The diet and habitat utilisation of the badger (Meles meles) in an area to the South of Durham city

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The diet and habitat utilisation of the badger (*Meles meles*) in an area to the south of Durham city

by

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CONTENTS

ABSTRACT

The study investigates the diet and habitat utilisation of five badger clans in an area of mixed woodland, pasture and arable land between mid May and mid July 1992. During the study period 244 faecal samples were collected and analysed to determine the badgers' diet. Bait marking was used to determine the extent of each clan's home range. Badger diet was then compared with prey availability.

The diet consisted predominantly of earthworms. A variety of other invertebrates and cereal were also taken. Earthworms were found to be consumed in greater volume on 'worm nights' than on 'non-worm nights' and this was the only correlation found between availability in the territory and presence in the diet for any of the prey types taken.

There was a negative relationship between the percentage frequency of occurrence of cereal and earthworms in the diet. This coupled with the fact that the only badger clan with no cereal available in its territory consumed a significantly greater volume of earthworms than the other clans suggested that there was a relationship between earthworms and cereal in the diet, with badgers replacing one staple food by eating more of another staple food according to availability.

The sizes of Coleoptera, larvae and Hymenoptera in the diet were compared with the sizes of these prey items available in the habitat. The results clearly showed that badgers were selecting against the sizes that were commonly available to them. They took significantly more of the larger prey items (>10mm) than if they were taking them in proportion to their availability in the habitat.

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1.0 INTRODUCTION

An animal's home range is the area over which it moves during the course of its activities. The home range must satisfy the animal's biological requirements and there is consequently a relationship between home range, size and body weight of individuals, group size, and prey abundance, mobility and distribution. Animals, such as carnivores, which actively search for their mobile or widely distributed food occupy home ranges that are, on average, four times larger than the home ranges of browsers that crop their food.

Badgers are large, clan living animals widely distributed throughout Britain. They are omnivorous and therefore feed on both mobile and sedentary prey. Badger density is a function of group size and territory size (Kruuk 1978a,b). Results of a study by Kruuk and Parish (1982) indicated that badger group size increases with the quality of food patches (i.e. amount of food per patch), whilst territory size is a function of dispersal of patches (related to climate and heterogeneity of the habitat).

Previous work by Kruuk and Parish (1981) has shown that badgers take consistently high levels of earthworms (*Lumbricus* spp.) in terms of both frequency and volume. Other prey items were taken in proportion to availability. It has been suggested that the size of badger territories is related not to the total biomass of the animals' main food, earthworms, but to the distribution of places where this food is available at night (Kruuk 1978a; Kruuk and Parish 1982).

A predator exploiting worms on the surface would need a range encompassing different habitats and different microclimates in order to have worms available as often as possible during the different seasons and weather types. Such a defended range could be occupied by one predator but the minimum range size in this case covering various habitats would have a contorted outline, with a higher ratio of border to surface area. A more efficient strategy would be to occupy, with several conspecifics, an area approaching a hexagonal shape, with a consequently more defensible border (Kruuk 1978a).

Although Kruuk and Parish (1982) found no correlation between territory size and the number of badgers inhabiting the territory (group size) the overall badger density increased strongly with earthworm biomass. The mechanism by which worm biomass may affect badger numbers is not yet known and it must be noted the worm biomass and productivity is vastly in excess of what the badger population is estimated to consume (Kruuk 1978a; Brown 1983).

The relationships between badger population size, dispersion and food resources are likely to hold only when badgers are not persecuted and where they have adequate places for digging their setts (Kruuk and Parish 1982).

This study aims to use faecal analysis to determine badger diet and to compare the food eaten with that available in a habitat comprising mixed arable farmland and deciduous woodland in County Durham. Badger diet will be investigated in terms of prey types taken and their relative frequency and volume within the diet. The home range of each badger clan within the study area will be assessed so that the type and proportions of habitat available to each clan can be calculated. Measurements of prey availability in each habitat type will allow a comparison to be made between the prey types (and their relative abundance) available to badgers in each territory. By comparing the food eaten by each clan with the food available to that clan, the degree of selectivity by badgers in the study area can be assessed and compared with the findings of Kruuk and Parish (1981).

1.1 Biology of the badger

The European badger (*Meles meles*) is a member of the family *Mustelidae* and is the only species of badger inhabiting Britain. They are the largest British carnivore and are powerfully built animals with a relatively small head, a thick, short neck, a long, wedge-shaped body and a stumpy tail. The legs of the badger are short but extremely strong and each foot has five toes. They have long, sharp claws, especially on the front feet and together these characteristics make the animal an efficient digger, capable of moving heavy material in confined areas. It is difficult to distinguish males (boars) from females (sows) in the field but boars do have a much broader head and thicker neck.

Although classified as a member of the Carnivora, the badger is in fact an omnivore and this is illustrated in the dentition. The incisors, canines and front premolars are typical of a carnivore, whilst the last premolar and the molars are flattened and modified for crushing and grinding like the teeth of a typical herbivore (Neal 1948, 1962, 1966, 1977; Kruuk 1989; Corbet and Harris 1991).

Being remarkably adaptable to a great variety of habitats, badgers are widespread throughout Britain and Ireland (Corbet and Harris 1991). However, their density is very variable due to requirements for suitable soil for digging, adequate food supply, sufficient cover for protection and freedom of disturbance from man and his activities.

The genus *Meles* appears to have evolved in temperate forests of Asia and spread into Europe. Primitive forms were present in the early Pleistocene. By the early Middle Pleistocene, badgers in Europe were very similar to modern forms. The earliest record for Britain is a 250,000 years old fossil from Cambridgeshire (Cowan 1955). Badgers have probably inhabited the North-east of England in fluctuating numbers throughout historic times. Bones of the badger have been found in a number of ancient caves in County Durham.

Since the First World War numbers of badgers in Britain steadily increased, reaching a peak in about 1960. After that, numbers fell mainly due to human activities, including road and rail accidents, persecution from gamekeepers, farmers and rabbit trappers, poisoning from highly toxic organochlorine cereal seed dressings (Jefferies 1969) and badger digging and baiting, shooting and gassing (Paget and Patchett 1978). Legislation (Badgers Act 1973) helped recovery but recently persecution has caused a dramatic drop in some regions particularly in parts of Yorkshire, the Midlands, Essex and S. Wales.

Badger densities vary immensely from habitat to habitat and also fluctuate on a seasonal and yearly basis. In the better habitats there can be up to twenty adults per km^2. A typical density where badgers are common is around ten adults per km^2.

The burrow system of a badger is known as a sett, provides shelter during the day and is also used for breeding. A sett consists of a system of tunnels and chambers and typically has three to ten entrances, although very large setts can have as many as forty or fifty. Chambers are usually lined with bedding which may consist of grass, bracken, straw, leaves or moss and appears to prevent heat loss. A badger sett can be distinguished from a fox's earth by the much larger heaps of soil outside the entrance and the presence of vegetation in the excavated soil.

The entrances to the sett are typically 300 to 350mm in diameter. Large rabbit holes can achieve a diameter similar to this but within a short distance of the entrance the tunnels narrow to about 150mm. The spoil heap or mound of earth outside each entrance can be very large, may contain up to $40m^3$ of soil weighing several tonnes and may have been excavated by generations of badgers.

The type of soil is an important factor in the choice of site. Sandy soil is normally preferred to clay as it is easy to dig, is dry and therefore relatively warm and there is less danger of the roof collapsing. Chalky strata are also used by badgers because these provide excellent drainage and are well protected by the hard rock. However, where the chalk is very hard softer strata will be chosen if available.

Another important factor in site choice is the presence of some kind of cover near a sett. Cover allows badgers to emerge inconspicuously and explains why badgers show a marked preference for deciduous woods and copses. Hedgerows and scrub are also frequently used as sites. Coniferous woodland contains comparatively few setts, probably due to a lack of ground cover and the scarcity of suitable food.

The vast majority of setts (88%) are dug on sloping land. This facilitates removal of the excavated soil, which spills down the slope and as sloping land is also usually well drained the sett is more likely to be dry and warm. The mound which forms outside the entrance builds up to form a platform. This formation catches wind eddies from any direction, so danger can be assessed by scents without the badger exposing itself fully (Neal 1977).

Near any occupied sett there is a well marked system of paths. These lead from active entrances to places of importance such as outlying setts, main feeding grounds, dung pits and drinking places. Constant trampling of paths may denude them of vegetation and distinct paths can often be followed in woodland for several hundred metres. Paths often follow man-made boundaries like fences, hedgerows and footpaths.

Badgers form social groups called clans comprising an average of six individuals, normally consisting of both boars and sows. The term clan denotes a number of individuals collectively inhabiting and usually defending an area. The individuals are usually though not always, related and do not necessarily travel together (Kruuk 1989). Each clan occupies a territory which is actively defended particularly during the first part of the year.

Faeces are usually deposited in funnel shaped dung pits about 150mm deep and with a similar diameter at the top. The pits are not covered after use and several may be dug close together. Such an aggregation of pits is called a latrine. About 70% of badger latrines are located on or near the territorial boundary and some dung pits are usually also found within 20m of the sett. Studies have been carried out to show that badgers mark their territories and that latrine use reflects territoriality (Kruuk 1978b; Cheeseman *et al.* 1981) and the findings of Kruuk (1978a) and Pigozzi (1990) both show that badgers defecate most frequently near the boundary of the territory.

Badgers have quite an extensive vocal repertoire which they use as a means of communication. However, scent is probably the most important means of communication both within and between social groups. There are various sources of scent including the subcaudal glands, the anal glands, sweat and sebaceous glands, urine and interdigital glands.

The large subcaudal gland is important in the maintenance of territory and in individual recognition within a social group. The anal glands of the badger are paired sac-like structures that produce a strong smelling, orange secretion which is frequently deposited with faeces at latrines. Davies *et al.* (1988) stated that there was little doubt that one primary function of anal secretion is to signal species identity. Their results also provide some evidence that anal secretion contains information about group identity and that the secretion would be well suited to long-term signalling. This is consistent with the idea that it is deposited around territory boundaries for the purpose of territory defence.

Badgers are largely crepuscular and nocturnal, emerging from the sett usually around dusk from May to August and after dark at other times. Although there is no true hibernation, emergence and activity are reduced in winter, especially in the north. During periods of severe frost badgers can survive underground for several days with no food. In secluded places daylight appearances are not unusual and badgers may lie in undergrowth away from the sett, particularly at times of drought and food shortage.

The home range is an area over which an animal normally travels in pursuit of its routine activities and is an area with a certain productivity that meets the energy requirements of the individual, or group, that occupies it (Jewell 1966). The range, or home range of the badger is a defended area, a proper territory in the accepted sense of the word. The ranges of individual badgers tends to be smaller than that of the whole clan or group who live more or less together in one main sett.

Various methods have been used to calculate badger home ranges. These include radio tracking and bait marking (Parish and Kruuk 1982). Kruuk (1978b) used bait marking and radio tracking to calculate the home ranges of badgers in Wytham Woods near Oxford. An average range of 80 hectares was found, with one being only just over 20 hectares in size. Work carried out in Scotland (Kruuk 1989) found badger ranges here to be larger than in Wytham Woods, with ranges of between 100 and 300 hectares. Home range size seemed to be related to food availability, in the Scottish study areas Kruuk found that a badger had to walk further to get to a good feeding site, compared to an animal living in Wytham.

With radio tracking a map can be drawn for each animal showing locations where it has been observed. A convex polygon drawn around all these observation points forms the area that lies in the badger's home range over that period.

The technique of bait marking involves leaving food marked with chopped-up plastic outside a sett. The following day this plastic (having passed through the digestive tract of a badger) can be recovered from latrines. Most latrines are located on territory borders so by using different coloured plastic for each sett a picture of each home range can be built up.

In every badger range the animals may use several feeding areas. Different parts of the range will be good feeding sites at different times and each site may gave periods when no food is available to the badgers. Badgers catch worms on the surface at night. When feeding in grassland, their foraging efficiency is related to grass length. Within their ranges, badgers avoid pasture with long grass which has relatively low worm densities and because it creates difficulty in finding and catching worms (Kruuk *et al.* 1979).

Kruuk and Parish (1982) suggested that the size of territory is related not to the total biomass of the badgers' main food, earthworms, but to the distribution of places where this food is available. This fits in with the resource dispersion hypothesis (Macdonald 1983) where territory size is related to dispersion of food patches. From this territories should be larger where patches are more dispersed. However, several observations by Kruuk and Parish (1987) were not compatible with the resource dispersion hypothesis and their study found that some changes in territory size were not related to food as a resource.

Territory boundaries are clearly marked and may be aggressively defended. Paths often radiate from setts but also occur exactly on the border between ranges. Border paths and latrines are scent marked and tussocks are also used for marking. Badgers spend a great deal of time on their boundaries and invest a lot of time and energy defending their active ranges. They are intensely territorial, more so than most other carnivores and can be very aggressive towards their neighbours (Kruuk 1989). If a badger should lose only a small part of its area, it might lose a vital patch of food which could make the whole home range non-viable.

Although territory size appears to be related to the distribution of food, this does not necessarily mean that it is only the food resource that is being defended. Fighting only occurs between badgers of the same sex, boars only fight boars and sows only fight sows. This suggests possible sexual competition and Kruuk (1989) has observed competition between females for a male rather than fights over food. It is also possible that a territory is defended because of the importance of knowledge of the distribution of resources within the area rather than the resources themselves. It is probably necessary for a badger to know an area very well in order to exploit it efficiently (Kruuk 1989).

A considerable amount of research has been carried out on the diet of the badger. Earthworms appear to be the most important item in the diet (e.g. Kruuk 1978b; Ashby and Elliot 1983; Henry 1985; Neal 1988), though as badgers are largely opportunistic foragers earthworms and other foods are taken according to availability. Therefore their diet varies with geographical location, habitat types present within their territory, the season and prevailing weather conditions at any particular time.

Dietary information can be obtained from direct observation, stomach content analysis and faecal analysis, the later two methods being the main ones used.

Determination of diet from analyses of stomach contents has several disadvantages (Neal 1977). Many corpses are obtained from road accidents occurring as badgers are leaving the sett at dusk to go foraging, so their stomachs will be empty. The primary disadvantage of stomach analysis is that not enough animals are ever killed to enable useful comparisons to be made between particular localities.

Dung analysis has important advantages. Material can easily be collected in large quantities throughout the year. This means there is an opportunity to compare the food actually eaten with what is available in the habitat and so determine any element of choice or preference. Also the diet of badgers from a wide range of habitats and geographical locations can be compared.

There have been many studies of the food of the badger in Europe. Studies in France have been carried out by Henry (1985) and Mouches (1981). Both of these studies showed by the use of faecal analysis that earthworms predominated in the diet. Mouches showed there was a seasonal preference for earthworms but that the badger also took a wide range of other food items. Henry found that the diet consisted largely of earthworms except during summer when they were not available and then toads (*Bufo* spp.) were taken as an alternative. Other prey items taken included beetles (Coleoptera), fruit, fungi and Hymenoptera.

Skoog (1970) in a study of the diet of the Swedish badger found that their feeding habits were affected by the availability of food. This was illustrated by variations between different seasons, years and areas. Kruuk and de Kock (1981) used faecal analysis to look at the frequency of occurrence of different foods in the diet of the badger in northern Italy. The most important prey item at all times of year was found to be fruit (particularly olives (*Oleaceae*)). Earthworms, arthropods, gastropods and various vertebrates were also taken.

Lups *et al.* (1987) carried out a study of the stomach contents of badgers in central Switzerland over a period of ten years (1973 to 1982). They found earthworms to be the most important prey item accounting for 25% by volume of stomach contents and occurring in 54% of stomachs. Although earthworms were eaten frequently they were often in small volumes, whilst other prey items e.g. wasps (Hymenoptera), cherries and plums (*Prunus* spp.) and maize (*Zea mays*) were taken infrequently but in larger volumes.

In Britain most recent studies have found that earthworms were the major food source of badgers (e.g. Kruuk 1978a; Kruük and Parish 1981; Neal 1988). Early studies may not have recorded earthworms in badger faeces as they were thought to be entirely digestible and to leave no traces in the dung (Davies 1936). Although dung analysis carried out by Davies ignored the earthworm content other prey items found included rabbits (Lagomorphs), beetles, wheat (*Agropyrum* spp.), oats (*Avena* spp.) and acorns (*Quercus robur*). Observation indicated that as well as earthworms, bee and wasp nests (Hymenoptera), birds eggs and poultry were also taken.

In fact, earthworms are not entirely digested and their chaetae and gizzard rings are easily detectable in badger faeces. The number of chaetae found can be correlated with the number of earthworms ingested (Kruuk and Parish 1981) to give an accurate estimate of earthworm consumption. However Bradbury (1977) favoured the technique of counting the absolute number of gizzard rings in the faeces. Each earthworm possesses only one gizzard ring, they are macroscopic and easy to identify and ring size can be related to the size of the earthworm.

Major work on the diet of the British badger has been carried out by Kruuk and Parish (1981, 1983). By means of faecal analysis they found earthworms to be the dominant food of badgers in six different areas of Scotland. Other less important foods included rabbits, cereals (taken from fields, farm buildings and places where supplementary feed was provided for livestock). Insects and tubers were often taken and consumed relative to availability. They suggested that badgers change their foraging effort to compensate for fluctuations in earthworm availability, consuming a range of secondary foods opportunistically.

The importance of earthworms in the diet varied little in time and between areas and there was no correlation with availability. The presence of earthworms on the surface depends on the weather so they used the concept of a 'worm night' to help assess earthworm availability. A worm night was defined as being when the temperature did not fall below 0°C and there had been at least 2mm rain during the previous 72 hours.

Work by Harris (1982, 1984) on urban badgers in Bristol showed a different situation since here earthworms were not the major food item in the diet. Harris showed by stomach content and dung analysis that the badgers ate an enormous variety of food and also large quantities of non-food items e.g. grass, dead leaves, paper and polythene food wrappers. They were not specialising in taking any one main food item, although in autumn fruit did predominate. In the urban area the badgers were exploiting a diversity of food types in response to an increased proportion of gardens in their foraging range.

Another British study which does not show earthworms as being the predominant prey type was conducted by Skinner and Skinner (1988). Their study, unlike most others, was carried out in an area where badgers were comparatively rare. Wheat was found to be the major food item and it was suggested that badgers foraged for wheat before it was ready for harvest, that they ate from grain stores and pheasant feeders and that they also gleaned wheat fields after the stubble had been burnt.

Although earthworms were frequently eaten throughout the year they were only taken in relatively small volumes.

Work by Bradbury (1974), Ashby and Elliot (1983), Neal (1988) and Shepherdson *et al.* (1990) all show earthworms to predominate in the diet. Neal examined stomach contents and found that earthworms were taken very frequently and often in huge quantities and to the exclusion of almost any other prey item. Other items were very variable and suggested random foraging. In the autumn there was an increase in plant material, particularly cereal (wheat and oats) and finely ground acorns.

Bradbury (1974), Ashby and Elliot (1983) and Shepherdson *et al.* (1990) all used faecal analysis. Shepherdson *et al.* (1990) worked in southern England and found earthworm intake to be correlated with worm biomass but not the number of worm nights. There was a significant correlation between the amount of time badgers spent foraging in a particular part of their territory and earthworm biomass in that location. They suggested that earthworm consumption was dictated primarily by availability.

Bradbury (1974) investigated the diet of badgers in Yorkshire and Humberside. Earthworms were found to be the predominant food, occurring frequently in the faeces and in large volume. Other prey items included wasp and bumble bee nests, beetles, centipedes (Chilopoda), earwigs (Dermaptera), spiders (Aranae), frogs (*Rana* spp.), birds, birds eggs, acorns, blackberries (*Rubus fruticosus*), windfall apples (*Malus domesticus*), cereals, fungi, bluebell bulbs (*Endymion non-scriptus*) pignuts (*Conopodium majus*) and coal fragments. Grass, clover (*Trifolium* spp.) and dead deciduous leaves frequently appeared in samples and were deemed to be probably accidentally ingested while foraging.

Ashby and Elliot (1983) studied the diet of the badger in County Durham. Earthworms predominated but were reduced in importance from September to February when their was an increased intake of seeds and fruit. Insects were mainly eaten from late spring to mid autumn; small birds and mammals were also a minor component.

1.2 Study aims

The primary aim of this study was to determine the diet of a number of badger clans inhabiting a heterogeneous farmland/woodland habitat and to compare food eaten with food availability in order to assess the degree of selectivity.

Bait marking trials were used to confirm the different areas utilised by the clans and to assess the percentage of each habitat type present within each range. Faecal analysis was carried out to assess the importance of major food types in the diet, over a two month period from mid May to mid June 1992. There was concurrent monitoring of food availability utilising pitfall trapping for invertebrates and earthworm counts. The changing availability of vegetable matter and the climate were also monitored over the study period.

2.0 STUDY AREA

2.1 Location and land use

The study was carried out between mid May and mid July 1992. The study area (174.3 hectares in total) is to the south of Durham city and covers Great High Wood, Hollinside Wood and Houghall Farm (NZ279404) (Fig. 1). Within this area are four major land use types; woodland, arable, pasture and farm buildings. The strip of woodland consisting of Great High Wood and Hollinside Wood is deciduous and approximately 2km long and a maximum of 300m wide. Houghall Farm covers an area of 148.4 hectares and consists of (3%) farm buildings, (29%) arable land (wheat and barley), (65%) pasture (including permanent pasture and silage) and (3%) small stands of trees (deciduous and coniferous) (Figs. 2&3).

All of the fields on the farm were fertilised with Nitram (nitrogen: phosphorous: potassium in a ratio of 20: 20: 10) between February and April (often two or three applications during this period). Crops (spring and winter wheat and spring and winter barley) were also treated with applications of herbicide, insecticide, fungicide, plant growth regulator and feed. while fields of grass did not receive any of these.

The study area is disturbed by human activities in a number of ways. Disturbance is concentrated around the farm buildings but parties of school children are also shown round the farm at intervals. This is restricted to the day time and will therefore have a relatively low impact on resident badgers. The farm workers however cover all parts of the farm and often work well in to the hours of darkness, frequently sighting and presumably causing disturbance to badgers. Another source of human interference on the study area is the recreational use (e.g. walking, jogging, cycling, exercising dogs and horse riding) of the woodland area and the Houghall Discovery Trail (Fig. 1) which covers part of the farm land. In the past badger baiting has been a problem in the area but recently there has been a welcome decline in this activity.

2.2 Geology

Since the ice age the River Wear has cut through an original drift of clay overlying fluvioglacial sand and more recently the river has formed a flood plain of

Fig. 1. The study area.

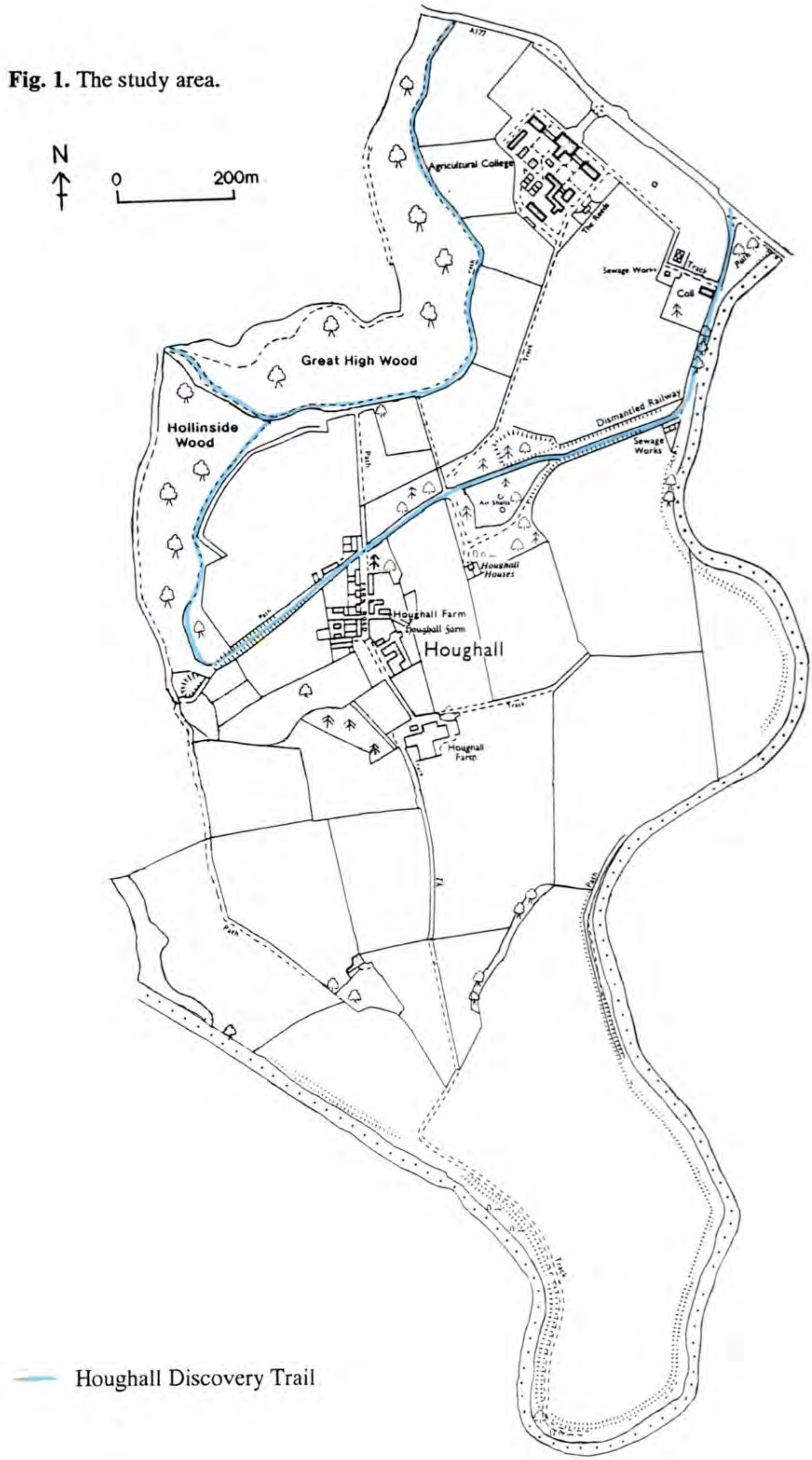


Fig. 2. Houghall Farm - showing field sizes (hectares).

