THE MOVEMENTS OF SMALL MAMMALS WITHIN THE ENVIRONMENTAL MOSAIC OF A RAILWAY JUNCTION

Thesis submitted by
DAVID MARK HICKLENTON
for the Degree of M. Phil.

University of London
(Royal Holloway College)

Supervisor: Dr. P. Morris

Spring 1986

CONTENTS: TEXT

CONTENTS: FIGURES

ABSTRACT

This study investigated small mammal movements within and between semi isolated habitat islands. The results are relevant to urban small mammal species in general and their movements in relation to man-made barriers in particular.

The study site was a railway junction consisting of railway tracks of different widths, dissecting an area of relict grassland in an other-wise urban environment.

For two years the small mammals in this area were trapped, marked and recaptured. They were also tracked using dyed bait markers and a grid of dropping boards from which were recovered faeces containing remains of the dyed bait.

The ability of the small mammals present (Apodemus sylvaticus, Clethrionomys glareolus and Microtus agrestis) to cross the railway lines was correlated with weight and sex; and also related to the width of the railway track and the vegetation on either side.

Conclusions were reached concerning the distribution and behavioural ecology of the three species within the study area, particularly in relation to the animals' capabilities for movement within heterogeneous habitats.

The biogeography of small islands such as these was considered, with reference to the effects of size and isolation on mammal movements. The effect of population density on such movements and possible local migratory effects were also investigated. The implications for conservation were discussed and it was shown that information from fieldwork such as this can aid biogeographical analysis in reserve design (for conservation of urban mammal populations) and aid in urban planning.

CHAPTER ONE

INTRODUCTION

1. INTRODUCTION

There have been many studies in the past on the interactions of man and mammals which have investigated the role of small mammals as economic pests. There have also been studies of man's effect on animal populations, and recently the study of animal ecology in urban environments has become important.

When natural or semi-natural communities form a continuum, the 'island' nature of populations is not important, but with agricultural reforms and urbanisation, areas of unsuitable habitat have been created, leaving wildlife to inhabit small pockets of land or islands.

To date, much work has been done showing the fragmentation of natural communities, (e.g. Curtis 1956, Levenson 1976, Webb and Haskins 1980, Mader 1984). It has been shown (Curtis 1956) that fragmentation of natural and semi-natural communities results in the formation of ecological islands.

Woodland in Wisconsin, North America, was reduced to 786 acres from 21,548 acres over the years 1931 to 1950. Similarly Moore et. al. (1967) showed that farming 'improvements' had led to the loss of hedgerows and the formation of islands of hedgerow habitat. Together with isolation caused by farming improvements has come the loss of habitats through urbanisation and the isolation of pockets of suitable habitat by the construction of linear barriers such as roads, canals, and railways. With this latter threat to natural communities, man-made wildlife preserves are being established in an attempt to prevent extinctions of animals caused simply by a reduction in living space.

CHAPTER ONE

INTRODUCTION

There have been many studies in the past on the interactions of man and mammals which have investigated the role of small mammals as economic pests. There have also been studies of man's effect on animal populations, and recently the study of animal ecology in urban environments has become important.

When natural or semi-natural communities form a continuum, the 'island' nature of populations is not important, but with agricultural reforms and urbanisation, areas of unsuitable habitat have been created, leaving wildlife to inhabit small pockets of land or islands.

To date, much work has been done showing the fragmentation of natural communities, (e.g. Curtis 1956, Levenson 1976, Webb and Haskins 1980, Mader 1984). It has been shown (Curtis 1956) that fragmentation of natural and semi-natural communities results in the formation of ecological islands.

Woodland in Wisconsin, North America, was reduced to 786 acres from 21,548 acres over the years 1931 to 1950. Similarly Moore et. al. (1967) showed that farming 'improvements' had led to the loss of hedgerows and the formation of islands of hedgerow habitat. Together with isolation caused by farming improvements has come the loss of habitats through urbanisation and the isolation of pockets of suitable habitat by the construction of linear barriers such as roads, canals, and railways. With this latter threat to natural communities, man-made wildlife preserves are being established in an attempt to present extinctions of animals caused simply by a reduction in living space.

In modern urban environments there exist animals with varying degrees of tolerance towards man, of varying populations, in a habitat which is a complicated mixture of natural 'relict' habitats and more recent man-made ones. The study of animal movements within this environmental mosaic is important as it can aid the formation of effective wildlife reserves.

In urban areas, if the habitats suitable for supporting many varied forms of wildlife are restricted to isolated patches or islands, movement of animals within and between these islands is important for the maintenance of species levels. If, as MacArthur and Wilson stated (1967), the size and isolation of an island is directly proportional to the number of species inhabiting it, then the nature of this isolation should be investigated.

Many studies have been carried out to show that there does indeed seem to be a direct relationship between island isolation and size and the number of native species present. One aim of this study is to investigate how nearly terrestrial habitat patches conform to biogeographic theory and to this end, the relative isolation of the habitat islands must be determined.

Wilson and Simberloff (1969) in experiments on oceanic islands found a direct correlation between island size and numbers of colonizing invertebrates. Work on islands consisting of patches in an environmental mosaic (as in this study) has been carried out on several insect and bird species but not to any great extent on mammals. (Terborgh 1975, Schodde and Calaby 1972, Mader 1984).

Brown (1971) found that mountain tops could not be regarded as islands at equilibrium (in the terms of MacArthur and Wilson) but rather as having a relict fauna, depleted since initial colonisation.

Emlen et. al. (1949) working on urban rats considered that street blocks acted as habitat islands in a man-made area. Such work on patchy terrestrial environments and also the use of urban environments as wildlife preserves, has led to the use of biogeographical theory in nature reserve design (May 1975, Diamond 1975, Wilson and Willis 1975).

The primary object of a nature reserve is usually to preserve at equilibrium level the maximum number of species possible and thus, in general, a large reserve is better than a small one. However, if a barrier to dispersal is placed across a reserve then it reduces the effective reserve area. Diamond (1975) set out various parameters for nature reserve design and concluded from biogeographical theory that if the effective area of a reserve is halved by (for instance) a road crossing it, then one sixth of the species present initially will become extinct when the system settles back to equilibrium. (This is assuming that the reserve can be treated as an island at equilibrium). If a wildlife preserve becomes split into several smaller preserves (or if a natural habitat becomes fragmented by urbanisation), then corridors between these reserves or islands may significantly increase the conservation effect.

Indeed, one way to raise the equilibrium number of species in a wildlife reserve of a haterogenous nature is to create many distinct wildlife islands with corridors of natural habitat between them. (May 1975).

In order to understand what constitutes a barrier to movement or even possibly gene flow (Mader 1984) of small mammals, studies of man-made barriers **must be made.** Such studies have been made in the past on roads, mainly connected with their impact on mortality rate (Reed and

Woodward 1975, Heinrich 1978 among others) or the extension of animals range along the verges (Huey 1941, Getz, Cole and Gates 1978). Oxley, Fenton and Carmody (1974) found that roads 90 meters wide are effective barriers to dispersal, as are bodies of water twice as wide. They also found that small mammals were reluctant to venture onto road surfaces where the distance between forest margins (i.e. the overall road clearance) exceeded 20 metres.

The nature of the barrier differs according to the species involved and **is also** dependant on the adjacent habitat. One important factor in the consideration of barriers to movement is that of the behaviour of small mammals at the interface between habitats. It is known that there is a tendency for the density and variety of organisms to be greater at borders between different plant communities than in the interior of the communities (Odum 1971) and this increased variety will affect animal movements. Bider (1968) in tracking work in various habitats suggested that the edge of a wood presented an "absorbent and biological barrier" to mammal movement and that motion of animals at the barrier tended to be parallel to it.

Such movement at habitat interface is of prime importance in studying movement routes in terrestrial mammals. It is known that man-made landscape features such as hedges are used for animal movements (Elton 1958, Grant 1969, Palmer 1984), indeed in urban areas this has led to planning with local animal movements in mind as much as those of the human residents (Laurie 1974, Kelcey 1975, Palmer 1984).

Many types of small mammal are found in urban areas often penetrating into the city centres along relict natural habitat routes or along man-made corridors of suitable habitat such as railway embankments (Yalden 1980). The study of these movements can aid in conservation efforts, not only in established built-up areas but also in areas where development is planned and there is a threat to native wildlife. This study then seeks to draw on several aspects of the interaction in urban areas of small mammals and man and, with specific reference to railway tracks, investigate animal movements within a patchy environment.

By studying mammal movements in a relict area intersected by man-made barriers it is hoped that light will be thrown on the use of such theoretical considerations as indicated above, and a better understanding of the extent to which railway tracks affect small mammal movement will assist in wildlife conservation efforts.

2. AIMS

3. THE SITE

4. PERIODS OF FIELDWORK

CHAPTER TWO

AIMS

This study was of small mammal movements within and between semi-isolated habitat islands in a terrestrial mosaic. This mosaic was formed by areas of differing habitat present in a railway junction; the railway lines acting as man-made interfaces between habitats. From the results of the study it was hoped that conclusions could be reached about the nature of the isolation of the areas involved and how this relates to biogeographic theories.

The aims could be summed up as follows:

(i) To study the number and type of movements of small mammals within the study area.

(ii) To determine to what extend the railway junction acts as an 'island system'.

(iii) To determine the nature of the barrier that a railway presents to mammal movements.

(iv) To investigate the implications of the above to mammal conservation and urban planning.

Within these areas of investigation, aspects of habitat and species difference can also be studied and so comparisons between the behavioural ecology of the three species present (*Apodemus sylvaticus*, *Clethrionomys glareolus*, and *Microtus agrestis*) can be made. It is a merging of the study of the autecology of the three species and also their interactions that can aid in the formation of ideas about island theory and corridor effects. From the study it should be possible to give an overall impression of small populations and movements in the entire study area and then assess the biogeographical implications of a 'Patchy' environment such as this.

CHAPTER THREE

THE SITE

The site chosen for the study is a railway junction in North West Kent two miles East of Bromley on the main line from Victoria to Sevenoaks. It is situated in farmland on the Hawkwood Estate between the urban areas of Bickley (to the North-West) and Petts Wood (to the South-East). The railway junction was laid out at the end of the nineteenth century and at that time the land was either pastureland on the estate or part of Petts Wood, which is possibly medieval in origin (Hall 1983). The urban areas around the junction grew up primarily in the nineteen thirties and the amount of open land in the area has been much reduced since then.

The intersection of the railway tracks has thus divided the site into areas of relict grassland which have been relatively undisturbed for about a century.

The junction covers a total area of 10 hectares and is divided by four intersecting railway lines into seven areas, each isolated from the surrounding land by railway track. In this study these areas are referred to as 'islands'.

They vary in size from 0.7. hectares to 2 hectares and are labelled in Map 3.1. as 'W', 'S', 'B', 'P', 'A', 'T' and 'C'.

TABLE 3.1: ISLAND SIZES

AREA	SIZE (Ha)	WIDTH OF BOUNDARY RAILWAY TRACKS
S	0.7	Single, Double, Four
W	1.1	Single, Double, Four
C	1.1	Single, Double, Four
T	1.1	Single, Single, Double
B	1.3	Single, Single, Double, Four
A	1.45	Single, Double, Four
P	2.0	Single, Treble, Four

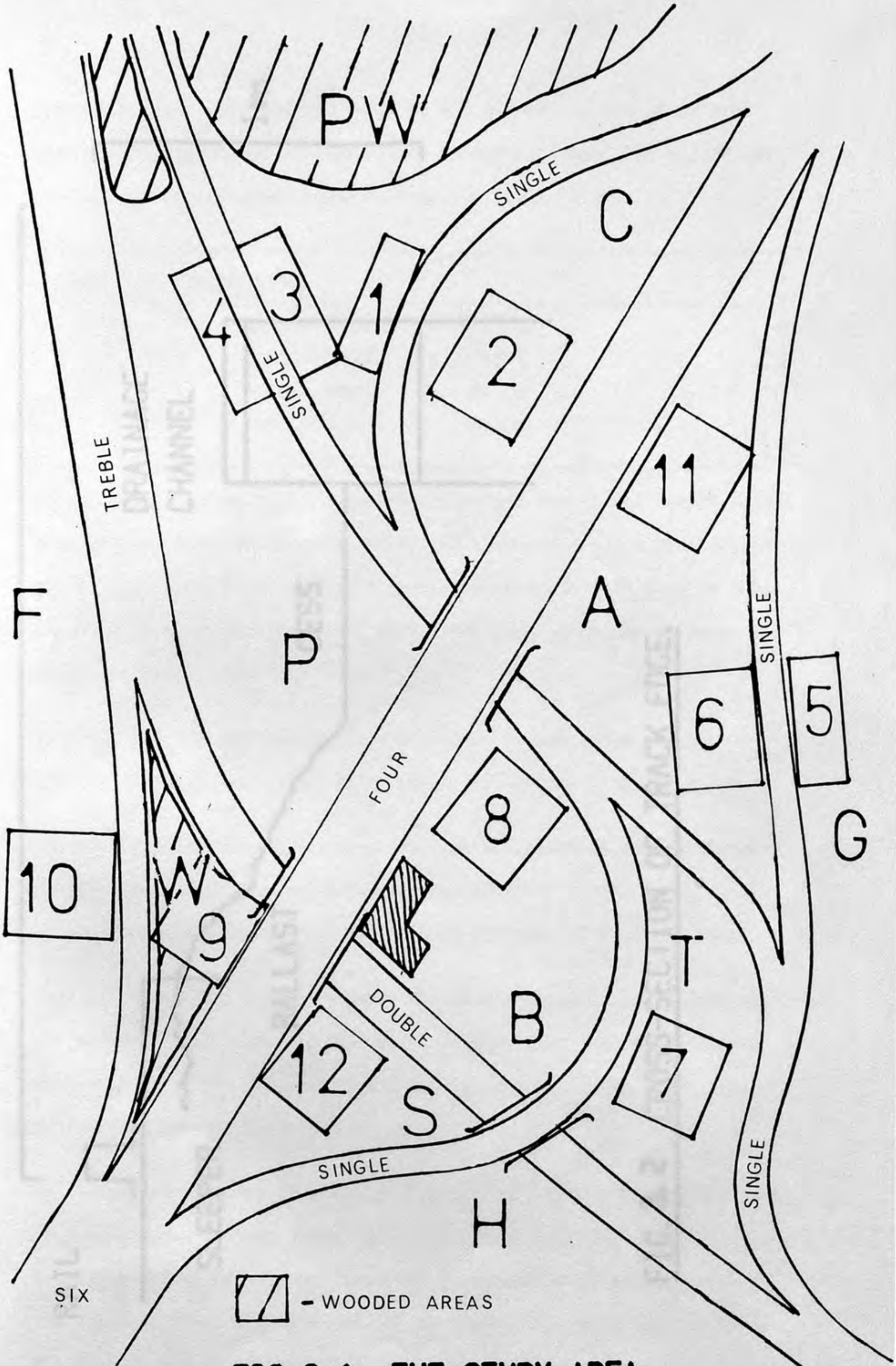


FIG. 3.1. THE STUDY AREA

NOT TO SCALE

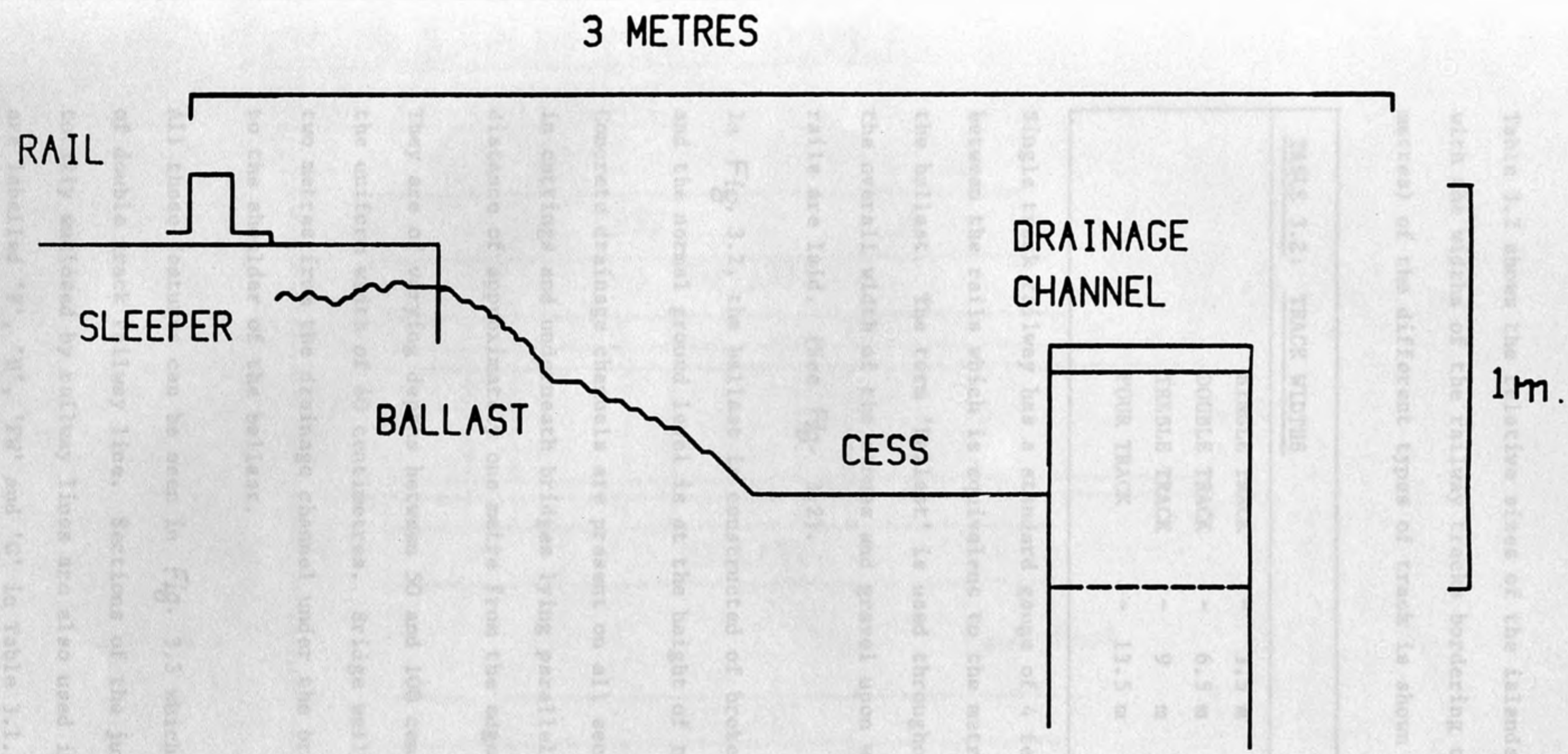


FIG. 3.2 CROSS-SECTION OF TRACK EDGE

Table 3.2 shows the relative sizes of the islands in the study area with the widths of the railway tracks bordering them. The widths (in metres) of the different types of track is shown below.

TABLE 3.2: TRACK WIDTHS		
SINGLE TRACK	-	3.5 m
DOUBLE TRACK	-	6.5 m
TREBLE TRACK	-	9 m
FOUR TRACK	-	13.5 m

Single track railway has a standard gauge of 4 feet 8 and a half inches between the rails which is equivalent to the metric 3.5 metres across the ballast. The term 'Ballast' is used throughout this work to mean the overall width of the stones and gravel upon which the sleepers and rails are laid. (See Fig. 3.2).

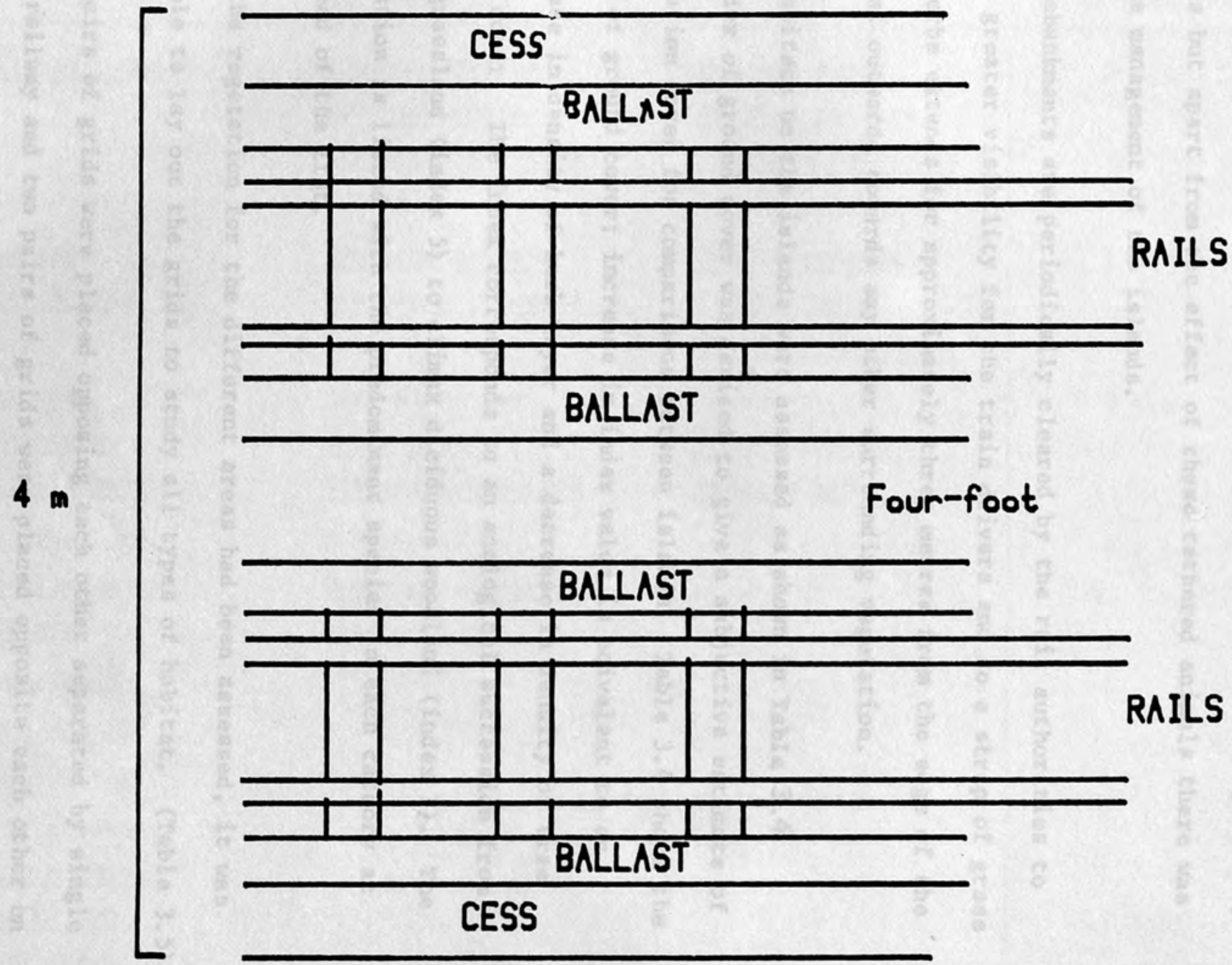
In Fig. 3.2, the ballast is constructed of broken rocks and gravel and the normal ground level is at the height of the 'Cess'.

Concrete drainage channels are present on all sections of the track in cuttings and underneath bridges lying parallel to the track at a distance of approximately one metre from the edge of the 'Shoulder'.

They are of varying depths between 50 and 100 centimetres and are of the uniform width of 40 centimetres. Bridge walls are approximately two metres from the drainage channel under the bridges, placed close to the shoulder of the ballast.

All these features can be seen in Fig. 3.3 which shows a general view of double track railway line. Sections of the junction which are not totally enclosed by railway lines are also used in this study, these are labelled 'F', 'H', 'PW' and 'G' in Table 3.1. Work for the study was carried out over the entire junction using grid systems as explained

FIG. 3.3. PLAN VIEW OF DOUBLE TRACK RAILWAY LINE



below. The twelve grids used were placed over the area so that each type of habitat and track width contained in the junction was studied.

The islands have varied habitats ranging from open grassland to climax deciduous woodland. A large central part of island 'P' was grazed by horses but apart from the effect of these tethered animals there was little management of the islands.

The embankments are periodically cleared by the rail authorities to allow greater visibility for the train drivers and so a strip of grass and herbs extends for approximately three metres from the edge of the ballast outwards towards any other surrounding vegetation.

The habitats on the islands were assessed as shown in Table 3.4
An index of ground cover was devised to give a subjective estimate of vegetation cover for comparisons between islands. Table 3.4 shows the index of ground cover; increase in index value is eqivalent to an increase in density of herb layer and a decrease in density of tree layer cover. The index corresponds to an ecological succession from open grassland (index 5) to climax diciduous woodland (index 1). The vegetation is listed with the predominant species in each cateory at the head of the list.

Once the vegetation for the different areas had been assessed, it was possible to lay out the grids to study all types of habitat. (Table 3.5)

Four pairs of grids were placed opposing each other separated by single track railway and two pairs of grids were placed opposite each other on both double and four track railway.

TABLE 3.4: VEGETATION USED TO DETERMINE HABITAT INDEX VALUE

Index Value	Vegetation: Herbs	Vegetation: Shrubs	Vegetation: Trees	Trapping grids with given index value
1	Oxalis acetosella	Ilex aquifolium Sambucus niger Crataegus monogyna	Quercus robur Quercus petraea Fraxinus excelsior Betula pendula	9 & 12
2	Rubus spp. Urtica dioeca	Sambucus niger Crataegus monogyna	Betula pendula Salix caprea Fraxinus excelsior	1 & 3 & 10
3	Rubus spp. Senecio spp. Digitalis purpurea	Many mixed inc. Malus spp. Crataegus monogyna	Immature Betula pendula Quercus robur	5 & 8
4	Many mixed inc. Leucanthemum spp. Vicia spp. Grasses inc. Lolium spp. Agropyron spp.	Occasional Crataegus monogyna Quercus spp. (saplings)	-	4 & 6 & 7
5	Mainly grasses, Agrostis tenuis Agrostis spp. Lolium spp.	-	-	2 & 11

TABLE 3.5: TRACK WIDTHS STUDIED

INDEX VALUE	GRID NO.	TRACK WIDTH	GRID NO.	INDEX VALUE
2	1	1	2	5
2	3	1	4	4
3	5	1	6	4
1	9	1	10	2
4	6	2	8	3
1	8	2	12	1
5	2	4	11	5
3	9	4	12	1

Table 3.5 shows the eight pairs of grids placed on opposite sides of differing track widths. E.g. Grid No. '1' has a vegetation index of '2' and is separated from grid '2' which has a vegetation index of '5' by a single track railway line. The term 'index value' used here refers to the vegetation index outlined in Table 3.4 above. It is a representation of the ground cover present ranging from Index '1' (Climax Woodland) to Index value '5' (Open grassland).

Vertebrate species present were recorded when either observed in the field or information was received from a reliable source.

TABLE 3.6: MAMMAL SPECIES PRESENT IN STUDY AREA

SPECIES	DETAILS	SOURCE
Sorex araneus	Probably present over most of junction. Only caught twice	Trapping/Caught by domestic cats
Apodemus sylvaticus	Widespread over area	Trapping/Tracking
Rattus norvegicus	Seen around rubbish on area 'P' and near signal box.	Personal observations
Clethrionomys glareolus	Widespread over area	Trapping
Microtus agrestis	Widespread over area	Trapping
Sciurus carolinensis	Widespread in wooded areas	Personal observations

TABLE 3.6: MAMMAL SPECIES PRESENT IN STUDY AREA (Contd.)

SPECIES	DETAILS	SOURCE
Mustela nivalis	Resident in basement of signal box	Railway employee
Vulpes vulpes	Resident in area PW and and travelling over most of junction	Personal observation
Meles meles	Resident in area F, travelling over north of study area	Railway employee and track deaths
Felis (domestic)	Resident in area B (three individuals)	Personal observation

The site was chosen for its suitability in answering the questions posed at the commencement of the study. Consisting as it does of a 'patchy' environment with varied habitats, comparisons could be made between varying track widths in different ground cover situations. The general public is denied access to the land adjoining the railways and the lack of disturbance to mammal traps as well as to the native mammals was another factor in the choice of site.

CHAPTER FOUR

PERIODS OF FIELDWORK

The study involved a total of 1775 "Trap nights effort" over a period of two years and was carried out in the following recording periods:

(i) March 1982 to September 1982: Preliminary trapping on embankments, woods and gardens adjoining the railway. (See Appendix 9.1).

(ii) November 1982 to February 1983: Trapping on embankments and preliminary trapping on the junction. (Two grids).

(iii) March 1983 to July 1983: Trapping grids on junction and also dyed bait work.

(iv) November 1983 to January 1984: Three trapping grids on the junction and dyed bait work.

Each of the twelve grids on the junction was used once in "Summer" and five were used once in "Winter", each being trapped for a period of five days.

Thus, for comparisons between the seasons, the "Winter" totals are those from trapping in periods (ii) and (iv) and the "Summer" totals are from trapping period (iii).

TABLE 4.1: TOTAL TRAP NIGHTS STUDIED

GRID NO.	NUMBER OF TRAPS	TOTAL TRAP NIGHTS STUDIED	
		WINTER	SUMMER
1	15	75	75
2	25	125	125
3	15	75	75
4	15	75	75
5	15	-	75
6	25	-	125
7	25	-	125
8	25	-	125
9	25	-	125

TABLE 4.1: TOTAL TRAP NIGHTS STUDIED (Contd.)

GRID NO.	NUMBER OF TRAPS	TOTAL TRAP NIGHTS STUDIED WINTER	SUMMER
10	25	-	125
11	25	125	125
12	25	-	125
	TOTAL	475	1300
	GRAND TOTAL	1775 TRAP NIGHTS	

Table 4.1 shows the total trap nights used for the study: 1 trap night = 1 trap set and placed in a grid for one night.

CHAPTER FIVE

METHODS

5. METHODS

The methods described here are field methods used in the study. Other (laboratory) work which was used in addition is found in Appendix 1. These other methods were used as a preliminary to the main field methods and were [illegible] part of the main body of the work.

