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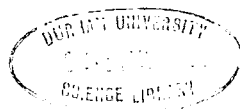
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AN INVESTIGATION
OF THE SPRING AND SUMMER DIET OF
FERAL MINK (MUSTELA VISON SCHREBER)
IN RIPARIAN AND COASTAL HABITATS

by

A. M. Rosser B.A.(Cantab.)

A dissertation submitted in part-fulfilment
of the requirements for the degree of
Master of Science in the University of Durham



An investigation of the spring and summer diet of feral mink (Mustela vison Schreber) in riparian and coastal habitats.

ABSTRACT

A total of 375 mink scats were collected from two riparian areas in Northumberland and a coastal site in Galloway during the period from April to July in order to investigate the composition of spring and summer feeding of mink. In the riparian habitat, the initial order of importance was:- fish, mammal, bird and amphibian; during the summer, though, the mammal group doubled in importance. At Galloway, a temporal variation in the diet was indicated, with lagomorph increasing in importance whilst fish and crab decreased. It was postulated that whilst the riparian diet was largely determined by prey availability coupled to some extent with preference for particular species, the variation in the coastal diet may have been due to the varying requirements of a female and kits.

The radio-tracking of a juvenile male highlighted the unreliability of using scats and tracks as indicators of mink activity. The tagged animal exhibited a mainly diurnal activity pattern with much exploratory behaviour, and it was suggested that the former may have been the result of maternal influence whilst the latter indicated attempts at territory establishment or the initiation of dispersion.

There was apparently no competition between mink and otter in the riparian habitat, but it is a distinct possibility in the coastal habitat and merits further investigation.



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A LIST OF ABBREVIATIONS USED IN FIGURES

Bullh	Bullhead	Crayf	Crayfish
Loach	Stone Loach	Insec	Insect
Salm	Salmonid	Amphi	Amphipod
Cypr	Cyprinid	Crab	Carcinus
Sback	Stickleback	Invert	Invertebrate
Lampr	Lamprey	Amph	Amphibian
Blenn	Blenny	Veg	Vegetation
S eel	Sand eel	Mamm	Mammal
Cott	Cottidae		
Rockl	Rockling		
Bfish	Butterfish		
SeaSn	Sea Snail		
SeaSc	Sea Scorpion		
NRock	Non-Rockling Gadoid		
Fbone	Unidentified fish bones		
Apode	Apodemus		
Lagom	Lagomorph		
Micro	Microtis		
Cleth	Clethrionomys		
Arvic	Arvicola		
Rat	Rattus		
Ralli	Ralliformes		
Anser	Anseriformes		
Colum	Columbiformes		
Chara	Charadriiformes		
Egg	Egg-shell		
Feath	Unidentified feathers		

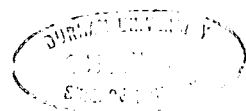
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INTRODUCTION

The American mink, Mustela vison Schreber, is a member of the family Mustelidae and shares sub-generic status with the European mink, Mustela lutreola L. The mink is a semi-aquatic carnivore inhabiting riparian, lacustrine, estuarine and coastal habitats throughout the temperate forest zones of North America. Feral populations of M. vison have become established in Northern Europe and may have contributed to the reduction of M. lutreola's range in Finland and Russia as the two species have many features in common, including habitat preference and diet (Novikov, 1962; Westman, 1968).

The mink has the typically long thin body of the mustelids. The natural pelage is a dark brown, almost black, with variable chin spots which facilitate individual identification by means of their characteristic pattern. Commercial breeding has exploited several mutations, however, and coat colours now range from Pastel and Silver-Blue to the natural colouration, dark brown and less commonly Silver-Blue being the most frequent in feral populations (Cuthbert, 1973; Birks, pers. comm.). It is similar in size to the polecat, Mustela putorius L., males weighing 950 g and measuring 400 mm head-body length, whilst females are considerably smaller, 580 g and 350 mm respectively (Hewson, 1972). Despite their aquatic predilection, mink show few adaptations pertinent to amphibious behaviour. The feet are no more webbed than those of the wholly terrestrial polecat, although the pelage contains a greater proportion of guard hairs. Although aquatic vision is inferior to that on land,



Dunstone and Sinclair (1978) have shown that, if the mink limits its aquatic hunting to bright light conditions, it is at no greater disadvantage than when hunting on land in twilight. In addition, Poole and Dunstone (1976) have postulated that the observed hunting method of prior fish location from a terrestrial vantage point (Herrick, 1892) may be a behavioural means of compensating for this poor vision.

The American mink was introduced into Europe in the 1920's when a number of fur farms were established. Soon after its introduction, escapes of ranch mink occurred in many countries as a result of inadequate security. Feral populations became established in Sweden in 1928 (Gerell, 1967a), in Norway in 1930 (Wildhagen, 1956) and in Britain in 1938 (Thompson, 1968), and have been reported in Iceland (Gudmunsson, 1952); Finland (Westman, 1966) and Ireland (Deane and O'Gorman, 1969).

The first confirmed report of feral mink breeding in Britain was in 1955 (Linn and Stevenson, in press). Being an opportunist and generalist carnivore, mink spread rapidly along water courses, as dispersing juveniles and transients extended the range. In Devon, Linn and Stevenson (in press) describe a two-stage colonization in which mink were initially restricted to the Teign valley, possibly due to the lower carrying capacity of the headwaters. The second phase was an explosive dispersion during which mink migrated long distances to find favourable habitats.

Mink are associated with freshwater habitats, particularly streams and rivers where there is considerable vegetation cover (Errington, 1961; Southern, 1964). Hall (1928), Gerell (1968) and Hatler (1971) have also described

coastal populations in the United States, Canada and Sweden respectively.

In Britain, mink are similarly associated with fresh water (Thompson, 1968), although Cuthbert (1973) has reported the presence of coastal mink on the rocky shores of Lewis and Arran and on the north-east coast of Scotland near Aberdeen. Thompson (1971) also maintains that, providing food is abundant, mink may inhabit areas away from water for some time. Gerell (1970) found, however, that they are mainly confined in their activities to areas near water; but during the winter when rivers are frozen, mink may depend on rodents in areas away from water courses (Gerell, 1967a). In addition to their preference for aquatic habitats, mink also require an area which contains potential den sites (Errington, 1946; Gerell, 1967a). In North America, they frequently inhabit deserted muskrat, Odonatra zibethica, burrows, whereas in Europe eroded tree root systems and rabbit, Oryctolagus cuniculus, burrows are favoured.

REPRODUCTION

As it is an organism of economic importance, the reproductive physiology of the mink has been well-documented (Enders, 1952). In ranch mink, mating occurs from February to March, although from a review of the literature, Chanin (1976) concluded that the mating season of feral animals lasts from February to April with a peak in March. The female may remain receptive for three weeks after the onset of the photoperiodically-induced oestrus and during this time, mating may induce ovulation.

In addition to being induced ovulators, mink also exhibit delayed implantation which restricts births to a limited period following a post-implantation gestation time of 27-33 days. The litter size of ranch mink is 3-6 kits; a similar range has been reported from feral populations (Gerell, 1971; Chanin, 1976). Parturition occurs in late April/May and the kits remain with the mother until late August when they begin to disperse, and finally reach sexual maturity at ten months. Enders (1952) reports that a female may remain fecund for seven years breeding every year, thus the potential for population increase is vast.

TERRITORY AND ACTIVITY

Mink are solitary except during the breeding season and tend to be territorial. The size of territory varies according to the suitability of the habitat, but the mean sizes found by Gerell (1970) were 2.63 km and 1.85 km of stream for an adult male and adult female respectively. There is intrasexual conflict over territory and a female may hold a territory against a male for some time (Gerell, 1970), particularly during pregnancy when aggression is increased (MacLennan and Bailey, 1969). Gerell (1970) concluded that, in his study area, population density was the main factor controlling home range size. Chanin (1976) noted that although food availability was relatively lower on his study area than that of Gerell's (1970), the territory sizes were only 20% larger, and he postulated that territory size was limited by an energetic constraint, after which point increased food intake did

not compensate for the energy consumed in patrolling the boundaries.

Gerell (1970) found a weak correlation between home range size and the number of dens used, the average number per territory being three, whilst Schladweiler and Storm's (1969) radiotracking study recorded the use of thirteen different dens by a female and her kits. The daily movement pattern recorded by Gerell (1969) consisted of a series of oscillations in which the mink tracked back and forth in a single area before repeating the procedure in another sector of the territory. The deposition of scats and scent marks at territorial boundaries is thought to discourage intruders (Gerell, 1970), but is probably more effective against resident neighbours than transient animals (Chanin 1976).

Gerell (1969) investigated the movements and activity patterns of feral mink using radiotracking techniques. A total of six animals, five males and one female were tracked for continuous periods of fourteen days. The males were mainly nocturnal at all seasons, and the activity peaks coincided with those of prey species. The single female showed a low level of activity during pregnancy and then became diurnal following parturition, during which time her activity also increased. Gerell (1969) concluded that individual activity patterns were determined by a combination of prey availability, reproductive season and environmental factors.

Hatler (1971) reported that, in a coastal area of British Columbia, mink hunted mainly at low tide and in Shetland the otter, which has similar habits, was

apparently active at all states of the tide (Watson, 1978). The difference between the hunting activities of coastal otters and mink can be attributed to their distinctive hunting strategies; otters actively dive and pursue fish whilst mink appear to hunt amongst rock pools on the intertidal zone.

DIET

The feeding ecology of the mink has been incompletely studied in North America, most of the work concentrating on the winter diet. More extensive studies have been prompted in Europe, however, where it has been necessary to discover the impact of feral mink on the native fauna.

Research in America (Dearborn, 1932; Hamilton, 1936, 1940, 1959; Sealander, 1943; Guilday, 1949; Errington, 1954; Wilson, 1954; Korschgen, 1958; Hatler, 1971, and Sargent, Swanson and Doty, 1972) has generally shown that mammals formed the greatest bulk of the diet, accounting for 32-54% of the items consumed. Muskrat was frequently the most important species taken, although Hamilton (1940), Guilday (1949), Wilson (1954) and Korschgen (1958) report that small rodents were taken more often. Fish were of secondary importance in all the studies, except that of Wilson (1954) where they accounted for 60% of the diet. Crayfish, Astacus astacus, and frogs alternated in tertiary importance, superceding birds which contributed only a minor percentage.

In Sweden, Gerell (1967b, 1968) found that the diet of mink varied with habitat and season, the greatest seasonal changes being in spring and autumn. The results from nine different habitats compiled over four years showed that fish provided the bulk of the diet, mammals were of

secondary importance, with arthropods, mainly crayfish, third in importance, whilst birds and amphibians accounted for the smallest proportions of the diet. Fish were particularly important during the winter and spring when water temperatures were low, whilst mammals and crayfish formed the greater part of the summer and autumn diets, and amphibians seemed to provide a buffer food source during the change from summer to winter diet. The majority of fish taken were small, perch and cyprinids of less than 15 cm and pike of less than 20 cm. Erlinge (1969) reported a similar size-range, but, in his area, mink appeared to take greater numbers of smaller fish. In his study, fish formed a larger percentage of the diet and were important in spring, autumn and winter, whilst the summer food consisted mainly of birds. Mammals formed a smaller proportion of the diet than in Gerrell's (1968) study, possibly due to differences in habitat.

In Britain, Day and Linn (1972) carried out the first mink diet study on material gathered from England and Wales, using the technique of gut content analysis. The order of occurrence of the major prey groups was as follows: bird, mammal, fish and crayfish. (The importance of fish is likely to have been underestimated by the study technique.) There was a significant increase in fish importance during the summer which contrasts with Swedish results. Due to the broad nature of this study, however, little value is gained by considering such details. The results of Akande (1972), who analysed both scats and gut contents from a wide area of Scotland, are more similar to those obtained in Sweden. Fish formed the majority of prey occurrences, birds were second in importance and

mammals third. She divided the year into warm and cold months, May-September and October-April respectively; during the cold months, fish were of major importance but decreased during the summer in favour of birds; mammals remained constant. Cuthbert (1979) collected scats from three rivers in Scotland and a coastal region. Fish formed the main food class, and were the most important prey at all times of the year. Mammals were the second most important dietary item, whilst birds contributed a smaller percentage of the diet. Cuthbert (1979) concluded that the overriding factor affecting mink diet is difference in prey availability, and that therefore regional studies are rarely comparable.

Chanin (1976) and Wise (1978) have both carried out detailed studies on mink feeding ecology in contrasting habitats, in order to link diet with prey availability in a quantitative manner. Their results were markedly different, possibly because Chanin (1976) used frequency of occurrence whilst Wise (1978) quoted bulk analysis data. Chanin (1976) found the order of prey importance on the river Teign in Devon to be fish, mammal and finally bird, whilst Wise's (1978) results placed mammals first followed by fish and bird. On an eutrophic lake, both authors agreed that fish were of primary importance followed by birds and then mammals, though the percentages calculated in the two studies varied significantly.

In summary, the feeding data from Britain show that, on an annual basis, fish form the major part of the diet, the relative importance of birds and mammals varying according to habitat. There also appears to be some seasonal variation, but this is less marked than in

Sweden. Generalisations about the specific composition of the diet are valueless unless the prey availability is also considered, due to the variation between habitats. When comparing results, the methods of analysis and presentation of results must also be taken into account.

COMPETITION WITH THE OTTER

The decline of the otter population in Britain has been attributed to competition with mink for prey, territory and den sites. From an analysis of hunting records, Chanin and Jefferies (1978) concluded that otters declined in many areas before mink became established. Recolonisation by otters may, however, be affected by the subsequent establishment of mink.

Food studies in Sweden have shown that there is a 60-70% food overlap composed mainly of fish. Of the fish taken by the otter, however, 30% exceeded the maximum size of those taken by the mink (Erlinge, 1969). Erlinge (1969) concluded that during the summer, the mink is less able to pursue fast fish and hence does not compete with the otter, but may do so during winter when general prey availability is reduced and fish become relatively more easy to capture due to low water temperatures. In a study of the interspecific relations between mink and otter, Erlinge (1972a) observed that mink did not succeed in colonising an area where the otter population was established.

In Britain, Chanin (1976), Wise (1978) and Cuthbert (1979) have compared the diets of sympatric mink and otter, whilst the workers investigating the diet of mink have compared their results with those published on otter diet (Akande, 1972; Day and Linn, 1972). Day and Linn

concluded that the mink is probably exploiting an unfilled niche and is unlikely to compete with any British carnivore, even the otter which takes 70-90% of its diet as fish (Stephens, 1957). Akande (1972) concluded from her Scottish study that the mink is unlikely to compete with the otter due to the amount of terrestrial prey and the size of prey which it selected. In contrast, Cuthbert (1979) in an investigation of the diet of both otter and mink in Scotland found no significant difference between the size or species of fish taken. Chanin (1976) studied the diet of otter and mink from two contrasting habitats in Devon, Slapton Leigh, an eutrophic lake and the oligotrophic river Teign. In both areas, the otter took 90% of the diet as fish, a prey group which comprised only 55% of mink diet. As both mustelids consumed a similar proportion of salmonids and eels on the river Teign, Chanin (1976) concluded that there is potential for competition. In contrast, the differing proportions of fish species and the availability of bird and mammal prey precluded competition at Slapton Leigh. Wise's (1978) results are similar to those of Chanin (1976), she recorded a diet overlap of 40%, of which 63% was fish, but with a greater number of large fish consumed by the otter. At Slapton the 38% prey overlap was composed mainly of fish (82%); there was no differential size selection in this area.

Several authors, (Jenkins, Walker and McCowan, 1979; Moors, 1975; King, 1971 and Lockie, 1961) have concluded that carnivore feeding behaviour varies according to prey availability within the study area and Erlinge (1969) and

Cuthbert (1979) assert that this is certainly so for mink. As little has been done on the diet of feral mink in Northumberland, it was planned to investigate the summer diet of mink in this area, with reference to prey availability. Although possibly contributing little to the overall understanding of mink feeding ecology, the local knowledge of interactions with the prey populations may prove useful in the management of riparian habitats. In addition, Northumberland has a relatively healthy otter population (K.Elliott pers. comm.) in comparison with other parts of England and Wales and hence provided an ideal opportunity to compare the diets of mink and otter.

The occurrence of mink on the Galloway coast may be due to a recent colonisation and it is possible that the animal may spread throughout the coastal districts of Scotland, which are at present inhabited by the otter, and hence the mink may be a potential competitor.

In addition to studying the diet of feral mink, it was planned to trap and radiotrack an individual to determine how much time was indeed spent in an aquatic environment and whether the animal does venture away from the river. This was necessary because during the early parts of the study very few scats were found and it was only once breeding dens were located that the sample size increased. Thus it was hoped to gain some knowledge of mink movements and presence in the area by trapping and tracking an individual. Knowledge of the regularity of activity bouts and the distances travelled within a single period may give some indications as to territoriality and the catchment from which prey is obtainable. (The radiotracking data are presented in the Appendix 1).