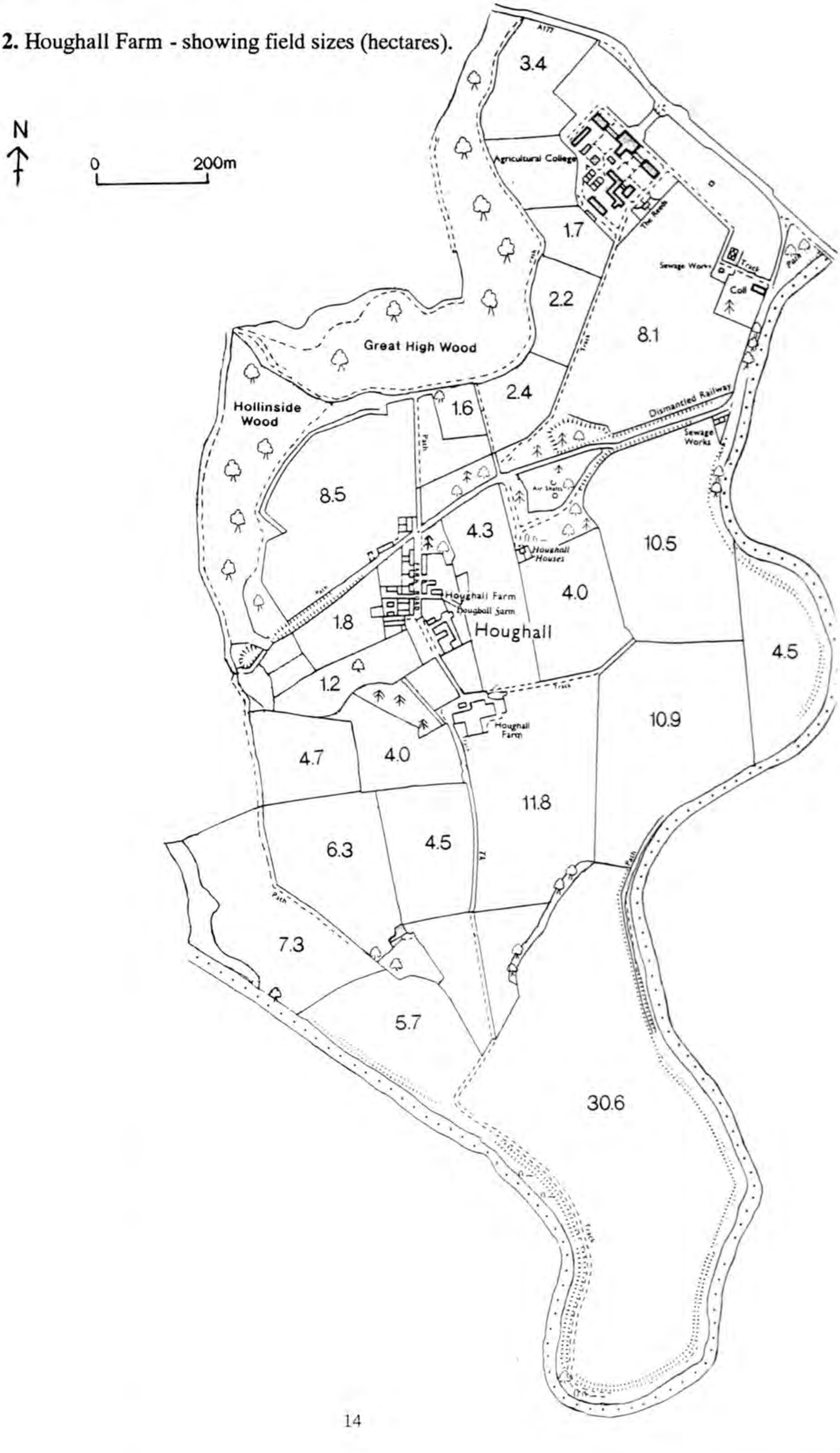
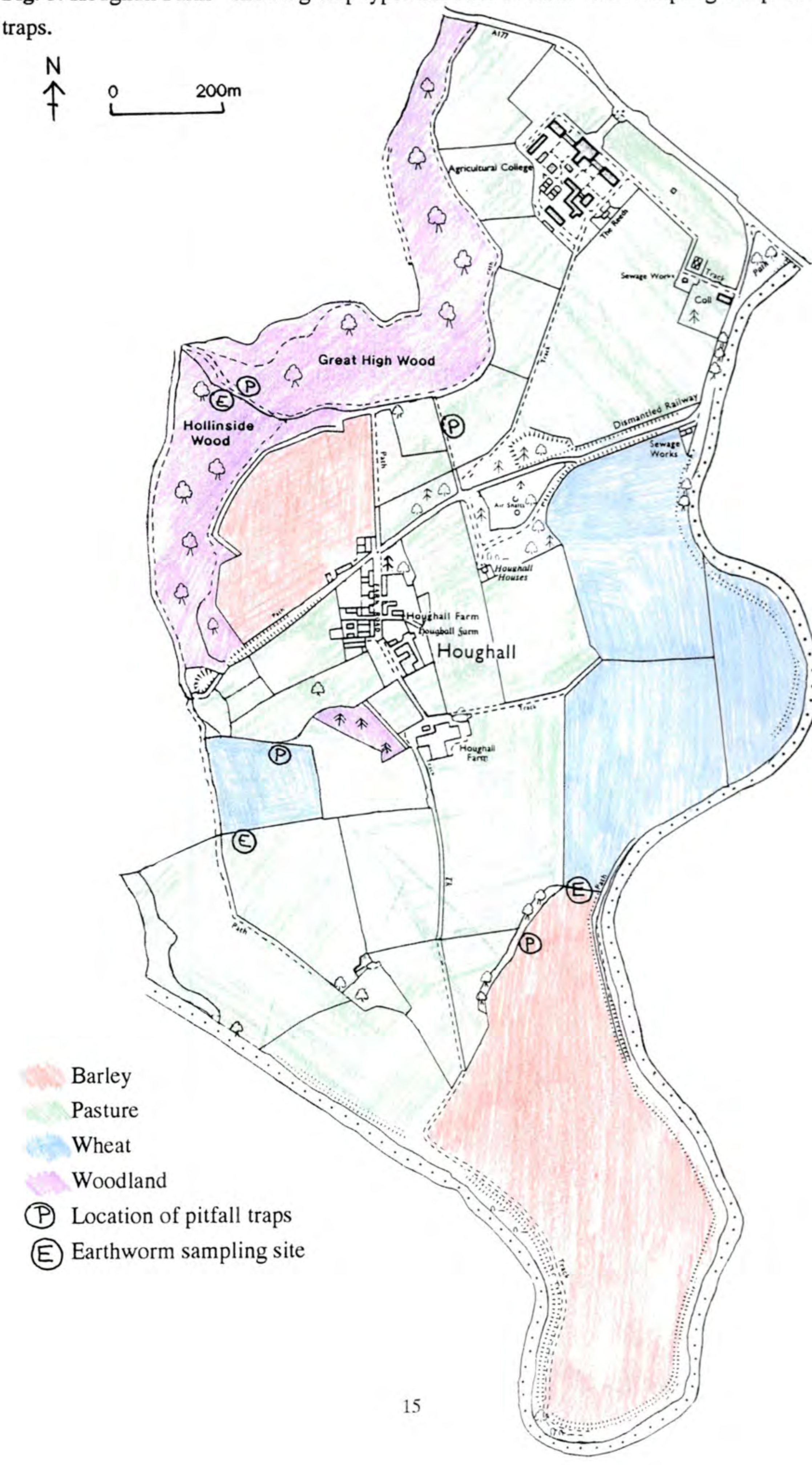


Fig. 3. Houghall Farm - showing crop types and sites of earthworm sampling and pitfall traps.



alluvium and gravel deposits. Within the study area three of these drift deposits are present; alluvium, gravel river terrace deposits and fluvioglacial sand (Fig. 4).

2.3 Sett locations

The variety of land use within the study area provides a range of habitats suitable for badgers. There are extensive slopes provided by the woodland and also on the banks of the river and at the sides of some fields. These slopes are an ideal site for sett digging; facilitating earth removal and drainage. Five badger setts are located within the study area (Fig. 5). As shown on the map the five setts were dug into either the fluvioglacial sand or the alluvium. These are softer and easier to excavate than the gravel river terrace deposits (Bowen-Jones 1970 and Moore 1977). Previous studies by Gunner (1986) and Porteous (1989) have both concentrated on investigating home ranges of badgers in these setts.

2.3.1 Hollinside sett (Fig. 6)

This sett consists of eleven entrances and is situated on a concave, east facing slope in Hollinside Wood. The mature trees near the sett include oak (*Quercus robur*), rowan (*Sorbus aucuparia*), beech (*Fagus sylvatica*), silver birch (*Betula pendula*) and sycamore (*Acer pseudoplatanus*). Other vegetation in the vicinity consists of holly (*Ilex aquifolium*) and elderberry bushes (*Sambucus nigra*), bracken (*Pteridium aquilinum*), bramble (*Rubus fruticosus*), ivy (*Hedera helix*) and dandelion (*Taraxacum* spp.). At the beginning if the study period (mid May) the whole area was covered by a huge number of bluebells *(Endymion non-scriptus*) which made the badger paths particularly easy to see. The bluebells then gradually decreased in number until none were left by the end of July.

2.3.2 Reservoir sett (Fig. 7)

This sett also has eleven entrances and is situated on a steep east facing slope in Great High Wood. It is less conspicuous than the Hollinside sett, being further from a footpath and well hidden by vegetation. The mature trees in the area include oak (*Quercus robur*), beech (*Fagus sylvatica*), silver birch (*Betula pendula*), rowan (*Sorbus aucuparia*) and sycamore (*Acer pseudoplatanus*). The sett entrances are mostly concealed by holly bushes (*Ilex aquifolium*), bracken (*Pteridium aquilinum*) and nettles (*Urtica dioica*). Other nearby vegetation includes bramble (*Rubus fruticosus*), clover

Fig. 4. Geology of the study area.

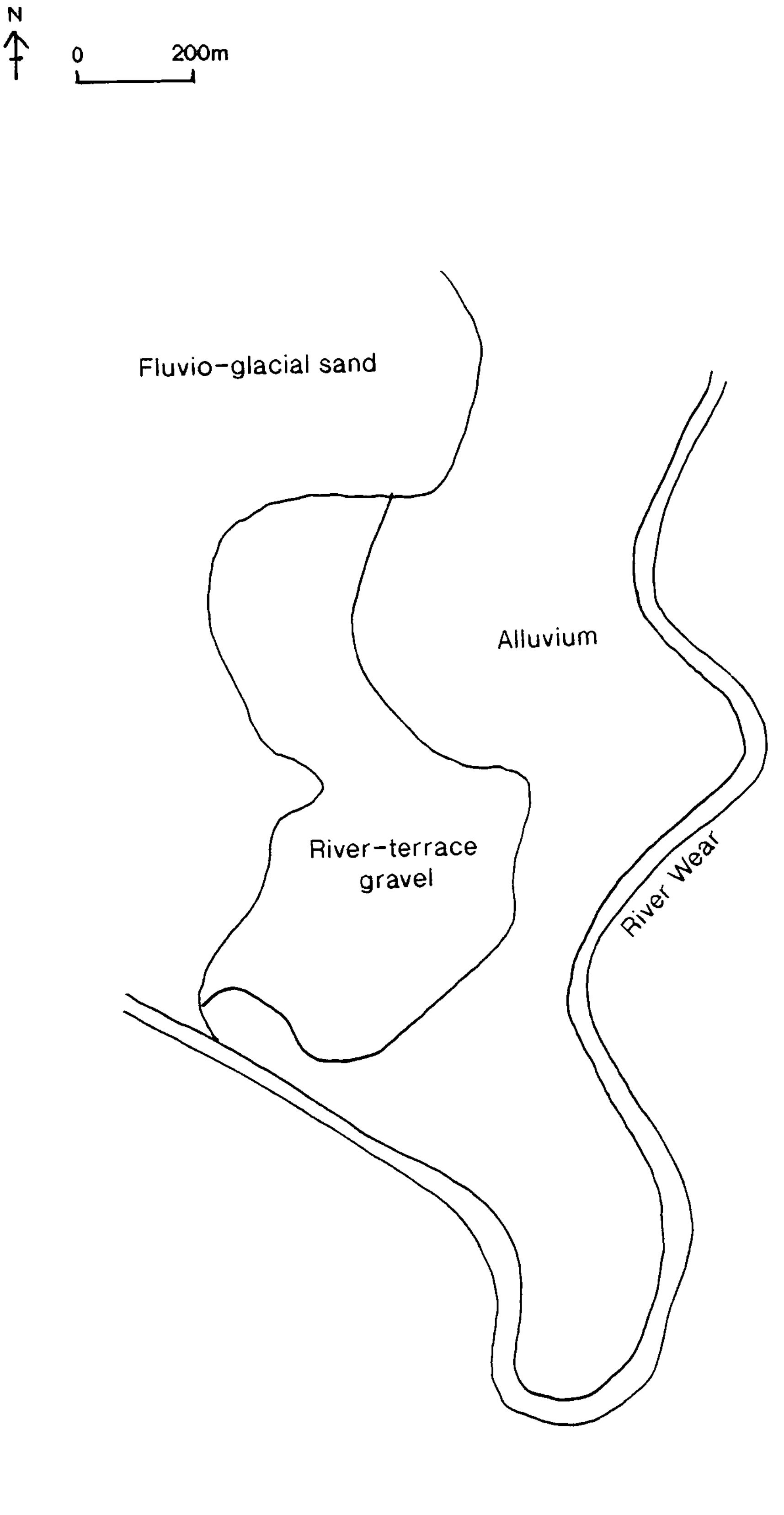


Fig. 5. Position of badger setts and outlying holes.

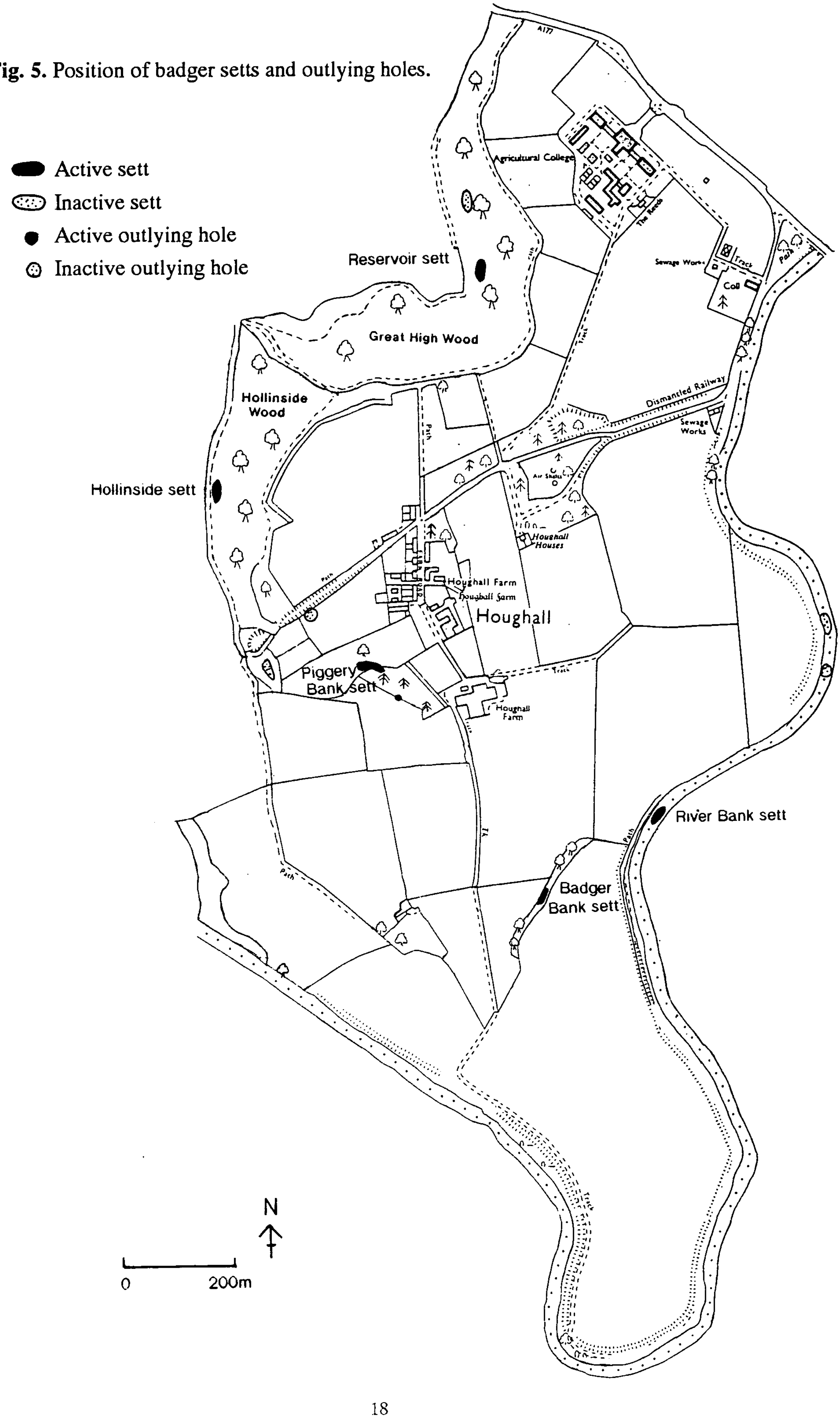


Fig. 6. Hollinside Sett.

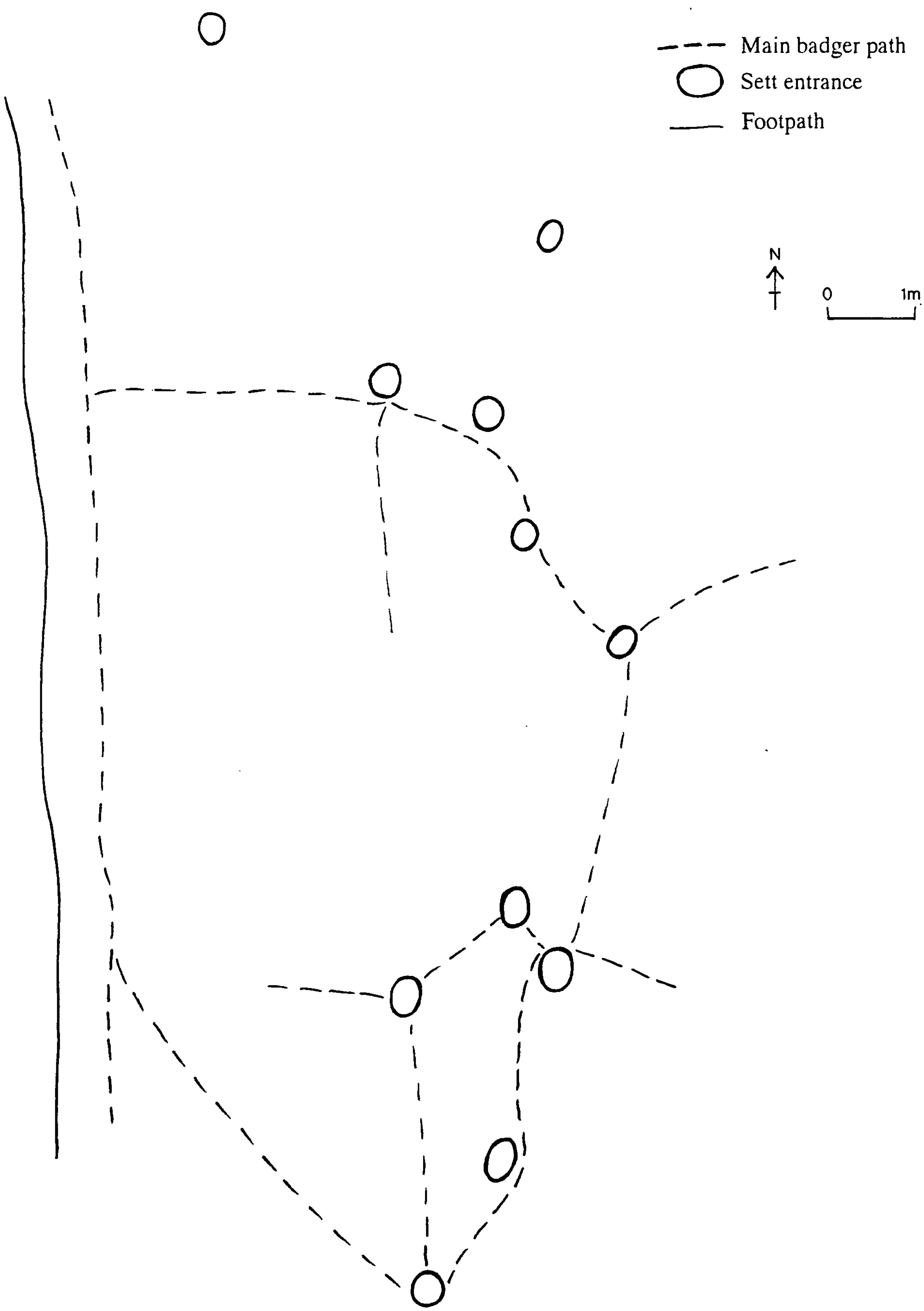
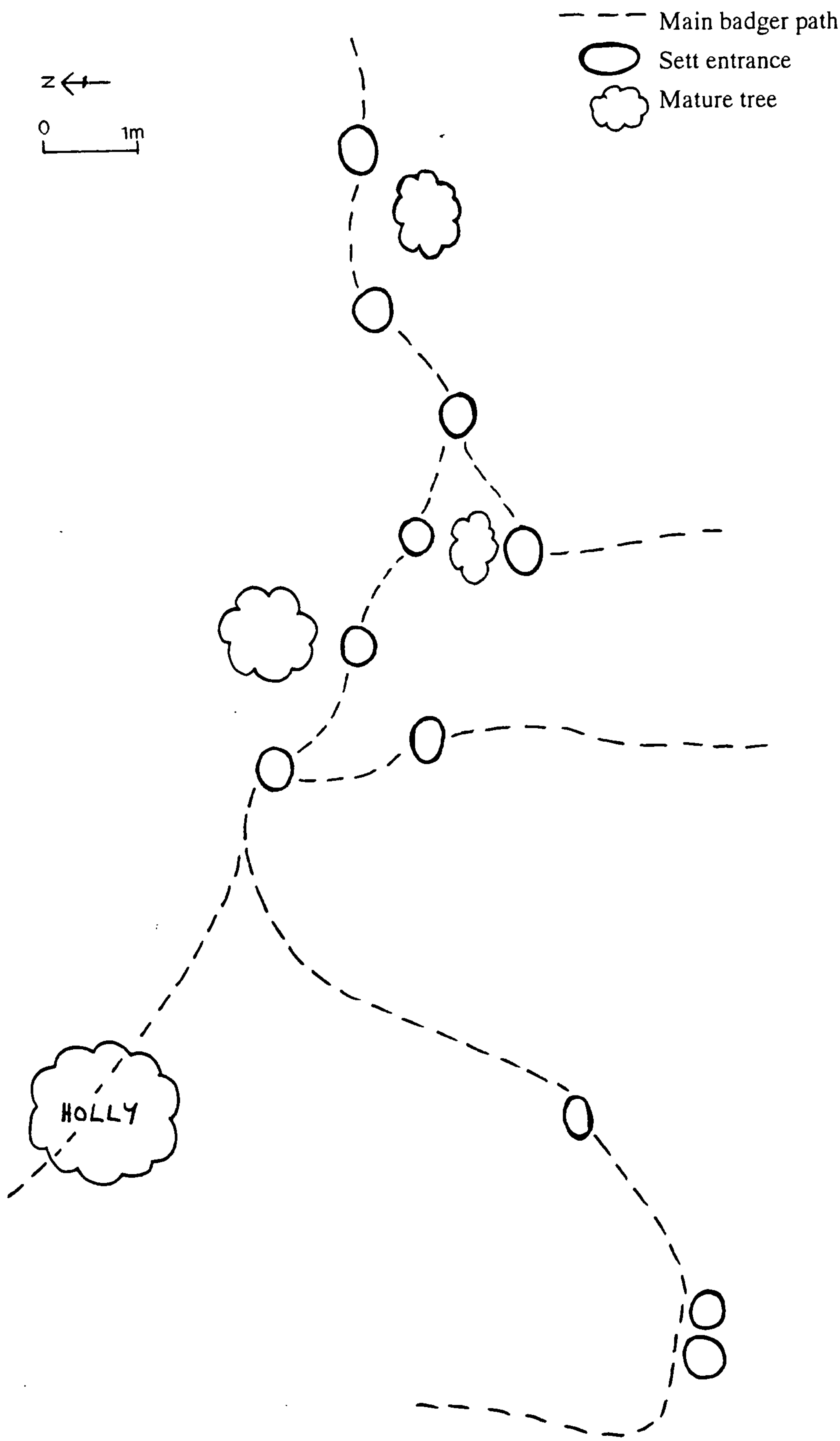


Fig. 7. Reservoir Sett.



(*Trifolium* spp.) and a small amount of grass (*Agrostis* spp.). Like the Hollinside sett there were large numbers of bluebells (*Endymion non-scriptus*) in the area at the beginning of the study period and these lasted for a few weeks, clearly showing badger paths around the sett.

2.3.3 Piggery Bank sett (Fig. 8)

There are a total of fourteen entrances to this extensive sett (two more than were found by Porteous in 1989). The sett is situated mostly on a steep, convex, north facing slope that curves round to the east. Unlike the previous two setts this one is largely located in a grass field with little ground cover and a few mature trees at its base. Six entrances are situated in a stand of young conifers and their low branches provide some cover. Apart from the conifers other trees in the vicinity include oak (*Quercus robur*) and beech (*Fagus sylvatica*). Some hawthorn bushes (*Crataegus monogyna*) are present at the top of the slope along with small amounts of dandelion (*Taraxacum* spp.), thistle (*Cirsium* spp.), nettle (*Urtica dioica*), clover (*Trifolium* spp.), buttercup (*Ranunculus repens*), dock (*Rumex* spp.), stitchwort (*Stellaria* spp.), speedwell (*Veronic*a spp.) and red dead nettle (*Lamium amplexicaule*).

2.3.4 Badger Bank sett (Fig. 9)

This sett has twelve entrances, one of which is very large and is located in a grass field. The other eleven are all on a fairly steep south facing bank in a small strip of trees and dense undergrowth situated between two fields on the farm (one field of grass and one of wheat). The sett is well concealed by tall grasses (*Agrostis* spp.), elderberry (*Sambucus nigra*) and hawthorn bushes (*Crataegus monogyna*). The only mature trees in the area are oak (*Quercus robur*). Vegetation around the sett also includes thistle (*Cirsium* spp.), nettle (*Urtica dioica*), dock (*Rumex* spp.), bramble (*Rubus fruticosus*), hogweed (*Heracleum sphondylium*), dandelion (*Taraxacum* spp.), cow parsley (*Anthriscus sylvestris*) and red campion (*Silene dioica*). Balsam (*Impatiens* spp.) and quite a lot of bluebells (*Endymion non-scriptus*) were present in May. By July rosebay willowherb (*Epilobium angustifolium*), harebell (*Campanula rotundifolia*), ragwort (*Senecio jacobaea*) and knapweed (*Centaurea* spp.) were also present.

2.3.5 River Bank sett (Fig. 10)

This is the smallest of the five setts with only four entrances. It is situated on a south east facing slope on the bank of the River Wear. It is well concealed by a large amount of vegetation including hawthorn (*Crataegus monogyna*), grass (*Agrostis* spp.), hogweed (*Heracleum sphondylium*), cow parsley (*Anthriscus sylvestris*), nettle (*Urtica dioica*), thistle (*Cirsium* spp), stitchwort (*Stellaria* spp.), ground ivy (*Glechoma hederacea*), dock (*Rumex* spp.), bracken (*Pteridium aquilinum*), campion (*Silene* spp.) and bramble (*Rubus fruticosus*). In June rosebay willowherb (*Epilobium angustifolium*) appeared along with smaller quantities of feverfew (*Tanacetum parthenium*), ragwort (*Senecio jacobaea*) and field scabious (*Knautia arvensis*).

Fig. 8. Piggery Bank Sett.

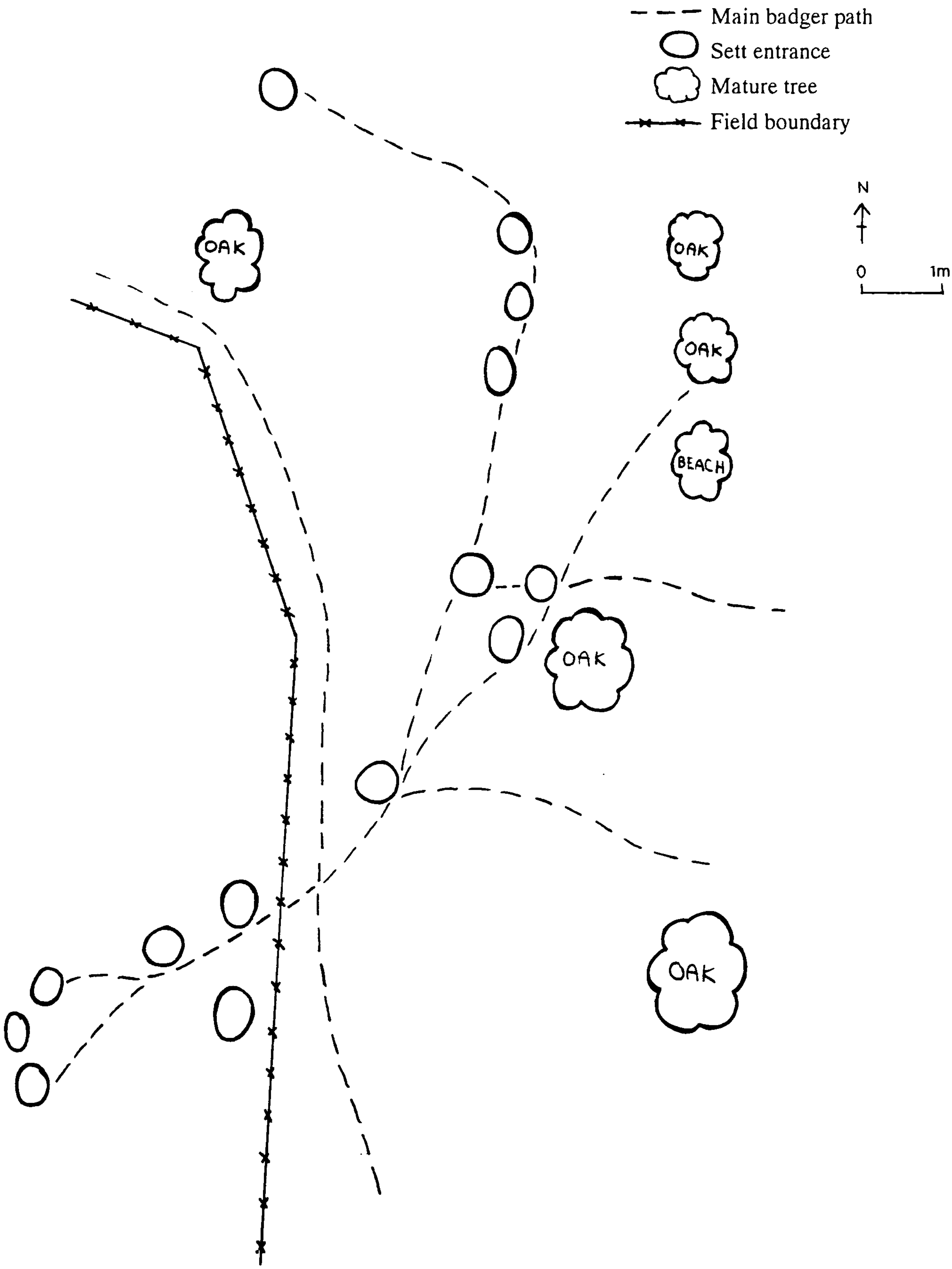


Fig. 9. Badger Bank Sett.

