunny mornings only were used and only the earliest sighting in each week was used (see Chapter Two, section 2.7.2.1) to construct Figs 4.3 and 4.4. Data from both study areas and from all years have been combined.

Section 4.3.3 deals with the basic question of how the activity of *L.agilis* and *L.vivipara* was related to the weather conditions available. This section was complicated because it has three sub-sections, each of which consists of a number of discrete sets of data which could not be combined to produce one overall picture but had to be looked at separately. The structure of section 4.3.3 is outlined below:

4.3.3 ACTIVITY IN RELATION TO WEATHER AND SEASON

4.3.3.1 Summer activity of *L.agilis* and *L.vivipara* in relation to season

4.3.3.1.1 Summer activity of *L.agilis*
    (i) from radio-tracked animals on East Gore, 1982 & 1983.
4.3.3.1.2 Summer activity of *L.agilis* and *L.vivipara*
    (i) from repeated walks of Morden Rides, 1983.
    (ii) from searching of Morden Rides, June to August 1982.

4.3.3.2 Autumn activity of *L.agilis* and *L.vivipara* in relation to weather
    (i) from repeated walks of Morden Rides, 1983.
    (ii) from searching of Morden Rides, September 1982.

4.3.3.3 Seasonal activity of *L.agilis* in relation to temperature
    (i) searching of East Gore, 1983.

The data used in this section comes from three main sources. Firstly that collected while searching the East Gore and Morden Rides study areas in connection with the habitat study (see 2.2.1). Secondly that collected while carrying out radio-tracking on East Gore (see 2.4) and thirdly that collected by doing 'repeated walks' of selected rides within the Morden Rides study area (see 2.7.2.2.2; Table 2.7). Each of these investigations provided information on the weather conditions encountered while searching and those when sightings of *L.agilis* and

L.vivipara were made. In this way a comparison could be made between the conditions available and those under which lizards were seen. Information from the radio-tracking study was particularly useful as when radio-tracking an animal it was generally possible to ascertain quite accurately whether the animal was 'visible' or not. When searching the habitat in general it would be easy to miss animals which were active or even basking. However, because the radio-transmitter allowed the area in which the animal was found to be located to a quite precise degree it was possible tell with considerable accuracy whether the animal was active or not.

Where both temperature and net radiation measurements were available the data was presented by plotting each L.agilis or L.vivipara sighting relative to these two weather variables. By also plotting the conditions encountered while searching on the same graph it was possible to compare the conditions under which lizards were seen with those when they were not. Where only measurements of air temperature were available a frequency histogram was plotted comparing the range of temperatures when searching with that when lizards were seen. A chi-square distribution was used to test for the significance of the difference between the two distributions.

RESULTS

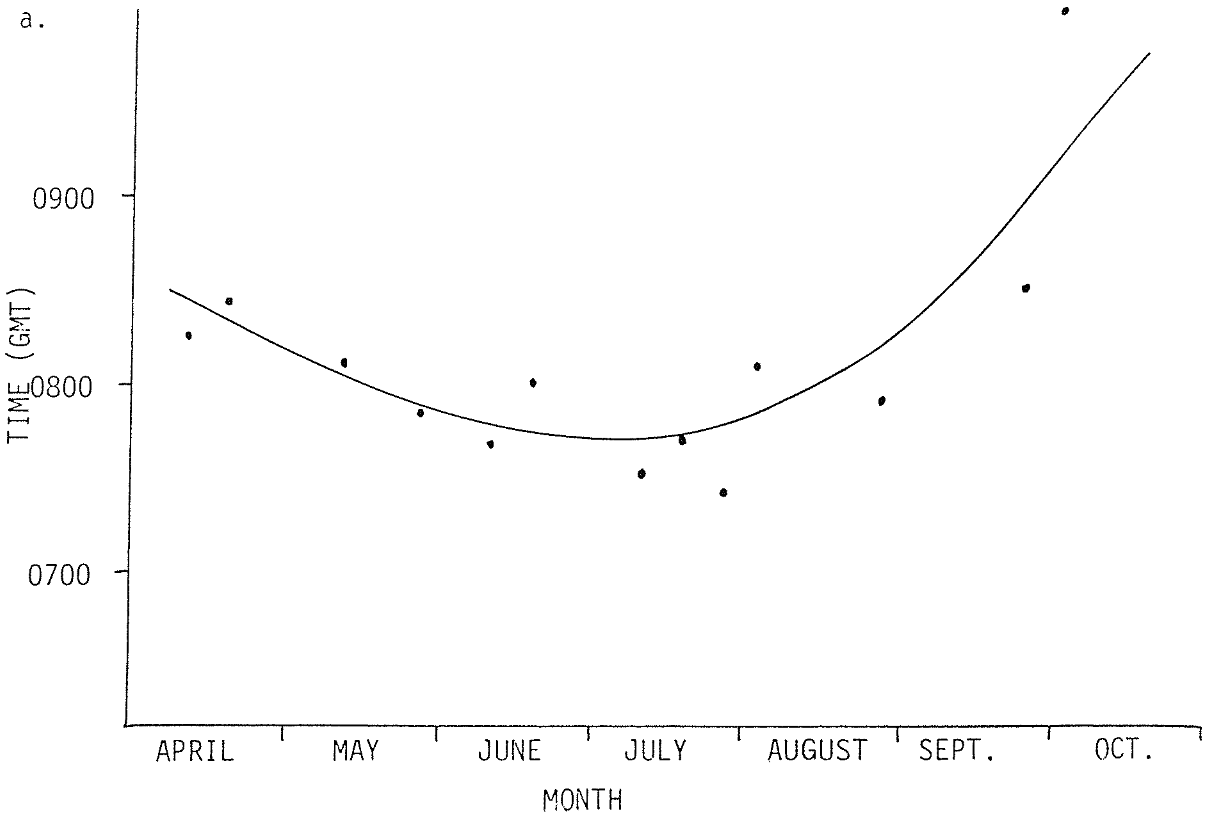
4.3.2 MORNING EMERGENCE

L.agilis : East Gore and Morden Rides, 1981,1982 & 1983
L.vivipara : Morden Rides, 1981, 1982 & 1983
Methods : 2.7.2.1

Emergence on clear sunny days occurs progressively earlier in the day from spring to summer and occurs earliest in June and July. The pattern of changes in daily emergence times is the same for both species and for adults and sub-adults/juveniles (Fig. 4.3, Fig. 4.4). Adult, sub-adult and juvenile L.vivipara all emerge earlier than the same age class of L.agilis. There were no obvious differences between the curves for adults and sub-adults/juveniles within each species. The curves for sub-adults/juveniles of both species are less steep than those for adults. That is, there was less difference between the emergence times of juveniles/sub-adults in the spring, summer and autumn than was found amongst adults. This difference was particularly noticeable in the autumn when adults emerge considerably later than they do in the summer.

Fig. 4.3 Daily activity patterns of <u>L.agilis</u> and <u>L.vivipara</u>. Morning emergence.

The time of daily emergence of a. adult and b. sub-adult (●) and juvenile (x) <u>L.agilis</u> on sunny days throughout the year.



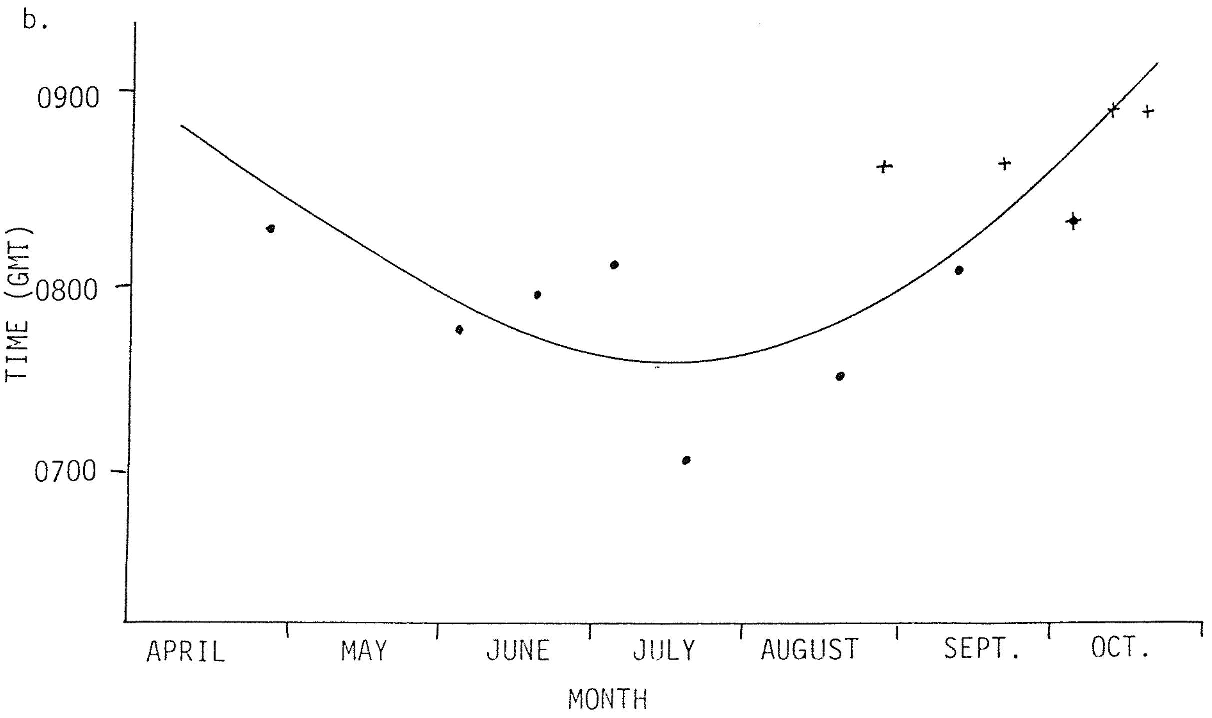
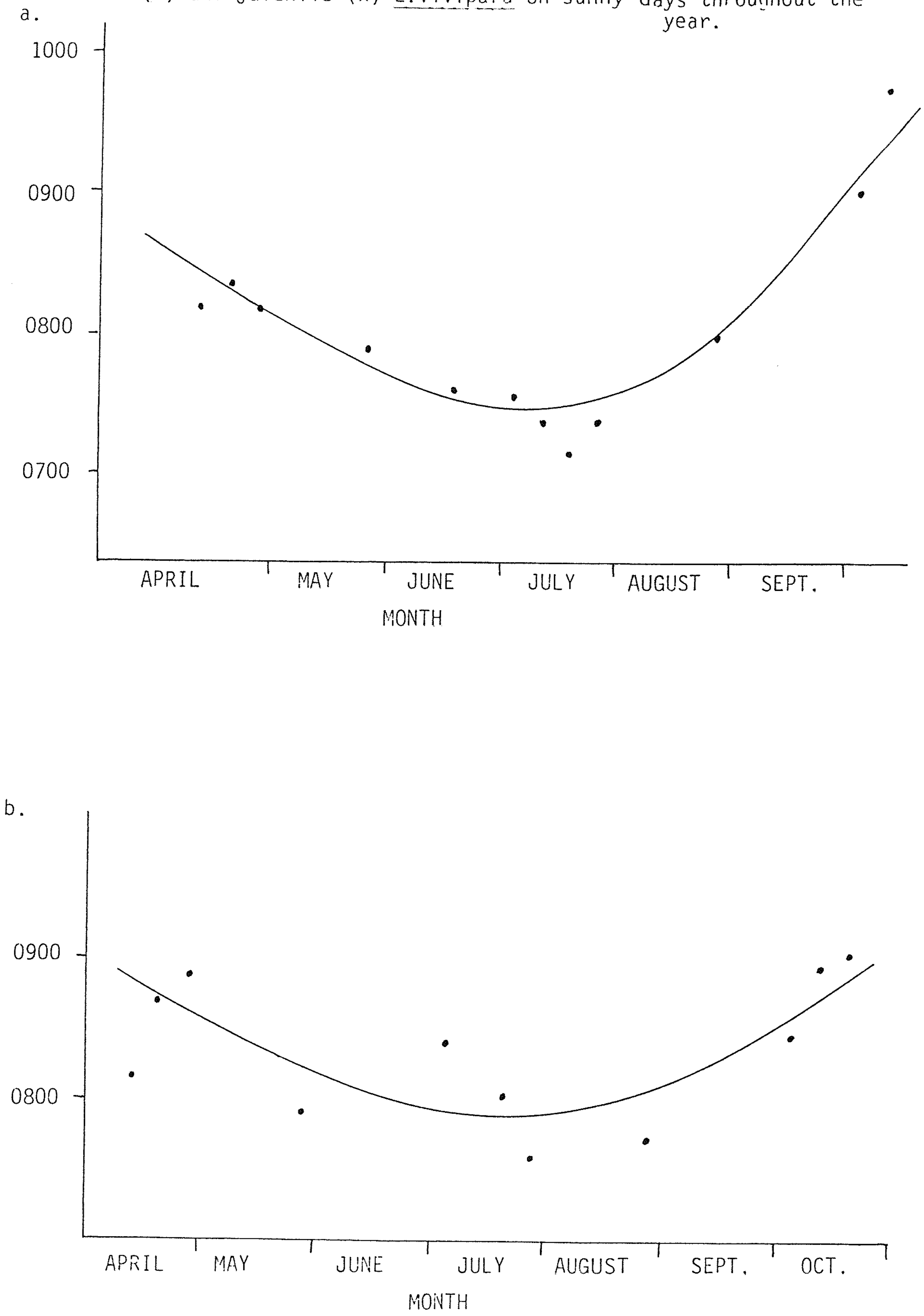


Fig. 4.4 Daily activity patterns of *L.agilis* and *L.vivipara*. Morning emergence.

The time of daily emergence of a. adult and b. sub-adult (●) and juvenile (x) *L.vivipara* on sunny days throughout the year.



4.3.3 ACTIVITY IN RELATION TO WEATHER AND SEASON

4.3.3.1 Summer activity of L.agilis and L.vivipara in relation to weather

4.3.3.1.1 Summer activity of L.agilis

L.agilis : radio-tracked animals on East Gore, summer 1982
Weather Data : Net radiation (Wm^{-2})
: Air temperature (ground level) ^{o}C
Methods : 2.7.2.2.1

The minimum temperature and net radiation at which L.agilis were seen basking was 15 ^{o}C and 125 Wm^{-2} (Fig. 4.5). The 'not visible' category includes both pre-emergence animals and those active but hidden in the vegetation. However, there was a concentration of 'not visible' positions in the low temperature, low net radiation area which presumably represents pre-emergence animals, this concentration was found below 20 ^{o}C and 300 Wm^{-2}. A few animals were observed at low levels of net radiation and temperature but these individuals were not basking.

4.3.3.1.2 Summer activity of L.agilis and L.vivipara

(i) L.agilis and L.vivipara : Repeated Walks of Morden Rides, 1983
Weather Data : Net radiation, Wm^{-2}
: Air temperature (1.5m), ^{o}C
Methods : 2.7.2.2.2.1

In this experiment L.agilis was found at lower temperatures and values of net radiation than L.vivipara (Fig. 4.6), however the overall limits to activity were the same as those previously found and the data set in this experiment was small. It should be noted that air temperatures were measured at a height of 1.5m which are generally less extreme than those at ground level and are higher at night and lower during the day than those at ground level.

(ii) L.agilis and L.vivipara : Morden Rides, June to August 1982
Weather Data : Net radiation, Wm^{-2}
: Temperature (ground level), ^{o}C
Methods : 2.7.2.2.2.2

This study was carried out during the same period as that using radio transmitters on East Gore above (4.3.2.1.1) but the range of weather conditions encountered was much smaller than that found in the

Fig. 4.5 Daily activity patterns: activity in relation to weather and season, Summer activity of L.agilis in relation to weather from animals radio-tracked on East Gore, summer 1982.

Activity in realtion to net radiation and temeprature. The behaviour of animals was defined as basking (●), visible (active or resting; +) or 'not visible' (o).

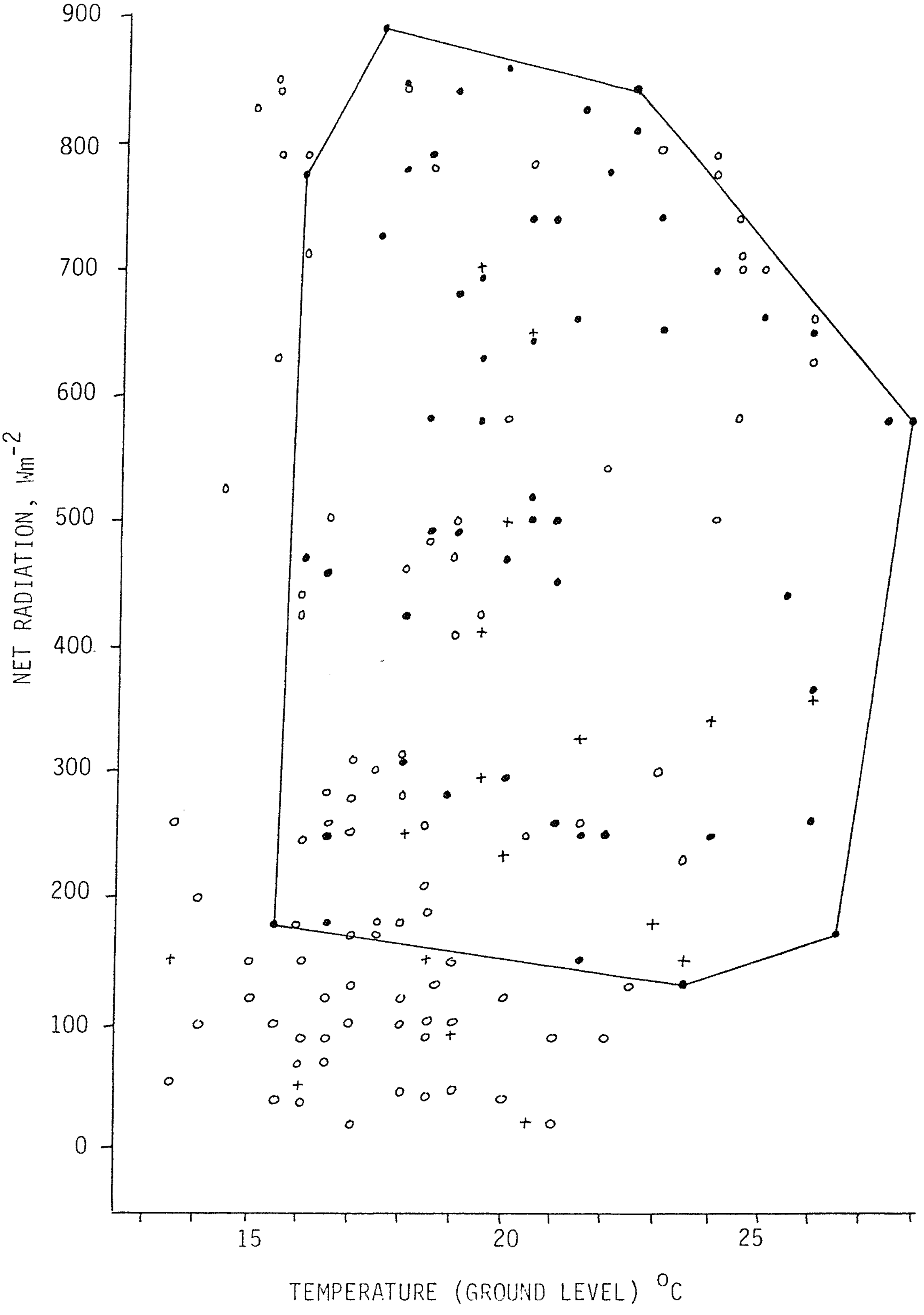
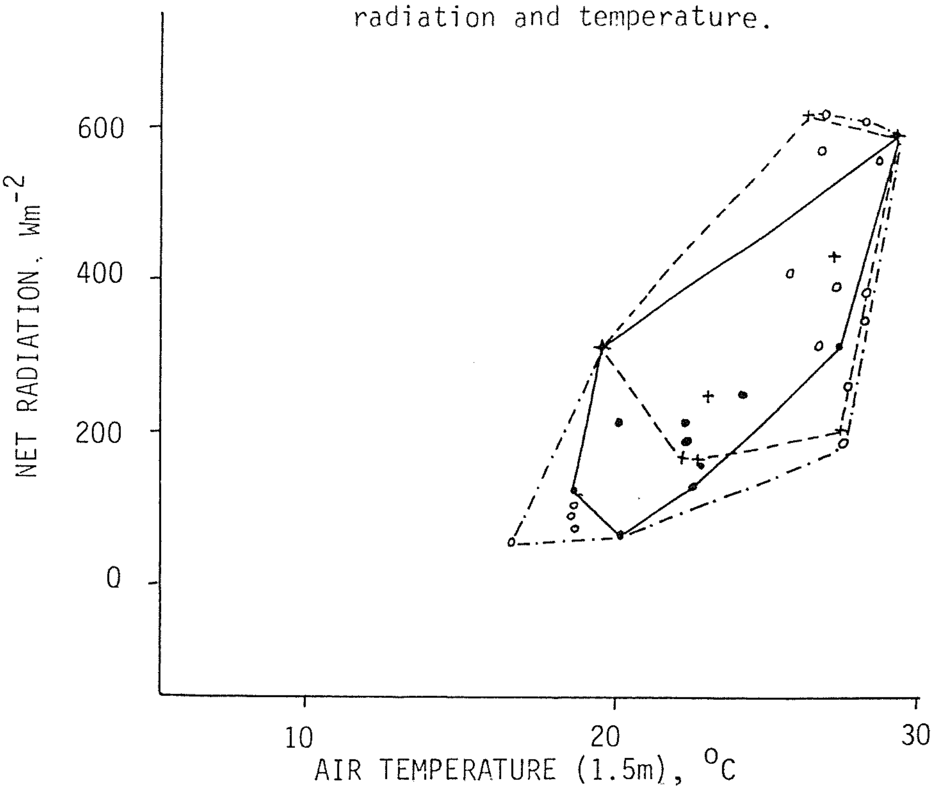


Fig. 4.6 Daily activity patterns; activity in relation to weather and season.

Summer and autumn activity of L.agilis and L.vivipara.

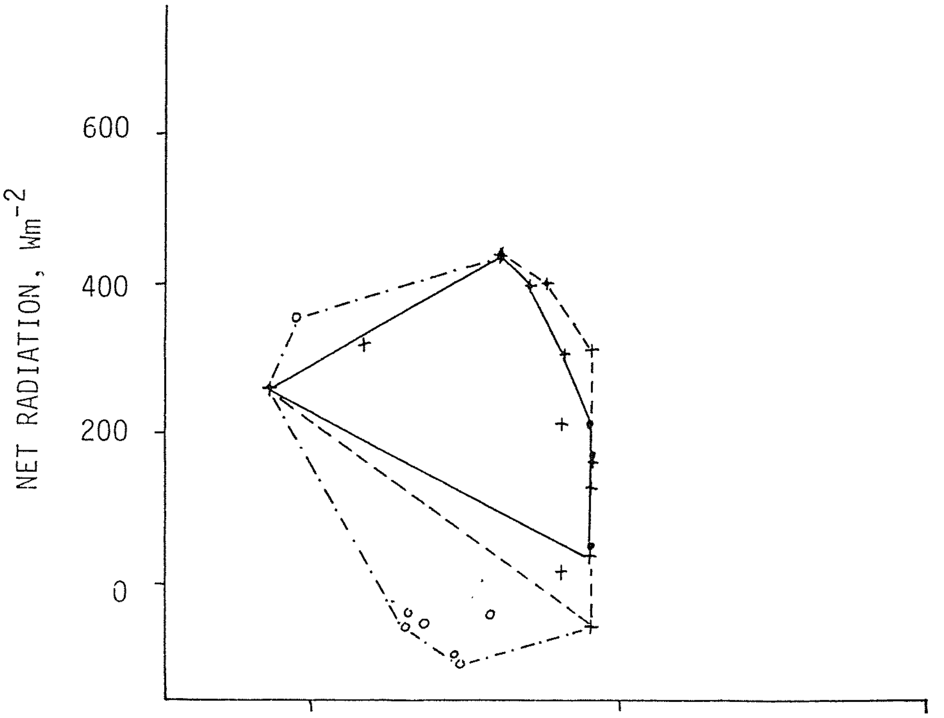
The activity of L.agilis (●) and L.vivipara (+) in a. July (summer) and b. September (autumn) in relation to net radiation and temperature.

a.



o = conditions encountered while searching the habitat in general.

b.



radio-tracking study (Fig. 4.7). The difference was mainly in terms of the range of temperatures utilised by the lizards rather than the net radiation. Despite this narrowed range, the same pattern of activity was present, with L.agilis not being found at low temperatures (below 18 °C) or values of net radiation (below 50 Wm^{-2}), whilst L.vivipara occurred at lower temperatures (not below 16.5 °C) and levels of net radiation (not below 0 Wm^{-2}; Fig. 4.7).

4.3.3.2 Autumn activity of L.agilis and L.vivipara in relation to weather

(i) L.agilis and L.vivipara : Repeated walks of Morden Rides in 1983
Weather Data : Net radiation, Wm^{-2}
: Temperature (1.5m), °C
Methods : 2.7.2.2.2.1

In September the range of net radiation levels and temperatures available was much lower than in the summer. Both L.agilis and L.vivipara were found at the lowest temperatures encountered (9 °C) but L.agilis was not found below net radiations of 50 Wm^{-2} or L.vivipara below -50 Wm^{-2} (Fig. 4.6). Overall neither species was encountered under conditions of combined low temperature and net radiation.

(ii) L.agilis and L.vivipara : Morden Rides, September 1982
Weather Data : Net radiation, Wm^{-2}
: Temperature (ground level), °C
Methods : 2.7.2.2.2 (ii)

In the autumn of 1982 on Morden Rides, L.agilis was not found below temperatures of 12.5 °C or net radiations of 50 Wm^{-2} (Fig. 4.8), L.vivipara was found almost throughout the range of conditions available, the lowest values at which it was found being 11 °C and 0 Wm^{-2} (Fig. 4.8). Sightings of juveniles were scattered throughout the area enclosed by each species.

4.3.3.3 Seasonal Activity of L.agilis in relation to temperature

L.agilis : East Gore 1983
Weather Data : Air temperature (ground level), °C
Methods : 2.7.2.2.3

The distribution of L.agilis sightings relative to air temperature was not significantly different from the distribution of time spent

Fig. 4.7 Daily activity patterns; activity in relation to weather and season.

Summer activity of L.agilis and L.vivipara; from Morden Rides June and August 1982.

The distribution of L.agilis (adults ●; juveniles x), L.vivipara (adults ▲; juveniles +) and conditions while searching (o) in relation to net radiation and temperature.

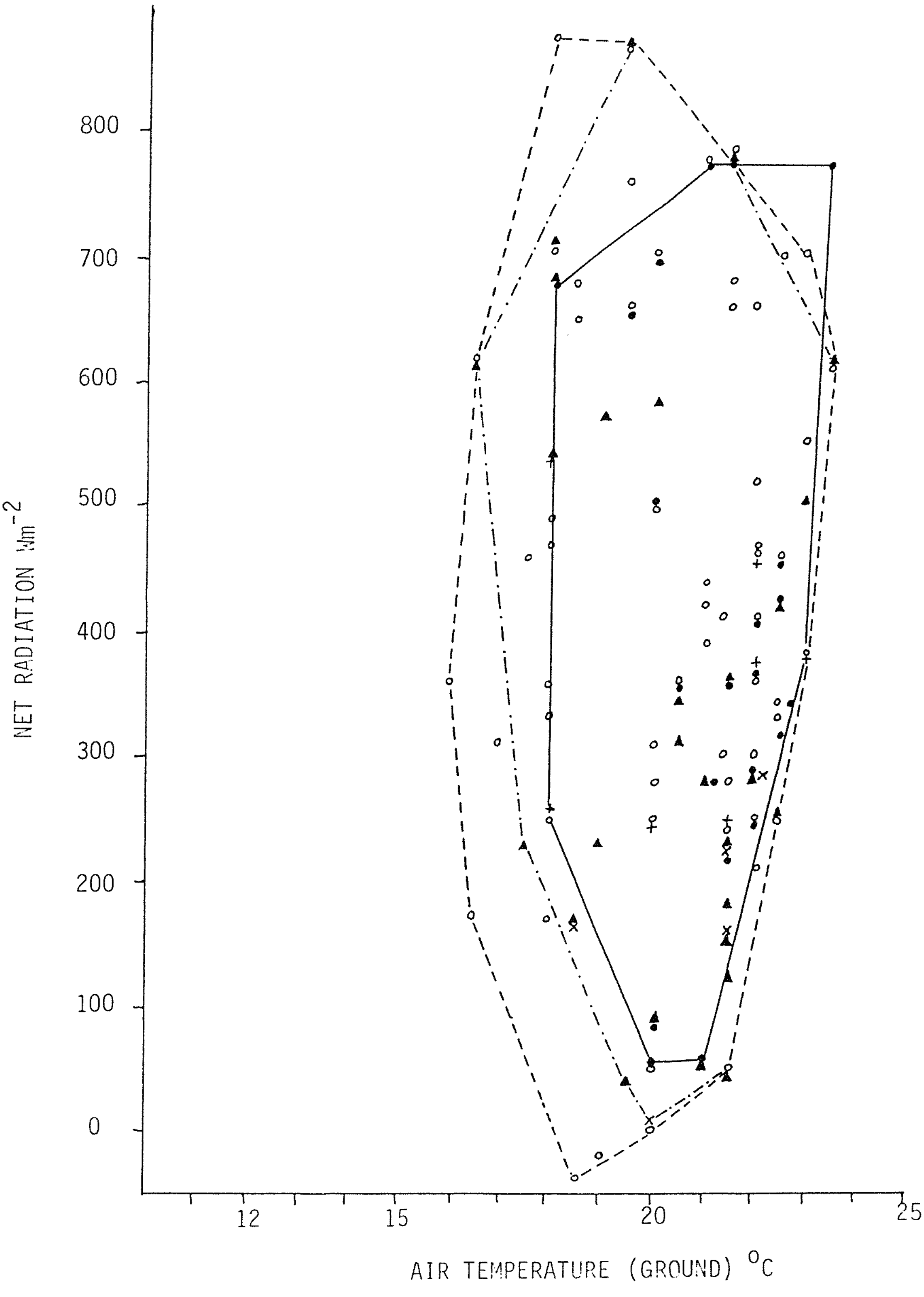
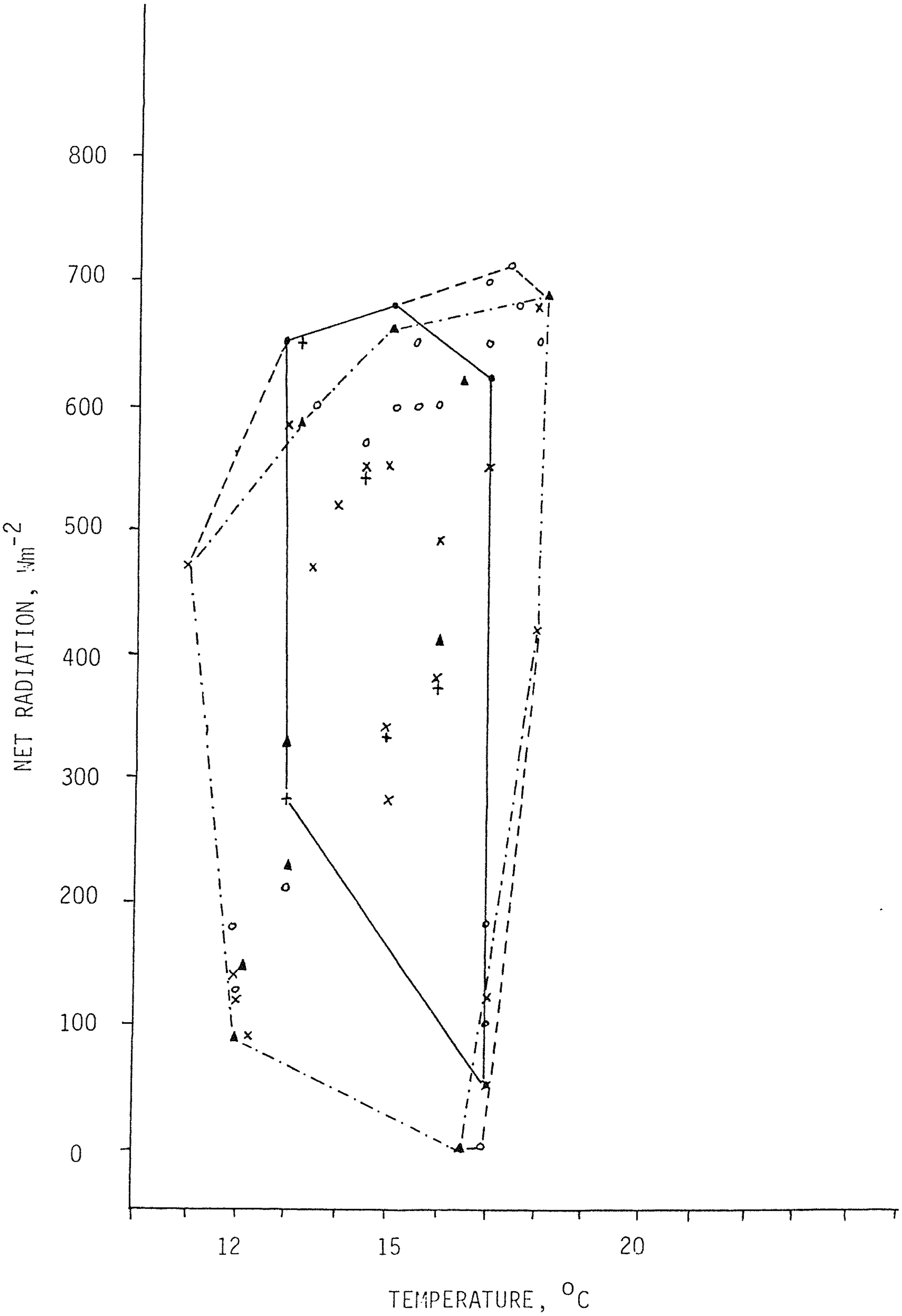


Fig. 4.8 Daily activity patterns; activity in relation to weather and season.
Autumn activity of L.agilis and L.vivipara, from searching of Morden Rides, September 1982.

The distribution of L.agilis (adults ●; juveniles +) and L.vivipara (adults ▲; juveniles x) sightings in relation to net radiation and temperature. Conditions encountered while searching (o) are also shown.



searching them for all three seasons (Spring, $\chi^2 = 20.7$, d.f. = 12, $P<0.10$; Summer, $\chi^2 = 12.6$, d.f. = 13, $P<0.50$; Autumn, $\chi^2 = 5.9$, d.f. = 5, $P<0.50$). In spring and autumn lizard sightings were associated with the higher end of the range of temperatures encountered, while no such pattern was apparent in summer (Fig. 4.9).