5.1: TRAPPING: BACKGROUND

Most of the present knowledge of field populations of small mammals is based on trapping results. The estimation of various population parameters is dependent on some basic assumptions, the most important of which, for the purposes of this study, are those concerned with the estimation of population by the Lincoln Index method. Davis (1963), Leslie (1952) and Hayne (1949) have all proposed modifications to the mathematics of the method, but two important assumptions remain, namely (a) the population is stable between sampling and (b) all animals have equal catchability throughout the trapping period. To minimise the variation in the population which might lead to instability (as in (a) above), the overall trapping period should be kept as short as possible yet still provide an opportunity to catch as many individuals as possible and the interval between sampling should be kept as short as possible. In this study, each study period lasted five days, during which the traps were checked twice daily at about 8.00 p.m. and about 3.00 p.m.

The Timing of Trap Rounds

The times of trap checking have been shown by past workers to be important; Kikkawa (1964) when investigating activity rhythms of voles and mice concluded that although both *Clethrionomys* and *Apodemus* can be active throughout the 24 hour period at all times of the year, the

CHAPTER FIVE

METHODS

The methods described here are field methods used in the study. Other (laboratory) work which was used in addition is found in Appendix 1. These other methods were used as a preliminary to the main field methods and were not an integral part of the main body of the work.

5.1: TRAPPING: BACKGROUND

Most of the present knowledge of field populations of small mammals is based on trapping results. The estimation of various population parameters is dependant on some basic assumptions, the most important of which, for the purposes of this study, are those concerned with the estimation of population by the Lincoln Index method. Davis (1963), Leslie (1952) and Hayne (1949) have all proposed modific ations to the mathematics of the method, but two important assumptions remain, namely (a) the population is stable between sampling and (b) all animals have equal catchability throughout the trapping period. To minimise the variation in the population which might lead to instability (as in (a) above), the overall trapping period should be kept as short as possible yet still provide an opportunity to catch as many individuals as possible and the interval between sampling should be kept as short as possible. In this study, each study period lasted five days, during which the traps were checked twice daily at about 8.00 p.m. and about 3.00 p.m.

The Timing of Trap Rounds

The times of trap checking have been shown by past workers to be important; KikKawa (1964) when investigating activity rhythms of voles and mice concluded that although both Clethrionomys and Apodemus can be active throughout the 24 hour period at all times of the year, the amount of activity varied greatly with time of day and day length. In deciding therefore on a trapping schedule, past work on the periodicity of small mammal activity was taken into account. Miller (1958) detected nocturnal preference in Clethrionomys and the pattern of movement found by Kikkawa (1964) in January for Clethrionomys was similar to that obtained by Davis (1933) for Microtus which showed a two to four hour periodicity of activity. More recently, the amount of time spent actively foraging by small mammals has been investigated using radio telemetry. The lengths of inactive periods have been measured over a whole year.

Wolton (1983) has shown that Apodemus will tend to have shorter and more frequent inactive periods in winter although in the summer months there tends to be more overall activity with increased diurnal movement. Thus it appears that, over a year there is large diurnal as well as nocturnal activity of both Apodemus and Clethrionomys. In winter Kikkawa (1964) found that Clethrionomys captures between 2000 hours and 0200 hours in January were less than 25% of the daily catch; thus population estimates taken from only nocturnal trapping in Winter will underrecord Clethrionomys in relation to Apodemus. Similarly the use of diurnal trapping (especially in the summer) will tend to favour the recording of Apodemus as opposed to Clethrionomys.

For this study therefore, the results used for the modified Lincoln Index estimate of population size (Haynes 1949) are the sum of two trap rounds made in each 24 hour cycle i.e. Round "one" captures (made on the morning of the first day the traps were checked) were added to the round 'two' captures (made in the afternoon of the first day) and the data used as if there had been one single trap round. As Southern (1973) pointed out, this results in a small number of marked animals in the figure for the first round (i.e. 1 + 2), which should only contain unmarked animals. He stated that, despite this, there was only a slight discrepancy in apparent popoiation size from other estimates.

This method has two benefits: It can be used for trapping at all times of the year with no resulting bias in captures towards nocturnal or diurnal species and the results can be compared with those of the preliminary trapping (see appendix) where there was only one trap round in 24 hours.

The traps used throughout the study were Longworth mammal traps (Chitty and Kempson 1949) as it was anticipated that with the study area being composed chiefly of private land, low trap loss would occur.

<u>The Size of Trapping Grid</u>

The size of trapping grids to be used for population estimates is important and Tapper (1976) reviewed the literature on the subject up to that date; Zejda and Holisova (1971) found that a grid of eight by eight traps covering a hectare (inter-trap distance of 12.5 m) gave the same results when assessing density as a larger grid of 16 by 16 traps. Pelikan (1971) considered that a four by four grid with a 15 metre inter-trap distance was adequate for assessing density and Myllymaki et. al. (1971) suggested that an even smaller grid of three by three traps was sufficient (10 metres between traps). The grids used in this study were either five by five traps or five by three traps, depending on the space available, with a 10 metre inter-trap distance. It is probably impossible to standardize a single method of trapping study permitting the maximum yield of information with the minimum expenditure of effort, for all aspects of population study, and so the design of trapping grids must be made with the specific purposes of the study in mind.

As this study was concerned with investigating mammal movements, possibly over large distances, the trapping grid system used to show this movement should be on as large a scale as possible. Unfortunately large numbers of traps became unmanageable, so the maximum number of traps used simultaneously in grids was 50.

The traps were not pre-baited as it was thought that with the population estimates being taken from five days study there was ample time for the majority of the population to be trapped. Also, prebaiting might have affected mammal movements on adjacent grids where dyed bait studies were being carried out. Southern (1973) found that over half the individuals in a population of Apodemus and Clethrionomys were caught within 24 hours and felt that trapping for three to four days was adequate to estimate total numbers. Thus the five days used in this study was ample as exact population figures were not essential.

Details of Trapping Techniques

To obtain as much useful data as possible from the grids they were placed in the study area with regard to the aims of the study. They were used to survey populations on all the islands and also on some of the surrounding land, to show any movement across railway lines of differing widths and between differnet habitats. 12 grids in all were used on the junction, eight on islands and four on neighbouring land (see Fig. 3.1).

Grids were laid out either on Friday afternoons or during the weekend and traps were left with the doors fixed open. On Sunday afternoon the traps were baited and set and the first trap round to check the captures was on the Monday morning. The final round of the week (number 10) was usually on a Friday afternoon. On a few occasions the first trap round was on a Tuesday and the final one on the following

Saturday. The trap rounds were at approximately 0800 hours and 1500 hours. The bait used was a mixture of rolled oats and proprietary mouse food and the trap nest boxes were filled with grass and shredded paper as nesting material. In the summer months in some areas, each row of traps was marked with a cane and a red plastic tag to enable the traps to be located easily. The traps closest to the railway lines were placed one metre from the drainage channel (where present) (See Fig. 3.2) or two metres from the edge of the ballast. The grids were placed so that the following track widths were studied: (see Fig. 3.5)

Single track line: 4 sets of opposite grids

Double track line: 2 sets of opposite grids

Four track line : 2 sets of opposite grids.

At each trapping round before release, the mammals caught were toe or fur clipped, weighed, sexed and released. The voles had the pencil of hairs at the end of the tail clipped also for quick identification of recaptures. The fur and toes were clipped according to the numbering system shown in Figs. 5.1 and 5.2.

With this system it is possible to mark 899 individuals using up to four toes in any combianation or 139 individuals if only two toes in any combination were clipped (as in this study).

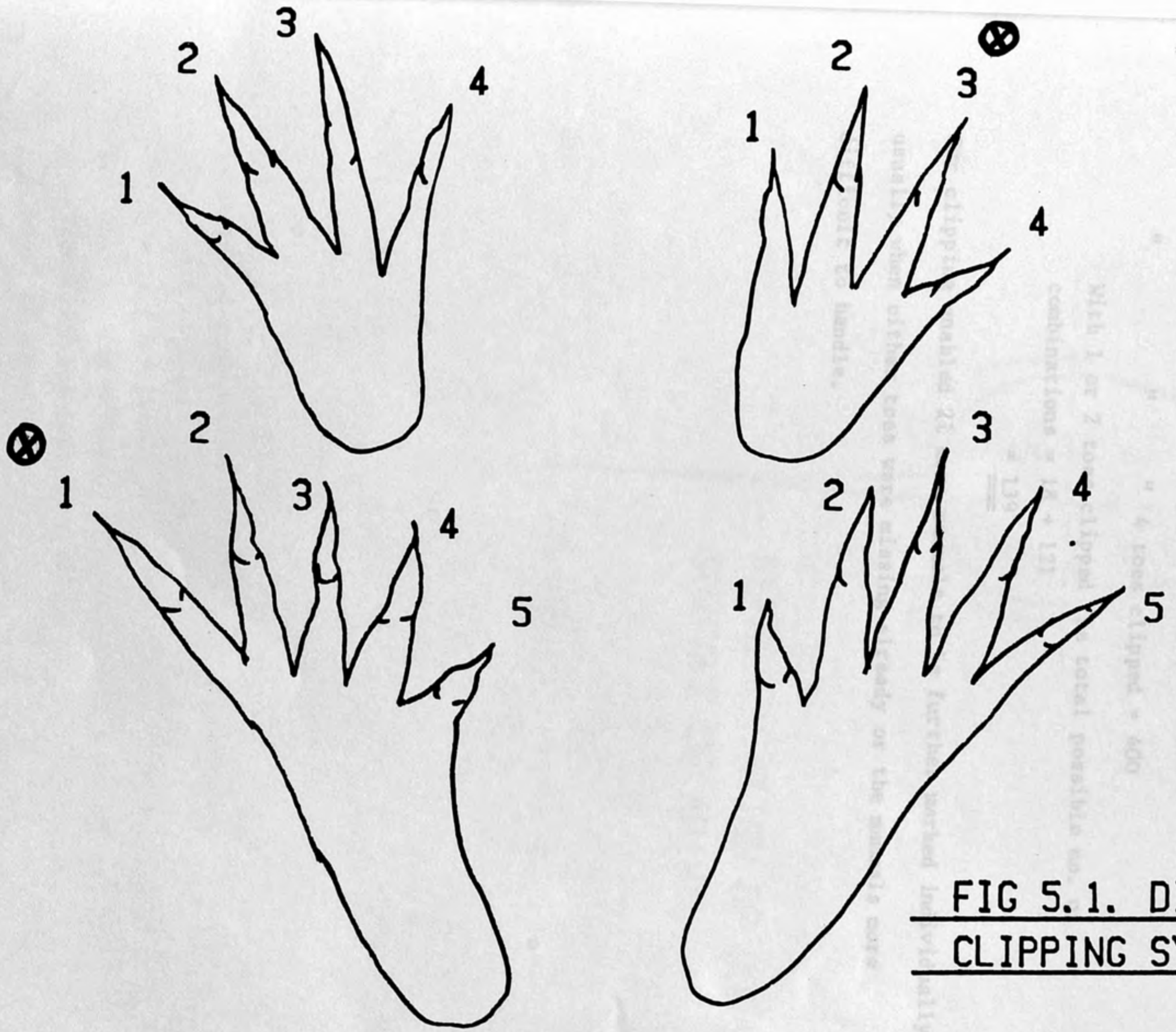


FIG 5.1. DIAGRAM OF TOE CLIPPING SYSTEM

Fig. 5.1

Vole no. 0310 would be clipped on the two toes marked ⊠. (0= not clipped)

0000 must be ruled out as it means no clipping at all so the possible combinations are as follows:

Combinations possible with 1 toe clipped = 18 (i.e. no. of toes)

" " " 2 toes clipped = (4x4)+(4x5)+(4x5)+(4x5)+(4x5)+(5x5)
= 121

" " " 3 toes clipped = 360

" " " 4 toes clipped = 400

With 1 or 2 toes clipped the total possible no. of combinations = 18 + 121
= 139

Fur clipping enabled 21 more mammals to be further marked individually usually when either toes were missing already or the mammals more difficult to handle.

IG. 5.2 DIAGRAM OF FUR
LIPPING SYSTEM

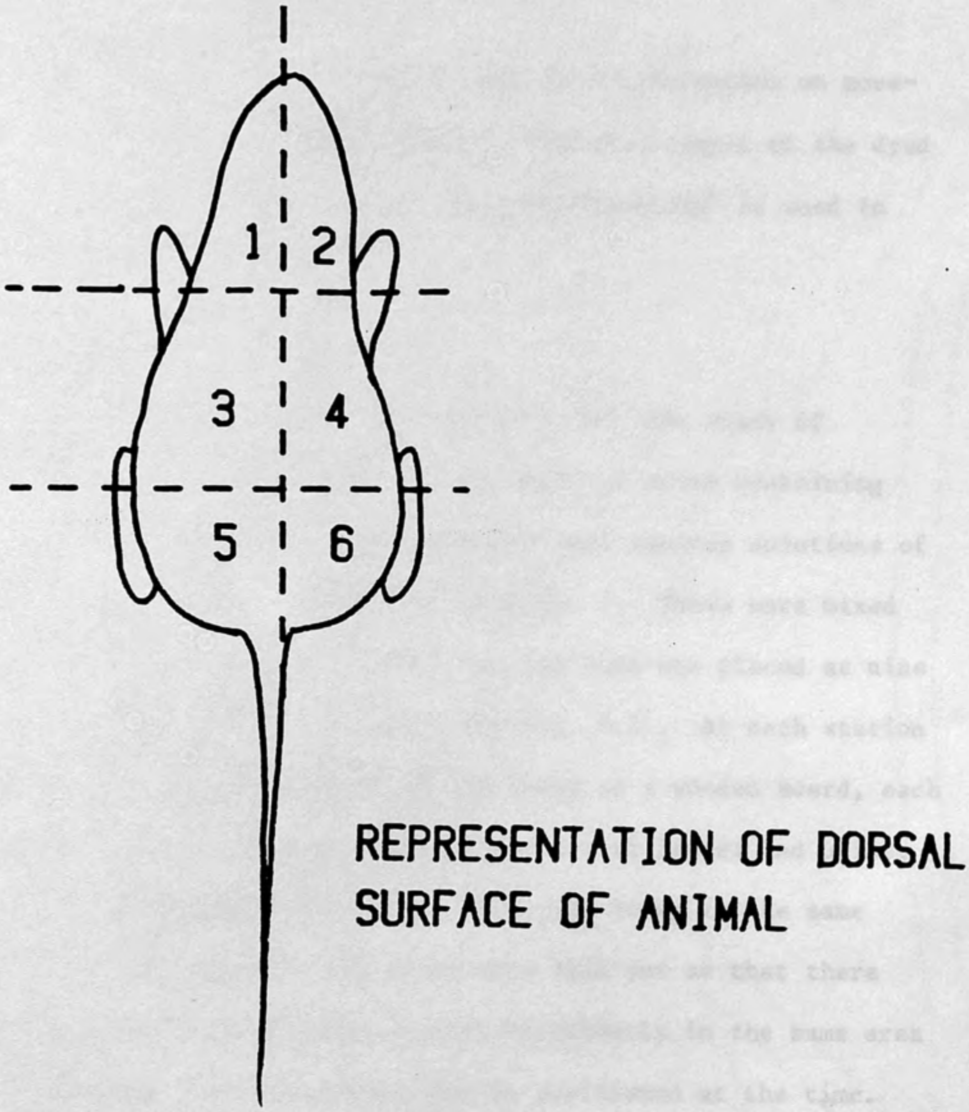


Fig. 5.2
Total no. of combinations possible
with 1 or 2 clippings
= 15 + 6 = 21
i.e. Vole clipped on right
"shoulder" and left 'central'
would be numbered 23.

5.2: DYED BAIT

Dyed bait work was used as a method to gain more information on movements with little extra fieldwork needed. The development of the dyed bait is outlined in Appendix (9.2). The term "Tracking" is used to cover all the dyed bait studies.

Tracking Grids

The work using dyed bait was in two sections: (a) the study of faecal pellets containing dye and (b) the study of urine containing dye. The two dyes used throughout the study were aqueous solutions of fluorescein & biological carmine (see Appendix). These were mixed with bait as described in the Appendix and the bait was placed at nine stations positioned in the study area (see Fig. 5.3). At each station about 500g of dyed bait was placed in two heaps on a wooden board, each heap containing one of the dyes. For collection of faeces and urine, grids of boards and bottles were used, the grids being in the same positions as the trap grids. The grids were laid out so that there were usually at least three grids in use concurrently in the same area away from where any trapping grids might be positioned at the time.

The grids were of the same dimension as the trapping grids, five by five with 10 m between collecting boards and bottles. On each grid a mixture of both boards and bottles was used as it was found after a few grids had been used that both were equally attractive to the mammals for use as dropping areas. Generally each line in a grid would consist of alternate boards and bottles. The grids were kept in position for up to three weeks and were checked about four times a week. Any droppings recovered were placed in five millilitres of water in a glass specimen tube and shaken. If the water colouration showed that the pellet had come from an animal which had eaten the

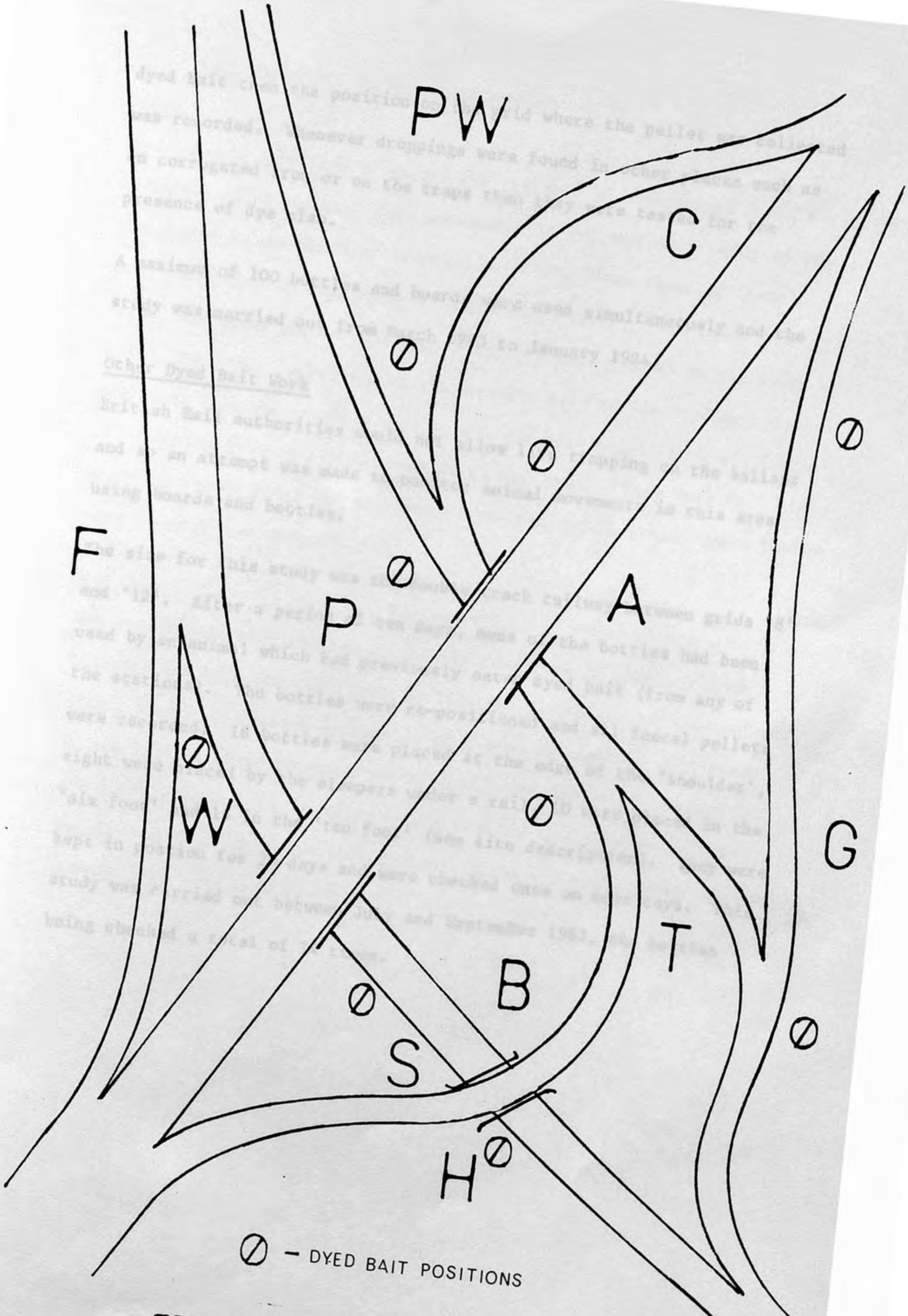


FIG. 5.3. DYED BAIT POSITIONS

dyed bait then the position on the grid where the pellet was collected was recorded. Whenever droppings were found in other places such as on corrugated iron or on the traps then they were tested for the presence of dye also.

A maximum of 100 bottles and boards were used simultaneously and the study was carried out from March 1983 to January 1984.

Other Dyed Bait Work

British Rail authorities would not allow live trapping on the ballast and so an attempt was made to monitor animal movements in this area using boards and bottles.

The site for this study was the double track railway between grids '8' and '12'. After a period of ten days, none of the bottles had been used by an animal which had previously eaten dyed bait (from any of the stations). The bottles were re-positioned and all faecal pellets were recorded. 18 bottles were placed at the edge of the 'shoulder', eight were placed by the sleepers under a rail, 10 were placed in the 'six foot' and 15 in the 'ten foot' (see site description). They were kept in postion for 20 days and were checked once on most days. This study was carried out between July and September 1983, the bottles being checked a total of 14 times.

5.3: OTHER TRACKING AND RECORDING METHODS

Tunnels

Tunnels were developed to record the presence of toe-clipped animals on smoked glass plates, (see Appendix 9.1) and used in a study on the embankment to the North of trapping grid '2'. Four lines of tunnels, each consisting of five tunnels, eight metres apart, were used, the first line being placed adjacent to the drainage channel on the track side. The other lines were on the opposite side of the drainage channel, one metre from the drain in open grass, and five metres from the drain. All the tunnels were placed parallel to the track. They were in position for 48 hours and the removed and the smoked glass tunnel floors were studies (see Appendix 9.1).

Run Counts

Run counts have been used to study vole densities in previous work by Lidicker and Anderson (1962) and by Lidicker (1973) and as a relatively simple method of density estimation they were employed in this study on the islands where Microtus was trapped. The number of runways in the surface vegetation crossing a 20 m transect was recorded. These counts were done in August when the vegetation was quite dense and the runways were easy to see. (See Fig. 5.4).

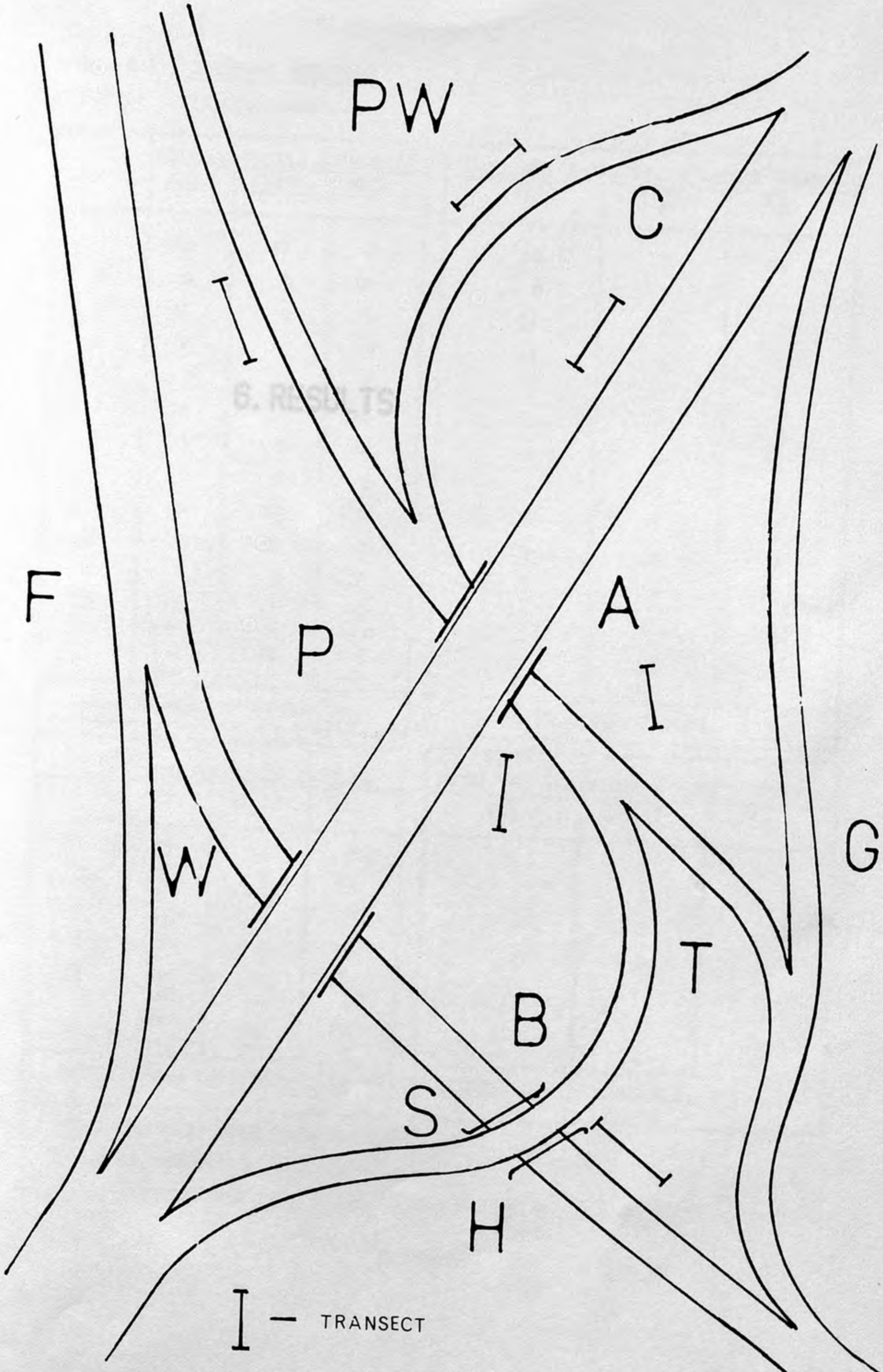


FIG. 5.4 VOLE RUN TRANSECTS

6. RESULTS

Table 6.1: TRAPPING RESULTS

TOTAL: 1775 trap nights.

GRID NO.	TOTAL CAPTURES (SUMMER) APO.	CLETH.	MIC.	TOTAL NO. INDIVIDUALS MARKED (SUMMER) APO.	CLETH.	MIC.
1	22	11	0	10	5	0
2	4	3	23	3	2	11
3	21	4	1	11	2	1
4	8	2	9	5	2	3
5	3	0	2	2	0	2
6	13	[illegible]	20	5	2	9
7	5	0	28	3	0	11
8	9	0	8	4	0	5
9	18	17	0	7	7	0
10	14	21	0	5	12	0
11	4	2	27	2	1	13
12	12	11	0	7	7	0
	135	73	118	64	40	55

TOTAL SUMMER CAPTURES: 324

TOTAL NO. INDIVIDUALS: 159

GRID NO.	TOTAL CAPTURES (WINTER) APO.	CLETH.	MIC.	TOTAL NO. INDIVIDUALS MARKED (WINTER) APO.	CLETH.	MIC.
1	19	13	0	11	7	0
2	7	5	18	3	4	8
3	17	6	0	9	2	0
4	8	0	15	5	0	7
11	8	0	22	5	0	8
	59	27	55	33	13	23

TOTAL WINTER CAPTURES: 136

TOTAL NO. INDIVIDUALS: 69

TOTAL CAPTURES OVER BOTH SEASONS: 459

TOTAL NO. INDIVIDUALS MARKED: 228

TOTAL CAPTURES PER TRAP NIGHT (SUMMER) = $\frac{324}{1300}$ = 0.25

" " " " " (WINTER) = $\frac{136}{475}$ = 0.29

CHAPTER SIX

Table 6.1: TRAPPING RESULTS

TOTAL: 1775 trap nights.

GRID NO.	TOTAL CAPTURES (SUMMER) APO.	CLETH.	MIC.	TOTAL NO. INDIVIDUALS MARKED (SUMMER) APO.	CLETH.	MIC.
1	22	11	0	10	5	0
2	4	3	23	3	2	11
3	21	4	1	11	2	1
4	8	2	9	5	2	3
5	3	0	2	2	0	2
6	13	2	20	5	2	9
7	5	0	28	3	0	11
8	9	0	8	4	0	5
9	18	17	0	7	7	0
10	14	21	0	5	12	0
11	4	2	27	2	1	13
12	12	11	0	7	7	0
	133	73	118	64	40	55
TOTAL SUMMER CAPTURES: 324				TOTAL NO. INDIVIDUALS: 159		

GRID NO.	TOTAL CAPTURES (WINTER) APO.	CLETH.	MIC.	TOTAL NO. INDIVIDUALS MARKED (WINTER) APO.	CLETH.	MIC.
1	19	13	0	11	7	0
2	7	5	18	3	4	8
3	17	4	0	9	2	0
4	8	0	15	5	0	7
11	8	0	22	5	0	8
	59	22	55	33	13	23
TOTAL WINTER CAPTURES: 136				TOTAL NO. INDIVIDUALS: 69		

TOTAL CAPTURES OVER BOTH SEASONS: 459

TOTAL NO. INDIVIDUALS MARKED: 228

TOTAL CAPTURES PER TRAP NIGHT (SUMMER) = $\frac{324}{1300}$ = 0.25

" " " " " (WINTER) = $\frac{136}{475}$ = 0.29

RESULTS

6.1: TRAPPING RESULTS

The data from which the totals shown in Fig. 6.1 are calculated are presented in the Appendix (Tables 10.1 - 10.4).

The population estimates shown below (Table 6.2) were calculated from this data also.

Table 6.2: POPULATION ESTIMATES (SUMMER)

GRID NO.	POPULATION ESTIMATE (INDIVIDUALS PER HECTARE)		
	A. sylvaticus	C. glareolus	M. agrestis
1	67	54	0
2	>3	>2	132
3	120	>2	>1
4	19	>2	73
5	>2	0	>2
6	44	>2	79
7	>3	0	146
8	38	0	47
9	67	62	0
10	48	141	0
11	>2	>1	134
12	83	91	0

Table 6.3: POPULATION ESTIMATES (WINTER)

GRID NO.	POPULATION ESTIMATE (INDIVIDUALS PER HECTARE)		
	A. sylvaticus	C. glareolus	M. agrestis
1	148	111	0
2	46	>4	122
3	116	>2	0
4	60	0	86
11	68	0	77

These figures (Table 6.3) are calculated as shown in the Appendix using a modified Lincoln index (after Hayne 1949). The figures correspond to the number of individuals per hectare and have only been calculated for those instances where there were more than five captures of a particular species on any one grid. By using this technique to estimate population sizes it becomes apparent that there is a large difference between using an index such as captures per trap night per hectare (this is the way that the 'density index' below was obtained) and population estimates (Tables 6.2 and 6.3).