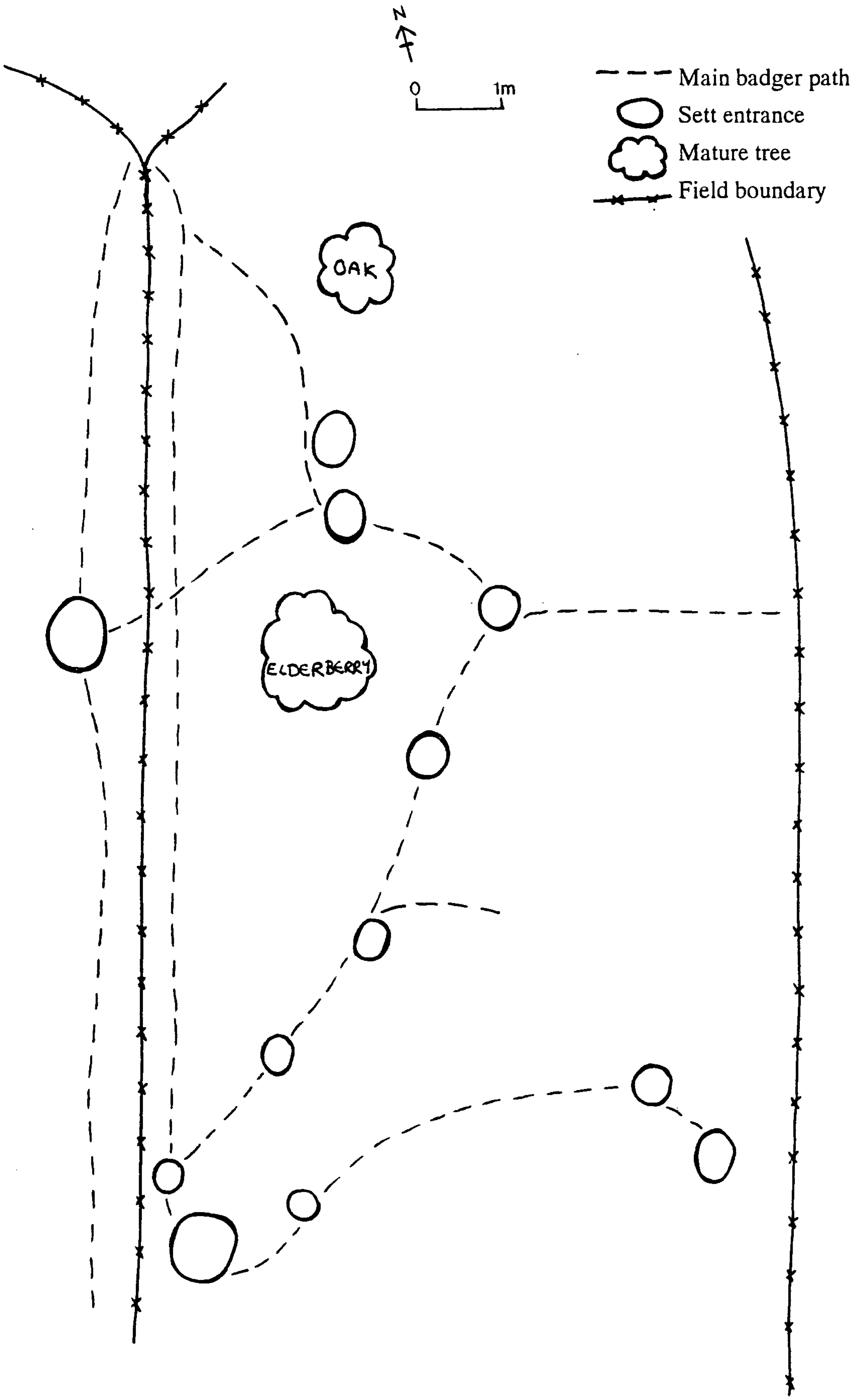
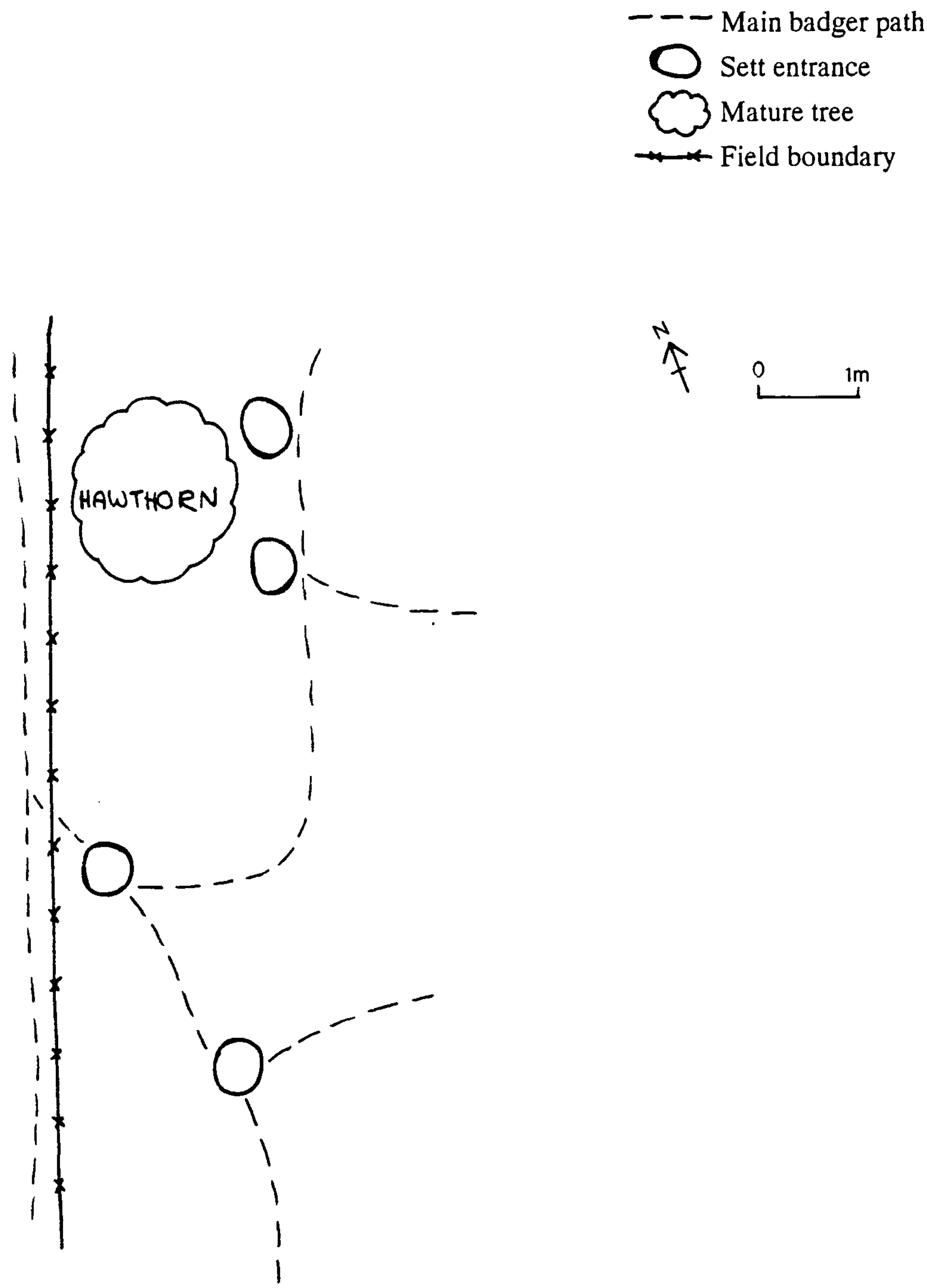


Fig. 10. River Bank Sett.



3.0 METHODS

The study area was searched for badger setts, outlying holes and latrines. These were carefully marked on a map. The setts were named as in previous studies (e.g. Gunner 1986; Porteous 1989) and the latrines were numbered for convenience. Once the setts and outlying holes had been located they were checked for occupancy. Signs of an active, occupied sett include freshly excavated earth at the entrances, badger hair around the entrance of along the badger paths, claw marks on near-by tree trunks, clean entrances free of leaf litter and cobwebs.

A pair of crossed twigs were placed in many sett entrances and these were then checked the following day to see if they had been disturbed. Although disturbance indicates the presence of an animal it is not possible to tell whether this was a badger or another animal e.g. fox or rabbit. Additionally the sticks may have been disturbed by a visiting rather than resident badger. Neal (1948) observed a badger knocking down sticks placed in four separate entrances of an unoccupied sett. Flattening the soil outside a sett and checking for paw prints the following day is also a useful indicator of badger presence, but as with the sticks method paw prints could be left by a visiting badger.

For each active sett that was located a sketch map was drawn to show the number and position of its entrances, nearby landmarks e.g. hedges, fences, mature trees, and the local badger paths (Figs. 6-10).

Latrines were located by searching near each sett and following badger paths. Many latrines were also discovered along footpaths and manmade boundaries e.g. fences and hedgerows. All human and badger paths were followed and all field boundaries and the area around the farm buildings were also searched.

Vegetation around and near to each sett was noted at the beginning of the study period and any changes to this during the time of study were also recorded.

3.1 Bait marking

Badgers defecate in latrines, these are often conspicuous and usually located on the range boundaries or in the vicinity of the sett. If it is known which clan of badgers is using each of the latrines found in the study area then these can be used to give an estimate of the home range for each clan. The method of bait marking (Kruuk 1989) involves feeding the badgers a conspicuous marker which they cannot digest and is therefore evacuated with their faeces and deposited in their latrines.

Small pieces (5mm by 5mm) were cut from brightly coloured plastic bags and mixed with peanuts and honey. A different colour plastic was allocated to each sett; white for Hollinside, red for Piggery Bank, pink for River Bank, blue for Badger Bank, green for Reservoir and yellow for the active outlying hole near Piggery Bank. A spoonful of the peanut and honey mixture and appropriate colour plastic was placed outside entrances to each sett.

The day following baiting scats were found with bits of coloured plastic in them. Bait marking was carried out for all the setts and the outlying hole simultateously a total of ten times throughout the study period (at intervals of approximately one week).

3.2 Dung collection

Each latrine was regularly checked for dung (approximately every other day) between May 11th and July 13th 1992. Any dung found was placed into a plastic bag using a trowel. Each dung sample (scat) consisted of the entire contents of one pit. Each scat was placed in a separate bag with a label recording the date of collection and the latrine number. Collected dung was then placed in a freezer as soon as possible to preserve it for subsequent analysis.

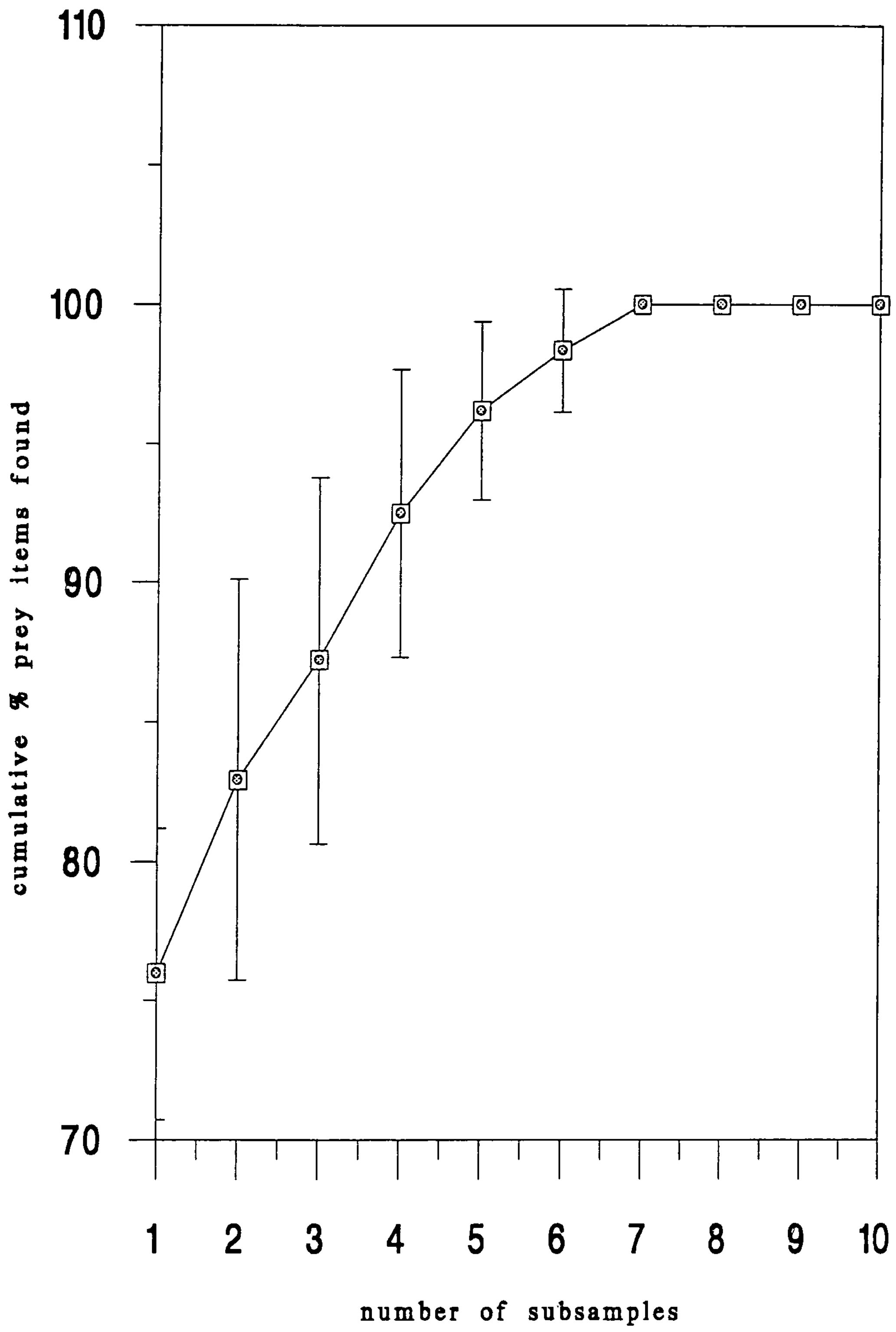
Results of the bait marking made it possible to know how many dung samples had been collected for each clan. By the end of the study period 52 samples had been collected from the Piggery Bank clan, 48 from River Bank, 51 from Badger Bank, 42 from Hollinside and 51 from Reservoir.

3.3 Dung analysis

In the laboratory the samples were defrosted in 2% formalin, then broken up and washed through a 1.3mm mesh sieve (procedure from Kruuk and Parish 1981). The food remains retained in the sieve were thoroughly rinsed, then examined under water in a large, shallow, white dish. They were identified by comparing with a reference collection.

In order to determine the minimum number of samples required for analysis the following procedure was used. For the first ten scats analysed, ten 5g subsamples were taken and the number of different prey items in each subsample was counted. The cumulative percentage prey items found was calculated for each scat. This information was then used to plot a graph showing the number of subsamples needed per scat to obtain 90% of the prey items (Fig. 11). It was found that five 5g subsamples from a scat would between them contain 90% of the prey items present in that scat.

Fig. 11. Number of subsamples needed to obtain 90% of the prey items per sample ($\pm$ 2 s.e.).



Subsequent analyses involved five 5g subsamples taken from each scat. For each subsample the total numbers of each kind of prey were counted, or estimated from the number of remains e.g. gizzard rings of earthworms (one per worm, Bradbury 1977), beetle elytra and skins of caterpillars and other larvae. Secondly, an estimate was made by eye, of the relative volume of each prey type as ingested by the badger. For each sample the estimated relative volume of food ingested was scored on a seven point scale: absent, <5%, 6-25%, 26-50%, 51-75%, 76-95%, >96% (Kruuk and Parish 1981). Additionally, an estimate was made of the size of individual prey items ingested. This was carried out for any larvae, Hymenoptera and Coleoptera in order to make a comparison with sizes caught in the field. Prey were placed into a size class based on their maximum dimension: <3mm, 4-6mm, 7-9mm, >10mm.

3.4 Earthworm abundance

The abundance of earthworms in the badgers' habitat was assessed using the formalin extraction method (Raw 1959; Satchell 1969). The procedure was carried out at ten different locations in each habitat and on three different dates during the study period (June 9th, June 23rd and July 7th).

Sampling was carried out in three habitats; pasture, woodland and arable land. 2l of 0.5% formalin was poured onto an area of $0.25m^2$. During the following twenty minutes this area was watched and any worms appearing on the surface were counted and collected and later weighed in the laboratory.

3.5 Pitfall trapping

Pitfall trapping was carried out to assess invertebrate availability on four different dates (May 28th, June 11th, June 25th, July 9th).

Plastic cups 6.5cm in diameter at the top and 9cm deep were placed in holes dug in the ground. The top of each cup was flush with the ground and 2% formalin was poured in to each cup to a depth of approximately 2cm. Five cups were placed in a line at 5m intervals in each of four habitats; pasture, woodland, wheat and barley, and left for a week before being collected.

At the end of the week they were then taken back to the laboratory where captures were identified, counted and measured. Each item was placed into a size class; <3mm, 4-6mm, 7-9mm, >10mm (based on the maximum dimension).

3.6 Weather

Weather data for the study period were obtained from the geography department of Durham University and included measurements of rainfall and minimum temperatures necessary for worm night assessment.

4.0 RESULTS

Five active badger setts were found within the study area (Fig. 5). Two of these were situated in the woodland area (Reservoir and Hollinside setts) and the other three were situated within Houghall Farm (Piggery Bank, Badger Bank and River Bank setts). The layout of each sett and the badger paths in its vicinity are shown in Figs. 6-10. Clear badger paths could be seen near every sett, often alongside boundaries such as fences and also between the different entrances of a sett.

Fig. 12 shows the twenty one badger latrines that were found within the study area. Some of these were located near setts and the others were all positioned on, or very close to, a man-made boundary e.g. fence, hedge, path.

Bait marking trials were carried out to ascertain the home range of each clan. Bait marking was carried out for all the setts and the outlying hole simultaneously a total of ten times throughout the study period. The results of these trials are shown in Table 1. Coloured markers were recovered from every latrine at some point during the study so each latrine could be attributed to a particular clan. Latrine numbers 2 and 3 both contained faeces with red markers and faeces with yellow markers. The red markers came from the Piggery Bank sett and the yellow markers from the active outlying hole near to this sett. It was concluded that badgers using the outlying hole and the Piggery Band sett were therefore part of the same clan. All the other latrines only ever contained markers of one colour.

Fig. 13 shows the positions where coloured markers were found. Lines were drawn to connect each latrine with the appropriate sett. six latrines could be attributed to the Piggery Bank clan, four to the Badger Bank clan, three to the River Bank clan, three to the Hollinside clan and five to the Reservoir clan. Home range could then be estimated by joining the latrines for each sett together to form a convex polygon (Fig. 14). From this the areas of the home ranges were estimated (Table 2). Badger Bank and Piggery Bank clans were estimated to have the largest and very similarly sized home ranges. The next largest home range belonged to the Reservoir clan. The Hollinside clan was estimated to have by far the smallest home range, being only about one third of the size of the largest home ranges.

The percentages of each habitat type (pasture, woodland, barley and wheat within each territory are shown in Figs. 15a-e. No habitat type is present in all territories and no territory is made up of one habitat alone. Pasture is the dominant

Fig. 12. Position of latrines.

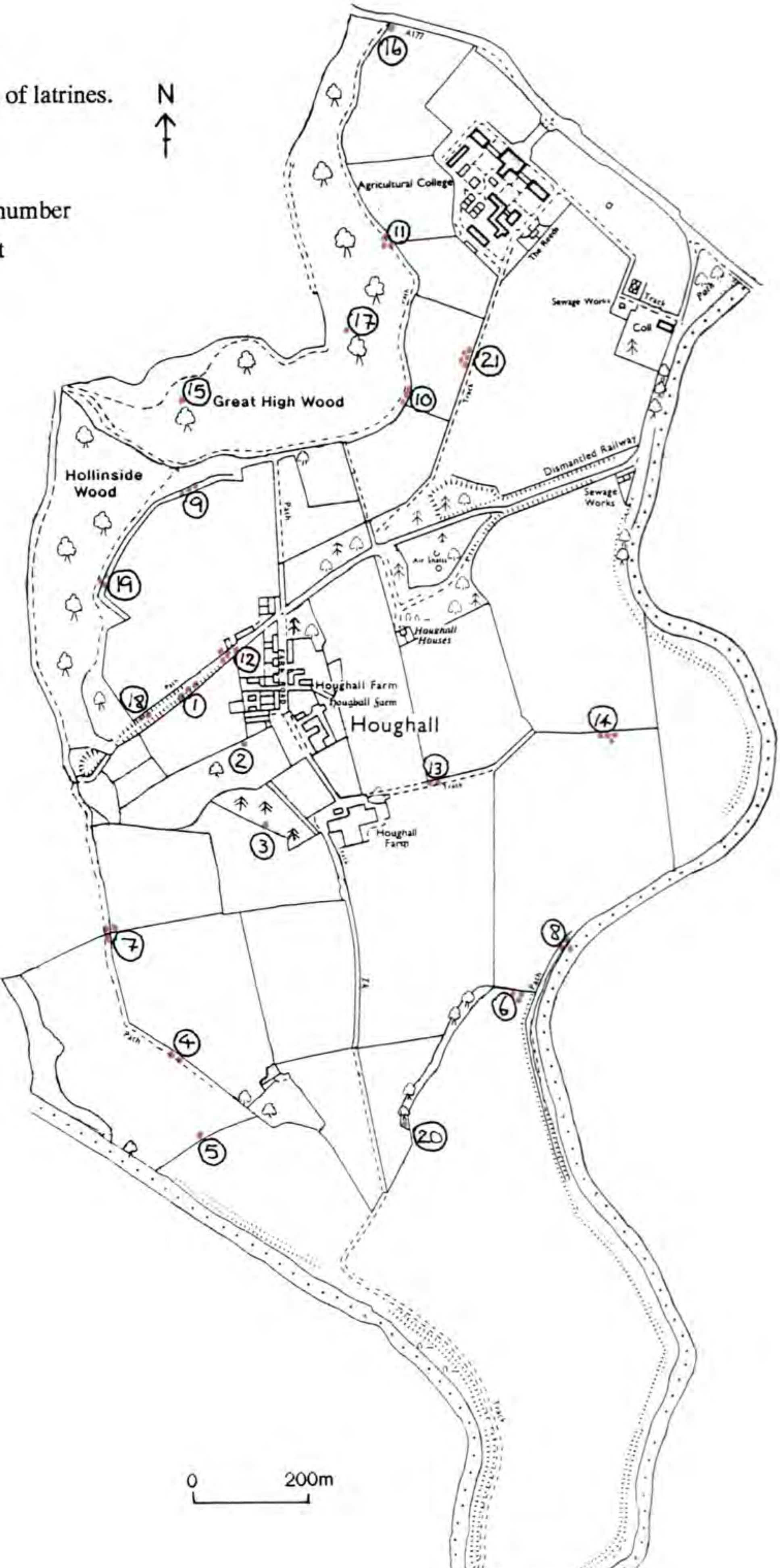


TABLE 1. The dates on which plastic markers were recovered from each latrine (numbered as in Fig. 12) and the colour of these markers.

	May 15th	May 18th	May 25th	May 31st	June 8th	June 15th	June 22nd	June 29th	July 6th	July 13th
1			R	R						
2					Y				R	
3						Y	R			R
4				B	B				B	
5							B			
6					B					
7	R	R							R	
8			P		P					P
9	W	W				W	W			
10	G									
11					G			G		
12						R	R			
13					P		P			
14						P	P			
15							W	W	W	
16								G		
17					G	G		G		
18								R	R	
19						W		W	W	
20										B
21						G				G

R = Red (Piggery Bank)
P = Pink (River Bank)
G = Green (Reservoir)
B = Blue (Badger Bank)
W = White (Hollinside)
Y = Yellow (Outlying hole)

TABLE 2. Home range estimates.

	HOME RANGE ESTIMATE (hectares)
PIGGERY BANK	46.1
RIVER BANK	29.3
BADGER BANK	46.6
HOLLINSIDE	15.5
RESERVOIR	35.7

Fig. 13. Positions where coloured markers were found and lines connecting them with the appropriate sett.