4.4 BEHAVIOUR IN RELATION TO WEATHER AND SEASON

4.4.1 INTRODUCTION

When radio-tracking L.agilis it was possible to quite accurately locate an animal without unduely disturbing it. Once the general area in which the animal was had been located, a thorough visual search often enabled the animal to be found even if it was not basking and was resting under the vegetation. In this way by recording the behaviour of the radio-tracked animals at regular intervals during the day it was possible to provide a good picture of how lizard behaviour varied throughout the day under different weather conditions. In this section the behaviour of radio-tracked L.agilis (on East Gore) has been related to the weather conditions (temperature and net radiation) at the time of each sighting.

The behaviour of L.agilis has been defined as follows:

(i) Not visible
(ii) Visible - active or resting
(iii) Basking - showing a 'flattened basking posture'
- not showing a 'flattened basking posture'.

Both L.agilis and L.vivipara use a 'flattened basking posture' in order to increase the rate at which they absorb thermal radiation. The rib-cage is expanded in such a way that the animal becomes dorso-ventrally flattened and the surface area of the lizards body exposed to solar radiation is increased.

4.4.2 RESULTS

L.agilis : Radio-tracked, East Gore 1982, 1983
Weather Data : Net radiation, Wm^{-2}
: Temperature (ground level), ^{o}C
Methods : 2.7.3

Fig. 4.10 shows a plot of the net radiation and temperatures at which lizards were first observed basking for any given day and any observation prior to this (pre-emergence). Most of the daily pre-emergence positions when lizards were not visible occur in the low net radiation and/or low temperature area, particularly below $18^{o}C$ and 300

Fig. 4.9 Daily activity patterns: activity in relation to weather and season.

Seasonal activity of L.agilis in relation to temperature, East Gore 1983.

The distirbution of L.agilis sightings (□) and time spent searching (▨) in relation to temperature for a.spring, b. summer and c. autumn.

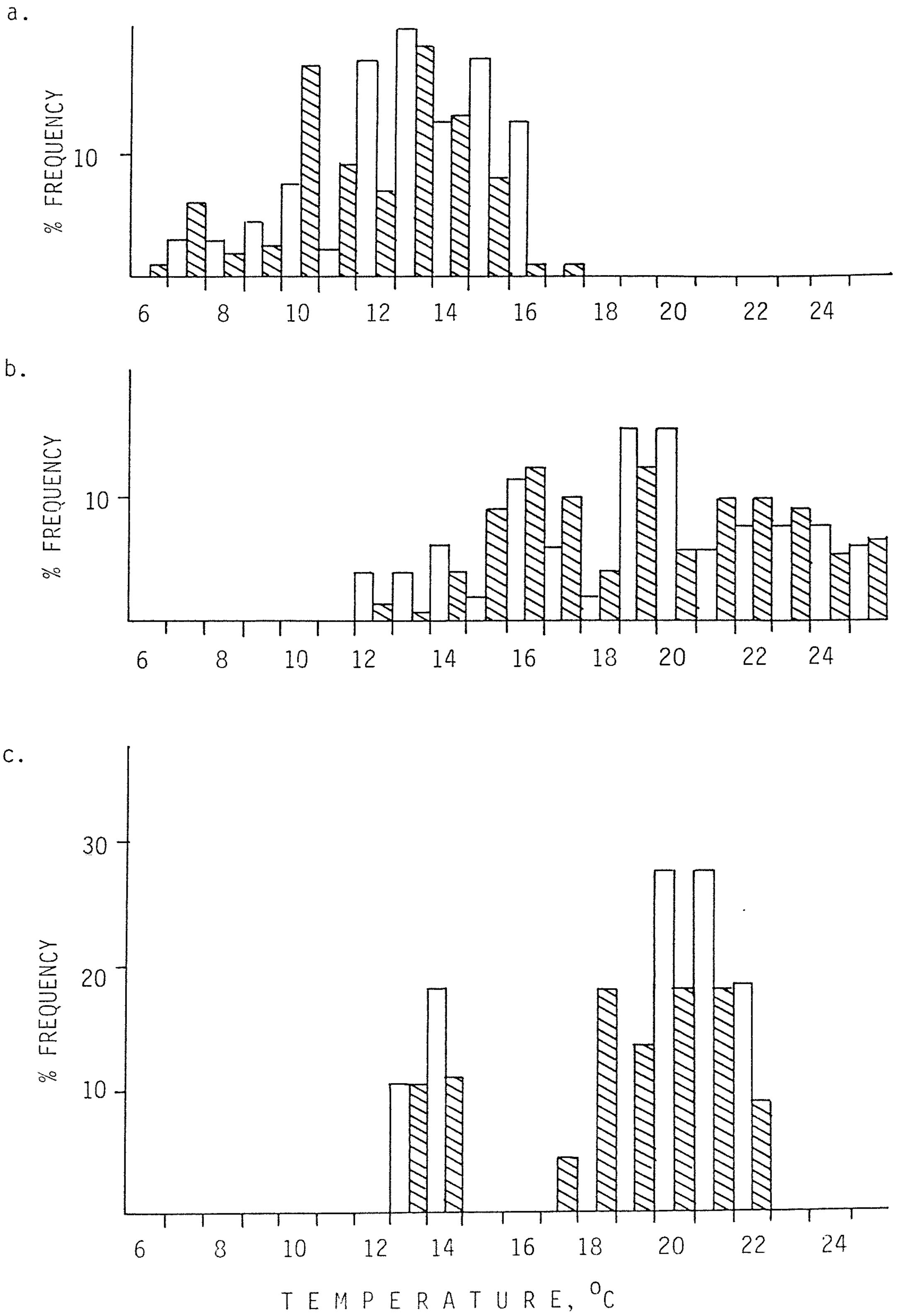
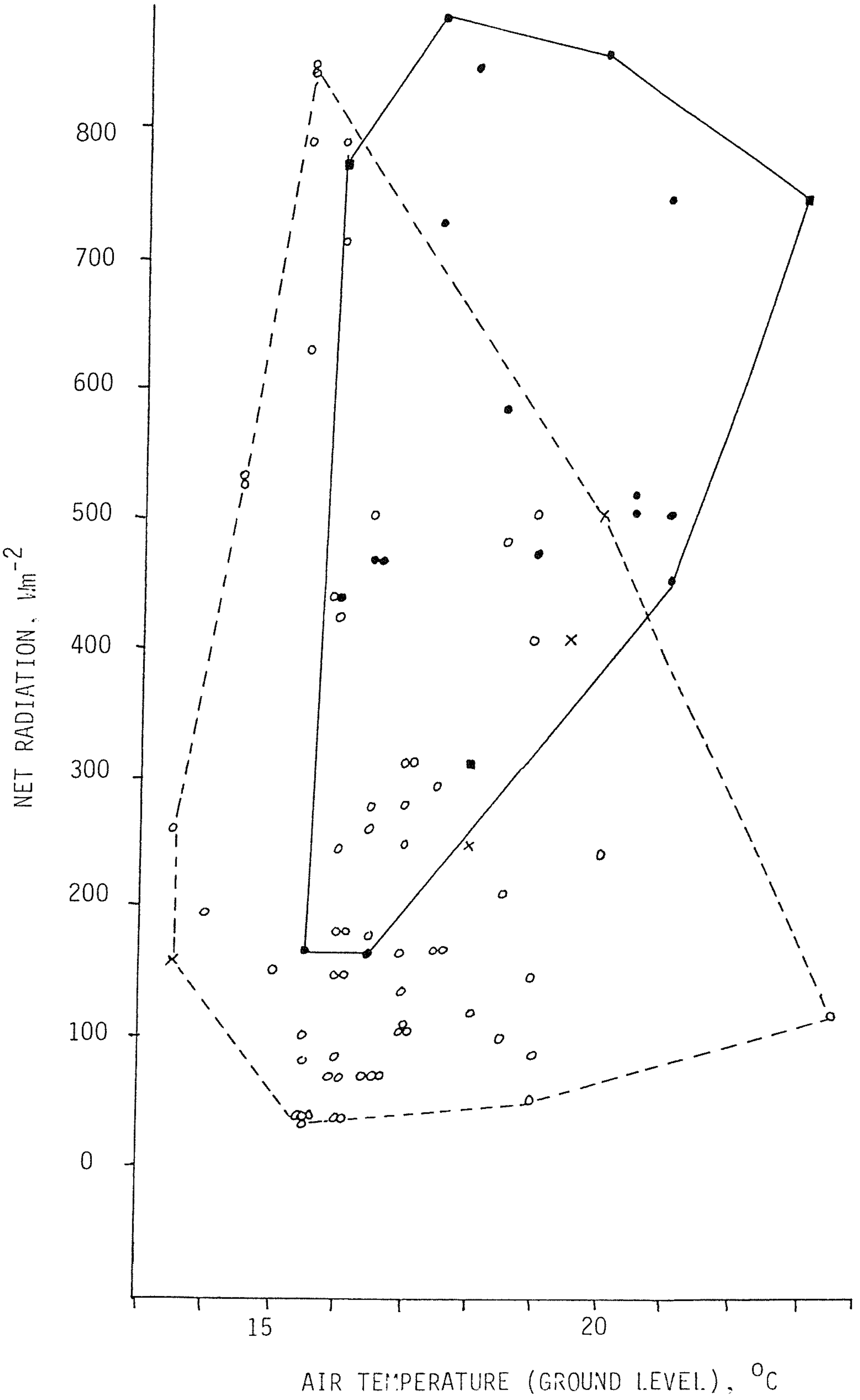


Fig. 4.10 Behaviour in relation to weather and season. Radio-tracked L.agilis, East Gore 1982 (summer).

The behaviour of L.agilis when first observed basking on a given day and any observations prior to this (pre-emergence; 'not visible', o; or visible but not basking, x) in relation to net radiation and temperature. Basking was defined as showing a flattened posture (●) or not(■).



Wm^{-2}. The range of conditions under which L.agilis were found basking was 15 - 23 ^{o}C and 150 - 900 Wm^{-2}. Of the animals seen for the first time in a day 83% were using a flattened basking posture.

Fig. 4.11 shows the conditions on the last occasion on which lizards were seen basking in a day and any subsequent recordings when animals were no longer visible or were resting under the vegetation (post-disappearance). In a similar manner to pre-emergence, most post-disappearance positions were for conditions under 800 Wm^{-2} but they occurred at greater temperatures (not under 20 ^{o}C). Although the range of net radiation was similar to that of the first daily basking (150 - 800 Wm^{-2}) the range of temperatures at which the last basking period occurred was considerably higher (16.5 - 27.5 ^{o}C). Only 25% of the lizards basking for the last time in a day used a flattened basking posture.

In Fig. 4.12 all sightings between the first and last basking occasions on a day have been plotted relative to net radiation and temperature. While the flattened basking posture was used across the full range of net radiation values available, it was restricted to the lower end of the temperature range encountered (Total range = 15 - 28 ^{o}C, flattened range = 16 - 22.5 ^{o}C). Non flattened basking occurred scattered throughout the whole range of temperatures and net radiation.

Although data on net radiation was not available for the animals radio tracked in the spring of 1982 or 1983, temperature (at ground level) readings were available for the spring of 1983. Fig. 4.13, shows the behaviour of radio tracked L.agilis males relative to temperature and time of day. Again flattened basking appears to be restricted to the lower temperatures encountered, while non-flattened basking occurs throughout the day. Fig. 4.14 shows the frequency distributions of occurrences of flattened and non-flattened basking through the day in spring and summer. In spring flattening was used throughout the day while in summer it is much more frequently found in the morning. Neither pair of distributions were significantly different to each other (spring, $\chi^2 = 11.6$, d.f.= 6, $P<0.10$; summer, $\chi^2 = 12.0$, d.f. = 8, $P<0.20$).

4.5 RELATIONSHIP BETWEEN RATE OF CAPTURE AND WEATHER

4.5.1 INTRODUCTION

It was obvious from time spent searching for L.agilis and L.vivipara that some weather conditions were better than others for finding lizards. While searching for animals in order to assess their

Fig. 4.11 Behaviour in relation to weather and season. Radio-tracked L.agilis in summer 1982, East Gore.

The behaviour of L.agilis when last observed basking in a day and any observations after this (post-disappearance; 'not visible', o; or visible but not basking, x) in relation to net radiation and temperature. Basking was defined as showing a flattened posture (●) or not (■).

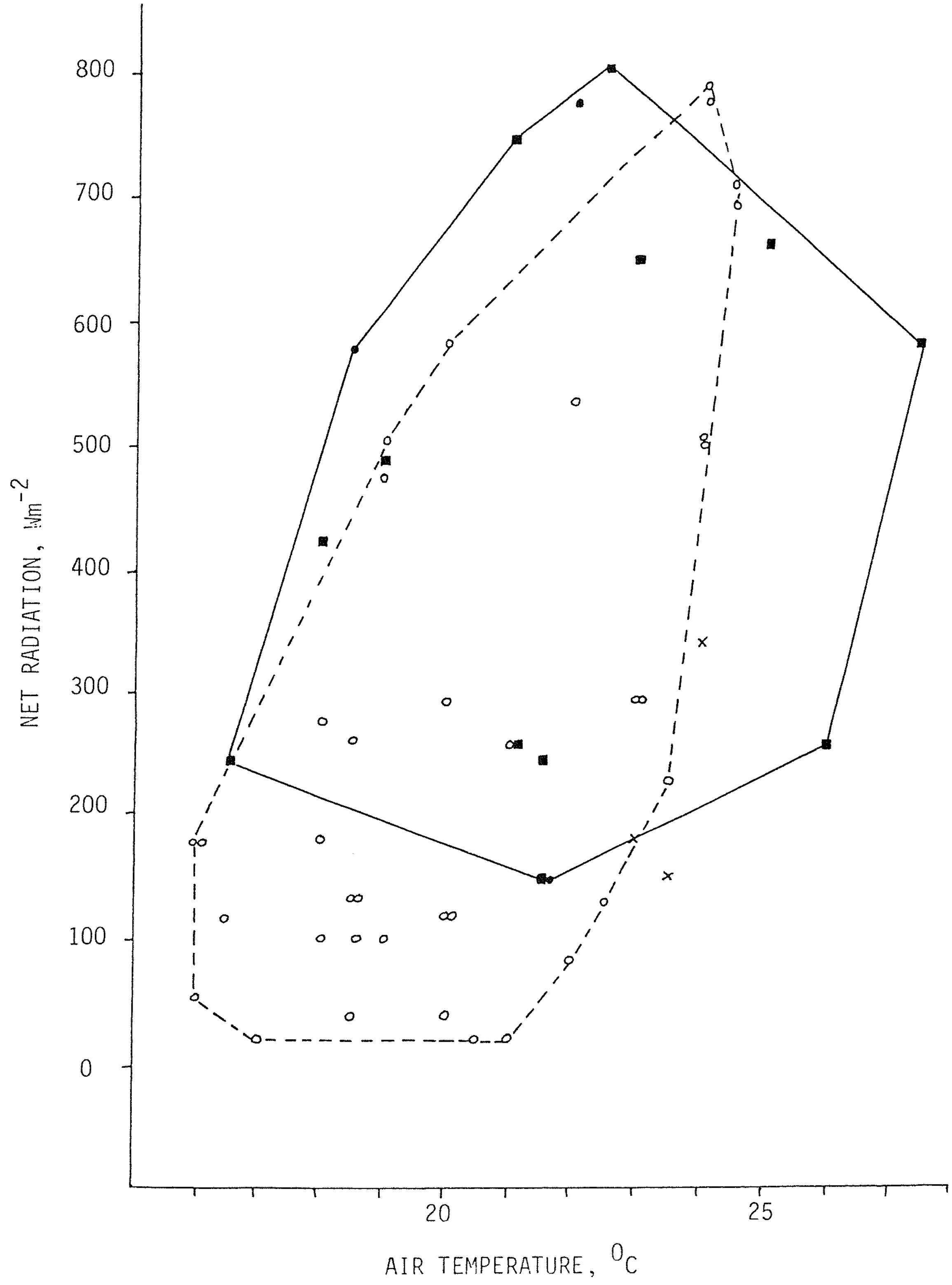


Fig. 4.12 Behaviour in relation to weather and season. Radio-tracked L.agilis on East Gore, summer 1982.

The behaviour of L.agilis between the first and last basking occasions on a day (inclusive) in relation to net radiation and temperature. Behaviour has been defined as visible (x), flattened basking (F), non-flattened basking (B) or 'not visible' (o).

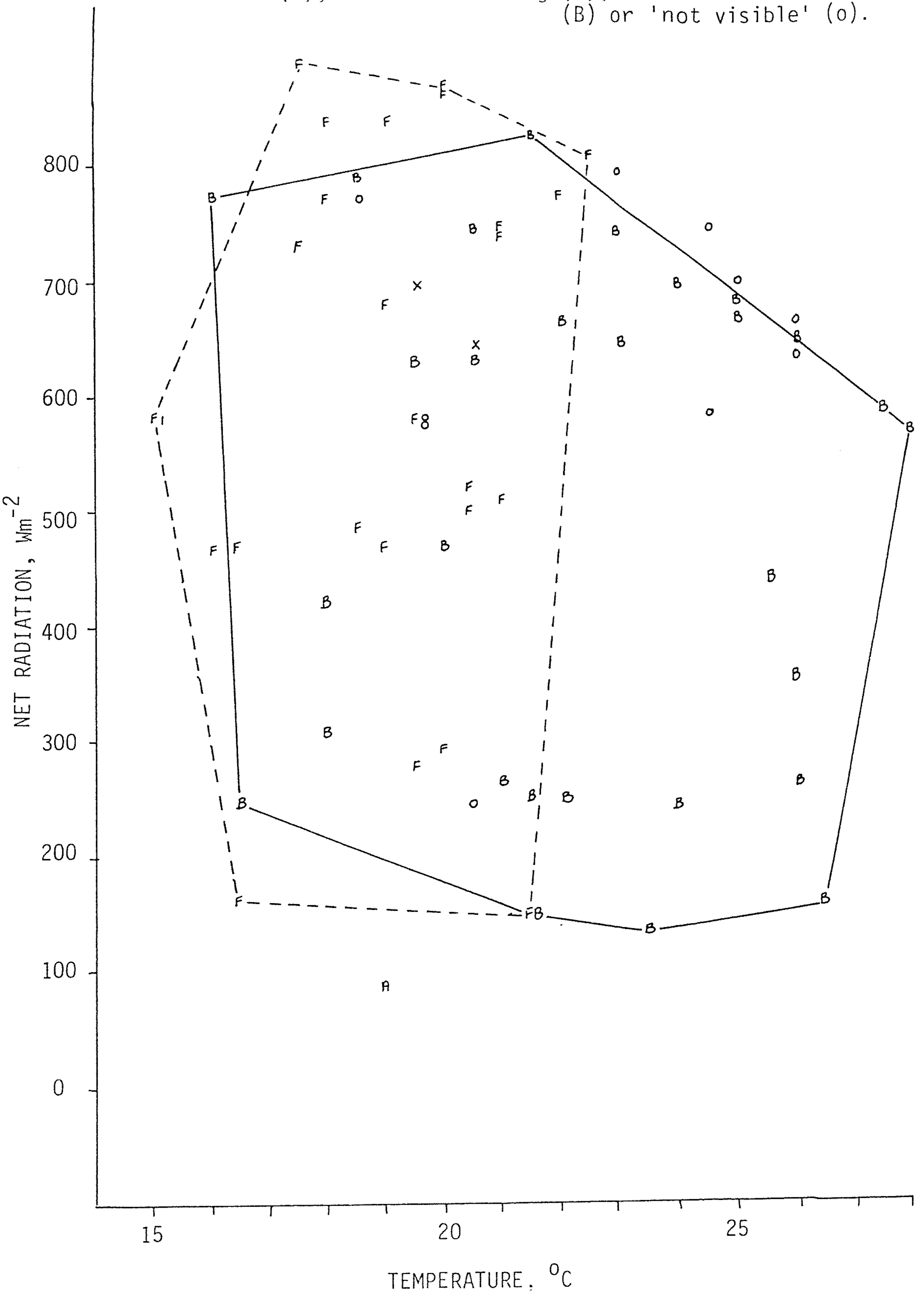


Fig. 4.13 Behaviour in relation to weather and season. Radio-tracked *L.agilis* on East Gore, Spring 1983.

The behaviour of adult male *L.agilis* in relation to temperature and time of day. Behaviour has been defined as visible (x), flattened basking (F), non-flattened basking (B) and 'not visible' (o).

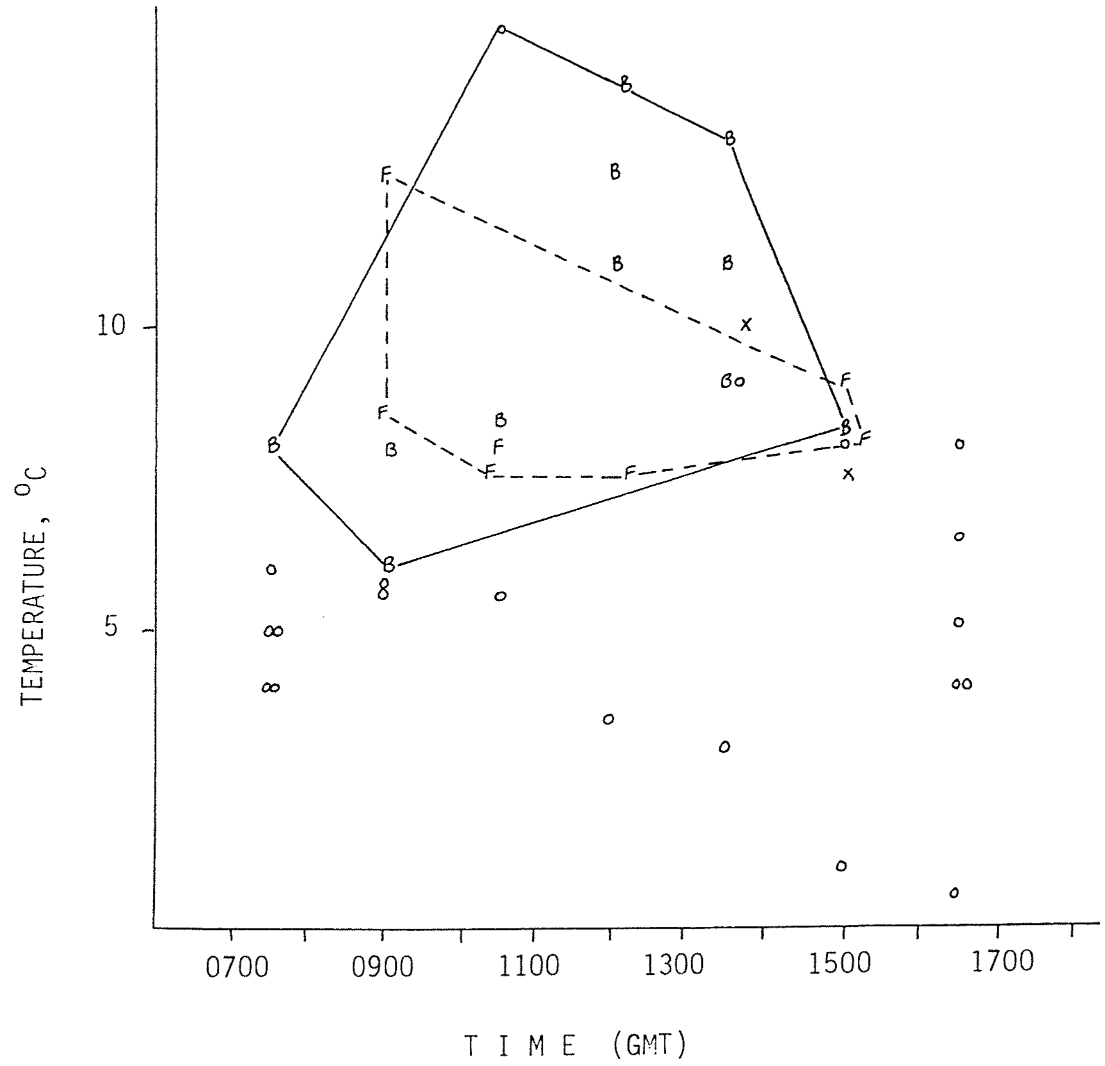
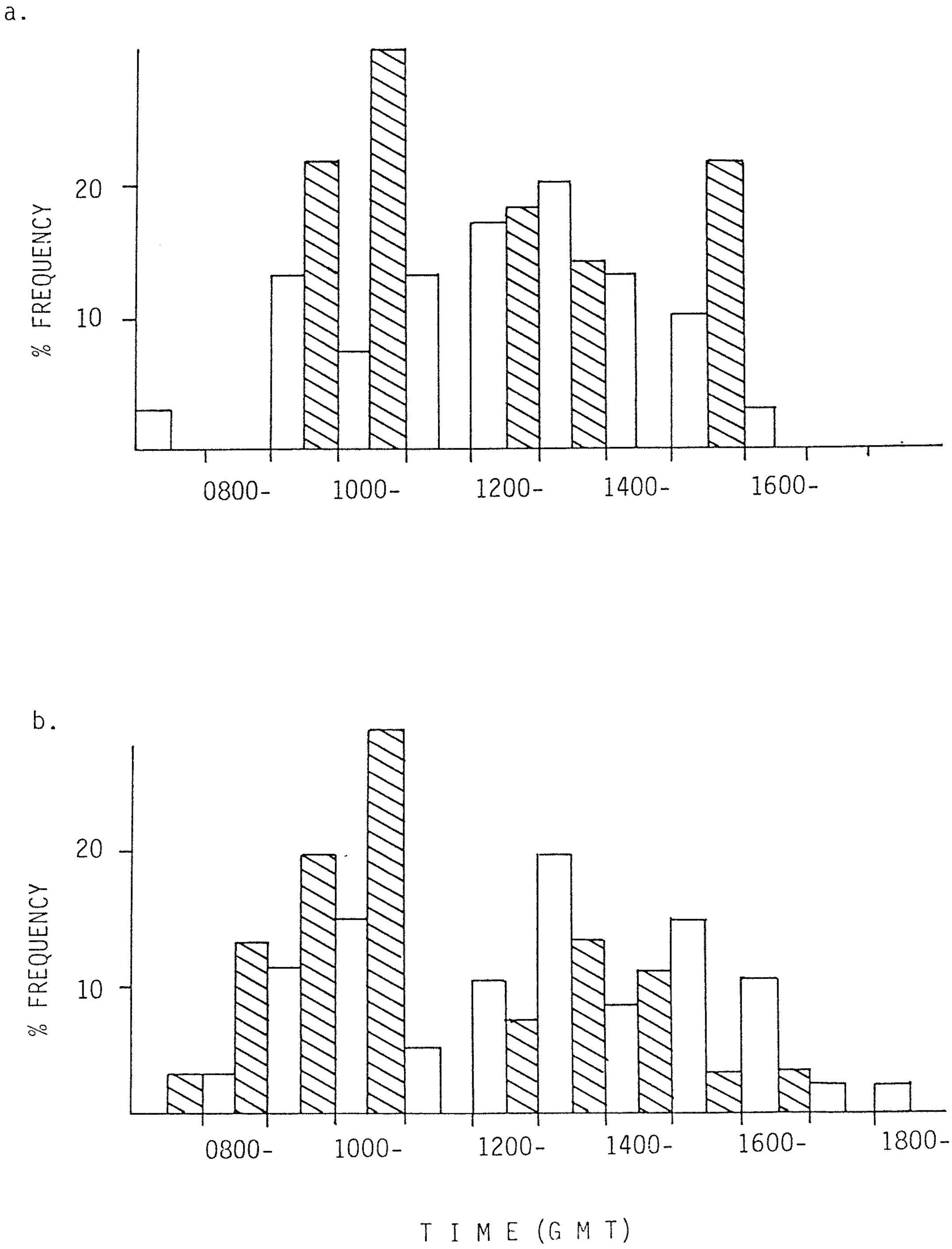


Fig. 4.14 Behaviour in relation to weather and season.
Radio-tracked L.agilis on East Gore, summer 1982 and
spring 1983.

The frequency distribution of the occurrence of flattened (▨) and non-flattened (☐) basking throughout the day in a. spring and b. summer.



habitat preferences a subjective assessment of the weather conditions was usually made in order to decide if there would be 'good' or 'bad' conditions under which to find lizards. An attempt has been made here to correlate the rate at which L.agilis were sighted while searching with the weather conditions during a given period of searching. The rate of sighting of L.agilis in relation to air temperature and net radiation has been dealt with.

4.5.2 RESULTS

L.agilis : East Gore, summer 1982 and 1983
Weather Data : Net radiation, Wm^{-2}
: Air temperature (ground level), ^{o}C
Methods : 2.7.4

The rate at which lizards were seen (rate of sighting) was plotted against both temperature and net radiation. The correlation between rate of sighting and temperature was not significant ($r = 0.110$, d.f. = 23, $P>0.05$). The relationship between rate of sighting and net radiation was curvilinear with the rate of sighting increasing steadily above a threshold value (300 Wm^{-2}) and the curve becoming increasingly steep as net radiation increased (Fig. 4.15). The rate of sighting was transformed to ln(rate + 1) and a regression analysis omitting an outlying point (marked on Fig. 4.15) was done. The rate of sighting against net radiation showed a significant positive correlation ($r = 0.772$, d.f. = 26, $P<0.001$).

4.6 DISCUSSION

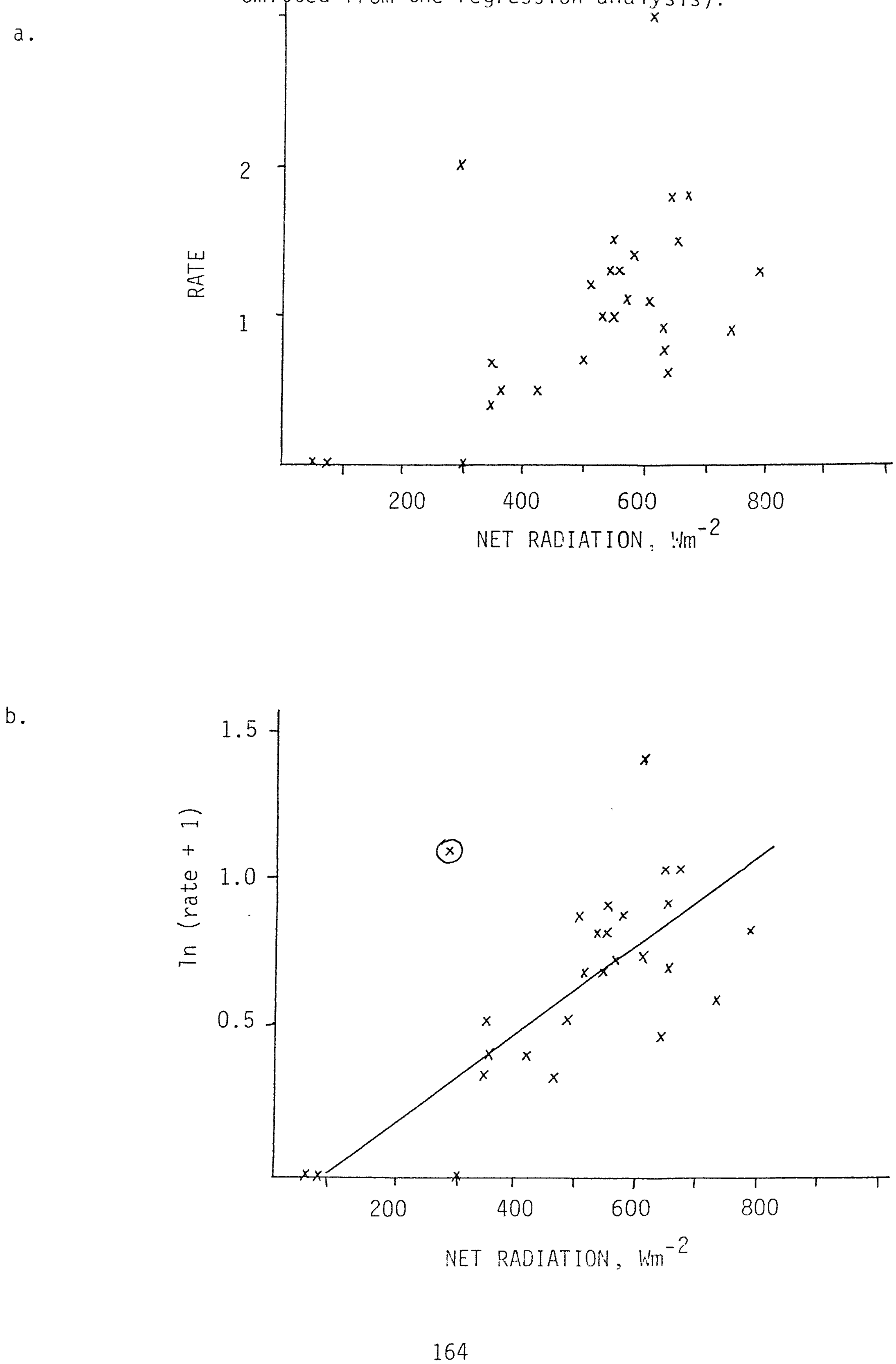
4.6.1 SEASONAL ACTIVITY PATTERNS

Distinct trends were visible in the sequence of emergence from and disappearance into winter dormancy within both L.agilis and L.vivipara populations. There were distinct differences not only between age-groups within each species, but also between males and females within each species. Also there were clear differences in the behaviour of the equivalent age and sex groups in L.agilis and L.vivipara.

The order in which L.agilis emerged from winter dormancy in these experiments was, male adults, then sub-adults and then female adults. The emergence of male L.agilis earlier than females has been noted previously (Nicholson 1980, Spellerberg & House 1980, Bauwens 1981, van Nuland & Strijbosch 1981). Although male and female L.vivipara could not be distinguished here, a similar trend has been noted for this species (van Nuland & Strijbosch 1981).

Fig. 4.15 Relationship between the rate of sighting of *L.agilis* and weather.

The relationship between the rate at which *L.agilis* were seen while searching (rate) and the level of net radiation while searching, a. rate agianst net radiation and b. $\log_n$(rate+1) agianst net radiation (the circled point was omitted from the regression analysis).



When male *L.agilis* emerge in the spring they spend most of their time basking (Spellerberg & House 1980) and often loose weight during this period (Nicholson 1980). Spermatogenesis occurs in the males during this post-emergence period (Saint Girons 1963, Tertyshnikov 1976). Mating occurs almost immediately after the females emerge from winter dormancy (van Nuland & Strijbosch 1981), in this work pair formation was recorded within two weeks of the emergence of the females from winter dormancy.

In *L.agilis* the sub-adults emerged one to two weeks after the males but still two to three weeks before the females. This result contradicts the findings of van Nuland & Strijbosch (1981) who found that female and sub-adult *L.agilis* emerged from winter dormancy almost simultaneously. However, the result agrees with the findings of Simms (1970) who states that in both *L.agilis* and *L.vivipara* the males and sub-adults emerge first followed by the females after some time.