With low capture rates on the grids the population estimates can vary widely e.g. on grid '10'; in summer there were 21 captures of Clethrionomys resulting in a population estimate of 141 voles per hectare. This corresponded to a capture rate of 0.67 captures per trap night per hectare. However on grid '3' there were also 21 captures, this time of Apodemus, resulting in a population estimate of 120 mice per hectare and equivalent to a density index of 1.86 captures per trap night per hectare. Thus despite the closeness of the two population estimates (140 and 120 animals per hectare respectively) there is a big difference in the number of captures per trap night. This could be caused by several factors, such as there being a difference in behaviour between the species with Apodemus being caught three times more often than Clethrionomys; possibly the Apodemus on grid three are more trap shy. However the most likely explanation is that there is no correlation at all between the two forms of population estimation. With small numbers of individuals involved there are bound to be some apparently strange results, e.g. grid eight there were nine captures of Apodemus resulting in a density index of 0.28 captures per trap night per hectare. On grid five there were three captures resulting in a similar index of 0.27 (captures per trap night per hectare).

In these instances there were respectively four and two individual animals involved. As has been stated in previous studies (Tanton 1965, Smirnov 1967), a capture index is not a reliable type of population index since captures can vary considerably, yet yield similar results.

6.2: TRACKING TOTALS

The tracking totals shown below are derived from the raw data presented in the Appendix (9.1).

Table 6.4: TRACKING RESULTS BY AREA

BAIT STATION	NUMBER BOARDS VISITED	NUMBER BOTTLES VISITED	CROSSINGS REVEALED:			TOTAL CROSSINGS REVEALED
			SINGLE TRACK	DOUBLE TRACK	FOUR TRACK	
W	17	7	6	2	4	12
S	10	6	1	2	1	4
H	4	2	0	5	0	5
P	4	2	0	4	0	4
B	10	8	0	3	0	3
Gi	5	1	4	0	0	4
Gii	3	0	3	0	0	3
C	8	11	2	0	4	6
PW	12	8	8	0	0	8
	73	45	24	16	9	49

6.3: OTHER METHODS

Run Counts

The totals shown below (Table 6.5) are from the vole run surveys carried out on six areas. The capture index in the table is calculated from the trapping results and the number of runways over a 20 metre transect were recorded.

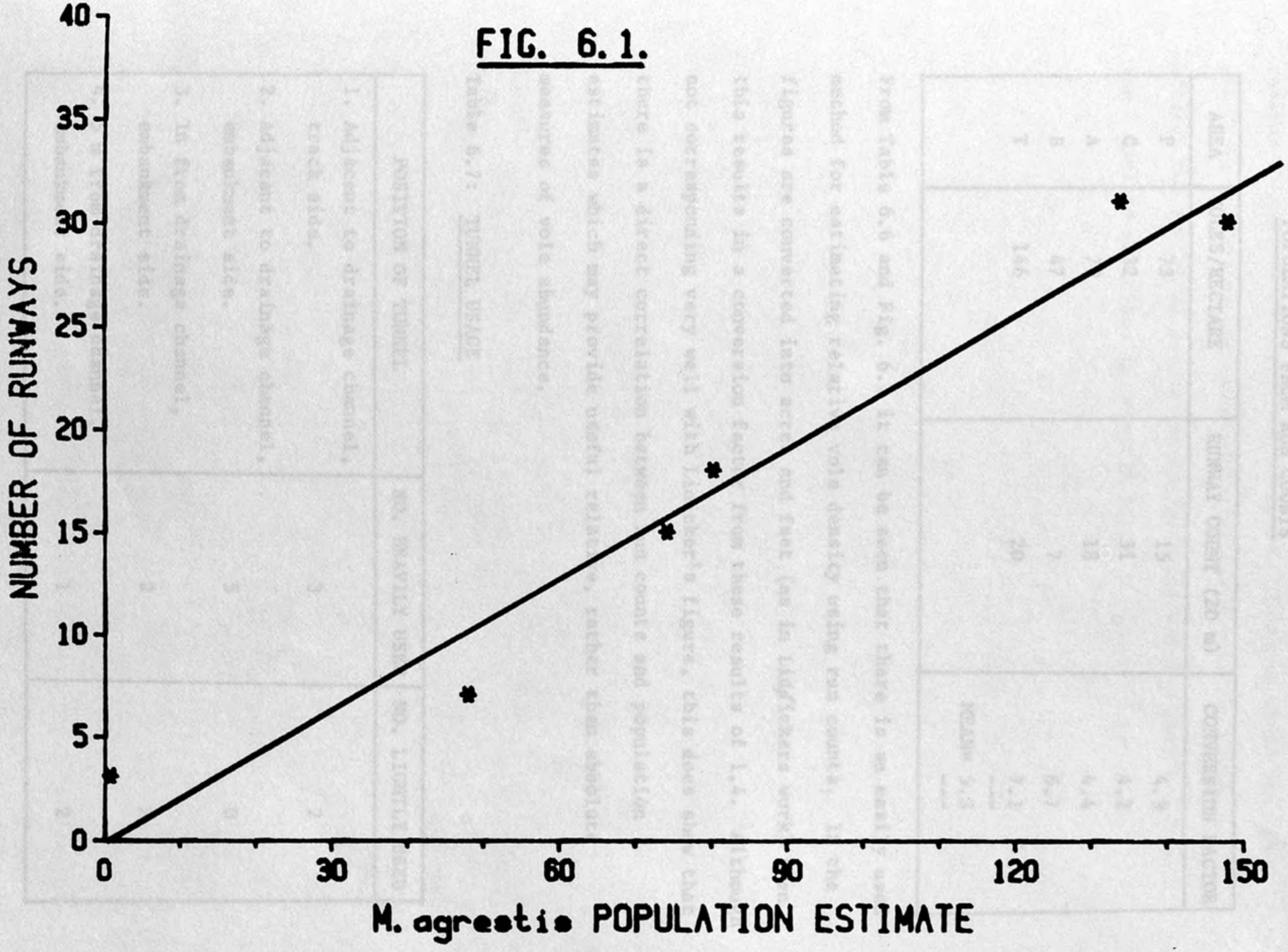
Table 6.5: VOLE RUNWAY COUNTS

AREA	NUMBER OF RUNWAYS (20m)	M. agrestis CAPTURE INDEX	M. agrestis POPULATION ESTIMATE
PW	3	0	0
P	15	80	73
C	31	122	132
A	18	107	79
B	7	43	47
T	30	130	146

Table 6.5 shows the number of runways in a 20 metre transect of the areas in question. The capture index is the number of captures per trap night per hectare.

Lidicker's (1973) work used the runway count from 100 foot (approx. 30 m) transects to estimate populations. He found that the population expressed as number of voles per acre (as found by trapping methods) was equal to the 100 foot runway count multiplied by a conversion factor of 9.7. Lidicker and Anderson (1973) used 200 foot transects (approx. 61 m) and at one stage in their survey, the same conversion factor was five. It seems that although run density will vary for different habitats, there is some correlation between the density of vole runways and population size. (See Fig. 6.1).

FIG. 6.1.



NUMBER OF RUNWAYS
40
35
30
25
20
15
10
5
0
0
30
60
90
120
150
M. agrestis POPULATION ESTIMATE

Table 6.6: CALCULATIONS OF CONVERSION FACTOR FOR ESTIMATING VOLE POPULATIONS FROM RUN COUNTS

AREA	VOLES/HECTARE	RUNWAY COUNT (20 m)	CONVERSION FACTOR
P	73	15	4.9
C	132	31	4.2
A	79	18	4.4
B	47	7	6.7
T	146	20	7.1
			MEAN= 5.3

From Table 6.6 and Fig. 6.1 it can be seen that there is an easily used method for estimating relative vole density using run counts. If the figures are converted into acres and feet (as in Lidickers work) then this results in a conversion factor from these results of 1.4. Although not corresponding very well with Lidicker's figure, this does show that there is a direct correlation between run counts and population estimates which may provide useful relative, rather than absolute measures of vole abundance.

Table 6.7: TUNNEL USAGE

POSITION OF TUNNEL	NO. HEAVILY USED	NO. LIGHTLY USED
1. Adjacent to drainage channel, track side.	3	2
2. Adjacent to drainage channel, embankment side.	5	0
3. In from drainage channel, embankment side.	2	2
4. 5 m from drainage channel, embankment side.	1	2

Table 6.7 shows the results from tracking tunnels placed close to the railway in various positions for 48 hours. "Lightly used" and "Heavily used" are subjective estimates of tunnel usage with the division between the two being equivalent to approximately two passages though the tunnel as described in Appendix 9.1.

6.4: RAILWAY TRACK CROSSINGS

Railway crossings were revealed by both trapping and tracking. These two methods are dealt with seperately below. Of the 459 captures over the course of the study, 18 were recaptures of individuals that had crossed a railway line since their initial capture. These are shown in Table 6.8 below.

Table 6.8: CROSSINGS OF RAILWAY TRACK AS REVEALED BY TRAPPING (SUMMER)

TRACK WIDTH	AREA FIRST CAUGHT	AREA RECAPTURED	SPECIES	SEX	WEIGHT	APPROXIMATE DISTANCE BETWEEN CAPTURES
Single	PW	C	Apo.	M	17g	45m
"	PW	C	Apo.	M	20g	35m
"	PW	P	Apo.	M	28g	30m
"	PW	P	Mic.	M	30g	60m
"	P	PW	Mic.	M	16g	25m
"	P	PW	Apo.	F	13g	20m
"	A	G	Apo.	M	14g	10m
"	W	F	Cleth.	M	18g	15m
"	W	F	Apo.	M	20g	50m
Double	A	B	Apo.	M	21g	25m
"	A	B	Apo.	F	24g	40m
"	B	A	Mic.	M	24g	45m
Four	C	A	Mic.	M	18g	25m
"	S	W	Apo.	F	16g	45m
"	S	W	Apo.	M	15g	40m

CROSSINGS OF RAILWAY TRACK AS REVEALED BY TRAPPING (WINTER)

TRACK WIDTH	AREA FIRST CAUGHT	AREA RECAPTURED	SPECIES	SEX	WEIGHT	APPROXIMATE DISTANCE BETWEEN CAPTURES
Single	PW	C	Apo.	M	26g	45m
"	P	PW	Apo.	F	20g	55m
Four	A	C	Apo.	M	28g	45m

These track crossings are shown again in Table 6.9 which compares the three species involved.

Table 6.9: TOTAL NUMBERS OF TRAP REVEALED CROSSINGS

SPECIES	NUMBER OF CROSSINGS			
	SINGLE TRACK	DOUBLE TRACK	FOUR TRACK	TOTAL
A. sylvaticus	8	2	3	13
C. glareolus	1	0	0	1
M. agrestis	2	1	1	4
	11	3	4	18

Crossings of railway track by small mammals were revealed by tracking methods as well as by trapping; a total of 49 crossings were detected by tracking methods detailed in the Appendix (Tables 9.12, 9.13, 9.14). The reason that the majority of crossings were detected by tracking methods was probably due to a combination of factors. The tracking grids were laid out for longer than the trapping grids and it is likely that animals are more trap-shy when out of their home range (Watts 1970).

In order to isolate the various factors which might affect track crossings, results are analysed from four "supergrids" each consisting of a pair of grids with a railway track between them. The pairs of grids are similarly placed with regard to habitat and distance from the railway line.

Figure 6.2 shows the position of two grids (one 'supergrid') in relation to the railway line. In this case (Fig. 6.2) the line is of double track.

If the results from the four pairs of grids placed similarly are taken (the four 'Supergrids') then it can be seen that up to 16% of captures occur after the animal has crossed a single railway line dividing what is effectively a grid of six by five traps. (Table 6.10).

FIG. 6.2. THE POSITION OF TWO GRIDS AND A DOUBLE TRACK RAILWAY LINE - A 'SUPERGRID'

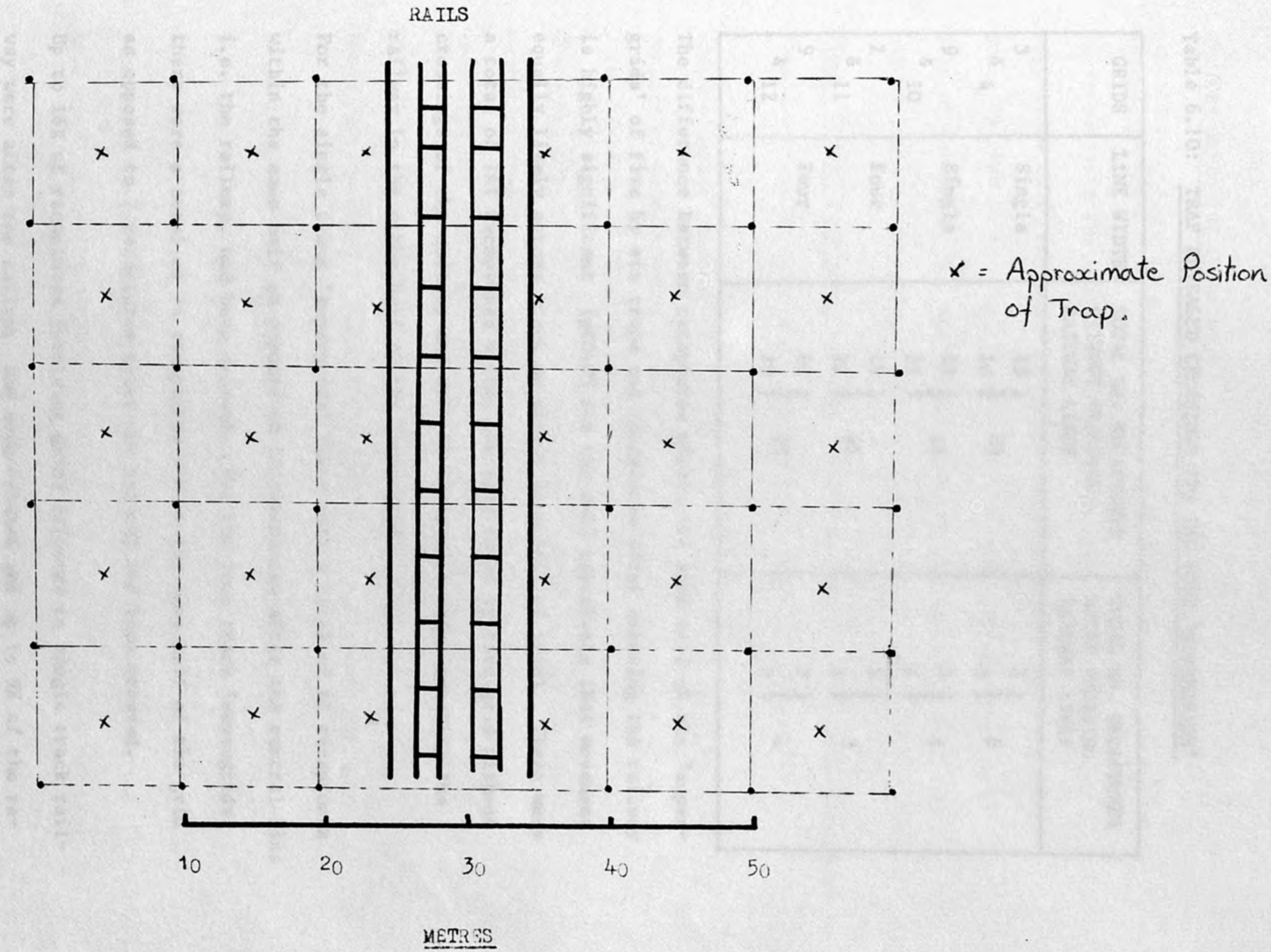


Table 6.10: TRAP REVEALED CROSSINGS FOR THE FOUR 'SUPERGRIDS'

GRIDS	LINE WIDTH	TOTAL NO. RECAPTURES WITHOUT CROSSING RAILWAY LINES		TOTAL NO. RECAPTURES AFTER CROSSING RAILWAY LINES	
3 & 4	Single	13 10	23	3 3	6
9 & 10	Single	23 21	44	3 2	5
2 & 11	Four	19 22	41	2 1	3
9 & 12	Four	23 10	33	2 2	4

The difference between recaptures within the same half of the 'supergrids' of five by six traps and recaptures after crossing the railway is highly significant ($p<0.05$ for the null hypothesis that movement equally likely across track as within same half of grid). There were a total of 141 recaptures within the same three by five grid without crossings of the railway and only 18 recaptures after crossing the railway in the other half of the 'supergrid'.

For the single track 'supergrids' there were a total of 67 recaptures within the same half as opposed to 11 recaptures after the central line i.e. the railway, had been crossed. For the four track 'supergrids' there were a total of 74 recaptures within the same half of the grid as opposed to 7 recaptures after the railway had been crossed.

Up to 16% of recaptures involving grids adjacent to single track railway were after the railway had been crossed and up to 9% of the recaptures on grids next to four track railway were after the railway had been crossed.

FACTORS AFFECTING CROSSINGS:

POPULATION SIZES

To investigate the effect of differential population sites on the supergrids it is necessary to reduce the population figures to an index so that it is possible to state the number of crossings per head of population for each grid. Once this is achieved then grids can be compared directly.

Single Track "Supergrids": Total number of crossings = 11 (all in summer)

Population estimates on the grids involved: Mean of 106 and 159 = 132/ha. (all spp.)

Capture index: Mean of 179 and 187 = 183 captures/100 trap nights/ha.

As size of grids = $8000m^2$, population for supergrid = $132 \times \frac{8}{10} = 106$

capture index for supergrids = $\frac{8}{10} \times 183 = 146$

These are only approximate estimates, but can be used to give the number of crossings per animal on the grid (0.103), and the number of crossings per animal per one hundred trap nights (0.075).

Four Track "Supergrids": Total number of crossings = 7

Mean capture index on the grids concerned = 164 captures/100 trap nights/hectare.

Doing a similar calculation to the above, approximate population of the supergrids was 132 animals. The capture index for the "supergrids was about 147 captures per 100 trap nights per hectare. Thus, for the four track "supergrids", the number of crossings per animal on the grid was 0.05 and the number of crossings per animal per hundred trap nights (i.e. per unit capture index) was 0.05.

This shows the details of crossing of Four Track as opposed to Single Track line once relative population sizes, capture rates and the size of the grids are made equal. It can be seen that, with population sizes taken into account, there are roughly half the number of crossings of four track as opposed to single track results. However when the capture index is used, the figures for Single and Four track line are more similar (0.075 and 0.05 crossings per unit capture index). Thus differences in the numbers of crossings are not greatly affected by the "trappability" of a population but are probably influenced by population size.

These results are shown in Table 6.11 below.

Table 6.11: CROSSINGS AND POPULATION SIZE FOR FOUR "SUPERGRIDS"

	Single Track	Four Track
Crossings per unit population	0.103	0.05
Crossings per unit capture index	0.075	0.05

Table 6.11 indicates that in an area such as PW where there were an estimated 120 Apodemus per hectare, there would have been an average 12 crossings of single track line if a "supergrid" was placed by it. However if the line was four-track then there would have been half that number of crossings.

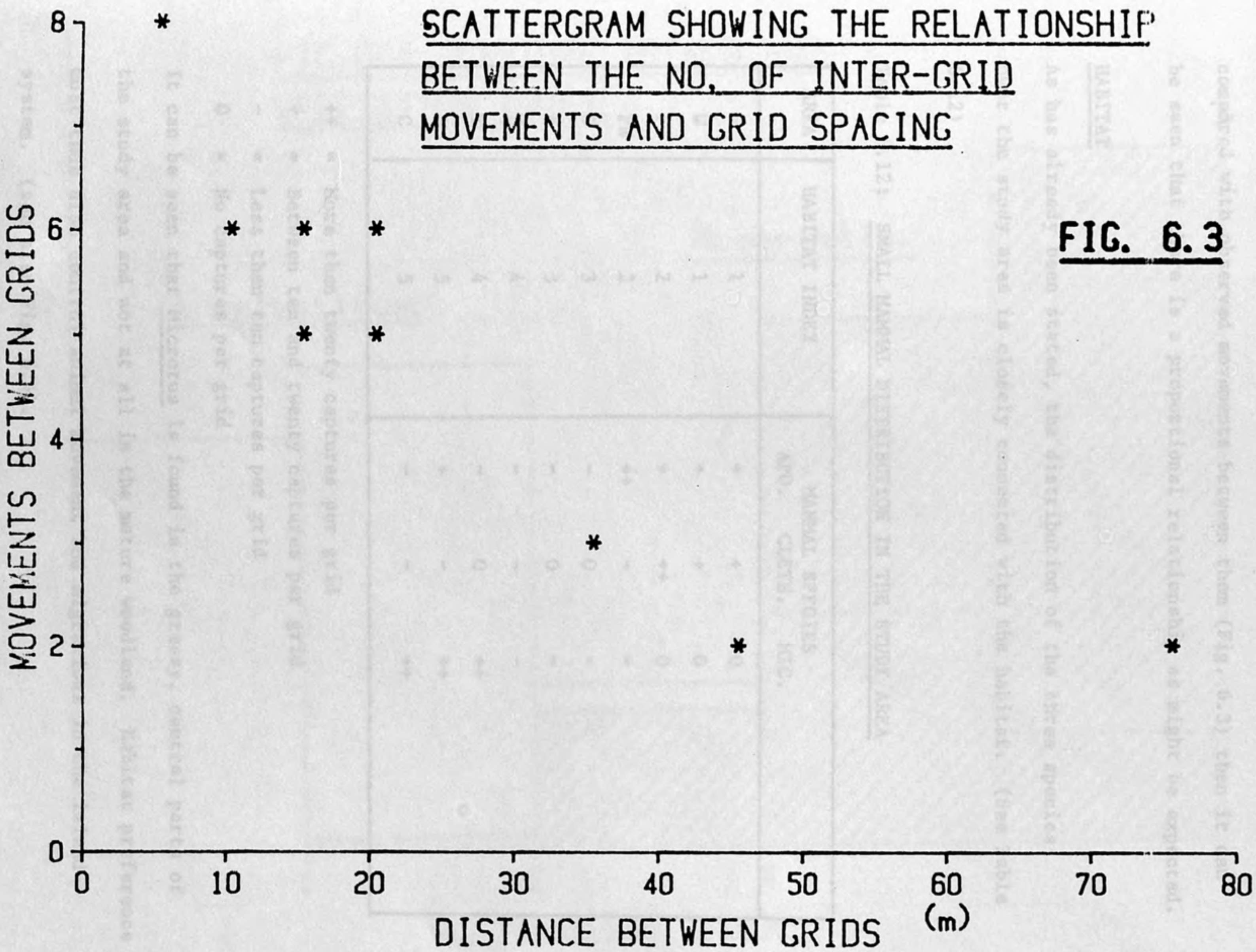
The number of track crossings are thus reduced as the track width increases, if the population size on both sides of the track is the same.

TRACK WIDTH

Of all the movements recorded which involved the crossing of railway lines, most were of single track railway. When the null hypothesis is put forward that tracks of varying width are equally easy to cross then this results in a X^2 value of 11.14 ($p<0.001$ for the null hypothesis). This indicates that there is a highly significant difference between the number of crossings of different widths of track.

SCATTERGRAM SHOWING THE RELATIONSHIP BETWEEN THE NO. OF INTER-GRID MOVEMENTS AND GRID SPACING

FIG. 6.3



This does not however take into account such factors as habitat effects and species differences. When the distance between grids is compared with observed movements between them (Fig. 6.3) then it can be seen that there is a proportional relationship as might be expected.

HABITAT

As has already been stated, the distribution of the three species over the study area is closely connected with the habitat. (See Table 6.12)

Table 6.12: SMALL MAMMAL DISTRIBUTION IN THE STUDY AREA

AREA	HABITAT INDEX	MAMMAL SPECIES		
		APO.	CLETH.	MIC.
S	1	+	+	0
W	1	+	+	0
F	2	+	++	0
PW	2	++	-	-
G	3	-	0	-
B	3	-	0	-
P	4	-	-	-
T	4	-	0	++
A	5	+	-	++
C	5	-	-	++

++ = More than twenty captures per grid

\+ = Between ten and twenty captures per grid

\- = Less than ten captures per grid

0 = No captures per grid

It can be seen that Microtus is found in the grassy, central parts of the study area and not at all in the mature woodland. Habitat preference must thus also control animal movement and migrations in the island system. (see also Fig. 6.4).

In order to investigate more fully the effects of habitat, the habitat index as cutlined in the site section (Fig. 3.4) was used to place grid pairs (supergrids) in the following table. (Table 6.13).

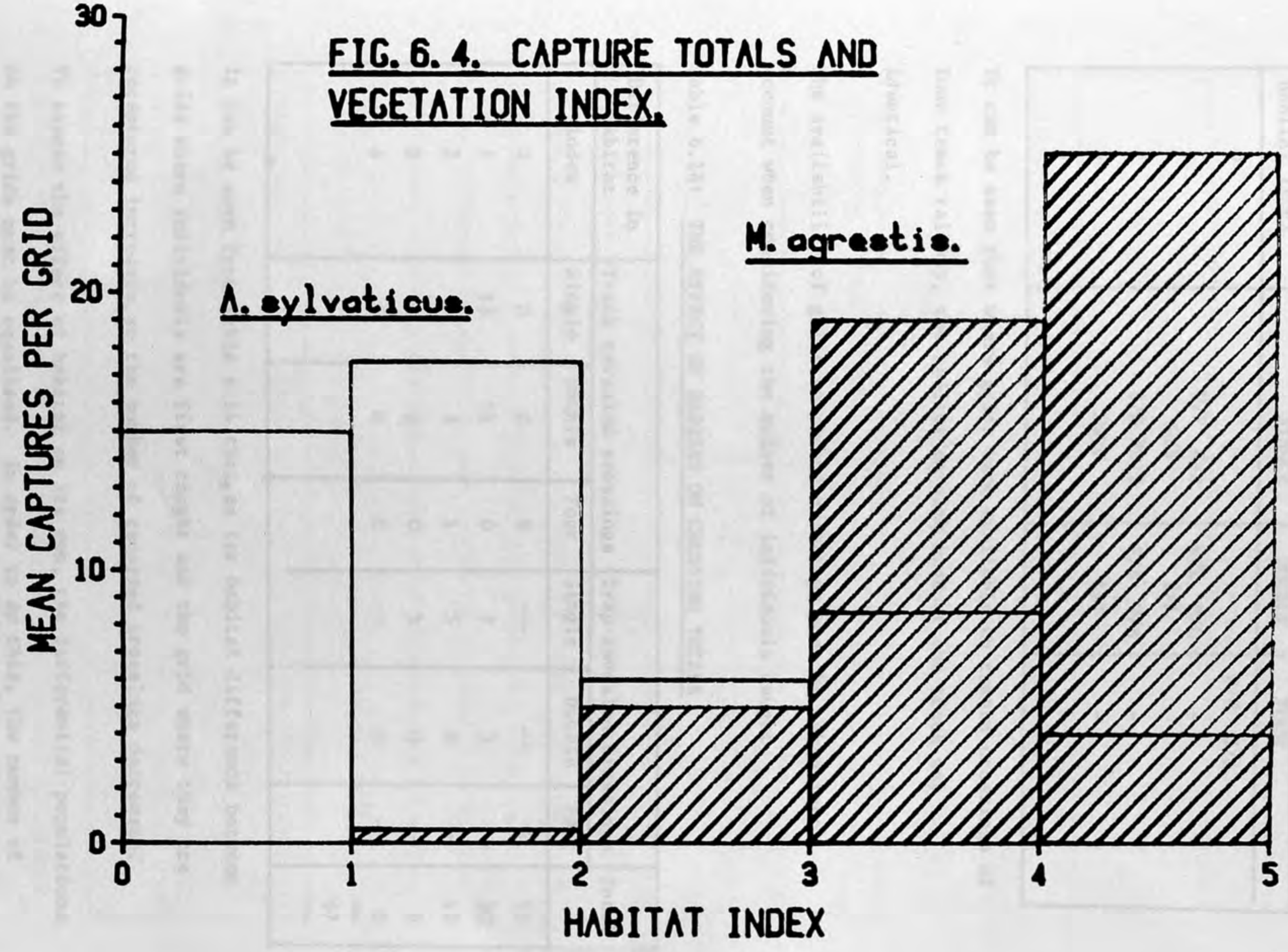


FIG. 6.4. CAPTURE TOTALS AND VEGETATION INDEX.

Table 6.13: HABITAT INDICES OF TRAPPING GRID PAIRS

DIFFERENCE IN HABITAT INDEX	TRACK WIDTHS OVER WHICH GRID PAIRS ARE SITUATED		
	SINGLE	DOUBLE	FOUR
0	-	-	W/S C/A
1	W/F G/A G/T	H/T P/C B/A	-
2	S/H PW/P	S/B W/B	-
3	PW/C	S/T	-
4	-	-	-

It can be seen that where grids were available to record crossings of four track railway, the habitat on each side of the track was identical.

The availability of grids to record crossings must be taken into account when considering the number of individuals caught.

Table 6.14: THE EFFECT OF HABITAT ON CROSSING TOTALS

Difference in Habitat	Track revealed crossings			Trap revealed crossings			Total
Index	Single	Double	Four	Single	Double	Four	
0	0	0	9	—	—	4	13
1	13	11	0	3	3	—	30
2	6	3	1	5	0	—	15
3	6	0	0	3	0	—	9
4	0	0	0	—	—	—	0
							67

It can be seen from Table 6.14 that, as the habitat difference between grids where individuals are first caught and the grid where they are recaptured increases, so the number of recorded crossings decreases.

To assess the effect of habitat on its own, the differential populations on the grids must be equalised. In order to do this, the number of crossings of grid pairs for each category of track is calculated. (Table 6.15).