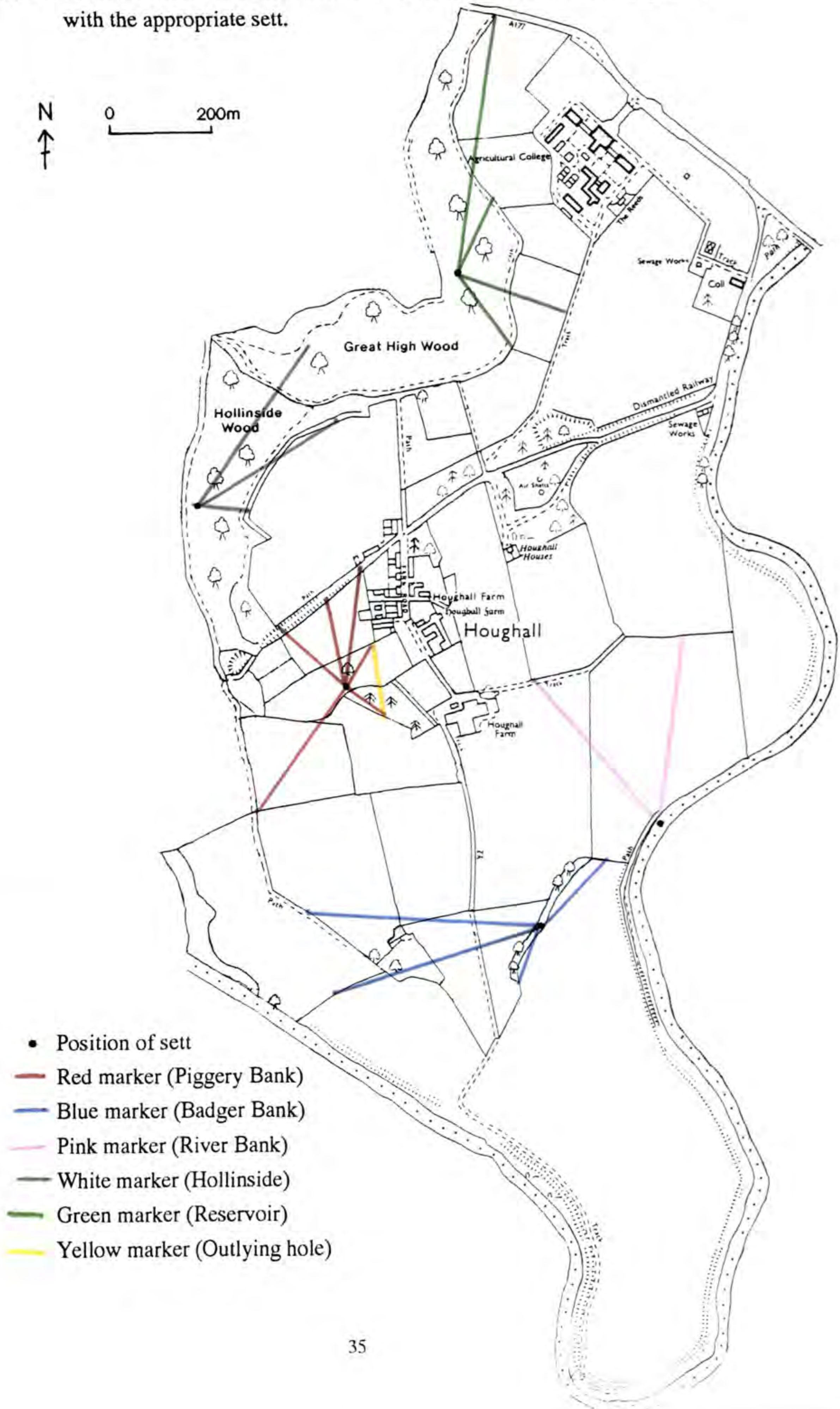
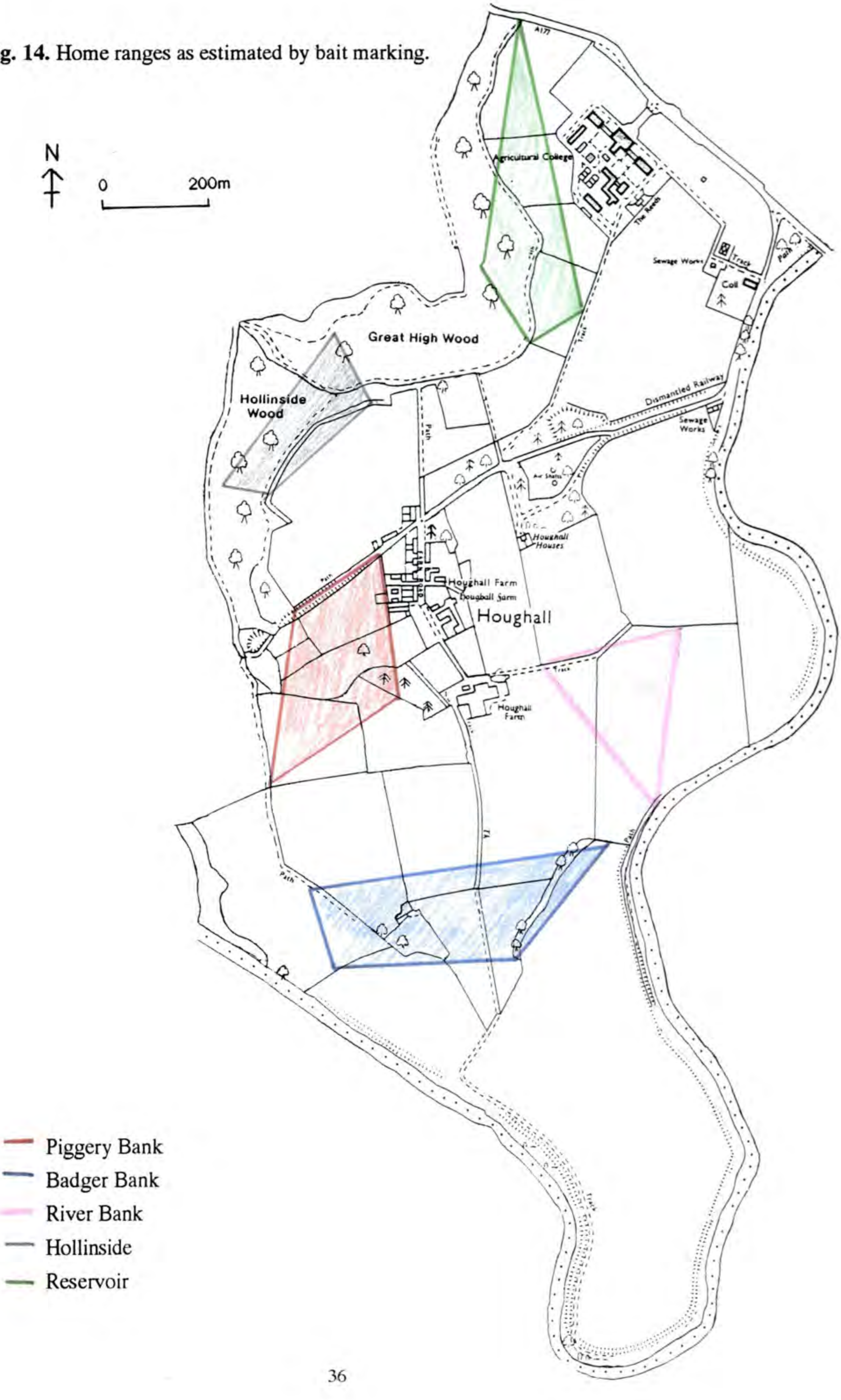


Fig. 14. Home ranges as estimated by bait marking.



Figs. 15a-e Percentage of each habitat type within each territory

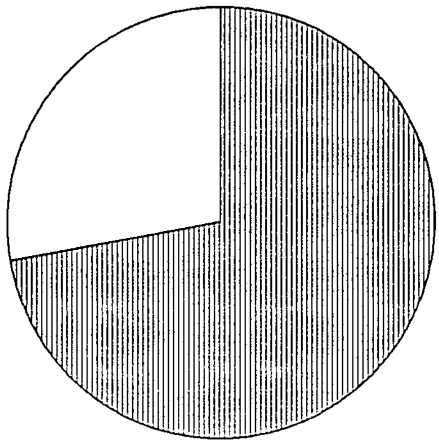


Fig. 15a Reservoir

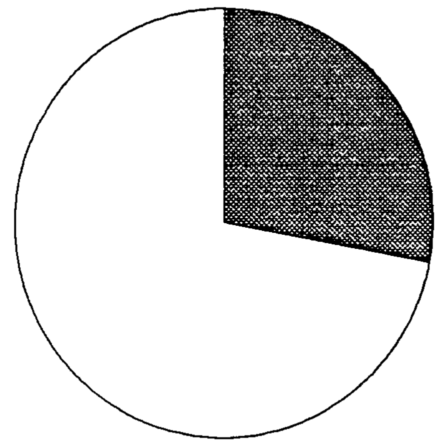


Fig. 15b Hollinside

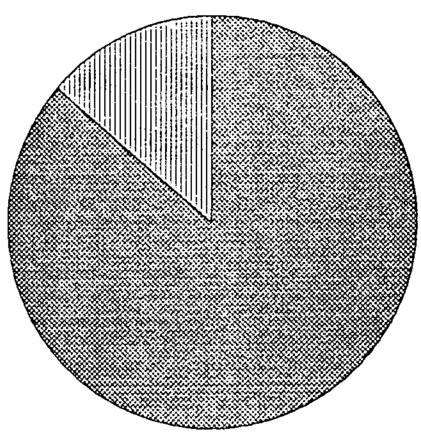


Fig. 15c River Bank

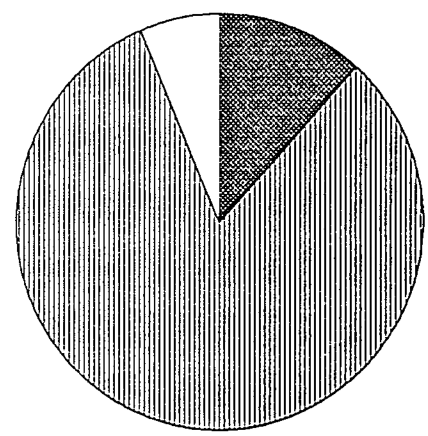


Fig. 15d Badger Bank

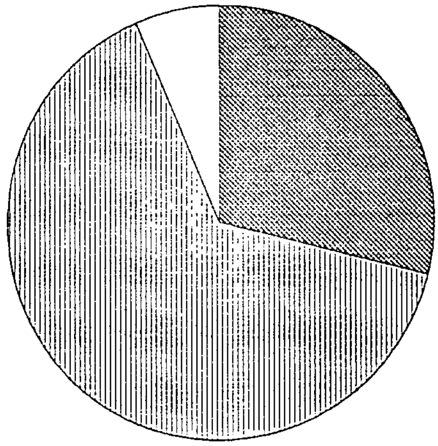
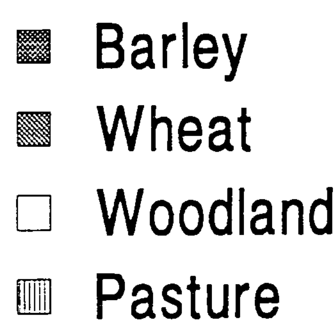


Fig. 15e Piggery Bank



habitat type in the Badger Bank, Reservoir and Piggery Bank home ranges. The Hollinside home range is the only one to contain no cereal (wheat or barley).

All of the following χ^2 tests were carried out on the actual numbers rather than the percentages displayed in the graphs. All t-tests and analyses of variance were carried out on data that had been arcsine transformed to produce a normal distribution.

An attempt was made to obtain some idea of the differences in the availability of each food category between habitats. Relative availability was estimated for each prey category. The results of the formalin method of earthworm sampling are displayed in Figs. 16a&b. In each habitat the relative number of earthworms present remained constant during the study period. Pasture ($F_{2,27} = 2.02$, $P > 0.05$), arable ($F_{2,27} = 0.80$, $P > 0.05$) and woodland ($F_{2,27} = 1.58$, $P > 0.05$). However there was a significant difference between the numbers of earthworms found in each habitat ($F_{2,87} = 817.19$, $P < 0.001$). The greatest abundance of earthworms was found in pasture and the least in woodland.

Similarly the relative volume of earthworms present in each habitat did not change during the study period (Fig. 16b). Pasture ($F_{2,27} = 1.74$, $P > 0.05$), arable ($F_{2,27} = 0.42$, $P > 0.05$) and woodland ($F_{2,27} = 2.95$, $P > 0.05$). As with the number of earthworms, there was a significant difference between the volume of earthworms found in each habitat ($F_{2,27} = 1{,}040$, $P < 0.001$). The greatest volume of earthworms was found in pasture and the least in woodland.

The numbers of Coleoptera found using pitfall traps in different habitats during the whole study period are shown in Fig. 17a. The number of Hymenoptera and larvae found using pitfall traps are similarly shown in Figs. 17b&c respectively. The number of Coleoptera found in different habitats although meaningless as absolute figures does give an indication of the difference in availability between the habitats ($\chi^2_4 = 1{,}171$, $P < 0.001$). Likewise the availability of Hymenoptera ($\chi^2_4 = 190$, $P < 0.001$) and larvae ($\chi^2_4 = 37.55$, $P < 0.001$) also show marked differences between habitats. There are marked differences between the invertebrates available in the two cereal crops wheat and barley. Wheat fields contained relatively more Coleoptera and Hymenoptera and relatively less larvae than barley fields. The pasture contained greater numbers of larvae than the other habitats but in contrast had the least Coleoptera number.

Fig. 16a A comparison between habitats in terms of number of earthworms per m²
(± 2 s.e.) (n = 10)

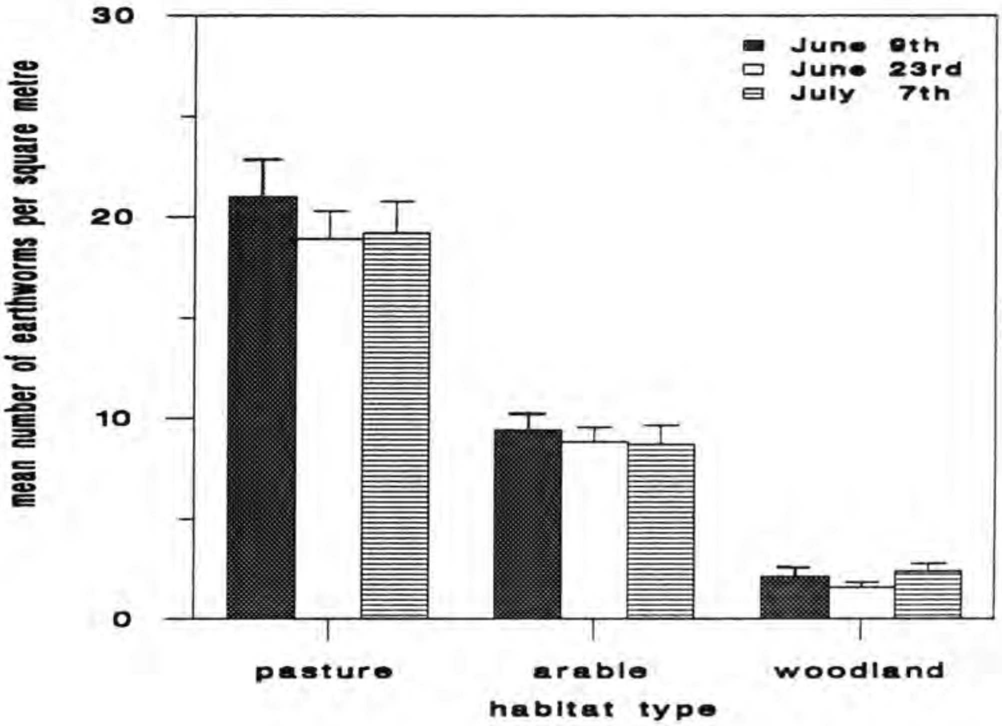


Fig. 16b A comparison between habitats in terms of mass (g) of earthworms per m²
(± 2 s.e.) (n = 10)

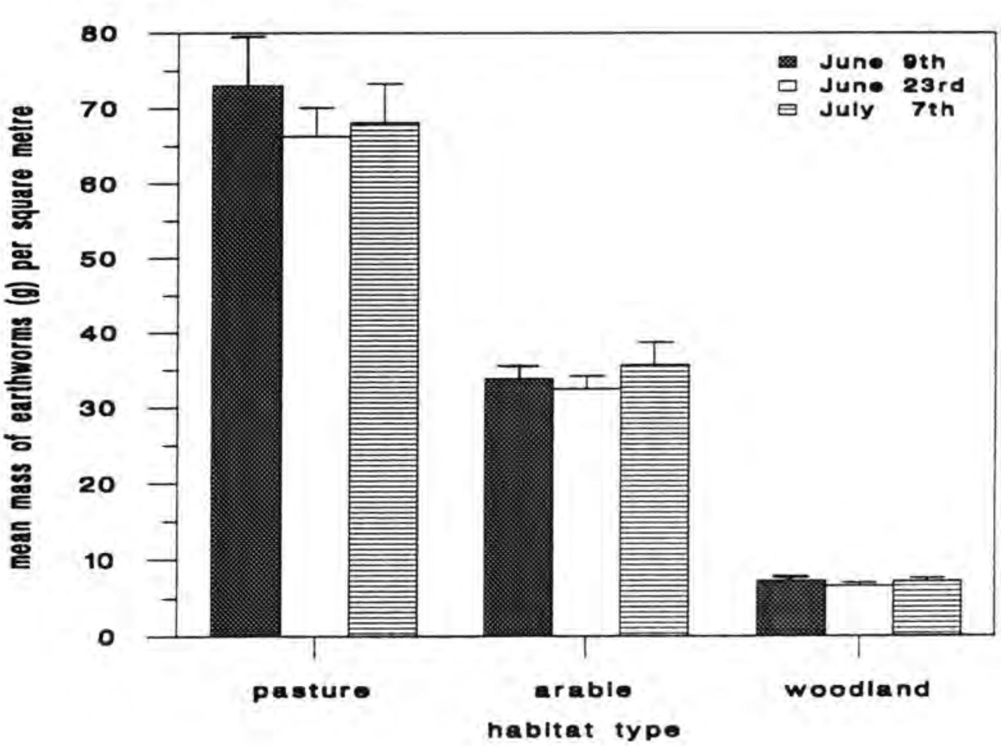


Fig. 17a A comparison between habitats in terms of Coleoptera availability (expressed as the total number of Coleoptera caught in pitfall traps in each habitat during the study period

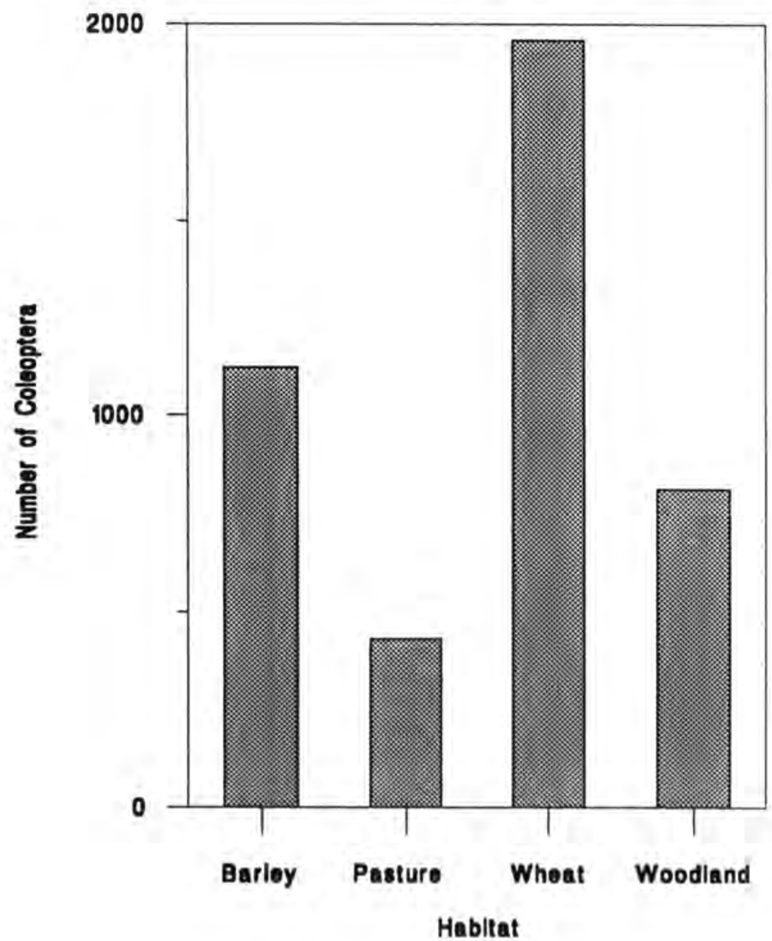


Fig. 17b A comparison between habitats in terms of Hymenoptera availability (expressed as the total number of Hymenoptera caught in pitfall traps in each habitat during the study period

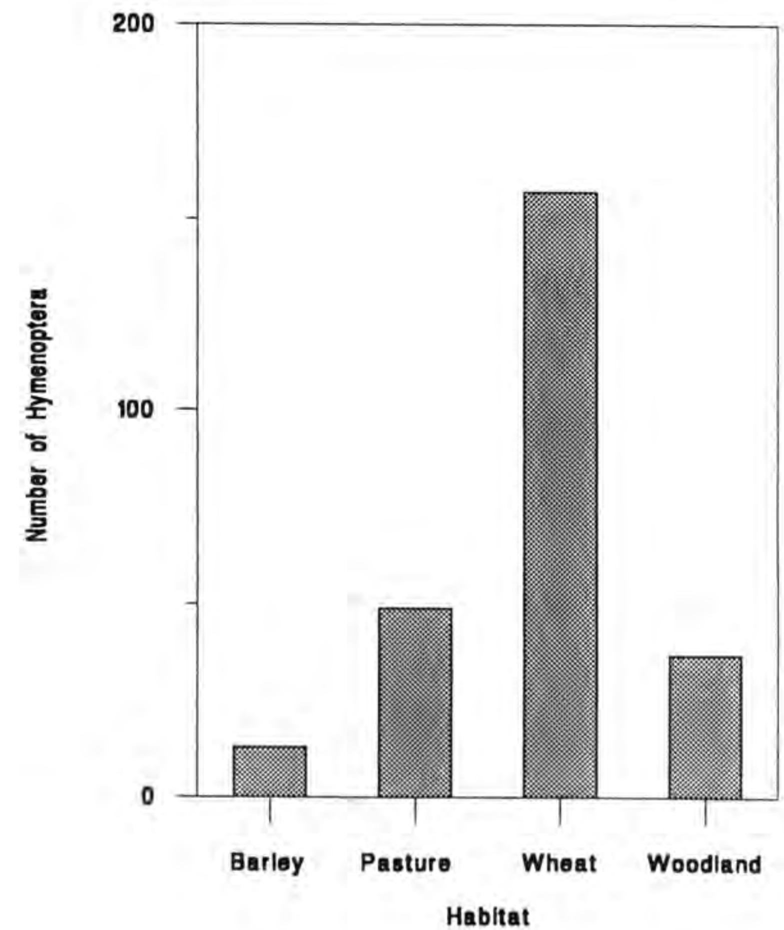
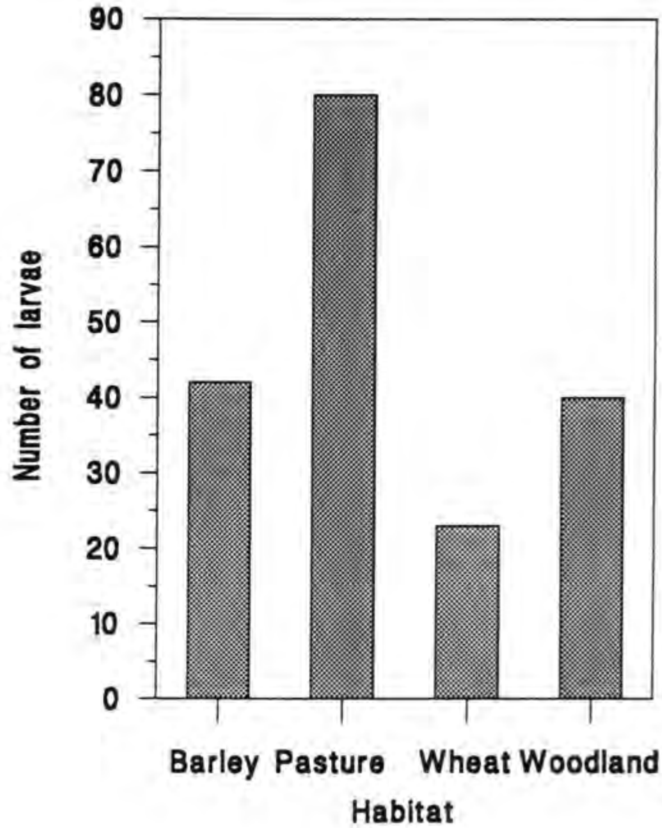


Fig. 17c A comparison between habitats in terms of larvaea availability (expressed as the total number of larvae caught in pitfall traps in each habitat during the study period



During the study period (mid May to mid July) a total of 244 dung samples were collected. The number of dung samples collected per clan per month are shown in Table 3. More samples were collected in June then in May or July because collection took place throughout June but only during the second half of May and the first half of July.

The results of the faecal analysis quite clearly show the predominance of earthworms in the diet, in terms of both volume and the frequency with which they are taken (Table 4). Many other foods were also taken and the table gives a clear indication of the badgers' varied tastes.

Three methods of data analysis and presentation have been previously used in the study of carnivore diets. They have been defined by Birks and Dunstone (1985) as follows:

Percentage occurrence: The relative frequency of each prey category expressed as a percentage of all prey occurrences.

Percentage of scats: The percentage of scats in which each prey category was present.

Percentage volume: The relative estimated volume of each prey category as ingested, expressed as a percentage of the total volume of prey ingested.

Table 4 Shows the total results of the faecal analysis using each of the three methods described above. In all cases earthworms and leaves were ingested very frequently and in large volumes while other prey items were taken less frequently and also in much smaller volumes. The leaves consisted mostly of grass or dead deciduous leaves and because they appeared to be largely intact and undigested it was assumed that they had been ingested accidentally while foraging. The badger hair would also have been ingested accidentally as a result of grooming. If the two non-food items (leaves and badger hair) are removed from the analysis the diet can be represented as in Figs. 18a-c.

From Table 4 and Figs. 18a-c it is clear that earthworms are the most important prey type in terms of percentage occurrence, percentage of scats and percentage volume. It is likely that the earthworm species taken most commonly was *Lumbricus terrestris*. The next most important prey category using percentage occurrence and percentage of scats was carabid beetles. The commonest carabid species found were *Carabus problematicus* and *Pterostichus* spp. However in terms of percentage volume the next most important prey category after earthworms was caterpillars. The next most important prey type in terms of percentage occurrence and percentage of scats was wheat. This was taken a lot more frequently than barley (the only other cereal

TABLE 3. The number of dung samples collected per clan per month.

	MAY	JUNE	JULY
PIGGERY BANK	13	30	9
RIVER BANK	4	36	8
BADGER BANK	9	23	19
HOLLINSIDE	4	23	15
RESERVOIR	7	30	14

TABLE 4. Results of the faecal analysis - expressed as percentage frequency of occurrence (n = 679), percentage of scats (n = 244) and percentage volume.