L.vivipara mate earlier in the year than *L.agilis* and also have a shorter incubation period (van Nuland & Strijbosch 1981). This shorter incubation period may be due in part, to the ability of the females of *L.vivipara* to optimise conditions for clutch development through their own thermoregulation. In *L.agilis* however, the rate of clutch development is dependent on the microclimate of the nest site. This may not receive the maximum number of sunshine hours available in the area on a given day, and even if it is in the sun it may not provide optimal conditions for development (Liberman & Pokrovskaja 1943, House & Spellerberg 1980). These differences may account for the more uniform emergence of *L.vivipara* juveniles in comparison with those of *L.agilis*. For example, in 1981 and 1982, *L.vivipara* juveniles appeared in the same quarter of August while *L.agilis* juvenile emergence times varied by four weeks between these two years. Also in 1983, juvenile *L.vivipara* appeared two weeks earlier than in 1982, while those of *L.agilis* emerged three weeks later than in 1982.

The sequence in which the two species and their age groups commence winter dormancy was as would be expected if body size was the most important factor affecting their thermoregulatory requirements. Adult *L.agilis* disappear first in late August and early September followed by adult *L.vivipara* in early October and juveniles of both species in late October. In *L.agilis* males disappear into winter dormancy at considerably higher temperatures and levels of solar radiation than those at which they emerge in the spring. Female *L.agilis* on the other hand disappear at higher temperatures but at approximately the same levels of solar radiation as at the time of spring emergence. Juveniles of both species disappear at lower temperatures and lower levels of solar radiation than those when they emerge in spring.

4.6.2 DAILY ACTIVITY PATTERNS

4.6.2.1 Morning emergence

It has been shown (Avery & McArdle 1973) that the time of morning emergence of L.vivipara on clear, sunny summer mornings can be predicted and is mainly determined by the warmth of the sun. The model developed by Avery & McArdle (1973), was based on the assumption that lizards emerge at a temperature and level of solar radiation at which they can achieve their PBT rapidly and so avoid the undue risks of predation imposed by excessively long periods of basking. The model predicts that under the conditions prevailing on an average June morning L.vivipara could first raise its body temperature form 15 to 25 °C at about 0530 hours, but it would take 15 minutes to do so. The rate at which L.vivipara can raise its body temperature from 15 to 25 °C increases rapidly and begins to level off at 0700 - 0800 hours. At 0700 hours an adult L.vivipara would take seven minutes to raise its body temperature from 15 to 25 °C, at 0900 hours six minutes and at 1200 hours 5.5 minutes (Avery & McArdle 1973).

In this study, L.vivipara emerged at approximately 0730 hours in mid June, which is in accordance with the model above. In June, L.agilis emerged at approximately 0745 hours.

Assuming that the emergence of both species was determined by the same criteria, that is, the need to avoid excessively long periods of post emergence basking, the later emergence of L.agilis compared to L.vivipara can be interpreted in two ways. Firstly it may mean that the heating curve of L.agilis is displaced to the right in comparison with that of L.vivipara, i.e. the rate at which L.agilis heats under a given set of conditions is slower than that for L.vivipara. Secondly, the difference could be the result of the extra time needed by L.agilis to reach its higher PBT.

Sub-adult L.agilis and L.vivipara appeared to emerge at similar times and not noticeably earlier than the adults in each species.

4.6.2.2 Activity in relation to weather and season

In summer L.agilis was not found basking at air temperatures below 15 °C or levels of net radiation below 125 Wm^{-2}. In the low net radiation and low temperature region these limits were nearer to 19 ^{o}C and 300 Wm^{-2} (Fig. 4.5). The presence of visible but not basking animals in these poor conditions may indicate that in the summer L.agilis does not always retreat into underground burrows, or even particularly deep into the vegetation at night. On one occasion a radio-tracked female was observed resting about 10cm off the ground in the heather when located at 1900 hours, at 0800 hours the following morning it was in exactly the same position and did not appear to have moved.

In the summer of 1982, L.agilis was found under a higher and narrower range of temperatures on Morden Rides (visual searching) than on East Gore (radio-tracked animals). While radio-tracking, the position of each animal was checked at regular intervals throughout the day regardless of the weather conditions, whereas on Morden Rides searching was carried out under those conditions which were considered most suitable for locating L.agilis. Hence the difference observed may be a reflection of the conditions 'chosen' for searching. For Morden Rides where the presence of both L.agilis and L.vivipara was recorded, L.vivipara was found at lower temperatures than L.agilis. The same general pattern of activity was found in the autumn as in the summer; L.agilis having a more restricted distribution relative to net radiation and temperature than L.vivipara (Fig. 4.5 & Fig. 4.7). Neither species was found at the lowest levels of net radiation and temperature (Fig. 4.5). It seems that there was a seasonal change in the range of conditions (particularly temperature) which the lizards could utilize. Temperatures at the top end of the range used in the autumn (Fig. 4.7) were in the area of those too low to use in the summer (Fig. 4.6).

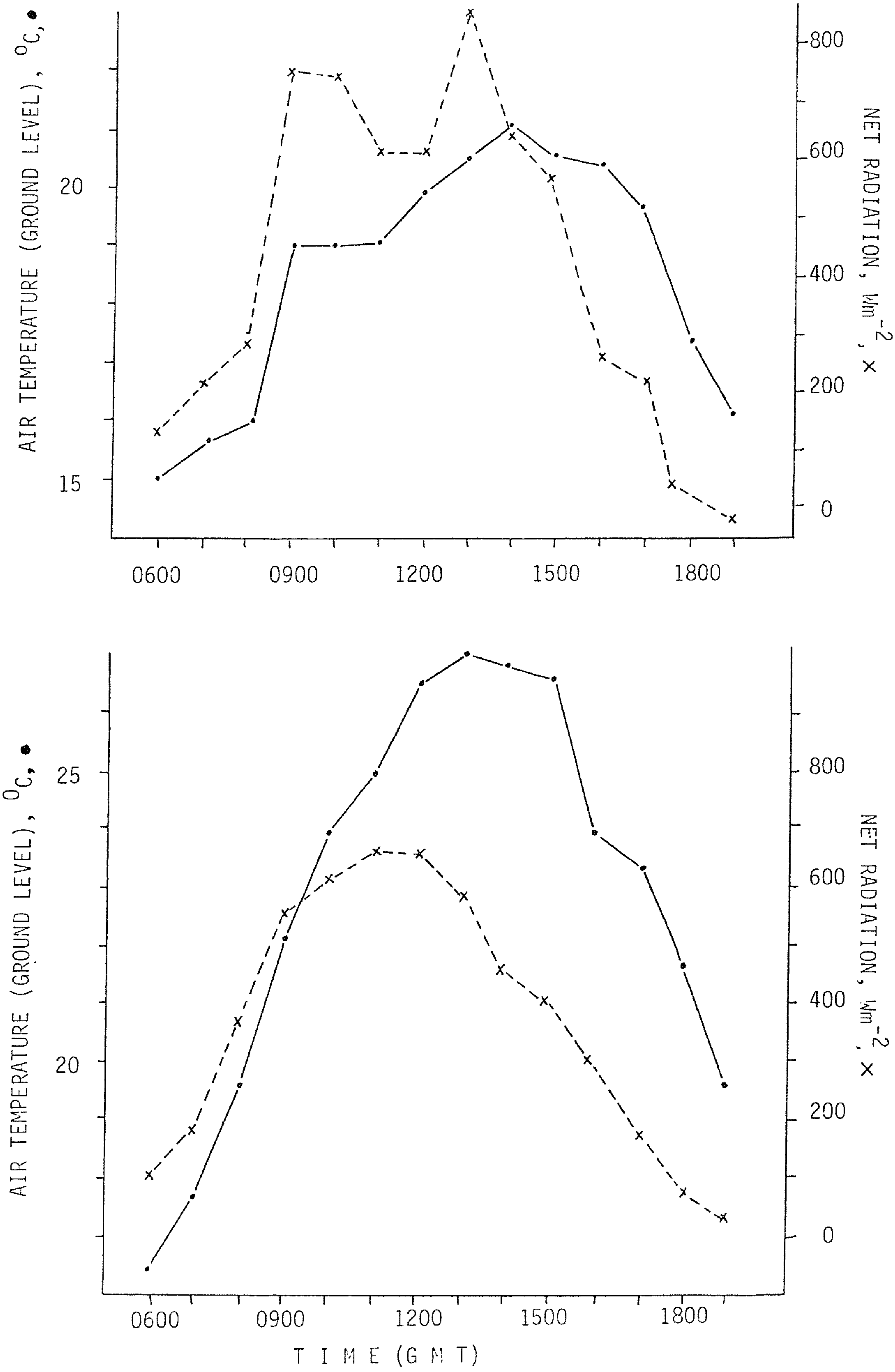
L.vivipara was active in conditions of zero net radiation in summer (4.6) and of negative net radiation in autumn (Fig. 4.5). Provided that the air temperature was high, L.vivipara appeared to be able to raise its body temperature sufficiently to remain active using radiant heat from the substratum. L.agilis does not appear to be capable of this.

4.6.3 BEHAVIOUR IN RELATION TO WEATHER AND SEASON

In the summer the range of air temperatures at which L.agilis was found on the first and last basking occasions on a given day varied considerably. However, the range of levels of net radiation used was much the same on both occasions. Fig. 4.16 shows the changes in air

Fig. 4.16 Discussion.

Changes in the levels of net radiation and temperature during the day in summer, for two days from the summer of 1982, a. 10.7.82 and b. 3.8.82.



temperature (ground level) and net radiation throughout two summer days in 1983. Net radiation tends to rise more quickly than temperature in the morning and fall more quickly than temperature in the evening. It would appear that the level of net radiation rather than temperature was most important in determining the end of activity on a summer day. In the morning there was both a temperature threshold (here 15 - 18 ^{o}C) and a net radiation threshold (here 150 - 300 Wm^{-2}) before _L.agilis_ emerged.

In the summer, the use of a flattened basking posture was limited to the lower half of the temperature range encountered (between 16 - 22.5 ^{o}C). Presumably above 22.5 ^{o}C the use of a flattened basking posture was not necessary because when the ambient temperature was high only short and non-flattened periods of basking were necessary to raise the body temperature up to the activity range. The flattened basking posture was most frequently used in the mornings presumably because this was when low air temperatures were most likely to be encountered, and when the body temperature of the lizards was particularly low having fallen close to the ambient temperature overnight.

In the spring, flattened basking occurred throughout the day, although generally at the lower end of the range of temperatures available. The pattern found in the summer (of flattened basking only at the lower end of the temperature range encountered) recurs in the spring despite the fact that the maximum spring temperatures used were less than the minimum summer ones.

4.6.4 RELATIONSHIP BETWEEN RATE OF SIGHTING AND WEATHER

The significant correlation between the rate of sighting of _L.agilis_ and the net radiation confirms the importance of net radiation in determining the extent of lizard activity in the summer. The relationship observed does not necessarily reflect the activity of _L.agilis_ per se. That is, the number of _L.agilis_ active at a given time, but rather was a measure of the 'apparency' of _L.agilis_ to the observer in relation to weather conditions. The limit below which no lizards were observed was 350 Wm^{-2}, a rather higher figure than had been found previously. However, this was a mean value and probably represents the overall lower limit of net radiation below which _L.agilis_ is not found in the summer.

The curvi-linear relationship between the rate of sighting and net radiation has to be interpreted bearing in mind the nature of the measurement of net radiation. A high level of net radiation indicates a considerable difference between the level of incoming and outgoing radiation, i.e. a high solar radiation but a low temperature. Under conditions of equally high solar radiation and high temperature, when L.agilis would not be seen so frequently the net radiation is lower.

4.6.5 CONCLUSIONS

The daily and seasonal activity period of lizards in temperate climates is determined mainly by thermoregulatory considerations. Emergence of L.vivipara in the morning occurs at levels of solar radiation at which it can rapidly reach an active body temperature, lizard submergence at the end of the day presumably occurs when they can no longer reach an active body temperature without basking for excessively long periods of time.

On a seasonal basis the weather conditions determining emergence from and disappearance into winter dormancy appear to be different. For instance, male L.agilis emerge in the spring under conditions of lower temperature and net radiation than those under which they disappear in the autumn. The timing of both emergence from and submergence into winter dormancy must be a balance between the costs of thermoregulation and the benefits gained from being active. In the case of spring emergence in males the costs are high. Males spend most of their time basking which presumably makes them susceptible to predation and they use stored fat reserves, probably in part because prey is scarce early in spring (Nicholson 1980). However, the benefit of this behaviour is that it enables males to complete spermatogenesis and so be ready to mate when the females emerge in late spring. Although conditions are poor it seems that males are able to maintain a high enough body temperature for long enough to make it worthwhile emerging this early.

In males autumn submergence into winter dormancy must be governed by different criteria. Males have not been reproductively active since May or June and so by late August have had two months of good conditions under which to recover from any weight losses incurred during the spring, and to gain weight in preparation for winter dormancy. Presumably there is a limit to how much weight they can gain or fat store prior to winter dormancy and once this point has been reached and weather conditions begin to deteriorate in the autumn they do no remain active.

Female L.agilis emerge from and submerge into winter dormancy under very similar conditions (this study). In two of the three years studied here female L.agilis submerged later than males. Females complete their annual reproductive cycle (i.e. lay their eggs) later than the males and so may not reach a suitable condition for winter dormancy until later than the males. For both sexes there is presumably little point in remaining active in the autumn once it is no longer possible to make a net energy gain. This tendency towards energy conservation in the autumn has been demonstrated in L.vivipara which shows low temperature acclimation (reduced metabolic rate) in the autumn but not in the spring (Patterson & Davies 1978b).

Juveniles of both L.agilis and L.vivipara show a reversed pattern to that found in males. That is, they disappear into winter dormancy in the autumn at lower temperatures and levels of net radiation than those under which they emerge in the spring. This late activity in the autumn may be important for the building up fat reserves for winter dormancy or it may be important for juveniles to reach a certain stage of development before they enter winter dormancy.

The PBT and activity range of a lizard species must be important factors in determining behaviour under different climatic and weather conditions. Two lizard species of the same size but having different PBTs would behave quite differently under the same climatic regime. For instance, the species having a higher PBT would bask for longer and more frequently. L.vivipara shows seasonal changes in PBT (Patterson & Davies 1978a) with females having a low PBT immediately after emergence from winter dormancy (April) but a higher one in May than in the summer. Males have a higher PBT immediately after emergence from winter dormancy (April) than in the summer. Both species have a higher PBT in autumn than in summer. Although no causal relationship can be established, it may be significant that the high PBT in the spring occur at periods of rapid development of the reproductive system in both sexes (Saint Girons 1963, Avery 1975). These periods of high PBT are also generally associated with those seasons when each sex spends prolonged periods basking (post emergence for males, post mating for females, Nicholson 1980). This behaviour may be symptomatic of an attempt to reach a higher PBT..In Denmark the mean active body temperature of L.agilis and L.vivipara caught in the field was lower in spring than in summer (Sveegaard & Hansen 1976), although this does not necessarily mean that the PBT was not reached for some of the time. Also the geographical distributions of both species include more southerly climates and in these areas they may be able to reach a higher PBT in spring and autumn.

In terms of both seasonal and daily activity L.agilis was more restricted than L.vivipara, the latter was capable of being active under a greater range of conditions (defined by net radiation and temperature) than the former. Within a season, daily activity seemed to be largely dependent on the level of net radiation available, while between seasons the range of temperatures available changed but the levels of net radiation remained the same (i.e. lower solar radiation and lower temperatures so there is little change in the level of net radiation with season).

The pattern of lizard activity relative to temperature and net radiation was the same in summer and autumn, despite the shifts in the temperature ranges in question. That is L.agilis was generally found over a smaller range of conditions than L.vivipara the latter being found under lower net radiation and temperature regimes. Conditions which were below the L.agilis activity range in summer may be at the top end of it in the autumn. This shift in the temperature range used with season may be a question of availability. In summer when 'low cost' climatic conditions are available for much of the time (i.e. ones in which the Activity range of body temperatures can be quickly obtained), conditions under which it would be more difficult to reach the activity range were not used. In spring or autumn however, the range of climatic conditions available was much more limited and conditions which it would be inefficient to use in summer may be amongst the best available.

It seems that the basic differences in the thermoregulatory potential of L.agilis and L.vivipara due to their relative size and PBTs are not being compensated for by other aspects of their metabolism, integumental reflectance or moisture retention. Both on a yearly and a daily basis L.vivipara can be active for longer than L.agilis, and it's viviparous habit may give it some independence from the influence of summer weather on the time of appearance of juveniles.

CHAPTER FIVE

HOME RANGE AND MOVEMENT

5.1 INTRODUCTION

The area of habitat within which an animal spends its time may be either a territory or a home range. A territory has been defined as 'any defended area' (Noble 1939) and is generally interpreted as implying 'the exclusion of at least certain other individuals' (Southwood 1982). A home range is 'the entire area within which a lizard moves. Food, retreats and mates are found within this area' (Rose 1982). Some definitions of home range have excluded 'occasional sallies outside of the regularly used area' (Burt 1943). However, without extremely detailed information on movement it is impossible to distinguish an 'occasional sally' from the 'regularly used area' and no such distinction has been made here.

Neither L.agilis or L.vivipara are territorial animals. Although males of both species may fight in the spring they do not maintain an area of habitat from which they exclude other individuals of their own species (Simms 1970, Avery 1978, Nicholson 1980). It has been shown however that within an open heathland habitat L.agilis does have a distinct home range within which it spends its time (Nicholson 1980). As in the study of Habitat use in Chapter Three information on the home range of L.agilis within an open heathland habitat may not be directly relevant to the Compartment and Ride verge habitats studied here. In these habitats the presence and proximity of trees may be having a short and/or a long term effect on L.agilis home range and movement in general.

In the short term the presence of trees within Compartments may effectively reduce the area of usable habitat available to L.agilis at any one time. The shade produced by the trees may reduce the area of suitable habitat directly by limiting the amount of solar radiation which reaches the ground level vegetation, or indirectly by causing the vegetation at ground level to die back. If the measured home range of L.agilis reflects the area of habitat necessary for an individual to survive (i.e. to provide food, shelter, mates etc.) then the actual ground area necessary may be greater within a Compartment than on an equivalent area of open heathland. The Ride verge habitat in itself does not have this problem as it does not usually include any tree cover, however the above factors may still be important if Ride verges are used in conjunction with adjacent Compartment areas.

In the long term the presence of tree canopy cover effectively limits the length of time for which an area of habitat will be suitable for use by *L.agilis* (or any reptile species). The useful life of Compartments in particular is limited to perhaps 10 or 15 years after which the deterioration of the ground level vegetation and/or the reduction in the amount of solar radiation reaching the ground apparently renders the area unsuitable for use by *L.agilis*. The habitat along Ride verges may well remain usable for considerably longer than that within Compartments, however the increasing shade produced by surrounding plantations will eventually also render these areas too would unsuitable for use by *L.agilis*.

The heathland habitat within a forest is thus a 'dynamic' system, even if the area of habitat available for *L.agilis* in the forest remains constant its position within the forest gradually changes over time. Areas of suitable/used habitat become unusuble and new areas of potential habitat are created by the progress of the forest itself. In the long term there are therefore two processes to be considered with regard to the movement of *L.agilis* within forests, the response of a resident population to a deteriorating environment and the potential for colonisation of newly available habitat.

There are two main ways in which populations of *L.agilis* could respond to long term deterioration in the suitability of their habitat. Individuals resident in an area where the habitat is deteriorating may stay in the area or they may move out. Nicholson (1980) found that for an open heathland habitat the position of individual *L.agilis* home ranges did not change from year to year. This may be simply because the habitat remained suitable and therefore there was no need to move, or it may be an indication that individuals of *L.agilis* tend to remain within their established home ranges and would not respond to changes in the habitat by moving from the area.

The response of existing *L.agilis* populations to their deteriorating environment is also relevant to the colonisation ability of the species in the forest as a whole. If populations of *L.agilis* do not respond to a deteriorating environment and remain in an area until it becomes so unsuitable that the population dies out, this population contributes nothing to the colonisation of new areas and is lost from the population pool of the forest as a whole. However, if a resident population does respond to a deteriorating environment by moving away from that habitat, they may not necessarily find a more long lasting or suitable habitat, but there is at least a possibility that they will colonise a suitable habitat and so continue to be a functioning part of the forest population. If there is no movement of existing populations from deteriorating areas then the colonisation of new areas and therefore ultimately the maintenance of the population within the forest as a whole must be a result of dispersion of migrant individuals from existing, flourishing populations.

By looking at the home ranges of L.agilis within Compartment and Ride verge habitats it was hoped to establish how the home range of L.agilis was affected by the presence of tree canopy cover. In a short term project of this kind it was not easy to detect long term trends in the movement of L.agilis however, any evidence that was available has been discussed. Data was available for L.agilis only as individuals of L.vivipara could not be identified.

There are basically two techniques which can be used to calculate home ranges, these can be loosely grouped as 'polygon' methods and probability density distributions. The most commonly used method in the latter category is the construction of recapture radii. This method assumes that the lizards home range is circular, that lizard movements are random and that the distribution of sightings follows a normal distribution. Rose (1982) has demonstrated that these assumptions have seldom been met in home range studies with much largersample sizes that those involved here. It therefore seems unlikely that the data available here will be suitable for probabilistic analysis of home range area.

There are two ways in which polygon home ranges can be calculated, by drawing the convex or the minimum polygon around all sightings when they are plotted in two dimensions. For the convex polygon the outermost sightings are connected so that the edges of the polygon never indent, whereas the edges may indent in minimum polygons. This latter method has been criticised because the procedure for drawing a minimum polygon has never been successfully defined (Jennrich & Turner 1969), whereas there is only one way in which a convex polygon can be constructed from one set of data. The convex polygon method was used to construct all home ranges in this chapter.

The time scale over which a set of home range data was collected may considerably affect the size of the resulting area. For instance, the total area transversed by a lizard in a year may be the same from year to year, but on a monthly basis (for example), the home range may shift throughout the area, i.e. the whole area may not be visited by the lizard all the time. For example, mean home range estimates for Uta stansburiana over three months were 2.5X larger than the one month estimates in males, and in 3X larger in females (Rose 1982). The time interval necessary to accurately estimate the home range varies with the behaviour of the species being studied. In an active species which essentially covers its entire home range in a day the home range may be estimated by intensive studies over a short period of time. In a species which only uses a small part of its annual home range at any given time, a longer term but not necessarily less intensive study may be needed.

The data presented here on the home range of L.agilis (Section 5.2) is not the result of an intensive population study of a common species and consists of rather low numbers of widely spaced observations on individual lizards. Within Compartments (East Gore) the data available has been used to look at the home range of L.agilis on two levels. Firstly using all observation made on an individual during the three years of study (Section 5.2.2). Secondly, data from the radio-tracking of individuals in the spring of 1982 and 1983 and the summer of 1982 was used to provide information on the short term (weekly and daily) home ranges of L.agilis (Section 5.2.4). Also on East Gore, four animals were recaptured frequently enough during each year to investigate the presence of seasonal shifts in the home ranges of male and female L.agilis (Section 5.2.3). Lastly the data from the radio-tracked L.agilis on East Gore has been used to see if there was any correlation between the weather conditions between lizard observations and the distance moved by the radio-tracked animal in the same period (Section 5.2.4).

For Ride verge habitats (Morden Rides) data from 1981, 1982 and 1983 has been pooled to study the large-scale, yearly home ranges of individuals (Section 2.5.5). Unfortunately because of the large size of the area studied, recaptures of individuals were rare and the data set is small.

5.2 HOME RANGE SIZE, COMPARTMENTS

5.2.1 INTRODUCTION

The convex polygon method was used to construct all home ranges from the Compartment habitat of East Gore. One of the drawbacks of the convex polygon home range is that it has a sample bias when the number of observations is small. That is, initially the home range size increases as the number of sightings increase (Rose 1982). Provided that an animal remains within the same area, the size of the home range should stabilise after a certain number of sightings, producing a logistic curve if cumulative home range area is plotted against the number of sightings. Estimates of the number of observations necessary to produce an unbiased home range area vary. For Sceloporus virgatus, 18 sightings described 80% of the home range (Rose 1982) whereas the home range size of Podarcis muralis in Italy continued to increase until 170 observations had been made (Boag 1973). Jennrich and Turner (1969) developed a 'correction factor' to adjust for the bias due to sample size in the convex polygon method. However, this method is based on the assumption that the sightings are random and that they conform to a bivariate normal distribution. Unless data can be shown to conform to these two restrictions the correction factor should not be used.

This correction factor has been used in earlier studies on the home range of L.agilis (Nicholson 1980). Therefore, the data presented here were tested to see if the use of this correction factor was valid or appropriate in this case. To do this, a regression analysis was carried out to see if there was a significant relationship between the home range size and the number of observations made on an individual (5.2.2).

The home range of L.agilis was looked at in both the long (all observations; 5.2.2) and the short term (radio-tracking; 5.2.4). This should allow a comparison to be made between the area used by L.agilis in a week and that used during the year as a whole. Another way of looking at home range usage is to look for seasonal shifts in the home range area. This has been done by plotting the cumulative home range against the number of sightings made on an individual. If a lizard remains in a single area throughout the period of observation, this graph should produce a simple logistic curve. However, if the lizard shifts its range a series of stepwise logistic curves is produced (Rose 1982; 5.2.3).

5.2.2 HOME RANGE SIZE, USING ALL OBSERVATIONS

L.agilis : East Gore 1981, 1982 & 1983
MethoDS : 2.8.1

The mean home range size of female L.agilis was 924 m^2 and that of males 1847 m^2 (Tables 5.1 & 5.2), these two values were significantly different ($F = 4.75$, d.f. = 1,19, $P<0.05$). The mean home range size of subadults was 232 m^2 but as the sample size was very small ($n=2$) no

Table 5.1 Home range size, Compartments,
All observations, East Gore 1981, 1982 & 1983.

The home range of *L.agilis* calculated using all observations, a. females, b. males and c. subadults.

	Lizard No.	Area (m^2)	No. Recaptures	Period of Observation
a.	3	1077	22	June 1982 – August 1983
	12	497	14	August 1981 – May 1983
	18	1881	14	July 1981 – June 1983
	21	846	9	Sept. 1981 – June 1983
	30	1904	10	May 1982 – June 1983
	31	618	13	May 1982 – August 1983
	15	322	5	August 1981 – May 1983
	16	466	7	August 1981 – June 1983
	19	40	5	Sept. 1981 – June 1982
	26	1133	5	July 1981 – July 1982
	27	1436	7	May 1982 – August 1983
	29	1049	7	May 1982 – June 1983
	33	153	6	Sept. 1982 – June 1983
	38	1215	5	June 1982 – May 1983
	39	1229	8	June 1982 – August 1983
b.	10	4016	22	June 1982 – August 1983
	8	2351	21	July 1981 – March 1983
	14	462	11	August 1981 – April 1983
	22	1067	8	March 1982 – Sept. 1982
	34	509	8	March 1983 – August 1983
	37	2676	6	June 1982 – May 1983
c.	32	206	5	May 1982 – Sept. 1982
	34	258	6	June 1982 – Sept. 1982

Table 5.2 Home range size; Compartments,
All observations, East Gore 1981, 1982 & 1983.

The mean home ranges of L.agilis males, females and subadults using all observations.

	Mean home range (m^2)	N	S.E.	C.V. (%)
Females	924	15	148.5	16.7
Males	1847	6	576.3	31.2
Subadults	232	2	25.9	11.2

conclusions can be drawn from this (Table 5.2).

To test for a correlation between home range size and the number of observations made on an individual animal, a regression analysis was done for males and females separately and for males, females and subadults together. There was no significant correlation between home range size and the number of observation for males ($r = 0.627$, d.f. = 5, $P>0.05$) or females ($r = 0.259$, d.f. = 14, $P>0.05$) when treated separately. However for males, females and subadults together there was a significant correlation ($r = 0.560$, d.f. = 22, $P<0.001$). This does not however, provide any justification for the use of a correction factor as the result is biased by the presence of males, which have a significantly larger home range size and subadults for which there are few observations and which have small home ranges. The lack of a significant correlation between home range size and the number of sightings for males and females when treated separately suggests that in this work the number of sightings made on an individual was not having a significant effect on the size of the home range, and therefore a correction factor has not been used.

5.2.2 SEASONAL SHIFTS IN HOME RANGE AREA

L.agilis : East Gore 1981, 1982 & 1983
Methods : 2.8.1

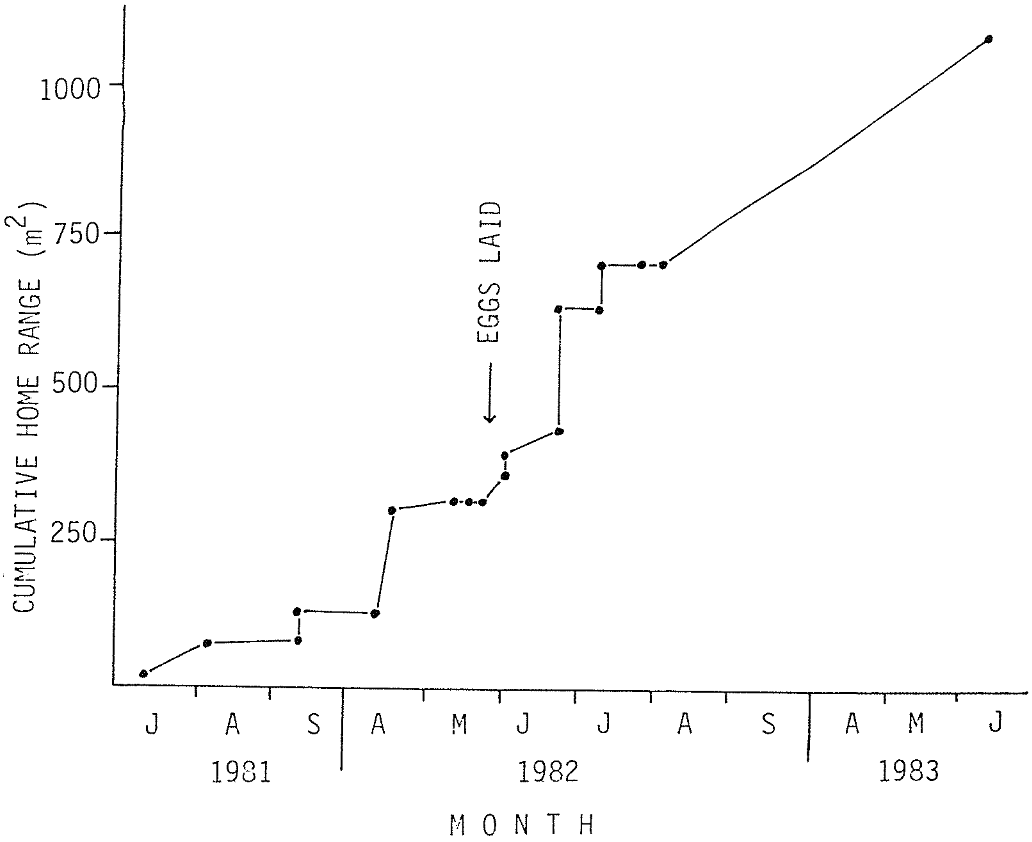
For most of the home ranges reported here the number of sightings made per individual were too low and were too widely spaced to be used to investigate seasonal shifts in the home range area. However, two males and two females were caught regularly enough to make an attempt at such an analysis worthwhile.

Adult female L.agilis show indications of a shift in home range occurring immediately after the eggs have been laid (Fig. 5.1). Neither of the two male L.agilis show any indication of a similar seasonal shift in home range, both show the 'expected' logistic curve of increasing home range size with sample size before a plateau was reached (Fig. 5.2). In both individuals the increase in home range size with number of sightings started to level out at 10 recaptures. However, in Lizard No. 10, there was a sharp increase of approximately 1,000 m^2 in home range after the area had remained steady for almost a year.

Fig. 5.1 Home range size; Compartments, Seasonal shifts in home range area.

The relationship between cumulative home range area and the number of recaptures made on an individual (plotted relative to month) for female L.agilis, a. Liz. No. 3 and b. Liz. No. 12, East Gore.

a.



b.