STUDY AREAS

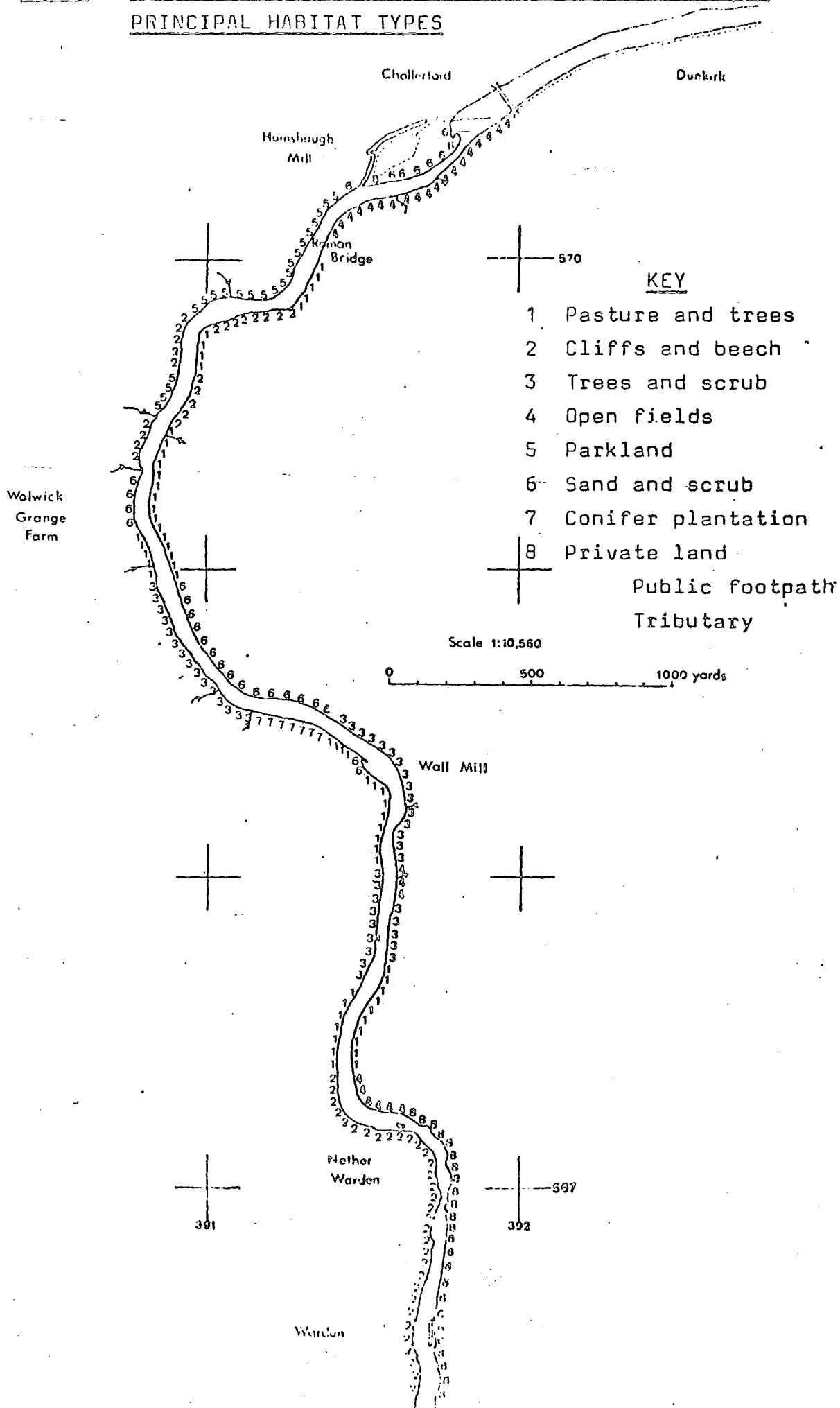
Scats were collected regularly from two main study areas, and a third was sampled on a single occasion. The main study was based on a comparison of mink diet from two sites on the river North Tyne, Chollerford and the Chirdon Burn, with that from two sites on the Galloway coast, a wooded area and the Ross Peninsula. During the initial stages of the study, stretches of the rivers Wansbeck, Font, Blyth, Tees and Greta were also surveyed for signs of mink presence (Fig 1). A small sample of scats was collected on the river Greta, a tributary of the river Tees, and on the Tees at Piercebridge. The Greta is a swift-flowing oligotrophic stream very similar to the Chirdon Burn, whilst the Tees has features in common with the North Tyne, hence only the main sites will be described.

CHOLLERFORD

The study area extended from one kilometre upstream of Chollerford Bridge (Nat. Grid Ref. NY 905693) to the confluence of the North and South Tyne near Hexham (Nat. Grid Ref. NY 917661), a total of 3.5 km. The whole area was searched at least once on both banks during the course of the study, but as signs of mink were few, the major survey was concentrated on a short stretch of 500 m from Nat. Grid Ref. NY 907691 to Nat. Grid Ref. NY 917683, which appeared to have the highest mink population.

The North Tyne rises in the Kielder Forest and flows south-east to its confluence with the South Tyne at Hexham. It is an oligotrophic river flowing through an area

FIG 2 A MAP OF THE CHOLLERFORD STUDY AREA SHOWING THE PRINCIPAL HABITAT TYPES



of limestone with an average width of 15 m and a maximum depth of 3 m in parts of the study area, although this varies with the waterflow characteristics. The surrounding land is agricultural, being mainly pasture interspersed with small copses. Within the study area there are several different habitat types, as can be seen from the map, Fig 2.

GEORGE HOTEL AREA

In this area the river is 20 m wide and flows slowly. The river is bounded by steep banks rising at an angle of 60 degrees to three metres above mean water level. Mature sycamore, Acer pseudoplatanus, and alder, Acer glutinosa, trees grow at the water's edge and overhang the river forming a dense canopy to the banks. At low water levels a muddy track is exposed running parallel to the river 0.3 m from the water's edge. The undergrowth consists mainly of grasses and is sparse due to the shading effect of the tree canopy. A public footpath runs along the top of the bank, 5 m from the water, separating the river from a background of arable and rough pasture land.

THE ISLAND

Below the bridge at Chollerford is a sandy area of approximately 0.3 ha, known as the "Island", separating the old mill from the river. The area is dissected by water runnels and depressions which temporarily fill during floods forming small pools in which fish become trapped. The dominant trees are ash, Fraxinus excelsior, and sycamore with a dense shrub layer of willow, Salix spp., and alder, and a ground flora comprising Petasites hybridus, Lysmachia

vulgaris, Centaurea nigra, Rubus fruticosus, Crepis mollis, and Phragmites australis. From the Island down to the junction with the South Tyne, several different habitat types alternate:-

Parkland:

Areas of open short grass (less than 5 cm high) reaching to the water's edge scattered with occasional beech, Fagus sylvatica, and oak, Quercus spp. Cover is virtually non-existent apart from an occasional alder at the foot of the bank.

Open fields:-

Similar to the above parkland, but used as rough grazing (grass 30 cm high) with a complete absence of trees; the only refuge is afforded by boulders or rabbit burrows.

Pasture with Trees:

Open fields of rough pasture with banks of gentle gradient bounded by a line of trees at the water's edge. Alder and sycamore are found at the foot of the bank with beech and oak several metres further from the water. In this habitat, soil is eroded from many of the tree roots forming a complex network of potential dens.

Sand and Scrub:

The banks are predominately sand, often forming flat sandy beaches, or may be boulder-strewn. The vegetation is very dense forming a low ground cover to a height of 1.5 m. The dominant species are willow and alder scrub with incidental sycamore and ash further from the water's edge. Stands of grasses, Phragmites, Crepis, Centaurea, and Lysmachia, add to the undergrowth in this habitat.

Trees and Scrub:

Boulders, willow and Phragmites at the water's edge leading to a tree layer bounding pasture. Similar to the pasture and tree habitat, but with a very different, more densely-covered waterline.

Cliffs with Beech:

There are several areas where the river cuts through a hard limestone, forming near-vertical cliffs. There is a heavy tree cover of mixed deciduous woodland species with a sparse herb/shrub layer, both surmounting the cliff and at its foot. In addition to the vegetation, den sites are afforded by piles of boulders, crevices and caves in the rock.

CHIRDON BURN

The Burn rises in the Wark Forest and flows in a north-easterly direction through coniferous forestry plantations out onto the exposed Chirdon Common. Just prior to its confluence with the North Tyne, the stream becomes wooded with fairly dense cover.

It is an oligotrophic burn 7-10 m wide with an average depth of 1 m and a maximum depth of 1.3 m when not in spate. The bed is covered with large boulders giving a turbulent flow pattern. The sandy banks are steep but only 3 m high, covered with a mixed woodland/waterside scrub vegetation of alder, ash, willow, oak, bramble, ferns and grasses.

Upstream of the Chirdon Burn, the banks of the North Tyne are covered with a dense scrub layer of alder, sycamore, willow, bramble and Phragmites. At Bent House Bridge, the bank type changes dramatically to a

FIG 3a RIVER FLOW FOR THE RIVER NORTH TYNE AT REAVERHILL STATION

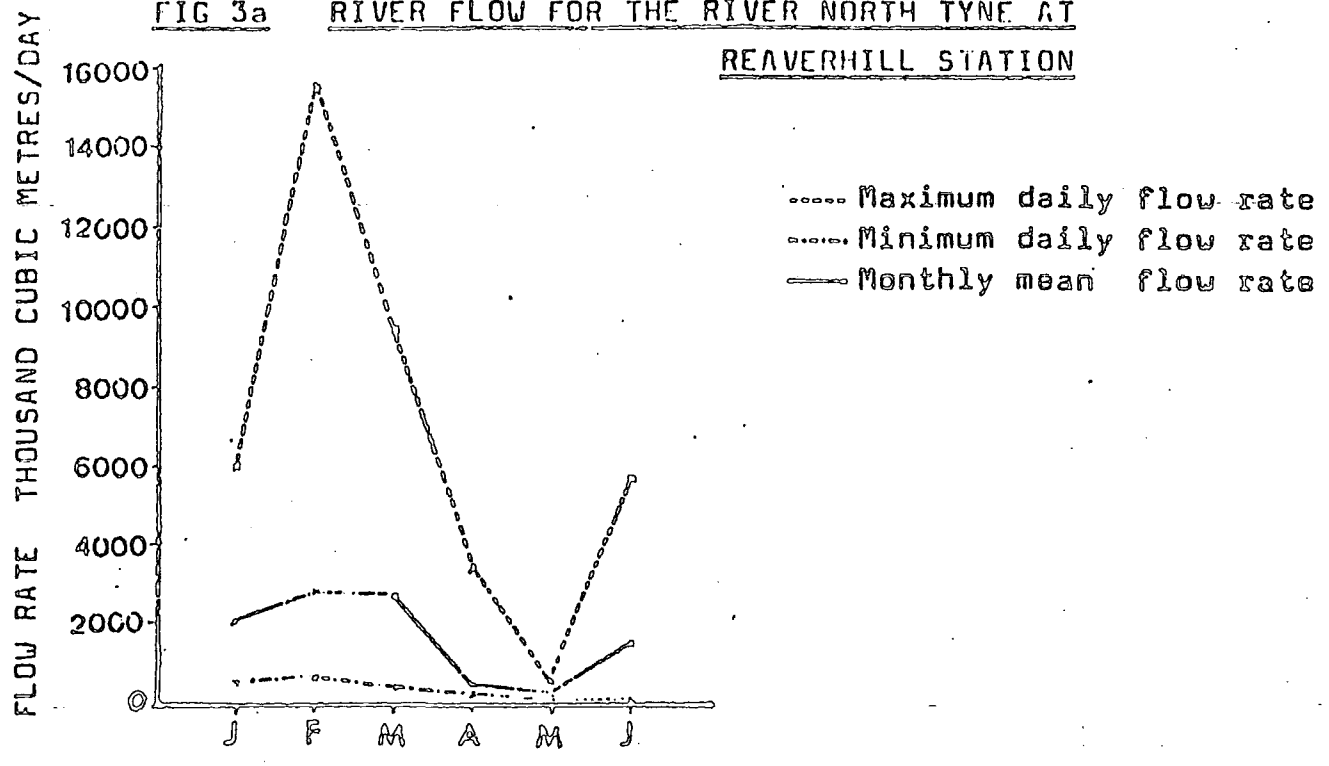
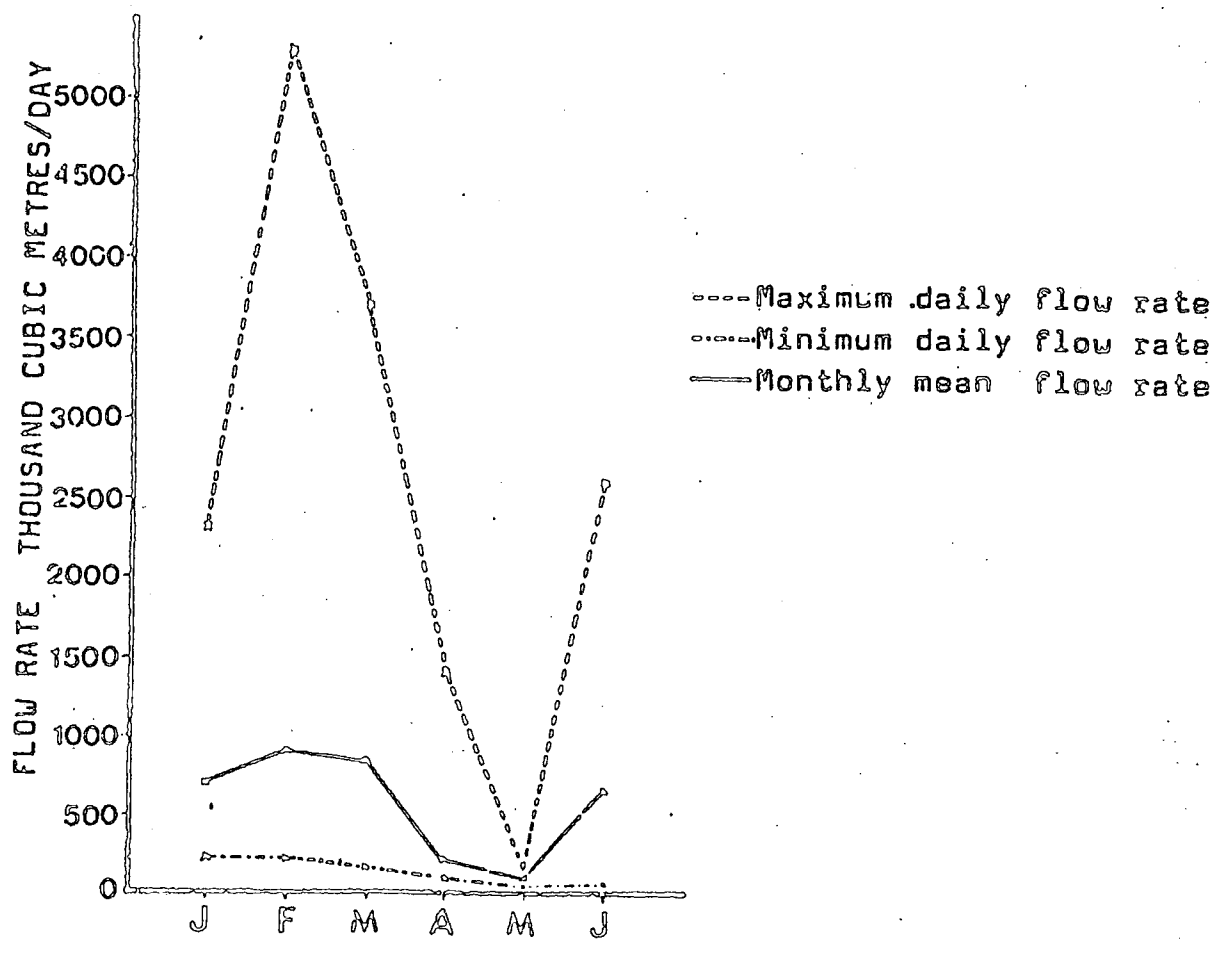


FIG 3b RIVER FLOW FOR TARSET BURN



preponderance of herb species, Umbelliferae, Compositae and Leguminae. Phragmites and grasses with small willow shrubs are also present. At this point, the North Tyne is 20 m wide and flows smoothly.

The Chirdon site is at no point more than 200 m from the road and anglers take advantage of the easy access. On almost each occasion that the river was visited, anglers were present.

River Flow:

River flow data for two areas on the North Tyne were obtained from the Northumbrian Water Authority for the months January to June 1980 inclusive. Figure 3a shows the data from Reaverhill Station on the main river. The high maximum daily flow rate in February was followed by a decrease in April and May, partly due to the end of the winter thaw, but also correlating with abnormally dry weather conditions for that time of year. June and July 1980 were the wettest months on record during the summer for some years and this is reflected in the much higher maximum daily flow rate for June compared with that of the preceding month.

Figure 3b shows data for Tarsset Burn, a tributary of the North Tyne joining the main river at the same location as the Chirdon Burn, but from the opposite direction. The pattern is very like that from Reaverhill Station, and shows that conditions were similar throughout the region, although of course gross flow in the tributary is much less than that recorded on the main river.

FIG 4 CONTRASTING AREAS OF THE RIVER NORTH TYNE



Fig 4a: Looking downstream from the profusion of vegetation in the foreground on the Island to the Roman Bridge.



Fig 4b: An area of rapids and turbulent flow downstream of the Mill, showing the contrast in amount of cover on the two banks.

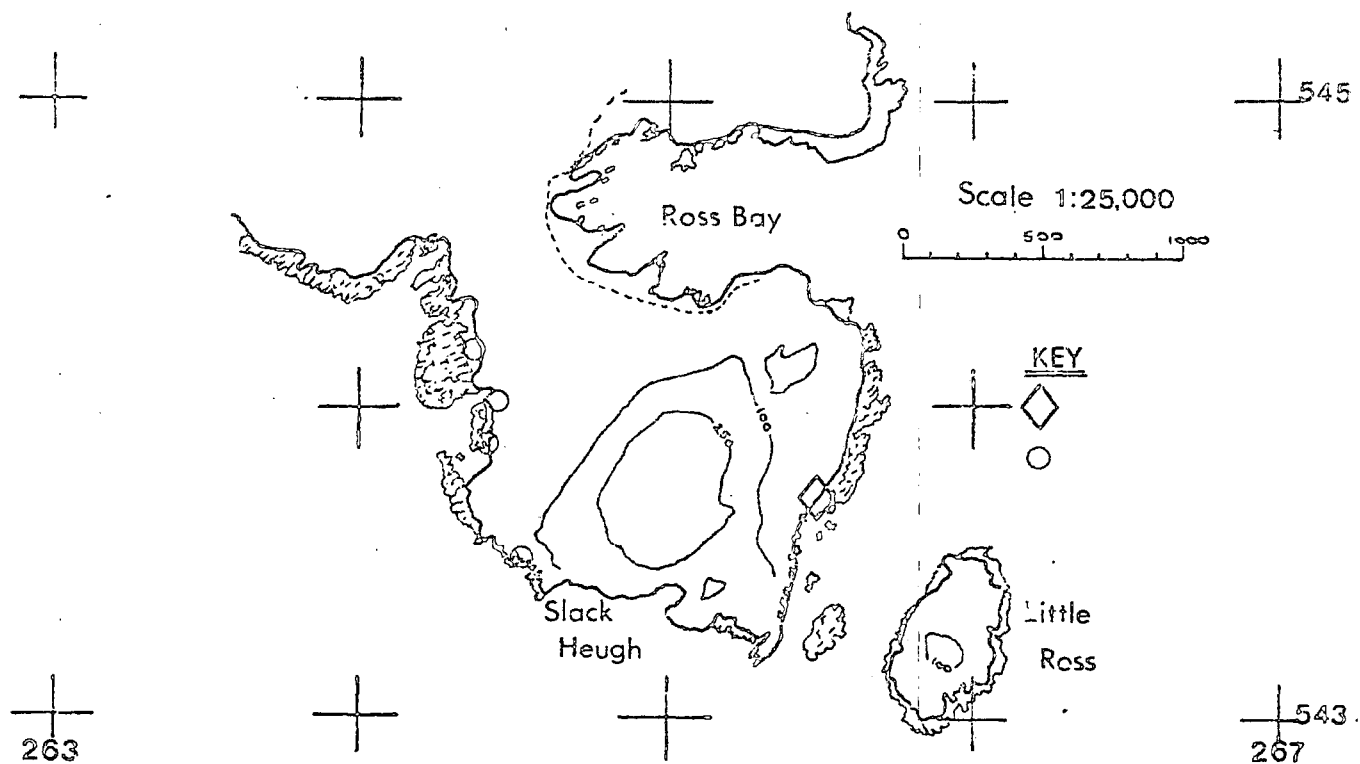


Fig 4c: A typical stretch of the Chirdon Burn.