	% OCCURRENCE	% OF SCATS	% VOLUME (N)
EARTHWORMS	33.86	94.2	44.9 (234)
CARABID BEETLES	13.12	35.5	4.61 (87)
STAPHYLINID BEETLES	1.53	6.5	2.50 (16)
OTHER BEETLES	0.57	1.6	2.50 (4)
SNAILS	0.37	0.8	2.50 (2)
FLIES	0.16	0.7	5.75 (2)
HYMENOPTERA	2.69	6.7	2.89 (16)
CATERPILLARS	2.08	5.6	6.07 (14)
OTHER LARVAE	1.63	4.9	3.15 (12)
WHEAT	5.67	15.3	3.56 (37)
BARLEY	0.82	2.2	2.50 (5)
FEATHERS	0.29	0.8	2.50 (2)
LEAVES	35.39	98.0	41.42 (239)
BADGER HAIR	2.00	5.3	2.50 (13)

Fig. 18a Percentage frequency of occurrence in faeces of each prey category, ignoring non-food items (n = 421)

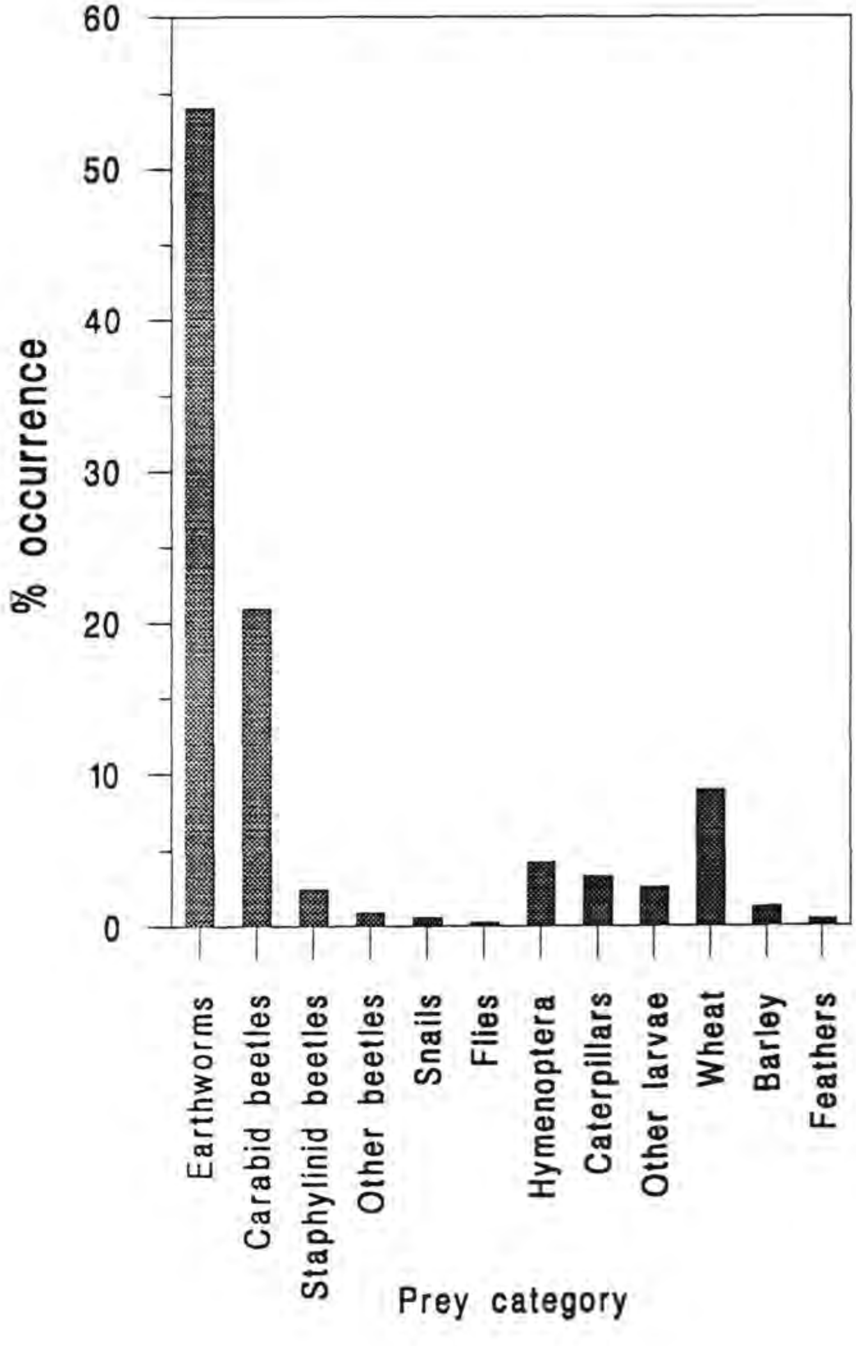


Fig. 18b Percentage of scats in which each prey category was present, ignoring non-food items (n = 244)

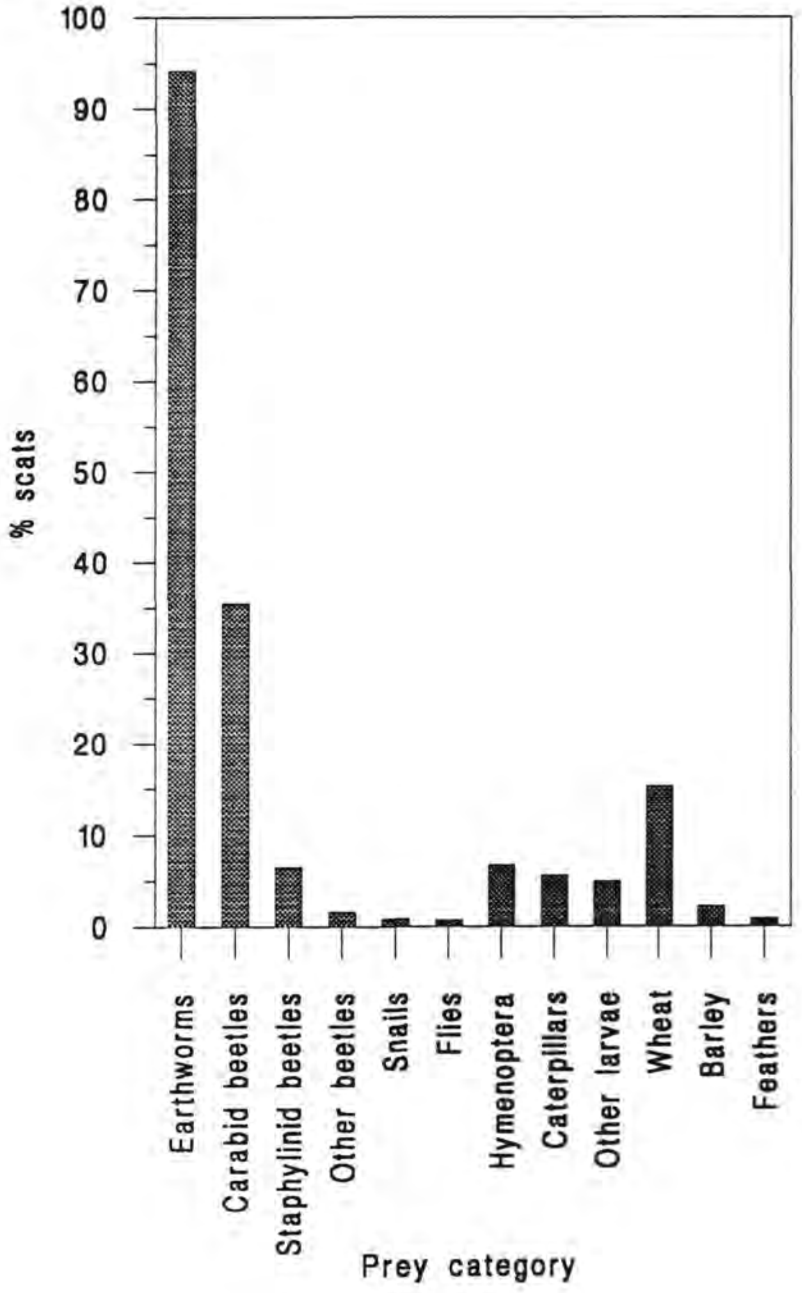
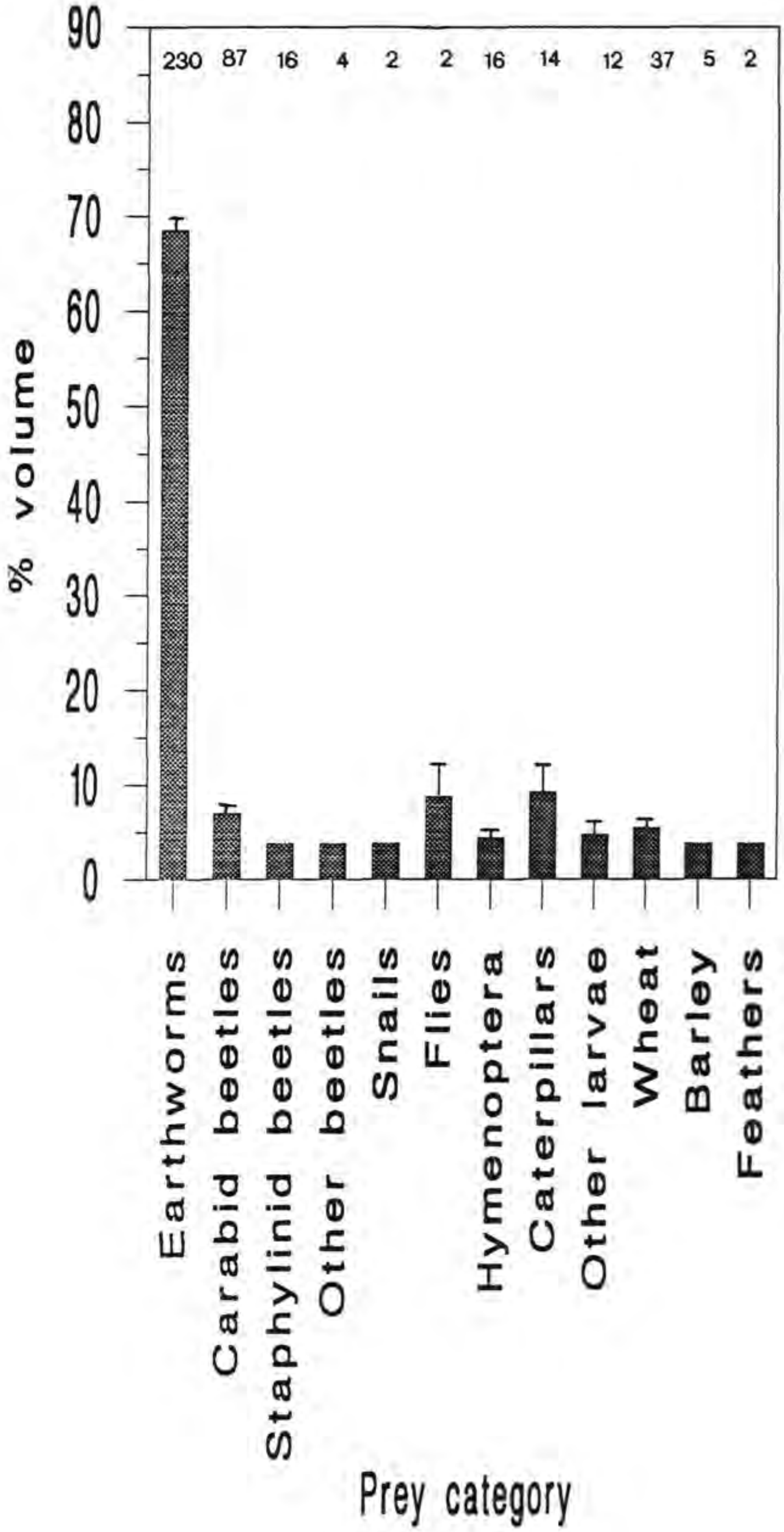


Fig. 18c Mean percentage volume of each prey category when present in the diet, ignoring non-food items (± 2 s.e.) (number above bars represents sample size)



consumed) and also in greater volume. Snails, flies, feathers and beetles other than carabids and staphylinids were all taken infrequently and all appeared in less than 2% of the scats.

Since many of the prey types occur infrequently in order to aid interpretation all subsequent graphs show the major food items grouped into larger categories eg. 'larvae' includes caterpillars and other larvae.

Figs. 19a&b show the diet of the badgers during each month of the study period. For each prey category there was no significant difference between the percentage occurrence during each month of the study. Earthworms (χ^2_2 = 0.02, P > 0.05), Coleoptera (χ^2_2 = 1.09, P > 0.05), Hymenoptera (χ^2_2 = 2.35, P > 0.05), larvae (χ^2_2 = 0.03, P >0.05) and Cereal (χ^2_2 = 3.71, P >0.05). In all months earthworms were taken most frequently and Coleoptera the next most frequently. In terms of percentage volume in the diet there was also no significant difference between each month of the study for each prey category. Earthworms ($F_{2,227}$= 2.48, P > 0.05), Coleoptera ($F_{2,104}$=2.59, P > 0.05), Hymenoptera ($F_{2,13}$= 1.96, P > 0.05), larvae ($F_{2,23}$= 0.80, P > 0.05) and cereal ($F_{2,39}$= 0.96, P > 0.05). Earthworms were taken in far greater volume than any of the other prey categories and cereal was probably taken in the smallest volume during all months of the study.

It is of interest to determine whether earthworms were taken at particular times e.g. particularly after rain. A worm night was defined by Kruuk and Parish (1981) as being a night when the temperature did not fall below 0°C and there was at least 2mm of rain in the preceding 72hrs. To determine when the worm nights occurred during the study the rainfall and minimum temperature values obtained from Durham University Observatory (station number 2165) from mid May to mid July were acquired (Fig. 20). Using these criteria Table 5 gives the worm nights during the study.

The percentage occurrence and percentage volume of each prey category were calculated for worm nights and for non-worm nights separately and the results are shown in Figs. 21a&b. There was no significant difference between the percentage occurrence for worm and non-worm nights for four of the prey categories; earthworms (χ^2_1 = 0.33, P > 0.05), Coleoptera (χ^2_1 = 0.41, P >0.05), Hymenoptera (χ^2_1 = 0.02, P > 0.05) and larvae (χ^2_1 = 0.98, P > 0.05). There was, however, significant difference between percentage occurrence of cereal on worm and non-worm nights (χ^2_1 = 4.47, P < 0.05) with cereal being consumed more often on non-worm nights. In terms of percentage volume in the diet there was no significant difference between worm and non-worm nights for four of the prey categories; Coleoptera (t_{109}= 0.11, P > 0.05),

Fig. 19a The percentage occurrence of each prey category taken during each month of the study

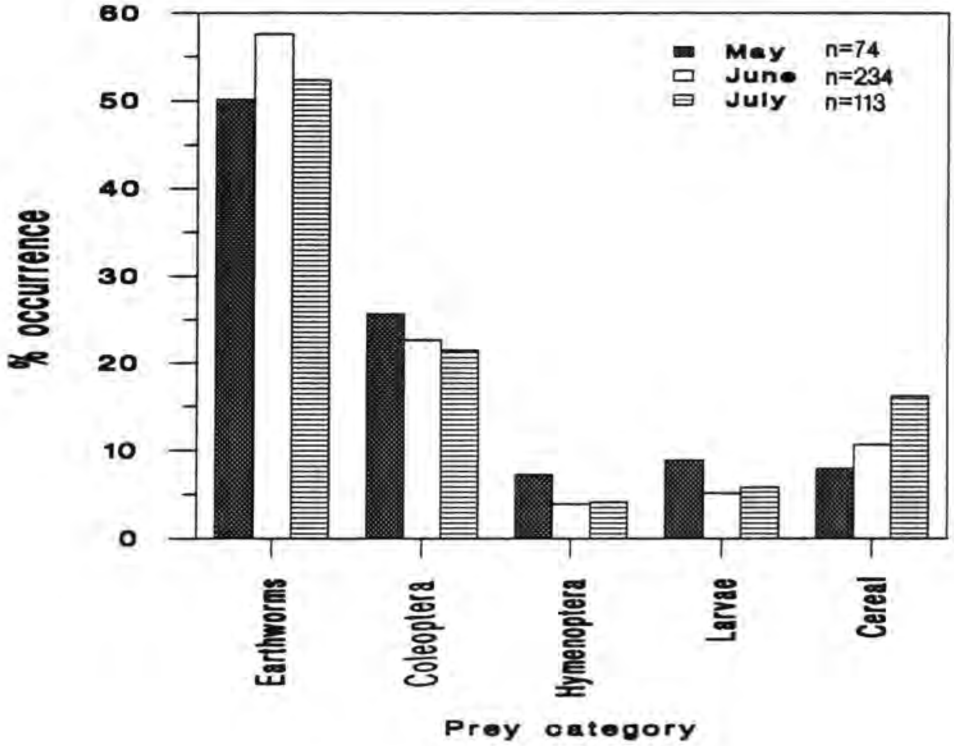


Fig. 19b The mean percentage volume of each prey category taken during each month of the study (± 2 s.e.) (number above bars represents sample size)

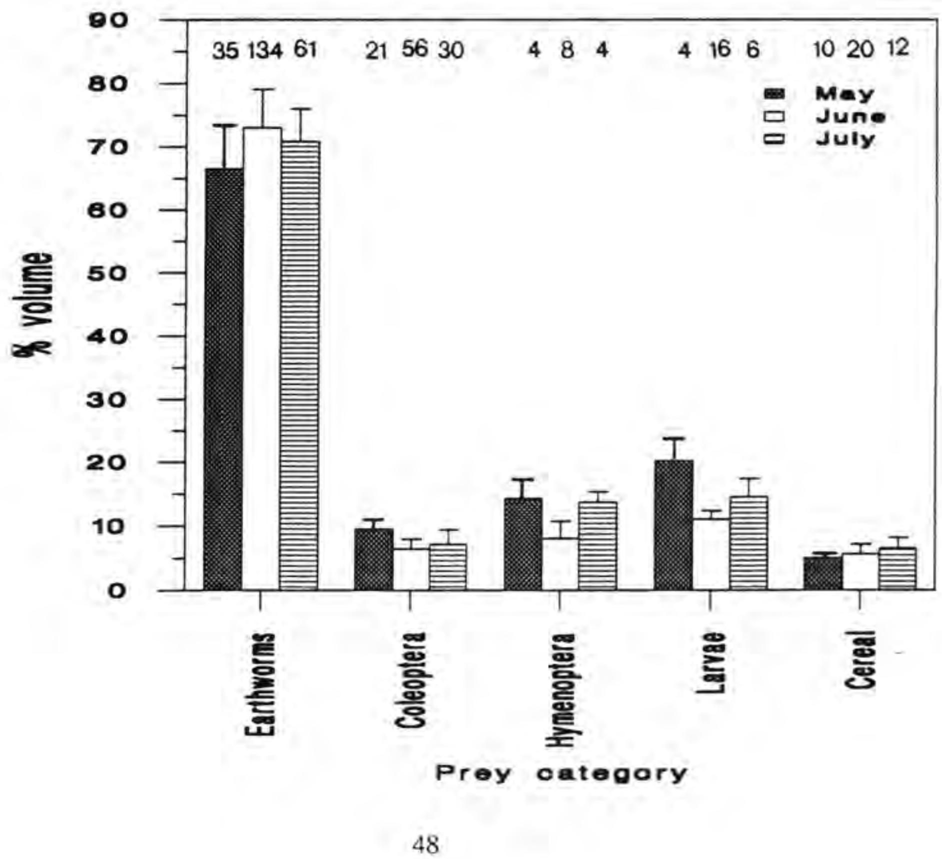


Fig. 20 Rainfall and temperature for the study period (data from Durham University Observatory, station No. 2165)

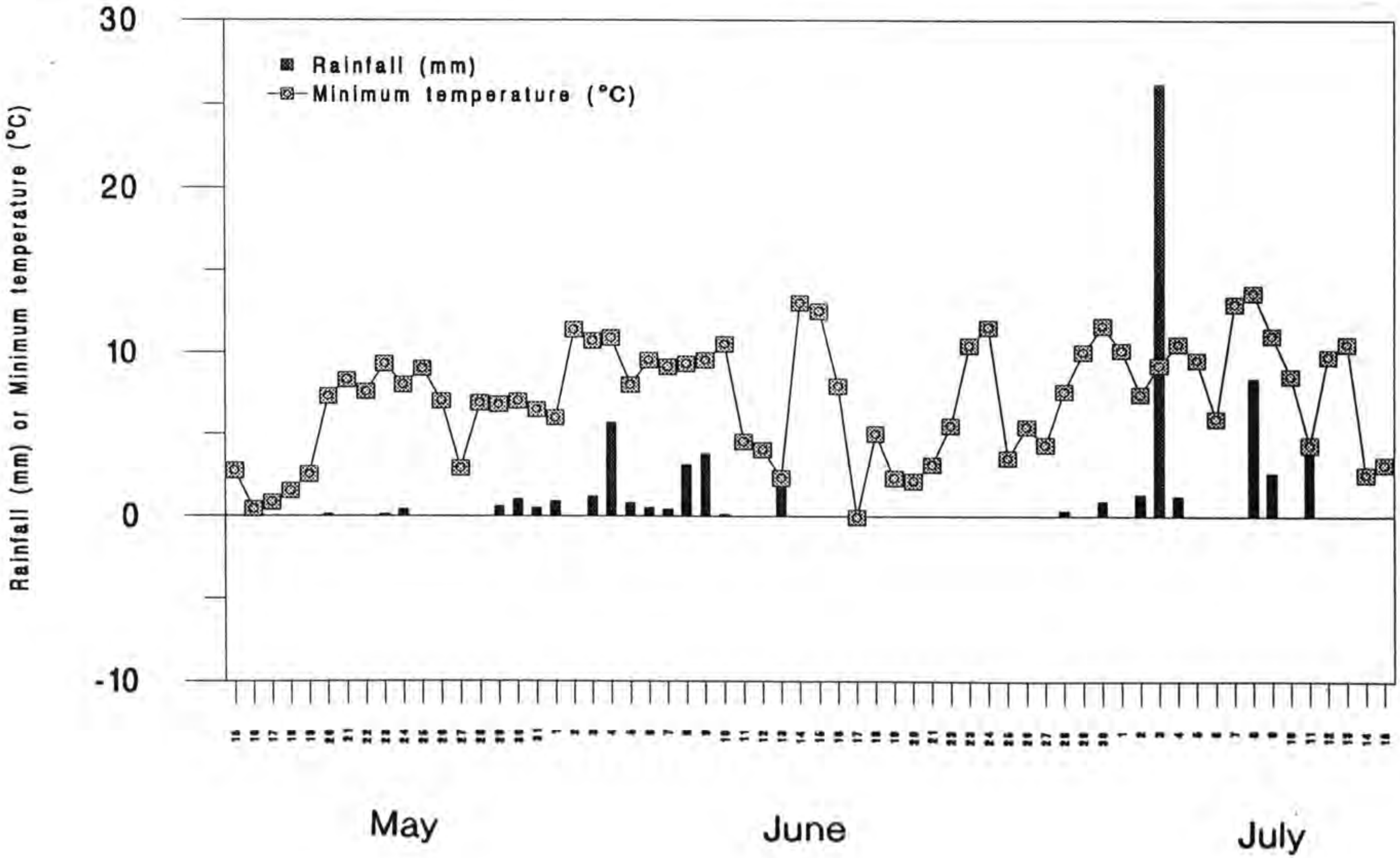


TABLE 5. Dates of worm nights that occurred during the study period (w).

	MAY	JUNE	JULY
1st		w	
2nd		w	
3rd			
4th		w	w
5th		w	w
6th		w	w
7th		w	
8th			
9th		w	w
10th		w	w
11th		w	w
12th	w	w	w
13th			w
14th		w	w
15th		w	
16th		w	
17th			
18th			
19th			
20th			
21st			
22nd			
23rd			
24th			
25th			
26th			
27th			
28th			
29th			
30th			
31st			

Fig. 21a Percentage frequency of occurrence of each prey category taken on worm nights and non-worm nights

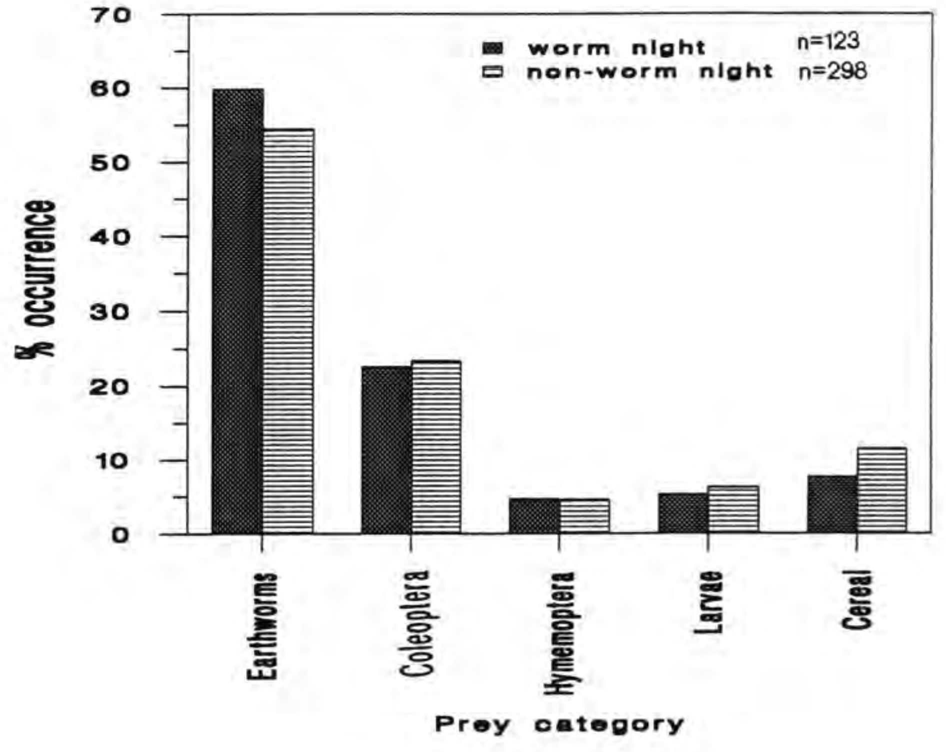
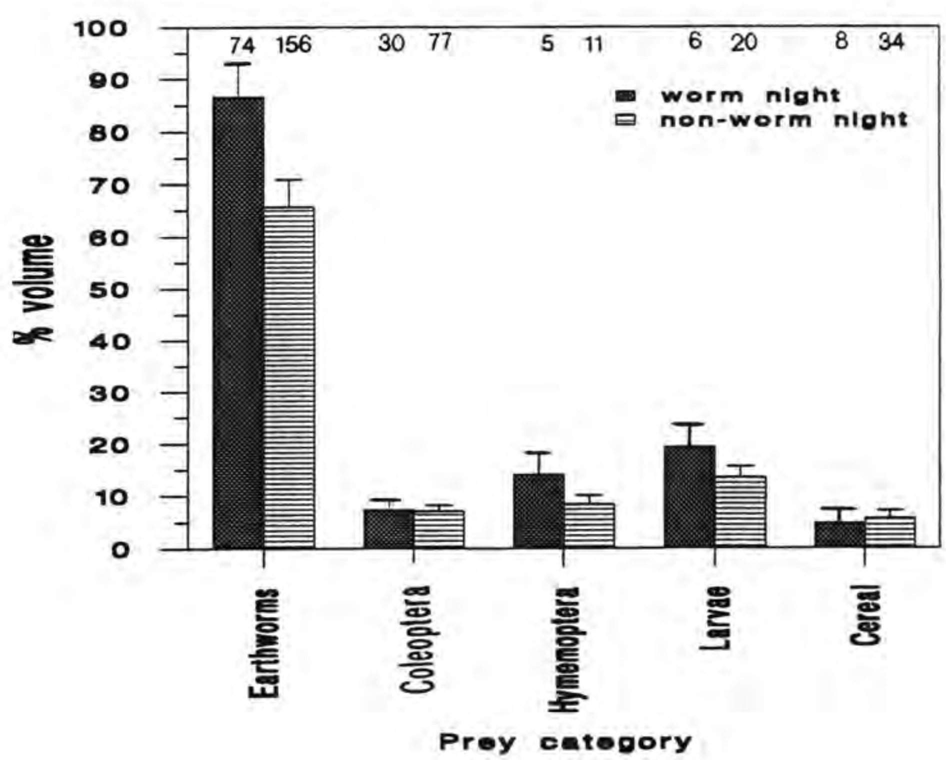


Fig. 21b Mean percentage volume of each prey category taken on worm nights and non-worm nights (± 2 s.e.) (number above bars represents sample size)



Hymenoptera (t_{14}= 0.19, P > 0.05), larvae (t_{24}= 0.68, P > 0.05) and cereal (t_{40}= 0.80, P > 0.05). The percentage volume of earthworms in the diet was significantly different on worm and non-worm nights (t_{228}= 7.7, P < 0.001), with a greater volume of earthworms being consumed on worm nights.

The bait marking trials showed which latrines each of the five badger clans were using (Fig. 13) and because each collected scat had been labelled with the latrine number it was possible to look at the diet of each of the clans separately (Figs. 22a&b). By separating the clans it can be seen that the Reservoir clan is the only one of the five in which cereal does not figure in the diet. All other prey categories are consumed by all five of the clans.

To show the differences between the clans for each prey category more clearly Figs. 23a -n were plotted. There was no significant difference between the five clans for the percentage occurrence of four of the prey categories taken; earthworms (χ^2_4= 5.23, P > 0.05), Coleoptera (χ^2_4 = 2.55, P > 0.05), Hymenoptera (χ^2_4 = 2.50, P > 0.05), and larvae (χ^2_4 = 5.23, P > 0.05). There was however a significant difference between the percentage occurrence of cereal (Fig. 23i) (χ^2_4 = 92.25, P < 0.001). In terms of percentage volume there was no significant difference between the clans for Coleoptera ($F_{4,103}$ = 1.64, P > 0.05), Hymenoptera ($F_{4,12}$ = 0.48, P > 0.05) or larvae ($F_{4,22}$ = 1.28, P > 0.05) consumption. There was a significant difference between the clans for percentage volume of both earthworms ($F_{4,266}$ = 44.17, P < 0.001) and cereal ($F_{4,38}$ = 31.58, P < 0.001) in the diet. The Reservoir clan consumed the greatest volume of earthworms and the Hollinside clan consumed the least volume (Fig. 23b).

For the clans that consumed cereal either wheat or barley were taken but never both. The Piggery Bank and River Bank clans ate wheat and the Badger Bank and Hollinside clans ate barley (Figs. 23k&n). The two clans that consumed wheat ate more cereal in terms of both percentage occurrence and percentage volume than the two clans that ate barley.