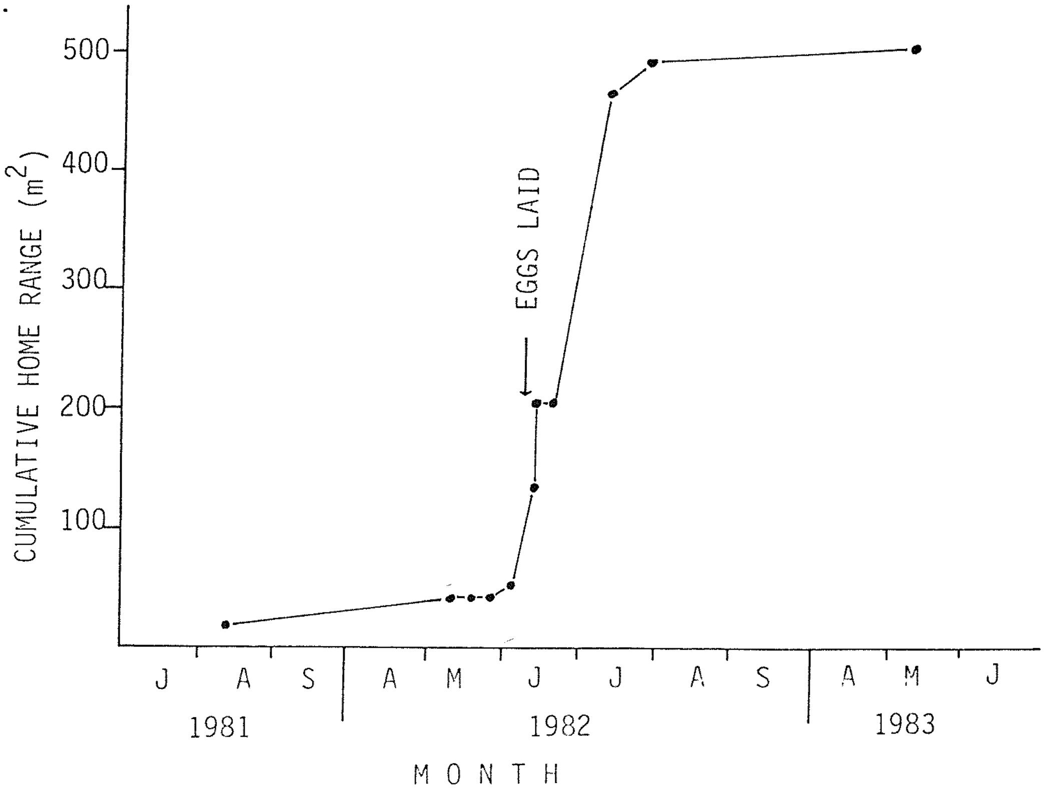
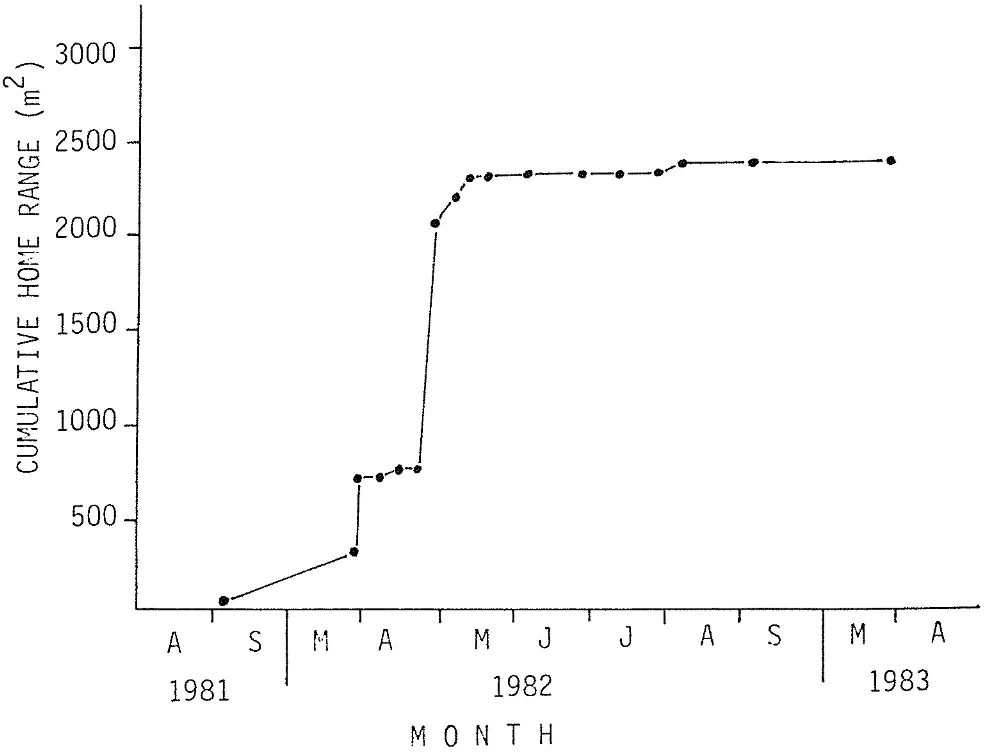


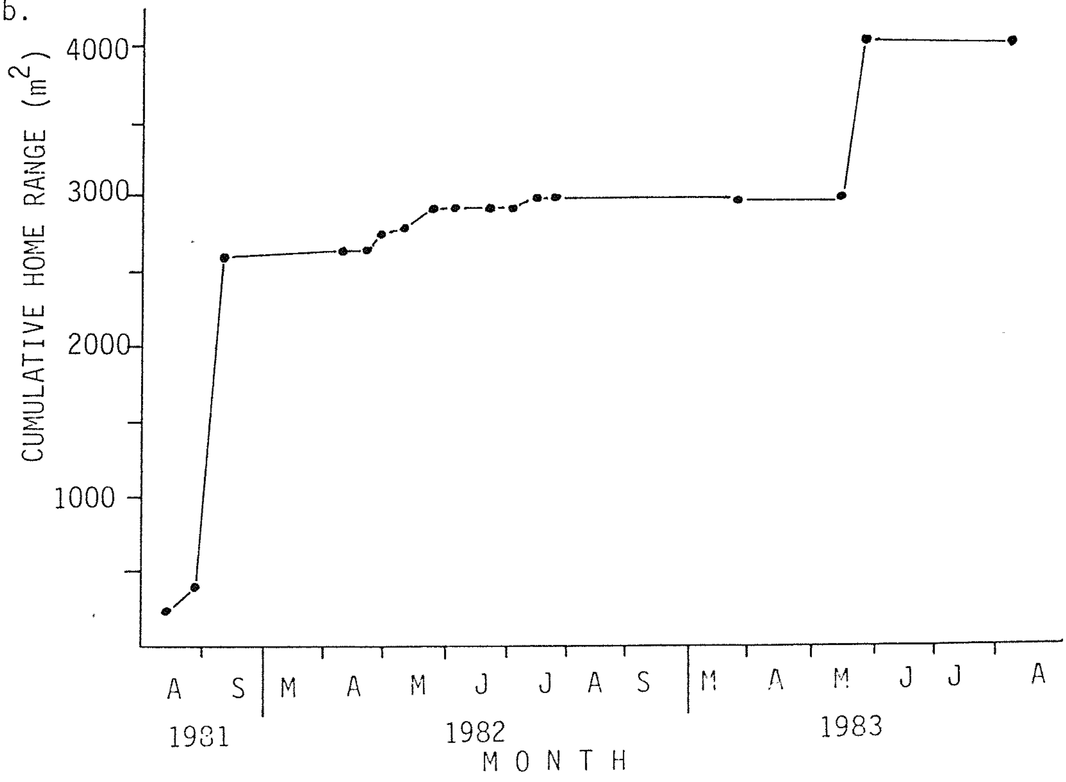
Fig. 5.2 Home range size: Compartments, Seasonal shifts in home range area.

The relationship between cumulative home range size and number of recaptures made on an individual (plotted relative to month) for male L.agilis. a. Liz. No. 8 and b. Liz. No.10 from East Gore.

a.



b.



5.2.3 SHORT TERM OBSERVATIONS ON HOME RANGE SIZE

L.agilis : Radio-tracking, East Gore 1982 & 1983
Methods : 2.8.1

The short term home ranges of male and female L.agilis were quite different. Females in general covered a smaller area than males over periods of measurement which varied from two to seven days.

In the spring males were much less active than in the summer.

In the spring there was no significant correlation between the distance moved per hour and the temperature ($r = 0.0714$, d.f. = 30, $P>0.05$), figures on the net radiation in the spring were not available. In the summer, the correlation coefficients for the relationship between both net radiation and temperature and the distance moved per hour, were significant (temperature, $r = 0.2327$, d.f. = 186, $P<0.05$; net radiation, $r = 0.2968$, d.f. = 186, $P<0.05$). However in both cases the amount of the variation in the data explained by the regression analysis was so small that the correlations cannot be treated as significant (percentage variance accounted for = 8.3% and 5.0%, for net radiation and temperature respectively).

5.3 HOME RANGE LENGTH, RIDE VERGES

5.3.1 INTRODUCTION

The position of L.agilis sighted on Morden Rides was recorded only with respect to the length of the Ride verge, the position of a sighting relative to the width of the verge was not recorded. Home range in the Ride verge habitat has therefore been analysed as a Home range length, that is the maximum distance between any observations of an individual. This has then been expressed as an approximate Home range area by multiplying the home range length by the mean width of all the Ride verges searched (4.5m).

It was also possible to compare the positions in which four male L.agilis were first sighted in the springs of 1982 and 1983 and hence to deduce whether or not they had spent their period of winter dormancy in the same area each year.

Table 5.3 Home range size, Compartments,
Short term observations of home range size.

The home range area of L.agilis from radio tracked animals on East Gore in 1982 and 1983, a. males, b. females.

	Area (m^2)	No. Days
a.		
Spring	2.0	5
	17.5	7
	16.6	5
	5.3	7
Summer	337.9	6
	132.7	2
	187.3	4
	216.4	4
	288.1	7
b.		
Summer	53.9	2
	40.3	6
	11.5	3
	29.4	6

5.3.2 HOME RANGE LENGTH, MORDEN RIDES

L.agilis : Morden Rides 1982 & 1983
Methods : 2.8.2

Only male L.agilis were recaptured frequently enough on Morden Rides to estimate a mean home range length (Table 5.5). Sightings have been divided into those caught regularly throughout the year and those caught in the spring only. The mean distance moved for animals caught throughout the year was 73 m, this is the maximum length of the ride covered during the period of observation. The mean width of the ride verges for all observations was 4.5 m, and assuming that only the ride verge habitat was being used, this would give a home range area of 328 m^2.

Four male L.agilis were seen early in the spring of both 1982 and 1983, the mean distance between the earliest sightings in both years was 4 m (Table 5.6).

The repeated use of hibernacular by L.agilis has been reported by Nicholson (1980) and while the exact location of the hibernacular used here was not known the appearance of the same individuals in almost identical positions in consecutive springs suggests that the same retreat was used on both occasions.

5.4 DISCUSSION

5.4.1 HOME RANGE SIZE, COMPARTMENTS

There was some evidence that the overall home range of L.agilis was greater within Compartments than for an open heathland habitat. The mean home range size of female L.agilis found in this study was 924 m^2, this is approximately in accordance with the figures found by Nicholson (1980; two study sites, 489 m^2 and 1924 m^2), whose study was carried out in an open heathland habitat. For males the value found in this study was 1847 m^2 and this is also very near to the figures given by Nicholson (1980; 1780 m^2 and 2130 m^2). However the figures given by Nicholson have been adjusted according to the correction factor of Jennrich & Turner (1969) to allow for the influence of the number of sightings on home range size. The uncorrected home range sizes from Nicholsons study were considerably smaller than those found here (males 400 m^2 and 378 m^2; females 505 m^2 and 85 m^2). The fact that the uncorrected values from this study were of the same order of magnitude as the corrected ones from Nicholsons study seems to indicate that the home range areas on East Gore (i.e. within Compartments) were actually greater than those for an open heathland habitat.

Table 5.5 Home range size, Ride verges;
Home range length, Morden Rides 1982 & 1983

The home range lengths of <u>L.agilis</u> in ride verge habitats using all observations, a. males b. females and c. subadults.

	Lizard No.	Distance (m)	N	Period of observation
a.	1	93.0	4	July 1981 - April 1983
	4	119.0	5	Sept. 1981 - April 1982
	24	37.0	5	April 1982 - April 1983
	58	55.0	5	Sept. 1982 - Sept. 1983
	99	60.0	4	July 1983 - Sept. 1983
b.	24	123.0	4	April 1982 - August 1982
c.	46	43.0	5	June 1982 - July 1983
	60	45.0	5	Sept. 1982 - Sept. 1983
	37	265.0	4	May 1982 - August 1983

Table 5.6 Home range size, Ride verges;
Home range length, Morden Rides 1982 & 1983.

The distance between sighting of male <u>L.agilis</u> in the spring of 1982 and 1983, Morden Rides.

Lizard No.	Date 1st spring	2nd spring	Distance moved (m)
12	28.3.82	14.4.83	1
15	14.4.82	8.4.83	6
22	15.4.82	21.4.83	3
29	27.4.82	21.4.83	5

There was also some evidence of seasonal patterns in the use of the overall home range area. For both males and females, if the home range area is plotted against the number of recaptures (plotted by month; see Figs 5.1 & 5.2) the graph showed the 'expected' pattern of a steady increase in home range area until an asymptote was reached. For three out of the four animals (two females and one male) for which this graph could be plotted, the recaptures began late in 1981 and continued through 1982, these graphs show the pattern of increase in the home range area relative to season. Once the asymptote has been reached unless there was a distinct shift in the established home range, no further increase in the home range area should be seen. In females (Fig. 5.1) there appears to be a distinct plateau in the home range area before and a rapid increase in the home range area after the eggs have been laid. Female <u>L.agilis</u> spend much of the time immediately prior to egg laying basking and would not be 'expected' to move far at this time. The rapid increase in home range area around egg-laying may be an indication of the onset of active behaviour after egg laying or it may be the result of a movement by the female away from the area in which she spent the spring to a site suitable for egg laying. Such large scale movements of females away from their normal or spring home ranges to find egg laying sites have been recorded before (Nicholson 1980).

The home range curve for male <u>L.agilis</u> showed a similar pattern to that for females. In this case, Lizard 8 (Fig. 5.2) in which the seasonal pattern of changes in home range area could be seen, showed a clear and rapid increase in home range area at the end of April. This would correspond closely with the emergence of female <u>L.agilis</u> in the spring. Prior to this, male <u>L.agilis</u> spend most of their time basking in an effort to exploit the relatively poor environmental conditions available at the time and in order to complete spermatogenesis and be ready for mating when the females emerge from winter dormancy (see Chapter Three).

Further evidence of this seasonal difference in the home range area of male <u>L.agilis</u> came from the radio-tracked animals. For these the short term home range of male <u>L.agilis</u> was much smaller in the spring than in the summer The magnitude of the difference between these two values is a clear indication of how inactive male <u>L.agilis</u> are immediately after emergence from winter dormancy.

In the summer, there was a considerable difference between the short term home ranges of male and female L.agilis (radio-tracking)

All radio-tracking in the summer was carried out after the mating season in males or after recovery from egg laying in females. As this was the case the difference found here was not likely to be a result of varying sexual roles but appears to show that in general males range more widely than females.

5.4.2 HOME RANGE LENGTH, RIDE VERGES

Based on the assumption that lizards were only using the verge habitat, the home range area of male L.agilis on Morden Rides (327 m^2) was approximately one twentieth that of male L.agilis on East Gore (1847 m^2), but was of a similar size to the uncorrected home ranges of Nicholson (1980; 400 m^2 and 378 m^2). This appears to support the supposition that the Ride verge habitat was quite different from a Compartment one and was in many ways very similar to an open heathland area. However, the difference between the figures for East Gore and Morden Ride was considerable and it seems unlikely that a difference of this size would result from the presence of trees on East Gore alone (part of the area had no tree cover at all). It seems probable therefore that the difference between the home range sizes on East Gore and Morden Rides indicates that on Morden Rides more than the measured habitat was being used by L.agilis. That is, lizards were using the habitat available under adjacent plantations and not only that of the Ride verge itself. While many of the plantations adjacent to the ride verges studied had closing tree canopies there was at least some ground vegetation surviving within many of them, such habitats might not be usable in their own right but may be usable in conjunction with an adjacent area of open ride verge.

Evidence of long-term population movements or dispersion was not readily available from a short term study of this type. The overall pattern of movement for L.agilis however is one of a fairly mobile animal. Home ranges were quite large and for instance, two of the four animals for which cumulative home range area was plotted against the number of recapture showed a second, rapid increase in home range area once the asymptote had been reached (Figs 5.1 & 5.2). This may represent only a brief movement outside the regularly used home range, rather than an actual shift of home range area, however it does show an ability to move outside the established home range area, which would be essential if individuals of L.agilis were to respond to deteriorating habitat conditions by moving until a more suitable habitat was found. The evidence from the study of habitat use within Compartments (see Chapter Three) suggests that L.agilis does respond to a deteriorating habitat, as it has been shown that L.agilis avoids areas of high tree canopy cover. If the assumption is made that in the past (i.e. when the trees were younger) the entire area of a Compartment was available to and used by L.agilis then this may indicate that the existing population had indeed responded to a deteriorating habitat by moving into the remaining suitable areas.

CHAPTER SIX
POPULATION BIOLOGY AND LIZARD GROWTH

6.1 INTRODUCTION

A considerable amount of information on the population biology of L.agilis was collected during this study. The interpretation of this data may provide information on the 'state' or 'condition' of L.agilis populations within Compartments (East Gore) and Ride verges (Morden Rides). A measure of the population density of L.agilis provides a comparison of the carrying capacity of the two habitats, although this must be interpreted in the light of other known factors such as the suspected use of areas under adjacent compartments by L.agilis observed on Ride verges. The distribution of the members of a population between various age and sex classes and the changes in this distribution from year to year may provide information on whether population size is increasing or decreasing.

Data concerning the patterns of growth found in L.agilis have also been reported here. While this may have no particular relevance to the forest heathland habitat in particular, it has been included as at least a contribution to the general knowledge available concerning L.agilis.

As L.vivipara was not captured regularly and could not be sexed without capture, there was no information available concerning the population biology or growth of L.vivipara.

Estimates of population size or density may be of two kinds, absolute estimates give the density of the population per unit area of the ground of the habitat available. Relative estimates give the density relative to some other unit of measurement such as unit effort. Both of the population estimates given here are of the former type.

Mark recapture studies are a frequently used method for producing an absolute estimate of population density. Although there are many techniques for the analysis of mark recapture data (Turner 1977), most analysis is based on the same principal. A proportion of the population is caught and marked in some way and then returned to the original population. After complete mixing of the marked animals with the original population, a second sample is taken. The number of marked animals in the second sample is assumed to have the same ratio to the total number in the second sample as the total number of animals originally marked had to the total population.

Most of the methods for estimating population density from mark recapture studies are based on the assumption that the probability of capture is the same for all members of the population. It has become clear that this is not often the case, the causes of deviations from this assumption can be summarised as:

"(a) The probability that a particular individual is caught in any sample is a property of the individual this 'catchability' having some distribution over the population.

(b) The probability that an individual is caught in any sample depends on its previous history of capture." (Cormack 1966).

That is, the probability of catching a particular individual depends on the one hand on inherent behaviour patterns and on the other on learning processes.

In an effort to produce a reasonable estimate of the population size and density of L.agilis within Compartments and Ride verges two methods of calculating the population size have been used. Firstly the observed frequencies of recapture of individual animals were used to produce an estimate of the population size of L.agilis. This method also tests whether or not captures (and recaptures) have taken place at random and with an equal probability of capture for all individuals (Eberhardt 1969). Secondly, data from the mark-recapture of L.agilis during all three seasons was used to produce an estimate of population size using the method described by Schumacher & Eschmeyer (1943) for the analysis of population size from a number of successive mark-recapture samples.

The use of population age structure as an indication of the stability of a population depends on the theory of a Stable Age Distribution. If the probabilities associated with the fecundity and mortality of each age group remain the same for every generation, the relative proportions of the age groups in the population approach with time a Stable Age Distribution (Poole 1974). This state is seldom found in natural populations (Krebs 1978) and in lizards it is particularly unlikely to be the case, especially in temperate climates and for an oviparous species such as L.agilis. Both fecundity and mortality may be closely linked to weather conditions, the population will probably experience 'good' and 'bad' years as a product of the climate. Survivorship in lizard populations has been shown to differ from year to year and it seems likely that the natality (in terms of hatching success) will also vary.

One of the chief characteristics of reptilian growth is that it tends to be discontinuous. Major changes in the growth curve are associated with hatching and sexual maturity, and with major shifts in the allocation of energy (Fig. 6.1: Andrews 1982). During pre-natal development the food source is provided by the mother, either via the placenta in viviparous species or the egg yolk in oviparous ones. This food source is an easily processed one and energy is mainly allocated to maintenance and size increase. After hatching the juvenile must not only learn to catch its own food and use energy to do so, but must also process the relatively indigestible food source, as well as escaping from predators and using energy for growth. The transition from embryo to juvenile is aided by the presence of the remains of the embryonic sac in neonates which provides an energy source for a short time after hatching, presumably while the juvenile obtains locomotory and feeding skills (Andrews 1982).

After the initial post hatching period growth resumes again in sexually immature animals and continues apace until the onset of sexual maturity. During this time energy is obtained by independent feeding and is used for growth, activity and maintenance. Growth slows at sexual maturity, the reduction being a consequence of the energy necessary for gonadal maturation and other costs associated with reproduction (Andrews 1982).

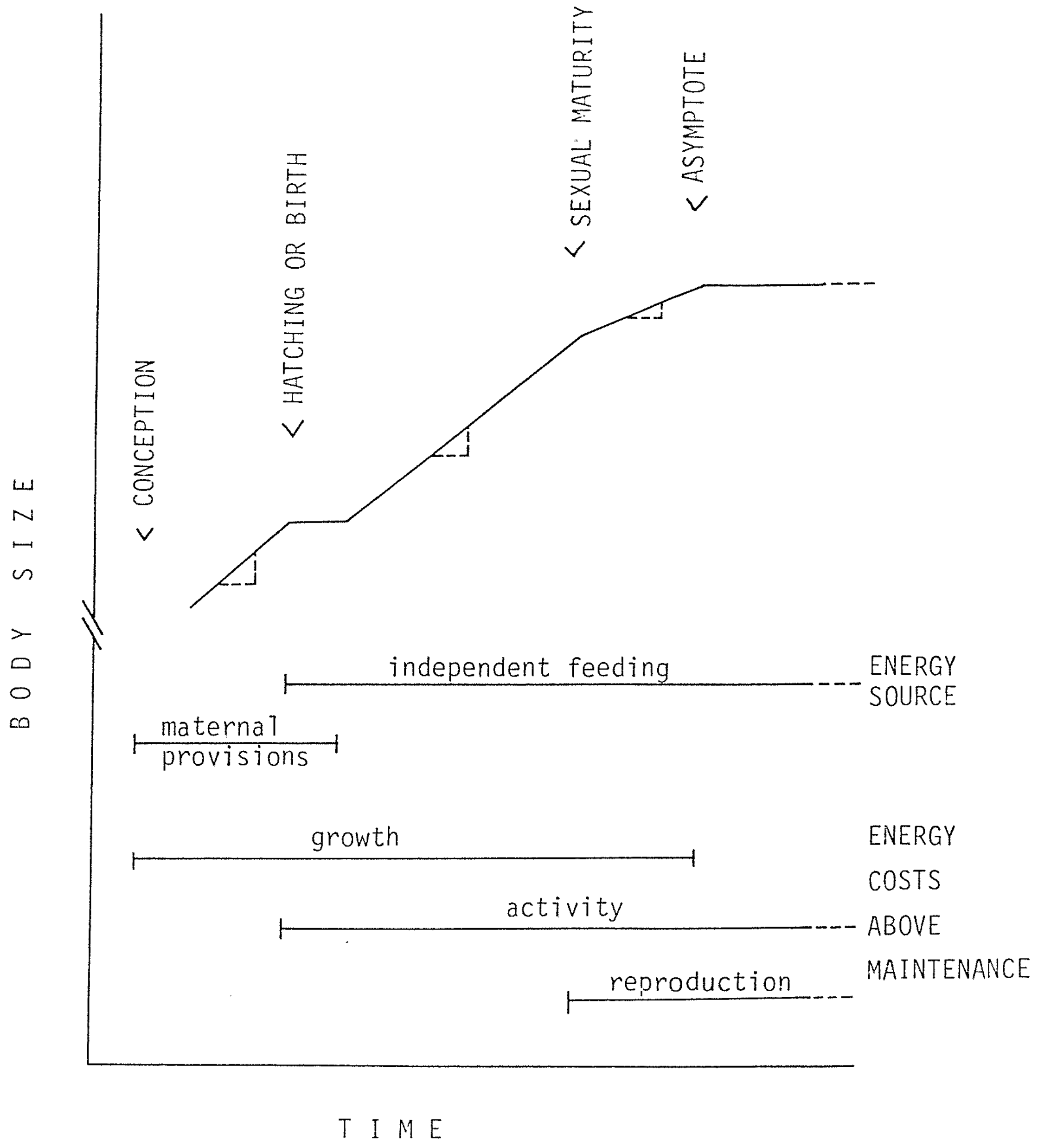
There are two main viewpoints concerning the continuation of adult growth, one that reptiles continue to grow throughout life (Porter 1972) and the other that individuals reach an asymptotic size after which growth is negligible (Andrews 1982).

Thus this chapter consists of two estimates of the population density of L.agilis within Compartments (East Gore) and Ride verges (Morden Rides). One has been calculated using the frequency of recapture of known individuals (6.2.2) and the other by comparing the proportion of marked and unmarked animals in a number of successive samples (6.2.3).

Comparisons of the age structure and sex ratio of L.agilis populations have been made both between years on each study area and between study areas (6.3).

The patterns of growth found in juvenile, sub-adult and adult L.agilis have been compared using data from both East Gore and Morden Rides (6.4).

Fig. 6.1 Lizard growth; introduction.
Schematic representation of reptilian growth throughout time as a function of the source of energy and the costs of growth, activity and reproduction. After Andrews (1983).



6.2 POPULATION DENSITY

6.2.1 INTRODUCTION

Eberhardt (1969) has suggested the use of the observed frequencies of recapture of individuals both as a test of equal catchability and as a basis for producing estimates of population size. The frequency of captures would be expected to follow an ordinary binomial distribution if:

(i) captures take place randomly with constant, equal probabilities of capture.

(ii) neither losses or recruitment occur in the population during the study.

The Poisson distribution provides a good approximation to the binomial and can be used to calculate the expected frequency distributions. Since the number of animals not seen is unknown, the distribution fitted to the observed data is truncated at the zero class. If the fit between the observed and Poisson distributions is good then it should be possible to estimate the number of animals in the zero class and hence the size of the population.

If the above analysis shows no significant differences between the Poisson and observed distributions this indicates that the population sample was random and not biased by unequal catchability of individuals. This not only means that it is possible to use the population estimate devised by Eberhardt (1969) but also that there is a good basis for the use of the multiple mark-recapture method of Schmacher & Eshmeyer (1943; 2.9.1.2).

6.2.2 FREQUENCY OF SIGHTINGS OF KNOWN INDIVIDUALS

<u>L.agilis</u> : East Gore & Morden Rides 1981, 1982 & 1983
Methods : 2.9.1.1

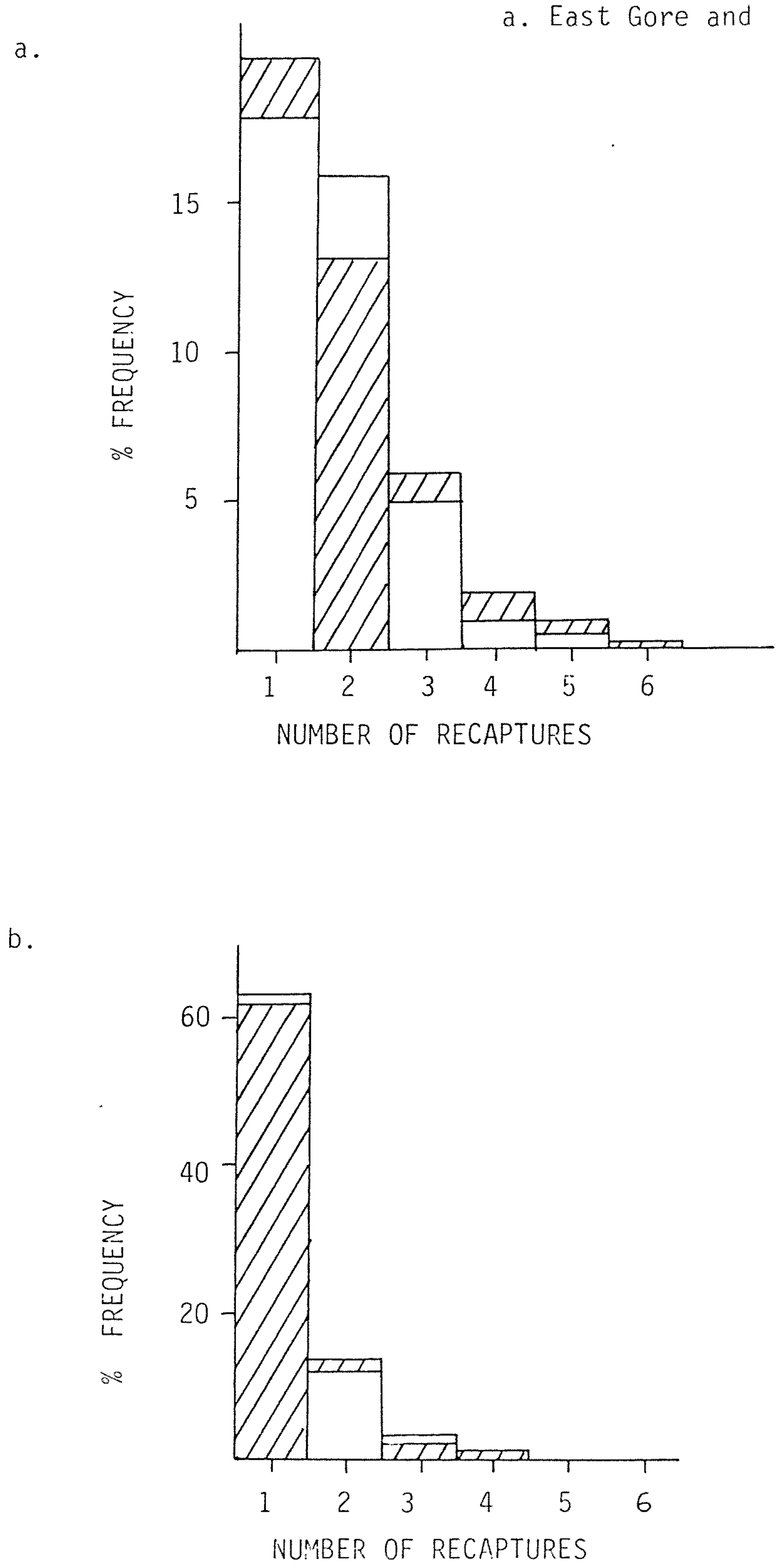
The recapture frequencies on both East Gore and Morden Rides (using all three years of data), did not differ significantly from a Poisson distribution truncated to allow for the missing zero class (East Gore, $\chi^2 = 1.04$, d.f. = 2, P>0.05, Fig. 6.2a; Morden Rides $\chi^2 = 0.50$, d.f. = 1, P>0.05, Fig. 6.2b). Since all three years of data were combined to produce this distribution it did not fulfill Eberhardts (1969) second assumption (6.2.1) of no recruitment or mortality during the period of study. However, as a Poisson distribution did describe the recapture frequencies of the population it seemed reasonable to proceed and calculate population densities from the data.

The estimated population sizes on East Gore and Morden Rides were

Fig. 6.2 Population density: frequency of sightings of know individuals.

Histograms showing the observed frequencies of recapture of <u>L.agilis</u> (☐) and the expected distribution of recaptures based on a truncated poisson distribution (▨)

a. East Gore and b. Morden Rides.



calculated from:

$$\hat{N} = \frac{\Sigma x \, n_x}{\hat{\lambda}} \qquad (6.1)$$

Where: $\Sigma x \, n_x$ = total number of individuals seen.
$\hat{\lambda}$ = estimated mean of Poisson distribution.

For East Gore

$$\hat{N} = \frac{74}{1.3254}$$
$$= 55.8 \text{ individuals}$$

For Morden Rides

$$\hat{N} = \frac{96}{0.4294}$$
$$= 223.6 \text{ individuals}$$

From the 1983 habitat survey of East Gore the area of suitable *L.agilis* habitat available on East Gore was estimated as 1.2 hectares, giving a population density of 47 individuals per hectare.

The Morden Rides consisted of approximately, 9660 m of verge, multiplying this by the mean width of ride verges for all observations in the rides survey (4.5 m) gave an area of 4.34 hectares, and a population density of 51 individuals per hectare.

6.2.3 ESTIMATION OF POPULATION SIZE FROM MARK-RECAPTURE DATA

L.agilis : East Gore & Morden Rides 1981, 1982 & 1983
Methods : 2.9.1.2

The method described by Schumacher & Eshmeyer (1943) gives a population size of 48 animals (SE = 6.31, d.f. = 14) on East Gore or a density of 40 animals per hectare (Table 6.1).

The population estimate for Morden Rides was 206 individuals (SE = 23.9, d.f. = 8) or a population density of 47 individuals per hectare (Table 6.1).

6.3 POPULATION AGE STRUCTURE AND SEX RATIO

6.3.1 INTRODUCTION

For East Gore (Compartments) the age structure and sex ratio of

Table 6.1 Population density; Estimation of population size from mark-recapture data.

Estimates of population size for East Gore and Morden Rides using Schumacher & Eshmeyer method.

	Estimated population size	S.E.	C.V. (%)
East Gore	43	3.8	8.8
Morden Rides	206	23.9	11.7

the population sampled has been calculated for all three study seasons. Three age classes have been distinguished, that is, adults, sub-adults and juveniles (see Section 2.2.3.1). Only adult animals were included in the data for sex-ratios as it was not always possible to determine the sex of sub-adult animals.

The population sample for each year included those animals seen while walking transects only, this was in order to prevent bias due to the repeated sighting of individuals on consecutive days etc..

For Morden Rides (Ride verges) data was available from the 1982 and 1983 study seasons only.

6.3.2 POPULATION AGE STRUCTURE

L.agilis : East Gore 1981, 1982 & 1983
: Morden Rides 1982 & 1982
Methods : 2.9.2.1

The proportion of each age class in the population on East Gore did not remain constant during the three years of this study (Table 6.2). In 1982 there was an increase in the proportion of juveniles observed and this was reflected in 1983 when there was a higher proportion of sub-adults in the population than in the previous two years. In 1981 and 1982 approximately 70% of the population sampled were adults, this figure fell to nearer 60% in 1983.

The proportion of the L.agilis population in each age class on Morden Rides was consistent for both 1982 and 1983 (Table 6.2). Approximately 50% of the population found were adults, 35% sub-adults and 15% juveniles.

6.3.3 POPULATION SEX RATIO

L.agilis : East Gore 1981, 1982 & 1983
: Morden Rides 1982 & 1983
Methods : 2.9.2.2

In all three years there were more females than males in the population on East Gore. The ratios of males to females were: 1981 = 1:2; 1982 = 1:5; 1983 = 1:4 and for all years approximately 1:4 (Table 6.3).

On Morden Rides the ratio of males to females found was very consistent in 1982 and 1983 and gave an overall ratio of 1 male to 1 female for the population (Table 6.3)

6.4

LIZARD GROWTH

6.4.1 INTRODUCTION

Whenever an individual of L.agilis was captured its weight (g) and snout to vent length (SVL; cm) were recorded. As the collection of

Table 6.2 Population age stucture and sex ratio; population age structure.

The age structure of the population of L.agilis on East Gore in 1981, 1982 and 1983 and on Morden Rides in 1982 and 1983. a. number of animals seen, b. proportion of population in each age class. The overall figures for all three years are also shown (Total).

		EAST GORE				MORDEN RIDES		
		1981	1982	1983	Total	1982	1983	Total
a.	Adult	23	33	33	89	61	73	134
	Sub-adult	4	4	17	25	43	53	96
	Juvenile	5	10	9	24	22	20	42
	Total	32	47	59	138	126	146	272
b.	Adult	0.72	0.70	0.56	0.65	0.48	0.50	0.49
	Sub-adult	0.12	0.10	0.29	0.18	0.34	0.36	0.35
	Juvenile	0.16	0.21	0.15	0.17	0.18	0.14	0.16

Table 6.3 Population age structure and sex ratio; population sex ratio.

The proportion of males and females in the adult population of L.agilis on East Gore in 1981, 1982 and 1983 and on Morden Rides in 1982 and 1983. a. number of males and females in the population, b. proportion of males and females in the population. Overall figures for all years are also shown (Total).

		EAST GORE				MORDEN RIDES		
		1981	1982	1983	Total	1982	1983	Total
a.	Males	7	5	6	18	18	28	46
	Females	15	26	22	63	16	22	38
	Total	22	31	28	81	34	50	84
b.	Males	0.32	0.16	0.27	0.22	0.53	0.56	0.55
	Females	0.68	0.84	0.73	0.73	0.47	0.44	0.45

6.3.4 MINIMUM SURVIVAL OF L.AGILIS POPULATIONS

By looking at the percentage of those animals identified during one field season which were also seen during the subsequent field season it is possible to produce a figure for the 'Minimum percentage survival' of the population being studied from one year to the next.