Fig 4d: The breeding den on the Chirdon Burn was situated amongst the roots of the sycamore tree in the centre of the photograph, at the Burn mouth.

FIG 5i A MAP OF THE ROSS PENINSULA, GALLOWAY, WITH THE MAIN SCAT COLLECTION SITES MARKED



GALLOWAY

Two sites were chosen on the west coast of the Dee estuary in Kirkudbright (Fig. 5). The first area consisted of 1 km of wooded coastline, below high at low tide approximately 10 m of rocks and seaweed were exposed, with numerous small rock pools. The main vegetational species which formed a continuous dense cover 1 m from the mean high tide level were :- ash, alder, sycamore, bramble, dog-rose, Rosa canina agg., sea thrift, Armeria maritima, sea plantain, Plantago maritima, and sea mayweed, Matricaria maritima, backed by a mixed deciduous wood of sweet chestnut, Castanea sativa, ash and oak with little ground cover, apart from occasional clumps of brambles and ferns. Jumbled piles of rocks and eroded tree roots provide a relatively small number of den sites, in contrast to the riparian areas.

ROSS PENINSULA

The second area, the Ross Peninsula, is a desolate area of exposed coastline at the edge of a steep hillside rising to 76 m. The centre of the peninsula consists of a mixture of arable, rough pasture, and forestry land. On the south-east side, above the mean high water mark, there is a 10 m strip of boulders devoid even of lichens. Above this is an area of rough ground consisting of boulders, scrub vegetation, grasses, sea thrift, sea plantain, sea campion, Silene maritima, stonecrop, Sedum spp., and bramble. Interspersed along the rough ground are thickets of gorse, Ilex spp., and hawthorn, Crateagus monogyna. At low tide, rock pools cover a substantial portion of the intertidal zone, approximately one quarter of the total surface area

FIG 5 CONTRASTING AREAS OF THE COASTAL SITE



Fig 5a: Little Ross, taken from the breeding den, showing the typical rocky coastline in the foreground. The vegetation and cover on Little Ross are similar to that of the mainland.



Fig 5b: The breeding den at Galloway. Fragments of scat containing crab carapace are visible amongst the grass in the foreground.

being underwater. Seaweeds, Fucus serratus and F. vesiculosus, did not form an extensive rock cover, but were present in rock pools.

At the tip of the headland, there is no access to the south-west side at sea level due to the steep cliffs. On the south-west, the character of the coast changes again from vertically tilted strata with large intervening rock pools at Slack Heugh, to a wide boulder-strewn, gently-shelving storm beach about 100 m wide, known as the Bents. The beach is separated from the low-lying fields by a short strip of marshy land. The flat boulder area has fewer rock pools than on the south-east side, and the majority of these are on the spits of rock which dissect the beach. The seaweed cover is much more extensive than on the south-east, possibly because the gentle gradient and numerous rocks provide more opportunity for attachment, despite the higher degree of exposure on this side.

On both sides of the peninsula, the large boulders and rocky crevices provide a number of potential den sites. There is, however, very little vegetation cover on the south-west.

Prey Availability:

It had been planned to census prey populations to gain an estimate of prey availability in the study area. Due to the limited time available, however, it was only possible to make observations on the presence and/or absence of the main prey species. Mammals were recorded by Longworth trapping and identification of tracks on the North Tyne; visual counts of lagomorphs at dusk were also attempted.

The different bird species seen during visits to the study areas were recorded and additional information was supplied by P.R. Evans (pers. comm.).

The species distribution of river fish on the North Tyne and Tees was made available by the Northumbrian Water Authority from electrofishing data and records of anglers' catches.

A rock pool survey was carried out at Galloway at low tide on two occasions, but remarkably few fish were found.

Two trap-lines were set in differing habitat types at Chollerford on the North Tyne, giving a total of 54 trap-nights. The first site was along the edge of a cereal field at the top of a 10 m high steep bank 100 m from the river, and the second site was 20 m from the river at the foot of a bank in a mixed deciduous and coniferous plantation, where there was little undergrowth.

The traps were set at 5 m intervals, baited with wheat and provided with nest material. Fourteen traps were set on two consecutive nights at Site 1 and during a total of 28 trap-nights, two bank voles, Clethrionomys glareolus, three field mice, Apodemus sylvaticus, and one shrew, Sorex araneus, were caught. At Site 2, thirteen traps were set on the same two nights in August as at Site 1. A total of five bank voles, four field mice (two in one trap), and one shrew were caught during the 26 trap-nights. In addition, whilst trapping for mink in June, a water vole, Arvicola terrestris, was caught in the same mink-trap on two consecutive nights.

Water vole and small rodent tracks were numerous at the water's edge. Red squirrels, Sciurus vulgaris, were

seen on several occasions. Few rabbits were seen in the study area on the west bank of the North Tyne, but a warren showing signs of use was located. On the opposite bank, a number of juvenile rabbits were seen from early April (S. Pickering, pers. comm.) to late August. There was no direct evidence of common rats, Rattus norvegicus, but due to the proximity of several farms, it is likely that these are available to mink.

The following bird species were seen on the North Tyne :-

Goosander	<u>Mergus merganser</u>
Mallard	<u>Anas platyrhynchos</u>
Little Grebe	<u>Podiceps ruficollis</u>
Moorhen	<u>Gallinula chloropus</u>
Kingfisher	<u>Alcedo attilis</u>
Pied Wagtail	<u>Motacilla alba yarrellii</u>
Grey Wagtail	<u>Motacilla cinerea</u>
Dipper	<u>Cinclus cinclus</u>
Heron	<u>Ardea cinerea</u>
Lapwing	<u>Vanellus vanellus</u>
Sandpiper	<u>Tringa hypoleucos</u>
Curlew	<u>Numenius arquata</u>
Redshank	<u>Tringa totanus</u>
Greenshank	<u>Tringa nebularia</u>
Oystercatcher	<u>Haematopus ostralegus</u>
Pheasant	<u>Phasianus colchicus</u>
Partridge	<u>Perdix perdix</u>
Pigeon	<u>Columba palumbus</u>
Rook	<u>Corvus frugilegus</u>
Woodland birds	

According to the electrofishing data, the following species are present in the North Tyne :-

Trout	<u>Salmo trutta</u>
Salmon	<u>Salmo salar</u>
Stone Loach	<u>Nomacheilus barbatulus</u>
Three-spined Stickleback	<u>Gasterosteus aculeatus</u>
Eel	<u>Anquilla anquilla</u>
Brook Lamprey	<u>Lampreta planeri</u>
Cyprinids	Cyprinidae
Bullhead	<u>Cottus gobio</u>

Trout were the most frequent species, followed by eels.

No adult amphibians were encountered on the North Tyne, but in early summer, concentrations of tadpoles, Rana temporaria, were found basking in the shallows.

It seems likely that the mammalian and bird species on the Tees were similar to those on the Tyne, with the possible exception of some of the waders, Charadriiformes.

The fish availability must also have been similar, although migratory fish are likely to be less numerous as few can penetrate the pollution of the Tees estuary. The main cyprinids are :-

Chubb	<u>Leuciscus cephalus</u>
Roach	<u>Rutilus rutilus</u>
Perch	<u>Percha fluviatilis</u>

On the coast, a rabbit census was carried out along a 500 m transect at dusk. Only eleven individuals were encountered. Brown hares, Lepus capensis, were also present as evidenced from skeletal remains and several sightings. No other mammals were encountered during the brief visits.

The sheer cliffs of the Ross Peninsula support

a sea-bird colony and the following species were recorded:-

Cormorant	<u>Phalacrocorax carbo</u>
Shag	<u>Phalacrocorax aristotelis</u>
Kittiwake	<u>Rissa tridactyla</u>
Herring Gull	<u>Larus argentatus</u>
Greater Black-backed Gull	<u>Larus marinus</u>
Oystercatcher	<u>Haematopus ostralegus</u>
Curlew	<u>Numenius arquata</u>
Sandpiper	<u>Tringa hypoleucos</u>
Knot	<u>Calidris canutus</u>
Redshank	<u>Tringa totanus</u>
Rock Dove	<u>Columba livia</u>
Rock Pipit	<u>Anthus spinoletta</u>
Woodland birds	

Blennies, Blennius pholis, butterflyfish, Pholis gunnellus, and rockling, Gaidropsarus vulgaris, were the only fish species found in the rock pools. In addition, the shore crab, Carcinus maenas, and edible crab, Cancer pagurus, were also found.

METHODS

SCAT COLLECTION

River banks were surveyed for the following signs of mink presence: tracks, scats and prey remains, the locations of which were marked as accurately as possible on 1:2500 maps.

Mink scats have an unpleasant odour when fresh, and are normally firm and tubular and may have a distinctive twist if containing fur or feather remains. In instances where the identity of a scat was uncertain, the scat was collected but excluded from the analysis. Where possible, the whole river bank area was searched, with particular attention being paid to characteristic sites for scat deposition, such as stones in mid-stream or by the water's edge, at den entrances, under bridges, on logs and occasionally on piles of grass (Gerell, 1968).

It was originally planned to visit each study area at fortnightly intervals in order to investigate the relative importance of prey species in the diet throughout the study period. Difficulty was experienced, however, in finding scats, due to the unusual weather patterns producing spate conditions which removed any mink signs, hence the interval between samples became longer and less regular.

TREATMENT OF SCATS

On collection, the scats were labelled with date, area, estimated age and site of deposition. The whole scat was removed intact wherever possible. Some authors

(Stephens, 1957; Wise, 1978) have pointed out that this procedure may affect the animals' behaviour. It was felt, however, that sufficient odour would remain in the ground. The scats were dried at 50° C for 24 hours and weighed to the nearest 0.01 g. Initially, a sample of ten scats was dried for a further 24 hours. As there was no significant difference in weights after 24 or 48 hours, the former was deemed to be a sufficient drying period to obtain a reliable measure of dry weight. Several authors have advocated crumbling the dry scat (Erlinge, 1968a; Gerell, 1968; Chanin, 1976; Wise, 1978), but it was felt that this procedure might damage fish vertebrae, hence the scats were soaked overnight in a 1% detergent solution to break down the binding mucous. "Steradent" and sodium hypochlorite solution have also been used (Stephens, 1957; Webb, 1975; Cuthbert, 1979), but it was thought that detergent had the advantage of being less corrosive. The remains were washed through a coarse 10 sieve followed by a 60 sieve. The washed remains were spread in petrie dishes and dried at 50° C prior to analysis. A binocular dissecting microscope was used when separating out the undigested fragments. Hair and feathers were examined under a microscope.

IDENTIFICATION OF PREY REMAINS

Mammalian prey was identified by hair characters, after Day (1966), and in some cases teeth and jaw bones were also diagnostic (Lawrence and Brown, 1967). The methods adopted of examining cuticular scale pattern and medullary configuration, by making gelatine casts and mounting in 70% alcohol were as described in Day (1966). To obtain

cross-sections, Mathiak's (1938a) method was used. A hair was embedded in ethyl acetate on a thin strip of balsa wood. When the substance was completely dry, sections of approximately 0.5 mm were cut with a razor blade. A reference collection of mammalian hair and teeth was obtained from the Hancock Museum and Sunderland Museum.

Birds were identified from feather remains, using Day's (1966) key, in conjunction with a reference collection. In several cases, however, the characteristic barbules of covert feathers were not available, making identification impossible. This was particularly so in juvenile birds which were likely to have been prevalent at the time of the study. One instance of egg-shell was confirmed by comparison with domestic hen egg-shell. As has been noted by Wise (1978), specific identification of egg-shell is normally impossible as the pigment is removed by the digestive juices.

Amphibians were identified by comparison with a set of reference bones.

Vertebrae, jaw and scale characteristics were used for identification of fish prey; otoliths were only found infrequently. The keys of Webb (1975) and Wise (1978) were followed for freshwater fish, and that of Watson (1978) for coastal fish. As vertebrae vary in character from the cranial to the caudal ends of the vertebral column, a reference collection was made to supplement these keys. The following fish were obtained:- trout, chubb, roach, dace, perch, eel, stickleback, bullhead and grayling. Specimens of butterfish, rockling and blenny were collected from the coast. Prior to removing the flesh from these fish, the

fork length was measured to the nearest centimetre. To obtain the vertebral column, the fish were boiled in water to facilitate dissection of the flesh, and the hard parts were soaked in a weak solution of sodium hydroxide in order to clean the bones.

Crustacea, particularly Decapoda, were identified by the characteristic pore pattern on the carapace (Watson 1978). Shore crabs, Carcinus maenas, edible crabs, Cancer pagurus, and velvet swimming crabs, Portunus puber, were collected from the shore.

Hitherto, lampreys have not been identified from mink scats and, as brook lampreys were known to be common in the North Tyne, a feeding experiment was conducted to determine whether digestion of lamprey leaves any undigested parts which may be characteristic. Three captive mink were starved for 24 hours prior to the feeding trial to ensure that the guts had been completely evacuated. Sibbald, Sinclair, Evans and Smith (1962) found that dyed food, irrespective of composition, passed through the digestive system of the mink in three hours. Each mink received three lampreys. The scats and uneaten lamprey remains were collected the following morning and analysed. In two cases, parts of the oral sucker and the eye lenses were found. Whilst none of the lampreys had been ingested completely, no single portion of the body was consistently rejected. As a result of this feeding trial, one occurrence of lamprey in a scat from the North Tyne was identified by parts of the oral sucker.

ESTIMATION OF FISH LENGTHS

All the vertebrae of salmonids, cyprinids, eels and stone loach, excepting those from the extreme ends of the vertebral column (as described by Wise, 1978), were measured to the nearest 0.1 mm using Vernier calipers. There was some inaccuracy due to compression of the vertebra by the calipers. It was assumed, however, that this error would be constant for all vertebrae. Using centrum length, the parameters of mean, maximum and minimum fork lengths of the fish were calculated from a regression of fork length against centrum length (Wise, 1980). In cases where there was no overlap between the maximum length calculated from one vertebra and the minimum length from another, it was assumed that two fish of different sizes had been consumed and the mean length of each was calculated. Where vertebral length indicated that only one fish had been eaten, the mean centrum length of all vertebrae was used to calculate mean fork length.

An alternative method of estimating fork length is to age fish from the annual ring pattern of scales posterior to the dorsal fin and near the lateral line. Knowing the age/size distribution of the population it is then possible to back-calculate the fish length. In this study, very few undamaged scales were encountered and the accuracy of the method would have been decreased as the position of the scales cannot be ascertained accurately.

PRESENTATION OF RESULTS

There has been some controversy over which is the most efficacious method for analysing the results of

dietary studies. When considering the advantages and disadvantages of each method, it is vital to define the objectives of the analysis. For a study in which a comparison of the relative importance of items is required, an error engendered by the method will be acceptable so long as the error is consistent throughout. When absolute importance is required, however, the error must be minimised.

The three possible methods of analysis are:

1. Percentage frequency of occurrence.
2. Percentage relative estimated bulk: a volumetric estimate of each item as a proportion of the total scat.
3. Dry weight of remains: based on the relative proportional weight of remains.

Conversion factors can be applied to any of the above three methods to correct for the differing proportions of hard parts to soft parts in the prey.

Frequency of occurrence may be calculated as a percentage of the total number of scats or as a percentage of the total number of prey occurrences:

$$i) \frac{\text{Frequency of prey A}}{\text{Total number of scats}} \times 100$$

$$ii) \frac{\text{Frequency of prey A}}{\text{Total frequency of all prey, A+B+C}} \times 100$$

The second method is preferable as the values total 100% which facilitates comparison with other sets of data. The main criticism of the frequency of occurrence method is that it underestimates the importance of small items which occur several times in a single scat, and also

underestimates large items of which no hard parts are ingested as only the flesh is consumed. In addition, it can also be argued that a single occurrence of a small prey item may be overestimated in importance as it would be scored on an equal basis to an item which in terms of proportion of the scat was more important.

The relative estimated bulk method was proposed by Lockie (1959) and involved washing the scat and estimating the volume occupied by the remains of each prey item in order to obtain a proportional value for the importance of each item. Wise (1978) modified this method by estimating the importance of the identified prey items on an arbitrary scale from one to ten, calculating the percentage of the scat that each item accounted for and multiplying this percentage by the dry weight of the scat to produce a "bulk estimate".

In addition to the time-consuming nature of analysis by bulk estimate, the method assumes that all prey remains have a constant weight relationship to one another. This could be misleading; for example, the comparison of two scats both containing 50% lagomorph and 50% fish in which the lagomorph remains of one scat are entirely fur whilst the lagomorph remains of the second consist mainly of bone. In this case, the second scat would be relatively heavier than the first and therefore, although the proportions of both prey types in each scat are similar, the weight of fish in the second scat is taken to be greater than in reality. This type of error, although acceptable for comparative purposes, would bias estimates of absolute importance and cannot be corrected for by the application of conversion factors.

A further criticism of bulk analysis is that it is based on a subjective estimate of relative importance or volume (Gerell, 1968). Although Wise (1978) shows that any worker error inherent in the estimation of importance is constant, the problem still arises as to how to rank bone in comparison with fur and/or feathers. Wise (1978) does not state on which criteria her "importance" estimations are based. Fur and/or feathers being less compact than bone, may appear qualitatively to constitute a large proportion of the scat whilst estimation on the basis of, for example, weight shows that this is not the case. The discrepancy arising from the assumption that fur and feathers have the same weight as bone is corrected for by use of conversion factors, but the estimate of importance cannot be corrected. A further criticism of Wise's (1978) work, which she acknowledges, is that items constituting less than 10% of the scat are overestimated on a scoring system of one to ten.