Table 6.15: NUMBER OF CROSSING OF GRID PAIRS WITH GIVEN DIFFERENCE IN HABITAT INDEX

Difference in Habitat index	Number of crossings of grid pairs	
	Single	Double
1	16	14
2	11	4
3	9	0

From Table 6.15 the number of crossings per grid pair are calculated for both track widths and each habitat index category:

Table 6.16: NUMBER OF CROSSINGS PER GRID PAIR FOR GIVEN DIFFERENCE IN HABITAT INDEX

Difference in Habitat index	Number of crossings per grid pair	
	Single	Double
1	5.33	4.66
2	5.55	2.0
3	9.0	-

If the figures in Table 6.16 are divided by the population estimate for the grids involved (Table 6.13), then the number of crossings per unit population will be given i.e. it will be possible to directly compare different track widths with increasing difference in habitat index across them with all population levels being reduced to unity.

Table 6.17: TOTAL CROSSINGS PER GRID PAIR (Per unit Population) FOR GIVEN DIFFERENCE IN HABITAT INDEX

Difference in habitat index	Total crossings per grid pair (Per individual)	
	Single	Double
1	2.05	1.6
2	1.55	0.95
3	2.02	0.00

From Table 6.17 it can be seen that there is no significant difference between the number of crossings of single railway as the difference in habitat on each side becomes greater all other things being equal . In the case of double line however there is a substantial decrease in the number of crossings as the difference in habitat on each side of the track becomes greater.

SPECIES DIFFERENCES

All three species are capable of crossing at least single track railway line although only one individual C. glareolus was detected crossing in this study. If an equal proportion of the three species cross railway lines then the ratio of total captures to the number of crossings should be the same for all species.

Table 6.18: CROSSINGS AND CAPTURES BY SPECIES

	Number of grids with species	No. captures	No. trap revealed crossings	Proportion of total captures
A.sylvaticus	12	192	13	0.42
C.glareolus	9	95	1	0.21
M.agrestis	8	173	4	0.37

The proportion of total crossings should be the same as that for captures if the three species are behaving the same i.e.

SPECIES	EXPECTED NUMBER OF CROSSINGS
A.sylvaticus	0.42 x 18 = 7.56
C.glareolus	0.21 x 18 = 3.78
M.agrestis	0.37 x 18 = 6.8

Thus if (null hypothesis) all mammal species have the same proportion of individuals in its population crossing, $X^2 = 15.19$ which for two degrees of freedom has a probability $p<0.0001$ i.e. null hypothesis must be rejected as there is a highly significant difference in the number of crossings of the three species.

Apodemus sylvaticus have the most crossings with Clethrionomys glareolus having least.

TRANSIENTS

The three species are widely distributed over the study area but their distribution is controlled largely by habitat (see Table 6.12). Microtus were present only in the grassy central areas of the junction and Clethrionomys were most prevalent in the peripheral wooded areas.

Where all three are found together in significant numbers (>0.1 captures per trap night per hectare), the habitat is the least varied. It is possible, that in this area (C) some of the captures of Apodemus and Clethrionomys were of 'transients' boosting the large resident Microtus population (approximately 130 per hectare). If animals caught only once in a grid are termed 'transients' then the different areas can be compared (Table 6.20).

Table 6.20: TRANSIENTS AND ANIMALS CAUGHT MORE THAN ONCE

AREA	GRID NUMBER	NO. OF SPECIES	NO. OF ANIMALS RECAUGHT AT LEAST ONCE			NO. ANIMALS RECAUGHT ONCE ONLY (TRANSIENT)			T
			Apo.	Cleth.	Mic.	Apo.	Cleth.	Mic.	
F	4	3	3	0	7	2	2	0	1.33
A	6	3	8	0	12	0	2	0	0.67
B	8	2	6	0	3	0	0	2	1.00
W	9	2	12	11	0	0	0	0	0
C	2	3	1	1	13	2	1	1	1.33
T	7	2	3	0	13	0	0	0	0
S	12	2	6	4	0	0	3	0	1.50

T = TRANSIENTS PER GRID PER SPECIES

Table 6.20 shows that indeed island 'C' has a large number of 'transient' animals (average 1.33 'transients' per grid per species) this being surpassed only by island 'S'.

WEIGHTS OF ANIMALS

From the histogram of weights of mammals trapped (Figs. 6.5 and 6.6) it can be seen that, in general, the trapped M. agrestis were heavier than

FIG. 6.5

BODY WEIGHT DISTRIBUTION: WOOD MICE AND FIELD VOLES

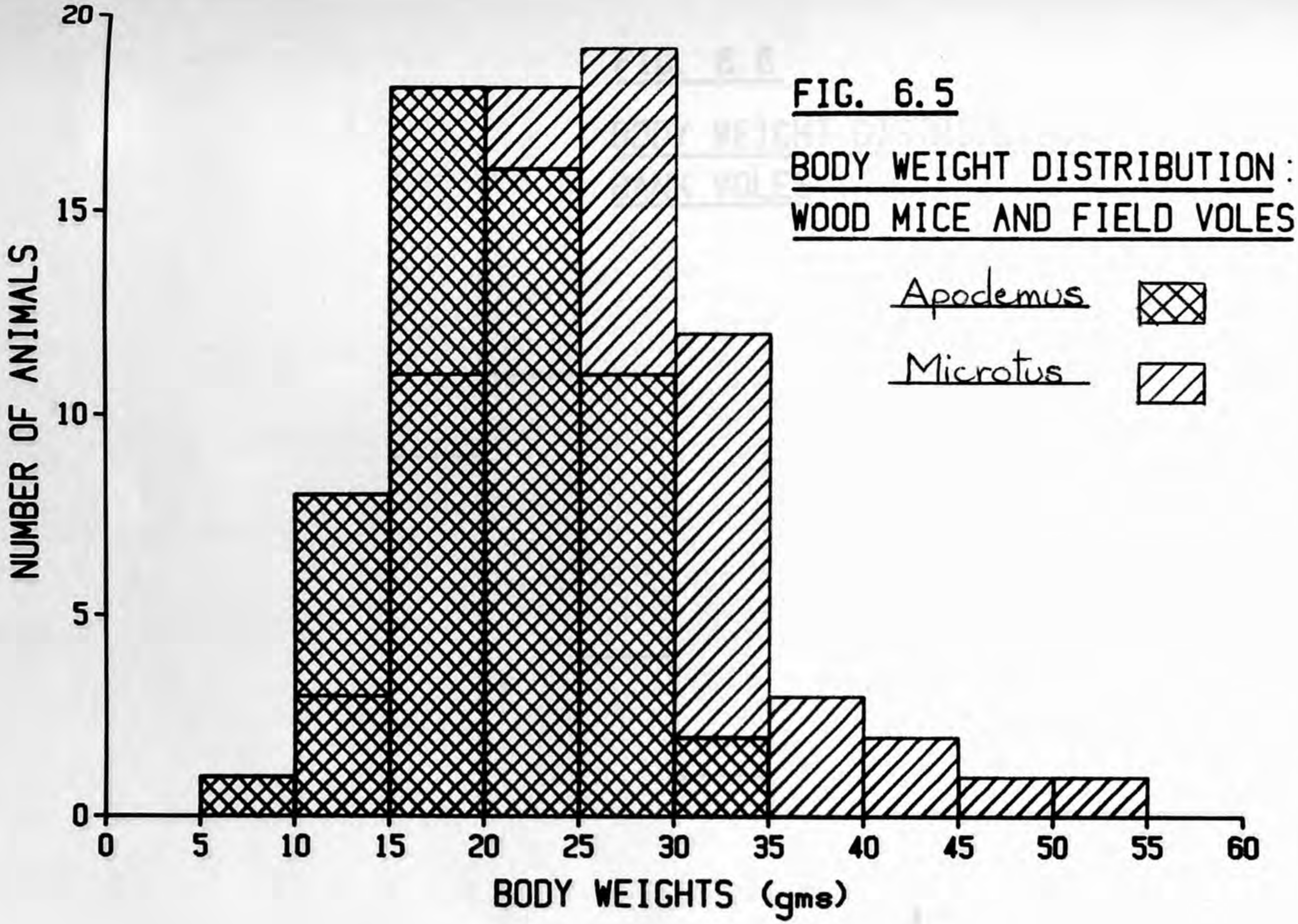
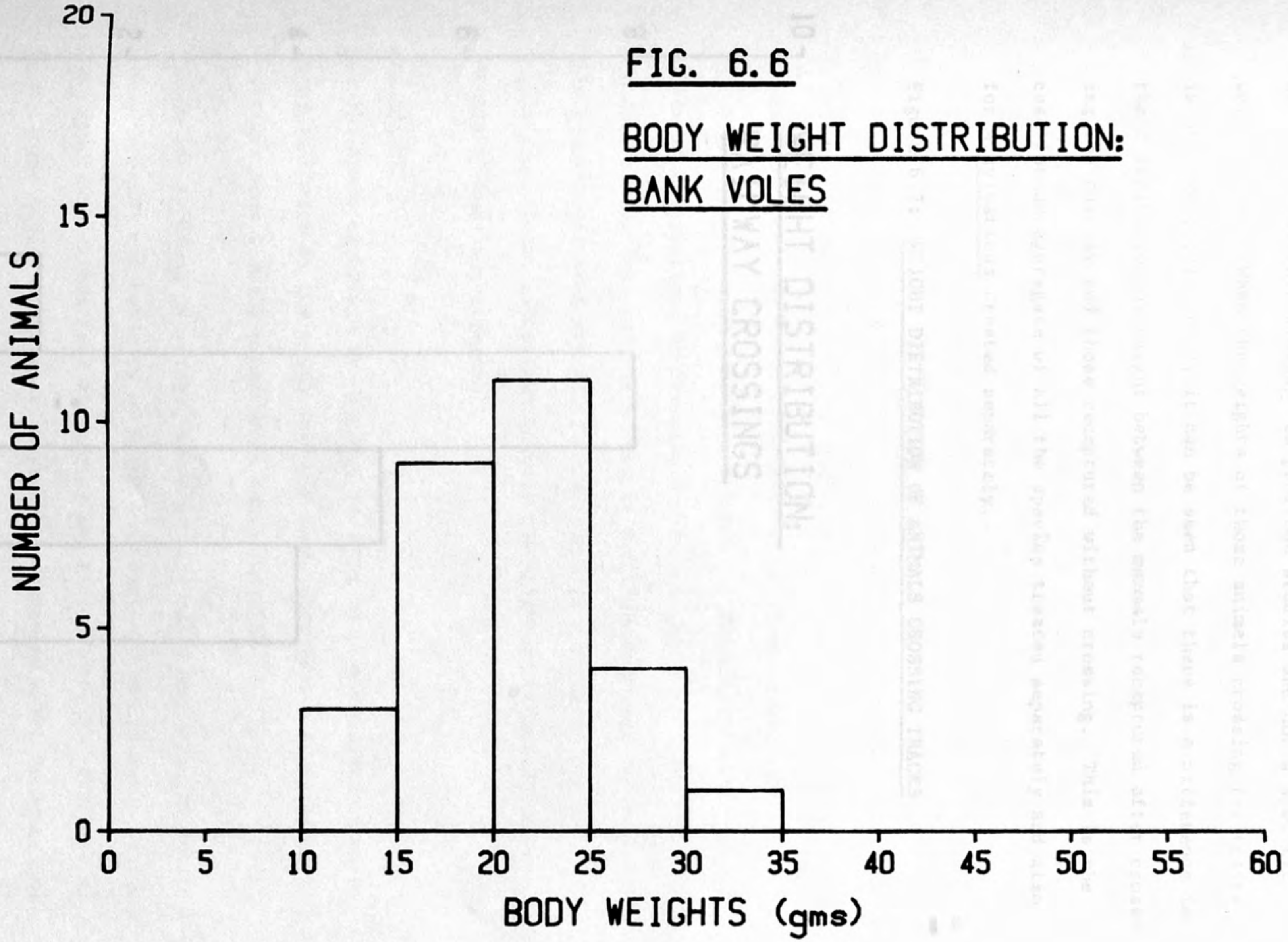


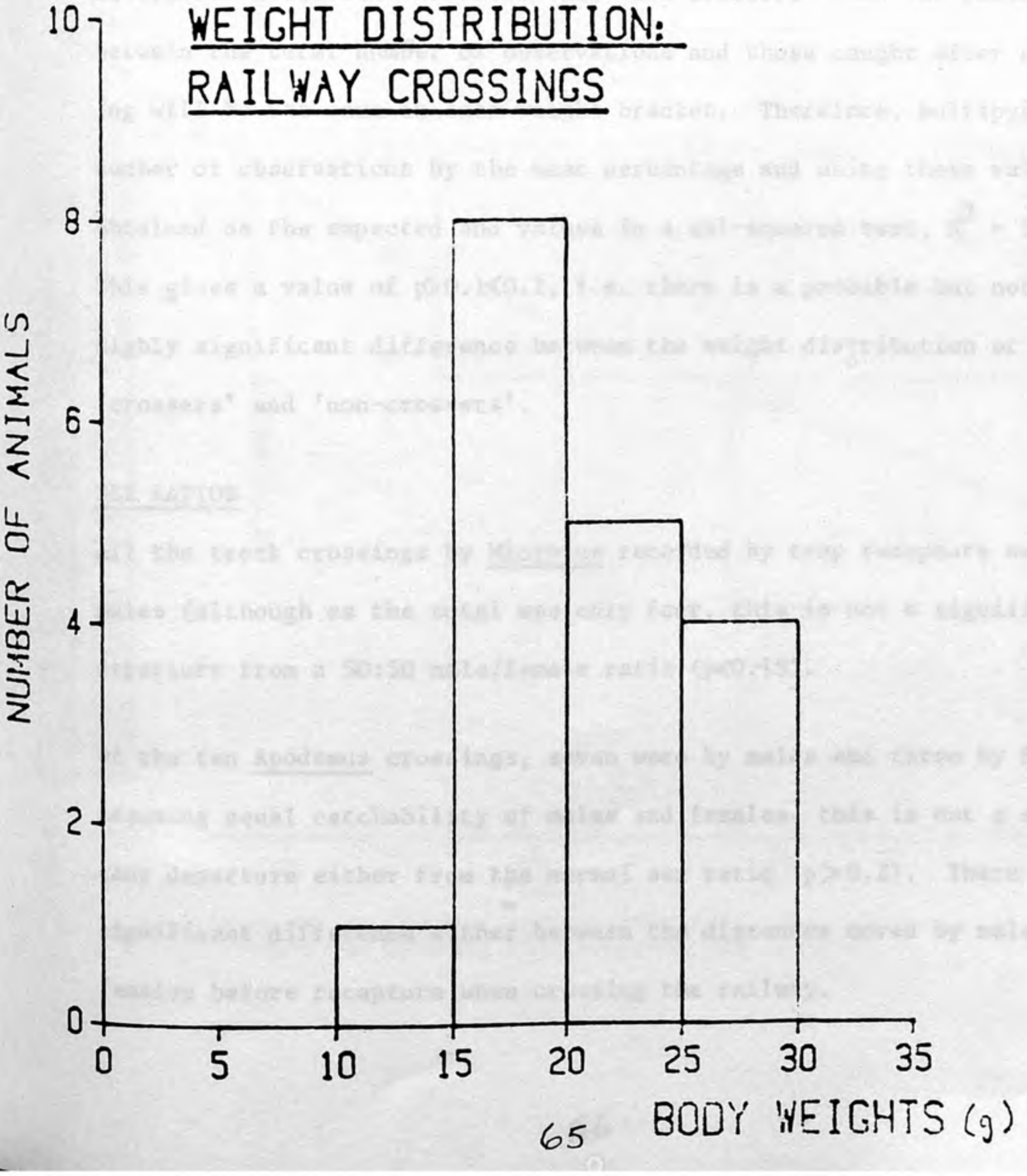
FIG. 6.6

BODY WEIGHT DISTRIBUTION:
BANK VOLES



Apodemus and Clethrionomys. This is in accordance with the expected weights from wild populations i.e. the traps are catching a cross section of weights similar to previous studies and not a specific weight range. When the weights of those animals crossing the tracks is observed, (Fig. 6.7), it can be seen that there is a difference in the distribution of weight between the mammals recaptured after crossing the railway and those recaptured without crossing. This is the case for an aggregate of all the species treated separately and also for A.sylvaticus treated separately.

Figure 6.7: WEIGHT DISTRIBUTION OF ANIMALS CROSSING TRACKS



By treating the numbers caught in each weight group as a percentage of the total caught, the different distribution in weights between "crossers" and "non-crossers" can be seen.

Table 6.21: WEIGHTS OF CROSSING ANIMALS (*A.sylvaticus*)

Weight Bracket:	11-15g	16-20g	21-25g	26-30g
Total No. Observations:	11	13	26	28
Total No. Crossings:	3	5	2	4
Percentage Crossing:	27.3%	38.5%	7.7%	14.3%

Mean Percentage - 21.95%

A Histogram comparing the numbers crossing and not crossing as percentages is shown below (Fig. 6.8). If there is no difference in weight distribution between 'crossers' and 'non-crossers' then the ratio between the total number of observations and those caught after crossing will be the same in each weight bracket. Therefore, multipying the number of observations by the mean percentage and using these values obtained as the expected and values in a chi-squared test, $X^2 = 5.61$. This gives a value of $p>0.1<0.2$, i.e. there is a probable but not highly significant difference between the weight distribution of 'crossers' and 'non-crossers'.

SEX RATIOS

All the track crossings by Microtus recorded by trap recapture were by males (although as the total was only four, this is not a significant departure from a 50:50 male/female ratio ($p<0.15$).

Of the ten Apodemus crossings, seven were by males and three by females. Assuming equal catchability of males and females, this is not a significant departure either from the normal sex ratio ($p>0.2$). There is no significant difference either between the distances moved by males and females before recapture when crossing the railway.

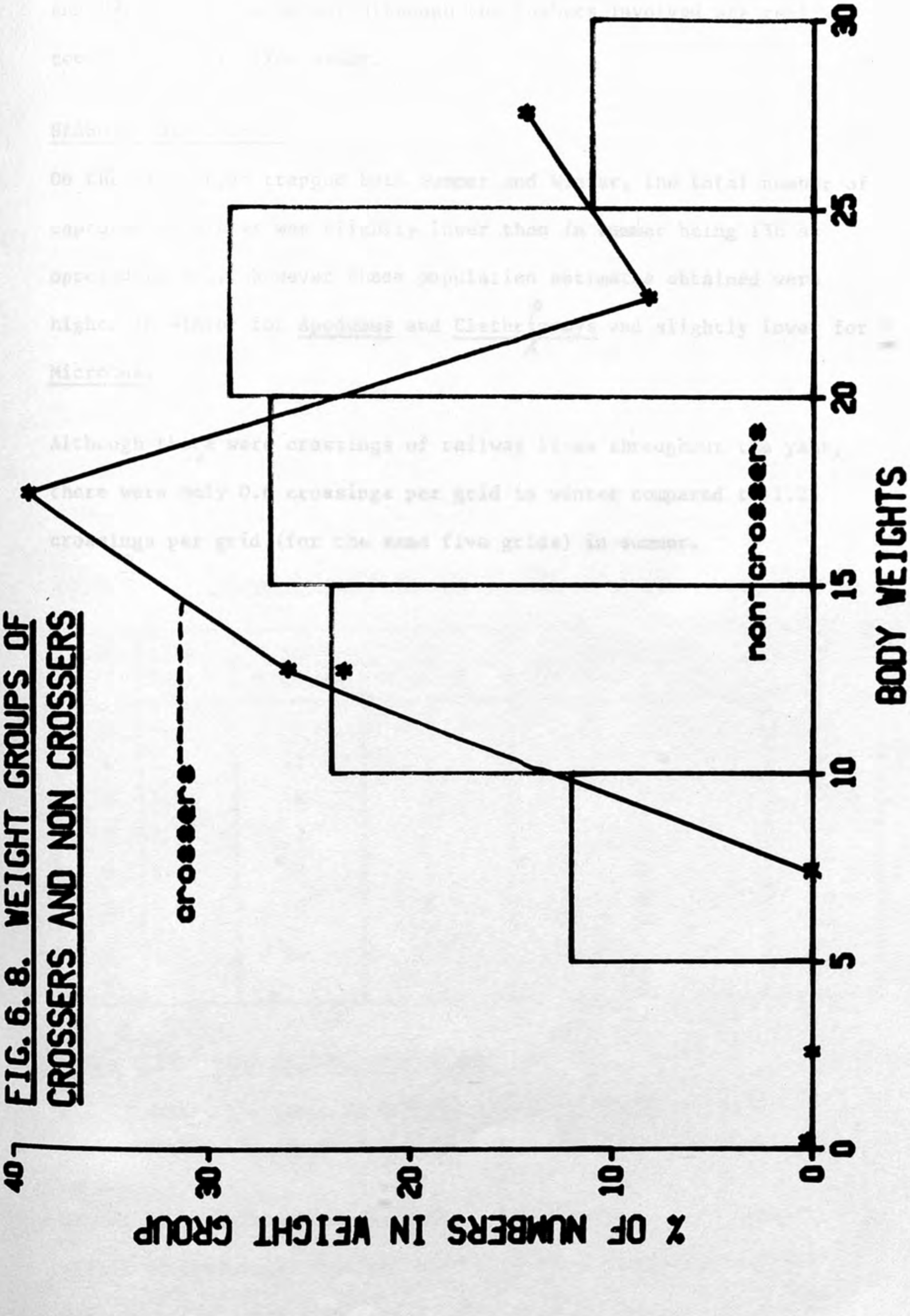


FIG. 6.8. WEIGHT GROUPS OF CROSSERS AND NON CROSSERS

There is no significant difference between the weight distribution of the female and male which cross the track (means of 17.6 g for female and 19.8 g for the males) although the numbers involved are really too low for detailed study.

SEASONAL DIFFERENCES

On the five grids trapped both Summer and Winter, the total number of captures in winter was slightly lower than in summer being 136 as opposed fo 142. However these population estimates obtained were higher in Winter for Apodemus and Clethrionomys and slightly lower for Microtus.

Although there were crossings of railway lines throughout the year, there were only 0.6 crossings per grid in winter compared to 1.25 crossings per grid (for the same five grids) in summer.

6.5: BIOGEOGRAPHICAL FACTORS AFFECTING SMALL MAMMAL MOVEMENTS

ISLAND SIZE

Despite being very different shapes, the islands studied are of similar sizes and although direct comparisons between them may be useful, the unusual topography of the area must be considered.

There is no correlation between the total number of movements in and out of the islands and the islands size (see Table 6.22) but no other factors such as population size and habitat are taken into account.

This only indicates that island size alone is no more important than any other combination of factors in determining the numbers of crossings.

Table 6.22: ISLAND SIZE AND MOVEMENTS 'IN' AND 'OUT'

AREA	SIZE (Ha)	MOVEMENTS 'OUT'		MOVEMENTS 'IN'		TOTAL
		Tracking	Trapping	Tracking	Trapping	
S	0.7	4	2	4	0	10
W	1.1	12	2	1	2	17
C	1.1	6	1	7	4	18
B	1.3	3	1	4	2	10
A	1.4	0	4	11	2	17
T	1.1	0	0	8	0	8
		25	10	35	10	80

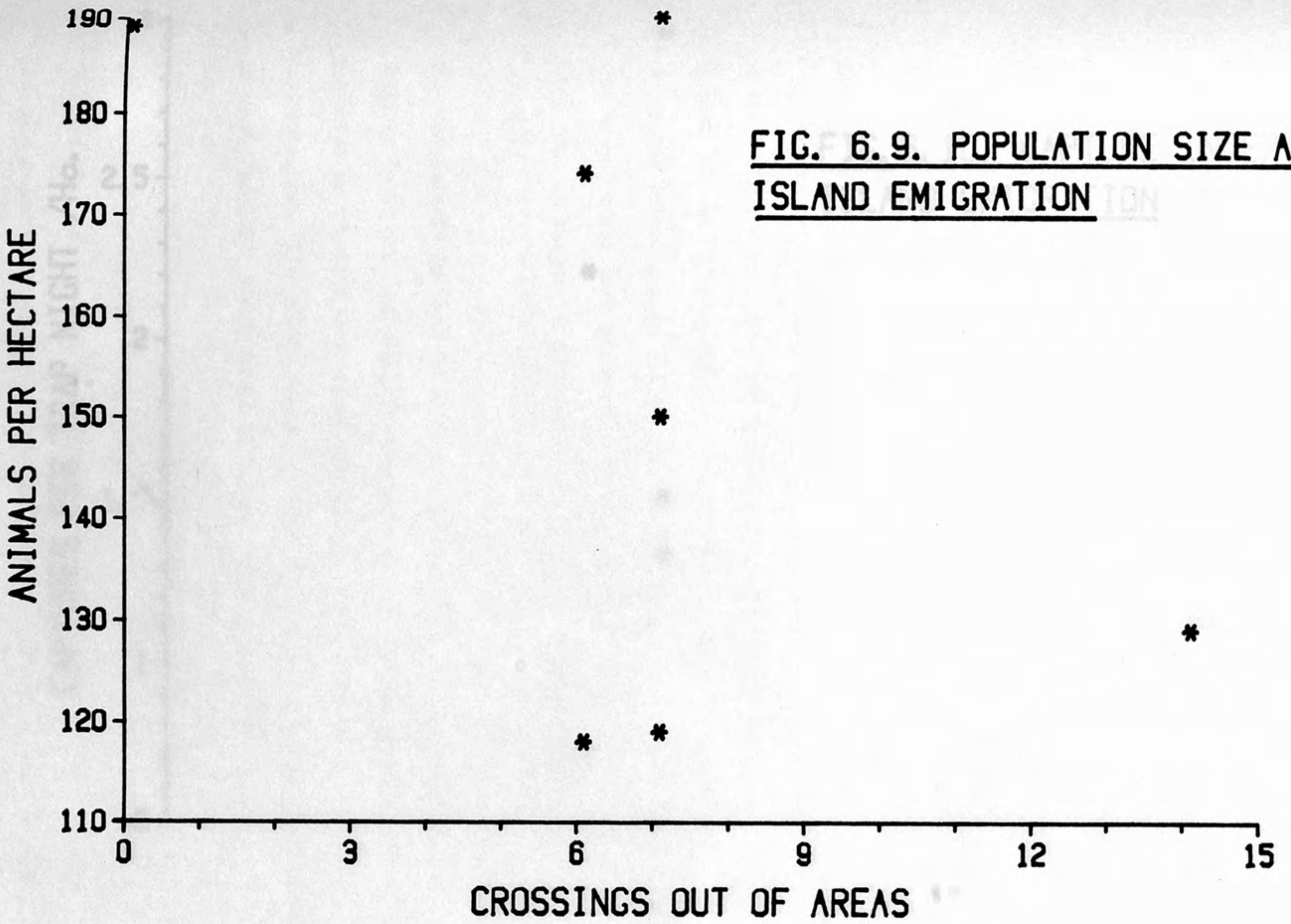
Table 6.23: TRAP RECORDED MOVEMENTS

SUMMER: 15 (From 12 Grids) 1.25 Crossings per grid

WINTER: 3 (From 5 Grids) 0.6 Crossings per grid

It can be seen from Table 6.22 that the islands with the highest totals of crossings recorded "out" also have the lowest recorded movements "in" and vice versa. This might be expected from common

FIG. 6.9. POPULATION SIZE AND ISLAND EMIGRATION



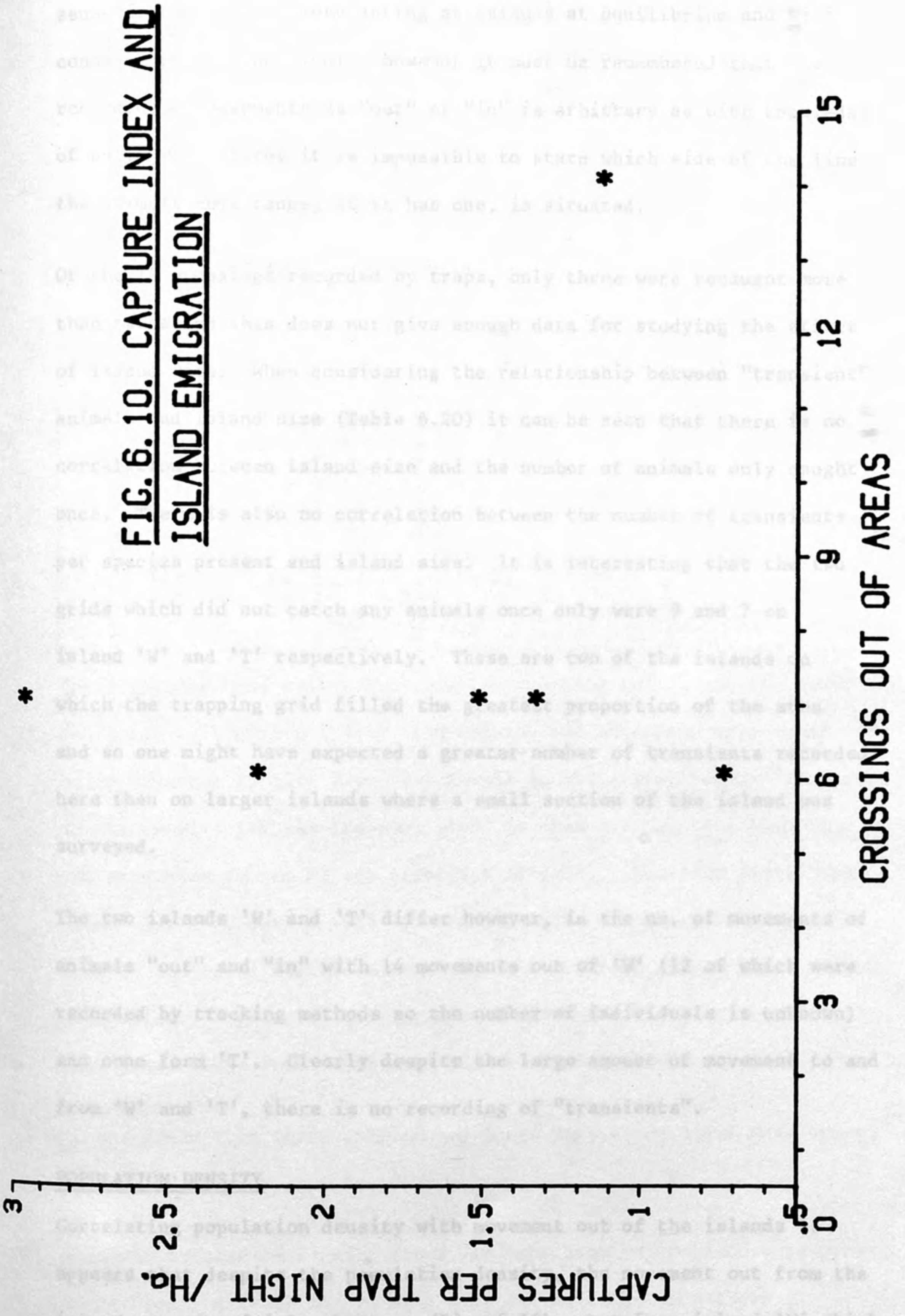


FIG. 6.10. CAPTURE INDEX AND ISLAND EMIGRATION

sense if the islands were acting as islands at equilibrium and with constant population levels; however it must be remembered that the recording of movements as "out" or "in" is arbitrary as with knowledge of only two captures it is impossible to state which side of the line the animals home range, if it has one, is situated.