On East Gore from 1981 to 1982 76.2% of the adult individuals identified in 1981 were also seen in 1982 (Table 6.3A), from 1982 to 1983 the minimum survival of adult L.agilis was 60.0% (Table 6.3A). The minimum survival of adult L.agilis on Morden Rides from 1982 to 1983 was much lower at 35.6%. Figures have also been produced for the minimum survival of juvenile and sub-adult L.agilis from 1982 to 1983, on both East Gore and Morden Rides. However, the location and identification of these age classes was more difficult than for adult animals and so less confidence can be placed in these results.

Overall, the minimum survival on East Gore was much greater than that on Morden Rides. However, it must be remembered that this is a minimum figure and that the sampling regime used on East Gore was much more intensive than that on Morden Rides.

Table 6.3A The minimum percentage survival of L.agilis populations from one year to the next on a. East Gore (1981-1982) b. East Gore (1982-1983) and c. Morden Rides (1982-1983).

	♀	♂	sub-adult (1981)	Juvenile (1982)	Adult	Total
a.						
No. seen 1981	14	7			21	
No. also seen 1982	11	5			16	
Minimum survival (%)	78.6	71.4			76.2	
b.						
No. seen 1982	20	99	5	7	29	41
No. seen 1983	12	4	3	3	16	22
Minimum survival (%)	60.0	44.4	60.0	42.9	55.2	53.7
c.						
No. seen 1982	17	28	16	9	45	70
No. also seen 1983	4	12	5	5	16	26
Minimum survival (%)	23.5	42.8	31.3	55.6	35.6	37.1

mark-recapture data could be pursued without necessarily catching the animals (using photographs of their back patterns; see 2.2.6.2) the sample sizes involved were not particularly large. However, sufficient data was available to enable some basic features of lizard growth to be investigated.

Data from East Gore and Morden Rides has been plotted separately on Figures but as there were no apparent differences between the two study areas, the data has been pooled for the purposes of regression or other statistical analysis.

The rate of growth of juvenile, sub-adult and adult (male and female) L.agilis has been looked at in terms of both increasing weight and SVL and also in terms of the relationship between weight and SVL (6.4.2 & 6.4.3).

Using animals caught regularly throughout the year an attempt has been made to look at changes in individual growth patterns throughout the sub-adult year (6.4.4).

Finally, a comparison has been made of the size distribution of L.agilis on East Gore and Morden Rides. This has been done by looking at the distribution of adult male and female L.agilis between SVL classes (6.4.5).

6.4.2 GROWTH OF JUVENILES AND SUBADULTS

L.agilis : East Gore & Morden Rides 1981, 1982 & 1983
Methods : 2.9.3

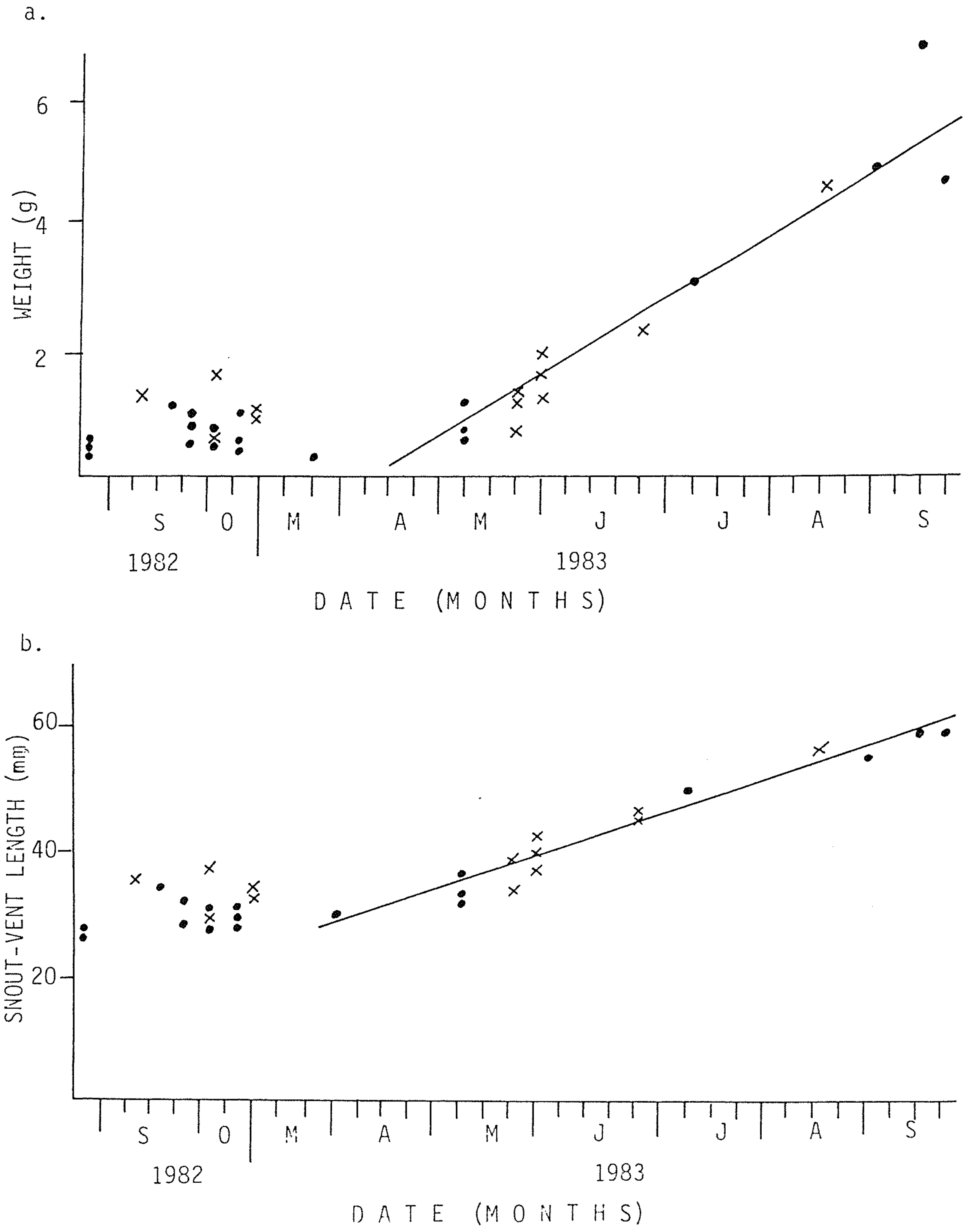
Neither the body weight (Fig. 6.3a)nor the snout to vent length (SVL; Fig. 6.3b) of juveniles show an increase during the autumn. This result however, could be biased by the spaced hatching of juveniles throughout the autumn period such that newly hatched animals were present throughout the sample. Only a single juvenile was caught twice during the autumn of 1982 and this had increased in weight from 0.6g to 0.7g and SVL from 28mm to 31mm in five weeks.

In sub-adults both weight and snout to vent length increased steadily. A regression analysis was applied to the increase of both weight and SVL relative to the number of weeks since one before the first capture. Both regressions were significant (weight, $r = 0.9527$, d.f. = 16, $P<0.01$; SVL, $r = 0.9704$, d.f. = 16, $P<0.01$). The rate of increase of weight was 0.25g per week and in length 13.2mm per week.

Although both of the above relationships appeared linear, a plot of weight against SVL for all sub-adult sightings showed that for the largest values of SVL and weight, the relative rate of increase in

Fig. 6.3 Lizard growth; growth of juveniles and sub-adults.

The growth of juveniles (1982) and sub-adults (1983) on East Gore (●) and Morden Rides (x). a. weight increase relative to time and b. snout-vent length increase relative to time. Regression lines are drawn for sub-adult (1983) observations only.



weight was greater than that of SVL (Fig. 6.4).

The maximum size obtained by a sub-adult by the end of 1983 was a SVL of 59mm and weight of 6.9g. The mean weight of all juveniles seen was 0.8g (N = 17, S.E. = 0.08) and the mean SVL was 30.8mm (N = 18, S.E. = 0.07).

6.4.3 ADULT GROWTH

<u>L.agilis</u> : East Gore & Morden Rides 1981, 1982 & 1983
Methods : 2.9.3

For both male and female <u>L.agilis</u> there was a significant relationship between weight and SVL (Figs 6.5 & 6.6) on both East Gore (Males, $r = 0.663$, d.f. = 32, $P<0.01$; Females, $r = 0.6950$, d.f. = 67, $P<0.01$) and Morden Rides (Males, $r = 0.8683$, d.f. = 26, $P<0.01$; Females, $r = 0.8375$, d.f. = 25, $P<0.01$). On both study areas, the regression line for females lay to the right of that of males.

On Morden Rides, the mean weight of males was greater than that of females (9.71g and 10.55g respectively) whereas on East Gore the reverse was the case (10.1g and 9.0g respectively; Table 6.4). There may be seasonal changes in the weights of both sexes and it is possible that one of these results was biased due to the time at which the sample was taken. The SVL is less likely than the weight to involve a bias and this was greater in females than males on both East Gore (males = 67.5mm, females = 73.1mm) and Morden Rides (males = 69.9mm, females = 71.0mm; Table 6.5).

Using all data the overall mean weight of adult males was 9.9g and of females 10.1g (Table 6.4), the total mean SVLs showed a greater difference between the sexes, that of males being 68.6mm and of females 72.5mm (Table 6.5).

6.4.4 CHANGES IN GROWTH RATE WITH AGE

<u>L.agilis</u> : East Gore 1981 & 1982
Methods : 2.9.3

It has been shown that there was a steady increase in weight and SVL throughout the sub-adult year and that it is likely that the rate of increase in SVL decreases towards the end of the year. Two animals known to have been born in 1981, were caught regularly enough in 1982 and 1983 to construct growth curves of weight and SVL against time.

The increase of SVL was already beginning to level out (Fig. 6.7) by the end of the sub-adult year, and it appears to do so earlier than the increase in weight. However during the first adult year, the rate

Fig. 6.4 Lizard growth; growth of juveniles and sub-adults.
The relationship between the weight and snout-vent length of all sub-adults L.agilis seen on East Gore in 1931 (■), 1982 (x) and 1983 (o).

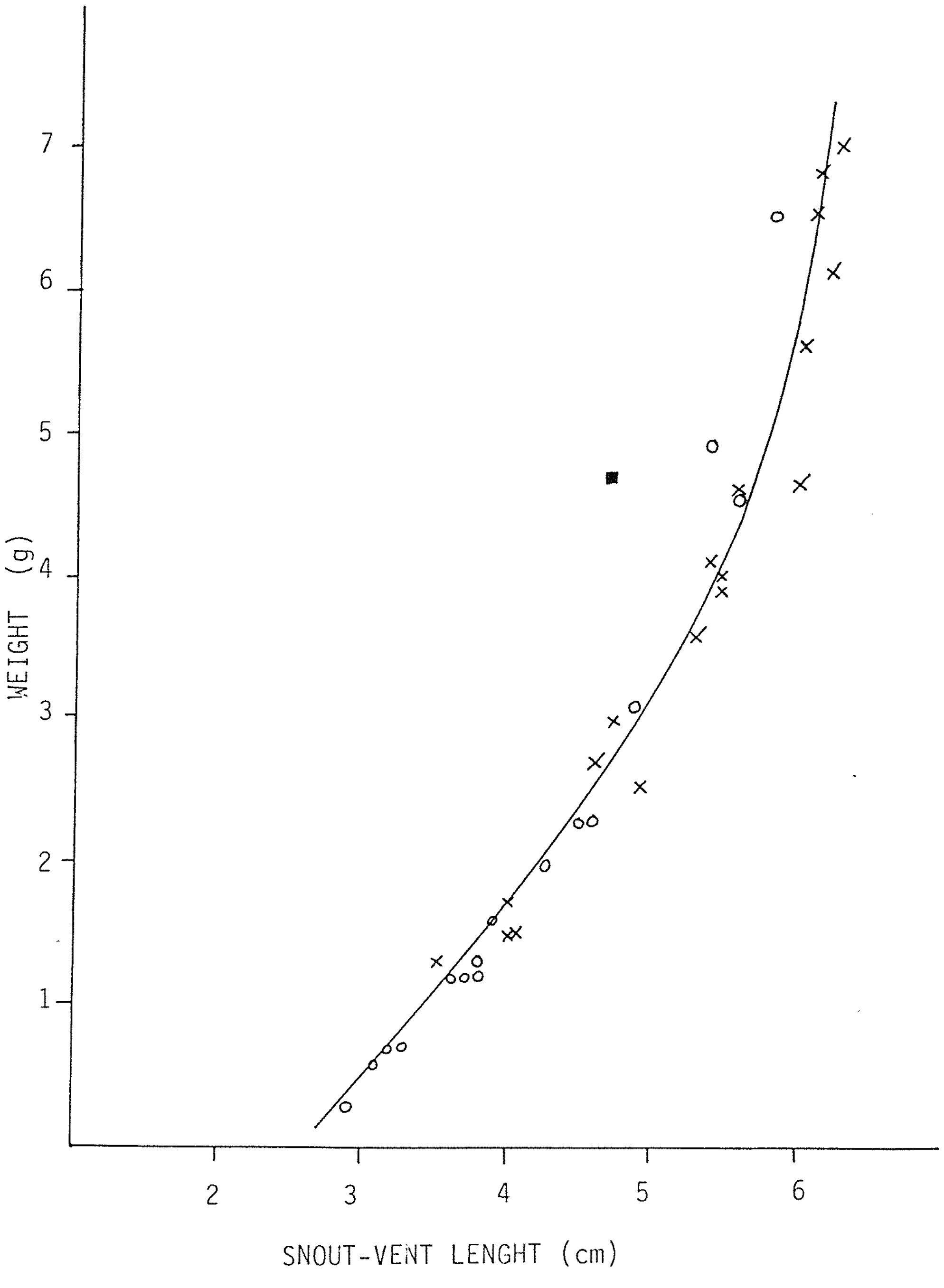


Fig. 6.5 Lizard growth; adult growth.

The relationship between adult weight and snout-vent length for male (●) and female (x) L.agilis. Data from all study seasons on East Gore has been combined.

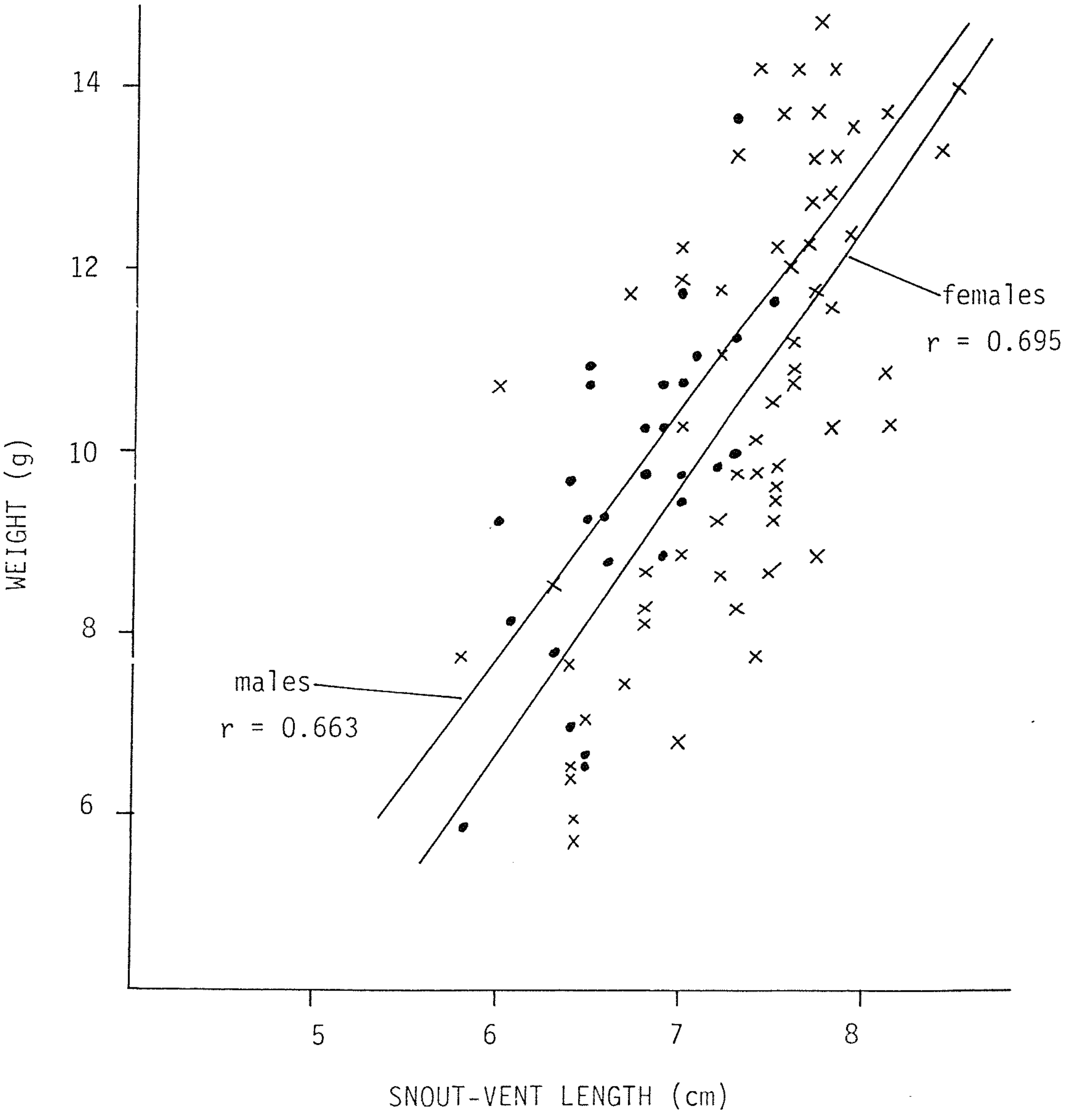


Fig. 6.6 Lizard growth: adult growth.

The relationship between adult weidht and snout-vent length for male (●) and female (x) L.agilis. Data from all study seasons on Morden Rides have been combined.

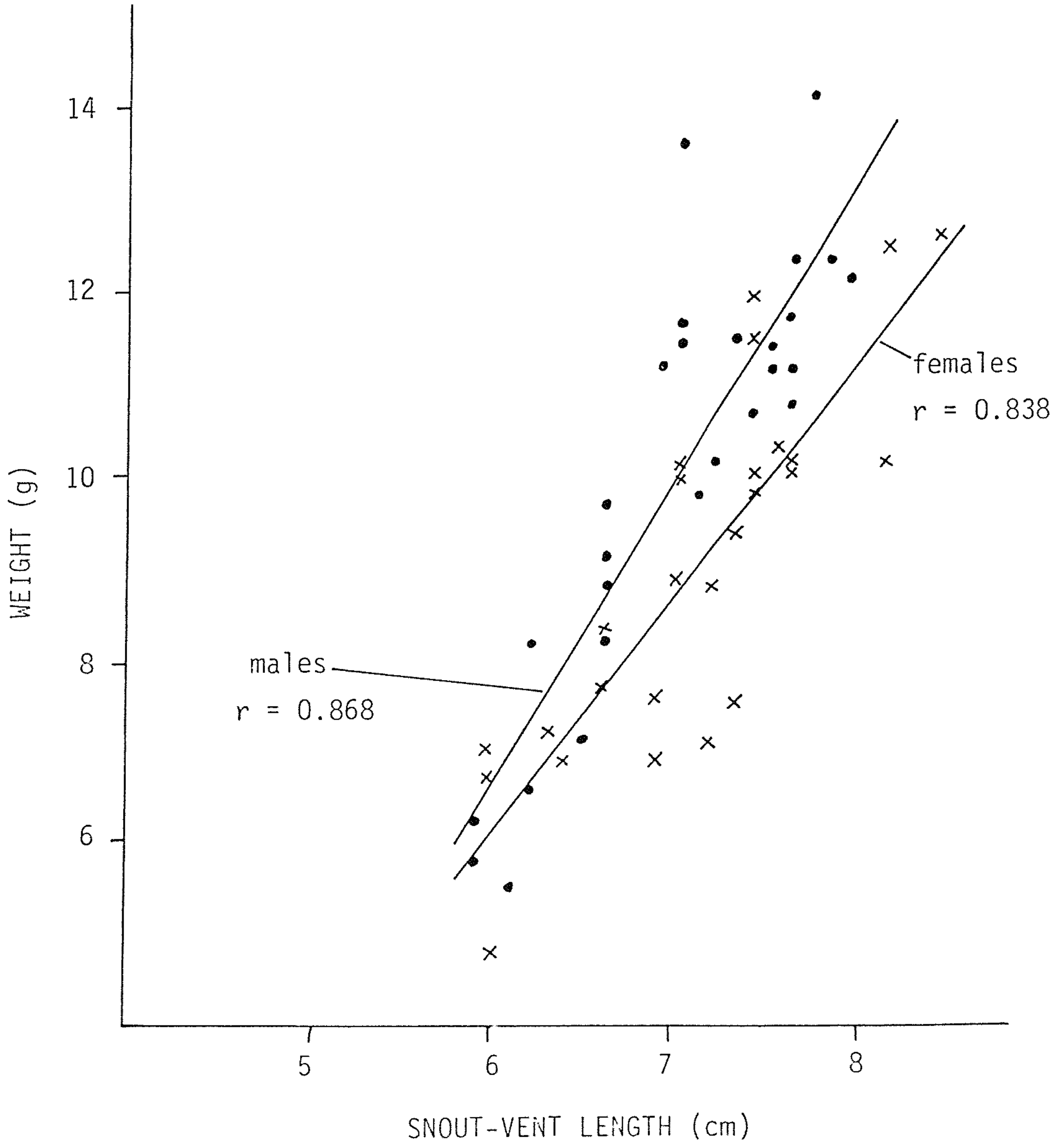


Table 6.4 Lizard growth, Adult growth.

The mean weight of male and female L.agilis on a. East Gore, b. Morden Rides and c. for all observations.

		Mean Weight (g)	Weight range	N	S.E.	C.V. (%)
a.	males	9.71	5.9 - 13.7	33	0.29	3.03
	females	10.55	5.6 - 14.7	68	0.29	2.78
b.	males	10.12	5.5 - 14.3	27	0.45	4.52
	females	9.02	4.8 - 12.7	26	0.39	4.36
c.	males	9.89	5.5 - 14.3	60	0.26	2.64
	females	10.12	4.8 - 14.7	94	0.25	2.45

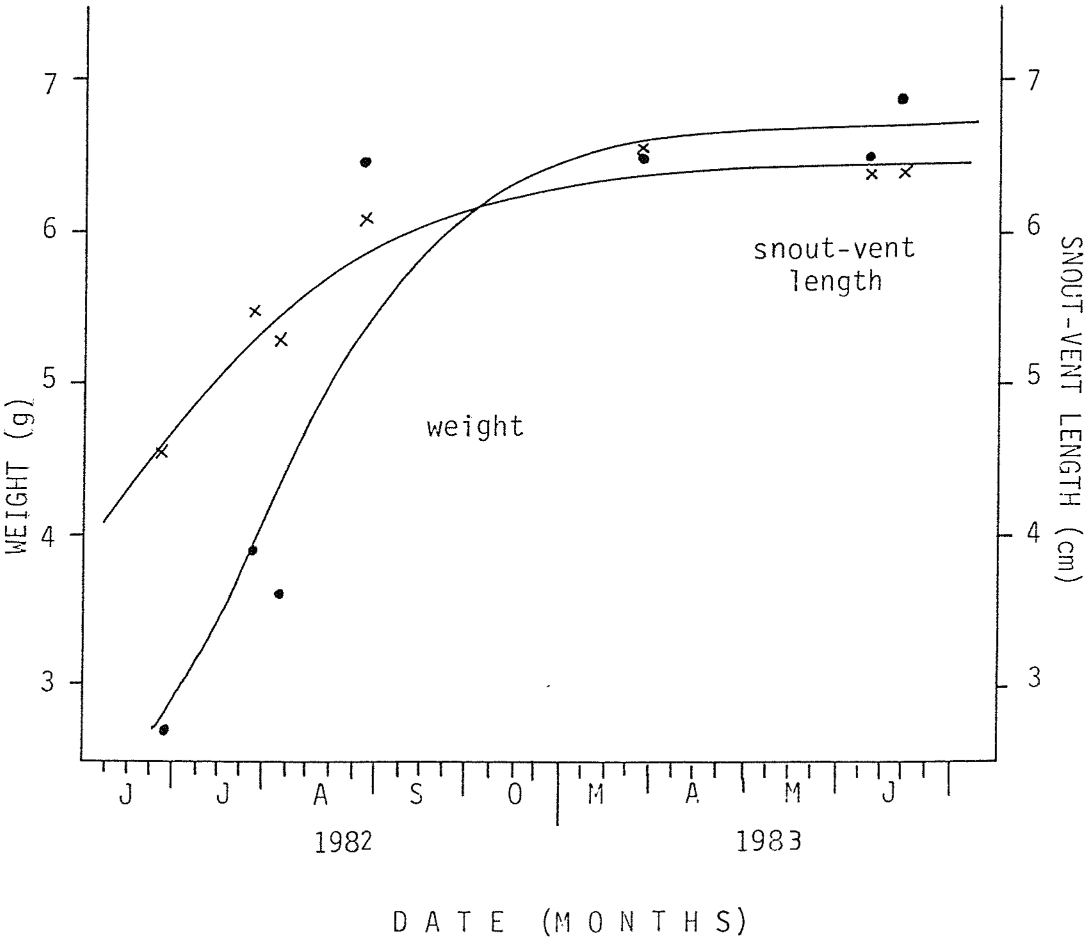
Table 6.5 Lizard growth, Adult growth.

The mean snout to vent lengths (mm) of L.agilis males and females on a. East Gore, b. Morden Rides and c. for all observations.

		Mean Length (mm)	Length Range	N	S.E.	C.V. (%)
a.	males	67.5	58.0 - 75.0	33	0.72	1.06
	females	73.1	58.0 - 85.0	68	0.69	0.90
b.	males	69.9	59.0 - 79.0	27	1.17	1.70
	females	71.0	60.0 - 84.0	26	1.25	1.76
c.	males	68.6	58.0 - 79.0	60	0.67	0.98
	females	72.5	58.0 - 85.0	94	0.61	0.84

Fig. 6.7 Lizard growth; changes in growth rate wtih age.

The changes in weight (g: ●) and snout-vent length (cm: x) during the sub-adult and first adult years in *L.agilis*. Data from two animals hatched in 1981.



of increase of both SVL and weight falls dramatically and only a small gain in weight was made during the first half of that year (Fig. 6.7).

6.4.5 DISTRIBUTION OF SIZE CLASSES IN THE ADULT POPULATION

L.agilis : East Gore & Morden Rides 1981, 1982 & 1983
Methods : 2.9.3

The SVL has been used rather than the weight to investigate the size structure of the populations on East Gore and Morden Rides because this seemed least likely to have been biased by seasonal fluctuations.

On East Gore for both males and females the majority of observations were in the largest SVL classes (Fig. 6.8a). A similar pattern was present for females on Morden Rides but for males the distribution between SVL classes was more even and included more of the smaller sizes.

6.5 DISCUSSION

6.5.1 POPULATION DENSITY

There are relatively little data available in the literature concerning the density of L.agilis populations. Spellerberg & House (1980) gave estimates of a maximum of 19 individuals per hectare for heathland sites in southern Britain and Nicholson (1980), using two study sites in the same area, found population densities of 48 and 52 individuals per hectare, which is in accordance with the results given here. There is a report of a density of 480 individuals per hectare for L.agilis in Moldavia, U.S.S.R. (Turner 1977). High densities of lizards (@ 1000/hectare) are often associated with tropical or subtropical species, or with species inhabiting particularly productive areas (Turner 1977). This difference in density for L.agilis may therefore be an indication that the habitat available in southern Britain is a poor one, relative to that available in other parts of its range.

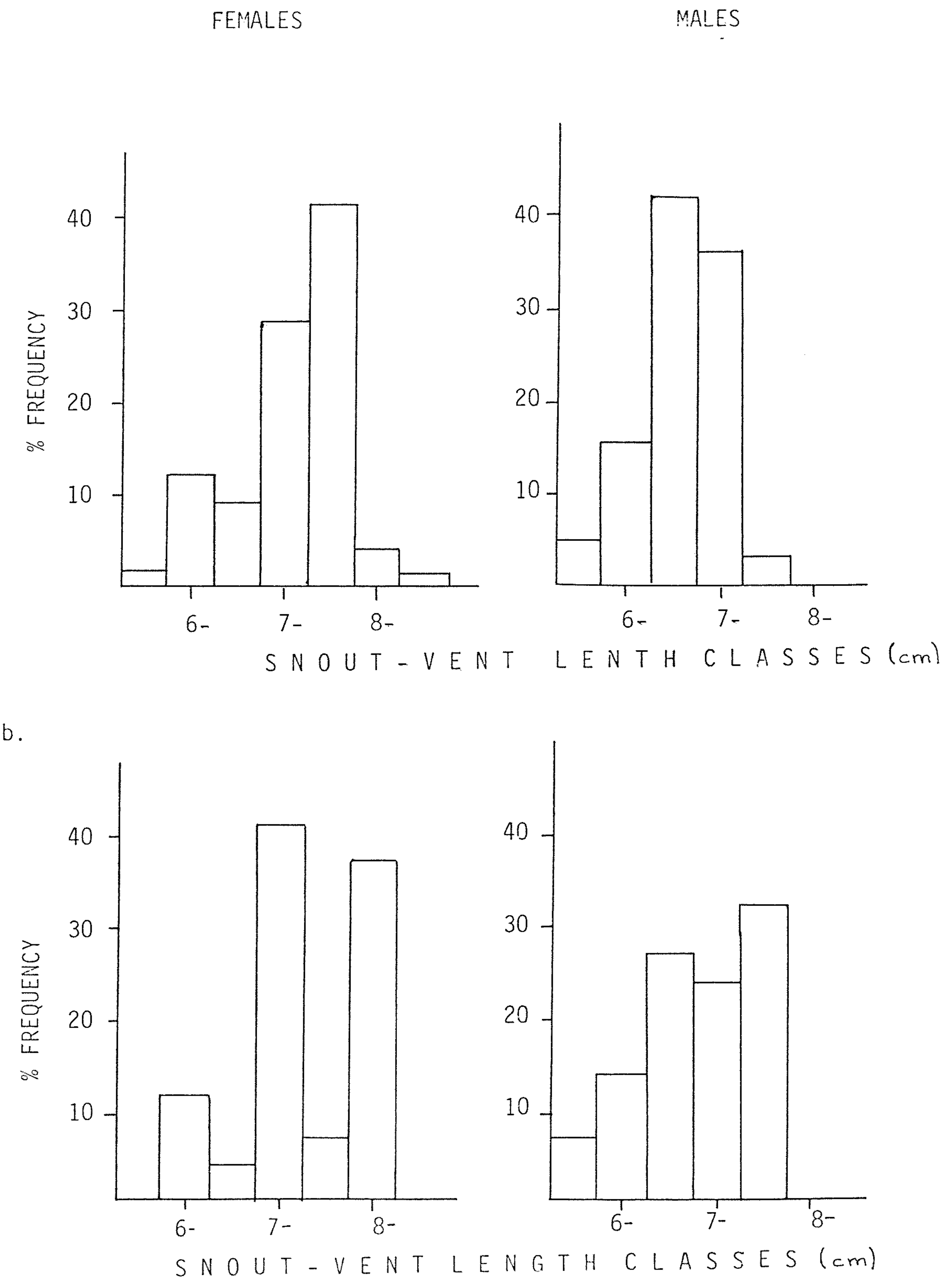
The population density of L.agilis found on Morden Rides was approximately the same as that found on East Gore. However, these estimates were calculated on the assumption that L.agilis was using the entire area searched. This may have been the case on East Gore but it was most unlikely on the Morden Rides study area. The estimate of the population density of L.agilis within Ride verge habitats was therefore probably a considerable underestimate of the actual density of L.agilis found within suitable Ride verge habitats.

6.5.2 POPULATION AGE AND SEX STRUCTURE

The populations being studied on East Gore and Morden Rides were

Fig. 6.8 Lizard growth, distribution os size classes in the adult population.

The distribution of adult male and female *L.agilis* throughout snout-vent length classes for a. East Gore and b. Morden Rides.



quite different. East Gore was a small and isolated site whereas Morden Rides covered a larger area and obviously had a considerably larger L.agilis population. In terms of both their age and sex structure the two populations were quite different. On Morden Rides the age structure of the population remained stable during the two years of study. During the same two years, the population on East gore showed considerable changes in age structure. Notably there appeared to be a large increase in the proportion of juveniles in the population in 1982 and an increase in the proportion of sub-adults in 1983. In 1981 and 1982 adult animals make up 70% of the L.agilis population on East Gore, whereas on Morden Rides the figure for 1982 and 1983 was approximately 50%. In 1983 after the apparently good hatching of juveniles in 1982 and good overwinter survival of juveniles from 1982 to 1983 the proportion of adults in the population on East Gore fell to 56%.

On Morden Rides the ratio of males to females was 1:1 whereas on East Gore there were an average of 4 females to each male. This difference could be the result of a difference in the sex ratio of juveniles born, a difference in the survival rate of males and females, or the product of a faster emigration rate in males compared with females. Tertyshnikov (1978) reports that the sex ratio among sub-adult L.agilis is close to one to one, and that during the subsequent years the proportion of males or females in the population may become greater depending on 'the conditions of existence of the lizards' (Tertyshnikov 1978). Tofan (1967) reported that the ratio of females to males increases with age, which suggests that females survive for longer than males.

The large ratio of females to males on East Gore may suggest that the population there is an old one with relatively low levels of recruitment of juveniles and sub-adults. This is also borne out by the high proportion of adults in the population.

6.5.3 INDIVIDUAL GROWTH

The growth of L.agilis follows Turners' (1977) discontinuous model of reptile growth with season. There was some evidence of growth during the juvenile period but this was very slight compared with the rapid increase in weight and SVL which occurred during the sub-adult year. Weight appears to increase consistently throughout this year, whereas the rate of increase in SVL slows down towards the end of the year. This decrease in the rate of increase of SVL may be indicative of the onset of the development of the reproductive organs which occurs in the autumn (Frazer 1983). Alternatively this decrease in growth could indicate a shift of energy resources from growth to the laying down of energy reserves for winter dormancy. The growth rate found here during the sub-adult year was 0.25g per week, Nicholson (1980) reported a very similar value of 0.27g per week. Nicholson (1980) found a logistic curve similar to that in Fig. 6.7 for the increase in SVL during the sub-adult year, he give the asymptote as being 62.5mm, slightly larger than the maximum SVL found here by the end of the sub-adult year of 59.0mm.