An additional source of error may arise using Wise's (1978) method as she only estimates the importance of identifiable remains; this assumes that the prey items in the unidentified remains are in constant proportions to those in the identified remains. This can be seen with reference to an hypothetical example in which only 50% of one scat is identifiable, of which half is lagomorph and half fish. These both obtain importance scores of 5 and, when multiplied by the total scat weight, the relative estimated bulk for each will be 50% of the scat weight, though in reality, the remaining 50% of unidentified remains may not be equally proportioned between the two prey items. This is often the case when mammal and fish remains are present in a single

scat, as the majority of mammal remains consist of hair which is easily identifiable whilst, of the fish remains, only the vertebrae are identifiable. In such a case, the relative importance of mammal would be overestimated at the expense of fish. Application of conversion factors would then increase the error.

The third method of analysis involves cleaning, weighing the scat and estimating the percentage volume of each constituent of the scat. This is obviously the most accurate method, but is extremely time-consuming and relies upon collection of the whole scat intact.

Comparing all three methods, Lockie (1959) maintained that a method of analysis which provided a constant error was a necessity and, from feeding studies on red fox, he concluded that both frequency of occurrence and estimated bulk gave inconsistent results; therefore he favoured the weight of undigested remains method. Gerell (1968) criticised this method on the grounds of its subjectivity and time-consuming nature.

Scott (1941) and Erlinge (1967a) concluded from feeding trials, on red fox and otter respectively, that frequency of occurrence, despite its shortcomings, is the only realistic method for estimating the relative importance of prey items. From feeding trials on mink, Wise (1978) concludes that the bulk estimate is superior to frequency of occurrence in its consistency and superior to the weight of undigested remains in its ease of execution.

Hewson (pers. comm.) advocates that only items constituting over 50% of a scat be scored in frequency analysis. Although applicable to his work comparing the

extent of fox predation on sheep in different areas, this method would give a somewhat biased view in a study attempting to describe the seasonal feeding ecology of a predator. In the present study, many scats would have been completely ignored as no single prey item would have provided 50% of the scat; this would tend to give a false impression of the diversity of prey taken. Hewson's method does, however, have the advantage of preventing the overestimation of the importance of small prey items.

In the present study, scats were analysed by two methods, frequency of occurrence as a percentage of total occurrence, and bulk analysis. For the frequency of occurrence estimate, items were scored for presence or absence rather than frequency of the item within a single scat, which would have been less accurate. The bulk analysis was similar to that of Wise (1978), but with some modifications. The importance of the identified prey items was estimated as a percentage volume of the whole scat and multiplied by the scat dry weight. In this case, the unidentified proportions of the scat are effectively ignored, which may lead to a systematic underestimation of some items. Conversion factors calculated by Wise (1978) were applied to the bulk estimates obtained for the river data. Appendix 2 shows the methods used in the calculation of a conversion factor for C. maenas.

TABLE 1

RESULTS OF SCAT COLLECTION

AREA	NUMBER OF SCATS	TOTAL PREY ITEMS	NUMBER OF PREY/SCAT ± STANDARD ERROR	SCAT DRY WEIGHT ± STANDARD ERROR
RIVER NORTH TYNE	99	142	1.49 ± 0.10	1.28 ± 0.22
Chirdon Burn	70	108	1.59 ± 0.84	0.95 ± 0.19
Chollerford	10	13	1.44 ± 1.04	0.83 ± 0.37
George Hotel	19	19	1.00 ± 0.85	0.35 ± 0.11
RIVER TEES	11	21	2.00 ± 0.41	2.19 ± 1.02
TOTAL RIPARIAN	110	163	1.55 ± 0.10	0.81 ± 0.13
SPRING	53	77	1.30 ± 0.21	0.49 ± 0.08
SUMMER	58	86	1.60 ± 0.19	1.12 ± 0.19
GALLOWAY				
Week 14	129	335	2.57 ± 0.09	0.83 ± 0.05
Week 16	102	183	1.79 ± 0.11	0.72 ± 0.20
Week 18	33	45	1.40 ± 0.09	0.94 ± 0.10
TOTAL COASTAL	265	565	2.14 ± 0.07	1.91 ± 0.12

RESULTS

The total number of scats and date of collection from each sampling site are shown in Table 1. As only a small number of samples was collected from the three sites on the North Tyne (Chollerford, the George Hotel Area and the Chirdon Burn), the data have been amalgamated in subsequent analyses.

Very little indication of mink presence was found on the North Tyne at Chollerford during the early stages of the study, thus necessitating widening of the study area to include the Chirdon Burn. In May, a possible breeding den was located on the Chirdon Burn in the root system of a sycamore tree close to the point where the burn joins the North Tyne. On the main river at this site, scats were also found in a drainpipe 15 cm in diameter and 80 cm above ground level, and also scattered along runways overhung by vegetation. On each visit to this site, numerous tracks were found and, on one occasion, these were followed continuously for 1 km as far as Bent House Bridge.

At the coastal sites, the majority of scats on the wooded coastline were found on exposed rocks or in crevices. On the Ross Peninsula, a second breeding den was located, as was confirmed by a sighting of the kits (H. Watson, pers. comm.). Other scats were found under boulders and in sheltered positions, mainly on the south-west coast.

It is apparent from Fig 6a that the majority of scats was collected from dens and in particular from breeding dens during the post-parturition period. Most of the scats

FIG 6a PERCENTAGE FREQUENCY OF HABITAT TYPE IN WHICH
SCATS WERE FOUND

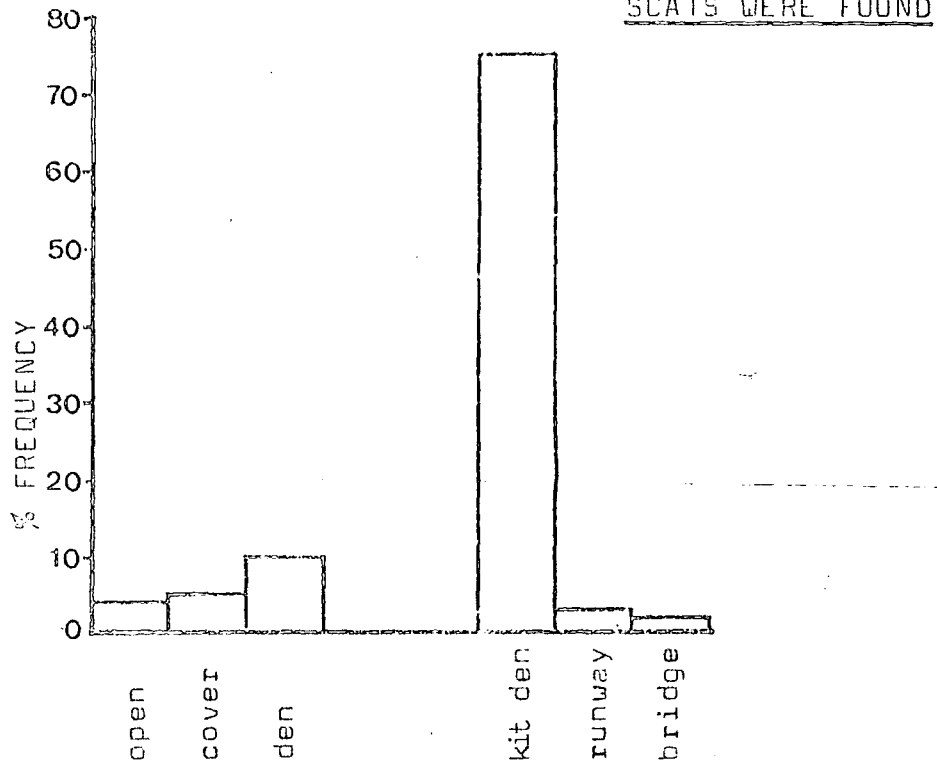


FIG 6b PERCENTAGE FREQUENCY OF SCATTING PLACE

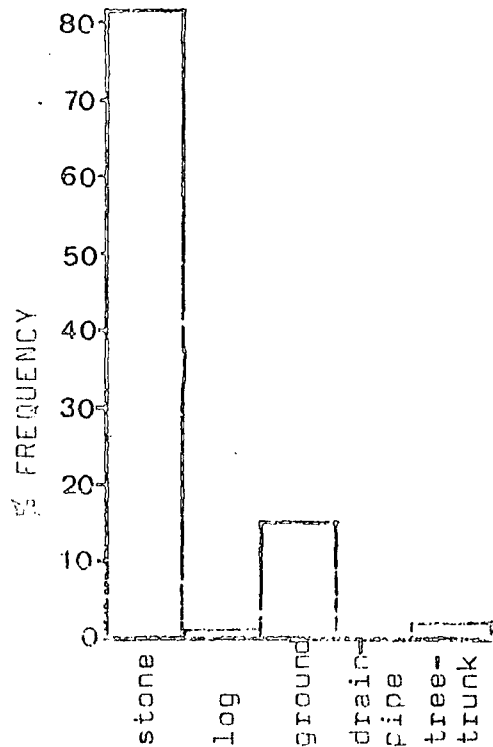


TABLE 2a: Comparison of the number of prey items comprising all scats collected (after Wise, 1978).

AREA	Chirdon Burn	Chollerford	George Hotel	River Tyne	River Tees	Riparian	Coastal
No. prey	108	13	19	142	21	163	565
No. scats	70	10	19	99	11	110	265
		= 1.5	N.S.		= 0.5	N.S.	= 6.3 *
	Season	Spring	Summer				
RIPARIAN	No. prey	77	86				
	No. scats	53	58				
		= 0.006	N.S.				
	Date	Week 14	Week 16	Week 18			
COASTAL	No. prey	335	183	45			
	No. scats	129	102	33			
		= 9.3	*				

were deposited on stones although 15% were found on the ground, usually along well-used runs (Fig 6b).

Table 1 also shows the total number of prey items found in the scats collected from each site. In order to avoid bias in analysing dietary results by frequency of occurrence as a percentage of total occurrence, there must be no seasonal variation in the frequency of prey per scat; or when a number of areas are to be compared, no variation between areas (Englund, 1965). This can be seen more easily with reference to a hypothetical example :-

	% Frequency of occurrence		% Frequency		Actual composition	
	Lagomorph	Fish	Lagomorph	Fish	Lagomorph	Fish
AREA I						
9 monospecific scats 100% lagomorph	10	1	91	9	95	5
1 polyspecific scat 50% lagomorph, 50% fish						
AREA II						
10 polyspecific scats 95% lagomorph, 5% fish	10	10	50	50	95	5

The actual percentage of fish in the scats does not differ between areas I and II. The frequency of occurrence method, however, greatly enhances small percentages when scats are polyspecific. Although the actual percentage of fish in both areas' scats is 5%, in area I it is calculated as 9% by frequency of occurrence and as 50% in area II.

Table 2a examines the variation in mean number of prey items per scat using Wise's (1978) method of analysis. This method does, however, tend to average differences and

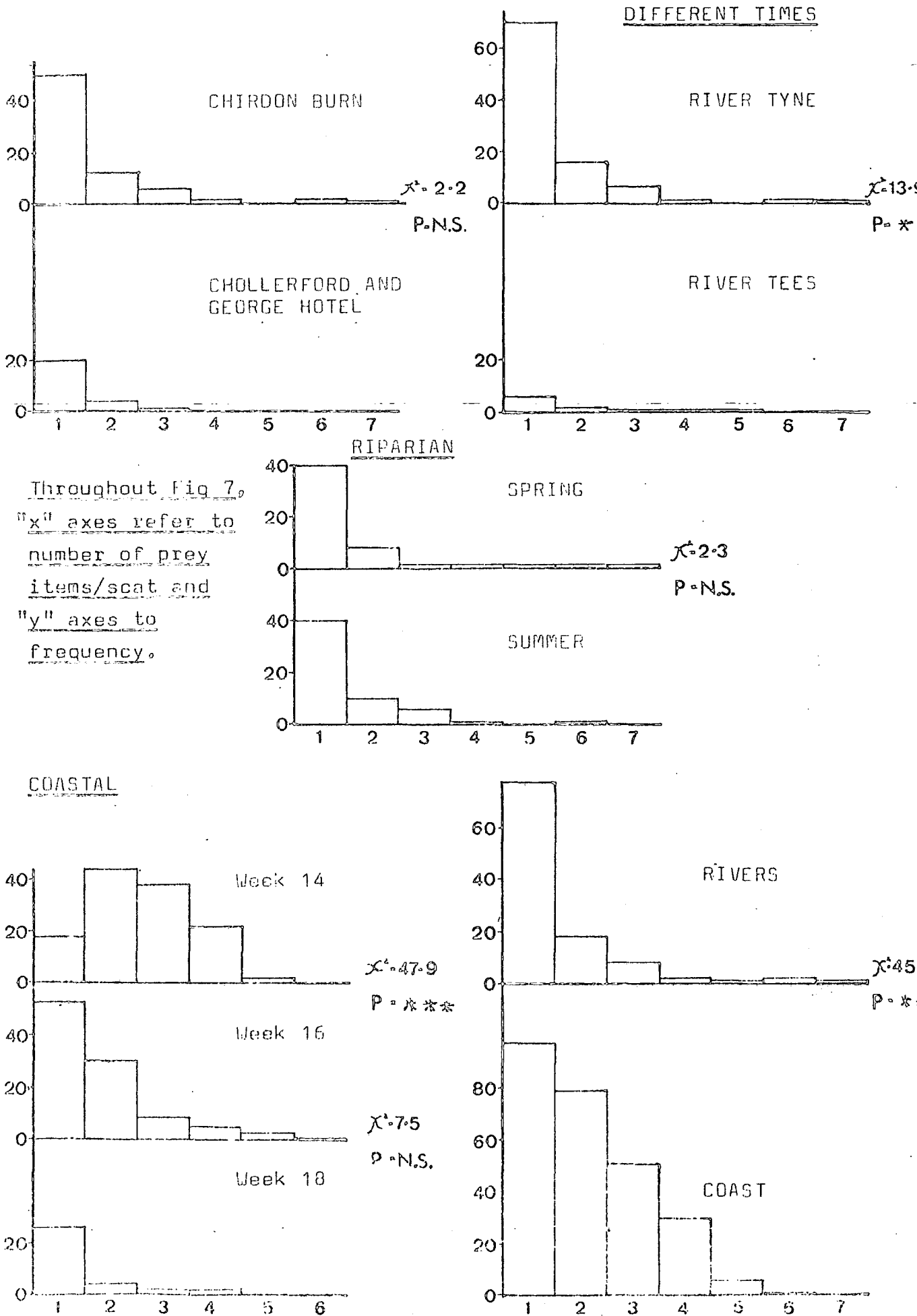
TABLE 2b: Frequency of prey items per scat collected at each sample site.

No. prey items/ scat.	FREQUENCY							
	Chirdon Burn	Chollerford	George Hotel	River Tyne	River Tees	Riparian	Coastal	
1	49	5	15	69	6	78	97	
2	12	4	-	16	2	18	79	
3	6	-	1	7	1	8	51	
4	1	-	-	1	1	2	30	
5	-	-	-	-	1	1	6	
6	2	-	-	2	-	2	1	
7	1	-	-	1	-	1	-	

Temporal frequency of prey items per scat in the coastal and riparian habitat.

No. prey items/ scat.	RIPARIAN			COASTAL		
	Spring	Summer	Week 14	Week 16	Week 18	
1	39	40	18	53	26	
2	8	10	44	30	4	
3	1	6	38	9	2	
4	1	1	22	5	2	
5	1	-	2	3	-	
6	1	1	-	1	-	
7	1	-	-	-	-	

FIG 7 A COMPARISON OF THE FREQUENCY OF PREY ITEMS PER SCAT FROM SCATS COLLECTED IN DIFFERENT AREAS AND AT



so the variation between frequency of number of prey per scat was tested. The raw data are given in Table 2b, and areas are compared in Fig 7.

The number of prey items per scat was similar at the two main sites on the North Tyne ($\chi^2=2.27$, d.f.=6, $p=N.S.$). A greater number of prey items per scat was found, however, in scats collected on the river Tees than in those from the North Tyne ($\chi^2=13.9$, d.f.=6, $p=0.05$). The data collected between March and the end of May were amalgamated to form a spring sample and from June and July to form a summer sample. Comparison of the variation in the number of prey items per scat failed to demonstrate any change with season ($\chi^2=5.27$, d.f.=6, $p=N.S.$).

Scats collected from the coastal sites were significantly more polyspecific than those from the rivers (Fig 7; $\chi^2=45.13$, d.f.=6, $p=0.001$). In addition, there was also temporal variation in the number of prey items per scat on the coast. Scats from Week 14 were more polyspecific than those from Week 16 ($\chi^2=47.9$, d.f.=5, $p=0.001$), whilst there was no difference in the number of prey per scat between Weeks 16 and 18 ($\chi^2=7.6$, d.f.=5, $p=N.S.$) as is apparent from Fig 7.

These differences must be borne in mind when considering both the percentage frequency of occurrence of prey species at the coast and the variation in coastal and riparian diets.