Of the 18 crossings recorded by traps, only three were recaught more than twice and this does not give enough data for studying the effect of island size. When considering the relationship between "transient" animals and island size (Table 6.20) it can be seen that there is no correlation between island size and the number of animals only caught once. There is also no correlation between the number of transients per species present and island size. It is interesting that the two grids which did not catch any animals once only were 9 and 7 on island 'W' and 'T' respectively. These are two of the islands on which the trapping grid filled the greatest proportion of the area and so one might have expected a greater number of transients recorded here than on larger islands where a small section of the island was surveyed.

The two islands 'W' and 'T' differ however, in the no. of movements of animals "out" and "in" with 14 movements out of 'W' (12 of which were recorded by tracking methods so the number of individuals is unknown) and none form 'T'. Clearly despite the large amount of movement to and from 'W' and 'T', there is no recording of "transients".

<u>POPULATION DENSITY</u>

Correlating population density with movement out of the islands it appears that despite the population density, the movement out from the islands remains fairly constant (Fig. 6.10) apart from island 'W' which has a much higher value of 'emigration' than the others.

TABLE 6.10: CAPTURES PER 100 TRAP NIGHTS PER HECTARE

GRID NUMBER	SPECIES CAUGHT (CAPTURES PER TRAP NIGHT PER HECTARE)					
	Summer			Winter		
	APO.	CLETH.	MIC.	APO.	CLETH.	MIC.
1	195	98	0	168	115	0
2	21	16	122	37	27	160
3	186	21	0	151	35	0
4	71	0	80	71	0	133
5	26	0	0	-	-	-
6	69	0	107	-	-	-
7	27	0	150	-	-	-
8	48	0	43	-	-	-
9	96	91	0	-	-	-
10	75	112	0	-	-	-
11	43	0	117	43	0	177
12	64	59	0	-	-	-

These indices were determined from the trapping results in the manner described by Southern (1973), the morning and afternoon trap rounds being together to give five trap rounds in all. Trap rounds "1" shown in the results for the trapping grids is thus a total of the morning and afternoon rounds on the first day of study. Southern (1973) has shown that this method will produce effective estimates of density as long as the total number of captures is over about 75% of the trappable population. Population estimates were only calculated in this study from grids where there were more than five individuals trapped.

It was found that below this number large population sizes were being calculated despite very few trappings.

When the population density index for each area is combined with movements 'out', then it can be seen that the scattergram pattern is almost random, there being no correlation between the population size and movement ($p<0.05$, correlation coeff. -0.08) See Figs. 6.9 and 6.10.

TABLE 6.11: POPULATION DENSITY AND ANIMAL MOVEMENTS

AREA	GRID NUMBER	POPULATION DENSITY	POPULATION ESTIMATE	TRAP RECORDED CROSSINGS'OUT'	TRACK RECORDED CROSSINGS'OUT'	TOTAL
PW	1	2.95	190	3	4	7
PW	3	2.21	118	2	4	6
P	4	1.51	119	3	4	7
C	2	1.33	150	1	6	14
W	9	1.12	129	2	12	0
F	10	1.12	189	0	0	0
S	12	0.73	174	2	4	6

POPULATION DENSITY = Captures per trap night per hectare

POPULATION ESTIMATE = Individuals per hectare

Table 6.11 shows the disparity in the number of crossings as recorded by the two methods. With the areas ranked here by capture index (captures per trap night per hectare) there appears to be no proportional relationship with the number of movements recorded 'out' of the islands. (See Fig. 6.9).

The percentage of movements recorded by traps increases as the capture index increases, being 42% at the highest level (grid 4 on P and grid 1 on PW). When the figures from seven grids equally spaced are taken (Table 6.11 above) then it seems that tracking techniques could be very important at low population levels as the proportion of trap-revealed crossings becomes very low. (See also Fig. 9.12 in the Appendix).

ISLAND ISOLATION

It is hard to give an estimate of island isolation other than by treating the railways as a form of barrier and by regarding the isolation of an area as proportional to the width of all its rail boundaries (see Table 1 in "site" section for details of track widths).

However this results in a very similar figure for all the areas studied. Perhaps a better method is to consider the habitat of an area with respect to its neighbours. As can be seen by Table 6.12, this results in practically the same degree of isolation for all the islands as the habits changes gradually over the whole study area and so no two adjacent islands differ by more than three points on the habitat index.

TABLE 6.12: HABITAT AND ISOLATION

AREA	HABITAT INDEX	NEIGHBOURING AREA	HABITAT INDEX	DIFFERENCE IN INDEX
S	1	B	3	2
		H	3	2
		W	1	0
				4
W	1	F	2	1
		P	4	3
		S	1	0
				4
C	5	PW	2	3
		A	5	0
				3
A	4/5	C	5	0
		G	3	1
		B	3	1
				2
B	3	T	4	1
		S	1	2
		A	4	1
		P	3	0
				4
P	3	PW	2	1
		B	3	0
		W	1	2
		F	2	1
				4
T	4	B	3	1
		H	3	1
		G	3	1
				3

The degree of isolation of an island on this railway junction will depend on the species being considered. If Clethrionomys glareolus are reluctant to cross anything other than single track railway the islands with wide tracks round them are more isolated to them than to Apodemus.

The habitat of the islands probably affects the presence of small mammals far more than the presence of a railway line, as the species all have the capability of crossing railways and will do so more readily if the habitat on each side is similar.

CHAPTER SEVEN

DISCUSSION

7.1 Discussion of Methods used

With a study of this sort, as much information as possible is desired from limited resources and so the use of two or more methods for investigating movements (if they can run concurrently) increases the available data. Access to the islands was limited to the hours when a look - out man was available and as this was a costly legal necessity in many situations, the shortest possible time was spent on the islands doing repetetive grid checking. The use of board and bottle grids as well as traps enabled all the grids in use to be checked on one outing whilst obtaining population information from the trapping grids and movement information predominantly from the tracking grids. The use of tunnels on the embankments and bottles on the stones of the ballast help to give furt her information about possible movement close to the lines. If the railway lines had constituted a major barrier to movement it was thought that live-trapping on the islands might not be very productive and so tracking was used in the hope that it might be better suited to revealing low incidence movements on the islands. Dropping boards must be placed out for longer than traps as although up to 50% of the population enter traps in the first 24 hours (Southern 1973), only up to 10% of the boards in any one grid were used in the first 48 hours (c.f. Pendleton 1956, who found similar results).

One aspect of the dyed bait study which might help ensure its success was first documented by Hansson (1971) who found the laboratory fed Microtus selected foods of high carbohydrate content. This means that in the field, voles would take bait as readily as naturally available foods. Hansson's (1971) work was done in connection with population cycle regulation but the preference for an artificial food (such as dyed bait) might ensure a high number of results from dropping boards/bottles in the field.

The Study of Territoriality

The two main methods used in this study; trapping and tracking using dyed bait, were both used to investigate animal movements and they gave different results. The main advantage of using tracking methods is that there is minimal disturbance of the animal's normal behaviour. Emlen (1949), when investigating rats in city blocks, believed that the bait station influenced the rats behaviour from up to 30 m away as they left their normal feeding routes to visits to bait. Of course this produces difficulties when determining the animal's home range as it is impossible to tell whether the animal has eaten the dyed bait in its own home range and then transported the dye internally to defaecate on a foray outside its range, or whether it has eaten the bait whilst outside its home range and defaecated inside it. Similar difficulties arise when live-trapping on grids adjacent to the railways as with only a limited number of captures per animal (usually about two or three in five days) it is impossible to state on which side of the railway (if a crossing has taken place) the animal's home range lies. Longer term studies are needed to investigate home range more fully, perhaps concentrating on one 'supergrid' constructed of smaller grids on opposite sides of the railway track.

The Study of Population Size and Density

Emlen et. al. (1957) used dropping board usage as a feature of population density to compare vole populations. In this study it was found that the use of dropping boards or bottles appeared to be too haphazard to construct population density estimates and the grids were probably too small. The trapping grids gave adequate density indices and also an estimate of population size. The differences in population size are important in movement studies of this sort as the size and structure of the populations on opposite sides of an obstacle (such as a railway line) is likely to directly affect the amount of movement across it.

With traps being used to provide population information, the size of the grid becomes important (see 'Methods'). Ideally the grids for all forms of recording should be as large as possible to maximise the data available, but with irregularly shaped areas, being studied, such as those in the railway junction, the largest grid that could fit into the smallest island (50 m by 50 m) was used where possible. One method of assessing populations that was not used was that of removal trapping; however break-back traps do not catch Microtus as efficiently as Longworths, (Tapper 1976). The use of run counts as a measure of vole density was found to be successful. The correlation between runways counted on a 20 m transect and trap revealed population size was high.

Problems Encountered with the Methods

There were 20 trap deaths when traps were only visited once in 24 hours (as in the preliminary trapping, see Appendix 9.1). These deaths were ignored in the results unless they were recaptures or on the last trapping round.

There were 20 trap-deaths in the preliminary trapping (18% of the captures), the majority being of A.sylvaticus. This compares with a 15% death rate experienced by Southern (1973) when visiting traps once in 24 hours. In the island trapping there were trap deaths at the commencement of the study but these were reduced by adding bedding material and visiting the traps twice a day. A total of 11 trap deaths occurred on the islands.

Difference Between Species

Using tracking methods in the manner described for this study it is very difficult to differentiate between species defaecating in the tracking grids. Although they were checked about four times a week, it was usually impossible to distinguish the species of animal using the boards or bottles. Attempts to produce species data from the tracking grids have been abandoned. In past work (Emlen 1949, Lidicker 1973) the species studied using dropping boards have included all three investigated here and, with practice, Emlen and co-workers claimed they could identify the species involved. Unfortunately in this study, species identification was found to be impossible. The run-count method of estimating vole density gives a good predictive method of estimating vole presence although other species may well have made runs that were included in the survey.

The Study of Track Crossings

Tracking methods revealed the majority of the crossings although of course they do not differentiate between species, weights or sex of animals involved.

The fact that animals tend to be trap-shy outside their home range (Watts 1970) could affect the trapping totals on the islands if animals were moving onto them mainly as forays from home ranges off the islands. The trapping totals however do not bear this out, and it must be assumed that individuals have home ranges on the islands to the same extent as the surrounding land. The main difficulty in using tracking techniques to study movements is the necessity to leave the collecting devices (bottles and boards in this case) in position for a long time, if population densities are low. As the dye is only present in the animals digestive tract and hence the faeces for two to three days, the animal must cross the railway line in this time in order to be detected. The collecting devices should therefore stay in position in order to detect as many movements as possible. The bait can be left in position for several days without any detrimental effect to its efficacy but it is possible that the presence of desirable bait in an area will affect animal movements. (Emlen 1949).

Emlen (1949) believed that a bait station attracted rats from up to 30 m away and so the presence of a bait station in an island might well prevent animals from leaving the island as they have a ready source of food in their own area.

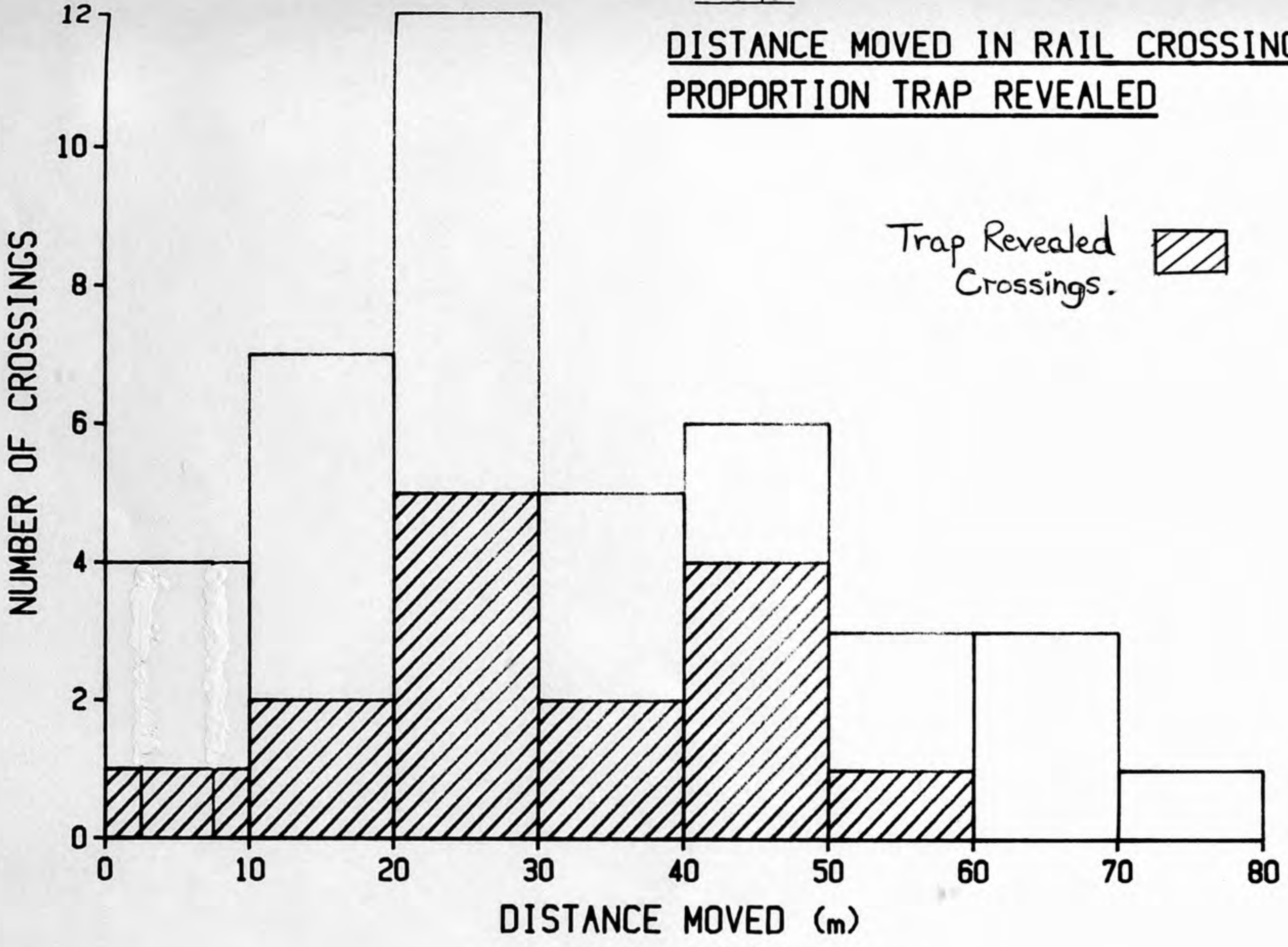
A long-term trapping study provides more information on movements as it can allow the study of home ranges. If home range is defined by a minimum number of three captures of an individual then no home ranges straddled a railway line. Indeed, even if a smaller number of captures is taken as the minimum needed to map home range, then no animals had a range crossing a railway as no animals were recaught more than twice after crossing a railway track.

Probably the biggest advantage of trapping as a method to reveal crossings is that much information can be gained from just two captures. If there have been several captures of an individual, the distance moved from its home range can be measured. In this study, measurement of distance moved in crossing was restricted to the inter-capture distance (the distance from the last point of capture before crossing, to the point of capture after crossing). Also the weight, sex and species of the animal are known.

The differences between the two methods must be considered when a project such as this is planned. If large amounts of data are required which simply show whether crossings have taken place or not, then tracking methods are best. (The ideal example of this being Bider's

FIG. 7.1

DISTANCE MOVED IN RAIL CROSSINGS: PROPORTION TRAP REVEALED



(1968) survey using sand-tracking in which 182,000 transect crossings were detected.) If however more detailed information such as breeding status is required, trapping is the best method despite the lower overall numbers detected. See Fig. 7.1.

7.2: DISCUSSION OF RESULTS

i) The Structure of the Populations

Species present

It is known that the three species in this study have different habitat requirements; A. sylvaticus is found in all kinds of woodland, arable farmland, grasland and moorland (Corbet and Southern 1977). Corke (1977) in connection with work on Yellow-necked mice (A. flavicollis.), hypothecised that A. sylvaticus migrated to arable fields during the breeding season from woodland areas Yalden (1980) found that A. sylvaticus penetrated into urban areas along corridors of semi-natural vegetation and in his study he caught 38 individuals on railway embankments which consisted of a mixture of open grass and bramble thickets. In this study, A. sylvaticus was found in all areas, in habitat ranging from mature deciduous woodland to open grassland. The areas with the highest numbers of A. sylvaticus caught were those where the grids were placed in mixed habitats, with both woods and some scrubby grassland (as in areas PW to the east of the study area).

Clethrionomys glareolus is known to favour areas of scrub with fairly dense ground cover (Corbet and Southern 1977) and so Yalden (1980) found in surprising that there were no Clethrionomys caught in his study in bramble thickets on the embankments. Although caught in lower numbers than Apodemus, bank voles were caught in nine of the grids, usually those with a mixture of shrubs and smaller plants. In fact out of a total of 95 captures of Clethrionomys over both winter and summer and including all the grids, only 8 were caught in habitat with an index value above 2. (See 'Site'). This is a reflection on their preference for wooded areas as opposed to ground without cover. Clethrionomys were also caught on the embankments in small numbers (two individuals in 150 trap nights) but as the embankments in question had a similar habitat to the woods adjacent to them, this figure is lower than might be expected. This could well be due to the fact that the shrubs on the embankments are periodically cut to give a strip of shorter vegetation between the tracks and the woods. This may well act as a deterrent to voles moving onto the embankments. Yalden (1980), who found no Clethrionomys on the embankments, was trapping in a predominantly urban area and so there was probably no vole population present "behind" the embankments as there were in this study with the vole populations in the woods. To back this up, no voles were caught from the gardens although there were eight captures of Apodemus.

Microtus agrestis has been studied before in connection with population fluctuations and the presence of vole runways in the surface vegetation has been used to indicate vole population sizes. (Lidicker 1973). These runways are made on grassland and this preference for grassland habitats was shown by this study as Microtus was only caught in areas which contained some open grassland. Indeed, in contrast to Clethrionomys, only eight Microtus were caught (from a total of 174 captures) in areas with a habitat index value of less than four. Thus the pattern of distribution is similar to that found by Bider (1968) who detected no Microtus activity in woodland at all but found many tracks in grassland. It would seem that Clethrionomys and Microtus do not tend to live in large populations simultaneously, out of the 12 summer trapping grids they were caught on the same grid on five occasions but there were never more than three captures of the species that was present in lower numbers. This form of 'diffuse competition' as defined by MacArthur (1972) is dealt with more fully in the discussion below.

Population Size

It is difficult to compare populations in this study with past work but Southern (1973) considered a population of 170 Microtus per hectare in an ungrazed field to be large. This is rather more than the figure obtained by the same method as his for a similar habitat in this study area (area C) which had an estimated 132 voles per hectare. Flowerdew and Gardner (1978) arrived at a figure of about 88 C. glareolus per hectare in their study which is lower than the figure obtained for the winter trapping in this study in similar habitat (111 per hectare). The highest population of Clethrionomys obtained by Bergstedt (1965) was much higher, at 200 individual voles per hectare when the population was at a maximum. With populations varying greatly in different types of habitat, it is probably more relevant to consider relative densities within the study area.

Clethrionomys were present at low densities throughout most of the area (less than ten captures on five of the grids over five nights) and the only grids on which there were large populations were the wooded areas 'S' and 'F'. The density indices in the preliminary trapping in the woods recorded a lower capture rate of both Apodemus and Clethrionomys than on the islands of the junction. This is probably due to the slightly different nature of the woods present on the islands and those investigated in the preliminary trapping. The woods on the railway junction are unmanaged and consist of a mixture of trees of different ages, the woods used for the preliminary trapping are more open and maaged for the recreational use of the local human population.

This has resulted in several wide footpaths and bridle paths crossing the trapping grids and with the large amount of human disturbance the populations of small mammals are consequently much lower than on the islands (or at least more trap-shy).

Lidicker (1973) found populations fluctuating between 494 per hectare and 1580 per hectare, (Microtus spp.), which are much higher estimates than the numbers caught in this study and, as he himself states, density estimates using run counts at low densities (as they sometimes were in his study) are probably not very reliable. His figure of 1580 voles per hectare seems high as it would mean an average 'living space' of 830 cm^2 over a wide area.

This is an exceptional circumstance being the highest population detected over 11 years but the implications are that this apparently high population density was caused, at least in part, by an extremely high trap density which was only used at this stage in his study. Ignoring these peaks in abundance, the average population density throughout his island study and also on the mainland was about 500 voles per hectare in the summer months (May to July) and about 100 voles per hectare in the winter months (September to December) These figures are higher than the densities in this study.

The population sizes in this study can be directly compared to those found by Kikkawa (1964) who found an estimated mean population of 100 *Apodemus* per hectare in June and 55 *Clethrionomys* per hectare in the same deciduous woodland habitat. These figures are for June, in winter the sizes of the populations were higher being about 160 and 80 per hectare respectively.

In this study, the populations varied between areas but in habitat similar to the woodland in Kikkawa's (1964) study, the *Apodemus* populations are lower in summer (between 60 to 100 per hectare) and also in winter (about 120 mice per hectare on average) and the *Clethrionomys* populations are slightly higher in both seasons being up to 140 in summer per hectare and 111 per hectare in winter on the only grid from which data is available.

In the preliminary trapping on the embankments out of a total of 150 trap nights there were 20 captures of 10 individuals (1 capture per 15 trap nights). Yalden (1980) trapping on embankments caught 41 individuals over 313 trap nights (1 capture per 8 trap nights) and so on this limited data it appears that there was more activity on the embankments in his study. It is likely that as the embankments in his study were in a more built-up area than this one, there was less alternative suitable habitat available for small mammals. The embankments studied here were often situated between railway tracks and large areas of deciduous woodland and so there was more choice in habitat available to the mammals.

The Weight of Individuals

The weight of small mammals has been used in previous studies to give an estimate of age distribution in a population. Watts (1970) considered that Bank voles disperse at about 12 g i.e. just prior to puberty (if this is reached in the year of birth (Smythe 1966). Thus in a movement study of this type, consideration of weight differences becomes important. In considering the problems connected with predicting vole plagues, Tapper (1976) presents weight distribution diagrams of *Microtus californicus*. In the instance of decreasing populations of *Microtus*, (probably equivalent to the months of January to March in British *Microtus* work, (Kikkawa 1964), the weight distribution becomes smaller, with most animals being in the central weight range of 25 to 35 grammes. In the time of increasing (trappable) population size, due mainly to juvenile recruitment, the overall weight distribution of the population becomes more extended with small numbers of very small animals (less than 10 g) being caught and a few over 40 g. Bearing these figures in mind, when the weights of animals caught in this study are considered, it appears that by the end of the summer trapping period there were juveniles being caught which had been born that year and were just entering the trappable population.

Seasonal Difference in Results

Despite population estimates generally higher, the total number of winter captures was almost identical to the summer total on the same five grids. This is surprising in the light of previous work (Evans 1942, Kikkawa 1964, Watts 1970, Tapper 1976) which have shown a low capture rate in June and July compared to the winter months. Part of the reason for capture rates being higher than expected in the summer (or conversely - lower than exptected in winter) in this study is perhaps connected with disturbance of some areas due to light building work in August and September. There was a fire also on the embankment to the south of island 'C' and this may well have caused a movement of small mammals either away from grid number two or across the track to the woodland areas of 'G' or 'PW', although there was no evidence of this in the trapping results. Because of these possible disturbances in the late summer (when there was no trapping done) it is hard to compare seasonal results. It is also made difficult by the trapping method employed; only two or three of the grids could be trapped simultaneously and so to cover the twelve grids took up to three months depending on trap availability and manpower. This meant that towards the end of the trapping season in the summer, juveniles were being caught which were untrappable when the first grids were trapped. The weight distribution of those crossing the tracks (discussed below) is therefore probably biased in favour of heavier animals as the juveniles which probably made up the majority of the crossers were not entering the trappable popualtion until well into the trapping season.

The population estimates for Apodemus on the same five grids in winter are, however, significantly higher than those in summer with the most marked difference being on grids two and eleven. Interestingly, on these two grids the populations of Microtus are significantly lower dring the winter trapping.

It has been reported in previous studies (kIkkawa 1964, Corke 1977) that Apodemus in woods next to arable fields show migration into the fields in summer, breed and return to the woodland in winter. This could partially account for the summer trapping totals for several areas being higher than those for the woodland in the preliminary trapping. Flowerdew (1976) considered that such movements are short range and so are of only local importance. In this study however a small change in capture rate can greatly increase population estimates and the local seasonal migration in the study area must be considered.

7.2 (ii): Track Crossings

Species Crossing

As explained previously, species determination was only possible for the 18 track crossings revealed by the trapping grids. All three species were recorded as having crossed the tracks although in the case of Clethrionomys it was only detected in one instance. Apodemus is known to make long distance movements to a greater extent than Clethrionomys (Watts 1970). If Watts' dividing line between movements within home range and without is taken (110 m for Apodemus and 130 m for Clethrionomys) then the only individuals which had moved outside their home ranges in this study were those which had necessarily crossed railway lines. These long distance moves were all detected by tracking methods; indeed all the movements involving crossings over 60 m long were recorded by tracking methods. Significantly higher numbers of Apodemus than the other two species crossed the railways and significantly lower numbers of Clethrionomys (relative for their population size) crossed than Microtus. The reasons may well be due to several different aspects of the species ecology acting together but some of these can be investigated separately. Randolph (1976) described a period of "great activity" in April and May to coincide with the onset of breeding condition in the females and increased territorial activity in the males resulting in an increase in distance between male home range centres. Similar effects have been found in Clethrionomys (Maya, French and Aschwanden 1973) and Microtus pennyaylvanicus (Mazurkiwicz 1971). Thus this increased activity could increase all track crossings during the spring and early summer. Randolph (1976) also described a reduction in range size in June and July followed by a new increase in August. Males move the position of the home range more than females. This might account in part for the majority of crossings being made by males. By the end of July the majority of juveniles have dispersed

(Brown 1956, Watts 1970) and so there are new home ranges established in the areas to which the juveniles have migrated. Kikkawa (1964) found that male voles moved further than females within a trapping period and further in summer than winter - however for Apodemus there was a less pronounced division between the sexes and seasons.

More recently Baird and Birney (1982) have shown by electrophoresis of blood samples from meadow voles (Mircrotus pennysylvanicus) that 'dispersers' are not a random sample of the resident population.

The animals they found dispersing were most likely in summer to be males and also juveniles or sub-adults (19-27 g). (See also discussion of weight difference below).

There was no statistically significant difference between the distances moved when crossing railways by Apodemus and the distances moved by Microtus but this was based on limited data. One would expect that, over a longer survey, Apodemus would be recorded moving further in all movements, whether involving crossings or not, as described in previous studies (e.g. Watts 1970, Wolton 1983).

The Effect of Population Density

One might expect that more movement would occur across railway tracks if animals on one side are at a high rather than low density. However, from this study it appears that there is a fairly constant movement across the railways despite the varying population densities of the islands. No matter how 'trappable' a population is (expressed as captures per trap night per hectare), the same proportion of the total population will cross the railway lines. It appears that there is a constant low level of movement between the islands in the junction averaging about three to four crossings per unit density index.

It can be stated however, that, all other facts being equal (including population sizes) on both sides of the railway, fewer crossings of double and four track railway will occur than those of single track line.

Assuming a constant proportion of individuals from any given species will cross the railway lines, then a large-population in a given area will increase the total number of crossings. With the low number of crossings detected in this study however it is unreasonable to state the exact relationship between population size and migration rates

The Effect of Weight on Crossing Results

There is a significantly lower weight distribution amongst animals crossing the railways than those recaptured without crossing. If the figures from Watts (1970) are taken for weight at puberty, then the majority of the *Apodemus* caught after crossing the tracks are animals having just reached maturity. It could be said therefore that the majority of crossings are by *Apodemus* during their juvenile dispersal phase. Watts found that there was a more marked dispersal in juvenile *Clethrionomys* then *Apodemus*; however this was not revealed by trapping in this study. The *Clethrionomys* were present at much lower numbers in this study than in his, and it was possible that although *Clethrionomys* may have dispersed in larger number than *Apodemus* they were not recaptured during this time. Watts noted that animals were probably trap-shy whilst dispersing although they re-entered the trappable population after moving over a long distance. In considering dispersal of adults, Watts considered that the incidence of adult dispersal of Wood mice was very low indeed (less than 2%) and that Bank voles showed dispersal moves when adult at a low level also. It can be concluded that long distance movements recorded by tracking methods in this study are therefore usually sorties from an established home range rather than dispersal moves. Flowerdew and Gardner (1978) arrived at a figure of about 16 g as the division between juvenile and adult Clethrionomys (based largely on pelage colouration) although in 1974 they stated that the division between the age groupings was between 18 g and 20 g. If a figure of 20 g is taken (which is higher than Watts (1970) estimate of 13 g) then most of the track crossings in this study could be considered as juvenile dispersal moves, as 10 out of 15 'summer' crossings were by individuals weighing 20 g or less. Kikkawa (1964) detected very little vole dispersal out of a small area~~s~~ of woodland surrounded by arable fields although there was a lot of Apodemus movement. He concluded that the "wandering" and dispersal movements ~~and dispersal movements~~ of mice seem just as much a part of their life as more restricted movements around the home site. In this study it appears that although there is evidence for juvenile dispersal as defined by Watts (1970), there is also some movement of an unspecified kind which is hard to describe in terms of dispersal or migration.

Seasonal Difference Between Crossings

It has been discussed previously (above) why there appears to be unusually low captures in the winter trapping and high capture rates in the summer trapping. When considering the crossings that took place there were only three crossings in winter as opposed to seven in summer on the same five grids. The weights of those crossing are not significantly different to those caught in summer, indeed one Apodemus was a recapture of one caught during the summer trapping having crossed a different track. For this individual it appears that home range may well have straddled a single track railway line. Despite the increase in population size of Apodemus in winter, there are fewer crossings of the track.