For adults, the relationship between SVL and weight is much less clearly defined than for sub-adults. In the adult population seasonal changes in weight produce a great deal of variation in the data, particularly in terms of weight. Male L.agilis were on average smaller (SVL) than females, which has also been found by Spellerberg & House (1980). Males of a given length were heavier than females of the same SVL. Nicholson (1980) predicted that if the SVL of an individual increased asymptotically the maximum size of males would be 82mm and of females 91mm. These figures were in close agreement with the maximum SVL's of adults found by Nicholson (1980) but were rather larger than those found here.

6.5.4 CONCLUSIONS

The populations of L.agilis on East Gore and Morden Rides appear to be quite different, overall it seems that the L.agilis population of Morden Rides was both more stable and more dense than that of East Gore.

The population age structure and sex ratio of L.agilis on East Gore fluctuated considerably from year to year, whereas that of Morden Rides remained relatively constant. These fluctuations may be symptomatic of the problems of a small, isolated population. Changes of a similar nature probably also occur in areas of Morden Rides, but a balance is achieved over the entire area and so the population as a whole remains more stable with time. If a population is small and isolated it may be susceptible to a succession of 'bad' years which might reduce its size to the extent that it cannot recover. If such an area constituted a part of a larger population then immigration from adjacent areas would be possible and might prevent extinction. Also a process of continual emigration and immigration probably occurs throughout a large area such that it is unlikely that the population in a single area would deteriorate to a dangerous extent, so long as the habitat remained suitable.

The population of L.agilis on East Gore also included a higher proportion of adults and of adults in large size (SVL; Fig. 6.8) classes than that on Morden Rides. It appears that the population of East Gore was an aging one with little recruitment of younger, smaller individuals. This may indicate that the resident population was not reproducing successfully so that relatively few new individuals were available to join the population each year, or it may be that the population was still reproducing successfully but that a high proportion of young animals were emigrating. If the area of habitat available was literally decreasing from year to year (as it presumably was on East Gore) it seems likely that that which remained would be held by the largest individuals leaving the smaller ones no choice but to disperse. The net result of this would be a population with a large proportion of large individuals.

It seems likely that the population density of L.agilis within the areas of suitable habitat on Morden Rides was greater than that on East Gore where at least on a seasonal basis the whole area of habitat searched was used by L.agilis.

It seems likely that the observed density of L.agilis along Ride verges was at least in part a genuine reflection a a greater density of L.agilis along Ride verges than within Compartments. While the L.agilis population of East Gore shows some evidence of being unstable, the population densities found here (47 and 36 individuals per hectare) were very similar to those found by Nicholson (48 and 52 individuals per hectare) on his two open heathland study areas. If Nicholsons' data and the results from East Gore were really representative of the open heathland situation, then the Ride verge habitat may be in some way 'optimal' and able to support relatively more individuals than an equivalent area of open heathland.

CHAPTER SEVEN

BEHAVIOUR AND FEEDING IN RELATION TO SHADE

7.1 INTRODUCTION

The thermoregulatory behaviour of lizards can be considered in terms of the costs and the benefits of maintaining a precise body temperature. As physiological processes in lizards are strongly influenced by body temperature, in an ideal environment a lizards net energy gain per unit time would be maximised if it was always active at its optimal body temperature (Huey & Slatkin 1976). However, there must inevitably be costs associated with maintaining a high body temperature which effectively reduce the physiological gains of precise thermoregulation. Such costs may be the energy expended in locomotion when shuttling between sun and shade or the increased apparency to predators as a result of such movements. Another factor which would reduce the net energy input even if a microhabitat was suitable for thermoregulation would be if an area were unsuitable for food acquisition. The ecological optimum body temperature therefore is the result of a balance between the costs associated with thermoregulation and the physiological gains from it and it is not always equivalent to the physiological optimum body temperature.

In a tropical climate lizards of the same species have been shown to behave differently in open (i.e. having no shade) and a closed (i.e. having a canopy cover) habitats (Huey 1974, Lee 1980). For example, Anolis sagrei was shown to thermoregulate less precisely in a closed as compared to an open habitat. Also, A.sagrei thermoregulated more precisely in closed but productive habitats than in closed but unproductive ones (Lee 1980). In this situation a closed habitat was an energetically costly one in which to thermoregulate because patches of sunlight were widely spaced and lizards had to expend energy shuttling long distances to reach them. In an open habitat however, sunny perches were numerous and so lizards only needed to move a short distance between sun and shade.

Superficially this appears to be analogous to the situation within forest Compartments being dealt with here. However, thermal passivity is probably an acceptable strategy only in a tropical climate where, while the body temperature may be closely related to the ambient temperature, the latter is high enough for the lizard to maintain an active, if imprecise, body temperature without thermoregulation. Both L.agilis and L.vivipara have quite high preferred body temperatures (@

30 - 32 °C) which in a temperate climate they could not maintain in an open habitat without active thermoregulation.

The amount of time which lizards in temperate climate must spend on basic activities such as thermoregulation and feeding has been demonstrated by a comparison of the behaviour of tropical and temperate lizard species. There is a trend from tropical to temperate climates of decreasing amounts of social and territorial behaviour in lizard species. It appears that lizards in temperate climates do not have the time available for elaborate behaviour patterns (Avery 1976). Hence in a temperate climate it may not be possible to offset the increasing cost of thermoregulation in a closed habitat. It may not be possible for temperate lizards to thermoregulate less precisely and still remain active, being in a closed habitat may then simply lead to a reduction in the net benefits gained from thermoregulation.

In a Compartment the presence of a canopy cover and the resultant pattern of shade throughout the habitat may be effectively increasing the costs of thermoregulation for L.agilis and L.vivipara when compared to an open unshaded habitat. If a species such as L.agilis or L.vivipara living in a temperate climate has little leeway within which to adjust it's thermoregulatory performance in response to increased costs of thermoregulation, then the presence of shade might be expected to affect behaviour directly. The experiments described here were aimed at investigating the effect of the presence of shade within a habitat, on the thermoregulatory and feeding behaviour of L.vivipara. By assessing the effect of the presence of shade on the thermoregulatory ability of L.vivipara, it was hoped to evaluate the importance of thermoregulatory limitations in restricting the use of shaded habitats by L.vivipara and L.agilis.

These experiments were carried out in an arena 2.5m square, the habitat within the arena was the same throughout its area but the amount of shade present could be varied. Direct measures of body temperature were not taken but behaviour was recorded throughout the day and was compared for three different shade regimes (Section 7.2). A comparison was also made of the relative use of shaded and unshaded parts of the arena by L.vivipara while active (Section 7.3) and on the affect of activity in the shaded areas on the length of the subsequent basking period (Section 7.4).

The position of and amount of feeding was recorded and analysed in relation to the position of shade areas (Section 7.5).

7.2 BEHAVIOUR IN RELATION TO SHADE

7.2.1 INTRODUCTION

The arena used for these experiments was divided into 25, 0.5m x 0.5m squares each of which contained food, water and a habitat consisting of hay, wooden blocks and cardboard shelters. Three treatments were carried out with 0, 10 and 15 squares of the arena shaded. Each experimental treatment consisted of two runs (termed sessions in remainder of text) of three days of observation each.

On each experimental day, two male and two female L.vivipara were observed for six hours, from one hour after the main arena lights were switched on to one hour before they were switched off, of this time a total of 350 minutes of observation per lizard per day were used in the analysis. During the period of observation the behaviour of each lizard was recorded and timed using a 20 channel chart recorder. The timing and position of any feeding occasions were also recorded.

7.2.3 FACTORIAL ANALYSIS OF VARIANCE

For analysis of variance taking into account the variation between treatments and between individuals a 2X factorial design was used, with three treatments (0 shade, 10 shade and 15 shade) against the three individual lizards which were used throughout the study. The design is illustrated in Fig. 7.1, each treatment/lizard combination consisted of two sessions and each session was made up of three days. The design was robust for unequal numbers of observations on any day.

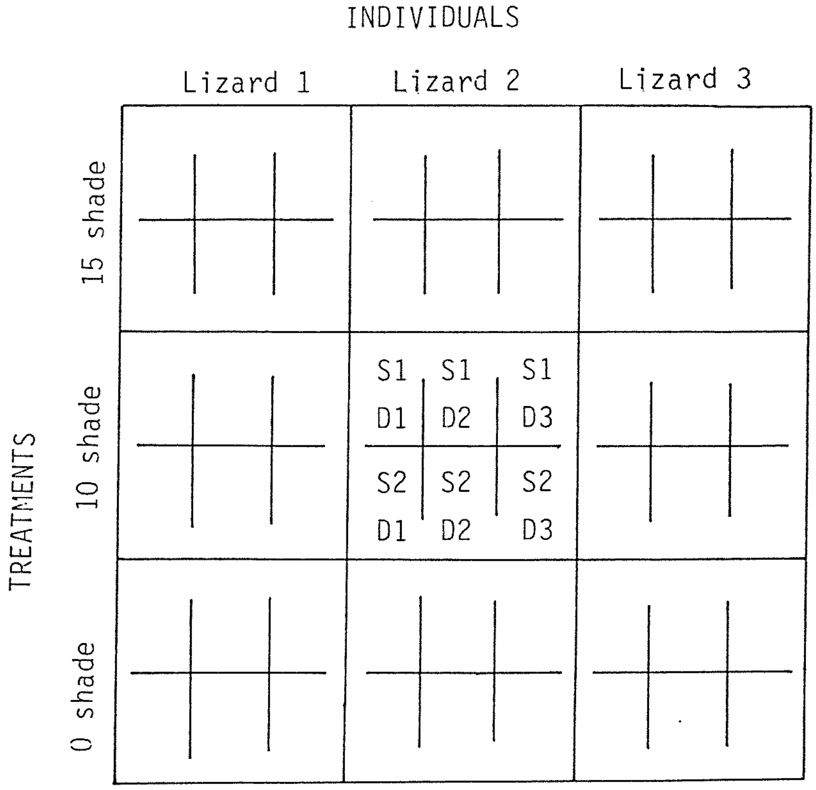
If there were significant day to day or session to session differences then the higher order comparisons between treatments and lizards were not valid.

Where there were significant treatment, individual or sex affects t-tests could be used to test for differences between the means for each pair of treatments or individuals or between the two sexes.

A second set of analyses were carried out in which the lizards were grouped according to sex rather than as individuals. On all days of observation three of the lizards observed were the same but the fourth animal varied from day to day (there were six animals present in the arena in total, only four of which were observed on a given day). Hence for the treatment/lizard analysis there were only three lizards for which data was available (two females and one male). For the treatment/sex analysis two animals from each sex were available as the fourth animal while it was not always the same individual it was always a male.

Fig. 7 1 Behaviour and feeding in relation to shade; analysis.

The 2X factorial design of analysis of variance used to analyse data on the behaviour of L.vivipara in relation to shade. Each square consists of two sessions (S1. S2) each of three days (D1, D2 and D3) of experimentation.



7.2.3 BEHAVIOUR IN RELATION TO SHADE

L.vivipara : Experimental work winter 1982/1983
Methods : 2.10.

A 2X factorial analysis of variance was used to test for the presence of significant differences in the behaviour patterns of L.vivipara under the three different shade regimes or treatments. The changes in the following behaviours were analysed, the abbreviations shown in brackets below for each behaviour have been used in the remainder of the text

(i) Total length of time visible per day (TOTAL)
(ii) Total length of time spent basking per day (TBASK)
(iii) Total length of time spent active per day (TACT)
(iv) Proportion of total time visible per day spent basking (PBASK)
(v) Proportion of total time visible per day spent active (PACT)
(vi) Length of Basking periods (MBASK)
(vii) Length of Activity periods (MACT)
(viii) Rate of movement (MRATE)

The number of squares which lizards moved through during each period of activity was known and this was used to calculate a rate of movement for each activity period (squares crossed per minute).

a. TOTAL, TBASK, PBASK, TACT and PACT

INTER-SESSION DIFFERENCES. There were no significant differences between the two sessions of each treatment for any of these behaviours (Table 7.1), this means that it was possible to the interpret any inter-treatment, individual or sex differences found.

TREATMENT (SHADE) DIFFERENCES. None of the differences between treatments were significant (Table 7.1).

INTER-INDIVIDUAL DIFFERENCES. There was significant inter-individual (lizard) variation present for TACT, TOTAL, PBASK and PACT, there were no significant differences between individuals in terms of TBASK. Comparing the mean values for the three individuals in each treatment the differences found were always between male (Lizard 3) and female animals (Lizard 1 and 2; Table 7.2). There were no significant differences between the two female animals for any of these behaviours.

INTER-SEX DIFFERENCES. For TACT, TOTAL, PBASK and PACT there were

Table 7.1 Behaviour and feeding in relation to shade; Behaviour.

The results of an analysis of variance for the TBASK, TACT, TOTAL, PBASK and PACT behaviour categories of L.vivipara for a. inter-treatment and inter-individual differences and b. inter-treatment and inter-sex differences. Figures shown are F-ratios, the levels of significancd shown are * = P<0.05 and ** = P<0.01.

a.

	F-RATIO					D.F.
	TBASK	TACT	TOTAL	PBASK	PACT	
Shade	2.51	2.37	0.84	3.34	2.72	2,9
Lizard	0.22	9.52**	3.19	11.30**	11.65**	2,9
Shade.Lizard	1.57	0.89	1.07	0.91	0.62	4,9
Shade.Lizard.Session	1.28	1.57	1.15	1.11	1.20	9,35

b.

	F-RATIO					D.F.
	TBASK	TACT	TOTAL	PBASK	PACT	
Shade	1.09	0.85	1.20	2.97	0.66	2,6
Sex	0.01	25.12**	8.82*	58.22**	36.45**	1,6
Shade.Sex	2.62	1.58	0.23	3.33	2.63	2,6
Shade.Sex.Session	1.58	1.32	1.32	0.32	0.76	6,24

Table 7.2 Behaviour and feeding in relation to shade; Behaviour.

The mean values per individual or sex or PBASK, TACT, PACT and TOTAL (see 7.2). Lizards 1 & 2 are females, lizard 3 is a male. t-tests have been used to make comparisons between individuals and sexes.

	Lizard/ Sex	Mean	Comparison	t	D.F.	P
PBASK	1	0.637	L1:L2	0.687	9	>0.05
	2	0.617	L2:L3	4.414	9	<0.01
	3	0.745	L1:L3	3.724	9	<0.01
	Male	0.749				
				7.625	6	<0.01
	Female	0.627				
TACT	1	101.7	L1:L2	1.064	9	>0.05
	2	114.6	L2:L3	4.197	9	<0.01
	3	63.7	L1:L3	3.135	9	<0.05
	Male	58.1				
				5.005	6	<0.01
	Female	107.6				
PACT	1	0.332	L1:L2	0.970	9	>0.05
	2	0.361	L2:L3	4.582	9	<0.01
	3	0.224	L1:L3	3.612	9	<0.01
	Male	0.211				
				6.036	6	<0.01
	Female	0.345				
TOTAL	1	22.5	L1:L2	0.659	9	>0.05
	2	24.3	L2:L3	2.454	9	<0.05
	3	17.6	L1:L3	1.795	9	>0.05
	Male	16.2				
				2.967	6	<0.05
	Female	23.5				

significant differences between the sexes present. Looking at the means for each behaviour, males were visible during the day for a shorter period than females (TOTAL) and spent a greater proportion of their time visible basking than females (PBASK)

b. MBASK, MACT & MRATE

INTER-SESSION AND INTER-DAY DIFFERENCES. For MBASK, MACT and MRATE a number of observations of each behaviour were available for each day of the experiment, hence there was potential variation within the data on both a day to day and a session to session level to take into account.

For MBASK, MACT and MRATE there were significant inter-session differences for the treatment/lizard analysis of variance (Table 7.3a). For the treatment/sex analysis of variance there were significant inter-session differences in MACT and MRATE and significant inter-day differences in MBASK (Table 7.3b). This indicates that in all cases the variation in the basic data set was too great to allow any conclusions to be drawn concerning the affects of the treatment, individual lizards or sex on behaviour.

7.2.4 USE OF ARENA IN RELATION TO SHADE

When 10 squares were shaded 40% of the arena was covered by shade. Therefore if the null hypothesis for this analysis was that the presence of shade had no affect on the use of the arena by L.vivipara an active lizard would be expected to spend 40% of its time in shade areas.

Lizards spent a mean of 40.2% of their time in shade areas. For the total values for all three lizards there were no significant difference between the observed and expected amount of time spent active in shade and non-shade areas (Table 7.4). However a chi square test between the observed and expected values for individual lizards showed a significant difference between the two distributions for two of the three individuals used (Table 7.4). Of these two individuals one spent a longer and one a shorter time in the shade that predicted. This suggests that there was a considerable amount of individual variation in the data leading to difficulties in interpreting the results.

A similar situation was found for 15 squares shaded (60% of the area of the arena). Here if the same null hypothesis was applied active L.vivipara would be expected to spend 60% of their time in the shade. Overall L.vivipara spent a mean of 58.7% of their time active in the

Table 7.3 Behaviour and feeding in relation to shade; Behaviour.

The results of an analysis of variance of the MBASK, MACT and MRATE behaviour categories of *L.vivipara* for a. inter-treatment and inter-individual differences and b. inter-treatment and inter-sex differences. The figures shown are F-ratios the levels of significance of which are shown as * = $P<0.05$ and ** = $P<0.01$.

a.

	F-RATIO			D.F.
	MBASK	MACT	MRATE	
Shade	5.46	0.82	1.03	2,9
Lizard	1.96	0.42	3.75	2,9
Shade.Lizard	0.60	0.15	0.20	4,9
Shade.Lizard.Session	3.17**	8.27**	6.57**	17,35
Shade.Lizard.Session.Day	2.68	1.39	2.54	35,26

b.

	F-RATIO			D.F.
	MBASK	MACT	MRATE	
Shade	5.03	0.94	0.78	2,6
Sex	5.27	0.00	5.53	1,6
Shade.Sex	0.89	0.02	0.14	2,6
Shade.Sex.Session	2.03	7.61**	8.13**	6,24
Shade.Sex.Session.Day	4.34**	1.64	2.40	24,3028

Table 7.4 Behaviour and feeding in relation to shade; Behaviour.

The use of the arena by active L.vivipara in relation to shade, a. for 10 squares shaded and b. for 15 squares shaded.

(N.B. χ^2 is not strictly valid because data was measured in minutes)

a.

Lizard	Total time active (minutes)	Time spent in shade OBS.	EXP. (40%)	Time not spent in shade OBS.	EXP. (60%)	χ^2	D.F.	P
1	2159	856	864	130	1295	0.1	1	>0.05
2	2632	1124	1053	1508	1579	8.0	1	<0.01
3	1061	371	424	690	636	10.9	1	<0.001
Total	5852	2351	2341	3501	3511	0.1	1	>0.05

b.

Lizard	Total time active (mins)	Time spent in shade OBS.	EXP. (60%)	Time not spent in shade OBS.	EXP. (40%)	χ^2	D.F.	P
1	1194	614	716	580	478	36.3	1	<0.001
2	2360	1508	1416	852	944	14.9	1	<0.001
3	715	386	429	329	286	10.8	1	<0.01
Total	4269	2508	2561	1761	1708	2.7	1	>0.05

shade and there was no significant difference between the observed and expected (60%) values (Table 7.4). However a chi square comparison between the observed and expected scores for individual lizards was significant was significant in all three cases (Table 7.4), indicating the presence of considerable inter-individual variation.

7.2.5 THE RELATIONSHIP BETWEEN THE LENGTH OF TIME SPENT IN THE SHADE AND THE DURATION AND RATE OF SUBSEQUENT BEHAVIOUR

Looking at each individual separately, only one animal shows a significant correlation between the length of a period of activity spent in the shade and the length of the subsequent basking period (Table 7.5a). All three animals showed a significant correlation between the length of time spent in the shade and the rate of movement while in the shade (Table 7.5b) under shade regimes. However, in all cases, the proportion of the variance of the data accounted for by the regression was too small for the regressions to be interpreted as expressing any real trends in the data.

7.3 FEEDING IN RELATION TO SHADE

An analysis of variance was used to test for differences in the number of mealworms eaten during each treatment (Table 7.6). The session to session variation was significant but not the treatment to treatment variation.

A chi square analysis was used to test for a difference between the proportion of mealworms eaten from shaded and from unshaded squares. If the distribution of feeding was not affected by the presence of shade it would be expected that for 10 shaded squares 40% and for 15, 60% of the mealworms eaten were taken from shaded squares. For 10 squares shaded, 31% of mealworms eaten were taken from shaded squares, there was no significant difference between the observed and expected distributions ($\chi^2 = 1.38$, d.f. = 1, $P>0.05$; Table 7.7a). For 15 squares shaded, 33% of mealworms were taken from shaded squares and this was significantly fewer than would be expected if feeding was not influenced by the presence of shade ($\chi^2 = 8.89$, d.f. = 1, $P<0.01$; Table 7.7b). The chi square distributions were applied to the total values for all days of observation only as the number of mealworms eaten on each day was too small to allow individual days to be analysed separately.

Table 7.5 Behaviour and feeding in relation to shade; Behaviour.

The relationship between the length of time spent in the shade and a. the length of subsequent basking periods and b. the rate of movement while active for L.vivipara.

P.V. = the percentage of variance in the data accounted for by the regression.

	Treatment	Lizard No.	r	D.F.	P	P.V. (%)
a.	10 shade	1	0.002	392	>0.05	0.00
		2	-0.061	349	>0.05	0.10
		3	0.055	217	>0.05	0.00
	15 shade	1	0.099	237	>0.05	0.60
		2	0.138	271	<0.05	1.60
		3	0.050	147	>0.05	0.00
b.	10 shade	1	-0.244	408	<0.01	5.70
		2	-0.146	361	<0.01	1.90
		3	-0.186	229	<0.01	3.00
	15 shade	1	-0.180	249	<0.01	2.90
		2	-0.214	284	<0.01	4.20
		3	-0.174	159	<0.05	2.40

Table 7.6 Behaviour and feeding in relation to shade; Feeding.

A comparison of the number of mealworms eaten per day by all animals under each treatment (ANOVA).

Treatment	F-RATIO	D.F.	P
Shade	0.354	2,3	>0.05
Shade.Session	3.815	3,12	<0.05

Table 7.7 Behaviour and feeding in relation to shade; Feeding.

A chi-square analysis of the proportion of those mealworms eaten which were taken from shade and non shade squares, a. 10 squares shaded and b. 15 squares shaded.

a.

	Day						Total	
	1	2	3	4	5	6	Obs.	Exp.
Shade - Obs.	0	2	0	3	2	5	12	15.6
Unshaded - Obs.	6	5	7	4	2	3	27	23.4
Total - Obs.	6	7	7	7	4	8	39	

b.

	Day						Total	
	1	2	3	4	5	6	Obs.	Exp.
Shade - Obs.	1	2	3	1	1	2	10	18
Unshaded - Obs.	3	5	4	5	2	1	20	12
Total - Obs.	4	7	7	6	3	3	30	

7.4 DISCUSSION

7.4.1 BEHAVIOUR

No effects of the presence of shade on the behaviour of L.vivipara were found. For the length of time spent basking and active per day and the rate of movement, the day to day and session to session variation was too great to allow any comparisons of treatment effects (i.e. of shade) to be made. Similarly although the mean time spent in the shade by active lizards was indicative that shade was used in proportion to its availability, there was so much inter-individual variation that no significance could be attached to the result. A significant difference in behaviour between the two sexes was apparent in terms of the total time visible per day, the total time active per day and the proportion of the total time visible per day spent active or basking. However, although the difference was statistically significant the sample sizes involved were small (n = 2 for males and females) and so any conclusions drawn must be tentative ones.

7.4.2 FEEDING

No effect of shade on feeding was apparent for 10 squares shaded but when 15 squares were shaded significantly fewer mealworms than expected were taken from shaded areas.

7.4.3 CONCLUSIONS

It proved impossible to effectively analyse data on L.vivipara behaviour from this experiment. The amount of variation between individuals and within the data set in general was too great. However the presence of shade was shown to affect the feeding behaviour of L.vivipara. Feeding was reduced within shaded areas although there was no significant effect of the presence of shade on the amount of food taken. Food was available throughout the arena, the amount present in each of the 25 squares of the arena being roughly equivalent to that necessary to feed all the lizards present in the arena for one day. Hence there was food in the arena (and in the unshaded areas alone) well in excess of that required by the L.vivipara present. It appears that under conditions of heavy shade but ready food availability within unshaded areas, L.vivipara respond by feeding prevalently within the unshaded areas. It might be expected that this response would be accompanied by a behavioural tendency to spend less time within shade as opposed to non-shade areas while active (than would be expected from the proportion of the arena which they cover). Unfortunately the behavioural data provided by these experiments was too variable to provide any evidence for or against this response.

It was hoped that these experiments would help to show how L.vivipara reacted to the presence of shade and give some idea of how much shade they could tolerate before a habitat became unusable. It seems likely however that while these experiments dealt literally with the responses of L.vivipara to the presence of shade within a habitat, they did not cause the costs of lizard thermoregulation or feeding to rise significantly. While the presence of shade reduced the area of thermal radiation available throughout the arena, the density of lizards was quite low (6 individuals), such that they could all co-exist as easily within $2.5m^2$ (unshaded area available when 15 squares were shaded) as in the $6.25m^2$ of the whole arena. This is probably particularly the case as food was available in excess throughout the arena. The most obvious follow-up to these experiments would be to reduce food availability within the unshaded areas such that it became necessary for animals to forage within the shaded parts of the arena. By necessitating the frequent use of the shaded areas this may produce an increase in the costs of thermoregulation and lead to a detectable behavioural response by the lizards.

Overall these results appear to suggest that shade areas within a habitat are avoided, provided there is enough food available within the non-shade areas of the habitat. Presumably this means that within a Compartment the effective area of habitat available is gradually reduced over the years as the area of shade present increases. The deterioration of the habitat as a potential area for use by lizard species may be accelerated as those individuals present tend to accumulate into smaller and smaller areas which may lead to both competition between crowded individuals and localised shortages of food within non-shade areas. There is however one major difference between the situation used in these experiments and that within forest Compartments. That is that within Compartments the shade areas move constantly within the habitat while in these experiments it remained static. So long as the trees in a Compartment are small they produce only an area of shade which moves during the day as the position of the sun changes. In this way while the area of habitat available at a given time may be reduced the whole of the area of the habitat is available during the day as a whole. It therefore seems unlikely that localised areas of food shortage would develop as a result of the tendency not to feed within shade areas. The actual area of habitat available in total will only be reduced when the trees become sufficiently tall and/or dense to produce areas of permanent shade within the habitat. At this stage the habitat may begin to decline rapidly in terms of its usefulness as a lizard habitat as the vegetation at ground level also probably begins to deteriorate rapidly at this point.

CHAPTER EIGHT

THE CONSERVATION OF L.AGILIS POPULATIONS WITHIN FORESTRY PLANTATIONS

8.1 INTRODUCTION

The conservation of L.agilis within afforested areas could be thought of in terms of the provision of permanent areas of suitable L.agilis habitat within a forest. With some maintenance (such as shrub and pine clearance etc.) such areas could remain suitable for use by L.agilis almost indefinitely and would provide a token presence of L.agilis within a forest. Such reserve areas would of necessity be small (a forest is planted to grow trees not sand lizards), and the work described here from the East Gore study area has given some indication of the instability of small, isolated populations of L.agilis. A conservation strategy for L.agilis within afforested areas which concentrated on the use of open areas only would also be ignoring the other potential L.agilis habitat within forests, i.e. that found along Ride verges and underneath the trees themselves (Compartments). The aim of this project has been to investigate the ability of L.agilis to exploit these less permanent habitats (i.e. Rides verges and Compartments) with a view to providing a conservation strategy for L.agilis within afforested areas which would make use of as much of the potential habitat available as possible.

The main difficulty with basing the conservation of L.agilis on the use of Ride verge or Compartment habitats is that neither is permanently available. That is, they only exist in a condition suitable for use by L.agilis for a limited number of years. Therefore if the conservation of L.agilis is to be dealt with on a "whole forest" basis some attempt must be made to ensure that;

i) there is always enough suitable habitat available within the forest at any one time to maintain a viable L.agilis population and

ii) there must be corridors available for movement between deteriorating and regenerating habitats.

It has been shown in this study (cf. Morden Site and East Gore study areas) that L.agilis is capable of using the habitat available within a Compartment. A habitat such as this probably remains suitable for use by L.agilis in it's own right for 10 to 15 years, depending on the species, rate of growth and density of planting of the tree crop. The habitat within Compartments may then be used for a number of years in conjunction with an adjacent area of suitable Ride verge habitat but the life span of Compartments as habitats in their own right is quite limited.

The life of Ride verges as a habitat for L.agilis is also limited but the time span involved is considerably longer than that for Compartments. Several of the Ride verges on which L.agilis was found in this study were adjacent to Compartments which contained little or no ground vegetation and a large number were adjacent to Compartments within which the ground vegetation was deteriorating. The Ride verges may then be an important habitat in terms of the long term survival of L.agilis within forestry plantations as a whole. Besides providing a habitat in their own right the Ride verges enable more marginal habitats such as those under Compartments to be exploited by L.agilis. The Ride verges may also provide corridors for dispersal within the forest which would help to prevent the formation of a large number of small, isolated and therefore unstable populations scattered throughout the forest.

The Ride verges may also represent a particularly favourable habitat in their own right. In open heathland habitats L.agilis has been observed to be associated with areas of disturbed ground and particularly the presence of banks or tumuli (Corbett 1980). Ride verges frequently include banks which provide not only good basking sites for L.agilis individuals but which also often provide areas of open ground suitable for egg laying.

Hence the conservation strategy explored here is based not on the concept of the provision of a certain area of permanently available habitat but on the exploitation of the potential habitat available throughout the forest at any given time. The Ride verge habitat is viewed as the key to maintaining a L.agilis population within a forest area. Being present throughout the forest as a whole and suitable for use by L.agilis for fairly long periods of time, the Ride verges could provide an extended and fairly stable basis for a L.agilis population. Such a basis would enable the use of Compartment habitats whenever they were available but would provide a habitat in their own right when they were not. The presence of areas of suitable open habitat is considered important in providing some stability to the system. While such areas might not provide a sound basis for L.agilis conservation if used on their own, in conjunction with an extended area of Ride verge habitat small open areas would provide concentrations of L.agilis within the system as a whole. They would also provide temporary refuges or habitat islands when there was not other suitable habitat available within an area.

If the Ride verge habitat is to be used as the mainstay of a conservation strategy for L.agilis within afforested areas then some guidelines must be available to indicate those characteristics of the Ride verge habitat which are particularly favourable to it's use by L.agilis. In Section 8.2 data from the Morden Rides study area has been used to indicate those features of the Ride verge habitat which are most important to its use by L.agilis. For this purpose where further analysis has been carried out (i.e. in addition to that reported in Chapter Three) the 1982 and 1983 study seasons from Morden Rides have been combined as they were found to be very similar in the earlier analyses (see Chapter Three). Section 8.3 looks at how each of the habitat preferences of L.agilis is affected or influenced by the forest surrounding the Ride verge habitat and by the implementation of some forest management techniques. This section includes a description of a basic model to predict the number of seasonal sunshine hours that will be received by an area of Ride verge taking into account its aspect, the height of the trees of the opposite and adjacent Compartments and the distance between those Compartments.

8.2 THE USE OF RIDE VERGE HABITATS

The analysis of the habitat use of L.agilis along Ride verges described in Chapter Three has been used here to give an indication of the main characteristics which affect the suitability of an area of Ride verge as a L.agilis habitat. There are three main factors which are important; the type of ground level vegetation, the area of habitat available and the seasonal number of sunshine hours received.

The relevance of each of these factors to the use of an area of Ride verge by L.agilis has been summarised below.

8.2.1 THE TYPE OF VEGETATION AVAILABLE

The data presented in Chapter Three showed that in a Ride verge habitat, L.agilis was frequently found associated with a dry heathland vegetation type dominated by C.vulgaris. Other species L.agilis was associated with included E.cinerea, L.agilis was not found in areas with a vegetation type dominated by E.tetralix.

Also discussed in Chapter Three is the strong association between the distribution of L.agilis in Britain and the presence of a sandy substratum.

8.2.2 THE AREA OF HABITAT AVAILABLE

The area of habitat available along any given area of Ride verge is determined by the length and the width of the verge. The length of the verge is determined by the size of the Compartment it is adjacent to and also by the condition of the vegetation of the Ride verges adjacent to the Compartments on either side of the one in question. The length of a verge may be important in an isolated area where there is no suitable habitat along adjacent Ride verges. However, the assumption has been made here that it is the width of a Ride verge which is most important or most readily manoeuvreable in determining the area of habitat available along a given Ride verge.

Table 8.1 gives the mean Ride verge widths for both L.agilis sightings and random points for the data collected from Morden Rides. Taking all observations (Table 8.1a) L.agilis were found on wider verges (5.5m) than random (4.0m), there was a significant difference between these two values. The difference between L.agilis sightings and random points was/even greater if only Ride verges adjacent to Compartments under which there was no vegetation suitable for use by L.agilis were considered (Table 8.1b). In this case the mean width of Ride verge L.agilis was found associated with was 6.5m as opposed to 4.1m for random points, again there was a significant difference between these two values (Table 8.1b).

When there is no vegetation under the adjacent Compartment the Ride verge must be the only habitat available to L.agilis. The width of the Ride verge used in this situation must therefore represent that necessary for a Ride verge to provide a habitat in it's own right i.e. one not used in conjunction with habitat under an adjacent Compartment. As this latter habitat is only available for a relatively short period of time whereas the Ride verges are being viewed as a long term habitat for L.agilis, it seems best to base any assumptions about the habitat requirements of L.agilis on the situation where no habitat is available under the adjacent Compartment. This will ensure that a Ride verge remains usable beyond the period during which there is suitable habitat under the adjacent Compartment.