Figs. 24a-e show for each clan the percentage of each prey category taken over the study period. The variation in the diet is quite small as the study took place over a relatively short time period. Fig. 24a shows the temporal variations in the diet of the Piggery Bank clan. At the beginning of the study period there appears to be an increase in the percentage occurrence of earthworms followed by a levelling off. The percentage occurrence of both Hymenoptera and larvae appear to decrease during the first half of the study period followed by a slight increase again towards the end of it. The temporal variations in the diet of the Badger Bank clan are shown in Fig. 24b. The percentage occurrence of earthworms in the diet increased at the start of the study period, levelled

Fig. 22a Percentage occurrence of each prey category taken by badgers of the five different clans in the study area

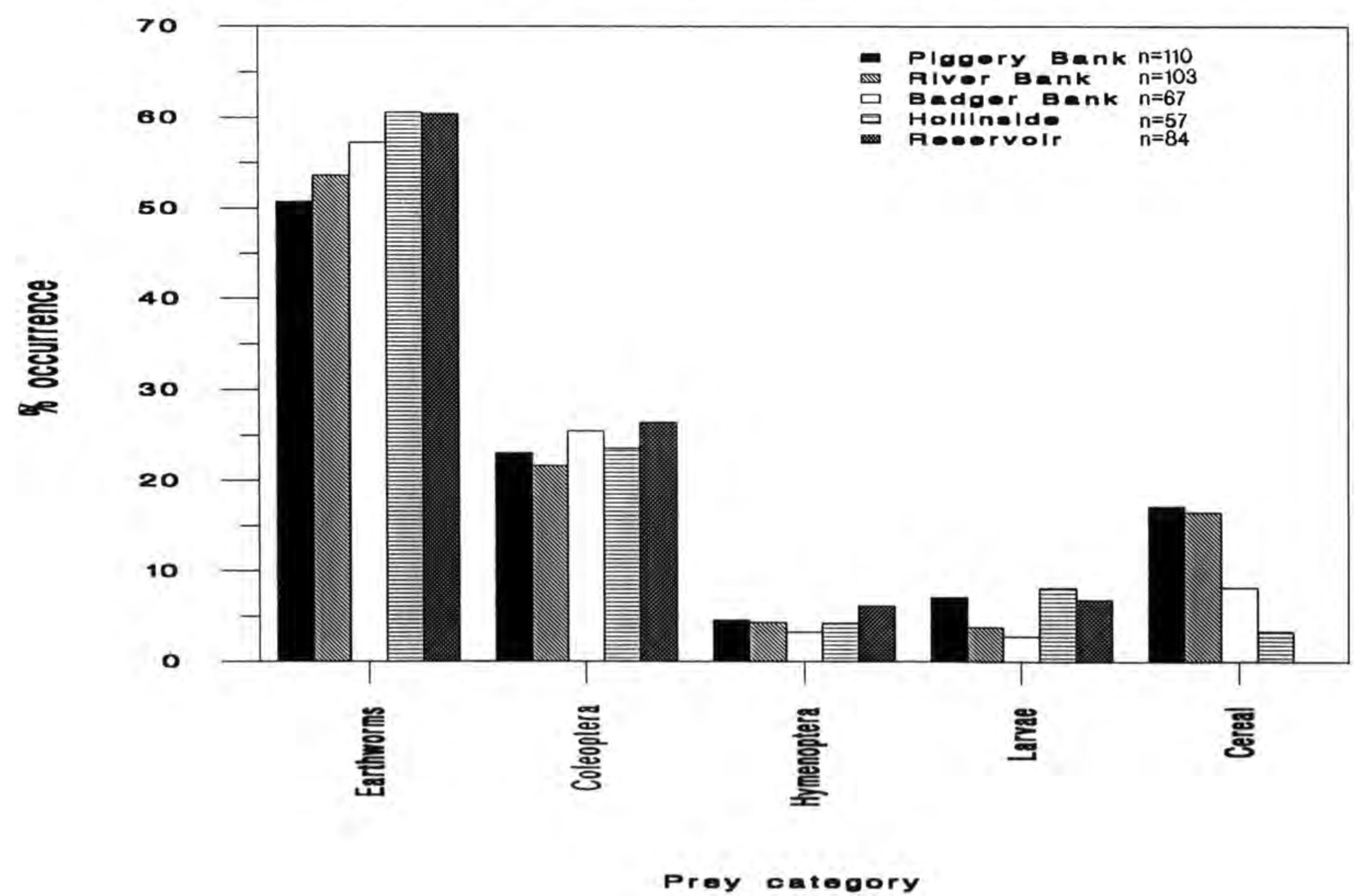


Fig. 22b Mean percentage volume of each prey category taken by badgers of the five different clans in the study area (± 2 s.e.) (number above bars represents sample size)

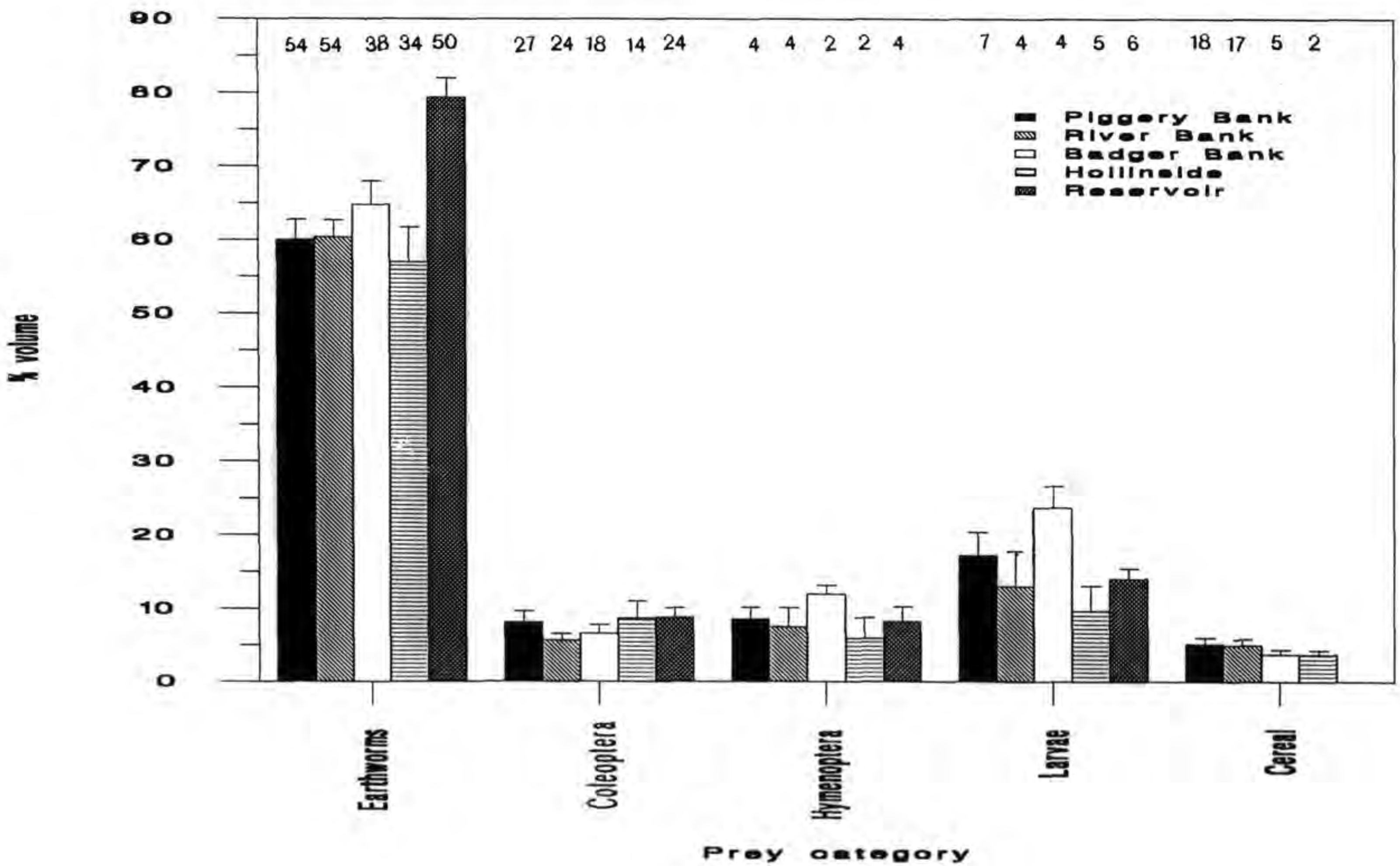


Fig. 23a Percentage occurrence of earthworms taken by the five clans (number above bars represents sample size)

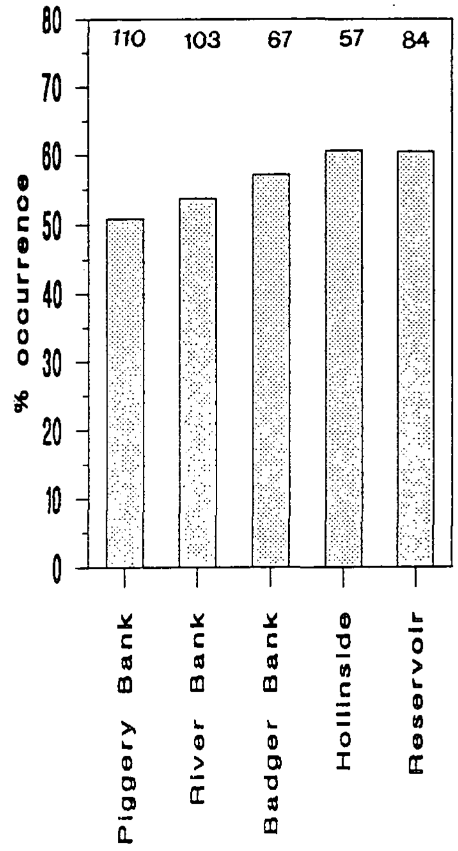


Fig. 23b Mean percentage volume of earthworms taken by the five clans (± 2 s.e.) (number above bars represents sample size)

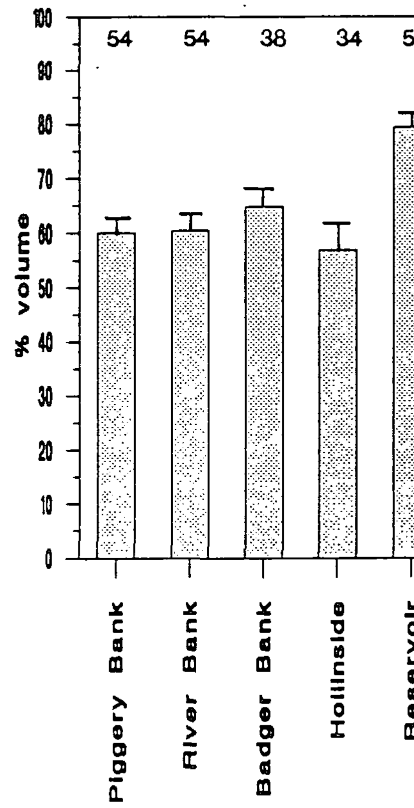


Fig. 23c Percentage occurrence of Coleoptera taken by the five clans (number above bars represents sample size)

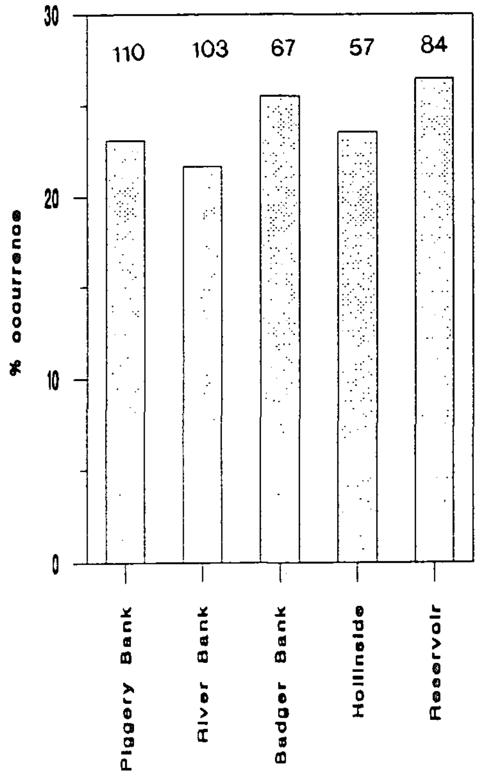


Fig. 23d Mean percentage volume of Coleoptera taken by the five clans (± 2 s.e.) (number above bars represents sample size)

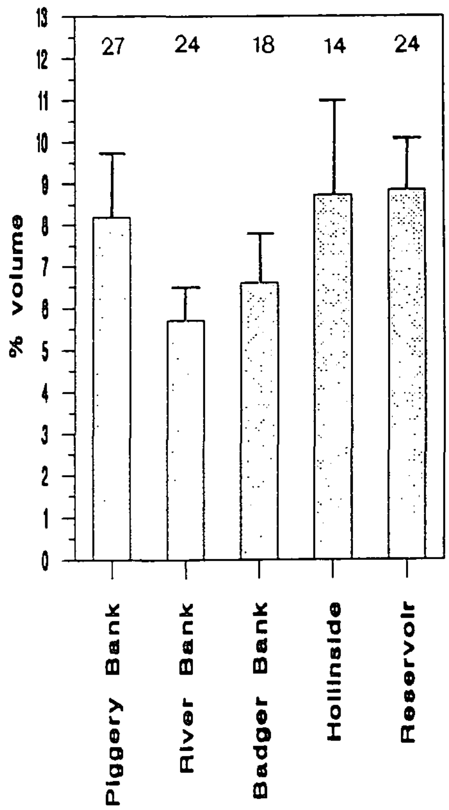


Fig. 23e Percentage occurrence of Hymenoptera taken by the five clans (number above bars represents sample size)

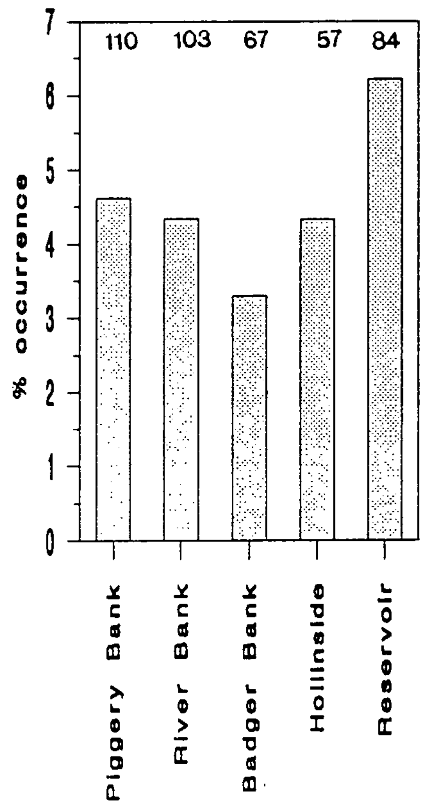


Fig. 23f Mean percentage volume of Hymenoptera taken by the five clans (± 2 s.e.) (number above bars represents sample size)

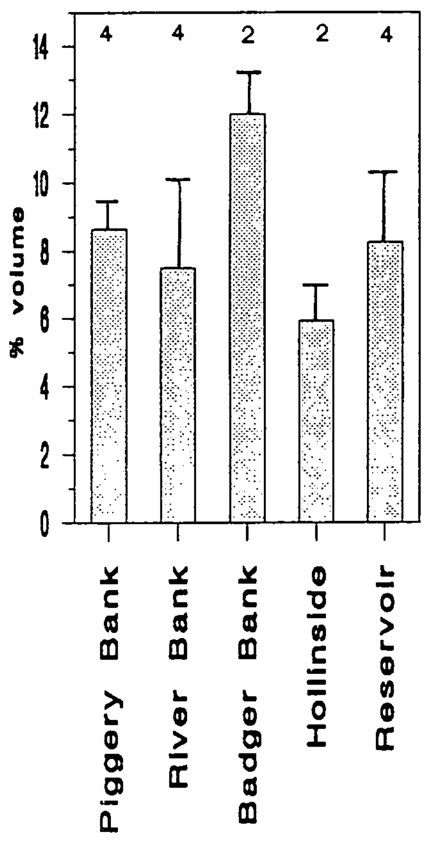


Fig. 23g Percentage occurrence of larvae taken by the five clans (number above bars represents sample size)

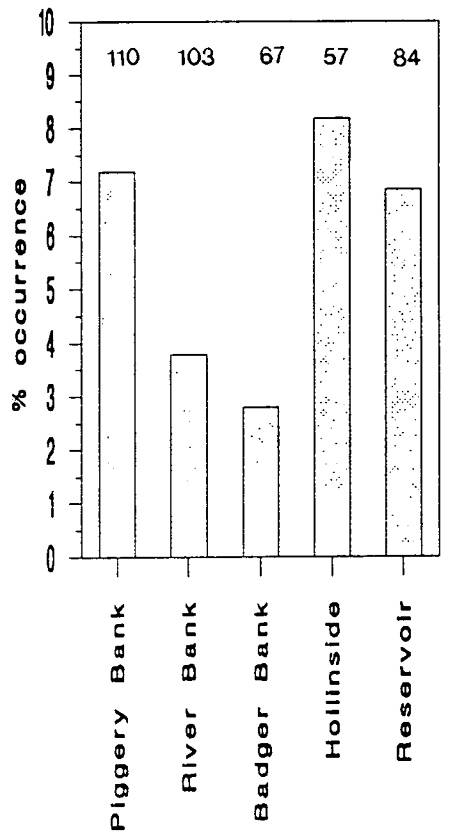


Fig. 23h Mean percentage volume of larvae taken by the five clans (± 2 s.e.) (number above bars represents sample size)

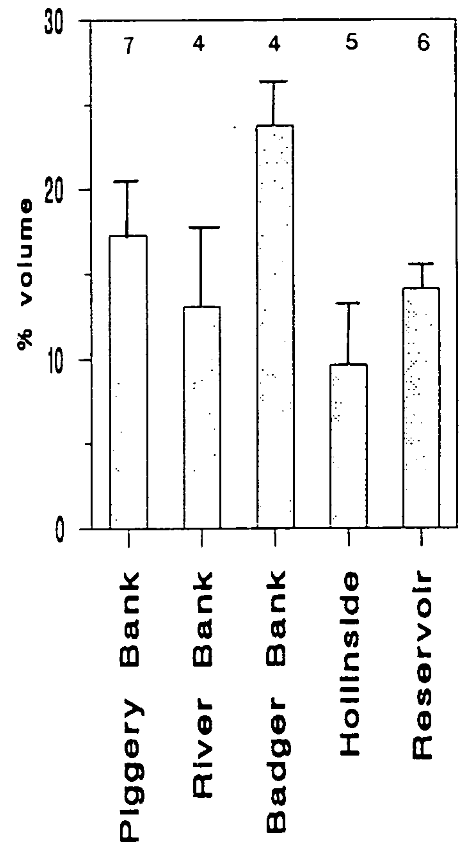


Fig. 23i Percentage occurrence of cereal taken by the five clans (number above bars represents sample size)

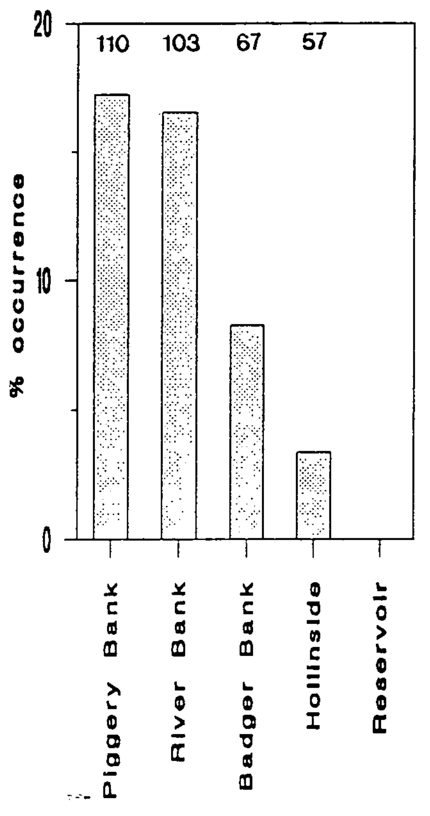


Fig. 23j Mean percentage volume of cereal taken by the five clans (± 2 s.e.) (number above bars represents sample size)

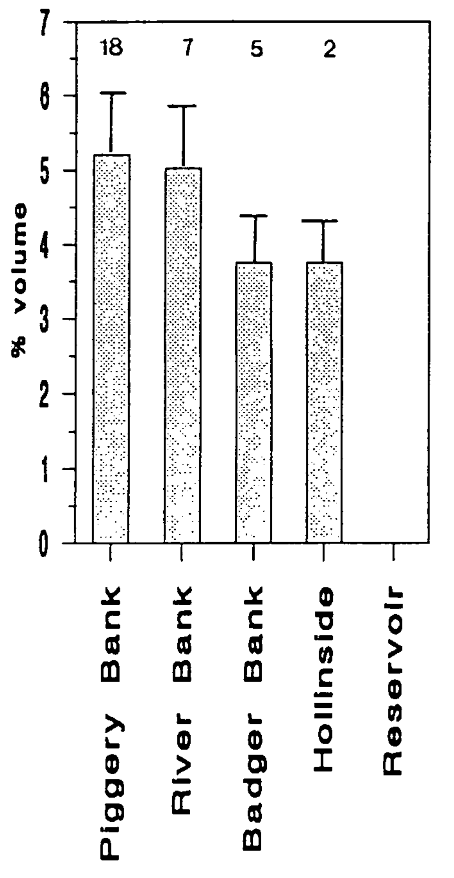


Fig. 23k Percentage occurrence of wheat taken by the five clans (number above bars represents sample size)

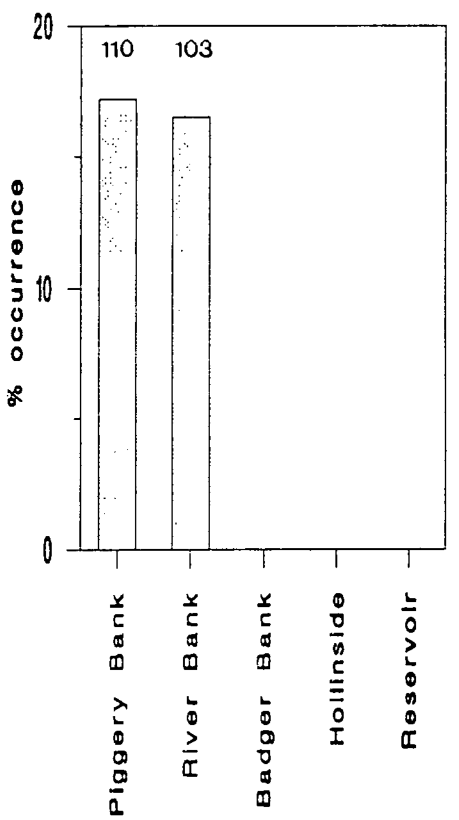


Fig. 23l Mean percentage volume of wheat taken by the five clans (± 2 s.e.) (number above bars represents sample size)

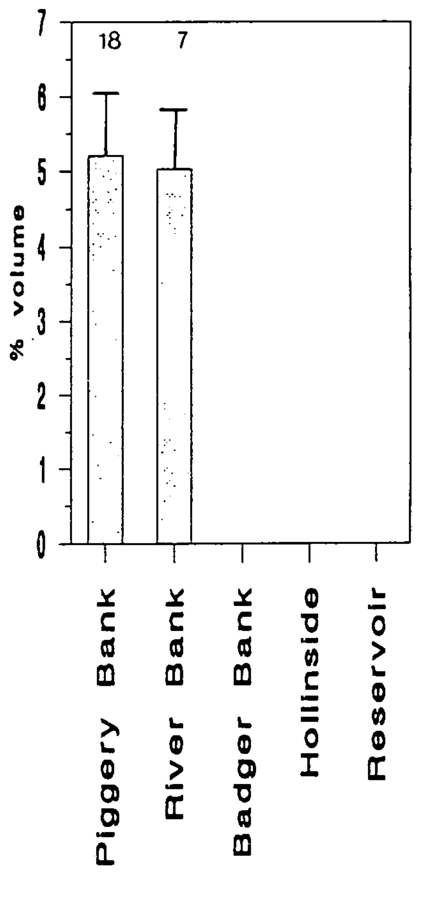


Fig. 23m Percentage occurrence of barley taken by the five clans (number above bars represents sample size)

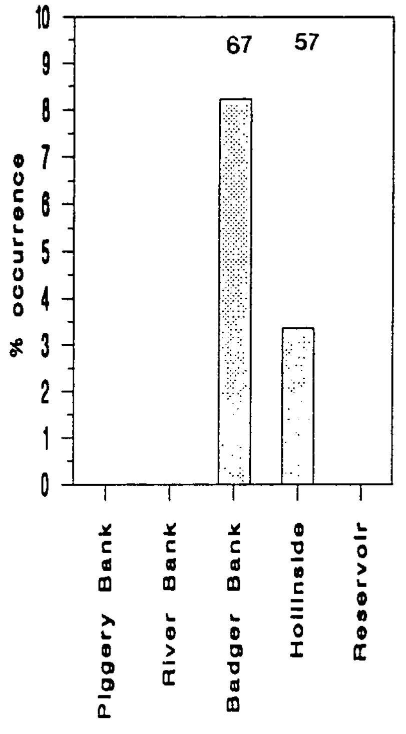


Fig. 23n Mean percentage volume of barley taken by the five clans (± 2 s.e.) (number above bars represents sample size)

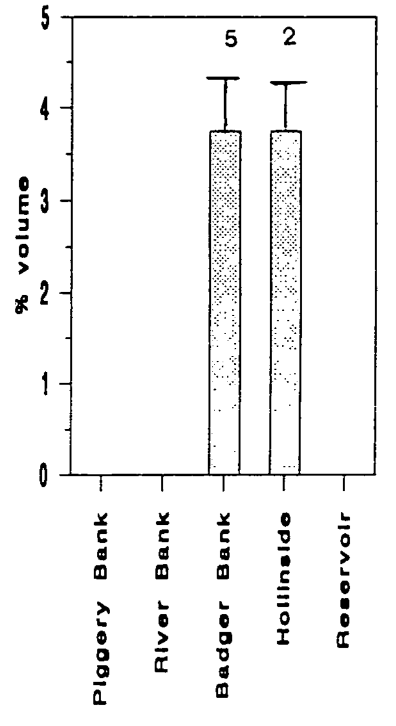


Fig. 24a Piggery Bank - Temporal variations in mean percentage occurrence of each prey category during the study period

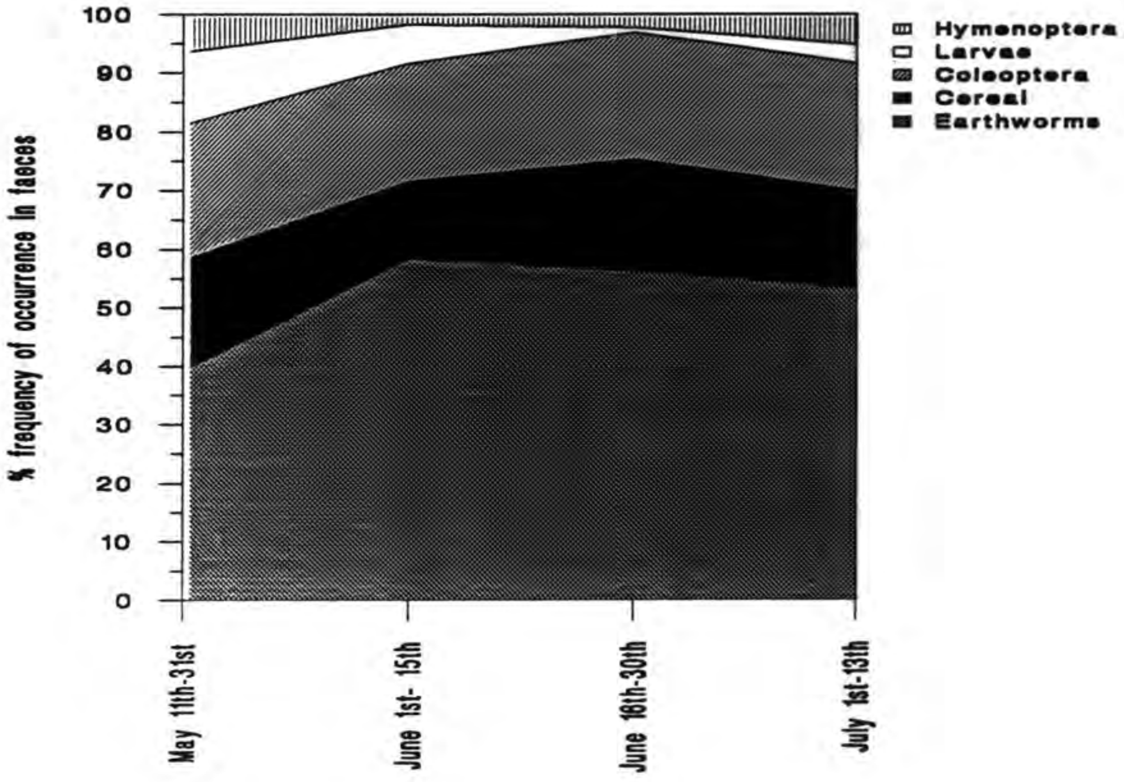


Fig. 24b Badger Bank - Temporal variations in mean percentage occurrence of each prey category during the study period