FIG 2a 3 COMPARISON OF THE THREE METHODS OF ANALYSIS OF WINK DIET ON THE RIVER NORTH TUNE

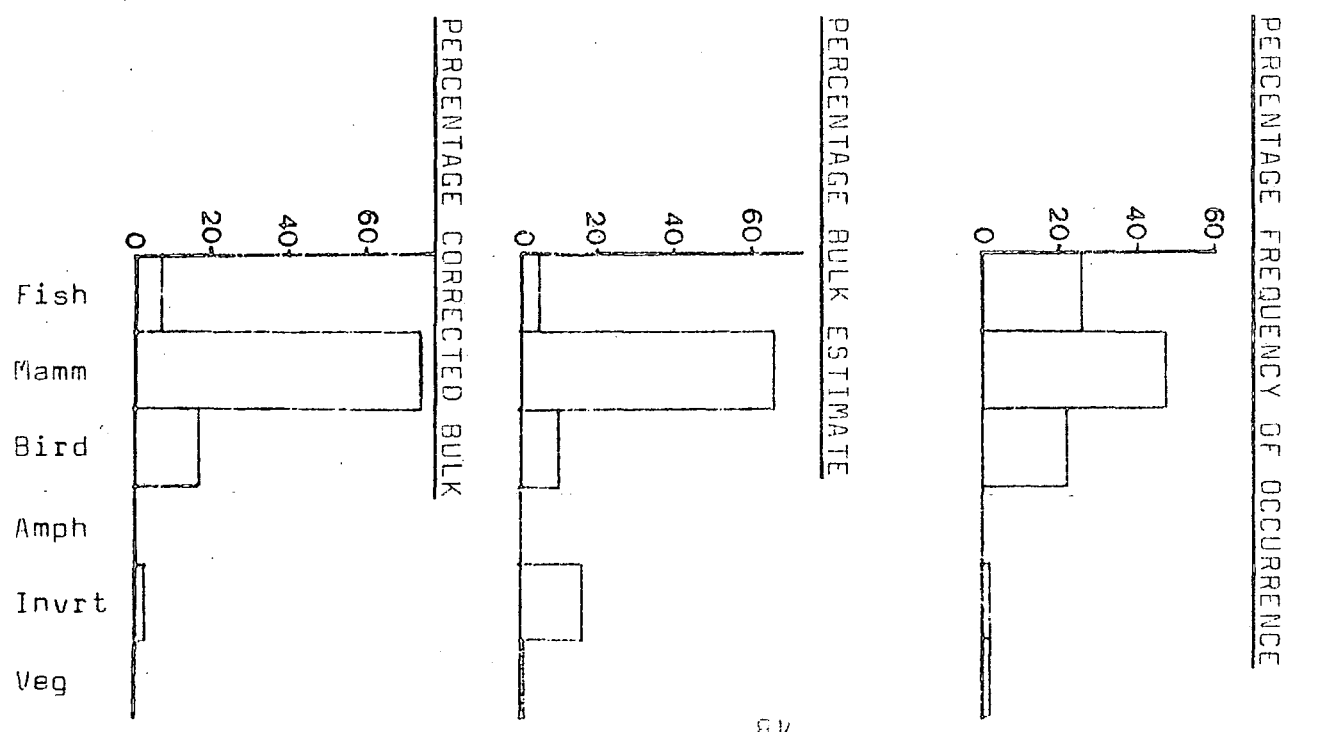
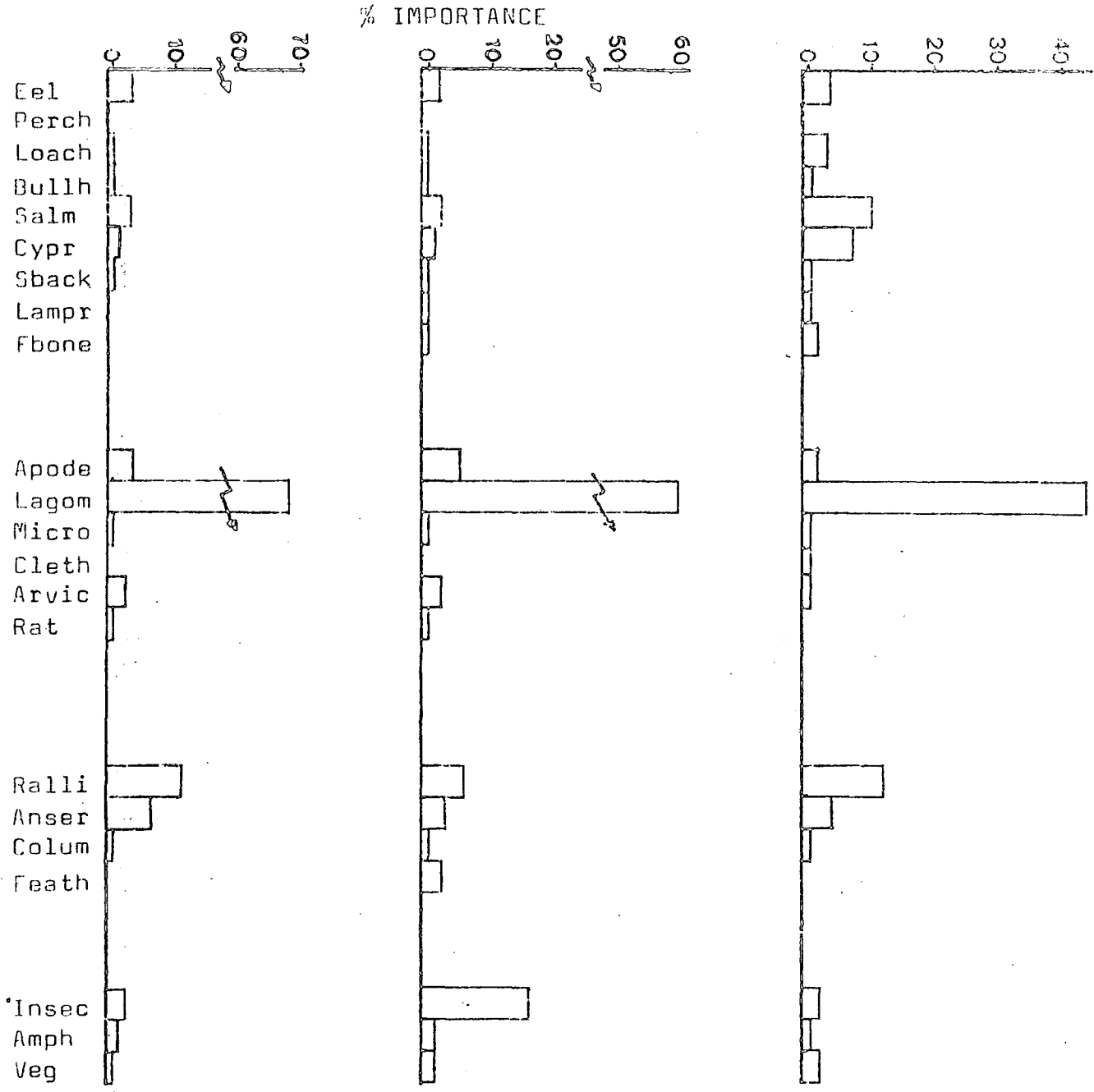


FIG 85 A COMPARISON OF THE THREE METHODS OF ANALYSIS OF MINK DIET ON THE RIVER TEES

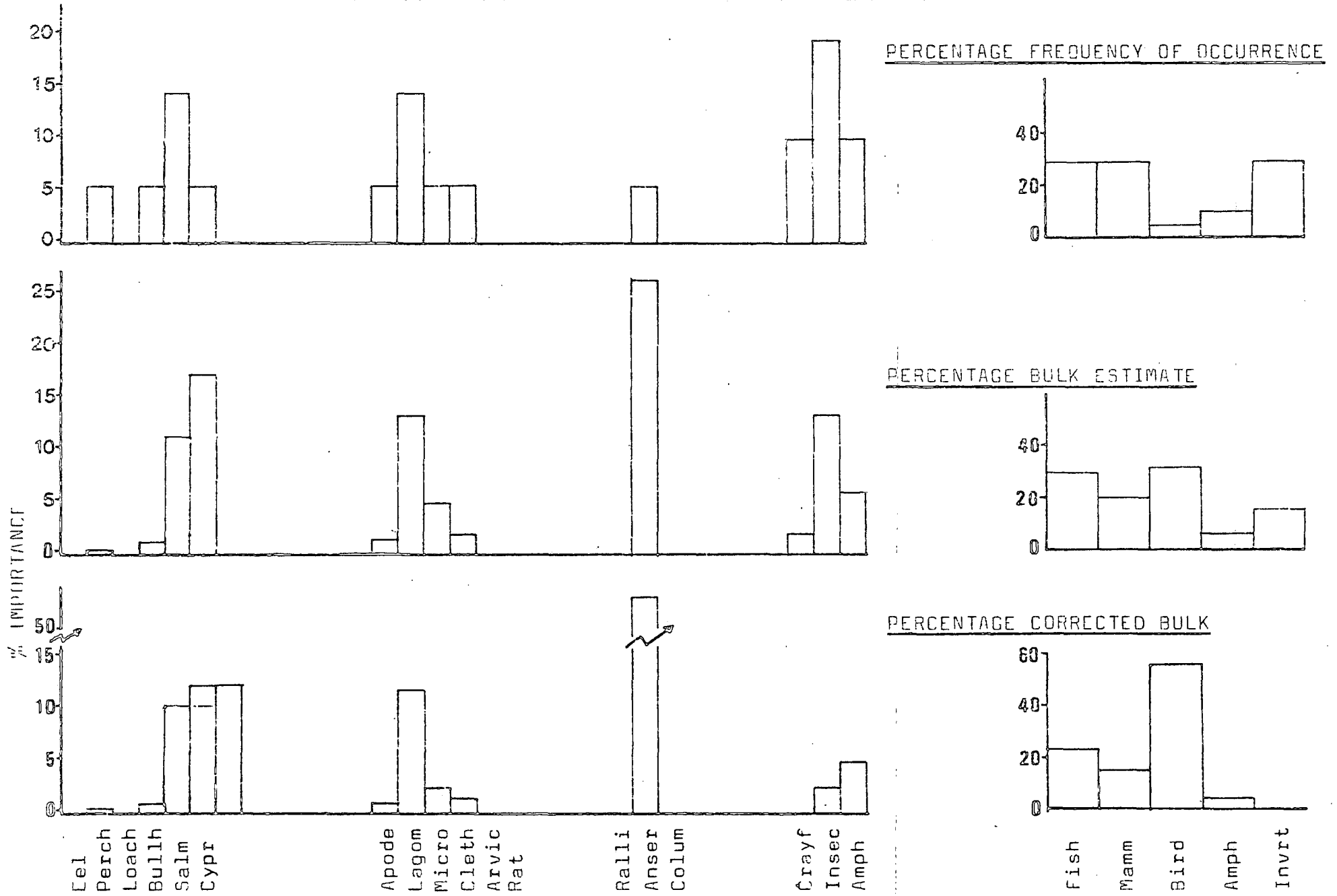
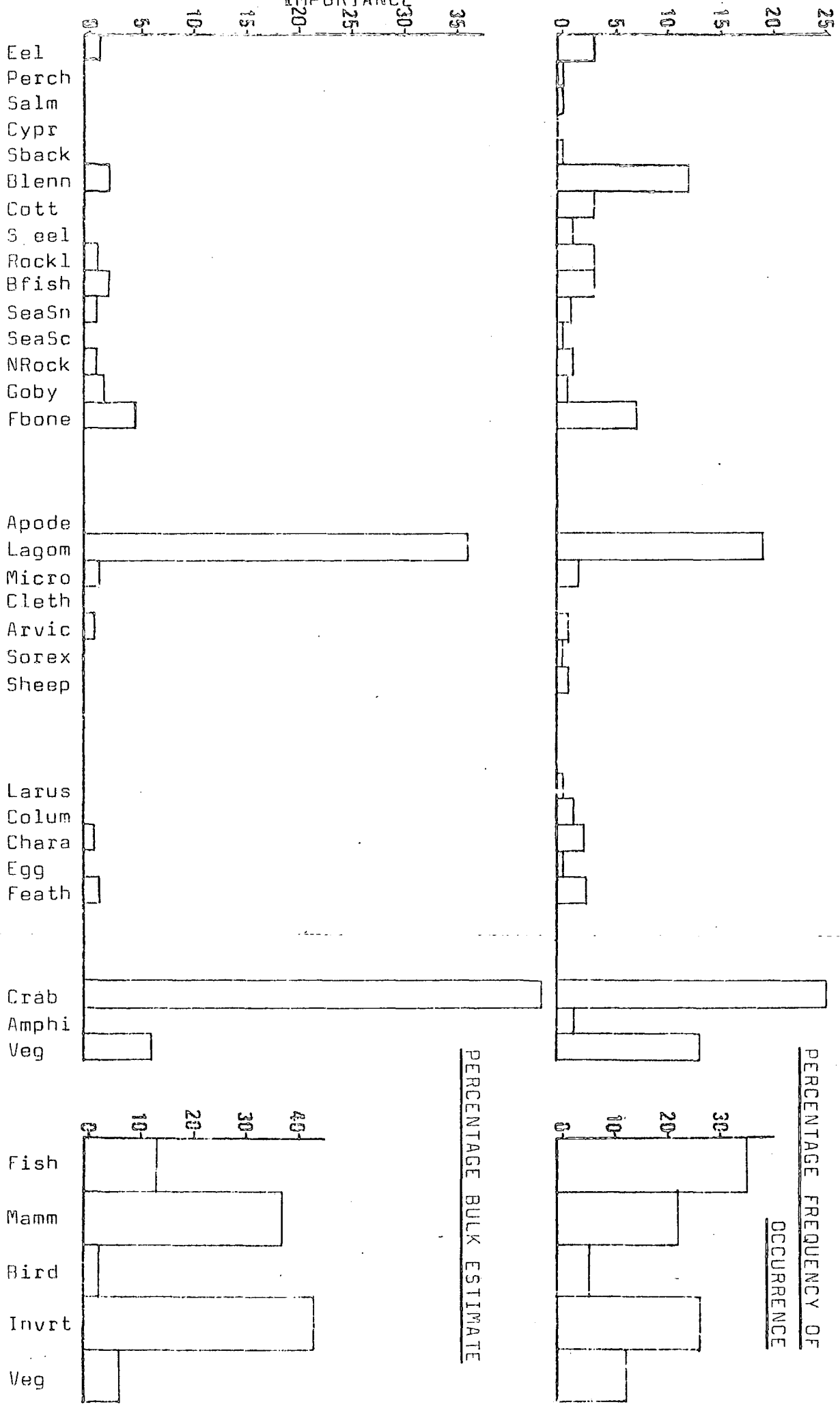


FIG 8c A COMPARISON OF THE TWO METHODS OF ANALYSIS OF MINK DIET AT GALLOWAY



COMPARISON OF METHODS OF ANALYSIS OF RESULTS

The relative merits of the three methods of analysis (percentage frequency of occurrence, bulk analysis, and bulk analysis corrected by application of conversion factors) will be deferred until the Discussion. In this study, where possible, the results have been analysed using all three methods. For coastal data, application of conversion factors was not practical, although it had been hoped to adapt those calculated for small freshwater fish.

Figures 8a, 8b and 8c show that bulk analysis and frequency of occurrence produce remarkably consistent results in terms of percentage importance in the diet. At each study area, these two methods of analysis were compared using the Wilcoxon matched pairs signed ranks test. Overall, no significant difference between the relative importance of particular prey species calculated by either method could be detected (Table 3). This test is apparently the only means of comparing these two methods of analysis. Being a non-parametric statistic, however, a great deal of information is lost. Although it is obvious from the raw data that in the majority of cases there is no difference between the methods, in several instances the two results seem to differ considerably from a biological if not a statistical point of view. The major discrepancy arises over the importance of mammalian and crustacean prey on the rivers and at Galloway (Figure 8a and Figure 8c). The percentage importance derived from the bulk estimate is much greater than that obtained from the percentage frequency of occurrence, the bulk estimate for lagomorph being approximately double the frequency

TABLE 3: Comparison of percentage importance calculated by frequency of occurrence and bulk analysis using the Wilcoxon matched pairs signed ranks test.

Prey species	TEES		TYNE		COAST	
	% Freq. of occur.	% Bulk	% Freq. of occur.	% Bulk	% Freq. of occur.	% Bulk
Eel	-	-	3.5	1.4	3.2	1.0
Perch	4.8	0.07	-	-	0.2	-
Stone Loach	-	-	2.8	0.3	-	-
Bullhead	4.8	0.7	0.7	0.3	-	-
Salmonid	14.3	10.9	9.9	2.0	0.2	-
Cyprinid	4.8	16.9	7.0	0.9	-	-
Stickleback	-	-	0.7	0.04	0.2	0.008
Lamprey	-	-	0.7	0.07	-	-
Unid. fish bones	-	-	1.4	0.4	7.1	4.4
Apodemus	4.8	1.1	1.4	4.8	-	-
Lagomorph	14.3	12.8	43.7	59.4	19.1	35.9
Microtis	4.8	4.6	0.7	0.07	1.4	0.9
Clethrionomys	4.8	1.6	-	-	-	-
Arvicola	-	-	1.8	0.7	0.4	0.4
Sorex	-	-	-	-	0.2	0.003
Rattus	-	-	0.7	0.1	-	-
Sheep	-	-	-	-	0.4	0.02
Moorhen	-	-	12.0	5.5	-	-
Anseriform	4.8	31.0	4.2	2.5	-	-
Columbiform	-	-	0.7	0.04	0.9	0.03
Charadriiform	-	-	-	-	1.8	0.4
Larus	-	-	-	-	0.2	0.2
Egg-shell	-	-	-	-	0.2	0.2
Unid. feather	-	-	5.6	2.2	2.3	0.8
Amphibian	9.5	5.6	0.7	0.8	-	-
Crayfish	9.5	1.5	-	-	-	-
Vegetation	-	-	2.1	1.1	12.7	5.9
Insects	19.1	13.3	2.1	16.2	-	-
Blenny	-	-	-	-	11.9	2.3
Cottidae	-	-	-	-	2.7	0.05
Sand Eel	-	-	-	-	1.1	0.07
Rockling	-	-	-	-	2.7	0.7
Butterfish	-	-	-	-	2.8	1.8
Sea Snail	-	-	-	-	0.7	0.06
Sea Scorpion	-	-	-	-	0.2	0.04
Non-Rockling Gadoid	-	-	-	-	1.2	0.7
Goby	-	-	-	-	0.4	1.4
Shore Crab	-	-	-	-	25.0	42.9
Amphipods	-	-	-	-	1.2	0.3
Wilcoxon T =		20		56		77
Wilcoxon N =		12		20		26
P =		N.S.		N.S.		N.S.

estimate on the coast and one and a half times as great on the North Tyne. Similarly, the bulk estimate for crab is almost double that obtained using frequency of occurrence. On the North Tyne (Fig 8a), the relative importance of salmonids and cyprinids calculated by the bulk method was less than that obtained from analysis of frequency of occurrence. This tendency for underestimation of fish results by the bulk method was, however, not so apparent on the coast (Fig 8c). On the North Tyne and at Galloway (Figure 8a and 8c), the bulk estimate for avian prey tends to be less than that obtained by frequency of occurrence, whilst on the Tees (Fig 8b) the importance of Anseriforms calculated by bulk analysis was six times the value obtained by the other method.