There is significant seasonal variation in track crossings due probably to several factors including a seasonal change in home range size (assuming some home range straddle railway lines) and less dispersal movement. (Watts 1970, did not detect any juvenile dispersal at all over the winter months.)

Baird and Birney (1982) found that, in the spring, males tended to move much greater distances than females and young males tended to disperse in summer as non-reproductives. This increase in summer male movement (as shown in this study also) is perhaps to increase potential encounters with oestrus females who are more static at this time. It is perhaps this factor coupled with juvenile dispersal that accounts for the majority of track crossings in this study.

Evidence for juvenile dispersal in other species has also been documented by Howard (1949) (*Peromyscus* spp.) and Kozakiewicz (1976) (*Clethrionomys glareolus*) and both these workers commented on the effect on trapping of this seasonal movement.

Differences Between the Sexes

Randolph (1976) described changes in home range size with breeding season and these occur to a much greater extent in the male than the female. In this study, the adult animals caught which crossed lines could have been crossing for several reasons. If the railways do not act as a comprehensive barrier to movements (which they patently do not) then it can be assumed that some animals have home ranges straddling tracks. If this is the case, then an increase in home range size at the outset of the breeding season (which coincides with the start of the 'summer' trapping will result in more track crossings of males than females. Gurnell (1978) also remarked on the increase in home range size in April and May and found that this coincided with an increase in male antagonistic behaviour. Watts (1970) also noticed a marked sexual difference between those moving long distances (and dispersing) and those not dispersing and stated that female Bank voles and Apodemus do not move as far as males when dispersing. He also indicated that male wood mice tend to roam over very large areas making true dispersal moves hard to identify. Kikkawa (1974) was of the opinion that as females were "more resident" than males, then males were drawn to traps from a larger area than females. This would result in a bias towards the number of males being caught, certainly in the case of recaptures after crossing tracks when long distances are often involved.

In this study there was no significant difference between the distances moved by females and males when the crossings were detected by trapping. However only four females of all three species were recaught after crossing a railway.

By using a Geiger-Muller counter and tracking individual voles, Kikkawa (1964) was able to state that in both voles and mice, movement was much greater for males than females and greater also in the summer than in winter. The results of this study confirm this.

The Effect of Habitat

As there were no crossings between habitats differing in index value by more than three, then it could be stated that this is an important factor in controlling crossings of the tracks. When crossings between habitats which are very similar are studied there is no significant difference in the number of crossings of single track railway with differences in habitat up to index value three. With double track line the difference in habitat on each side of the track becomes more important with the number of crossings per grid (per unit population density) dropping from 1.6 to 0.95 as the difference in habitat index increases from 1 to 2 on opposite sides of the railway.

There are no crossings of double track line when there is a habitat difference present greater than 3 in index value.

With four track line the difference in habitat becomes still more important, resulting in only one crossing of four track line with anything other than identical habitat on both sides of the railway track.

It seems that although habitat affects single track crossings little, it affects wider track crossings markedly and in all crossings of all widths of track there were no crossings between areas with gross differences of habitat. This is discussed further in 7.2 below.

7.2 (iii): Railways as barriers to animal movement

The Nature of the Barrier

Ballast used in railway tracks consists of irregularly shaped pieces of rock up to about 750 g in weight on which the sleepers and then the tracks are laid. This sort of uneven substrate provides nesting sites for small mammals and the irregular nature of the surface must give some cover to small indidividual mammals which can squeeze in between the rocks. The rails are raised on sleepers above the ballast and so small mammals can walk across the ballast without coming into contact with the rails at all. In this respect, a railway line could be considered as an area of open rocky ground acting in the same way as perhaps a road in limiting animal movements (Oxley, Fenton and Carmody 1960, Adams & Geis 1983). If an open highway of 90 m is an effective barrier to dispersal and there is a reluctance by small mammals to cross roads 20 m wide (Oxley et. al. 1960) then there ought to be a similar reluctance shown by small mammals to cross rocky ballast this wide. Emlen (1949) and Davies (1948) state that city streets discourage free movement of rats as their range rarely bridges a street. There may be a similar system of home ranges on the islands to that of rats in urban areas; most home ranges appear to be within islands (revealed by trapping - 18 captures after crossing a track compared to over 200 recaptures within islands - see 'Results'). The main feature of the railway apart from its physical width which acts in a limiting way is habitat disconformity and lack of ground cover. This disconformity of habitat on its own is enough to discourage some animal movements without the width of the strange habitat (in this case uneven rocks on the ballast) having any effect.

Bider (1968) in discussing the absence of Microtus from the woodland areas in his study area, focuses attention on the edge of the wood acting as a barrier to movement. He termed it "a biological barrier" and was of the opinion that animals encountering it would move parallel to it for some distance. This sounds similar to the effect the drainage channels in this study may have on the small mammals encountering them, with much movement immediately adjacent to them but very little recorded a few metres away. The presence of some sort of biological interface between populations of small mammals would greatly influence their movements and, in this context, the edges of the woods and the edge of the ballast may act as barriers in this study. From work on mammals in the vicinity of roads, it appears that the edge effect of habitat bordering on road may influence the movement of small mammals alongside it. Adams & Geis (1983) stated that the two main factors influencing small mammal use of roadside habitat are the effect of "habitat edge" and the mobility of animals which are less habitat specific (e.g. Apodemus sylvaticus).

The effect of the edge of a habitat is obviously important in considering mammal movement and the railway provides a site where several decisions must be made by the animal at habitat boundaries. In order to cross a railway track running through woods, a small mammal must first leave a wooded area with perhaps little ground cover except dead leaves, enter a dense area of herbs at the edge of the embankment, cross a three metre strip of grass, cross the rocky ballast and then move through these different areas again on the other side of the track.

It is probably the combination of the "habitat edge effects" and the relative similarity of adjacent habitat that affects the crossing rates.

Movements Across the Barrier

As only a small proportion of adult (i.e. over 18 g see (iii)) animals crossed the railway lines in the course of the trapping study, it seems that railways do have an effect in limiting the free movement of small mammals. There are probably some animals which have railway lines inside their home ranges but only two individuals in the study caught four or more times were trapped in more than one area. Sometimes individuals were trapped at three separate points in a line parallel to the railway and within 5m from the rails but were not caught on the opposite side. The results from the tunnels placed close to the rails might well suggest that mice will often travel along the drainage channels and the ballast without actually crossing over to the vegetation on the other side. From observations of mice (Mus musculus) on London underground railways Kendrick and Munro (1982 unpubl. and personal observations,) it appears that small mammals are very active on the areas below station platforms and close to the rails where they presumably feed on human litter. If this is the case then small mammals in this study area may well forage close to the rails without crossing over to feed on the other side, presumably out of their home range. The movements classed as dispersal moves i.e. movements over 75 m (Crawley 1969) or 110 m (Watts 1970) probably occurred mainly with juveniles although tracking methods could not distinguish the age of the animal involved.

Due to the structure of the study area, all such long movements were recorded with the crossing of at least one railway line. Thus most railway crossings were probably in the course of dispersal movements by juveniles. The crossings recorded by trapping were not over very great distances (the longest inter-capture distance being 60 m) but the maximum distance that could be recorded using a pair of opposite grids is only about 120 m and that assumes that the initial and final capture were both on the trap-line furthest from the railway. Due to the trapping method it would have been difficult to record dispersal over very long distances (or indeed home ranges such as the 400 m in length described by Hacker and Pearson (1951)). From trapping results it appears that mice and voles had overlapping ranges in this study. Sometimes the majority of the traps nearest the railway, if situated by a wire fence on drainage channel, caught individuals, whilst on other rows most traps might well be empty.

This supports the idea of mice and voles using the embankments and track area for foraging activity.

It may well be that the railways appear to act as a barrier to movement simply because the animals have no need to cross the tracks.

Clethrionomys was not caught in the gardens despite being present in the woods and this might be a reflection on its reluctance to cross railway lines. There was only one Clethionomys trapped having crossed a line and at 18 g that could well have been part of a dispersal move. Clethrionomys are known to prefer habitat with fairly dense ground cover such as brambles or nettles and in a study of stone dykes, Healing (1980) found that their movements were limited to field edges. Pollard and Relton (1970) stated that Clethrionomys was rarely found more than five metres away from hedges and so in the light of this, the lack of track crossings for this species does not seem surprising. Clethrionomys therefore seem to be more limited in their movements than Apodemus partly because of habitat preferences. Movement studies on Microtus have shown them also to be affected by habitat. Bider (1968) in his sand transect study of various ecosystems found no tracks of Microtus pennysylvanicus in the woodland areas, yet many hundreds in the open field areas, and Adams and Geis (1983) found that Microtus was the most habitat-specific genus of small mammal that they trapped.

They found that Microtus pennysylvanicus would only cross habitat borders and move onto roadside verges where there was a grassy verge present similar in habitat to the surrounding fields.

Thus it appears that the edge of a wood may well be as much of a barrier to *Microtus pennsylvanicus* movement as a railway line or similar open area such as a road (Oxley, Fenton and Carmody 1974).

Movements On the Embankments

Over most of the study area the embankments were kept clear of vegetation and so there was generally an area of a few metres between the rails and any shrubs or trees near the track. This lack of cover on most embankments must be taken into account when considering habitat prferences of animals:

Clethrionomys: The *Clethrionomys* individual which was trapped after crossing single track railway was recaught after having only moved about 15 m, of which about eight metres was short grass. This represents an unusual movement in the view of Pollard and Renton (1970) who considered movements of *Clethrionomys* more than five metres from hedges to be rare. The embankment usually provides a strip of grassland habitat adjoining the railway irrespective of the surrounding vegetaion. *Clethrionomys* are present at a low density on the embankments although Yalden (1980) caught none in 313 trap nights in an urban area on railway embankments.

Apodemus: These were caught at a higher rate on the embankments than in the adjacent woods and at a much higher rate than in gardens on the opposite side of the railway. This is perhaps further evidence for the use of embankment areas for foraging by mice. The only observed nest site was on an embankment, discovered after a pregnant female *Apodemus* had given birth in a Longworth mammal trap! With the door propped open, the young were carried to the nest site which was a few inches from the trap. Often on the embankments the only feature which seeemed to play a part in the trapping success was the distance that the trap was placed from the drainage channel or similar feature. As was stated earlier, animals were sometimes caught in all the traps in a line if they were placed adjacent to the drainage channel, and the tunnel usage (Table 6.7 in results) bears this out.

Microtus: The absence of Microtus from the preliminary trapping area is a reflection on its marked habitat preferences. The unimproved grassland of the railway junction being ideal habitat (Corbet and Southern 1977), it was completely absent from the wooded areas. The embankments probably played little part in its movements since the areas with high populations of Microtus were all close to one another and all consisted of grassland, similar in species composition and ground cover to the embankment strips.

The Railways as a Barrier to Larger Mammals

During the period of this study three Badgers (Meles meles) were killed by electrocution on the railways. Presumably being fairly large mammals, they were electrocuted whilst crossing the 'live' rail. Foxes were seen to jump over the rails as were domestic dogs, and there were no casualties of either. The presence of the electrified rail probably acts in limiting movements of large mammals such as Badgers which would normally climb over such obstacles if encountered in any other situation. Mole hills were observed on two of the islands and so it appears that moles can cross beneath lines, or over the ballast.

7.2 (iv): The Railway Junction as an Island System

The Junction as Islands at Equilibrium

As the railway lines have been found to act as a partial barrier to free movement, the populations on the islands in the junction are not completely isolated from each other or from the surrounding land. There is movement between the islands and this may carry on at a level independent to population size and so be hard to predict. With tracking methods, 12 movements out of island 'W' were recorded although only 2 were recorded by trapping. Allowing for under-recording of movements by both methods there are probably movements between islands going on all the time particularly in summer with juveniles reaching puberty and dispersing.

For the three species studied here, there was no correlation between migration rates (as elucidated by tracking and trapping) and the size of the islands, nor did migration rates correlate with population density. A much longer study over several years and involving more species would have to be carried out to investigate the relationship between migration of juveniles and the island's size or population density. If terrestrial islands become seperated from each other by urbanization then a different pattern of migration takes effect. In the case of isolated woodlands separated by either arable farmland or urban developments, there is a strong case for supposing that they behave as islands with an equilibrium number of species, (Curtis 1956). If these islands become further separated then they will tend to act as isolated units with migration between them eventually becoming impossible. Brown (1971) concluded that mammal populations on mountain-tops represented a relict fauna and did not show equilibrium between colonization and extinction. Indeed, the rate of colonization was found to be effectively nil. The importance of studies such as this in the long term is that by having an understanding of local animal movements, it becomes easier to predict the capability of animals to colonize and migrate between isolated or semi-isolated habitat islands.

It appears that M. agrestis is now limited in its distribution in the South-East London area simply because of a loss of grassland and the nearest known populations to those studies here are over 3 kilometres away (Gillett 1983). Microtus and Clethrionomys, both having distinctive habitat preferences will continue to have their range restricted as this habitat declines until they eventually occupy isolated habitat islands. Already the junction as a whole could be said to be a habitat island for reptiles such as the viper (Vipera berus) and the Common lizard (Lacerta vivipara) whose nearest known populations are probably 10 km away (Keston Common, Gillett 1983 pers. comm.). Thus the definition of an island at equilibrium as set out by MacArthur and Wilson (1963) applies at species level in different ways. For the three species studied, they do not act within the junction as animals with equilibrium populations as 'colonization' rates and 'extinction' rates are not the same and also the railway tracks are not a sufficient isolating mechanism. For smaller species however, or animals with different habitat requirements, the areas within the junction may well act as islands at equilibrium number of species and their isolation may well be a direct function of the track width.

On the other hand, the entire study area could be regarded as a group of islands with migration occurring between similar habitat patches in the area. However for some species, notably reptiles, the junction now has a relict fauna and migration both out from and into the area is probably nil.

The Railways as Corridors Between Habitat Islands

Railways, along with other transport routes, have contributed in a large way to the distribution of plant species around the country; similarly, although not usually actively transporting mammal species lng distances, they have acted as corridors of semi-natural vegetation which is suitable for animal movements. Elton (1958) described the use of man-made landscape features for animals movement such as hedgerows and fences and Yalden (1980) applied this idea to railway embankments. Yalden found Wood mice penetrating a long way into an urban area, and there Microtus agrestis and Brown rats (Rattus norvegicus) were also trapped. The role of railway embankments is probably similar to that of roadside verges in that animals such as small mammals with natural habtitats similar to embankments will use the verges to extend their range, whilst not necessarily crossing over the railway.

Getz, Cole & Gates (1978) and Adams & Geis (1983) have pointed out the role of roadside verges for the range extension of small mammals and Palman (1977) has indicated that roadside habitats often support a greater variety of animal species than surrounding land. Krodska (1982) has investigated this form of "edge effect" on bird populations and found that there is a greater variety of breeding birds found at a wide habitat boundary (in his case, a power-line corridor) than in the interior.

There does seem therefore to be a strong case for hypothesising that not only may embankments prove useful for mammal movments parallel to the railway, rather than across it, but it may also be advantageous in some way for mammals to inhabit the boundary areas of patchy environments. The railway staff who patrol the tracks reported during the course of this study any animals they had observed whilst on night duties, and as a result of this there were well over a hundred sightings of Foxes recorded as well as Badgers and a Weasel. It would appear that the railway is used by larger mammals as a route for movement as it provides an area free from human disturbance that penetrates into urban areas (where many foxes feed) and still has a large amount of natural vegetation adjacent to the embankments as well as on junction areas.

7.2 (v): Implications For Nature Conservation

Nature Reserve Design

Preston (1962) states that it is impossible to preserve in a nature reserve complete replica, on a small scale, of the fauna and flora of a larger area. As soon as the prescribed area is set aside from urbanization or another form of "disclimax" habitat, the wildlife preserve becomes an isolate or an approximation of one and so the number of species accommodated must fall to a lower level. This dilemma of reserve size confronts all workers who seek to preserve habitats and much work has been done to investigate the design of reserves so as to minimize extinction rates and keep the equilibrium number of species as high as possible. One approach to the problem is the use of corridors of habitat to link nature reserve areas and this is dealt with below.

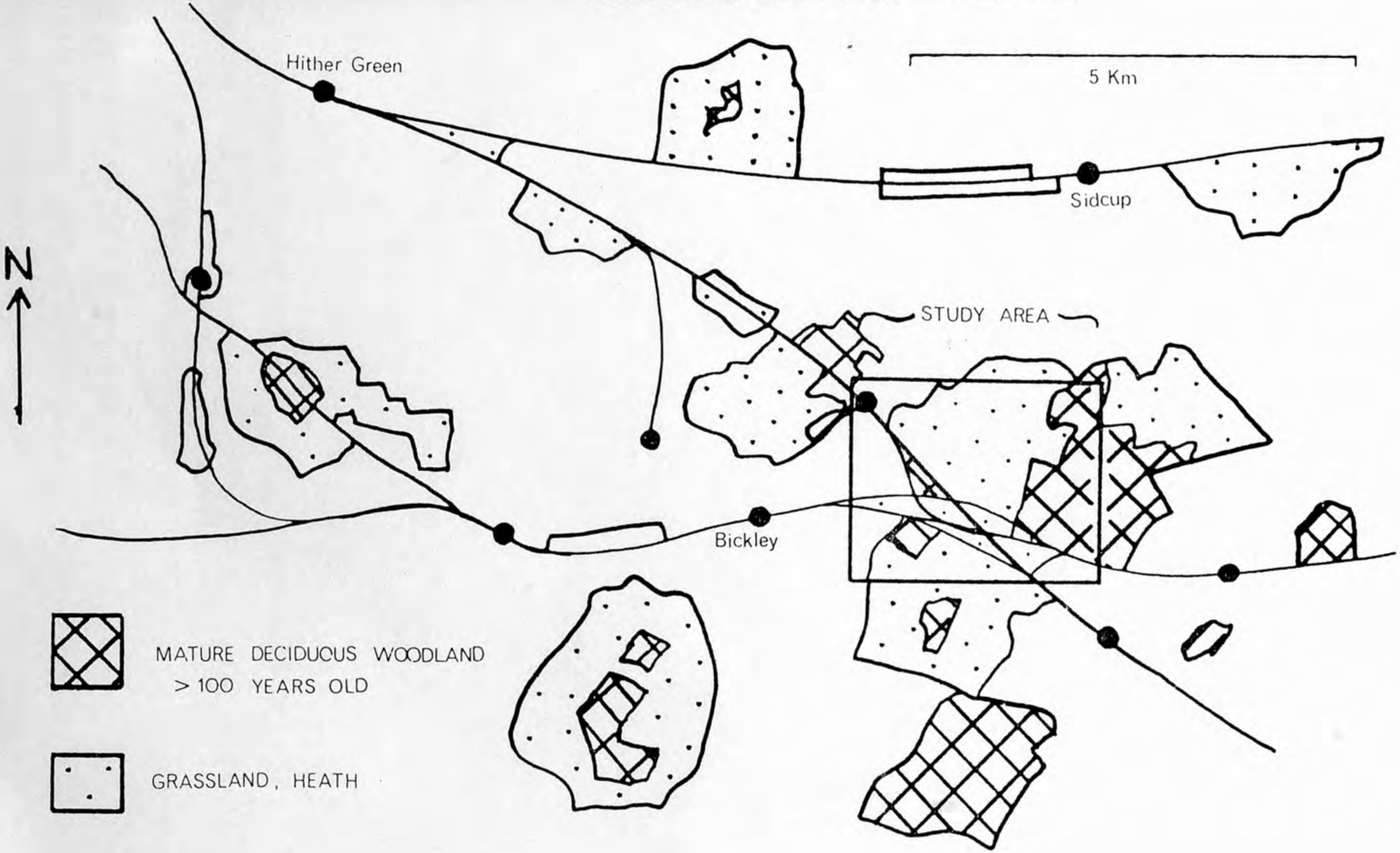
Diamond (1975) states that because a tenfold decrease in area of habitat corresponds to halving the number of species at equilibrium, as large a nature reserve as possible is desirable; however many large reserves are effectively a group of small reserves separated by barriers to movement such as wide roads. If an effective barrier to dispersal such as wide roads (Oxley et. al. 1974) is placed in a nature reserve, and effectively bisects the habitat, then when the species settle back to their new equilibrium levels, about 1/6th of the species will have become extinct. Thus in reserve design, it must be remembered that one large area is not biogeographically equal to a cluster of smaller ones; the smaller areas will hold a lower equilibrium number of species despite being the same total size as the larger area. If an area must be broken up into smaller separate units (such as in the case of urbanization) then it is possible to maximise immigration rates into the 'isolates' by providing a form of corridor between them. (Preston 1962, Willis 1974). The geometry of wildlife refuges has been developed by Diamond

(1972) who has suggested shapes for reserves based on minimising extinction rates. In studies such as Merriam and Wagner's (1973) and this one, it is possible to investigate the use by animals of possible corridors between habitat isolates and thus assess their potential use in reserve design. Merriam and Wagner (1973) found that small mammals (Peromyscus leucopus and Tamias striatus) moved from a wood to connecting fencerows four times as often as they moved between traplines in the wood, indicating that fencerows connecting the wood to the surrounding agricultural mosaic concentrated the activity of small mammals (and birds) into a habitat corridor. Animals using the embankments in this railway study show that railways could play a similar role in forming corridors between areas of similar habitat isolated by urbanization. (See Fig. 7.2). It is impossible to state categorically whether an individual mammal used the embankment in a movement parallel to the railway, but where two captures of the same individual are made close to the track with an inter-capture distance of, say, fifty metres, then this seems likely.

A longer study involving intensive trapping of the embankments is needed to clarify the situation.

Despite acting as corridors for movement penetrating into urban areas railways also act in a limiting way as a barrier to free movement in some species. Although Clethrionomys was found in the woods to the north of the railway in the preliminary trapping, it was not found in the gardens south of the railway, and, in the light of the crossing studies on the islands, it appears to have been limited in its distribution by the presence of the railway, acting together with other factors such as habitat preference.

FIG. 7.2 RAILWAYS IN SOUTH EAST LONDON



Many areas shown in Fig. 7.1 which are suitable habitat for small mammal species could not be colonised other than by movement of individuals along the railway embankments.

Relict Sites in Urban Areas

These act in a manner similar to Preston's (1962) isolates in that once the areas of relict habitat become sufficiently separate, there can be no migration between them and the number of species present will fall. As can be seen from Fig. 7.2 the areas of relict woodland in South East London are often linked by railways and the embankments will often provide the only areas of vegetation between them. The presence of wood mice in gardens indicates that the role of large gardens must not be underestimated when considering animal movements. As can be seen from Fig. 9.1 in the 'Preliminary Trapping' the gardens are very large (up to 250 feet in length) and contain a woodland flora very similar to that on the opposite side of the railway tracks. As there were no crossings detected in the region of the gardens, it is possible that the mouse populations in the gardens are isolated from the woodland ones and are developing independantly. However as crossings of four track line occurred on the junction then it is possible that the population in the gardens is boosted by immigrants from the woods.

Urban Planning and Wildlife Conservation

In recent years, there has been a development in urban planning pioneered by such workers as Gill and Bonnett (1973) and (Kelcey (1975) which has led to the use of urban areas as nature reserves as well as areas of human habitation.

Work such as the study of chipmunks (Tamias striatus) in residential areas (Ryan and Larson 1976) has led to the use of biogeographical theory in landscape planning. Simmons (1979) pointed out that urban areas such as Los Angeles, where he worked, were refuges for high numbers of mammals such as coyotes (Caris Lations) and Gill and Bonnet (1973) mention other animals living in areas of natural vegetation within large towns. Road verges have been used as wildlife preserves, indeed in the new town of Milton Keynes, Kelcy (1975) pointed out the use of road verges as a matrix of wildlife refuges. Railway verges act in a similar way to road verges in providing a vegetation corridor and the use of suburban gardens as similar refuges has been investigated (Owen and Owen 1979). Urban planners can take account of such studies and incorporate them into urban design. Goldstein, Gross and de Graaf 1981), describe the design of housing estates with deliberately placed patches of wood and hedgerow to maximise the "reserve effect" for bird populations. They state that as humans "prefer" single layer planting of trees and shrubs and birds "prefer" clumps and islands, they suggest that planners design estates on triangular lots with a network of hedges, and that service roads should be peripheral and not cul - de - sacs in the middle of the estate.

The value of such advice has yet to be determined, and the amalgamation of biogeography and urban design is still in its infancy but from studies such as Ryan and Larson (1976) it is known that judicious planting of semi-natural vegetation can lead to an increase in some animal populations.

With reference to the area in this study; large areas such as this junction with varied and large populations of small mammals, act as important reservoirs of population which might in future re-colonise other suitable areas with low populations at present.

The only way in which isolated woodlands, parks and open areas of rough grassland could be populated by Microtus would be if connecting habitat corridors (i.e. railway embankments) had suitable grassland habitat.

The conservation priorities for small mammals in urban areas are thus similar to those proposed for woodland birds by Foreman, Galli and Lech (1976). Initially large woods must be protected (or large areas of grassland and shrubs depending on the species in question) and secondly as high a density as possible of small woods with interconnecting routes of suitable habitat, must be preserved.

For species such as Microtus agrestis in urban areas, tracts of relict grassland, such as parts of the junction studies here, can only be connected to similar areas by wide roadside verges or railway embankments.

Many workers have highlighted the importance of such nature corridors in practical use (e.g. Huey 1941, Getz, Cole & Gates 1978, Palman 1977) and from this study and similar work by Yalden (1980) it appears that railway embankments provide ideal routes for movement of animals between otherwise isolated habitat patches.

Furthermore, railway junctions can provide areas of relict habitat with the minimum of human disturbance and they can act as a reservoir of population for otherwise thinly distributed species.

CHAPTER EIGHT

CONCLUSIONS

8.1. Small mammal populations in the urban environment

It has been demonstrated previously (e.g. Yalden 1980) that small mammals will penetrate into urban areas along corridors of natural or semi-natural vegetation and Huey (1941) and Getz, Cole and Gates (1978) have hypothesised that mammals will often use such corridors to extend their range. It this study three small mammal species were investigated in a comparatively small (10ha) area connected to other areas of similar habitat by railway embanKments. A.sylvaticus was found in the largest numbers with C. glareoolus and M.agrestis found to a lesser extent. Although the islands are often of similar habitat, they have differing population densities of animals (Table 6.2) indicating that the railways split the study area into 'islands' with limited movements between them.

There were higher numbers of small mammals caught on the juction than in the surrounding land (Tables 9.1 - 9.11) and this is probably caused by the greater human disturbance in those areas. Unlike Yalden's (1980) work, C.glareolus were caught on the embankments in this study although overall this study produced fewer captures. The most limited species in distribution is M. agrestis which is absent from the gardens and woods investigated and only found in the grassland areas of the junction (Table 6.12). Other mammals seen during the study indicate that the junction and the adjacent embankments are used by larger mammal species both for nesting sites and movements, The lack of human disturbance is probably one of the most important factors in the presence of these animals.

8.2 <u>Biogeography of railway junctions</u>

Just as the edge of woodlands present 'an absorbent and biological barrier' (Bider 1968) to small mammals, the railway line forms a similar sort of obstacle. Animals can cross railway lines (Table 6.8) and to a greater extent than a similar distance of open road (Mader 1984).

The site was originally (pre 1850) open pastureland which was subsequently split up by the railway construction at the turn of the century. It was virtually enclosed by urban development in the nineteen thirties leaving a group of partial isolates composed of grassland and scrub. The barrier that the railway presents between these isolates is such that in trapping 'supergrids' (Table 6.10) straddling railway lines, there were only 18 recaptures following a railway crossing compared to 141 other captures within 'supergrids' without a railway crossing. There were only two individuals that possibly had a detectable home range incorporating a railway line.

The habitat adjacent to the railway is very important in determining the likelihood of mammal movements. There were no crossings of line where a subjective index of vegetation differed on each side by more than three (Table 6.13) With double track and four track line the disparity in habitat becomes increasingly important in limiting movements (Table 6.14). There was only one detected crossing of four track line where the habitat was not the same on each side of the track. The barrier effect is however not as great as if the distance was totally without cover as in the case of a road. Mader (1984) showed that out of 376 marked individuals living by roadsides, none crossed the roads (maximum width 16m) to be subsequently recaptured. In this study, 228 individuals were marked and 18 were trapped after crossing varying widths of railway track. (maximum width 13.5 m) A further 49 individuals were observed by tracking methods to have crossed the railway. The difference in the number of detected crossings between this study and a similar one involving roads is presumably due to the difference in substrate ; railways provide some cover by sleepers and in the ballast, unlike roads. There was a higher capture index of A.sylvaticus on embankments than in adjacent woods and gardens (Table 9.3) suggesting that (as the habitats are very similar) they are used for either foraging behaviour or movements parallel to the railway rather than across it. The fact that very few crossings took place might bear this out.

8.3 Small mammal movements within the junction

Tracking methods reveal far more track crossings than trapping (49 as opposed to 18), (Table 6.2). Tracking works better than trapping when identifying animal movements out of their home range, presumably due to their increased trap-shyness. Obviously many track crossings were taking place undetected by trapping. There were no discernible seasonal movements occurring within the junction. In fact the population estimates are surprisingly similar in both seasons. This could be due to building disturbance lowering capture rates in the winter, or the summer fire (See 'Seasonal variation' in Chapter seven) affecting the island populations. Despite the total number of captures being similar throughout the year, there were a higher proportion of A.sylvaticus caught in the winter, which could possibly be evidence of migration from the woods (Corke 1977).

The majority of long distance movements and track crossings are by A.sylvaticus (Table 6.8) and most track crossings occurred in summer. (Table 6.8). The animals crossing tracks were generally juveniles or sub-adults; less than half the animals crossing of all three species weighed more than 20g. There is fairly constant movement across the railway at a low level despite the varying population densities(Fig. 6.9, 6.10) The majority of crossings being of single track line. Watts (1970) stated that there was higher juvenile disperaal of C.glareolus than A.sylvaticus. The results of this study do not support this, although there is only limited data available with only one individual C.glareolus being detected crossing.