Hence, using data from Ride verges adjacent to Compartments with no suitable vegetation underneath them a histogram has been plotted showing the distribution (percentage frequency) of L.agilis sightings and random points relative to the width of the undisturbed Ride verge (Fig. 8.1). This shows a clear division in the use of Ride verges by L.agilis, below a Ride verge width of 5m L.agilis sightings occurred

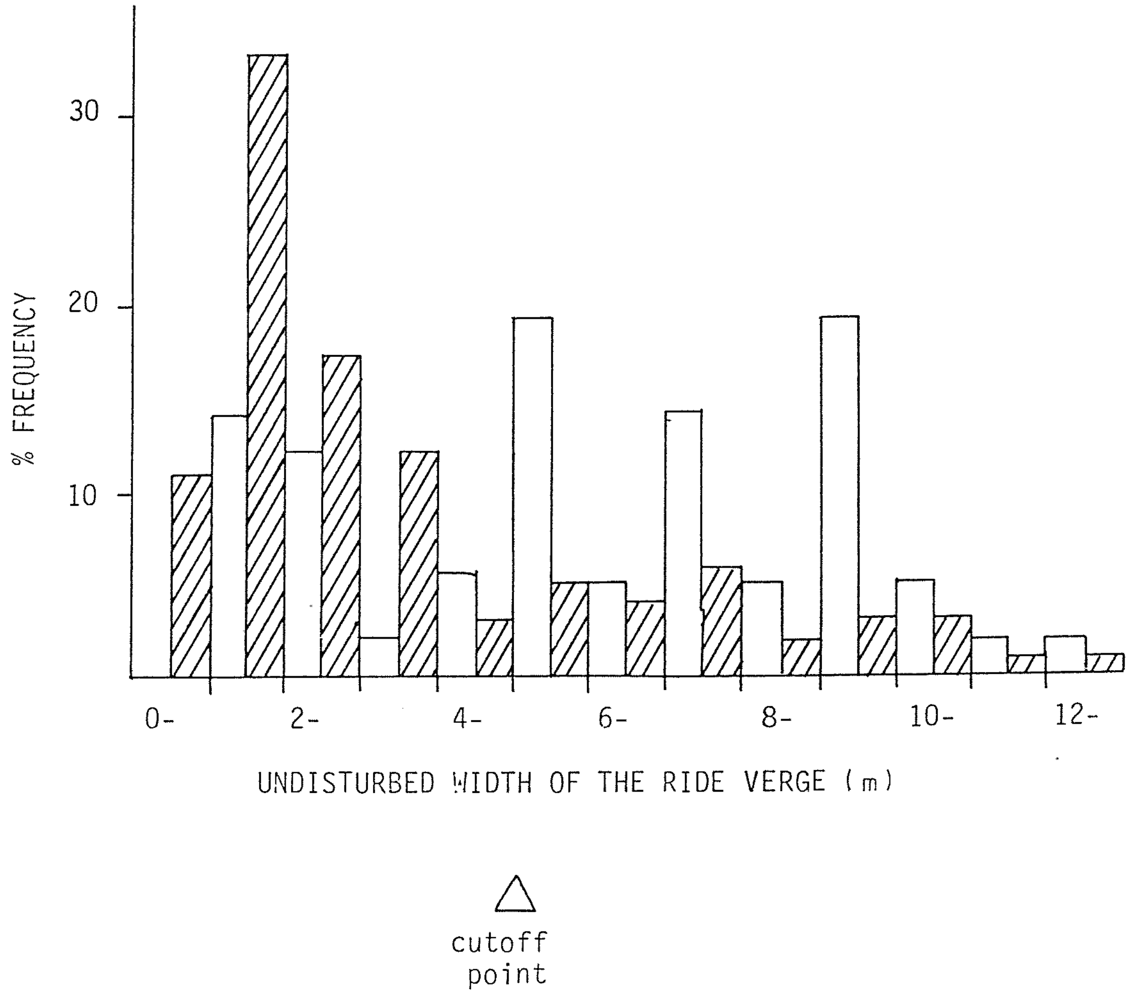
Table 8.1 The conservation of *L.agilis* populations within forestry plantations.

The mean width of the Ride verges associated with *L.agilis* sightings and random points, a. for all observations of *L.agilis*, b. for observations of *L.agilis* adjacent to Compartments with no usable ground vegetation and c. for observations of *L.agilis* adjacent to Compartments including some ground vegetation.

	Ride Width (m)				
	L.agilis	Random	t	D.F.	P
a.	5.5	4.0	8.04	854	<0.001
b.	6.5	3.7	9.31	612	<0.001
c.	5.3	4.1	5.88	640	<0.001

Fig. 8.1 The conservation of *L.agilis* populations within forestry plantations.

The frequency distribution of *L.agilis* sightings (□) and random points (▨) relative to the undisturbed width of the Ride verge.



much less frequently than expected from the random distribution. However, above a Ride verge width of 5m, L.agilis sightings occurred more frequently than expected from the random distribution.

8.2.3 THE SEASONAL NUMBER OF SUNSHINE HOURS RECEIVED BY AN AREA OF RIDE VERGE

Using the overall, seasonal measure of the number of sunshine hours received by an area of Ride verge described in Chapter Two (2.6.3.4) frequency histograms were plotted of the distribution of L.agilis sightings and random points relative to the seasonal number of sunshine hours received by an area of Ride verge. Two histograms were drawn one using data from all L.agilis sightings (Fig. 8.2a) and one from sightings of juveniles only (Fig. 8.2b).

For all sightings of L.agilis there appeared to be a clear cut-off point at 22 seasonal sunshine hours received (Fig. 8.2a). Below this point L.agilis sightings occurred less frequently and above it more frequently than expected from the random distribution. However, this figure should be viewed bearing in mind that only 7% of the observations of L.agilis were made below this point. From the data in Chapter Three, the mean seasonal number of sunshine hours received by Ride verges associated with L.agilis sightings was 32.7 and for random points 26.9 hours.

The distribution of L.agilis juveniles (Fig. 8.2b) is found at a higher range of seasonal sunshine hours received than that for all L.agilis sightings. A suitable minimum cut-off point for this distribution appears to be at 30 hours, below which 17% of the observations of juvenile L.agilis were made.

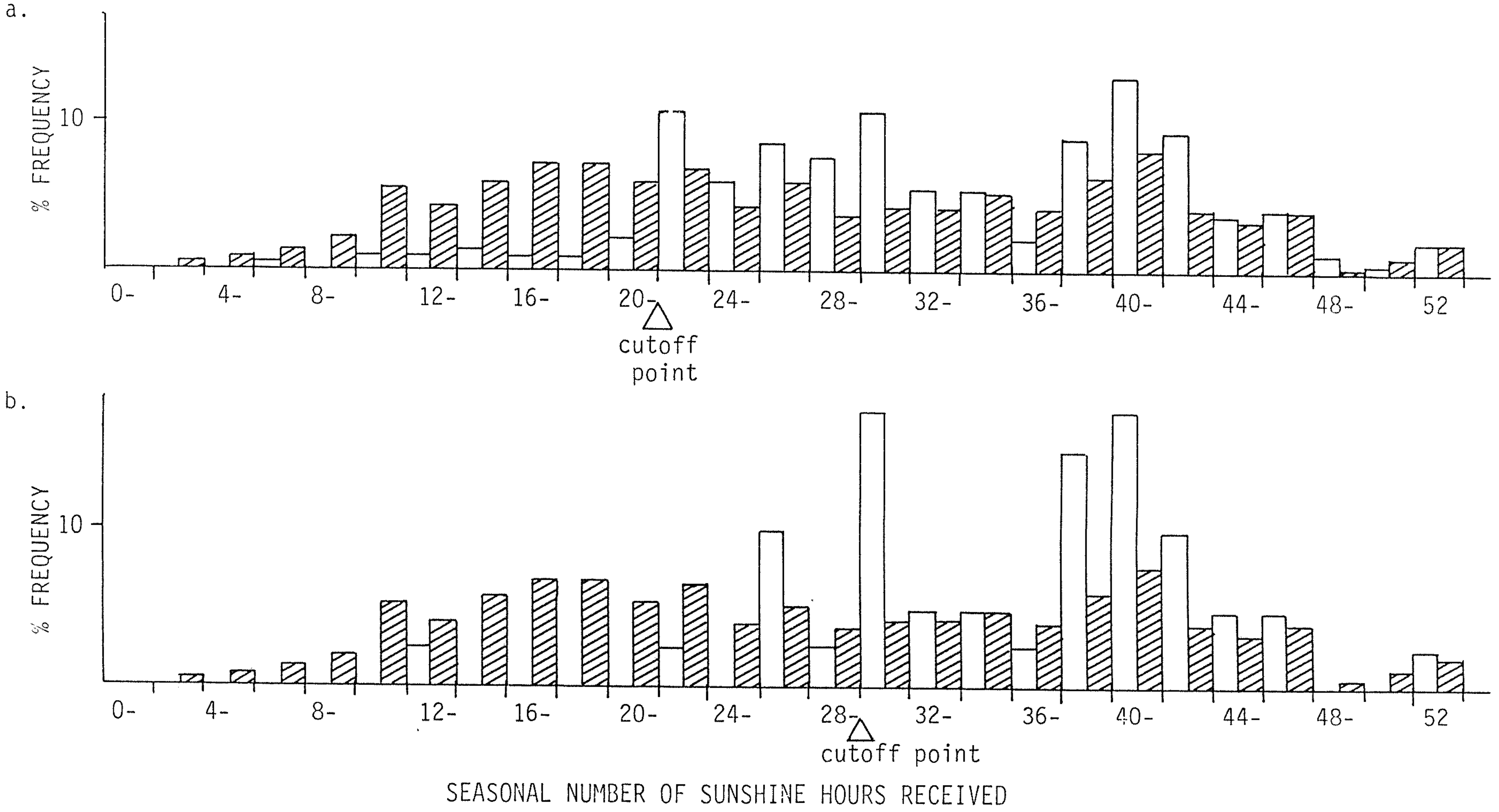
8.3 THE INTERACTION BETWEEN FOREST MANAGEMENT AND THE HABITAT POTENTIAL OF RIDE VERGES

Each of the three factors which has been outlined as affecting the suitability of a Ride verge habitat for use by L.agilis is to some extent open to manipulation by forest management. The discussion below looks at the ways in which the presence of the forest itself and the use of some techniques of forest management can affect the potential of Ride verge areas as L.agilis habitat.

8.3.1 THE TYPE OF VEGETATION AVAILABLE

The basic vegetation type of an area (i.e. wet or dry heathland etc.) largely depends upon the physical conditions prevalent in that

Fig. 8.2 The conservation of L.agilis within forestry plantations.
The frequency distribution of L.agilis sightings (☐) and random points (▨) relative to the seasonal number of sunshine hours received by an area of Ride verge, a. for all observations of L.agilis and b. for observations of juvenile L.agilis only.



area (i.e. the soil type, amount of moisture present in the soil etc.). The presence of trees and the mechanical processes involved in planting and maintaining them may have a considerable affect on the soil conditions present in an area. Thus the vegetation found in an area after afforestation may not necessarily be the same as that which existed prior to afforestation. This process would not be easy to control and it would not necessarily be a desirable objective to convert the vegetation of all the Ride verges present within a forest into a dry heathland vegetation type. Hence the basic vegetation type of a Ride verge is considered here to be a product of that area and as such not open to manipulation by forest management. However, the suitability of an area of Ride verge with a vegetation type preferred by L.agilis could be improved or at least maintained by the use, disuse or re-timing of certain forest management practises. Those factors which most affect the potential of an area for use by L.agilis are outlined below.

(i) Positive influences

It has already been suggested that the suitability of an area for use by L.agilis may be enhanced by the presence of a bank between the Ride verge and the ride proper. The presence or absence of a bank may be within the control of the forester. Also, when a bank is produced if it has a totally vertical surface it is unlikely to be of particular use to L.agilis at least in the short term, until erosion has produced a more suitable surface. The angle of the bank need not be far from vertical but a slight slope outwards from the top to the bottom of the bank would produce a surface more suitable for use by L.agilis either as a basking or an egg laying site.

(ii) Negative influences

The length of time for which an area of habitat is useful to L.agilis may be reduced by forest management practises, particularly those which tend to harm or destroy the habitat of the Ride verge. The ericoid shrub C.vulgaris and the heathland vegetation in general are extremely sensitive to trampling and mechanical damage and being slow growing they can take a long time to recover from such disturbance (Moore 1962, Chapman, Hibble and Rafarel 1974, NCC 1981). The mowing of Ride verges may reduce an area with habitat suitable for use by L.agilis to one with no vegetation at all. Similarly, extensive trampling of the Ride verge while thinning or working on the adjacent crop may irrevocably damage a previously suitable habitat. The avoidance of excessive trampling of or damage to the vegetation of the

Ride verge may be particularly important when the adjacent crop is being clear felled. The most critical situation being that where a population of L.agilis still exists beside the area to be clear felled. Such a population could provide a nucleus for the colonisation of the adjacent Compartment when it has been replanted and would also ensure that the Ride verge itself was colonised, an occurrence which is left to chance when it is reliant on the immigration of animals from surrounding areas. However, if the Ride verge is badly disturbed or damaged during the process of clear felling, individuals of L.agilis may be killed or the habitat may deteriorate to the point where it can no longer support the existing population.

(iii) The re-timing of management routines

The timing of certain management practises may be important for maintaining populations of L.agilis along Ride verges. In particular the ploughing of firebreaks or improving or widening of rides during the period during which L.agilis eggs are incubating (April to August) may disturb and destroy egg clutches laid in open ground at the junction of the verge and the ride proper.

8.3.2 THE AREA OF HABITAT AVAILABLE

The data presented in section 8.2.2 indicated that a Ride verge needed to be 5m wide in order to be suitable for use by L.agilis, this is one metre wider than the mean Ride verge width of the area in which this study was carried out.

This recommended width of the Ride verge is that necessary to ensure the long term suitability of an area for use by L.agilis, that is its usefulness when there is no vegetation remaining under the adjacent Compartment and the Ride verge is being used as a habitat in its own right. It should be borne in mind that this is very much a minimum figure and that 68% of the observations of L.agilis made on Ride verges adjacent to Compartments with no usable vegetation under them occurred on verges greater than 5m wide (Fig. 8.1). Also, the overall mean width of Ride verge on which L.agilis was found i.e. regardless of the condition of the vegetation under the adjacent Compartment, was 5.5m (Table 8.1)

8.3.3 THE SEASONAL NUMBER OF SUNSHINE HOURS RECEIVED BY AN AREA OF RIDE VERGE

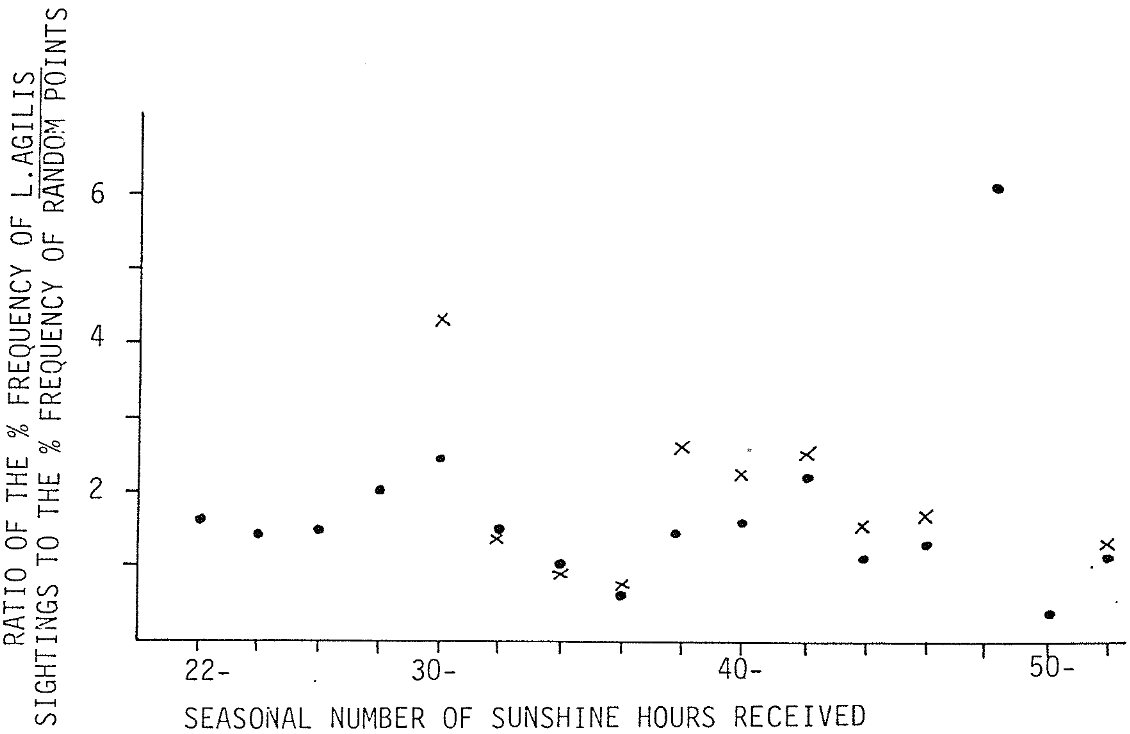
In the context of the planned management of Ride verges for use by L.agilis it is necessary to know the minimum number of seasonal sunshine hours which are required for an area to be suitable for use by L.agilis. In looking for such a figure an assumption has been made that there is a minimum or threshold number of seasonal sunshine hours, above which a Ride verge receives sufficient solar radiation during the year to allow L.agilis to thermoregulate and to breed successfully. If this was the case it might be possible for L.agilis to exist under conditions below this threshold, but the continued survival of the population under these conditions could not be assured. Also, if such a threshold exists, it might be expected that once above it, further increases in the number of sunshine hours would be advantageous to L.agilis but not necessarily essential for the survival of the species in an area.

For all observations of L.agilis there does appear to be a clear cut-off point above which L.agilis was usually found (22 hours, Fig. 8.2a). Above this point the frequency of occurrence of L.agilis is quite evenly distributed between the remaining categories of sunshine hours received and shows no tendency to be strongly associated the the highest available seasonal number of sunshine hours received. However, as the distribution of L.agilis sightings in these histograms must be viewed relative to the random distribution (i.e. to the availability of each number of seasonal sunshine hours) this appearance of an even distribution could be deceptive. To test this result, for each category of seasonal sunshine hours above the chosen threshold (22 hours, see Section 8.2.3) a ratio has been calculated between the percentage frequency of L.agilis sightings and the percentage frequency of random points. A ratio greater than one indicates that L.agilis sightings occurred more frequently than expected from the random distribution, a ratio of less than one indicates that L.agilis sightings occurred less frequently than expected. Above one the value of the ratio indicates how much more frequently than expected L.agilis occurred. If an increase in the seasonal number of sunshine hours received above the chosen threshold increases the potential of an area for use by L.agilis then the size of the ratio would be expected to increase as the seasonal number of sunshine hours received increased. Fig. 8.3 shows that this is not the case and that the ratio of L.agilis observations to random points remains quite constant with increasing numbers of seasonal sunshine hours.

The threshold required has been defined in terms of the ability of L.agilis individuals not only to survive in an area but also to breed successfully. Therefore, the threshold described above does not fulfill

Fig. 8.3 The conservation of <u>L.agilis</u> within forestry plantations.

The ratio between the percentage frequency of sightings of <u>L.agilis</u> and the percentage frequency of occurrence of random points, for each category of the seasonal number of sunshine hours received by an area of Ride verge. Data is shown for all observations of <u>L.agilis</u> (●) and for those of juveniles only (x)



the necessary requirements as it deals only with the distribution of the overall population of L.agilis. If the assumption is made that the sighting of juveniles indicates that eggs have been laid and successfully hatched in the area, then the minimum number of seasonal sunshine hours at which juvenile L.agilis are found may provide a suitable level for the threshold required. A suitable cut-off point in the distribution of juvenile L.agilis relative to the seasonal number of sunshine hours received occurs at 30 hours (Fig. 8.2b). Fig. 8.3 shows that the ratio of the frequency of juvenile L.agilis sightings relative to the frequency of occurrence of random points shows no strong tendency to increase with increasing numbers of seasonal sunshine hours received. Hence it seems reasonable to assume that 30 seasonal sunshine hours received would be a suitable threshold value above which a population of L.agilis might be expected to both survive and breed successfully.

The threshold of 22 seasonal sunshine hours received which was derived from all observations of L.agilis along Ride verges may be a suitable level at which to assess the potential of Ride verges as temporary habitats or corridors between deteriorating and establishing habitats. * PTO

Unlike the vegetation type or the width of the Ride verge these thresholds cannot be applied directly to the forest situation. In the context of the management of a particular area of Ride verge the threshold is expressible only in terms of that set of physical characteristics which affect it. That is;

- the width of the adjacent Ride verge (i.e. that being as potential L.agilis habitat).
- the width of the ride and of the opposite Ride verge.
- the height of the trees of the opposite and adjacent plantations.
- the aspect of the adjacent Ride verge.

In Section 8.3.4 a simple model is described which explores the way in which each of the variables above influences the seasonal number of sunshine hours received by an area of Ride verge. Using this model the seasonal number of sunshine hours received by a given area of Ride verge could be assessed, and a prediction for any point in its future could be made based on a knowledge of the growth rate and future of the trees of the opposite and adjacent plantations.

*

A third potentially useful threshold which can be derived from this data is the absolute minimum number of seasonal sunshine hours necessary for L.agilis to exist. In this case L.agilis was not found on Ride verges which received fewer than 10 seasonal sunshine hours (Fig. 8.2). Above this level and below the threshold of 22 seasonal sunshine hours described above, L.agilis may be able to survive but probably only in the very short term. At this level there must also be an increased chance that other factors such as the deterioration of the Ride verge vegetation may be limiting.

A similar concept could be applied to the width of the Ride verge which L.agilis was found associated with. The threshold already described (5m) was considered to be that necessary for the long term survival of L.agilis populations. The minimum Ride verge width used by L.agilis was one metre so that Ride verges wider than one metre but narrower than five metres may have a potential as short term or corridor habitats for L.agilis.

In this way it is possible to produce three thresholds for the use of Ride verge habitats by L.agilis:

1. That above which L.agilis can breed successfully.
   Seasonal sunshine hours received - 30
   Ride width - 5m
   Habitat - essentially dry heathland vegetation with a sandy, dry substratum.
2. That above which adult L.agilis can exist successfully.
   Seasonal sunshine hours received - 22
   Ride width - 5m
   Habitat - essentially dry heathland vegetation.
3. That above which L.agilis may be able to exist in the short term or which may be suitable for use as corridors for movement between more long term habitats.
   Seasonal sunshine hours received - 10
   Ride width - 1m
   Habitat - essentially a dry heathland vegetation. The ability of L.agilis to move through areas of 'unsuitable' habitat is not known.

This final threshold would be difficult to apply and might be best considered as determining a set of conditions below which L.agilis would definitely not be found. In terms of the planned management of forest areas for the conservation of L.agilis, it is hoped that the first two thresholds incorporate sufficient 'leeway', such that their application would produce the desired L.agilis habitat. The third threshold would perhaps be best used to eliminate those areas totally unsuitable for use by L.agilis.

8.3.4 A MODEL TO PREDICT THE SEASONAL NUMBER OF SUNSHINE HOURS RECEIVED BY AN AREA OF RIDE VERGE

In Section 2.6.3.4 the seasonal number of sunshine hours received by an area of Ride verge of a given aspect was related to the angle between the Ride verge and the tops of the trees of the opposite and adjacent plantations. This relationship was used in Sections 3.4.5 and 8.2.3 to calculate the seasonal number of sunshine hours received by the Ride verge for each L.agilis sighting or random point. It has been used again here to produce a simple model to predict the seasonal number of sunshine hours which would be received by an area of Ride verge.

There are five physical characteristics of the Ride verge and the forest surrounding it which may affect the seasonal number of sunshine hours received by that Ride verge. The model described here could calculate the seasonal number of sunshine hours received by an area of Ride verge under any combination of values of those five variables. However, for the purposes of this report certain limitations have been made to the values of each variable. The variables used and the range of values used are listed below:

VA = THE WIDTH OF THE ADJACENT RIDE VERGE (i.e. the area which is being assessed as a potential L.agilis habitat).

Values of VA between four metres and 14 meters were used with one metre intervals. Four metres was used a a minimum value as this has been shown to be the minimum width at which a Ride verge is suitable for use by L.agilis (see 8.2.2). The maximum value was set at 14m as the maximum width of any verges used in this study was 13.8m.

WRVO = WIDTH OF RIDE (PROPER) AND OF OPPOSITE VERGE.

Values of WRVO between four and 24 metres were used at two metre intervals. A minimum value of four metres was used as this was viewed as the minimum width necessary to allow for passage of forest traffic i.e. the minimum width at which an area would be considered a proper ride. A maximum value of 24 metres was used as the maximum ride width encountered was 10.5m and verge width 13.8 metres.

THO = THE HEIGHT OF THE TREES OF THE OPPOSITE COMPARTMENT (i.e. that on the opposite side of the ride to VA)

Values of THO between zero and 35 metres were used with five metre intervals. Thirty five metres was the maximum value used as this was considered to be the maximum height to which the majority of tree crops would be left to grow. Five metre intervals were used for logistic reasons in running the model in this instance. If required intervals of one or two metres could be used however the volume of output produced in these cases would be large. Ideally if access to computing facilities were available individual cases could be fitted precisely to the model.

THA = THE HEIGHT OF THE TREES OF THE ADJACENT COMPARTMENT.
Values of THA between zero and 35 metres were used with five metre intervals for the reasons described in THO above.

ASPECT = THE ASPECT (i.e. the direction facing away from the adjacent tree crop) OF THE RIDE VERGE BEING ASSESSED.
The model was run for eight aspects; north, north-east, east, south-east, south, south-west, west and north-west. Again, if required the model could be run for aspects at intervals of ten degrees but this is the finest division available from the information in Section 2.6.3.4.

The Basic programme used to run the model as described here is listed in Appendix 1. The range of conditions for which the model was run is summarised below.

ASPECT = N, NE, E, SE, S, SW, W and NW
THO = 0 - 35m, 5m intervals
THA = 0 - 35m, 5m intervals
WRVO = 4 - 24m, 2m intervals
VA = 4 - 14m, 1m intervals

The output obtained from this model is illustrated in Table 8.2 which shows the results for one particular set of variables where;

ASPECT = South
THO = 5m
THA = 0 - 35m
WRVO = 4 - 24m
VA = 4 - 14m

For each combination of these variables the output gives the seasonal number of sunshine hours received by an area of Ride verge under these conditions.

Figs 8.4 and 8.5 show a summary of the output from the complete model when it was run for the full range of the conditions listed above. For each Aspect, the range of THO and THA values used (0 - 35m, 5m intervals) are shown forming the sides of a square. For each box within that square (i.e. for each combination of THO and THA values)

Table 8.2 The conservation of L.agilis within forestry plantation.

An example of the output from the model described in section 8.3.4 to predict the seasonal number of sunshine hours received by an area of Ride verge. The conditions dealt with here are, Aspect = south, THO = 0-35m, THA = 5m, VA = 4-14m and WRVO = 4-24m.

THO = 0 THA = 5

VA

		4	5	6	7	8	9	10	11	12	13	14
	4	45	45	46	46	47	47	47	48	48	48	48
	6	45	45	46	46	47	47	47	48	48	48	48
	8	45	45	46	46	47	47	47	48	48	48	48
	10	45	45	46	46	47	47	47	48	48	48	48
	12	45	45	46	46	47	47	47	48	48	48	48
WRVO	14	45	45	46	46	47	47	47	48	48	48	48
	16	45	45	46	46	47	47	47	48	48	48	48
	18	45	45	46	46	47	47	47	48	48	48	48
	20	45	45	46	46	47	47	47	48	48	48	48
	22	45	45	46	46	47	47	47	48	48	48	48
	24	45	45	46	46	47	47	47	48	48	48	48

THO = 5 THA = 5

VA

		4	5	6	7	8	9	10	11	12	13	14
	4	30	32	33	35	36	37	39	40	40	41	42
	6	34	36	37	38	39	40	41	42	43	43	44
	8	38	39	40	41	42	42	43	44	44	45	46
	10	40	41	42	42	43	44	45	45	46	46	47
	12	41	42	43	44	45	45	46	46	47	47	48
WRVO	14	43	44	44	45	46	46	47	47	48	48	48
	16	44	45	45	46	46	47	47	48	48	48	48
	18	45	45	46	46	47	47	47	48	48	48	48
	20	45	45	46	46	47	47	47	48	48	48	48
	22	45	45	46	46	47	47	47	48	48	48	48
	24	45	45	46	46	47	47	47	48	48	48	48

THO = 10 THA = 5

VA

		4	5	6	7	8	9	10	11	12	13	14
	4	19	21	22	24	25	26	28	29	80	31	32
	6	23	25	26	28	29	30	31	32	33	34	35
	8	27	28	30	31	32	33	34	35	35	36	37
	10	30	31	32	33	34	35	36	37	37	38	39
	12	32	33	34	35	36	37	38	38	39	40	40
WRVO	14	34	35	36	37	38	39	39	40	40	41	41
	16	36	37	38	39	39	40	41	41	42	42	43
	18	38	38	39	40	40	41	42	42	43	43	44
	20	39	40	40	41	42	42	43	43	44	44	44
	22	40	41	41	42	42	43	43	44	44	45	45
	24	41	41	42	43	43	44	44	45	45	45	46

THO = 15 THA = 5

VA

	4	5	6	7	8	9	10	11	12	13	14
4	14	15	17	18	19	20	21	22	23	24	25
6	17	19	20	21	22	23	24	25	26	27	28
8	21	22	23	24	25	25	27	28	29	30	30
10	23	25	26	27	28	29	29	30	31	32	32
12	26	27	28	29	30	31	31	32	33	34	34
14	28	29	30	31	32	32	33	34	35	35	36
16	30	31	32	33	33	34	35	35	36	37	37
18	32	33	33	34	35	36	36	37	37	38	38
20	33	34	35	35	36	37	37	38	39	39	39
22	34	35	36	37	37	38	39	39	40	40	40
24	36	36	37	38	38	39	39	40	40	41	41

THO = 20 THA = 5

VA

	4	5	6	7	8	9	10	11	12	13	14
4	11	12	13	14	15	17	18	18	19	20	21
6	14	15	16	17	18	19	20	21	22	23	24
8	16	18	19	20	21	22	23	23	24	25	26
10	19	20	21	22	23	24	25	26	26	27	28
12	21	22	23	24	25	26	27	27	28	29	30
14	23	24	25	26	27	28	29	29	30	31	31
16	25	26	27	28	29	29	30	31	31	32	33
18	27	28	29	30	30	31	32	32	33	33	34
20	29	29	30	31	32	32	33	34	34	35	35
22	30	31	32	32	33	34	34	35	35	36	36
24	31	32	33	33	34	35	35	36	36	37	37

THO = 25 THA = 5

VA

	4	5	6	7	8	9	10	11	12	13	14
4	9	10	11	12	13	14	15	16	17	17	18
6	11	13	14	15	15	16	17	18	19	20	20
8	14	15	16	17	18	19	19	20	21	22	22
10	16	17	18	19	20	21	21	22	23	24	24
12	18	19	20	21	22	22	23	24	25	25	26
14	20	21	22	23	23	24	25	26	26	27	28
16	22	23	24	24	25	26	27	27	28	28	29
18	23	24	25	26	27	27	28	29	29	30	30
20	25	26	27	27	28	29	29	30	31	31	32
22	26	27	28	29	29	30	31	31	32	32	33
24	38	38	39	30	31	31	32	32	33	33	34

Table 8.2 (cont. 1)

THO = 30 THA = 5

		VA										
		4	5	6	7	8	9	10	11	12	13	14
	4	8	9	10	11	12	12	13	14	15	15	16
	6	10	11	12	13	14	14	15	16	17	17	18
	8	12	13	14	15	15	16	17	18	19	19	20
	10	14	15	16	17	17	18	19	20	20	21	22
	12	16	17	17	18	19	20	21	21	22	23	23
WRVO	14	17	18	19	20	21	21	22	23	23	24	25
	16	19	20	21	22	22	23	24	24	25	26	26
	18	21	21	22	23	24	24	25	26	26	27	27
	20	22	23	24	24	25	26	26	27	28	28	29
	22	23	24	25	26	26	27	28	28	29	29	30
	24	25	25	26	27	28	28	29	29	30	30	31

THO = 35 THA = 5

		VA										
		4	5	6	7	8	9	10	11	12	13	14
	4	7	8	9	10	10	11	12	13	13	14	15
	6	9	10	10	11	12	13	14	14	15	16	16
	8	10	11	12	13	14	15	15	16	17	17	18
	10	12	13	14	15	15	16	17	18	18	19	19
	12	14	15	16	16	17	18	18	19	20	20	21
WRVO	14	15	16	17	18	19	19	20	21	21	22	22
	16	17	18	19	19	20	21	21	22	23	23	24
	18	18	19	20	21	21	22	23	23	24	24	25
	20	20	20	21	22	23	23	24	25	25	26	26
	22	21	22	23	23	24	25	25	26	26	27	27
	24	22	23	24	24	25	26	26	27	27	28	28

Fig. 8.4 The conservation of L.agilis within forestry plantations.

The seasonal number of sunshine hours received by an area of Ride verge for eight aspects with varying THO and THA. Each THO by THA square represents a square of VA(4-14m, 1m intervals) and WRVO (4-24m, 2m intervals). Those squares within which all values were above (⊡) or below (▨) 30 seasonal sunshine hours received are shown.