The differences between the frequency of occurrence and the bulk methods are consistent within prey groups, but vary between groups. With respect to the frequency values, bulk analysis apparently overestimates the relative importance of mammalian and invertebrate prey whilst underestimating the importance of fish and the majority of avian prey.

Application of conversion factors to the bulk estimates yields a relative importance value corrected for the differing proportions of hard to soft parts in the various prey species. This value may not be satisfactory for a small sample as any errors in estimating the relative importance can be greatly magnified if the particular species had a large conversion factor. This is particularly well illustrated in Figure 8b on the Tees where the corrected relative importance of Anseriform is 56.3% compared with a bulk estimate of 31% and percentage frequency of occurrence of 5%. As the percentages calculated are relative, an error

for a single prey species will affect the relative percentage of all other prey items; thus, if the result for Anseriforms is anomalous, the other relative importance values are likely to be lower than in reality. If this is the case on the Tees, the percentage importance calculated by the correction method is remarkably similar to that calculated by the other methods.

Throughout the dissertation, only the frequency of occurrence data will be discussed as these are amenable to statistical techniques and provide comparison with published data.

Results of Faecal Analysis:-

NORTH TYNE

On the North Tyne, 99 scats were collected between March and July with a total of 142 prey occurrences giving a mean of 1.49 ± 0.1 standard error prey items per scat and a mean scat dry weight of 1.28 ± 0.22 g.

It is apparent from Fig 9a that mammals were the most important prey group encountered in the diet (47.2% frequency of occurrence) followed by fish (26.7%), bird (10.24%), invertebrates and vegetation (2.1% each) and finally amphibians (0.7%). Lagomorphs were the most frequent prey item comprising 43.7% of the diet. Only single occurrences of Rattus norvegicus, Arvicola terrestris, Microtis agrestis and two cases of Apodemus sylvaticus were recorded. The majority of these small mammals were all found in the George Hotel area (Fig 9b), whilst the two instances of Apodemus were collected downstream of the bridge at Chollerford (Fig 9b). On the Chirdon Burn, lagomorphs were again the only mammals encountered and here accounted for 55.6% of the total prey taken (Fig 9b).

The most frequent fish groups were salmonids comprising 38.8% of the total fish prey taken, followed by cyprinids (27.8%) and eel (13.8%), with stickleback, bullhead, stone loach, lamprey and unidentified fish bones comprising a further 19.4%. Salmonids were rated third in overall importance, 9.9% of the total diet. It is interesting to note that the eel and lamprey remains were restricted to the Chirdon Burn, whilst salmonids and cyprinids were equally distributed between the three sites. Scats containing

bullhead, stickleback and stone loach were all collected from the Chirdon Burn.

Moorhen (Ralliform) was the most frequent species of avian prey, constituting 53% of the group and 12% of the total diet. Anseriforms accounted for 18.7% of the birds, and there was a single occurrence of Columbiform. Unidentified feathers formed a large proportion of this group (25%) and may have been from juveniles which do not exhibit the characteristic covert feathers used in identification. The diet on the Chirdon Burn (Fig 9b) had the greatest diversity of avian prey, having instances of all three taxonomic groups, whilst the majority of moorhens were encountered at Chollerford.

The amphibians, invertebrates (Coleoptera) and vegetation formed only a small proportion of the diet, and it is possible that the latter two groups were ingested incidentally whilst other prey was consumed.

TEES

On the river Tees, eleven scats were collected from two sites on a single visit in May. There was a total of 21 prey occurrences giving a mean number of items per scat of 2 ± 0.41 and a mean scat dry weight of 2.19 ± 1.02 g.

The order of importance of the major prey groups was, firstly, invertebrates, 28.5% of the diet, followed by fish and mammal prey both accounting for 28% of the diet, amphibians comprising 9.5% and birds contributing a minor 4.8% (Fig 9a). Coleoptera (19.1%) were the single most important invertebrate Order and crayfish, Astacus astacus, formed the remainder of this group. Salmonids accounted for

TABLE 4: Results of χ^2 tests for a difference between mink diets on the rivers North Tyne and Tees.

Prey species	TYNE		TEES			
	No. of scats with prey	No. of scats without prey	No. of scats with prey	No. of scats without prey		
Fish	36		6			
Mammals	67		6			
Birds	32		1		34.4	***
Amphibians	3		2			
Invertebrates	1		6			
Vegetation	3		0			
Eel	5	137	0	21	0.7	N.S.
Salmonid	14	128	3	18	0.4	N.S.
Cyprinid	10	132	1	20	0.1	N.S.
Lagomorph	62	80	3	18	6.6	*
Ralliform	17	125	0	21	2.8	N.S.
Anseriform	6	136	1	20	0.1	N.S.
Amphibian	1	141	2	19	7.5	**
Crayfish	0	142	2	19	11.5	***
Insect	3	139	4	17	12.9	***

Method of calculation of χ^2 for a comparison of the importance of a single species in two areas

Area	TYNE	TEES	
No. scats with prey	a	b	a+b
No. scats without prey	c	d	c+d
	a+c	b+d	a+b+c+d
Expected value of a	= $\frac{(a+b)(a+c)}{a+b+c+d}$		
	= $\frac{(O-E)^2}{E}$		

50% of the fish prey, followed in importance by cyprinids, perch and bullhead which each constituted 16.7% of the group. Of the mammalian remains present, lagomorphs accounted for 50% of the group and were the second most important species in the diet; Apodemus, Clethrionomys and Microtis each occurred once. The amphibians were represented by a single species, Rana temporaria, and the avian group consisted of a single occurrence of Anseriform.

COMPARISON OF MINK DIET ON THE RIVERS TEES AND NORTH TYNE

A comparison of the diet of mink in two areas, when based on such a small sample size at one area (Tees, 11 scats) must be viewed with extreme caution. Bearing this limitation in mind, however, there was a significant difference in dietary composition, as can be seen from Table 4. This table also shows which prey species were responsible for the differences between the two areas. On the Tees, mink were more dependant on amphibians and invertebrates and less so on lagomorphs than on the North Tyne. It is of interest that the proportions of fish and bird taken in the two areas are not significantly different (Table 4).

SEASONAL VARIATION IN THE RIPARIAN DIET

The study period was divided into Spring (from March to the end of May) and Summer (June and July). Originally the data were divided on a monthly basis, but there was no significant variation in the diet, possibly due to the small sample size. In the Spring, 53 scats containing 77 prey occurrences were collected, whilst 58 scats with a total of 86 prey items were obtained during

TABLE 5: Results of χ^2 tests for a difference in mink diet on the North Tyne between spring and summer.

Prey species	SPRING		SUMMER			
	No. of scats with prey	No. of scats without prey	No. of scats with prey	No. of scats without prey		
Fish	34		14			
Mammals	20		53			
Birds	17		15		28.6	***
Amphibians	3		0			
Arthropods	8		3			
Vegetation	1		2			
Fish	34	49	14	73	13.6	***
Salmonid	14	69	5	82	5.3	*
Cyprinid	7	76	5	82	0.4	N.S.
Eel	3	80	3	84	0.4	N.S.
Mammal	20	63	53	34	17.9	***
Lagomorph	14	69	52	35	32.5	***
Microtis	2	81	6	81	1.9	N.S.
Bird	17	66	15	62	0.6	N.S.
Ralliform	14	69	3	84	8.4	**
Anseriform	6	81	1	82	3.4	N.S.
Amphibian	3	80	0	87	3.1	N.S.
Insect	19	64	1	86	19.2	***

the Summer. There was no significant variation in the number of prey items per scat during the two seasons (Table 5).

During Spring, fish was the most important prey group comprising 41% of the diet and was followed by mammalian prey (24%), birds (20.5%), amphibians (3.6%) and invertebrates (7.2%), (Fig 10).

During Summer, mammals became the more important prey group, 59.8% of the total diet, followed by fish and bird, which were of approximately equal importance, 17 and 18.3% respectively (Fig 10). At this time no amphibians were taken and insects contributed only 1.1% of the diet. A more detailed analysis of fish prey showed that more salmonids were taken in Spring compared with Summer (Table 5) and that stone loach, bullhead and cyprinids also occurred marginally more often in Spring.

In contrast, the mammalian group was represented more often in scats from the Summer sample due to the vast increase in the number of lagomorphs taken. Microtis and Clethrionomys also increased in absolute terms, but not significantly so.

There was no seasonal variation in the frequency of avian or amphibian prey taken, although moorhen was appreciably more important in Spring (see Table 5).

GALLOWAY

A total of 265 scats was collected at Galloway on three separate occasions. The total number of prey occurrences was 565 with a mean of 2.14 ± 0.07 items per scat and a dry weight of 1.91 ± 0.12 g.

The order of importance of the main prey groups was fish (34.6%), invertebrates (26.2%), mammals (21.5%), vegetation (11.5%) and finally birds (5.4%).

Of the fish group, littoral fish provided the bulk of the diet, 30.8 in comparison with 3.8% of freshwater fish. Of the freshwater fish, eels were the most important (18 occurrences) whilst single cases of perch, salmonid and stickleback were also recorded. Of the littoral fish, the blenny was the most important species followed by cottidae, rockling and butterfish contributing 11 - 12 % each of the fish total.

The main invertebrate prey was the shore crab, providing 25% of the diet; amphipods only contributed 1.2%. When amphipods occurred in the same scat as blennies, the former were ignored as they are often found in the gut contents of blennies; it is also quite possible that mink ingested them accidentally as large numbers were never encountered.

Lagomorphs were the single most important mammalian prey comprising 19.1% of the total diet. Microtis, Arvicola, Sorex and sheep (presumably carrion) all occurred in trace amounts.

The inclusion of vegetation, mainly grass, was an interesting feature, as it was present in large amounts and did not appear to have been ingested accidentally.

TABLE 6: Results of χ^2 test for temporal variation in the diet of coastal mink.

Prey species	WEEK 14		WEEK 16		WEEK 18		Week 14&16	Week 16&18
	No. of scats with prey	No. of scats without prey	No. of scats with prey	No. of scats without prey	No. of scats with prey	No. of scats without prey		
Fish	146		47		4			
Mammals	7		85		29			
Birds	10		9		12		174.9***	11.9***
Crabs	104		26		11			
Vegetation	68		10		0			
Fish	146	189	47	130	4	41	55.0***	6.2 *
Eel	15	320	2	175	-	-	4.1 N.S.	- -
Blenny	49	286	16	161	2	43	3.3 N.S.	1.8 N.S.
Mammal	7	328	85	92	29	16	165.8***	4.0 *
Lagomorph	7	328	77	100	24	21	145.0***	1.4 N.S.
Microtis	-	-	4	173	4	41	- -	4.5 *
Bird	10	325	19	158	1	44	2.1 N.S.	1.2 N.S.
Crab	104	231	26	151	11	34	16.3***	2.4 N.S.
Vegetation	68	267	10	167	-	-	19.3***	- -

TABLE 7: The temporal change in diversity of the diet of coastal mink

Week	n	$\frac{n}{N}$ %	% of diet formed by n
14	13	81	21.6
16	16	84	31.0
18	3	50	8.8

n = No. of species contributing less than 5% of the diet

N = Total no. of prey species consumed

Avian prey was apparently of minor importance on the coastal site, with 23.8% of the occurrences consisting of unidentified feathers. Charadriiformes were the most frequent group, comprising 33.3% of the total avian prey, whilst columbiformes accounted for the remaining 16.7% of occurrences. There was a single instance of egg-shell.

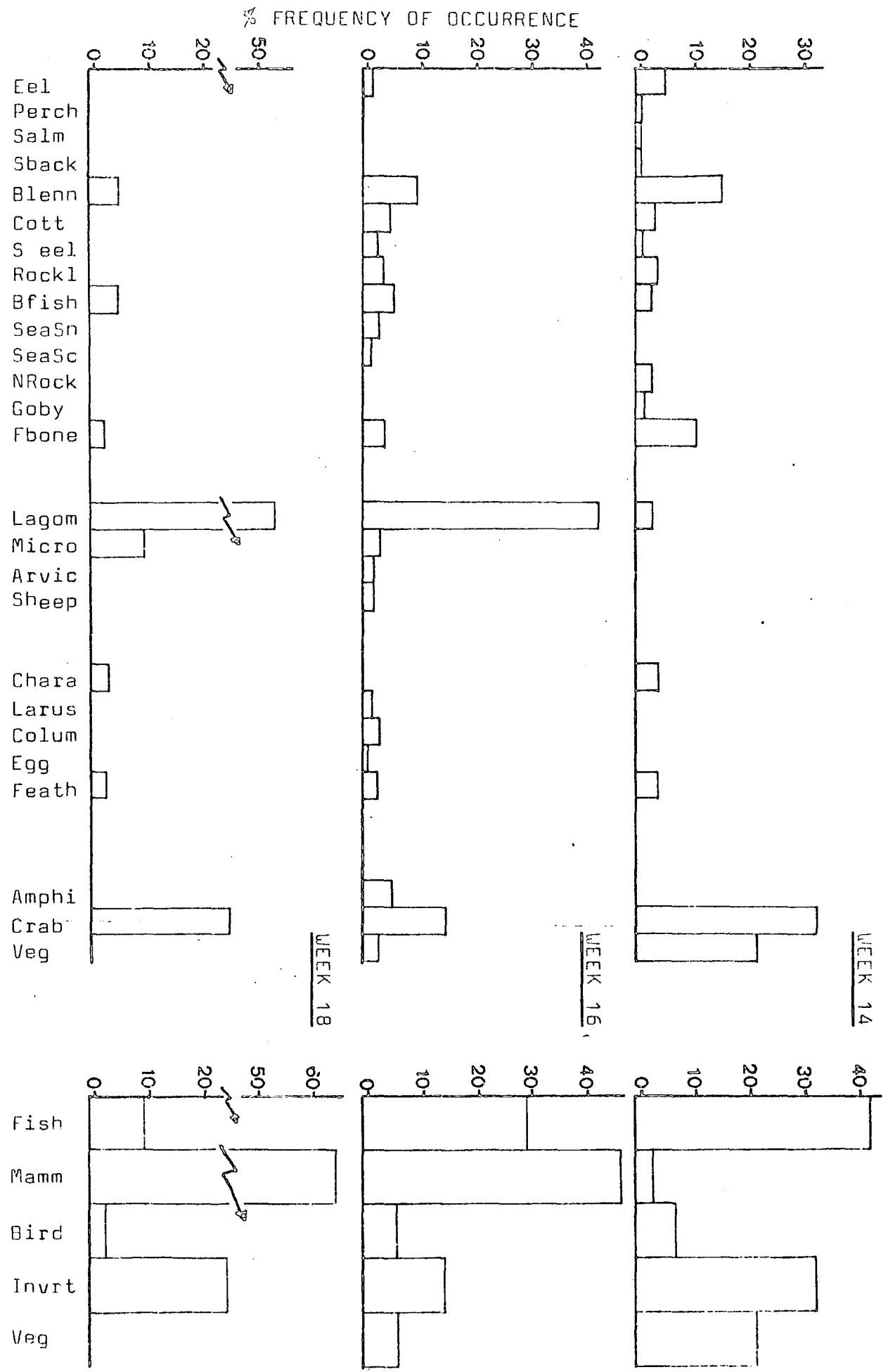
TEMPORAL VARIATION IN THE COASTAL DIET

It has already been mentioned that three separate scat collections were made at the coast. In week 14, a total of 129 scats with 335 prey items were obtained, 102 scats containing 183 items in week 16, and finally 33 scats with 45 items during week 18. There was a significant temporal variation in the number of prey items per scat, those from week 14 being more polyspecific than those from later in the season (Table 2a).

Table 6 and Figure 11 show that in respect of the main prey groups, scats collected in week 14 are significantly different from those obtained in week 16; this is particularly interesting as the scats represent the diet of a single individual. In the week 14 collection, fish was of primary importance followed by shore crab, vegetation, bird and finally mammalian prey, in that order. At the species level, significantly more lagomorph and eel were consumed during week 14. By week 16, mammalian prey had become the most important group, followed by fish, crab, vegetation and bird.

The frequency of prey groups taken during week 16 was significantly different to that from week 18, when mammal was still the most important group (Table 6), but crab had increased to 24.4%, whilst fish and bird were only 8.8%

FIG 11 TEMPORAL VARIATION IN THE DIET OF COASTAL MINK



and 2.2% respectively (Fig 6). The values for crab do not differ significantly between the two dates, thus the overall difference and the apparent increase in the importance of crab is due to the change in the importance of lagomorph and fish.

In addition to the changes in importance of the major prey groups, there is some variation in the number of species taken which contribute less than 5% of the diet (Table 7).