8.4 Implications for conservation and planning

Small mammals are present in gardens adjacent to railway embankments and also in woods nearby. The role of gardens as areas of habitat suitable for small mammals must not be underestimated, however often the habitat present is only suitable for a limited number of species. Only A. sylvaticus were trapped there. Animals such as M. agrestis with distinct habitat preferences are limited in their range and it is possible that railway embankments might provide the only possible method of recolonisation of suitable habitats by M.agrestis. If they act in this way then they will be playing a similar role to hedgerows (Merriam and Wagner 1973)in the movements of some mammal species. The only way in which individuals could disperse to other suitable areas from this study site is along embankments or through gardens. Other animals find the lack of human disturbance attractive - there is a'Site of Special Scientific interest on the embankment 500m to the north of the junction (designated as such 1981) in order to protect the reptile fauna.

From this study, observations can be made which are important for urban conservation efforts. The railway junction provides a varied and ideal habitat for many species of animal. The railway also acts in a limiting manner on the free movement of small mammal populations, probably encouraging movement along the embankments. The embankments provide a corridor of suitable habitat for dispersal moves of some animals in urban areas. There are larger populations of small mammals present on the railway junction than in the natural adjacent woodland habitat. This is possibly a result of the animals reluctance to cross the railway tracks and also the effects of human disturbance in the woods.

If areas of natural relict grassland support large populations of small mammals and other animals including their predators, then attempts should be made to link them togehher with suitable habitat. Such corridors linking these isolates in urban areas are already present in the form of railway embankments and large suburban gardens. The tendency of animals to move parrallel to, rather than across, railway enhances the utilisation of embankments as routes for amall mammal movements.

As movement across railways has been demonstrated albeit in a limited amount it is unlikely that gene pools on either side of the line will be drastically affected by the partial isolation. The extent to which this occurs must be investigated further. Town planners and developers, if they wish to consider the conservation of small mammal (and other) species, must make allowances for the needs for dispersal movements of animals or else they will not be able to recolonise 'lost' habitats, isolated by urbanisation.

Methods to enable this to happen could include the 'management' of disused railway lines and embankments, the maintenance of hedges and the provision for either gardens or parks as 'nature corridors' as well as civic amenities.

CHAPTER NINE

APPENDIX 1

9.1: Preliminary Fieldwork

PRELIMINARY TRAPPING: Woods, Embankments and Gardens.
DYED BAIT/DROPPING BOARDS/BOTTLES.

These are details of work carried out prior to the study on the junction. The dyed bait, boards and tunnels were all later used in the main part of the work.

9.1: (i) TRAPPING

The area selected for the study appeared geographically to be ideal but investiagion of the mammal species present was necessary to ensure a resident population which could be worked with.

It was felt that trapping of the land adjacent to the railway would be useful for comparative purposes when access was gained to the railway junction and so trapping grids were laid out in the woods adjoining the railway, the embankments and gardens which were adjacent to the embankments. Grids of five by five traps were used with ten metre inter-trap distance in the woods and gardens. Often in the gardens the grids had to be distorted to allow for man-made features such as fences and walls, but on the whole the grids were of uniform size (250 square metres). Two grids were used in the gardens, three in the woods and two on the embankments. (See Fig. 9.1).

The traps were baited with rolled oats and proprietary mouse food and left out for five consecutive nights. The traps were not pre-baited. They were checked once every 24 hours (usually between 15.00 and 18.00 hours).

Animals caught were sexed, weighed and toe clipped before being released. The position of the trapping grids is shown on the map. For embankment trapping, two grids of five by three traps was used, the lines of five traps running parallel to the railway lines. All other details were the same as for the garden trapping.

FIG. 9.1. PRELIMINARY TRAPPING AREA.

121

PRELIMINARY TRAPPING RESULTS

In these preliminary trapping results, as there was only one trap round every 24 hours, there were no marked mice caught in round 'I' (c.f. main trapping results).

In the tables,	APO.	- Apodemus sylvaticus
	CLETH.	- Clethrionomys glareolus
	MIC.	- Microtus agrestis

RESULTS - TRAPPING TOTALS

PRELIMINARY TRAPPING: WOODS

TABLE 9.1

GRID 1

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	3	3	0	1	1	0	0	0
2	2	2	4	1	1	2	0	0	0
3	2	2	4	1	0	1	0	0	0
4	4	1	5	1	0	1	0	0	0
5	5	1	6	1	1	2	0	0	0
	TOTAL:		22	TOTAL:		7	TOTAL:		0

TOTAL CAPTURES ON GRID 1 = 29

GRID 2

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	2	2	0	3	3	0	0	0
2	0	2	3	1	1	2	0	0	0
3	1	2	3	2	1	3	0	0	0
4	3	1	4	2	0	2	0	0	0
5	4	1	5	2	0	2	0	0	0
	TOTAL:		17	TOTAL:		12	TOTAL:		0

TOTAL CAPTURES ON GRID 2 = 29

GRID 3

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	3	3	0	2	2	0	0	0
2	1	2	3	0	1	1	0	0	0
3	3	1	4	2	0	2	0	0	0
4	3	0	3	1	1	2	0	0	0
5	4	0	3	1	0	1	0	0	0
	TOTAL:		17	TOTAL:		8	TOTAL:		0

TOTAL CAPTURES ON GRID 3 = 25

RESULTS Contd.

PRELIMINARY TRAPPING: GARDENS (Grids 2x5 and 3x5 added to give single grid of 5x5)

TABLE 9.2

GRID G1 (G1a+G1b)

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	2	2	0	0	0	0	0	0
2	1	1	2	0	0	0	0	0	0
3	1	0	1	0	0	0	0	0	0
4	0	1	1	0	0	0	0	0	0
5	2	0	2	0	0	0	0	0	0
	TOTAL:		8	TOTAL:		0	TOTAL:		0

TOTAL CAPTURES ON GRID = 8

GRID E1 EMBANKMENTS

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	2	2	0	0	0	0	0	0
2	0	1	1	0	1	1	0	0	0
3	1	0	1	0	0	0	0	0	0
4	2	1	3	0	1	1	0	0	0
5	1	0	1	0	0	0	0	0	0
	TOTAL:		8	TOTAL:		2	TOTAL:		0

TOTAL CAPTURES ON GRID = 10

GRID E2

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	2	2	0	0	0	0	0	0
2	0	1	1	0	0	0	0	0	0
3	1	1	2	0	0	0	0	0	0
4	2	0	2	0	0	0	0	0	0
5	2	0	2	0	0	0	0	0	0
	TOTAL:		9	TOTAL:		0	TOTAL:		0

TOTAL CAPTURES ON GRID = 9

PRELIMINARY TRAPPING: WOODS

DENSITY INDICES: Caputures/Trap night/Hectare

TABLE 9.3

	A. sylvaticus	C. glareolus
Grid 1	0.703	0.22
Grid 2	0.54	0.38
Grid 3	0.54	0.25
GARDENS		
Grid 1	0.26	0
EMBANKMENTS		
Grid 1	0.8	0.177
Grid 2	0.8	0

DISCUSSION

The two species were present in all the locations trapped with the exception of the gardens where there were no C. glareolus caught. This is interesting in the light of work done by Yalden (1980) who, when trapping on embankments in an urban area caught no C. glareolus at all over a total of 313 trap nights. C. glareolus however are present in the woods and on the embankments although at a low density (0.17 per hectare per trap night). It may well be that this is a reflection on the ability of Bank Voles to cross railway lines; the gardes are separated from the wood by a four-track railway line. Whether the apparent absence of C. glareolus is caused by the presence of the railway as a barrier or by other factors such as intolerance of man or habitat preference has to be determined.

A grid of five by five traps is too small to effectively monitor long distance movements such as those occasionally shown by Wood Mice (Watts 1970). However by positioning several grids over an area where small mammals are individually marked, movements can be seen. This method is not as satisfactory as using a large grid but larger grids tend to be unwieldy and time consuming Other methods (see later) can be used for movement studies and these supplement the trapping results which are used primarily for obtaining population and density estimates. The trap grids of five by five traps are useful for recording short range movements across the rail lines but there is the possibility that movements of this type would be under-recorded, mammals tending to be trap-shy out of their own range. (Watts 1970).

Further discussion of these results and statistical treatments will be found in the main 'Results' and 'Discussion' sections.

DYED BAIT METHODS

The freqeuncey of features which can be related to mammal density has used extensively in the past by many workers. to assess population sizes.

Dye fed in bait to small mammals will show up in the faeces and urine and so may be used to show movements of bait-fed individual mammals or that of whole populations.

Dyes can also be injected sub-cutaneouslyas pellets which will also colour the urine.

Chitty and Southern (1954) fed Eosin and Methylene Blue dyes with gypsum to show them up in the faeces of house mice (Mus musculus).

Emlen et. al. (1957) conducted an extensive survey using dropping boards to record vole presence. Animals of all species used these boards as sites for defaecation and the authors were able to discern the different types of dropping and construct density indices for each of the small mammal species in the area.

Larthe (1958) in surveying the dyes suitable for studying rat movements concluded that these made the bait less palatable. She found four dyes which stained droppings consistently: Chlorazol Sky Blue FF200, Erythrosine 108678 (0.05%), Acid Green EC (0.5% and Brilliant Blue FCF (0.5%). All of these used with glycerine as adhesive were suitable for movement studies where good bait acceptance was desirable.

In this study a dye was needed which would remain in the faeces or urine for up to four or five days. Various methods of collection have also been used. As well as the plywood dropping boards as used by Emlen (1957), workershave used Aluminium squares, roofing tiles and waxed paper cartons (Randolph 1973).

For a complete review of the literature regarding the use of dyes See New (1956). The aims of this investigation were therefore to determine which dyes would be suitable to feed to small mammals and which method of recovery would give the most consistent results.

Methods

Dyes

(a) Three dyes from those initially presented were accepted by captive A. sylvaticus and these were all eaten readily when mixed with a flour based bait, the bait was made from crushed biscuit and bread made into a paste with flour and water. The three dyes, Fluorescein, Fast Green and Carmine (the latter two being cellulose dyes) were presented to captive A. sylvaticus for one night (from 16.00 to 09.00 hours) and droppings and urine rmoved from the cage for analysis, for the following four days. The faeces were mixed with water and the urine dropped by pipette onto chromotography paper. If the urine was dried up, it was washed off the board/tile or bottle with about 10 mls distilled water and then dropped onto chromotography paper.

(b) Once it was found that the dye would stay in the faeces and urine for more than one day it was necessary to determine the quantity of dye necessary to colour the faeces and urine noticeably in the field. Three petri dishes of bait were presented to A. sylvaticus for different lenghts of time ranging from 30 minutes to 30 seconds. The A. sylvaticus were offered the bait in addition to proprietary mouse food and water which was always available to them.

The dishes of bait were made up with ten drops of Carmine to 500 g of solids, 5 g of Fast Green to 500 g of solids and 5 g of Fluorescein to 1000 g of solids. The faeces were removed and studied for the next four days.

RESULTS: DYE TESTING

These tables show the number of pellets required to give a noticeable colour change to five mls of water when mixed and shaken. A. sylvaticus individuals were allowed differing ingestion times. (- indicates no positive result)

TABLE 9.4

FAST GREEN

INGESTION TIME	DAYS AFTER INGESTION 1	2	3	4
30 s	-	-	-	-
1 min.	10	-	-	-
10 mins.	5	10	-	-
20 mins.	5	10	15	-
30 mins.	1	5	10	-

TABLE 9.5

CARMINE

INGESTION TIME	DAYS AFTER INGESTION 1	2	3	4
30 s	-	-	-	-
1 min.	-	-	-	-
10 mins.	2	10	-	-
20 mins.	1	5	-	-
30 mins.	1	1	3	-

Dye Testing Contd.

TABLE 9.6

FLUORESCEIN

INGESTION TIME	DAYS AFTER INGESTION 1	2	3	4
30 s	10	-	-	-
1 min.	10	-	-	-
10 mins.	10	-	-	-
20 mins.	5	-	-	-
30 mins.	5	10	-	-

The table below shows the way in which ingestion time affects the fluorescein in faecal pellets. The faecal pellets were inspected under ultra-violet light. The figures in the table are, as above, the number of pellets required to give a positive result i.e. the number of pellets studies before a fluorescent effect was seen.

TABLE 9.7

INGESTION TIME	DAYS AFTER INGESTION 1	2	3	4
30 s	-	-	-	-
1 min.	1	-	-	-
10 mins.	1	1	-	-
20 mins.	1	1	3	1
30 mins.	1	1	1	-

Dye Testing Contd.

Bait left for 12 hours with A. sylvaticus. The figures in the table show the number of faecal pellets needed to colour five mls of water, varying numbers of days after bait ingestion.

TABLE 9.8

DYE	NUMBER OF DAYS AFTER INGESTION			
	1	2	3	4
Fast Green	1	2	10	-
Carmine	1	1	1	5
Fluorescin	1	1	10	-

DISCUSSION

It can be seen that for Fast Green and Carmine at least 20 minutes of animal contact with the dyed bait is necessary to give positive results with faecal pellets, using one per five millilitres of water. This may seem to be drawback to the method but it was apparent that the mice ate the bait more readily than the supplied grain and cereals. This would indicate that in the field the bait would be taken readily in sufficient quantity for pellet analysis.

The fact that fluorescein produces a fluorescent effect in the urine enable surveying of boards or bottles using an ultra violet lamp in the laboratory. Brown and Conoway (1961) used fluorescein as a substitute for Tropaclin O to study small mammal movement and found that a subcutaneous insertion of the dye would colour faeces or urine for four to five days. They did however question its use in the field as rain water tended to wash the dye out of the filter paper which they used for its collection. It appears that, as the mice took the bait readily and suffered no apparent ill affects over their period of captivity, the carmine would be most suitable with the dropping boards and the fluorescein most suitable for the urine samples, (the fluorescein continuing to fluoresce under ultra violet light even after most of the urine had evaporated). The fact that the colour dyes are completely expelled from the mice three days after ingestion means that long term study results will not be affected by dye present in the study area from previous tests.

Dyed bait work has many applications in small mammal work - mammals can be fed in the laboratory and then released and tracked individually or bait "dumps" can be laid out to show low-incidence movements e.g. across railway lines (see Method section).

Methods Contd.

Boards/Bottles

Various types of dropping board to collect faecal material have been used in the past. Miller (1957) used four inch square Aluminium sheet set at 20 foot intervals to collect radioactive excretory products from voles. Other materials used have included waxed paper cartons (Randolph 1973) and plywood squares (Emlen et. al. 1957).

In this study urine collection was needed also and so more enclosed containers as well as open containers were investigated. It was noted that the captive mice frequently urinated on petri dishes used as food containers and also in plastic bottles intended for their nest sites. These were included in the survey of potential receptacles for faeces.

Each of the following was placed in a cage with a captive A. sylvaticus for 24 hours. (Often two or three were placed in a cage simultaneously.)

1. White ceramic tile 15 x 15 cm.
2. Polythene bottle, 4 cm. diameter. 12 cm. long.
3. Empty tin can (on its side).
4. Empty glass screw top jar (on its side).
5. Square of plywood/hardboard, 15 x 15 cm..
6. Polythene bottle with 8 cm. diameter neck, 10 cm. long.

After 24 hours thepresence of absence of faeces and urine on each of the above was recorded. The most popular were then placed together in a cage for a week. Of these, three were used by the mice, the tile (No. 1) the large polythene bottle (No. 2) and the wood square (No. 5). It was hard to distinguish any favourite between these three when they were all placed in a cage together, all were used equally over seven days for defecation but urine was only noticeable in the polythene bottle. (The receptacles were changed each day and the cages cleaned out).

DISCUSSION

The bottle has the advantages that it can be sealed and brought back to the laboratory, is light and easily washable.

The tile is transportable and washable in the field and has been used with success in previous studies (Emlen 1957, Lidicker 1973).

The wood squares are the lightest of all three, and least likely to be tampered with or broken. The plastic bottles were popular at all stages for urinating and as the material was translucent, it was simple to recognise the coloured urine caused by the dyes. Because of the shape of the bottle any liquid inside was unable to run out and also the contents were protected from rain.

Thus, for grid studies, bottles as described here and wood squares (plywood or hardboard) were used, the wood squares being 10 cm. x 10 cm. Bait placed in the plastic bottles increased their usage and so a small amount of rolled oats and sunflower seeds were placed in each bottle when used in the field. On dry days a piece of filter paper was added to help prevent evaporation of urine. The only results from preliminary field testing of a grid of boards and bottles were used as the results for tracking returns from grid 1 in area PW.

(c) Tunnels

Short tunnels or runways for small mammals have been used in part studies to construct animal frequency indices. Lord et. al. (1970) used plastic floor tiles with one half blacked with printers ink to track mice and voles.

Plastic tunnels were made in this study from plastic pelmet material (see Fig. 9.2). It was found that animals would readily enter them in captivity and so a method of recording movements through them had to be found.

Sheets of glass 20 x 8 centimetres were smoked and placed on the "floor" of the tunnel. These were then left in the cages over 24 hours.

To count the number of animals using the tunnels smoked glass sheets were placed in the appartus described in Fig. 9.3 and captive A. sylvaticus were observed running over them for various times.

The glass sheets were then placed on photographic paper and the paper was exposed and developed as a contact print (see Fig. 9.4).

Four mice were tested and each was sent across the glass on three occassions, once for two passages, once for four passages and again for eight passages.

FIG. 9.2. TRACKING TUNNELS

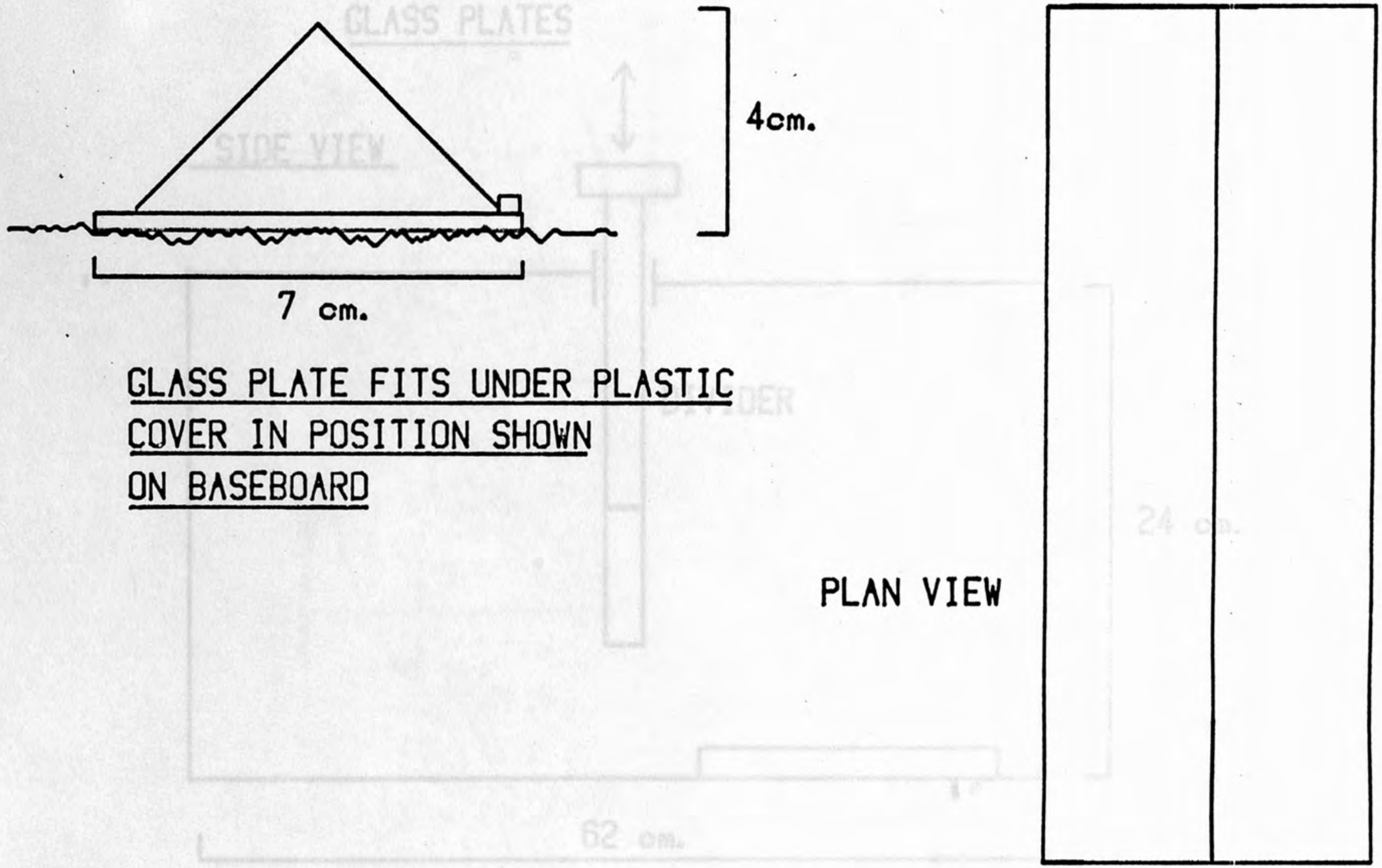


FIG. 9.3. APPARATUS FOR MAKING SMOKED GLASS PLATES

SIDE VIEW

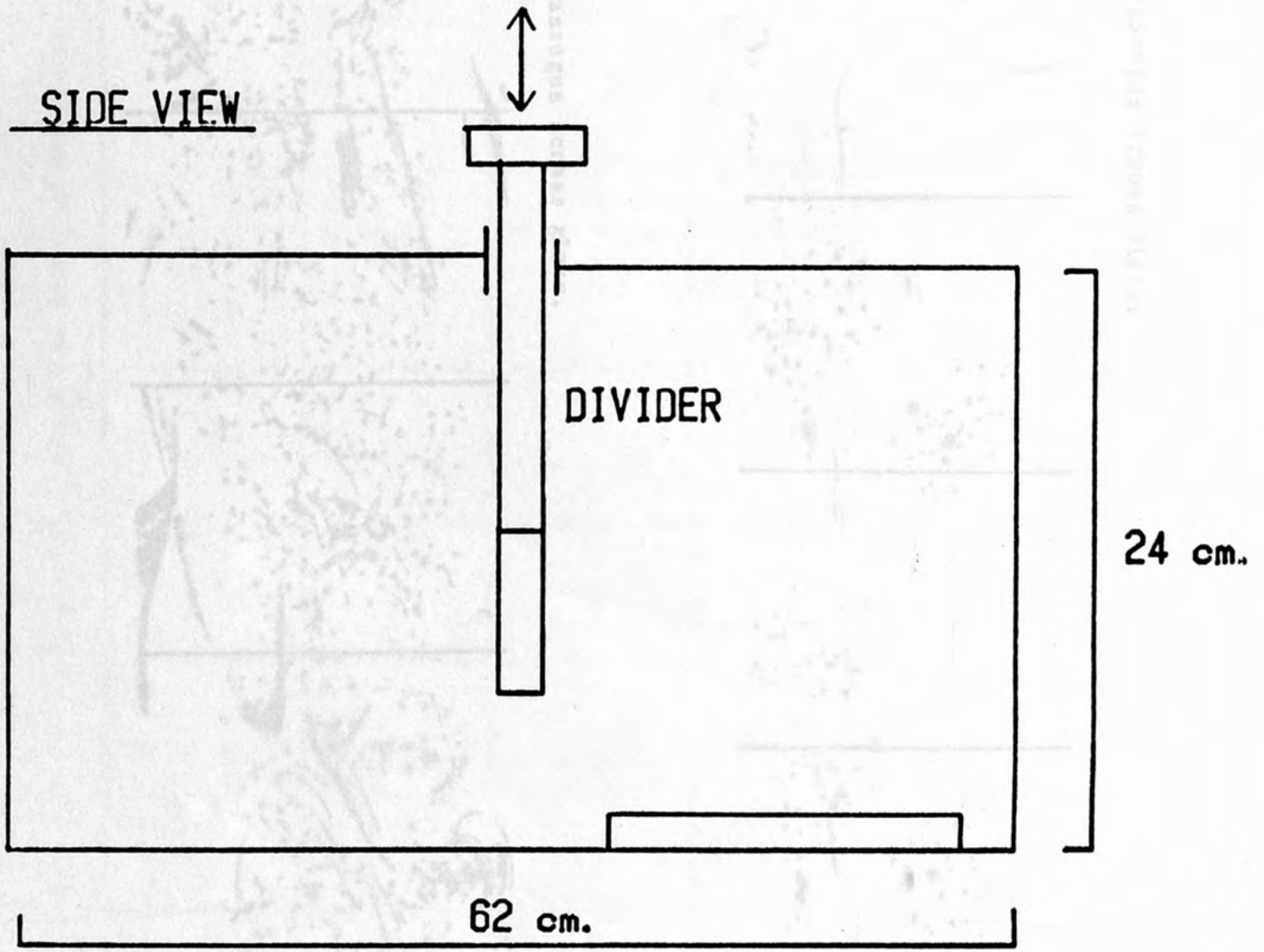
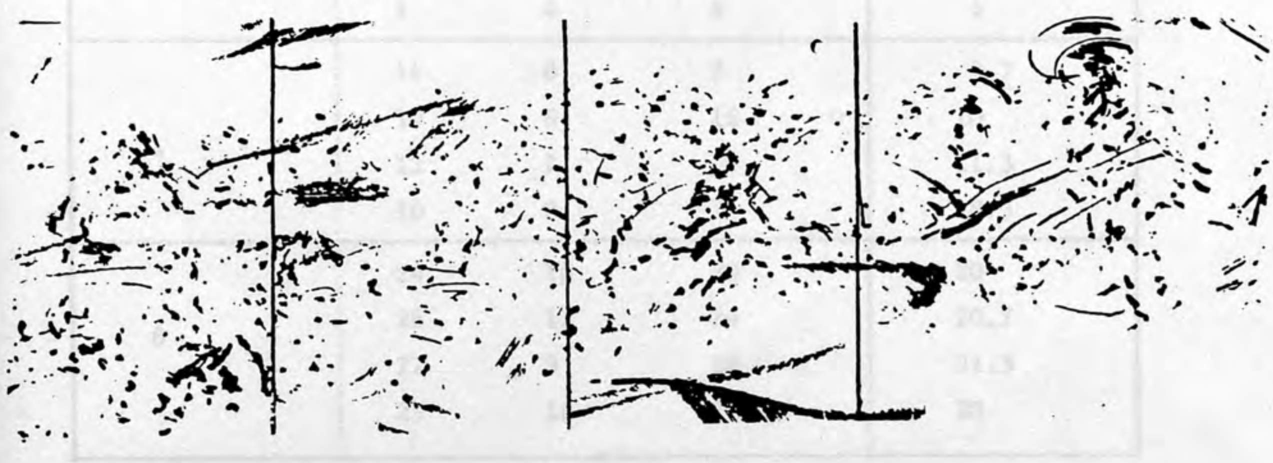


FIG. 9.4. CONTACT PRINTS OF SMOKED GLASS PLATES

1. 2 passages across glass.

2. 4 Passages across glass.



The vertical lines on the contact prints of the crossings shown below are used to give an index of movement across the glass plate. Three lines are 4 cm. apart and the number of times a trace crosses or touches one of these transects is recorded. (See "Trace count" below). It was hoped initially that individually toe-clipped mice and voles could be identified by this recording methods (after Justice (1961 and 1962) and Sheppe (1965)), however as can be seen from the contact sheets, the tracks become very confused even with the only two passages across the packed plate.

TABLE 9.9

No. of Passages	Trace Counts			Mean
2	5	6	7	6
	6	6	8	6.7
	5	5	4	4.7
	2	4	6	4
4	14	8	7	9.7
	10	8	12	10
	13	7	14	11.3
	10	8	7	8.3
8	24	16	20	20
	26	17	24	20.7
	27	9	28	21.3
	23	16	21	20

These figures are presented as a graph (Fig. 9.5)

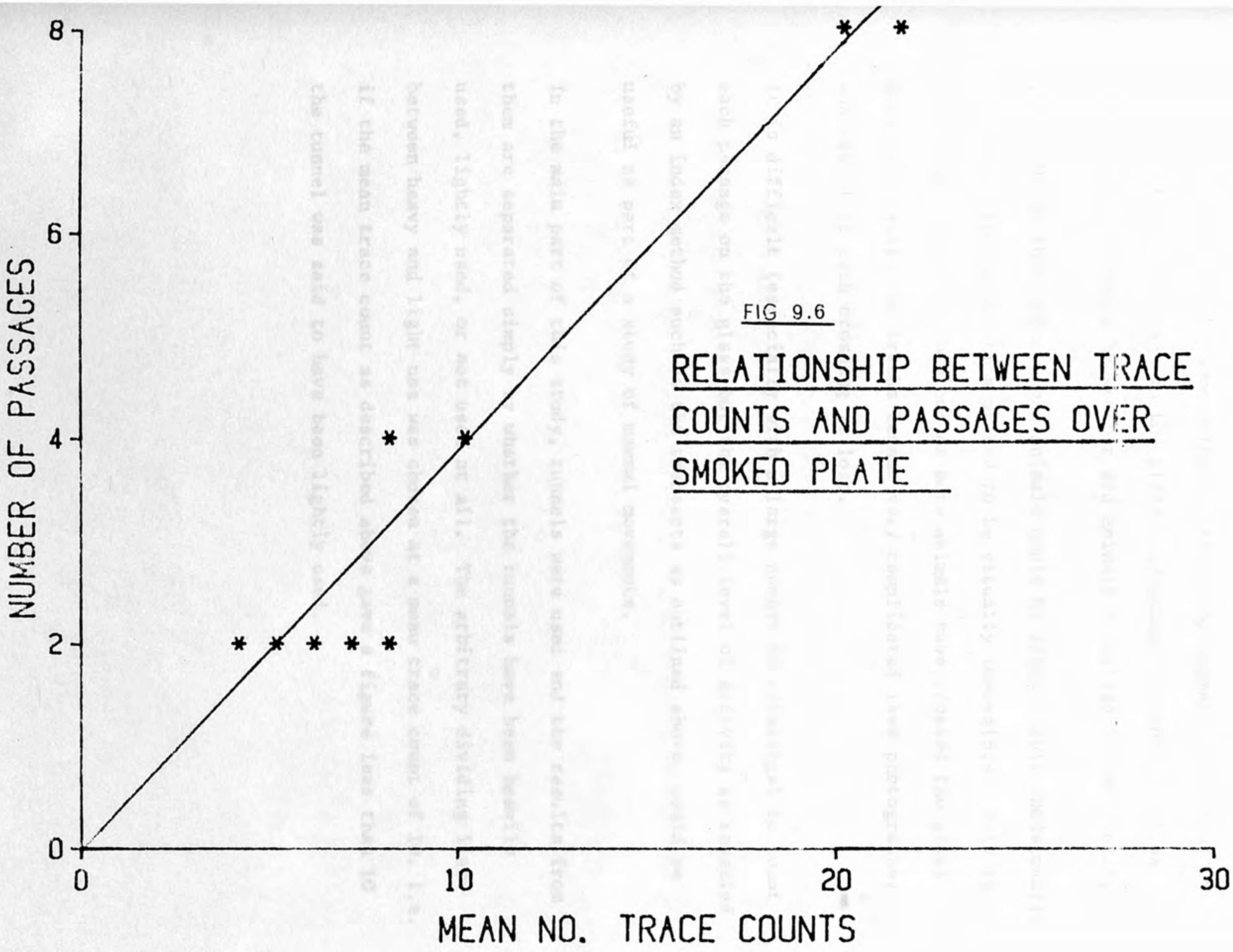


FIG 9.6

RELATIONSHIP BETWEEN TRACE COUNTS AND PASSAGES OVER SMOKED PLATE

DISCUSSION

This is a rather cumbersome method of recording mammal presence and the clarity of the trace on the glass is dependant on many variables including disturbance by weather and animals urinating in the tunnel.