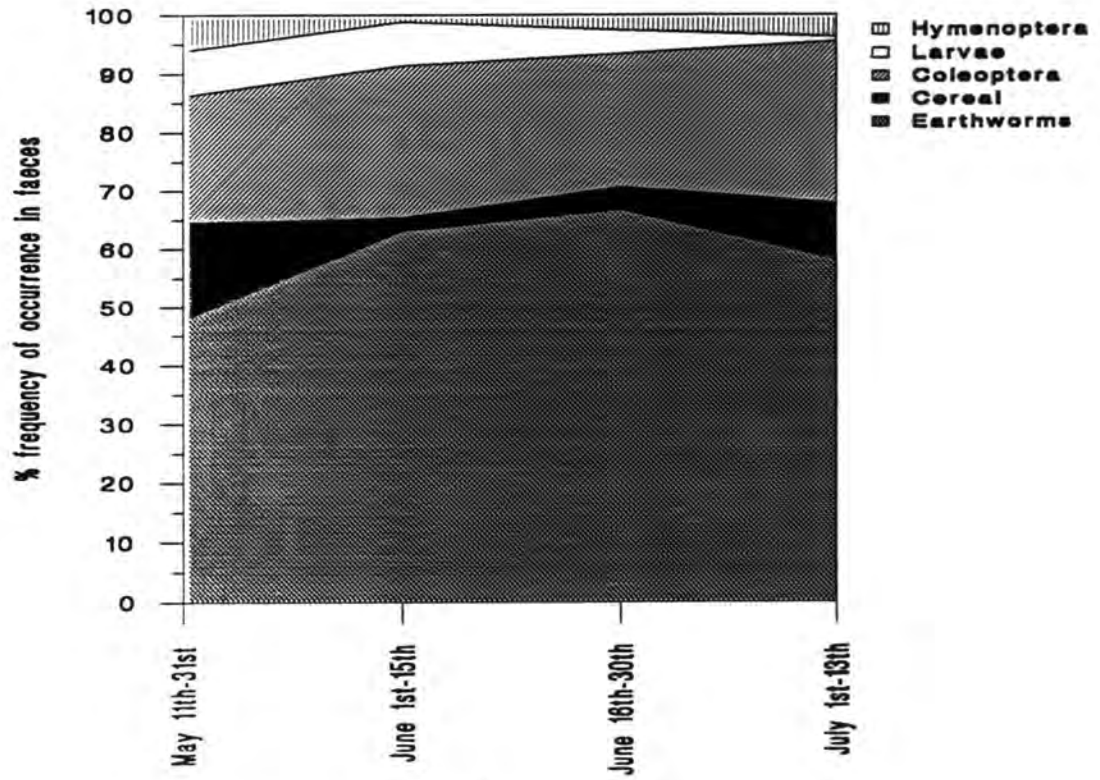


Fig. 24c River Bank - Temporal variations in mean percentage occurrence of each prey category during the study period

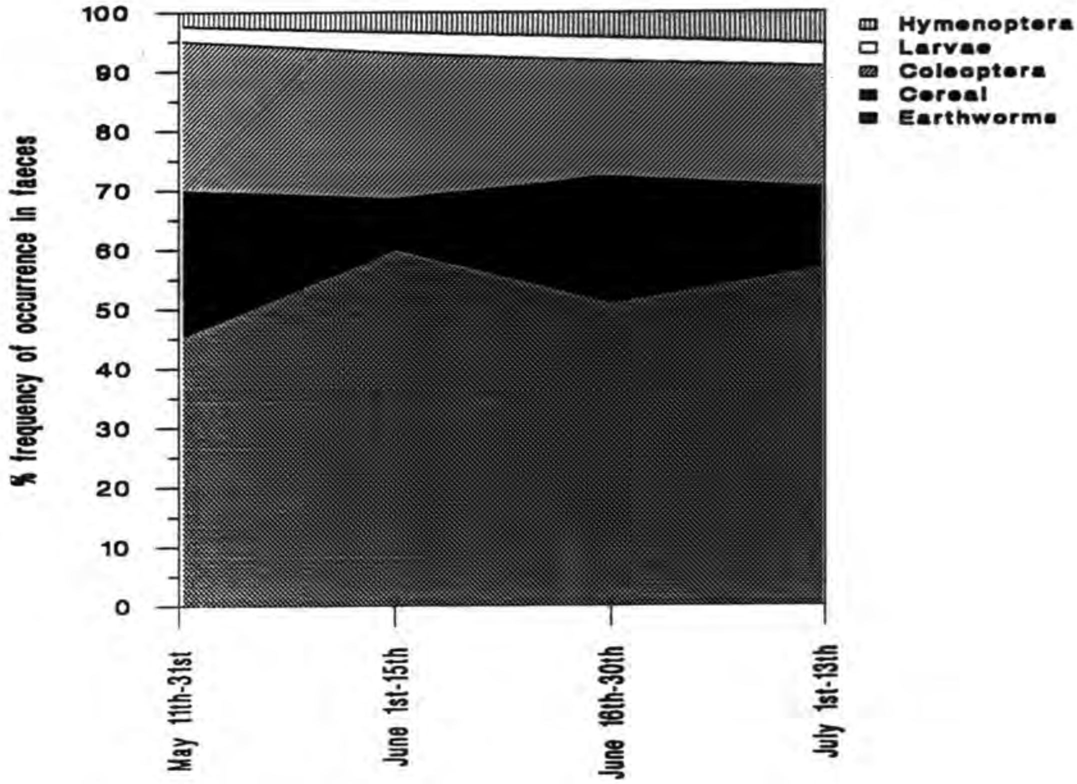


Fig. 24d Hollinside - Temporal variations in mean percentage occurrence of each prey category during the study period

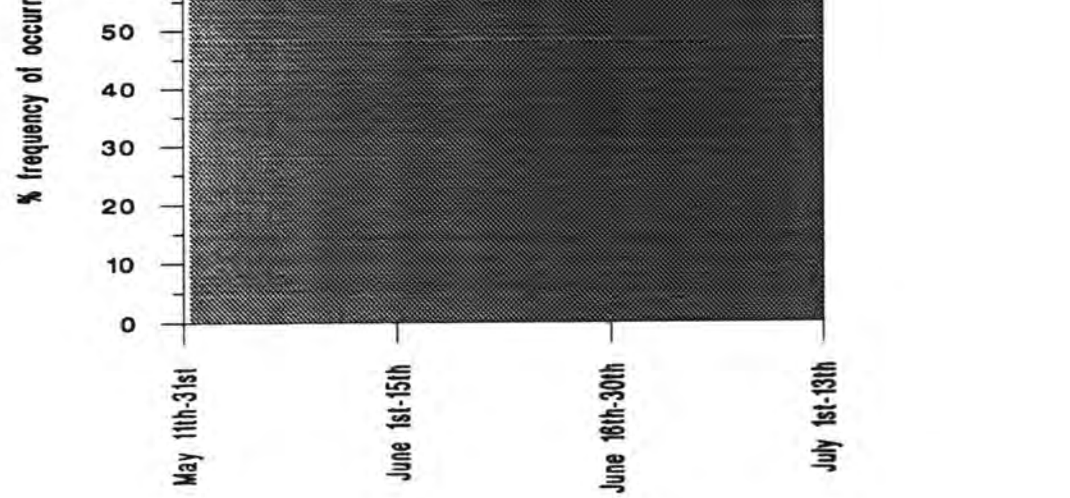
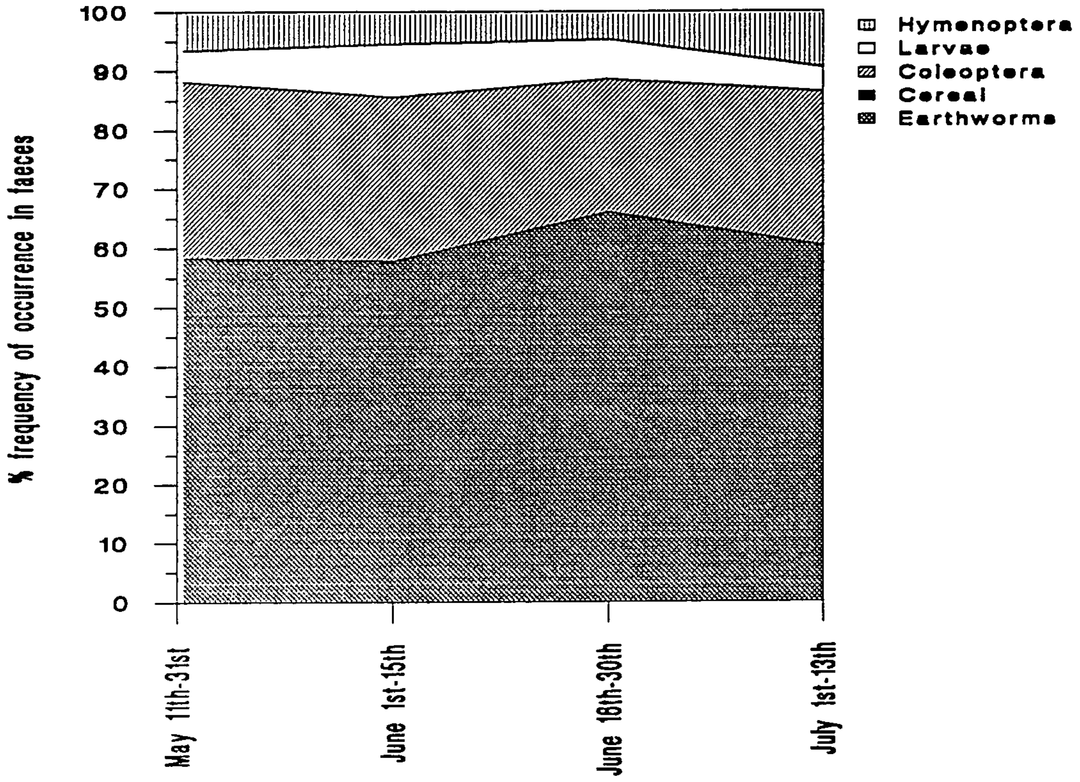


Fig. 24e Reservoir - Temporal variations in mean percentage occurrence of each prey category during the study period



off and then decreased again at the end of the study. This is possibly compensated for by a decrease in the percentage occurrence of cereal at the start of the study followed by an apparent increase at the end of the study period.

Fig. 24c shows the dietary variations of the River Bank clan. The percentage occurrence of earthworms in the diet appears to fluctuate during the study period. As with the Badger Bank clan these fluctuations are possibly compensated for by simultaneous fluctuations in the percentage occurrence of cereal. The temporal, dietary variations of the Hollinside clan are displayed in Fig. 24d. The earthworm percentage occurrence seems to fluctuate during the study period. However with this clan the percentage occurrence of cereal appears to remain fairly constant. The percentage occurrence of larvae in the diet possibly decreases towards the end of the study period. Fig. 24e shows the temporal variations in the diet of the Reservoir clan. There is no cereal in the diet unlike the other four clans. All of the prey categories present in the diet appear to remain fairly constant in terms of percentage occurrence throughout the study period, with no major fluctuations.

Fig. 25a compares the mean values for percentage occurrence of all the prey categories over the whole study period for each clan. The differences between the clans in percentage occurrence of cereal can clearly be seen, with the Reservoir clan consuming none at all . There is a significant difference between the clans in the percentage occurrence in the diet of different prey classes. ($\chi^2_6 = 92.21$, $P < 0.001$). All the clans took earthworms a lot more frequently than anything else. The second most frequently taken prey type for every clan was Coleoptera.

Fig. 25b shows the mean values of relative percentage volume of each prey category for each clan over the whole study period. From this it can be seen that earthworms are taken in far greater volume than any other prey type. Larvae were the prey type taken in the next greatest volume. Taken together the graphs Figs. indicate that Coleoptera are taken more frequently but in smaller volume than larvae.

Having calculated the percentage of each habitat type within each territory and measured the relative availability of major prey categories within each habitat it was possible to work out the relative availability of each prey type to each clan of badgers (Figs. 26a-e). For each clan and prey type this was calculated by multiplying the availability of the prey type in a habitat (expressed in terms of the total number caught in that habitat in pitfall traps during the study period or in the case of earthworms the number per m^2) by the percentage of that habitat in the territory of the clan and adding together the values obtained for each of the habitats present in that clan's territory. E.g. to calculate relative availability of Coleoptera to the Reservoir clan: (% woodland in

Fig. 25a Comparison between clans. The mean percentage occurrence of each prey category taken over the whole study period

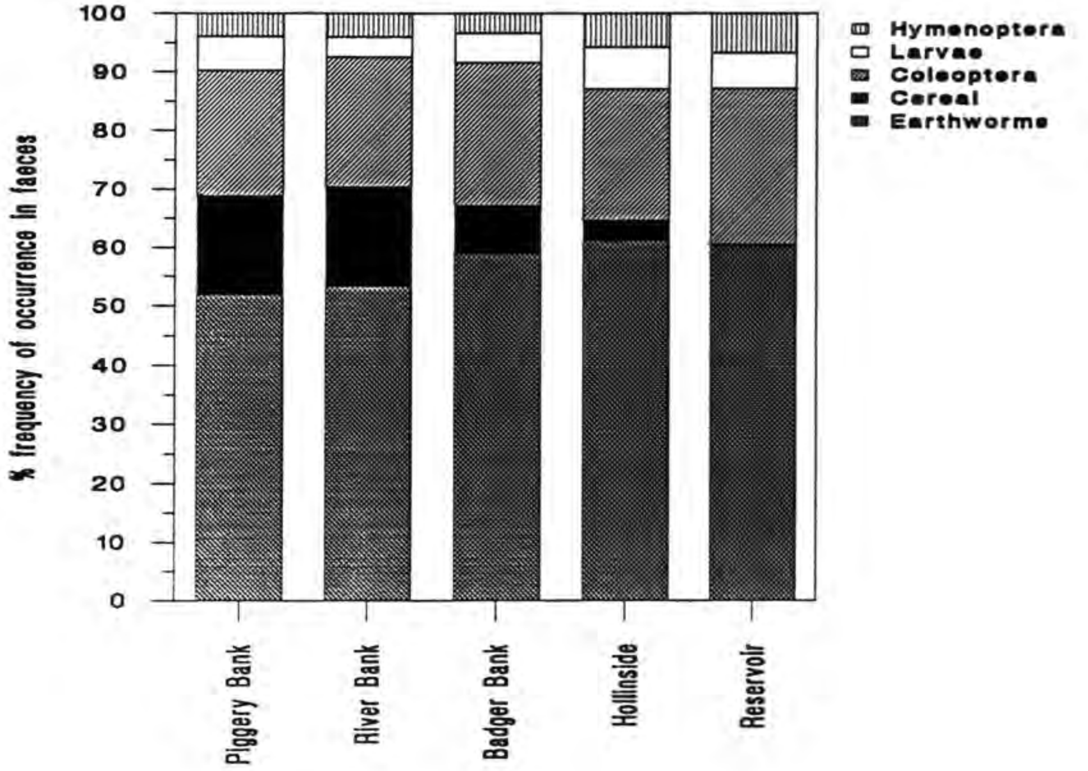


Fig. 25b Comparison between clans. The mean percentage volume of each prey category taken over the whole study period

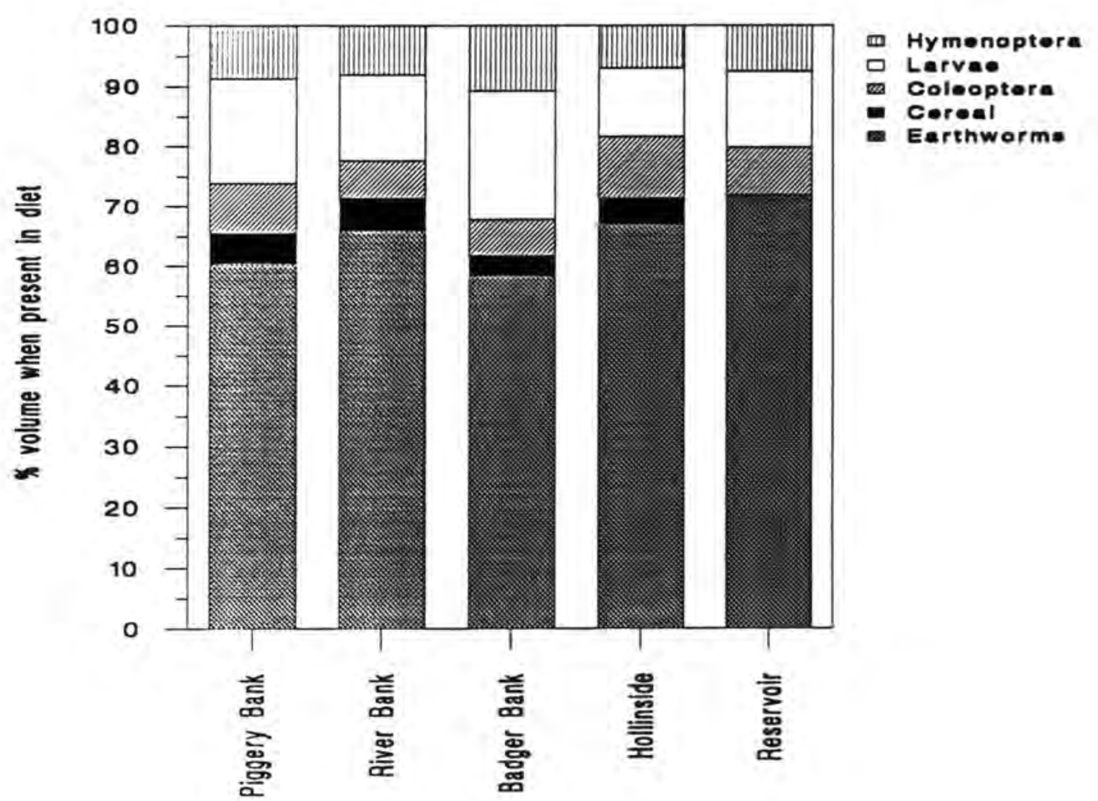


Fig. 26a Relative availability of earthworms in each territory

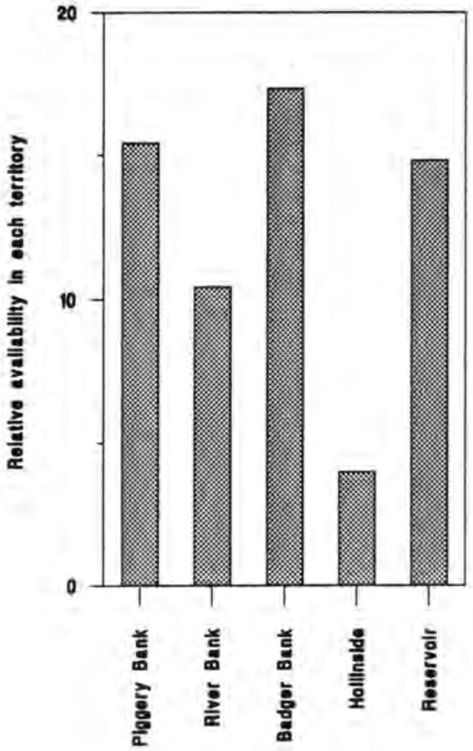


Fig. 26b Relative availability of Coleoptera in each territory

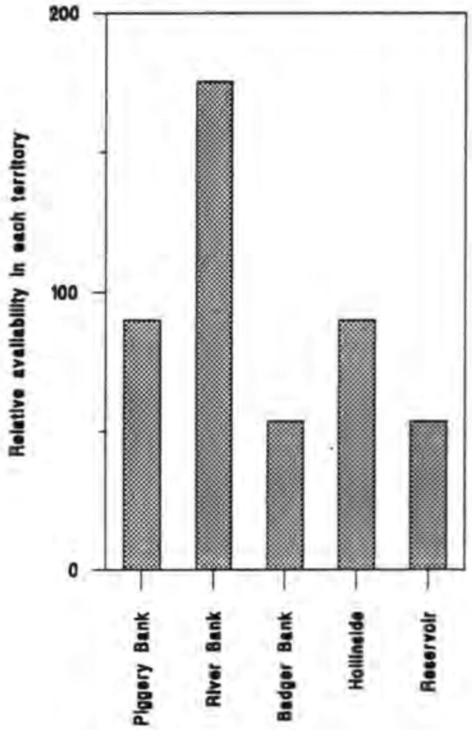


Fig. 26c Relative availability of larvae in each territory

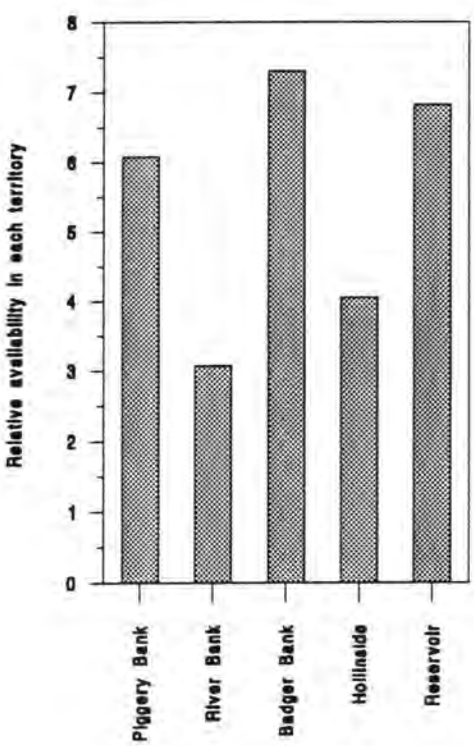


Fig. 26d Relative availability of Hymenoptera in each territory

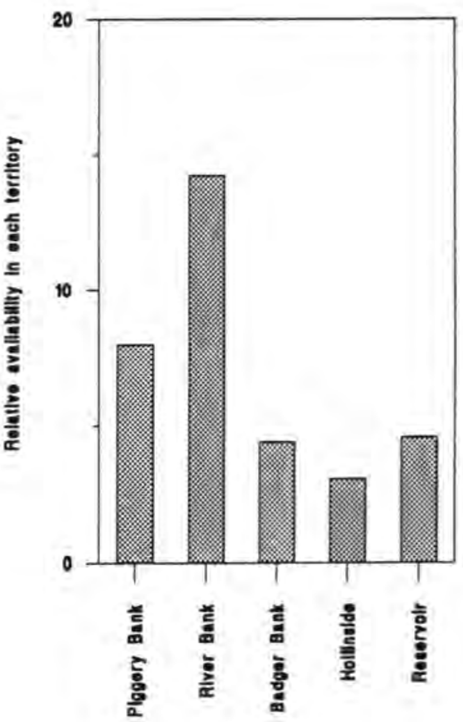
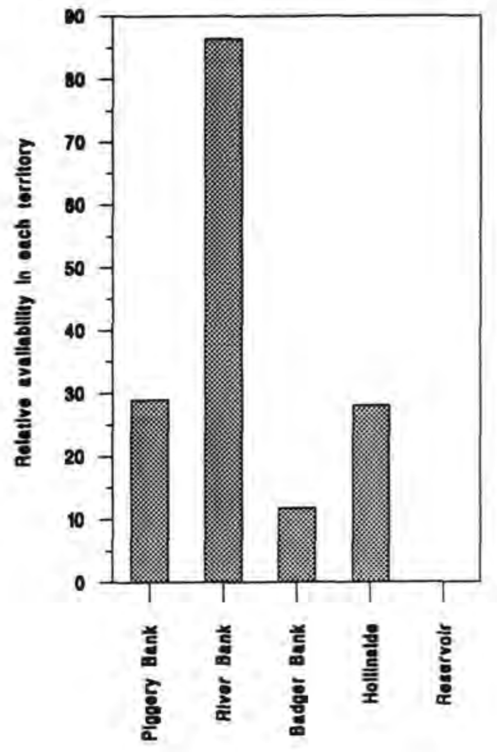


Fig. 26e Relative availability of cereal in each territory



territory x availability of Coleoptera in woodland) + (% pasture in territory x availability of Coleoptera in pasture) = relative availability of Coleoptera to the Reservoir clan. Availability of Coleoptera, Hymenoptera and larvae was expressed as numbers caught in pitfall traps. Earthworm availability was based on the mean number per m^2 using the formalin extraction method and cereal availability was taken to be the percentage of the clan's territory that was covered by cereal. Because the numbers are not absolute figures of availability it means that comparisons cannot be made between availability of different prey types e.g. the number of Coleoptera available cannot be compared with the number of Hymenoptera available nor with the number of earthworms. However it is possible to draw meaningful comparisons between clans e.g. the relative number of earthworms available to one clan can be compared with the numbers available to the other clans. Cereal availability was calculated on the basis of the percentage of each territory that was covered by either barley or wheat. It was not possible to measure other sources of cereal e.g. from pheasant feeders. Also the crops matured during the study period so although the availability of cereal may have increased slightly during the time it would have been difficult to obtain a meaningful measure of this.

It has been suggested (Kruuk and Parish 1981) that badgers take earthworms in large numbers and volume whatever their relative availability and that other minor foods are taken in proportion to their availability. That, excluding earthworms, badgers simply take whatever is available in their range in an opportunistic manner. To test this hypothesis, availability in the territory was correlated with percentage occurrence in diet for each prey type (Table 6). There appeared to be no significant correlation between availability and occurrence in diet for any of the prey types.

The percentage volume for each prey type when present in the diet was also correlated with prey availability for each territory (Table 7). As with the previous set of results there was no significant correlation between availability of prey in the territory and volume of prey in the diet.

It is of interest to see if the presence of one type of prey in the diet can compensate for another. A negative correlation between either the percentage occurrence or the percentage volume of two prey types would suggest that lack of one prey type in the diet was being compensated for by increased consumption of the other type.

TABLE 6. Prey availability in the territory as a function of percentage occurrence of prey in the diet.

	REGRESSION LINE EQUATION	r^2
EARTHWORMS	y = 59.97 - 0.22x	0.080
CEREAL	y = 3.99 + 0.17x	0.512
COLEOPTERA	y = 25.93 - 0.03x	0.397
HYMENOPTERA	y = 5.74 - 0.14x	0.207
LARVAE	y = 4.43 + 0.20x	0.071

TABLE 7. Prey availability in the territory as a function of percentage volume of prey in the diet.

	REGRESSION LINE EQUATION	r^2
EARTHWORMS	y = 69.99 - 0.43x	0.180
CEREAL	y = 2.19 +0.05x	0.531
COLEOPTERA	y = 8.47 - 0.01x	0.052
HYMENOPTERA	y = 8.45 - 0.002x	0.0001
LARVAE	y = 8.51 + 1.23x	0.331

To see if there was any relationship between the percentage occurrence of different prey types in the diet the correlations shown in Table 8 were carried out. The only significant correlation was between the percentage occurrence of earthworms and cereal (Fig. 27). There was a negative correlation between earthworms and cereal in the diet in terms of percentage occurrence suggesting the clans that consumed cereal less frequently consumed earthworms more frequently and *vice versa.*

Table 9 shows the correlations between different prey types in the diet in terms of percentage volume. The only significant correlation was between larvae and Hymenoptera consumption (Fig. 28). There was a positive correlation between the volume larvae in the diet and the volume of Hymenoptera in the diet.

The sizes of all Coleoptera, Hymenoptera and larvae found in the scats were estimated and so were the sizes of all these invertebrates found in the pitfall traps. Figs. 29a-c show the differences between the sizes of each prey type caught in the traps compared with the size of the prey items found in the scats. For each prey type a 2x2 χ^2 test was carried out to compare the number of prey in the habitat and diet in terms of prey >10mm and prey <10mm in size. For all three prey types the badgers eat significantly more of the largest prey size (>10mm) and significantly less of the smaller prey sizes (<3mm, 4-6mm, 7-9mm) than if they were taking prey sizes in proportion to those available in the habitat. Coleoptera ($\chi^2_1 = 99.91$, $P < 0.001$), Hymenoptera ($\chi^2_1 = 466.00$, $P < 0.001$) and larvae ($\chi^2_1 = 44.75$, $P < 0.001$).

Fig. 29a shows the sizes of Coleoptera available in the habitat, and the greatest number was in the 4-6mm class. However it shows that in the diet the size class predominantly taken was >10mm. This suggests that the badgers were selecting against the sizes that were most commonly available to them. Fig. 29b shows that the only size class of larvae taken by the badgers is >10mm despite the availability in the habitat of smaller larvae. Fig. 29c shows that most Hymenoptera available in the habitat are in the <3mm size class. The badgers however took no larvae that were smaller than 7mm and most of the larvae in their diet were larger the 10mm in size.