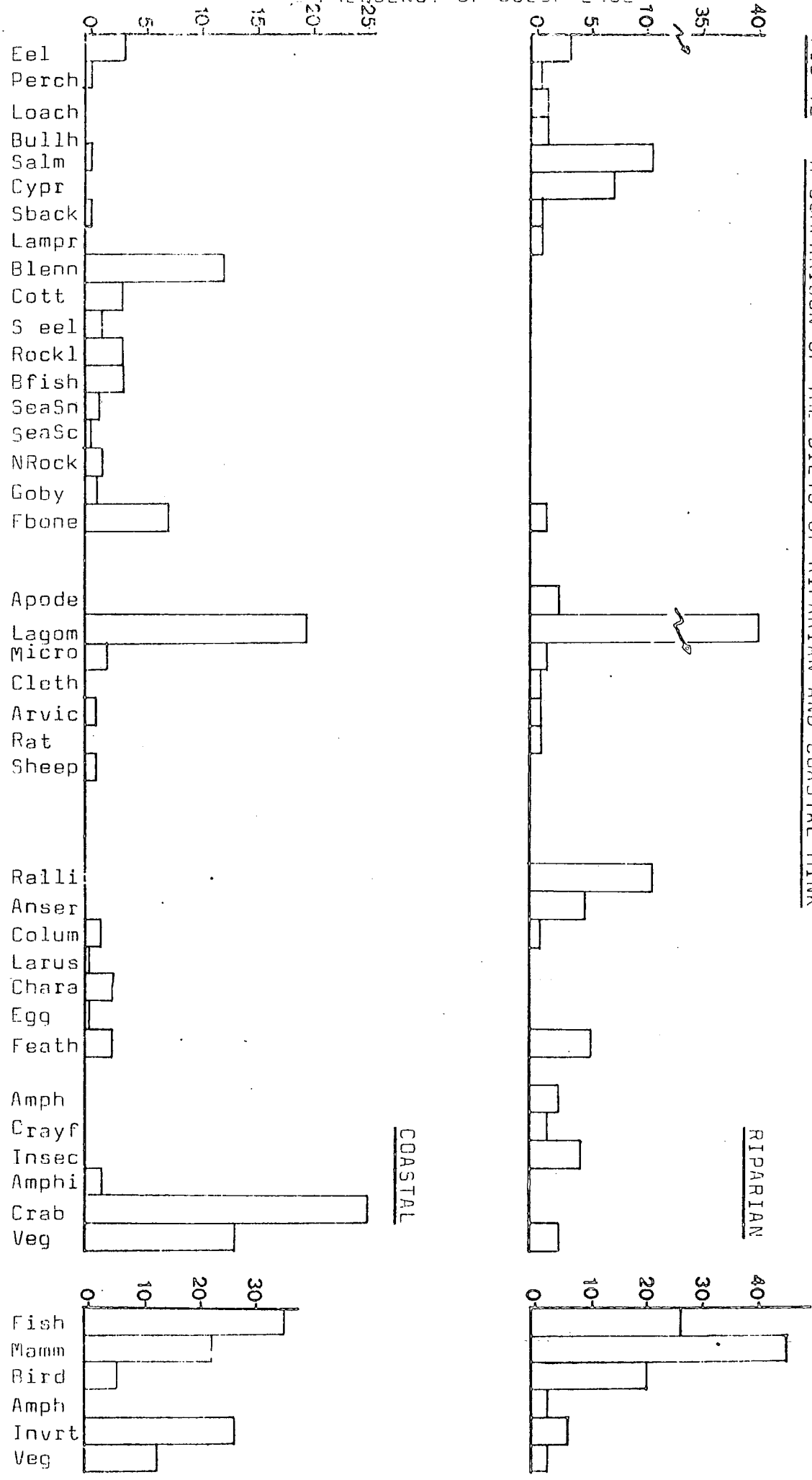
There seems to be a tendency towards increasing specialisation from weeks 14 to 16 as initially only 22% of the diet is obtained from 81% of all the species consumed, but this increases marginally to 31% of the diet from 84% of all the species. By the third sampling date, the diet spectrum broadened and 50% of all species consumed accounted for 8.8% of the diet.

TABLE 8: Results of tests for a difference between mink diet in a riparian and a coastal habitat.

Prey species	RIVERS		GALLOWAY			
	No. of scats with prey	No. of scats without prey	No. of scats with prey	No. of scats without prey		
Fish	42		194			
Mammals	73		121			
Birds	33		30		96.4	***
Amphibians	3		-			
Invertebrates	9		148			
Other	3		72			
Salmonid	17	146	1	564	75.5	***
Eel	5	158	18	547	0.007	N.S.
Lagomorph	65	98	108	457	30.2	***
Microtis	2	161	8	557	0.03	N.S.
Arvicola	1	162	2	563	0.2	N.S.
Apodemus	3	160	0	565	10.4	**

FREQUENCY OF OCCURRENCE

FIG 12 A COMPARISON OF THE DIETS OF RIPARIAN AND COASTAL MINK



COMPARISON OF THE DIET OF COASTAL MINK WITH THAT
OF RIPARIAN MINK

Although prey availability, in terms of species composition, differs between the coastal and riparian habitats, as obviously there are no marine species on the rivers and vice versa, it was thought worthwhile to compare the frequencies of the major prey groups. It was found that the percentage of the diet composed of the major prey groups did differ between the two areas (Table 8).

Mammals and birds were more important on the rivers than on the coast, and although fish had a relatively greater importance on the coast of only 5%, crab was a significant addition to the diet not found on the river (Table 8).

Within groups, apart from the obviously marine species, there are several differences in the contribution of various species to the diet (Table 8). The proportion of salmonids in the coastal diet is much less than on the river. Lagomorphs form a greater proportion of the riparian diet. Of the small mammals, only the proportions of Apodemus differ in the two areas, being absent from the coastal diet.

DIVERSITY OF DIET

A further measure of diversity and importance of specific items in the diet can be gained by reference to Table 9a, which shows the total number of prey species taken by mink in any one area and the number of species which individually provide less than 5% of the total diet. There is a significant difference between the total number of prey items taken in each of the three study areas (Table 9b).

TABLE 9a: Comparison of prey diversity in terms of the proportion of the total number of species consumed which individually constitute less than 5% of the total diet.

Area	a) Total no. species in diet	b) No. species contributing less than 5% of diet	$\frac{b}{a}$ %	% of total diet contributed by b)
TYNE	18	14	77.8	21.0
TEES	12	7	58.3	33.6
GALLOWAY	25	21	84.0	22.3

TABLE 9b: A χ^2 test for a difference between number of individual species consumed at each area.

Area	TYNE	TEES	GALLOWAY
No. Scats	99	11	265
Total no. prey species	18	12	25
		= 35.5	p = ***

On the North Tyne and at Galloway (Table 9a), a similar proportion of the whole diet (22%) is composed of items which individually contribute less than 5% of the total diet. This proportion of prey species is, however, slightly larger on the Tees (33%). The diversity of prey items seems to be greater at Galloway where 84% of the total number of species taken account for only 22.3% of the diet, whilst on the North Tyne, 78% of the total number of prey species contribute 21% of the diet and on the Tees, 58.3% of the prey species provide 33.6% of the total diet.

FIG 13a SIZE FREQUENCY DISTRIBUTION OF TOTAL FISH PREY
TAKEN DURING THE STUDY

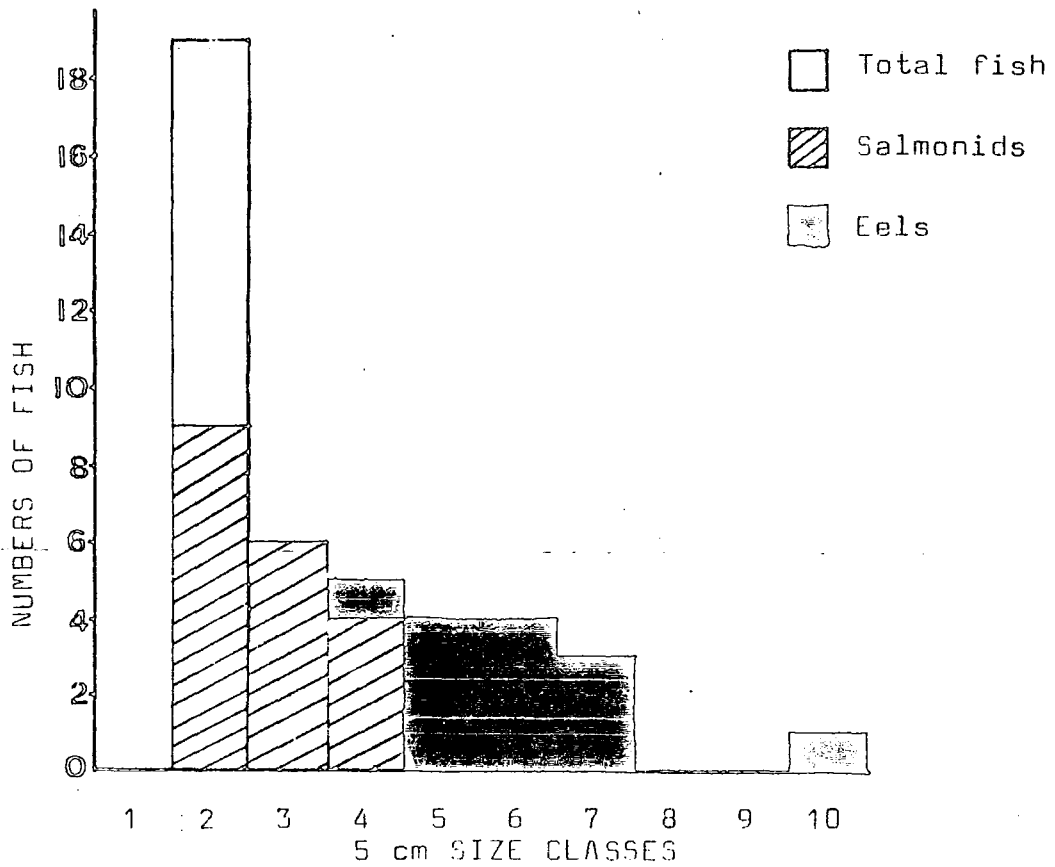
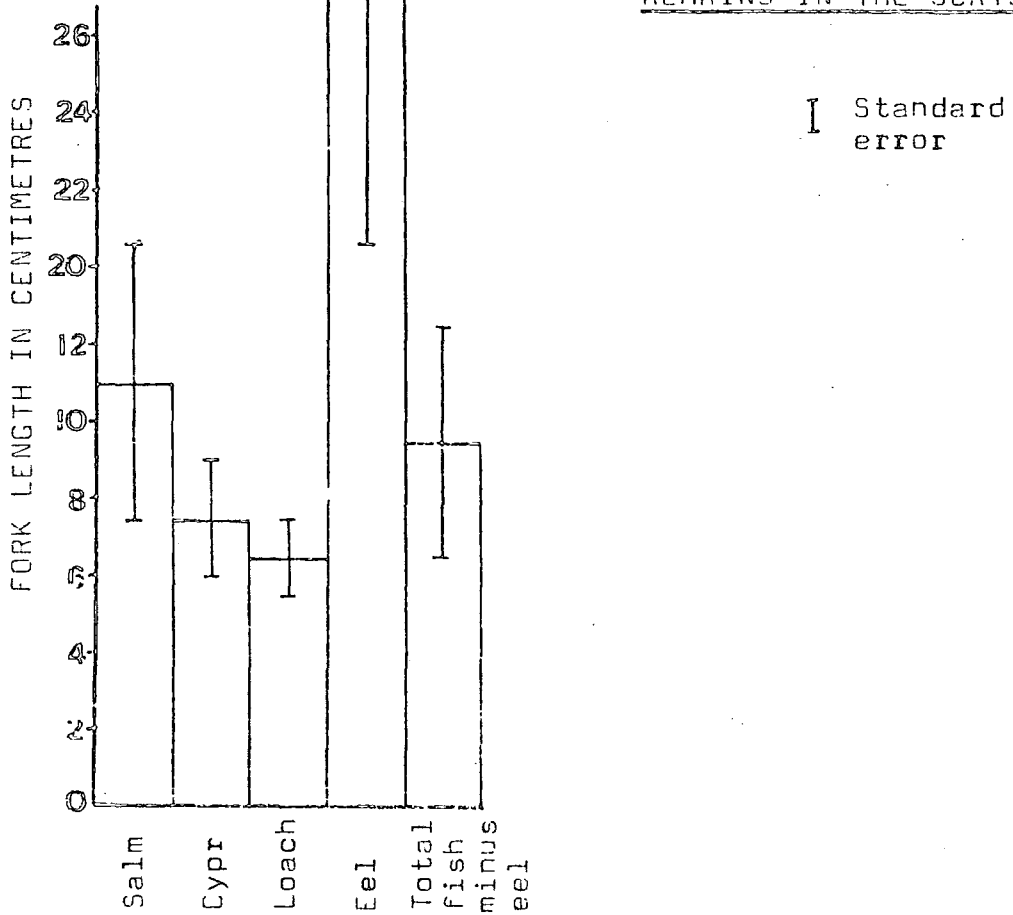


FIG 13b MEAN SIZE OF FOUR FISH SPECIES IN THE DIET OF
MINK, CALCULATED FROM VERTEBRAL
REMAINS IN THE SCATS



SIZE OF FISH IN THE DIET OF MINK

Using Wise's (1980) method of calculating fish fork length, from the size of the vertebrae, it was possible to estimate the size of 42 of the fish taken by mink during the study period.

It can be seen from the size-frequency histogram (Fig 13a) that fish in size class II (5 - 9.9cm) were taken most often. There were no records of fish less than 5 cm in length occurring in the scats, although as fish length was only calculated for four species, it is quite possible that small fish of other species were in fact taken.

If eels are excluded from the analysis, the mean size of fish taken was 9.62 ± 3.3 cm (Fig 13b). The mean sizes of cyprinids and stone loach were 7.48 ± 1.62 cm and 6.53 ± 1.11 cm respectively, no fish of greater than 9.9 cm being taken in either case. The majority of salmonids occurred in the second size category, with several fish in the third and fourth classes giving an overall mean of 10.95 cm; greater than that of the coarse fish.

There is apparently no significant difference in sizes of prey taken at each of the four separate study sites. Table 10 shows the mean size of salmonids taken at three sites and the mean eel size from two sites. It was not possible to estimate the size of any species other than eels at the coast due to the fact that the vertebrae of all the freshwater fish were damaged.

TABLE 10: Mean lengths of fish taken at different study sites.

Prey	Area	Mean size \pm S.E.
Salmonid	Tees	11.63 \pm 4.8
	Chirdon Burn	11.15 \pm 3.35
	Chollerford	10.0 \pm 5.47
Eel	Chirdon Burn	30.63 \pm 10.98
	Galloway	25.97 \pm 4.07

DISCUSSION

Difficulty was experienced in collecting scats during the study period, particularly on the North Tyne where the river level fluctuated rapidly, rising as much as six inches in one hour (pers. obs.), and this during the summer, a season not associated with spates. Even when a single individual was tracked for four days in late August, no scats were encountered, even though the precise path of the mink was known. In the present study, the scat sample size was increased by collection from breeding dens. Chanin (1976) and Wise (1978) both collected a larger number of scats during spring and summer than in winter, but make no mention of scat collection from breeding dens. Collection of the majority of the sample from a single den has the advantage that one is possibly studying the feeding ecology of a single individual, which reduces the inaccuracy inherent in obtaining the average prey preference, but has the danger that the individual may not be truly representative of the population as a whole. This is particularly the case with a breeding female, which must be subject to very different energy and nutrient requirements, in order to suckle her young, than non-breeding animals. In addition, it is possible that once the young are weaned, they may have different requirements to those of adults.

Whilst considering the reliability of the present study, it is also useful to consider the weather patterns over the study period. Conditions were abnormally dry during April and May in Northumberland, thus the river levels were far lower than is normal. This effectively reduces the area

to be searched for fish prey, and may have increased the susceptibility of fish to mink predation, in land-locked pools for example. As if in compensation for the lack of rain during April and May, the following two months were the wettest on record for some years. This produced turbulent spate conditions which not only made access to the banks for scat collection impossible, but must have also removed many scats. These conditions lasted for several days on a number of occasions and may well have influenced the normal feeding habits of mink. Predation on aquatic prey is likely to have been reduced due to the strong current flow and turbulence. In addition, the activities of many terrestrial prey species may also have been affected. Rabbits, for example, are known to increase their feeding rate prior to rain to compensate for their later confinement in the burrow (Southern, 1964).

The method of analysing dietary results is also open to discussion. The various methods available have been introduced previously (Methods). As the relative rather than the absolute importance of prey items was required for comparison between sites, it was felt that the frequency of occurrence method of analysis was most suitable, particularly as such results are amenable to statistical techniques and allowed comparison with published studies.

At the riparian sites, mammals comprised almost half of the total prey intake, whilst fish and birds respectively accounted for the remaining two quarters (Fig 12). In the spring weeks, fish were marginally more important than mammals and birds. As the season progressed, however, there was a shift of emphasis, lagomorphs accounting for three-fifths of the diet, with fish and bird items providing the other

two-fifths (Fig 10). This was due to both an increase in the number of rabbits taken and a decrease in moorhen prey. Due to freak weather conditions, it is uncertain whether the greater importance of fish in spring was due to lower water levels effectively increasing the ease of location of fish or to warmer summer water temperatures which facilitate the avoidance of capture by the poikilothermic fish prey (Gerell 1967b).

During spring and summer, the most important fish species in the diet were salmonids and cyprinids which were taken in approximately equal numbers. The mean size of cyprinids and stone loach taken were 7.5 cm and 6.5 cm respectively, several centimetres smaller than that of the salmonids (11.0 cm). On the North Tyne, Ottaway (1979) found the mean size for year class I+ stone loach to be 6.2 cm whilst that of a similarly aged trout was 11.6 cm. The size-frequency distributions of the two species were, however, quite different, stone loach age classes I and II were the most abundant, whilst the majority of the trout were in the 0+ age class, with a mean size of 4.6 cm. From these results, it appears that mink may be taking the most frequent size class of loach encountered whilst actively selecting larger salmonids. Mann (1971) found that 0 year salmonids in a trout-stream in Dorset did not reach 6 cm until late July/August. Fish are known to grow more slowly in Teesdale than in Dorset (Crisp, pers. comm.) and it is possible that development would be similarly delayed on the North Tyne, so that year class 0+ salmonids would be less than 4.5 cm during the study period and may pass unnoticed; thus, effectively the most frequent size class encountered would

be the 10 cm class.

The estimation of fish sizes from scat analysis should only be considered in the context of mink feeding behaviour. Several researchers (Chanin, 1976; Wise, 1978) have reported that whilst mink tend to consume small fish whole, they only take the flesh from larger fish, and hence these size classes may be underestimated in scat analysis.

Eels were completely absent from the diet on the Tees and occurred at only one site on the North Tyne, despite their known presence in the rivers. This under-representation may simply have been the result of a small sample size as Chanin (1976) and Wise (1978) both found that the importance of eels increased in the summer.

During summer, the only mammalian prey taken on the rivers was lagomorph (Fig 10). This is in agreement with Wise's (1978) results; she noted that lagomorph became more important during spring and summer. The increase in importance of lagomorph in the present study during the summer was partly due to an absolute increase in the amount of lagomorph, but also due to a decrease in the proportions of fish and invertebrates taken. The breeding season of the rabbit starts in January and lasts until the end of June, reaching a peak in April/May. This would seem to be at odds with a summer increase in the importance of rabbits in the diet from June to July. The spring young start breeding, however, when aged three months and the gestation period is 28 - 30 days after which weaning does not occur for three weeks. It is thus possible that the population may show an increase towards the end of the breeding season, namely June and July.

Apodemus, Clethrionomys, Microtis, Arvicola and Rattus were only encountered in the diet infrequently (Fig 12). Akande (1972), Chanin (1976) and Cuthbert (1979) all found rodents, particularly voles, to be the most important mammalian prey, and Wise (1978) noted that small mammals accounted for just under half of the total mammalian prey. The low incidence of non-lagomorph mammals in the present study is in contrast to the results of previous workers and may be explained by the fact that all previous studies have been on the annual diet.