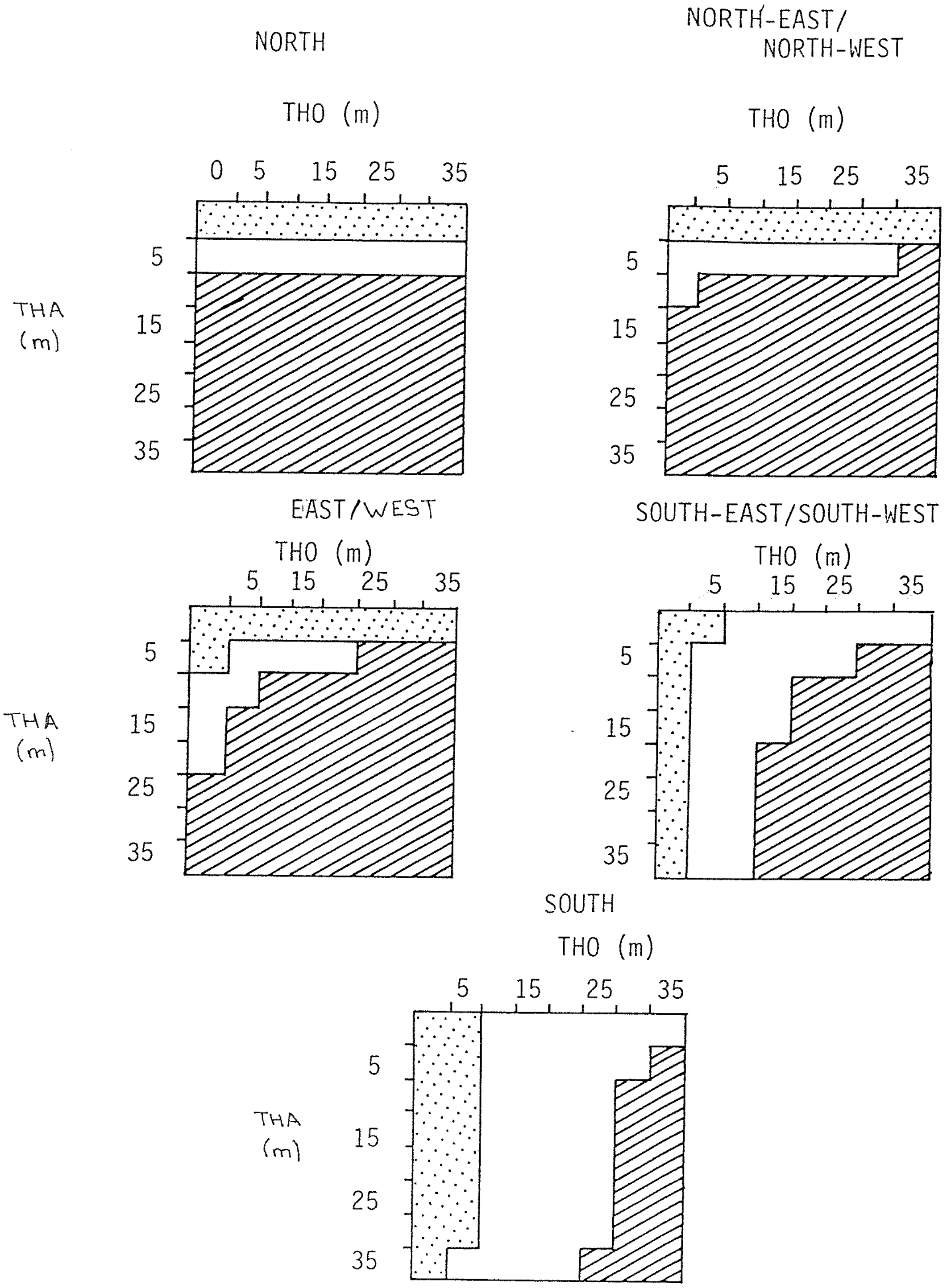
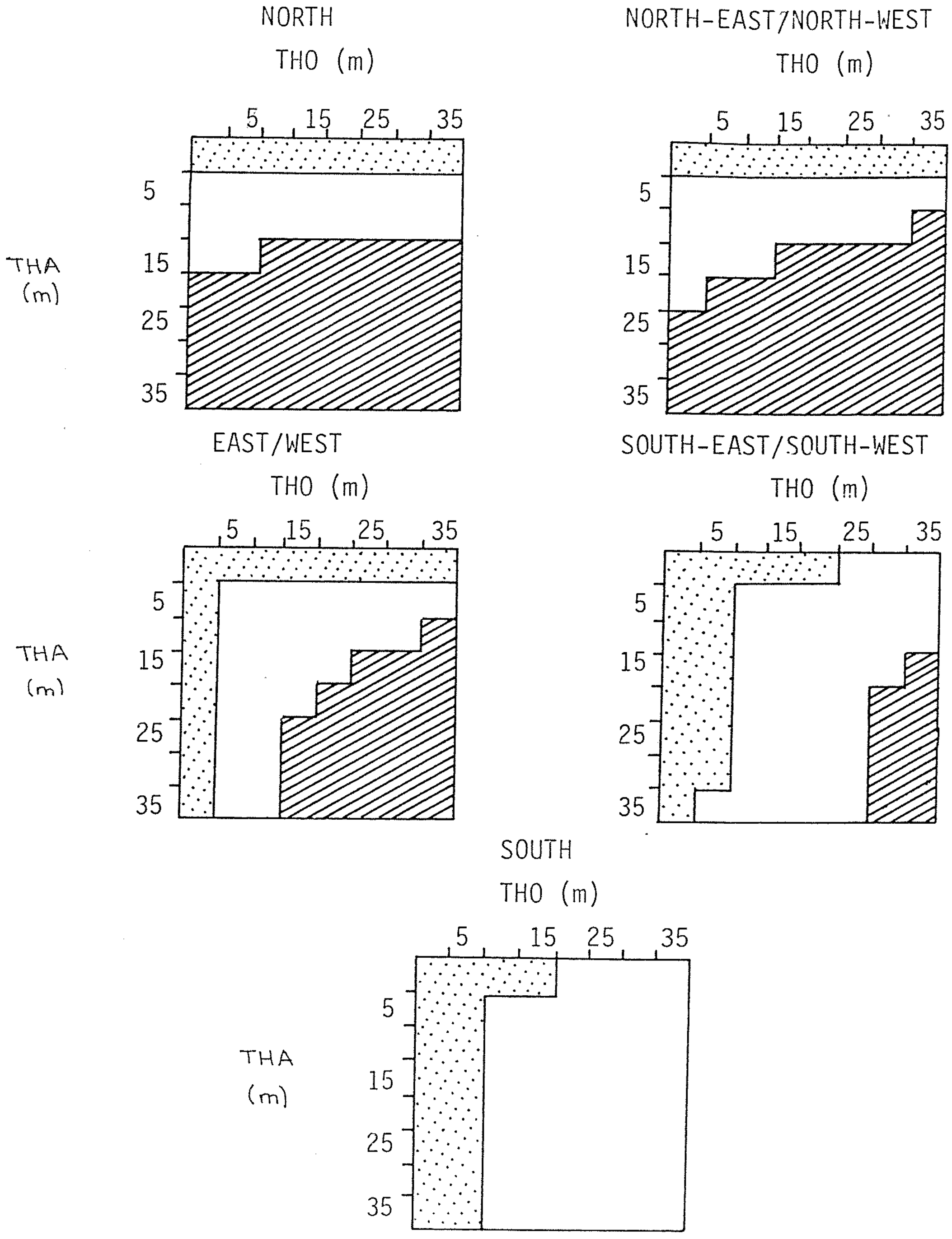


Fig. 8.5 The conservation of *L.agilis* wtihin forestry plantations.

The seasonal number of sunshine hours received by an area of Ride verge fir eight aspects with varying heights of opposite (THO) and adjacent trees (THA). Each THO by THA square itself represents a square of adjacent verge width (VA, 4-14m, 1m intervals) by the with of the Ride and the opposite verge (WRVO. 4-24m, 2m intervals). Those squares within which all values were above (░) or below (▨) 22 seasonal sunshine hours received are shown below.



the model produced a further square of values of VA by WRVO, as shown in Table 8.2. Therefore each combination of THA by THO includes 121 estimates of the seasonal number of sunshine hours received by areas of Ride verge under all the combinations of VA and WRVO used. This data has been summarised in Figs 8.4 and 8.5 by showing those combinations of THA by THO where all the values in the VA by WRVO set were either above or below the threshold numbers of seasonal sunshine hours derived in Section 8.3.3 above. Fig. 8.4 shows those THA by THO combinations where all values were above or below 30 seasonal sunshine hours received and Fig. 8.5 shows those THO by THA combinations where all values were above or below 22 hours. In the remaining squares there is a mixture of values above and below these thresholds depending on the exact values of VA and WRVO.

Although Figs 8.4 and 8.5 are a very simplified representation of the output produced by this model there are some basic principles which can be deduced from them. In particular:

- the importance of Aspect in determining how much potential an area has for use by L.agilis. There were very few circumstances (i.e. combinations of THO, THA, VA and WRVO) under which a north facing Ride verge could be used at all by L.agilis. Whereas for a south facing Ride verge for most combinations of THO by THA there was at least a chance that if VA and/or WRVO were large enough an area would receive sufficient seasonal sunshine hours to be used by L.agilis.

- the importance of the forest perimeter (i.e. where the forest adjoins the surrounding countryside) where there may be no trees opposite to the outer Ride verge. South, south-west and south-east facing edges are particularly important as these would receive enough seasonal sunshine hours to be suitable for use by L.agilis no matter how tall the trees of the adjacent plantation (Fig. 8.4). East and west facing verges would also always receive enough seasonal sunshine hours to be suitable for use by L.agilis as adult habitats or corridors (Fig. 8.5) although they may not be suitable for use as breeding habitats.

- there are some combinations of THO by THA where no matter how wide VA or WRVO (within the limits defined earlier for this model) the Ride verge does not receive sufficient seasonal sunshine hours to be suitable for use by L.agilis. This is particularly noticeable in terms of potential breeding habitat (Fig. 8.4) the amount of potential corridor habitat available (Fig. 8.5) is less restricted.

Thus the two threshold values suggested here can be used to indicate whether or not an area of Ride verge receives sufficient seasonal sunshine hours to be suitable for use by L.agilis. The model described could (with minor changes) be used to calculate the seasonal number of sunshine hours received by an area of Ride verge both at the time of measurement and for any point in the future (as long as the future of the surrounding plantations is known). In this way it should be possible to assess not only whether or not an area of Ride verge is suitable for use by L.agilis but also for how long it would be available.

8.4 DISCUSSION

The data presented in this Chapter defines a minimum set of conditions which are considered necessary for continued use of the Ride verge habitat by L.agilis. This information could be used to produce a set of guidelines which, if applied to a forest management system, would allow the survival of L.agilis. However, it is not considered possible to produce any set 'recipe' for the conservation of L.agilis within an afforested area, it is felt that this process will have to be carried out on an individual forest basis.

It is felt that the 'key' habitats for L.agilis within afforested systems are those of the Ride verges and of any open areas which may be present within the forest. The first step in assessing the amount of habitat available to or potentially available to L.agilis within a forest would be to identify any areas of habitat which would be permanently available. As mentioned earlier these areas would aid the stability of L.agilis populations in an otherwise shifting habitat. The results described in this chapter could be used to assess any Ride verge habitats in this category (i.e. those adjacent to open unafforested areas). These results could also be extended to assess the habitat potential of any open areas, in particular those characteristics of the Vegetation type which are important for Ride verges would be equally important for open areas. In this way the area of permanent habitat suitable or potentially suitable for use by L.agilis could be identified.

The next step in assessing the potential of an afforested area for use by L.agilis, would be to consider all those Ride verges which were both opposite to and adjacent to plantations of growing trees and which would therefore only be available for use by L.agilis for a limited period of time. For a Ride verge of this type to be used by L.agilis it must have a suitable vegetation type, be wide enough and receive sufficient seasonal sunshine hours (as defined in Section 8.3).

A Ride verge which does not fulfill the conditions necessary in any one of these categories cannot be considered as habitat suitable for use by L.agilis, unless appropriate modifications could be made to bring it within the limits recommended. Hence there will be three types of temporary Ride verge habitat within a forest;

1. those which are totally unsuitable for use by L.agilis. For instance, a Ride verge beside a narrow Ride with tall trees on either side of the ride, or a Ride verge with a damp substratum and a Molinia spp dominated vegetation.

2. those which are potentially suitable for use by L.agilis i.e. Ride verges which could be used by L.agilis if appropriate changes were made. It might be possible to adjust for Ride width or the seasonal number of sunshine hours received but the vegetation type of an area is essentially either suitable or not and generally cannot be modified.

3. those which are suitable for use by L.agilis.

For Ride verges in the second of these categories it would then be necessary to assess whether or not the changes required could be made, and if they were made for how long the area would then be available for use by L.agilis. For Ride verges in the third category it would be necessary to assess for how long they would be available and whether or not it would be possible to prolong their useful life. Any changes in forest management or Ride verge structure which were necessary in this context would have to be viewed in terms of the costs of such changes (i.e. labour, loss of production, loss of forest area etc.) and the gains made from them (i.e. length of time for which an area might then be useful to L.agilis, the area of suitable habitat produced etc.).

If the Ride verges within a forest were graded as outlined above it should be possible to map out those areas belonging to each of the categories suggested. This together with a map of any existing or potential areas of Open habitat would allow the relative importance of existing or potential habitats to be assessed so that some priority could be attached to the management of particular areas. For instance, the upgrading of an area of potential habitat might not be as important in an area with a lot of existing suitable L.agilis habitat as in an area with only a small area of existing suitable habitat.

In this context it would be very useful to be able to map out the changes in habitat availability in subsequent years. This could be done as outlined in section 8.3.4 above using the seasonal number of sunshine hours received as a gauge of the length of time for which an area of Ride verge would be suitable for use by L.agilis. Of the other two variables used to assess the suitability of an area of Ride verge habitat for use by L.agilis, the Ride width is essentially an all or nothing characteristic, that is it is either suitable for use by L.agilis or it is not. The Vegetation type of a Ride verge is also essentially suitable or not for use by L.agilis. However the vegetation of a Ride verge deteriorates due to the shading produced by the surrounding trees and it would eventually reach a point where it was no longer suitable for use by L.agilis. An assumption has been made here that as long as a Ride verge receives more than 30 seasonal sunshine hours the vegetation of that area will remain suitable for use by L.agilis. The threshold number of seasonal sunshine hours as defined here is that necessary for L.agilis individuals to survive and breed successfully in an area. Implicit in this threshold is that an area of Ride verge must receive sufficient solar radiation for thermoregulation and egg incubation but this alone would not be sufficient , the area must also include a habitat suitable for use by L.agilis. Therefore, it is possible that at the threshold used here the vegetation of a Ride verge is deteriorating due to reduced incoming solar radiation but it is assumed that this deterioration is not sufficient to affect the habitat quality of that vegetation for use by L.agilis. Equally it is assumed that at a threshold of 22 seasonal sunshine hours the deterioration of the vegetation of the Ride verge is not sufficient to affect the use of that vegetation as a habitat or particularly as a corridor for individuals of L.agilis.

If the existing and predicted habitat available for L.agilis within afforested areas were mapped out in this way it should be possible to plan the conservation of L.agilis with a minimum of disturbance to forest routines or loss of suitable forest area. Maps of this kind would allow the existing status of L.agilis within forests to be identified and the future status to be estimated based on a continuation of current forestry practises. It would then be possible to identify where and what changes were necessary to ensure the future availability of habitat for L.agilis. In the short term this may lead to the implementation of apparently drastic conservation measures which would nonetheless be ensuring the long term survival of L.agilis within afforested areas.

8.4.1 CONCLUSIONS

The scheme of events described here could be used to ensure that there is always a certain area of habitat suitable for use by L.agilis available within an afforested area. However, the implementation of such a conservation strategy for L.agilis would be of little use if it was carried out to the exclusion of all other heathland habitat within the forest. The conservation of L.agilis within afforested areas cannot be carried out in isolation from the conservation of the heathland and other habitats in general. While the use of a forest management 'recipe' might not ensure the survival of L.agilis within afforested areas the application of some of the more general recommendations made here on a forest wide scale might be significant in preserving the more generalised heathland vegetation and fauna in the forest as a whole.

CHAPTER NINE
GENERAL DISCUSSION

While the main aim of this project was to study the ecology of L.agilis within forestry plantations it has also provided a good opportunity to compare some aspects of the ecology of L.agilis and L.vivipara. As this comparison was made within the forest environment it is only relevant to the relative status and distribution of L.agilis and L.vivipara within this particular habitat. However, if the factors which are important in distinguishing between the distributions of L.agilis and L.vivipara in a forest habitat can be identified it may then be possible to extrapolate from this to a more general situation. In particular it may be possible to identify those factors which lead to the very different distributions of L.agilis and L.vivipara within Britain as a whole.

A comparison can be made between L.agilis and L.vivipara using data from the Morden Rides study area, where L.vivipara was considerably more widespread and numerous than L.agilis. The information available on both the habitat use and thermoregulatory requirements of L.agilis and L.vivipara within this afforested area is summarised below:

The thermoregulatory ability of L.agilis and L.vivipara individuals has been looked at in two ways. Firstly the response of L.agilis and L.vivipara individuals to varying weather conditions (expressed in terms of air temperature and net radiation) has been investigated (see Chapter Four). This has been looked at for both seasonal behaviours such as emergence from or disappearance into winter dormancy, and for daily behaviours such as the time of morning emergence. This data can be used to make a direct comparison between the thermoregulatory ability of L.agilis and L.vivipara, however it is difficult to relate this information directly to the distributions of L.agilis and L.vivipara within an afforested habitat. Secondly, response of L.agilis and L.vivipara to the number of hours of solar radiation received by an area of habitat (expressed here as the seasonal number of sunshine hours received by an area of Ride verge) was investigated. This measure is both directly relevant to and quite specific to the distribution of L.agilis and L.vivipara within an afforested habitat.

The seasonal number of sunshine hours received by an area of Ride verge can also be used to provide a useful comparison between the relative egg incubation or development needs of *L.agilis* and *L.vivipara* respectively. This has been done by comparing the seasonal number of sunshine hours received by Ride verges with which all observations of individuals of each species were associated, with the seasonal number of sunshine hours received by Ride verges with which observations of juveniles only were associated. This relationship has been shown for *L.agilis* in Chapter Eight, Fig. 8.2 and is shown for *L.vivipara* in Fig. 9.1.

The final way in which a comparison can be made between *L.agilis* and *L.vivipara* is in terms of the vegetational habitat use of each species (see Chapter Three). Again this is an assessment which is directly relevant to the distribution of *L.agilis* and *L.vivipara* in an afforested habitat. However, unlike the seasonal number of sunshine hours received which is a difficult measure to relate to a countrywide situation, this measure has an almost direct equivalent in an open heathland habitat.

The habitat within which an animal species is found must be one which supplies all the basic requirements for life of that species. For a reptile species such as *L.agilis* or *L.vivipara* those requirements may be summarised as food, shelter, thermoregulation and reproduction. While *L.agilis* and *L.vivipara* are sympatric over much of their range and are frequently found in the same habitat, the work described here has shown that there clearly are differences between *L.agilis* and *L.vivipara* which influence their distribution within the forest habitat. The following is a summary of those factors (i.e. of food availability, shelter, thermoregulation and reproduction) which are important in distinguishing between the habitat use of *L.agilis* and *L.vivipara* in an afforested area.

Firstly it seem unlikely that the distribution and abundance of food items within the available habitat is having an affect on the relative distribution of *L.agilis* and *L.vivipara*. Nicholson (1980) has shown that *L.agilis* and *L.vivipara* have different preferred food items, *L.agilis* taking larger, harder-bodied prey than *L.vivipara*. However, there is no evidence to suggest that this is linked to differences in prey availability in different habitats.

Secondly, *L.agilis* and *L.vivipara* have been shown to have distinct habitat preferences in terms of the vegetation present (or dominant) in an area. The distributions of both *L.agilis* and *L.vivipara* relative to vegetation type were significantly different from a random one (see Chapter Three). L.agilis was associated with dry heathland vegetation types dominated by C.vulgaris with E.cinerea, P.aquilinum and V.myrtillus. The distribution of L.vivipara was associated with a dominance of E.tetralix and also with the presence of M.caerulea, U.minor and grass species preferred. These differences however, may be an expression of other factors influencing the type of habitat within which each species was found, rather than indicating a distinct preference on the part of each species for a particular type of vegetational habitat per se. For instance it seems unlikely that a dry heathland vegetation type differs substantially from a damp or wet heathland one in terms of the amount of shelter which it provides. Work carried out by Spellerberg & House (1983) has suggested that it is the 'structure' of the vegetation rather than its precise species compositon which is important for L.agilis habitat. This work showed that L.agilis was most frequently found associated with vegetation between 3 cm and 50 cm high which included a mosaic type of structure with frequent interfaces between vegetation types and between vegetation and open ground. This description would appear to fit either a dry, a wet or a damp heathland vegetation type. Hence, while L.agilis and L.vivipara were found to have distinct preferences in terms of the vegetational habitat in which they were found, it seems unlikely that this preference was a product of the species composition of the vegetational habitat itself. This hypothesis is supported by the use of wet, M.caerulea dominated habitats by L.agilis observed on the East Gore study area (see Chapter Three).

The third and fourth habitat requirements of reptile species are that a habitat must be a suitable one for thermoregulation and for reproduction, to a large extent these two factors are interrelated. A habitat must include a microclimate suitable for individual thermoregulation and for egg or clutch incubation. In the case of L.agilis, a habitat must also include a substratum suitable for egg incubation, which is not necessary for the viviparous L.vivipara.

The data presented in Chapter Four indicates that there is a real difference in the thermoregulatory abilities of individuals of L.agilis and L.vivipara. L.vivipara was shown to be capable of activity under a greater range of weather conditions (expressed in terms of net radiation and air temperature) than L.agilis. Hence, L.vivipara could be active for longer than L.agilis on both a daily and a seasonal basis. Unfortunately the microclimate data collected in the course of this work was not sufficient to see if this difference was great enough to produce the habitat preferences discussed above. It must however be possible that the thermoregulation of individual animals is relevant to the restriction of L.agilis to a dry heathland habitat. Also, the observed tendancy for L.agilis to occur in dry and L.vivipara in wet or damp heathland areas may not be entirely due to the inability of L.agilis to use the damp or wet habitats used by L.vivipara. It has been shown that L.agilis has the ability to restrict moisture loss from its skin a facility which L.vivipara does not have (Glandt 1979). Therefore to some extent, L.vivipara may be restricted to damp or wet heathland habitats and may be unable to exploit the dry heathland areas with which L.agilis was most frequently associated.

The distribution of L.agilis and L.vivipara along forest Ride verges could also be related directly to the seasonal number of sunshine hours received by Ride verges. Individuals of L.vivipara were found on Ride verges which received fewer mean seasonal sunshine hours than individuals of L.vivipara (see Chapter Three). This measure of the thermoregulatory needs of L.agilis and L.vivipara also gives a useful indication of the relative importance of egg or clutch incubation in the two species. Juveniles of L.vivipara were found over approximately the same range of seasonal sunshine hours received as the L.vivipara population as a whole (Fig. 9.1). Juveniles L.agilis however, were noticeably more restricted in their distribution and were found on Ride verges which received more seasonal sunshine hours that the Ride verges on which the L.agilis population as a whole was encountered (Fig. 8.2).

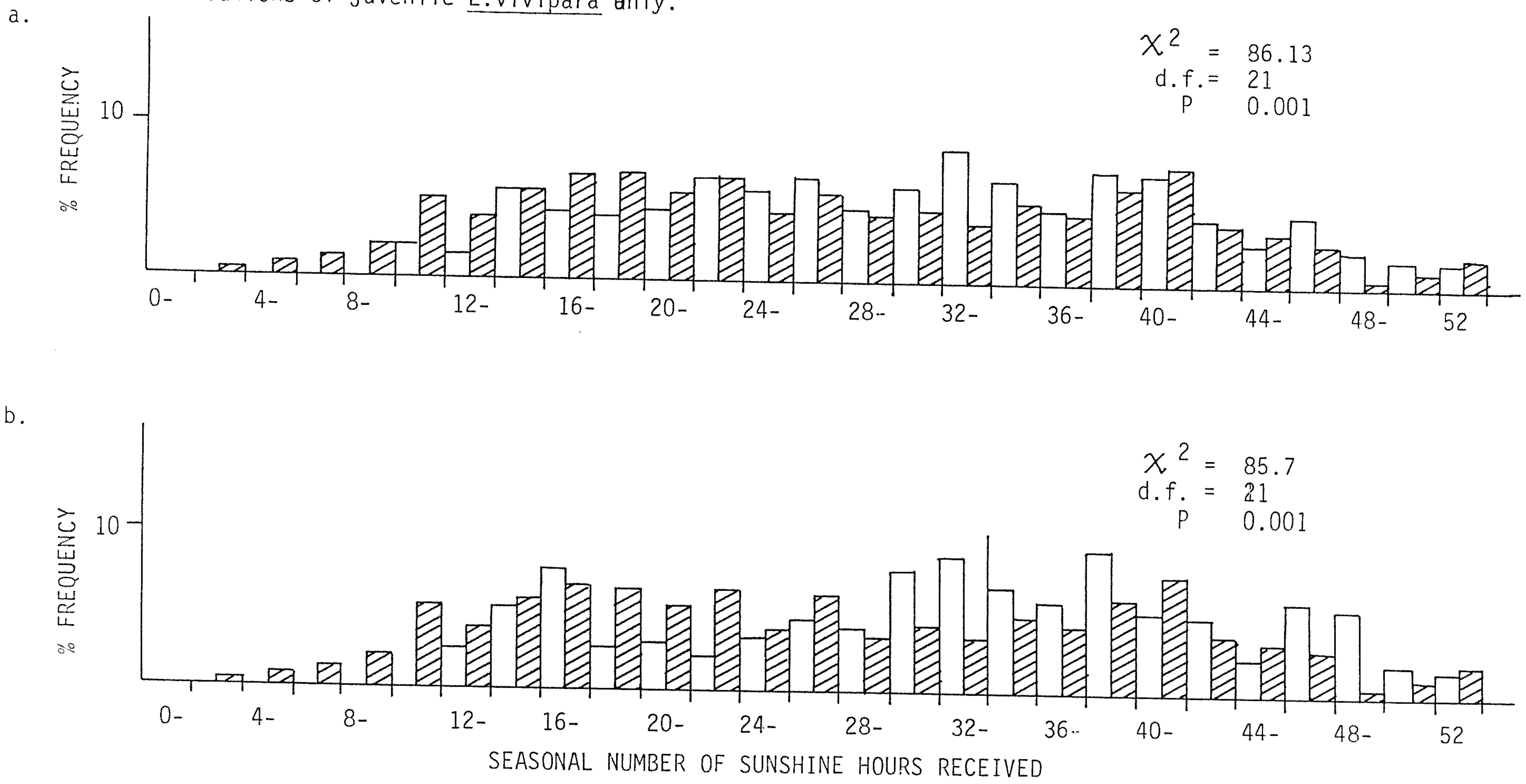
The final factor which may be influencing the observed habitat preferences of L.agilis is the need of this species for a substratum suitable for the incubation of its eggs. No data was collected on this point in this work but the distribution of L.agilis in Britain as a whole shows a strong tendency to be associated with sandy substrata (Smith 1981, Simms 1970, Corbett & Tamarind 1979, House & Spellerberg 1980) and sand is a particularly stable and suitable medium for egg incubation (House & Spellerberg 1980). Thus the presence of L.agilis in dry heathland vegetation types may in part be an expression of the requirement of this species for a sandy well drained substratum for egg incubation.

In summary, the distribution of L.agilis and L.vivipara within Ride verge habitats has been shown to be described by two characteristics of this habitat in particular;

i. the vegetation type of an area.

Fig. 9.1 General discussion.

The frequency distribution of L.vivipara sightings (□) and random points (▨) relative to the seasonal number of sunshine hours received by an area of Ride verge. a. for all observations of L.vivipara and b. for observations of juvenile L.vivipara only.



ii. the seasonal number of sunshine hours received by an area.

It has been suggested that these associations, in particular the vegetation type of an area, may be an indirect expression of other habitat requirements which cannot themselves be measured directly. The basic habitat requirements of an oviparous reptile species such as L.agilis can be summarised as being;

i. food

ii. shelter

iii. a microclimate suitable for individual thermoregulation

iv. a microclimate suitable for egg incubation

v. a substratum suitable for egg incubation.

Only the first four of these factors would be important for an viviparous reptile species such as L.vivipara.

As discussed above, factors i. and ii. are unlikely to differ significantly between the dry heathland habitat preferred by L.agilis and the wet or damp heathland habitat preferred by L.vivipara. The thermoregulatory ability of L.agilis and L.vivipara has been shown to differ in two ways. Firstly, L.vivipara can be active under a wider range of weather conditions than L.agilis, although this difference could not be related directly to the relative distributions of the two species within Ride verge habitats. Secondly, L.vivipara has been shown to be able to use habitats which received fewer seasonal sunshine hours than L.agilis. This factors was also shown to be important in egg or clutch incubation in the two species. Juveniles of L.vivipara were found (and therefore it has been assumed that clutches were successfully incubated) throughout the range of seasonal sunshine hours received under which adults of L.vivipara were found. For L.agilis juveniles were found under a more restricted and higher range of seasonal sunshine hours received than adults, suggesting that the distribution of L.agilis was being restricted not only by the thermoregulatory needs of adult individuals but also and further by the incubation requirements of egg clutches. Finally, from the distribution of L.agilis in Britain as a whole it appears that L.agilis requires a sandy substratum in which to lay its eggs.

It is therefore suggested that the observed differences in the distributions of L.agilis and L.vivipara within the forest heathland habitat are a result of the following causal factors;

i. the differences in the thermoregulatory capacities of adults of the two species, particularly in terms of the number of hours of solar radiation received by an area. The observed differences in the ability of the two species to utilise the available weather conditions may also be significant although this could not be shown here.

ii. the microclimate requirements of egg incubation in L.agilis. L.vivipara appeared to be able to successfully incubate embryos under any conditions which could be used by adult individuals. In L.agilis egg incubation appeared to require 'better' microclimate conditions than were necessary for the thermoregulation of individual animals.

iii. the requirement of L.agilis for a sandy substratum for egg incubation.

Hence, the wet or damp heathland habitats with which L.vivipara was most frequently found associated do not usually include a sandy well drained substratum which would be suitable for the incubation of eggs. The microclimate of such damp or wet heathland areas may also be unsuitable for use by L.agilis individuals, at least for part of the year. On the East Gore study area (see Chapter Three) L.agilis was observed to use M.caerulea dominated areas, where such habitats occurred closely adjacent to dry heathland areas. There was also some evidence to suggest that there was a seasonal pattern to the use of these wet or damp areas on East Gore. Such habitats were used mostly in the summer or whenever the high water levels prevalent in the wet or damp heathland areas in the spring had receded. This seasonal movement could be interpreted in two ways. Firstly it may indicate that the microclimate of wet or damp areas was unsuitable for use by L.agilis during the spring but could be used in the summer when weather conditions were more favourable and/or the area had dried out compared with its spring condition. Secondly, these movements could be interpreted as a post reproduction shift by adult animals from a habitat suitable for mating and egg laying to an adjacent area which was equally suitable for thermoregulation but which was unsuitable for egg laying. For one of these reasons, or for some combination of them both L.agilis is restricted to basic dry heathland habitats within afforested areas although adjacent damp or wet heathland areas or areas without a sandy substratum may be used on a periodic basis.

Thus it has been shown that within afforested areas the distribution of L.agilis relative to L.vivipara is restricted at least to some extent by the requirements of L.agilis for adult thermoregulation and egg incubation. In the context of the British and European distributions of L.agilis and L.vivipara the constraints identified within afforested areas probably also apply. In Britain there are apparently only two habitats, dry heathland and sand dune systems, available to L.agilis which provide a sandy substratum, a vegetational habitat suitable for the provision of food and shelter and a microclimate suitable for both individual thermoregulation and egg incubation. The microclimate necessary for adult thermoregulation and egg incubation in L.agilis when compared to L.vivipara may be important in limiting the distribution of L.agilis in Britain to mainly southerly areas, although the evidence presented here from afforested habitats can not be related directly to the countrywide distribution. The manner in which the set of habitat requirements of L.agilis are interrelated may be demonstrated by comparing the habitat use of L.agilis in Britain with that in continental Europe. In continental Europe L.agilis is associated with a wider range of vegetational habitats than in Britain (see Chapters One and Three) and is associated with loose, dry soils in general rather than with sandy ones in particular. It seems likely that in continental Europe the microclimate conditions available for adult thermoregulation and egg incubation are better than in Britain and that because of this the habitat requirements of L.agilis are less stringent than in Britain.

ACKNOWLEDGEMENTS

I would like to thank the S.E.R.C. for the financial support for this research and the Forestry Commisssion for an additional grant towards field work expenses.

I would like to thank everyone who has given me help, support or encouragement during the process of this work. My particular thanks go to:

- my two supervisors, Dr.I.F.Spellerberg and the late Miss J.Rowe for their advice, encouragement and enthusiasm.

- the staff and technicans of the biology department of Southampton University.

- the Forestry Commission for permission to carry out field work in Wareham Forest, Dorset. In particular I would like to thank Mr.A.Dunning and Mr.R.McKinley and the foresters and staff at Wareham who gave much support and encouragement while field work was in progress.

- the Institute of Terrestrial Ecology, Furzebrook Research Station which provided bench space, facilities and a much needed base during summer field work.

- the Nature Conservancy Council which kindly loaned the radio-tracking equipment used in this study. In particular thanks are due to Dr.A.S.Cooke for his advice and help.

This manuscript was written at the International Crops Research Institute for the Semi-Arid Tropics, India where the authors husband was a post-doctoral Intern. I would like to thank the Training department at ICRISAT for their help in the production of this manuscript. My particular thanks go to Mrs.D.Faris for her encouragement and support.

Finally I would like to thank my parents and Dr.D.R.Dent for being there.

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Appendix 1 The conservation of *L.agilis* within forestry plantations.

The 'Basic' computer programme used to calculate the seasonal number fo sunshine hours received by an area of Ride verge. Abbreviations and restrictions used are listed in sections 2.6.3.4 and 8.3.4.

```
10  REM "SUNSHINE HOURS PROGRAMME"
20  DIM THO(18),W(13),VA(15),HRS(12,15),BO(8),CO(8),BA(8),CA(8)
30  REM "INPUTTING RIDE CHARACTERISTICS"
40  DATA 0,5,10,15,20,25,30,35
50  DATA 4,6,8,10,12,14,16,18,20,22,24
60  DATA 4,5,6,7,8,9,10,11,12,13,14
70  FOR R = 1 TO 8
80  READ THO(R)
90  NEXT R
100  FOR C = 1 TO 11
110 READ W(C)
120 NEXT C
130 FOR B = 1 TO 11
140 READ VA(B)
150 NEXT B
160 DATA -32.72,59.73,-5.89,51.99,-25.07,53.81,-10.55,51.90,-16.53,
170 DATA 51.14,-16.53,51.14,-10.55,51.90,-25,07,53.81,-5.89,51.99,
180 DATA -32.72,59.73,-10.55,51.90,-25.07,53.81,-16.53,51.14,-16.53,
190 DATA 51.14,-25.07,53.81,-10.55,51.90
200 FOR T = 1 TO 8
210 READ BA(T),CA(T),BO(T),CO(T)
220 NEXT T
230 LPRINT CHR$(27);"!",CHR$(20)
240 INPUT THA
250 FOR T = 1 TO 8
260 FOR R = 1 TO 8
270 FOR C = 1 TO 11
280 FOR B = 1 TO 11
290 LET OPPO = THO(R)
300 LET ADJO = W(C) + (VA(B)/2)
310 LET HYPO = SQR(OPPO² +ADJO² )
320 LET ANGO = ATN(OPPO/ADJO)
330 LET HRSO = (BO(T)*ANGO)+CO(T))
340 IF HRSO<52 GOTO 360
350 LET HRSO = 52
360 LET HRSO = 52 - HRSO
370 LET HRS(C,B) = 42
380 IF THA = 0 GOTO 480
390 LET OPPA = THA
400 LET ADJA = (VA(B)/2)
410 LET HYPA = SQR(OPPA² +ADJA² )
420 LET ANGA = ATN(OPPA/ADJA)
430 LET HRSA = (BA(T)*ANGA)+CA(T)
440 IF HRSA<52 GOTO 460
450 LET HRSA = 52
460 LET HRSA = 52 - HRSA
470 LET HRS(C,B) = HRS(C,B)-HRSA
480 LET HRS(C,B) = HRS(C,B)-HRSO
490 NEXT B
500 NEXT C
510 LPRINT "ASPECT OF RIDE",T
520 LPRINT "THO & THA",THO(R),
530 LPRINT THA
540 LPRINT
550 LET Y = 8
560 FOR B = 1 TO 11
570 LPRINT TAB(Y);VA(B);
580 LET Y = Y+4
590 NEXT B
600 LPRINT
610 LPRINT
620 FOR C = 1 TO 11
630 LPRINT W(C);
640 LET X = 8
650 FOR B = 1 TO 11
660 LET HRS(C,B) = CINT(HRS(C,B))
670 LPRINT TAB(X);HRS(C,B);
680 LET X = X + 4
690 NEXT B
700 LPRINT
710 NEXT C
720 LPRINT
730 LPRINT
740 NEXT R
750 NEXT T
```