TABLE 8. Correlations between percentage occurrence of different prey types in the diet. (* = $P < 0.05$)

	REGRESSION LINE EQUATION	r^2
COLEOPTERA vs. HYMENOPTERA	y = -3.77 + 0.36x	0.301
COLEOPTERA vs. LARVAE	y = 3.04 + 0.11x	0.028
COLEOPTERA vs. CEREAL	y 74.66 - 2.80x	0.585
COLEOPTERA vs. EARTHWORMS	y = 2.67 + 0.59x	0.425
HYMENOPTERA vs. LARVAE	y = 30.20 - 4.41x	0.391
HYMENOPTERA vs. CEREAL	y = 47.65 + 1.99x	0.642
HYMENOPTERA vs. EARTHWORMS	y = 30.12 - 3.80x	0.422
LARVAE vs. CEREAL	y = 46.77 + 1.66x	0.433
LARVAE vs. EARTHWORMS	y = 46.77 + 1.66x	0.343
CEREAL vs. EARTHWORMS	y = 107.14 - 1.71x	0.911*

TABLE 9. Correlations between percentage volume of different prey types in the diet. ($** = P < 0.01$)

	REGRESSION LINE EQUATION	**r^2**
COLEOPTERA vs. HYMENOPTERA	$y = 13.15 - 0.61x$	0.507
COLEOPTERA vs. LARVAE	$y = 27.32 - 1.54x$	0.433
COLEOPTERA vs. CEREAL	$y = 4.13 - 0.05x$	0.002
COLEOPTERA vs. EARTHWORMS	$y = 55.40 - 1.20x$	0.148
HYMENOPTERA vs. LARVAE	$y = -7.14 + 2.68x$	0.971**
HYMENOPTERA vs. CEREAL	$y = 2.21 + 0.81x$	0.014
HYMENOPTERA vs. EARTHWORMS	$y = 90.21 - 3.03x$	0.692
LARVAE vs. CEREAL	$y = 2.17 + 0.00x$	0.032
LARVAE vs. EARTHWORMS	$y = 82.92 - 1.18x$	0.760
CEREAL vs. EARTHWORMS	$y = 18.88 - 0.23x$	0.321

Fig. 27 Correlation between earthworm and cereal consumption in terms of percentage occurrence in the diet

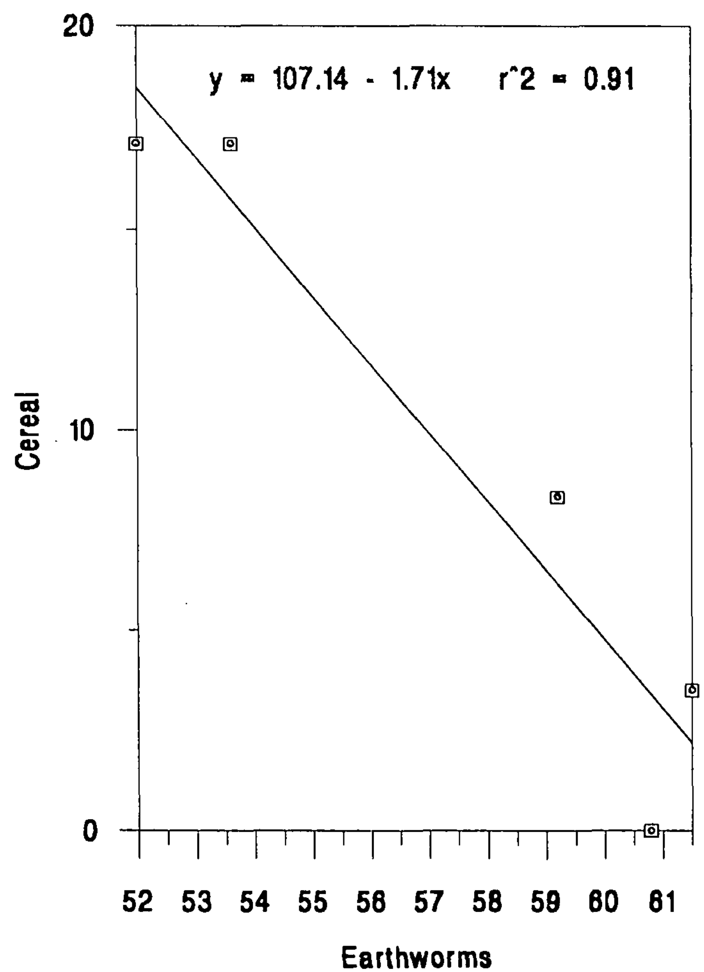
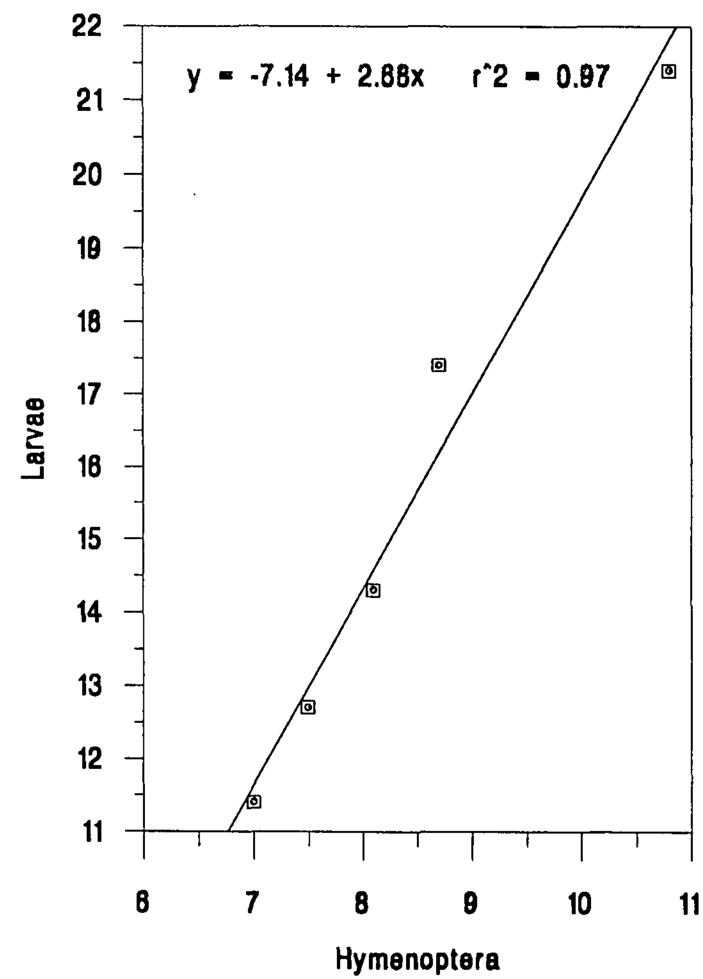


Fig. 28 Correlation between larvae and Hymenoptera consumption in terms of percentage volume in the diet



Figs. 29a-c Comparison between percentage frequency of occurrence of each size class in the diet and in the habitat

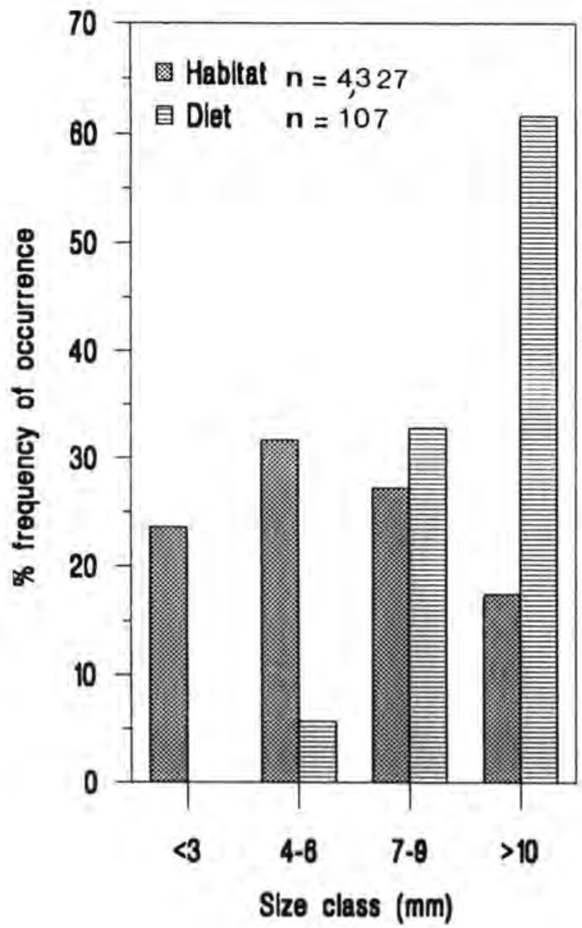


Fig. 29a Coleoptera

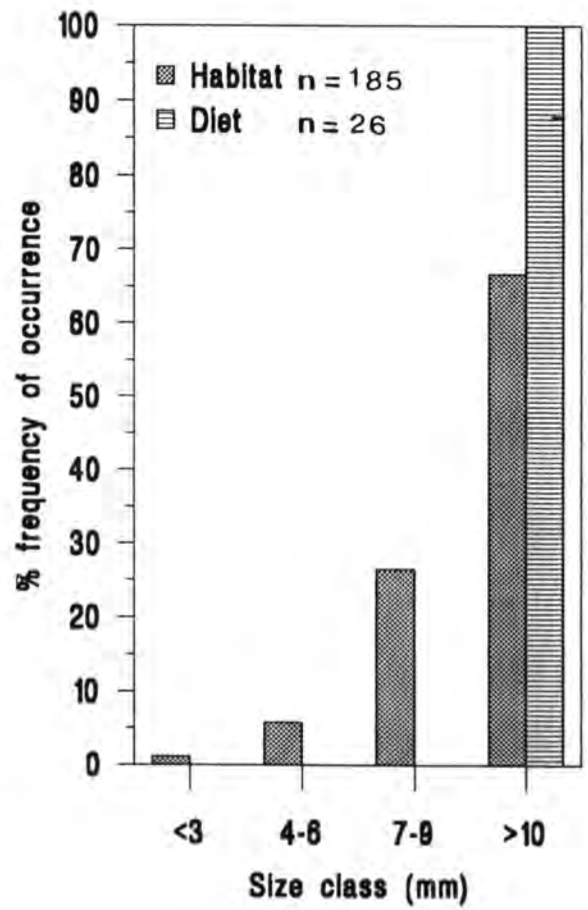


Fig. 29b larvae

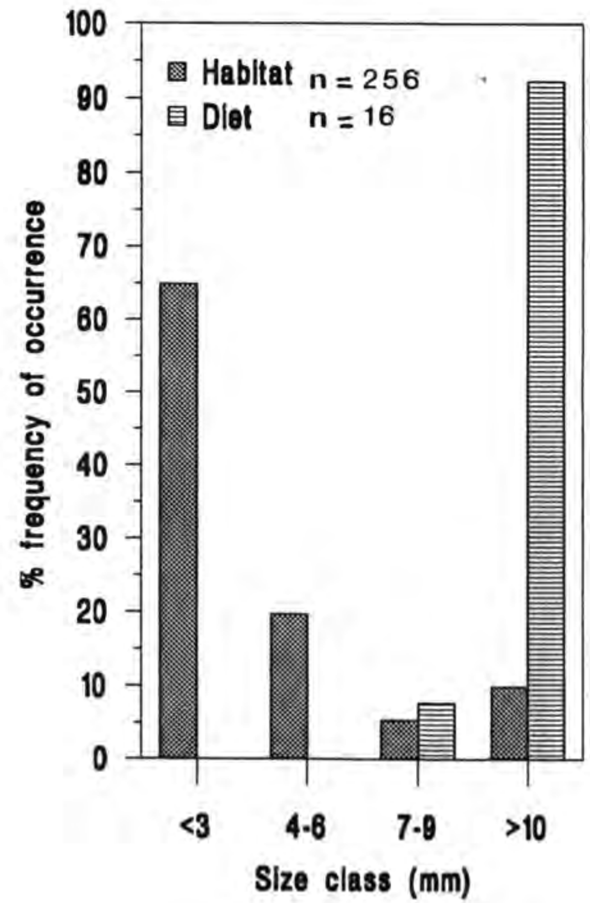


Fig. 29c Hymenoptera

5.0 DISCUSSION

Badger diet and prey availability were assessed and then compared to see if there was any relationship between them. Bait marking allowed each faecal sample collected to be attributed to one of five distinct groups (clans) of badgers with separate and measurable home ranges. Knowledge of the home range of each clan enabled prey availability for each of these clans to be compared.

The five badger clans found in the study area appeared to have home ranges of quite different sizes (Table 2). These sizes are fairly similar to home ranges of badgers near Oxford (Kruuk 1989) where sizes varied from 20 hectares to 80 hectares with an average of about 50 hectares. In Scotland Kruuk (1989) found badgers to have much larger home ranges of up to 300 hectares. He suggested that the size of the ranges of badger clans was correlated with the dispersion of their main food source. Therefore perhaps the relatively small home ranges of the badgers in this Durham study are related to relatively small distances between worm concentrations compared to a wider dispersion of food resources in Scotland.

It is quite possible that home range estimates were inaccurate because they relied solely on finding each clan's latrines. It is impossible to say that all of the latrines were found despite thorough searching. Missing one or more latrines belonging to any of the clans would have resulted in miscalculations of home ranges and of the percentage of each habitat within the range. Fig. 14 shows the estimated home rangd for each clan. It might be expected that these ranges would be contiguous due to badgers territorial behaviour. The fact that there are gaps between the ranges indicates that they may actually extend beyond the estimated area. The method of joining together known points of a territory with a convex polygon ignores the face that badgers tend to follos boundaries such as fences and footpaths. For example, it is likely that the Reservoir clan utilises the whole of the pasture fields present in their home range and not just the sections indicated on the map. For the purpose of this study it was necessary to assume that the estimated home ranges were reasonably accurate.

There were dissimilarities in the type and percentage of different habitats available in each of the home ranges (Figs. 15a-e). The availability of each prey category differed between habitats and therefore there was a difference in the prey available in each home range.

Earthworm availability was assessed using the formalin extraction method. There was found to be no significant difference in the number or mass of earthworms available during the different months of the study. However there was a large difference in worm availability between the different habitats. Pasture contained the greatest number and mass of earthworms and woodland clearly contained the least. This agrees with the findings of Kruuk *et al.* (1979) who used formalin sampling to assess earthworm availability in England and Scotland. They found earthworms were most common in pasture with fewer worms in arable land and woodland. Some Scottish coniferous woods were found to contain no earthworms at all. Brown (1983) also found a greater number and biomass of earthworms in pasture than in arable land and least of all in woodland.

Cereal availability was based on the percentage of either wheat or barley fields in each of the clans' home ranges. Skinner and Skinner (1988) found that badgers not only foraged for wheat from fields but also had access to spilt of stored grain sources e.g. grain stores of pheasant feeders. Kruuk and Parish (1985) also found that cereals were taken by badgers not only from the fields, but also from farm buildings and from places where livestock were provided with supplementary feed. The home range of the Piggery Bank clan in this study included an area where pheasants were kept and was close to the farm buildings so it is possible that these badgers had access to cereal that was not taken account of.

The availability of Coleoptera, Hymenoptera and larvae was assessed using pitfall traps but this method suffers from several problems. The catches depend not only on the density of the population being sampled but also on the activity of individuals in it. Pitfall catches are also influenced by weather and species may show differential susceptibility to trapping according to size, behaviour and ground vegetation (Greenslade 1964). Despite their drawbacks pitfall traps are often the only or the simplest method available for studies on invertebrate populations. They do have some advantages however, they are cheap and they are easy and quick to operate. Although a comparison could be drawn between the number of Coleoptera caught in different habitats no comparison could be made between e.g. the number of Coleoptera and the number of Hymenoptera caught in any one habitat. Any difference in the numbers of Coleoptera, Hymenoptera and larvae found in any one habitat may simply be a product of the trapping method i.e. one prey category is more prone to being caught than another.

Faecal analysis was used to determine the diet of the badgers. The methods used were; percentage occurrence, percentage of scats and percentage volume (as defined in the results section). The first two methods involved the numbers of each prey category and the third method used the estimated ingested volume of each prey category. There are advantages and disadvantages to using each type of method. Faecal analysis can only give an approximate indication of dietary composition; differential digestibility of different foodstuffs will result in absolute proportions of residues in the faeces which may differ from the proportions in which the foodstuffs were actually ingested. Plant and animal fragments may occur in the faecal material in a variety of different sizes. Dietary analyses that rely on counting number of fragments only, treat as equivalent particles of different size. Food items show markedly different digestabilities and so recovery of equal numbers of fragments of two different foodstuffs in the faeces may reflect markedly different proportions of the two species as ingested.

An adjustment which may be made in analyses of carnivore diet is in terms of relative contribution to total food value of prey items which may differ markedly in size (Putnam 1984). Kruuk and Parish (1981) estimated relative *importance* of various prey species in the diet of Scottish badgers by calculating the percentage *volume* of different prey items in the diet. Thus taking account of differential digestibility and the problem of overestimating the importance of smaller prey items which occurs when using methods that rely solely on numbers of remains.

The results of the faecal analysis show earthworms to be the badgers' most important food item in terms of number and volume and this agrees with the findings of many other studies on badger diet both in this country and other European countries (e.g. Bradbury 1974; Kruuk 1978a; Kruuk and Parish 1981; Ashby and Elliot 1983; Neal 1988). A range of other prey items were taken but always in much smaller number and volume the earthworms. The only hair found in the dung samples was badger hair, unlike several other British studies (Kruuk and Parish 1981; Neal 1988; Skinner and Skinner 1988) no rabbit (lagomorph) hair or bones were found. It is possible that the badgers ate rabbits at other times of the year. Although leaves occurred in a large number of samples and often in a large volume they appeared to be largely undigested and were therefore ignored as a prey item. Other studies have also found that leaves frequently appear in faecal samples and are probably ingested accidentally (e.g. Bradbury 1974; Kruuk and Parish 1981; Harris 1984).

By separating the results for each month of the study period it was possible to look for any temporal variation in the badgers' diet (Figs 19a&b). There was no difference in the percentage occurrence or percentage volume of any of the prey categories between the different months. This was not unexpected as the study period of mid-May to mid-July was relatively short. A longer study may have shown dietary, temporal variation as may have a study that compared a summer month e.g. June with a winter month e.g. January.

By separating the faecal analysis results into samples from worm and non-worm nights it was hoped to show any differences that occurred in the diet due to weather conditions and hence worm availability (Figs. 21a&b). It was found that a greater volume of earthworms were taken on worm nights than on non-worm nights and that cereal was taken more frequently on non-worm nights than on worm nights. This suggests that badgers take advantage of the increased availability of earthworms on worm nights by consuming earthworms in greater volume and that on non-worm nights they compensate for a reduced earthworm availability by taking cereal more frequently.

When the diets of the different clans were compared a couple of differences were found. There were significant differences between the percentage occurrence and percentage volume of cereal in the diet. The badgers of the Reservoir clan consumed no cereal. This would be expected since there was no cereal within their home range. Piggery Bank and River Bank clans ate wheat and Hollinside and Badger Bank clans ate barley and this correlates with the type of cereal available in each home range. The clans that consumed wheat had a greater percentage occurrence and percentage volume of cereal in their diet than the clans that ate barley. The only other significant difference between the clans was in terms of percentage volume of earthworms in the diet. The greatest volume of earthworms was consumed by the Reservoir clan and as they ate no cereal it is possible that this increase in earthworm consumption is related to the lack of cereal available to them.

A relationship between availability and consumption of earthworms was found, as previously stated, where badgers ate an increased volume of earthworms on worm nights. However there was no significant correlation between the percentage occurrence or percentage volume of earthworms in the diet and availability in the habitat as measured by the formalin extraction method. This is in contrast to a study by Shepherdson *et al.* (1990). They found that earthworm intake was correlated with worm biomass as measured by formalin-sampling, but not with the number of worm nights.

By comparison Kruuk and Parish (1981) found no correlation between any of their indices of worm availability and occurrence in the badger diet and they suggest that badgers compensated for any variation in earthworm availability by changing the foraging effort. This would be the foraging pattern of a worm-specialist which makes use of opportunities provided by the availability of other foods. Badgers emerge earlier during dry periods when worm supply is short (Neal 1977) and they tend to cover longer distances, abandoning their 'patch feeding strategy (Kruuk 1978a). Many direct observations suggest that badgers forage more actively when conditions are adverse to worm catching (Kruuk and Parish 1981) and Cresswell and Harris (1988) found that there was a decrease in badger activity and range of movements with increasing rainfall in the autumn.

Results of a badger study by Mellgren and Roper (1986) suggested that when a patch is encountered for the first time, a strategy of area-restricted searching keeps the animal's trajectory largely within the patch boundary. After a single exposure to a novel patch, however, badgers show evidence of being able to remember its location and extent, apparently with reference to distal landmarks. It was suggested that the animals have an inherent, tendency , once they have captured a prey item by chance, to search more thoroughly in the immediate vicinity of the capture (area restricted searching). When they are hunting for worms, badgers slow down and search more thoroughly immediately after making a capture (Shepherdson *et al.*1990) and this makes sense as earthworms are found in local pockets of dense concentrations within a larger patch.

It must be noted that Kruuk (1978a) and Brown (1983) found worm biomass and productivity to be vastly in excess of what the badger population is estimated to consume. So even in territories where worm availability was relatively less than other territories there could still have been a superabundance of earthworms so that they were not a limiting factor.

The measurement of earthworm availability in the habitat using the formalin extraction method and weather data (from an observatory over half a mile north of Great High Wood) to calculate worm nights may be too simplified. Kruuk (1978a) found that the distribution of worms was extremely heterogeneous in space and time e.g. the worms could disappear within minutes if there was a slight change in weather conditions, such as wind. Climatic conditions were important determinants for worm availability on the surface at night, these conditions varied not only in time, but at any particular moment there would also be large differences between various parts of the badgers' range. Within a territory there could be large variations in micro-climate and the overall effect of this heterogeneity within a badger's range was that usually worms were to be found on the surface in relatively small areas only.

This study found that there were differences in availability for all prey types that were not reflected in the diet of the clans. It was expected that availability of minor prey categories would correlate with their percentage occurrence or percentage volume in the diet but this was not the case. It is possible that there was a superabundance of prey during the study period and that they would only become limiting during the colder months of the year. Henry (1985) found that badgers were generalists when food was scarce and specialists when food was abundant and that when food was abundant they were able to select food without respect to apparent availability.

The availability of each prey type to each clan was based on the assumption that the badgers used all parts of the territory. The proportion of each habitat type in the territory was thought to represent the proportion of time spent in each of these habitats. However this may not have been true and badgers could be favouring certain habitats for foraging and spending a disproportionate amount of time there. Kruuk (1978a) found that the time badgers spent in various areas was significantly different from the expectation based on the surface area of the vegetation types e.g. 27% of the time was spent in young plantations which only occupied 8% of the home range area.

In order to obtain an accurate estimation of habitat utilisation it would be necessary to use a radio tracking system. The observation of individual badgers with radio transmitters is essential for investigating individual differences in range use within the group range system. An automatic location recording system would give continuous range boundary and utilisation data but would be very costly (Parish and Kruuk 1982).

As with the invertebrate prey categories there was no correlation between cereal consumption and availability. This may be due to the fact that two clans had wheat available to them and two had barley available to them. Cereal was taken more frequently and in greater volume by the two clans that consumed wheat than by the two clans that consumed barley. If badgers prefer wheat to barley then this could help explain why there was no correlation between cereal availability and consumption. Clans with wheat in their territories would eat relatively more cereal and clans with barley in their territories would eat relatively less than would be predicted from the quantities available.

Skinner and Skinner (1988) found that wheat was the major food item of badgers in their study area, forming 32.1% of the diet. Kruuk (1978a) also found that wheat was eaten frequently and tat along with acorns it was the next most important food to earthworms. Kruuk and Parish (1981) found that oats, when they were available were highly preferred to barley by the badgers, and barley was left almost untouched if there were oats nearby. In other areas too, barley is commonly grown but left largely untouched by badgers (Skoog 1970; Neal 1977). Faecal analysis by Kruuk and Parish (1981) has shown that the digestion of barley is very inefficient.

The relationship between different prey items in the diet in terms of both percentage occurrence and percentage volume was looked at. The only significant correlations between different prey types in the diet were between earthworms and cereal (in terms of percentage occurrence) and between larvae and Hymenoptera (in terms of percentage volume). There was a negative correlation between percentage occurrence in the diet of earthworms and cereal. The clans that ate the least cereal (or none) ate the most earthworms. Kruuk and Parish (1981) also found a strong negative correlation between earthworms and cereal in badger diet but in terms of relative volume rather than percentage occurrence. They suggested that this negative correlation might have an underlying causal relationship i.e. it could be that badgers compensated for a lack of earthworms by eating more cereal, replacing one staple food by eating more of another staple food, rather than increasing the intake of all other foods.

Another example of a possible relationship between earthworms and cereal consumption is the fact that the one badger clan (Reservoir) with no cereal available in their home range ate significantly more earthworms in terms of percentage volume than the other four clans.

There was a positive correlation between the percentage volumes of larvae and Hymenoptera in the diet. Clans that ate relatively more larvae also ate relatively more Hymenoptera. Perhaps they forage for larvae and Hymenoptera in a similar way and so if there is a localised abundance of one they concentrate on it and then also detect more of the other as a consequence. This is however fairly unlikely as Hymenoptera and larvae are not similar in appearance and Hymenoptera are far more mobile.

The final set of graphs in the results section of this study show that badgers took larger prey items (>10mm) in preference to prey items from smaller size classes. They selected against the commonest size classes for Coleoptera and Hymenoptera and all the larvae taken were in the >10mm size class despite the availability of smaller larvae. Selection of larger prey items may be because these are easier to detect and/or catch than smaller individuals. It is possible that the smaller prey items were eaten but were harder to detect in the faeces and are therefore under-represented. However all the dung samples were examined very carefully so this can probably be ruled out. Selection of the larger prey items probably represents a strategy for maximising foraging efficiency, as badgers would have to consume far more of the smaller prey items in order to satisfy their energy requirements.

This study highlights the importance of earthworms in the diet of the badgers and the wide range of other minor prey items taken. There were found to be differences in the prey availability for the five separate clans. These differences were not reflected in the diet. From previous work by Kruuk and Parish (1981) it was expected to find a relationship between prey availability and consumption for the minor prey categories. The lack of any correlation in this study may be due to superabundance of prey items at this time of year, all cereal being treated as one prey category when badgers may prefer to eat wheat rather than barley, inadequate measurements of prey availability (e.g. .not being able to measure micro-climates within the study area) or lack of information on exact habitat usage. Perhaps a study involving radio tracking would be able to provide more accurate home range measurements and give and indication of the relative amounts of time spent in each habitat type.

Several different factors point to there being a relationship between earthworm and cereal consumption. They were related in terms of percentage occurrence in the diet, the Reservoir clan ate no cereal and a greater volume of earthworms than the other clans and there was an indication that on non-worm nights the decreased intake of worms in terms of volume may have been compensated for by an increased occurrence of cereal in the diet.

Finally badgers were shown to be selective over the size of the prey items that they took (Coleoptera, Hymenoptera and larvae). The selection of larger prey suggests the use of an optimal foraging strategy.

6.0 SUMMARY

1. The diet of the badger (*Meles meles*) was assessed for on area of pasture, arable land and woodland to the south of Durham city.

2. The diet consisted predominantly of earthworms with a range of other minor prey items taken including cereal, Coleoptera, Hymenoptera and larvae.

3. The home range of each clan within the study area was estimated using bait marking.

4. Prey availability in each habitat type was measured using formalin-extraction for earthworms, and pitfall trapping for other invertebrates.

5. Relative prey availability for each clan was calculated on the basis of the percentage of each habitat in each home range.

6. Prey consumption and availability were compared to see if there was any relationship between them. The only significant correlation found was an increase in the volume of earthworms in the diet on worm nights.

7. Several aspects of the study indicated that there was a negative relationship between earthworm and cereal consumption. The lack of availability of one possibly being compensated for by an increase in the consumption of the other.

8. The sizes of Coleoptera, Hymenoptera and larvae in both the diet and the habitat were measured and compared with each other.

9. It was found that badgers were taking larger prey items more frequently than if they had been selecting them in proportion to their availability in the habitat. It was suggested that this indicated an optimal foraging strategy.

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