It was hoped that toe-clipped animals would be identifiable individually from their tracks but this proved to be visually impossible. This is due to the fact that once one or more animals have crossed the glass more than twice, the tracks became very complicated (see photographs) and detail of each crossing is lost.

It is difficult (especially with a large number of crossings) to count each passage on the glass but the overall level of activity as revealed by an index method such as the transects as outlined above, could be useful as part of a study of mammal movements.

In the main part of this study, tunnels were used and the results from them are separated simply by whether the tunnels have been heavily used, lightly used, or not used at all. The arbitrary dividing line between heavy and light use was chosen at a mean trace count of 10. i.e. if the mean trace count as described above gave a figure less than 10 the tunnel was said to have been lightly used.

Problems

There were few problems to overcome with the preliminary trapping; there was some trap loss in the woods near public rights of way but on the embankments and on the islands the biggest disruptive factor was foxes tampering with the traps. In one case four traps out of a grid of twenty five had been broken and the two halves separated.

The animals tended to favour particular bottles or boards in the field, perhaps because of topography or perhaps simply because they had been used before. The bottle occasionally collected rainwater and this diluted any urine in them and dissolved any faceal material. In the case of dyed faecal pellets this proved to be something of an advantage as the dye could often then be seen in the field. To help prevent loss of dyed urine through evaporation or washing by rainwater chromatography or filter paper could be placed in the bottles.

9.2: Data

RESULTS - TRAPPING TOTALS

S U M M E R

All 12 grids

In the following results;

The trap round 1 shown below is the sum of rounds 1 and 2, trap round 2 shown below is the sum of rounds 3 and 4 etc.

APO.	=	Apodemus sylvaticus
CLETH.	=	Clethrionomus glareolus
MIC.	=	Microtus agrestis

RESULTS - TRAPPING TOTALS

S U M M E R

All 12 grids

TABLE 9.10

Numbers caught

GRID 1

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	3	3	0	2	2	0	0	0
2	1	4	5	1	2	3	0	0	0
3	3	0	3	1	0	1	0	0	0
4	4	2	6	2	1	3	0	0	0
5	4	1	5	2	0	2	0	0	0
	TOTAL:		22	TOTAL:		11	TOTAL:		0

TOTAL CAPTURES ON GRID 1 = 33

GRID 2

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	0	0	0	0	0	1	3	4
2	0	1	1	0	0	0	1	2	3
3	0	1	1	0	1	1	3	3	6
4	1	0	1	0	1	1	4	2	6
5	0	1	1	1	0	1	4	0	4
	TOTAL:		4	TOTAL:		3	RORAL:		23

T T

TOTAL CAPTURES ON GRID 2 = 30

GRID 3

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	1	3	4	0	0	0	0	0	0
2	1	2	3	0	1	1	0	0	0
3	2	2	4	0	0	0	0	0	0
4	3	2	5	1	0	1	0	0	0
5	4	1	5	1	1	2	0	1	1
	TOTAL:		21	TOTAL:		4	TOTAL:		1

TOTAL CAPTURES ON GRID 3 = 26

Trapping total results - Contd. TABLE 9.10

Summer

Numbers Caught

GRID 4

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	1	1	0	0	0	1	1	2
2	0	2	2	0	0	0	1	1	2
3	1	1	2	0	1	1	2	0	2
4	1	0	1	0	1	1	1	0	1
5	1	1	2	0	0	0	2	0	2
	TOTAL:		8	TOTAL:		2	TOTAL:		9

TOTAL CAPTURES ON GRID 4 = 19

GRID 5

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	1	1	0	0	0	0	1	1
2	1	0	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0	1	1
4	0	1	1	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
	TOTAL:		3	TOTAL:		0	TOTAL:		1

TOTAL CAPTURES ON GRID 5 = 5

GRID 6

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	1	1	0	0	0	1	2	3
2	1	1	2	0	1	1	2	3	5
3	2	1	3	0	0	0	4	1	5
4	3	1	4	0	1	1	3	2	5
5	2	1	3	0	0	0	2	0	2
	TOTAL:		13	TOTAL:		2	TOTAL:		20

TOTAL CAPTURES ON GRID 6 = 35

Trapping totals results - contd. TABLE 9.10

Summer

Numbers caught

GRID 7

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	1	2	3	0	0	0	1	3	4
2	2	0	2	0	0	0	4	4	8
3	0	0	0	0	0	0	4	2	6
4	0	0	0	0	0	0	5	1	6
5	0	0	0	0	0	0	4	0	4
	TOTAL:		5	TOTAL:		0	TOTAL:		28

TOTAL CAPTURES ON GRID 7 = 33

GRID 8

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	1	1	2	0	0	0	0	0	0
2	1	1	2	0	0	0	1	3	4
3	2	0	2	0	0	0	1	0	1
4	1	1	2	0	0	0	1	0	1
5	1	0	1	0	0	0	0	0	0
	TOTAL:		9	TOTAL:		0	TOTAL:		8

TOTAL CAPTURES ON GRID 8 = 17

GRID 9

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	1	3	4	1	3	4	0	0	0
2	4	2	6	3	0	3	0	0	0
3	3	0	3	2	2	4	0	0	0
4	2	1	3	2	1	3	0	0	0
5	2	0	2	3	0	3	0	0	0
	TOTAL:		18	TOTAL:		17	TOTAL:		0

TOTAL CAPTURES ON GRID 9 = 35

Trapping totals - Contd.

TABLE 9.10

Summer

Numbers caught

	TRAP ROUND	APO.			CLETH.			MIC.		
		Marked	Unmarked	Total	Marked	Unmarked	Total	Marked	Unmarked	Total
GRID 10	1	1	1	2	2	3	5	0	0	0
	2	2	1	3	2	2	4	0	0	0
	3	2	2	4	2	1	3	0	0	0
	4	3	0	3	1	3	4	0	0	0
	5	2	0	2	4	1	5	0	0	0
		TOTAL: 14			TOTAL: 21			TOTAL: 0		

TOTAL CAPTURES ON GRID 10 = 35

	TRAP ROUND	APO.			CLETH.			MIC.		
GRID 11	1	1	1	2	0	0	0	2	8	10
	2	1	0	1	0	0	0	4	1	5
	3	1	0	1	0	1	1	1	1	2
	4	0	0	0	0	0	0	1	1	2
	5	0	0	0	1	0	1	3	0	3
		TOTAL: 4			TOTAL: 2			TOTAL: 27		

TOTAL CAPTURES ON GRID 11 = 34

	TRAP ROUND	APO.			CLETH.			MIC.		
GRID 12	1	1	1	2	0	2	2	0	0	0
	2	0	2	2	1	2	3	0	0	0
	3	1	1	2	0	2	2	0	0	0
	4	2	2	4	2	1	3	0	0	0
	5	2	0	2	1	0	1	0	0	0
		TOTAL: 12			TOTAL: 11			TOTAL: 0		

TOTAL CAPTURES ON GRID 12 = 23

RESULTS - TRAPPING TOTALS

WINTER

Grids 1, 2, 3, 4, 11.

TABLE 9.11

GRID 1

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	2	2	1	2	3	0	0	0
2	0	3	3	1	2	3	0	0	0
3	2	3	5	0	1	1	0	0	0
4	2	2	4	2	1	3	0	0	0
5	4	1	4	3	0	3	0	0	0
	TOTAL:		19	TOTAL:		13	TOTAL:		0

TOTAL CAPTURES ON GRID 1 = 32

GRID 2

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	1	1	0	0	0	1	3	4
2	1	1	2	0	2	2	1	2	3
3	1	1	2	0	0	0	3	1	4
4	2	0	2	1	1	2	2	1	3
5	0	0	0	0	1	1	4	0	4
	TOTAL:		7	TOTAL:		5	TOTAL		18

TOTAL CAPTURES ON GRID 2 = 30

GRID 3

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	1	1	2	0	0	0	0	0	0
2	1	3	4	0	1	1	0	0	0
3	1	1	2	1	1	2	0	0	0
4	3	2	5	1	0	1	0	0	0
5	3	1	4	0	0	0	0	0	0
	TOTAL:		17	TOTAL:		4	TOTAL:		0

TOTAL CAPTURES ON GRID 3 = 21

Trapping total results Contd.
Winter

TABLE 9.11

Numbers caught

GRID 4

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	1	0	1	0	0	0	1	2	3
2	0	2	2	0	0	0	0	2	2
3	1	1	2	0	0	0	2	1	3
4	1	0	1	0	0	0	3	1	4
5	1	1	2	0	0	0	3	0	3
	TOTAL:		8	TOTAL:		0	TOTAL:		15

TOTAL CAPTURES ON GRID 4 = 23

GRID 11

TRAP ROUND	APO. Marked	APO. Unmarked	APO. Total	CLETH. Marked	CLETH. Unmarked	CLETH. Total	MIC. Marked	MIC. Unmarked	MIC. Total
1	0	1	1	0	0	0	0	2	2
2	0	2	2	0	0	0	2	3	5
3	1	1	2	0	0	0	4	1	5
4	1	1	2	0	0	0	4	1	5
5	1	0	1	0	0	0	4	1	5
	TOTAL:		8	TOTAL:		0	TOTAL:		22

TOTAL CAPTURES ON GRID 11 = 30

TRACKING RESULTS

Tracking totals showing railway crossings TABLE 9.12

SINGLE TRACK CROSSINGS

BAIT STATION	AREA DYE RECOVERED	BOARD OR BOTTLE	APPROXIMATE DISTANCE BAIT - RECOVERY POINT
W	F	Bd.	45 m
W	F	Bd.	70 m
W	F	Bd.	125 m
W	F	Bd.	50 m
W	F	Bot.	60 m
W	F	Bot.	60 m
S	H	Bd.	45 m
Gi	T	Bd.	80 m
Gi	T	Bd.	80 m
Gi	T	Bot.	130 m
Gii	A	Bd.	45 m
Gii	A	Bot.	60 m
Gii	A	Bd.	30 m
Gii	A	Bd.	45 m
PW	P	Bd.	20 m
PW	P	Bd.	15 m
PW	P	Bot.	25 m
PW	P	Bot.	45 m
PW	C	Bd.	35 m
PW	C	Bot.	45 m
PW	C	Bd.	60 m
PW	C	Bd.	35 m
C	PW	Bot.	25 m
C	PW	Bot.	30 m

TABLE 9.13

DOUBLE TRACK CROSSINGS

BAIT STATION	AREA DYE RECOVERED	BOARD OR BOTTLE	APPROXIMATE DISTANCE BAIT - RECOVERY POINT
W	B	Bd.	110 m
W	B	Bd.	120 m
S	B	Bd.	100 m
S	B	Bd.	45 m
H	T	Bd.	40 m
H	T	Bd.	35 m
H	T	Bd.	50 m
H	T	Bot.	25 m
H	T	Bot.	30 m
P	C	Bd.	70 m
P	C	Bd.	70 m
P	PW	Bot.	80 m
P	C	Bot.	60 m
B	A	Bd.	40 m
B	A	Bd.	30 m
B	A	Bd.	20 m

TABLE 9.14

FOUR TRACK CROSSINGS

BAIT STATION	AREA DYE RECOVERED	BOARD OR BOTTLE	APPROXIMATE DISTANCE BAIT - RECOVERY POINT
W	S	Bd.	30 m
W	S	Bd.	35 m
W	S	Bd.	40 m
W	S	Bot.	55 m
S	W	Bot.	75 m
C	A	Bd.	130 m
C	A	Bd.	35 m
C	A	Bot.	80 m
C	A	Bot.	40 m

CHAPTER TEN

APPENDIX 2

10.1 Working for calculations used in main body of text

Haynes (1949) modification of Lincoln Index used to estimate population size from trapping results.

EXAMPLE: Grid No. 1, 5 trap rounds, *Apodemus sylvaticus* captures only.

Results from Summer trapping session.

Round No.	No. Marked	No. Unmarked	Total (w)	Proportion Marked (y)	Cumulative Total of those Previously Marked. (x)
1	0	3	3	0	0
2	1	4	5	0.2	3
3	3	0	3	1.0	7
4	4	2	6	0.66	7
5	4	1	5	0.8	9

$$\text{Population} = \sum \frac{wx^2}{wxy}$$

$$\text{Therefore } P = \frac{0 + 45 + 147 + 294 + 405}{0 + 3 + 21 + 27.72 + 36}$$

$P = 10.15$ i.e. 10 individuals per $1500m^2$ (size of grid)

$= 6.66$ (i.e.7) individuals per $1000m^2$

= 67 individuals per hectare.

Capture Index (Captures per trap night per hectare)

EXAMPLE: Grid No. 1, as above, 3 x 5 traps, 10m inter-trap spacing .

22 captures in all i.e. $\frac{22}{75}$ captures per trap night.

i.e. $\frac{22}{75} \times \frac{10000}{1500}$ captures per trap night per hectare

= 1.95 captures/t.n./ha.

CHAPTER 11

REFERENCES CITED

Adams, L. W. & Geis, A. D. 1983. Effects of roads on small mammals J. App. Ecol. 20, 403 - 415.

Baird, D. D. & Birney, E. C. 1982. Characteristics of dispersing meadow voles (Microtus pennysylvanicus). AM. Mid. Nat. 107, 262 - 283.

Bergstedt, B. 1965. Distribution, growth and dynamics of the rodent species Clethrionomys glareolus, Apoedemus sylvaticus, and Apodemus flavicollis in southern Sweden. Oikos 17, 132 - 160.

Bider, J. R. 1968. Animal activity in uncontrolled terrestrial communties as determined by a sand transect technique. Ecological Monographs 38, 269 - 308.

Brown, L. E. 1956. Field experiments on the activity of the small mammals Apodemus sylvaticus, Clethrionomys glareolus and Microtus agrestis. Proceedings of the Zoological Society of London. 126, 549 - 564.

Brown L. E. 1969. Field experiments on movements of Apodemus sylvaticus using trapping and tracking techniques. Oecologia, 2, 198 - 222.

Brown, J. H. 1971. Mammals on mountaintops: non - equilibrium insular biogeography. American Naturalist. 105, 467 - 478.

Brown, L. N. & Conaway, C. H. 1961. Dye excretion as a method for determination of small mammal home ranges. American Mid. Nat. 66, 128 - 137.

Chitty, D. & Kempson, D. A. 1949. Prebaiting small mammals and a new design of a live trap. Ecology 30, 536 - 542.

Chitty, D. & Southern, H. N. 1954. Control of Rats and Mice. Vols. I and II, pp. 1 - 532. Vol III. pp 1 - 225. Oxford.

Corbet, G. B. & Southern, H. N. 1977. The handbook of British mammals. 2nd. Ed. Blackwell, Oxford.

Corke, D. 1977. A combination of extensive and intensive survey techniques for the study of the occurrence of Apodemus flavicollis in Essex. J. Zool. 182, 171 - 175.

Crawley, M. C. 1969. Movements and home ranges of Clethrionomys glareolus and Apodemus sylvaticus in north - east England. Oikos 20 , 310 - 319.

Curtis, J. T. 1956. The modification of mid latitude grasslands and forests by man. pp. 721 - 736 in 'Man's role in changing the face of the earth.' Ed. W.L. Thomas. Pub. Uni. Chicago Press. Chicago.

Davies, D. E., Emlen, J. T. & Stokes, A. W. 1948. Studies on the home range in the Brown Rat. J. Mammalogy 29, 207 - 225.

Davis, D. E. 1953. Analysis of home range from recapture data. J. Mammalogy 34, 352 - 358.

Detwyler, T. R. & Marcus, J. 1972. Urbanisation and environment in perspective. in 'Urbanisation and environment' Eds. Detwyler and Marcus. Pub. Belmont, California, Duxbury Press.

Diamond, J. M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of nature reserves. Biological Conservation 7, 129 - 146.

Diamond, J. M. 1975 Assembly of species communities. in 'Ecology and evolution of communities' Eds. Cody, M. C. & Diamond, J. M. pp. 342 - 444. Pubs. Belknap, Cambridge, Mass.

Diamond, J. M. & May, R. M. 1976. Island biogeography and the design of nature reserves. in 'Theoretical ecology, principles and applications' Ed. May, R. M. pp. 163 - 186. Pubs. Blackwell, Oxford.

Elton, C. 1958. The ecology of invasions by animals and plants. Longmans, London.

Emlen, J. T., Hine, R. L., Fuller, W. A. & Alfonso, P. 1957. Dropping boards for population studies of small mammals. J. Wildlife Management, 21, 300 - 314.

Emlen, J. T. Stokes, A. W. & Davis, D. E. 1949. Methods for estimating populations of Brown Rats in urban environments. Ecology, 30 , 430 - 442.

Evans, F. C. 1942. Studies of small mammal populations in Bagley Wood, Berkshire. J. Anim. Ecol. 11 , 182 - 197.

Fitzgerald, B.M., Karl, B. J. & Moller, H. 1981. Spatial organisation and ecology of sparse population of House Mice in a New Zealand forest. J. Anim. Ecol. 50, 489 - 518.

Flowerdew, J. R. 1972. The effect of supplementary food on a population of Wood Mice. (Apodemus sylvaticus). J. Anim. Ecol. 41, 553 - 566.

Flowerdew, J. R. & Gardner, G. 1978. Small rodent populations and food supply in a Derbyshire Ash wood. J. Anim. Ecol. 47 , 725 - 740.

Foreman, R. T., Galli, A. E. & Leck, C. F. 1976. Forest size and avian diversity in New Jersy woodlots with some land use implications. Oecologia, 26, 1 - 8.

Getz, L. L., Cole, F. R. & Gates, D. L. 1978. Interstate roadsides as dispersal routes for Microtus pennysylvanicus. J. Mammalogy, 59 208 - 212.

Gill, A. E. & Bonnett 1973. Nature in the urban landscape: a study of city ecosystems. Pub. Baltimore, York Press.

Gillett, K. 1983. Pers. Comm. Co - ordinator, Bromley Field Study Centre, Bromley, Kent.

Grant, P. R. 1969. Colonization of islands by ecologically similar species of birds. Can. J. Zool. 47, 41 - 43.

Green, R. 1979. The ecology of Wood Mice (Apodemus sylvaticus) on arable farmland. J. Zool. 188, 357 - 377.

Golstein, E. L., Gross, M. & De Graaf, R. M. 1981. Explorations in bird - land geometry. Urban Ecol. 5, 113 - 125.

Hacker, H. P. & Pearson, H. S. 1952. The growth, survival, wandering and variation of the long -tailed field mouse (Apodemus sylvaticus) III Wandering power and distribution. Biometrika. 39, 389 - 413.

Haigh, M. J. 1979. Ruderal communities in English cities. Urban ecology 4, 329 - 338.

Hall, T. 1983. Pers. Comm. Warden, Petts Wood, The Wardens House, Chislehurst Road, Petts Wood, Kent.

Hansson, L. 1971. Habitat, Food and population dynamics of the Field Vole, Microtus agrestis, in southern Sweden. Viltrevy 8, 268 - 375.

Hayne, D. W. 1949. Two methods for estimating population from trapping records. J. Mammalogy, 30, 399 - 411.

Healing, T. D. 1980. The dispersion of Bank Voles (Clethrionomys glareolus) and Woodmice (Apodemus sylvaticus) in dry stone dykes. J. Zoology. 191, 406 - 411.

Howard, W. E. 1949. Dispersal, amount of inbreeding and longevity in a local population of Prairie Deermice on the George Reserve, S. Michigan.

Contrib. Lab. Vertebr. Biol. Univ. Mich. 43 , 1 - 52.

Huey, L. M. 1941. Mammalian invasion along the highway. J. Mammalogy, 22, 383 - 385.

Justice, K. E. 1961 A new method for measuring home ranges of small mammals. J. Mammalogy 42 , 462 - 470.

Justice, K. E. 1961 Nocturnalisation in three species of desert rodents Dissertation Abstracts 21, 708.

Kelcey, J. G. 1975. Oppertunities for wildlife habitats on road verges in a new city. Urban Ecology 1, 271 - 284.

Kendrick, H. L. & Munro, R. J. Pers. Comm. c/o 50 Strathmore Crescent, Benwell, Newcastle upon Tyne.

Kikkawa, J. 1964. Movement, activity and distribution of the small rodents Clethrionomys glareolus and Apodenus sylvaticus in woodland. J. Anim..Ecol. 33 , 259 - 299.

Kroodsma, R.L. 1982. Edge effect on breeding forest birds along a power line corridor. J. Appl. Ecol. 11 361 - 370.

Larthe, Y. 1958. Dyes suitable for use in studies of rat movements. J. Mammalogy. 39, 450 - 451.

Laurie, I.C. 1974 The return of the Dutch natives. Landscape Architecture, 64, 411 - 413.

Leslie, P. H. 1952. The estimation of population parameters by the means of the capture - recapture method. II The estimation of total numbers. Biometrika 39 , 363 - 388.

Levenson, J. R. 1976. Forested woodlots as biogeographic islands in an urban - agricultural matrix. D. Phil. thesis. University of Wisconsin, Milwaukee.

Levenson, J. R. 1981. Woodlots as biogeographic islands in south east Wisconsin in 'Forest island dynamics in man - dominated landscape' Eds. Burgess, R. L. & Shapre, D. M. pp. 13 - 39. Springer - Verlag, N. York.

Lidicker, W. Z. 1973. Regulation of numbers in an island population of the California vole: a problem in community dynamics. Ecological Monographs, 43 , 271 - 302.

Lidicker, W. Z. & Anderson, P. K. 1962. Colonization of an island by Microtus californicus, analysed on the basis of runway transects. J. Anim. Ecol. 31 , 503 - 517.

Mc Harg, I. L. 1971. Design with Nature. Garden City New York. Publ. for the Am. Mus. Nat. Hist. by Doubleday/Nat. Hist. Press.

Macarthur, R. H. 1972. Geographical Ecology - Patterns in the distribution of species. Pubs. Harper and Row, New York.

Macarthur, R. H. & Wilson, E. O. 1963. An equilibrium theory of insular zoogeography. Evolution, 17, 373 -387.

Macarthur, R. H. & Wilson, E. O. 1967. The theory of island biogeography, Pubs. Princeton University Press, Princeton, New Jersey.

Mader, H. J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29, 81 - 96.

May, R. M. 1975. Island biogeography and the design of wildlife preserves. Nature 254, 177 -178.

Maza, B. G., French, N. R. & Aschwanden, A. P. 1973. Home range dynamics in a population of heteromycid rodents. J. Mammalogy. 54, 405 - 25.

Miller, L. S. 1957. Tracing vole movements by radioactive excretory products. Ecology 38, 132 - 136.

Miller, R. S. 1958. A studyof a wood mouse population at Wytham Woods, Berkshire. J. Mammalogy, 39, 477 - 493.

Montgomery, W. I. 1978. Stu ies on the distribution of Apodemus sylvaticus and Apodemus flavicollis in Britain. Mammal Review, 8, 177 - 184.

Montgomery, W. I. 1980 Population structure and dynamics of sympatric Apodemus species. (Rodentia: Muridae.) J. Zoology. 192, 351 - 377.

Moore, N. W., Hooper, M. D. & Davis, B.N. K. 1967. Hedges 1. Introduction and reconnaissance studies. J. Appl. Ecol. 4, 201 - 220.

Myllymaki, A. & Paasikallro, A., Pawakoski, E. & Kanero, V. 1971. Removal experiments on small quadrats as a means of rapid assessment of abundance of small mammals. Annales Zoologici Fennici, 8, 177 - 185.

New, J. G. 1958 Dyes for studying the movements of small mammals. J. Mammalogy. 39, 416 - 429.

Odum, E. P. 1971. Fundemantals of Ecology, 3rd. Edition. Publ. W. B. Saunders Co. Philadelphia, Pennsylvania.

Owen, J. & Owen, D, 1979. Suburban gardens: Englands most important nature reserve ? Environmentlal Conservation 2, 53 - 59.

Oxley, D. J., Fenton, M. B. & Carmody, G. R. 1974. The effects of roads on populations of small mammals. J. Appl. Ecol. 11, 51 - 59.

Palman, D. S. 1977. Ecological impact of interstate 95 on small and medium sized mammals in Northern Maine. Unpub. MSc. thesis, Uni. Maine, Oregon.

Palmer, J. F. 1984. Neighbouhoods as stands in the urban forest. Urban Ecology, 8, 187 - 188.

Pelikan, J. 1971. Quadrat size and density estimation of small mammals. Zool. Listy. 20, 93 - 102.

Pendleton, R. C. 1956. Uses of marking animals in ecological studies: labelling animals with radioisotopes. Ecology 37, 686 - 689.

Pielou, E. C. 1975. Biogeography in'Ecological Diversity'. Publ. John Wiley and sons, New York.

Pollard, E. & Relton, J. 1970. Hedges V. A study of small mammals in hedges and cultivated fields. J. Appl. Ecol. 7, 549 - 557.

Preston, F. W. 1962. The canonical distribution of commonness and rarity. Part III. Ecology, 43, 410 - 431.

Randolph, S. E. 1973. A tracking technique for comparing individual home ranges of small mammals. J. Zoology. 170, 509 - 620.

Randolph, S.E. 1976. Change in home range size of Apodemus sylvaticus with breeding season. J. Anim. Ecol. 46, 653 - 676.

Robinson, W. L. & Falls, J.B. 1965. A study of homing of meadow mice. Am. Mid. Nat. 73, 188 - 224.

Ryan, D. A. & Larson, J. S. 1976. Chipmunks in residential environments. Urban Ecol. 2, 173 - 178.

Sanderson, G. C. 1966. The study of mammal movements - a review. J. Wildlife Management. 30, 215 - 235.

Schodde, R. & Calaby, J. H. 1972. The biogeography of the Australo - Papuan bird and mammal faunal in relation to the Torres strait. In 'Bridge and barrier: the natural and cultural history of the Torres Strait. Eds. D. Walker, pp. 257 - 300. Pubs. National Uni. Aust., Canberra.

Sheppe, W. 1967. The effect of live-trapping on the movements of Peromyscus. Am. Mid. Nat. 471 - 480.

Simmons, A. G. 1979. Biogeography, natural and cultural. Edward Arnold.

Smyth, M. 1966. Winter breeding in woodland mice, Apodemus sylvaticus and voles, Clethroinomys glareolus and Micortus agrestis near Oxford. J. Anim. Ecol. 35, 471 - 485.

Southern, H. N. 1973. A yardstick for measuring populations of small rodents. Mammal Review, 3, 1 - 10.

Tanton, M.T. 1965. Problems of live - trapping and population estimation for the Wood Mouse, Apodemus sylvaticus. J. Anim. Ecol. 34, 1 - 22.

Tanton, M. T. 1969. The estimation and biology of the populations of the Bank Vole Clethrionomys glareolus and the Wood mouse Apodemus sylvaticus. J. Anim. Ecol. 38, 511 - 529.

Tapper, S. C. 1976. Population fluctuations of field voles, Microtus: a background to the problems involved in predicting vole plagues. Mammal Review 6, 93 - 117.

Terborgh, J. W. 1975. Faunal equilibrium and the esign of wildlif preserves in 'Tropical Ecological Systems: Trends in terrestrial and aquatic research. Eds. Golly, F. B. & Medina, E. Pubs. Verlag, New York, Academic Press.

Twigg, G. I. Marking mammals: Chapter III in 'Techniques in Mammalogy', pp. 101 - 116.

Watts, C. H. S. 1966. The ecology of woodland voles and mice with special reference to movement and population structure. D. Phil. thesis: Oxford University.

Watts, C. H. S. 1970. Long distance movement of Bank voles and Wood mice. J. Zoology. 161, 247 - 256.

Wegner, J. F. & Merriam, G. 1979. Movements by birds and small mammals between a wood and adjoining farmland habitats. J. Appl. Ecol. 16, 349 - 357.

Williamson, R. D. & De Graaf, R. M. 1975. Habitat associations of ten bird species in Washington D.C. Urban Ecol. 1 , 125 - 135.

Willis, E. O. 1974. Populations and local extinctions of birds on Barro Colarado Island, Panama. Ecol. Monographs. 44, 153 - 169.

Wilson, E.O. & Simberloff, D. A. 1969. Experimental zoogeography of islands (4 parts) Ecology 50 , 267 - 314.

Wilson, E.O. &Willis, E.O. 1975. Applied Biogeography: The design of nature reserves. In. 'Ecology and Evolution of communties' Eds. Cody, M.L. Diamond, J. M. PP. 522 - 534. Pubs. Harvard Uni. Press., Cambridge, Mass.

Wolton, R. J. 1983. The activity of free ranging Wood Mice, Apodemus sylvaticus . J. Anim. Ecol. 52, 781 - 784.

Yalden, D. W. 1980, Urban Small mammals. J.Zool. 191, 403 - 433.

Zedja, J. & Holisova, V. 1971. Quadrat size and prebaiting effect in trapping small mammals. Annales Zoologici Fennici. 8, 14 - 16.

CORRIGENDA: ADDITIONAL REFERENCES.

Gurnell, J. 1978. Observations on trap response in confined populations of Wood Mice, Apodemus sylvaticus . J. Zool. 185, 279 - 287.

Heinrich, D. 1978. Untersuchengen zur Vehrsopferrate bei Saugetieren und Vogeln. Die Heimat 8 , 192 - 208.

Webb, N. R. and Haskins, L.E. 1980. An ecological survey of heathlands in the Poole Basin, Dorset, England. Biological Conservation 17, 281-296.

Woodward, T. N. 1975. Deer - vehicle accidents. Colorado Game Reserve Review. 8 - 12.