It is interesting to note that no insectivores were taken on the rivers. Several authors, Newby (1951), Lockie (1961) and Moors (1975) have reported an avoidance of these species by carnivores. All work on mink in this country has shown, however, that they take insectivores in relation to their abundance. Their absence in the present study may simply be a corollary of the general low incidence of small mammals in the diet.

Avian prey formed almost a quarter of the total diet throughout spring and summer. The most important species during the spring was moorhen, superceded by Anseriformes, probably mallard, during summer. This may reflect a slight difference in the breeding behaviour of the two species. Wood (1974) reports that moorhen breed from late March to early August with a peak from the end of April to mid-May, whereas Ogilvie (1964 in the Atlas of Breeding Birds in Britain and Ireland) reports that the peak of mallard breeding is from mid-April to July, rather longer than that of the moorhen. The more likely explanation, however, seems to be one of local abundance; the majority of scats which

contained moorhen were collected from the George Hotel area of the North Tyne whilst those containing mallard were from the Chirdon Burn alone (Fig 9b).

The three occurrences of amphibian, Rana temporaria and/or Bufo bufo were indistinguishable and were all encountered during the spring. Gerrell (1967b) also found a spring peak in amphibian prey and postulated that they formed a buffer food refuge which is exploited during the change from one major prey type to another.

In discussing the results from Galloway, it is important to remember that scats from week 14 were more polyspecific than those collected during June, since this tends to overemphasise the importance of minor items occurring in polyspecific scats whilst underestimating major ones. The amalgamation of data from week 14 with that from weeks 16 and 18 results in a lower value for the relative importance of lagomorph than is the true case, as this prey item constituted 60% of the monospecific scats. In addition, on a numerical basis, fish attain a greater overall importance. The bulk estimate should account for this, and apparently does so, the relative frequency of occurrence of fish being 39.8% whilst that obtained by bulk analysis was 14.21%.

There was a decrease in the relative importance of fish, bird and vegetation in the diet over the three successive collection dates, whilst the importance of mammalian items steadily increased (Fig 11). The proportion of crab in the diet fluctuated, reaching the lowest level in week 16. Although the relative importance of crab was apparently higher in week 18, there was no significant

difference in its frequency over these weeks; thus, the relative increase of crab must have been due to a decrease in the importance of one of the other prey items. This is most likely to have been caused by the decrease in fish because, although the frequency of mammals decreased, their relative frequency in scats increased. It is possible that the decrease in the importance of fish during the study period may simply be an artefact caused by the high degree of polyspecificity of scats collected in week 14, which would tend to inflate the importance of fish in that period. It can also be argued, however, that in order to increase the polyspecificity, the numbers of fish taken must also have increased.

The temporal variation in the diet merits further attention as it relates mainly to a single mink, and a breeding female at that. The major feature was a decrease in the diversity of prey associated with a change in emphasis from crab to lagomorph (Fig 11). Due to the smaller sample size in week 18, the fall in diversity may simply have been an artefact. The change from crab to lagomorph was convincing, though, particularly if the large proportion of vegetation which provided no nutrients is discounted from week 14. The vegetation was included in calculations of the relative importance of various prey items for completeness, following Wise (1978). On reflection, however, the validity of this practice is questionable as the vegetation does not apparently contribute to the diet. If it is removed from the analysis, the percentage importance of crab in week 14 increases from 32% to 40.5%, whilst the other items also increase minimally in relative importance.

As kits were seen at this site during May (Watson, pers. comm.), and as Gerrell (1969) reports weaning at five weeks of age, it was calculated that scats collected from late May coincided with the suckling period. In the present study, the increase in lagomorph in the diet from June 2nd onwards apparently coincided with the weaning period. Gerrell (1969) noted a female mink delivering prey to the den at this time. Thus the increase in lagomorph may have been the result of a preference for prey which was relatively easily transported and which provided a large food source. The increase in lagomorph may, however, have been in compensation for a decrease in the absolute availability of crabs in May/June as was reported by Naylor (1962).

Between weeks 14 and 16 when fish formed an appreciable part of the diet, there was little marked variation in the importance of individual species, although the frequency of eels decreased significantly over this period, whilst the apparent decrease in blennies from week 14 to 16 was not significant. This shift in emphasis for fish could simply be due to a greater availability of lagomorphs. It is interesting that blennies are by far the most common of the rock pool fish eaten. An attempt to assess the availability of littoral fish at low tide showed blennies to be encountered most frequently.

The mammalian prey was composed almost entirely of lagomorph with a few occurrences of Microtis, Arvicola and a single Sorex, but with a notable lack of Apodemus, Clethrionomys and Rattus. Lawrence and Brown (1974) note that Apodemus is more common when Microtis is absent from the area, although a trapping program would be required to

substantiate this. The absence of Rattus norvegicus in the diet is surprising as there is a farm in the study area, although this food source may only be exploited when all else is rare. It is possible that there is insufficient habitat cover for Clethrionomys, but the most plausible reason for its absence is simply one of sample size combined with a glut of lagomorph. Cuthbert (1979) has suggested that the paucity of Clethrionomys and Apodemus in the diet is due to their burrowing habits and use of dense cover making them less accessible. The increase of importance of lagomorph in early June is similar to that found on the rivers and may again be due to increase in juvenile rabbits available at this time. Several brown hares were encountered at the coastal site and two carcasses were found close to the breeding den. Although mink could probably kill an adult hare, it is possible that these prey were obtained as carrion; sheep carrion was apparently also taken.

Results from other studies of the diet of coastal mink are in accordance with the results presented here. Gerell (1968) noted that Microtis and Arvicola were the most frequent mammalian items in the diet of mink on some Swedish islands, whilst Cuthbert (1979) found that lagomorphs, common rats and Microtis were the most frequent mammalian species on his coastal site in Scotland.

The three groups of birds encountered in the diet were Charadriidae, Laridae and Columbidae. The relative importance was lower than that found by Cuthbert (1979). The major avian prey item in his study was Laridae whilst Charidae were most important in the present study. Of the thirty occurrences of feather, almost half were unidentifiable and

therefore possibly from juvenile birds. Gerell (1968) found two peaks of bird predation, in March and June. In the present study, the percentage relative importance was marginally greater in week 14, but probably not significantly so.

Carcinus was the major invertebrate prey and was the only species of decapod encountered. Whilst this is in accord with Gerell's (1968) and Cuthbert's (1979) results, Watson (1978) noted that otters took a large number of the velvet swimming crab, Portunus puber. This may have been due to different habitat conditions or to different hunting behaviour of otters in comparison with mink.

The large amount of vegetation present in scats collected during week 14 is interesting. The vegetation was mainly grass and although it had obviously passed through the digestive tract, it was undigested. During the course of radio-tracking studies at the riparian site, mink were seen to purposely ingest grass. Both Chanin (1976) and Wise (1978) found that grass comprised only a small proportion of the diet and they concluded that it was ingested accidentally. It is possible in the present study that the mink collected it as nesting material and accidentally ingested some, but this seems unlikely. Another possibility is that grass is ingested to form a cover around fish bones to prevent damage to the intestine, but this too seems improbable, since, were it the case, one would expect a higher incidence of vegetation in the scats from all localities and throughout the year when fish are consumed. A final suggestion is derived from the correlation between crab and grass in the diet. It is possible that the grass acts as an anti-emetic counteracting

the ingestion of quantities of sea-water or as roughage.

Gerell (1968) found fish to be the most important coastal prey item, followed by arthropods and finally mammals and birds. In Cuthbert's (1979) study, C. maenas was the most important prey item, accounting for 33% of the diet, followed by fish, mammals and birds. The present study is similar to that of Gerell's (1968) in establishing the primary importance of fish. Different species were represented, however, and the total relative importance was less, possibly because lagomorph and crab are more important during summer and thus a comparison of a seasonal with an annual study may produce spurious differences.

The greater importance of fish in the coastal diet than on the rivers (Fig 12) may be somewhat inaccurate due to an overestimation of the importance of fish resulting from the use of frequency of occurrence analysis and the differing polyspecificity of the scats. It may also, however, be due to differences in fish behaviour; in the rivers, warm summer water facilitates rapid movement, whilst on the coast, the majority of fish taken are of the rock pool species which possibly do not depend so much on sustained speed of movement for escape. In addition, the availability of crab on the coast must reduce the mink's dependence on fish and mammalian prey.

The diversity of the coastal diet is greater than that in a riparian habitat, though it is unclear whether this is because the coastal habitat is less optimal and thus food harder to obtain or whether it is simply a reflection of a greater diversity of available prey. Both Kruuk and Hewson (1978) and Watson (1978) found the density of otters

to be higher in a coastal area than in a riparian habitat suggesting a more optimal environment. Hatler (1971), whilst conceding that potential food sources are widely and abundantly distributed, points out that temporal restrictions are placed on hunting by the tidal cycle and notes that this can result in considerable stress on mink at certain times of the year.

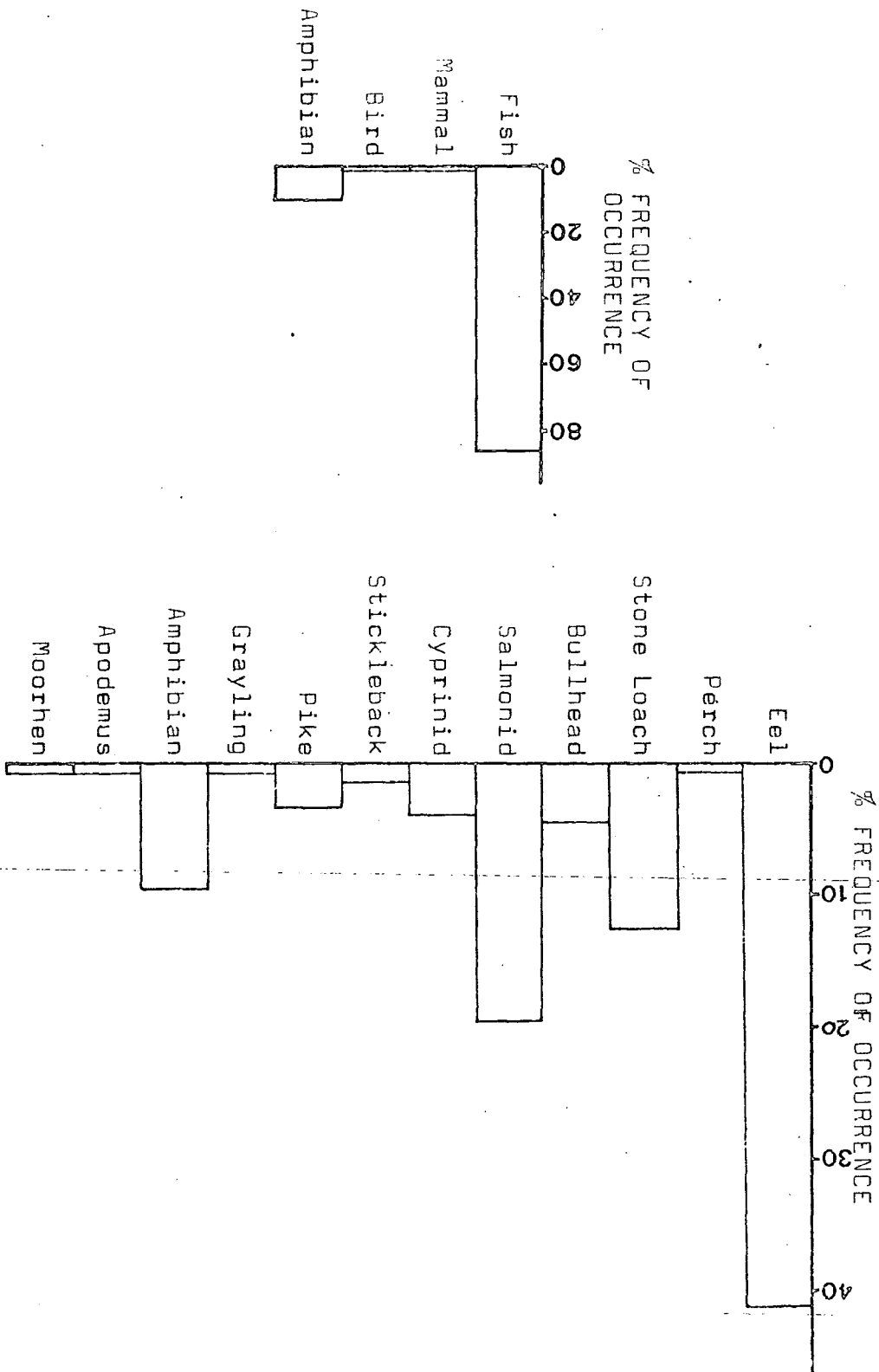
As no measure of the density of the prey species available has been obtained, the discussion of mink diet has necessarily been very superficial. It seems reasonable to assume, however, that during spring and summer the numbers of many of the prey species will be at their most abundant; thus apparent differences in numbers taken may well be the result of specific preferences rather than simply reflecting absolute availability. All the species of small mammals which appeared in the diet on the North Tyne were trapped with relative ease, hence the explanation for the large proportion of lagomorph in the diet may simply have been that this was a preferred food, when availability of all species was similar, or that more scats are produced from a rabbit kill than from small mammals.

The present results differ from those of previous workers at the specific level, whilst the importance of major groups, fish, mammal and bird, is fairly consistent. The high incidence of lagomorph seems to be the only major anomaly at the species level and this may be partially due to the fact that Day and Linn (1972), Akande (1972), Chanin (1976) and Cuthbert (1979) only presented data for the annual diet.

The majority of scats in the present study were

PERCENTAGE FREQUENCY OF OCCURRENCE OF PREY ITEMS
IN THE DIET OF THE OTTER ON THE RIVER NORTH TYNE

FIG 14



Total spraint number = 80
Total prey occurrences = 131

collected from breeding dens and this may have introduced bias in the results. Gerell (1969) noted that a female mink became more diurnal in the post-parturition period, whilst the radio-tracking study described in Appendix I showed that a juvenile male was apparently diurnal; hence these animals may be subject to a slightly different prey availability than those which have provided the results of previous studies.

An analysis of otter diet from spraints collected on the North Tyne at the same time as this study, was made available by N. Pautard (1980). Comparison of Figure 8a with Figure 14 shows there to be minimal overlap between the diet of these two predators. The principal prey group in the otter diet was fish, comprising 86.2% of the total diet, whilst fish were of secondary importance to mink, forming only 26.7% of the total diet. Amphibians formed 9.2% of the otter diet but only 0.7% of mink diet. Salmonid, cyprinid and stickleback were taken in similar proportions, although even then, the frequency of occurrence in the otter diet was double that in the mink's diet. The mink's food spectrum was apparently wider than that of the otter as mink consumed a total of 18 different prey species of which 15 comprised individually less than 5% each of the diet and accounted for only 21% of the total diet. In contrast, the otter concentrated on a total of 12 prey species of which 8 formed only 16% of the total diet. Thus the otter obtains 84% of the diet from only four prey species and must therefore be a specialist predator. 89% of the otter's diet consists of completely aquatic prey, and a further 10% of semi-aquatic prey, whilst the mink's diet is composed largely of terrestrial prey (50% of the diet) with aquatic and semi-aquatic prey forming a further 25% each. A further separation

occurs in the size range of fish selected; the mean size of salmonids taken by mink is 11.0 ± 0.8 cm, whilst the mean taken by otter is nearer 15 cm.

From these results, it is apparent that mink and otter do not compete for food during the summer in this study area. All the authors who have previously studied this problem in Britain have come to a similar conclusion. The only possible instance of competition for dietary requirements was reported by Erlinge (1969) in a Swedish habitat during the winter months when conditions are likely to be more extreme.

A comparison of the results from the present investigation of the diet of coastal mink with those of Watson's (1978) study of the diet of coastal otters in Shetland indicates a distinct separation of diet. For the period May-June, Watson (1978) calculated that fish comprised 84.8% of the diet with the remaining 15.2% being accounted for by Crustacea. In contrast, the mink took 34.6% of its diet as fish, crab accounted for 26.2%, mammal 21.5%, bird 5.4% and vegetation 11.5%. Within the fish group the most important species to the otter were, in rank order, butterfish, Yarrell's blenny and rockling, whilst the common blenny, eel and butterfish were the most important fish species to the mink, although contributing a much smaller proportion of the diet overall.

Watson (1978) noted that the diet of a juvenile otter was different to that of its mother and suggested that this was because the cub was not very adept at catching the fish prey preferred by the mother and therefore was forced to take crabs and other prey which are less favoured

by its parent. It is possible that, if the mink is only a recent colonist, it too has not learned to cope with swifter prey species. It does seem more likely, however, that the mink's inferiority to the otter as an aquatic predator in a riparian habitat also extends to the coastal habitat. If this is the case, there may be cause for alarm that the mink will compete with otter cubs which take a large proportion of crab.

From a comparison of these two studies, it seems that the mink is less completely a coastal animal than the otter and, in the event of competition, may be able to take advantage of a mammalian prey food refuge.

Although the present study is incomplete, the trends indicate that there is a change in the composition of mink diet in the riparian habitat between spring and summer. Initially, the order of importance of the major prey groups was fish, mammal, bird, amphibian and invertebrate, although during the summer the mammal group doubled in importance. This change seems to be mainly due to a variation in prey availability coupled to some extent with preference for particular species.

At Galloway, where the majority of scats were obtained from a single breeding den, there was a temporal variation in the diet, lagomorph increasing in importance during the sampling period whilst both fish and crab declined. It was postulated that this variation may have been due to the varying requirements of a female and kits during the breeding season.

On the rivers, half the diet was composed of terrestrial species with the remainder equally divided between aquatic and semi-aquatic prey. On the coast, however, the

proportions of aquatic, semi-aquatic and terrestrial prey types were approximately equal.

The radio-tracking data showed that numbers of scats encountered and padding are unreliable indicators of mink presence or absence. In addition, the juvenile male tracked exhibited a diurnal activity pattern which may have been a result of maternal influence. It engaged in much exploratory behaviour indicating either the establishment of a territory or the initiation of a dispersive phase. From the random use of den sites it was postulated that denning may be related to either prey capture or convenience.

There was apparently no dietary competition between the riparian mink and otters and the excess of potential den sites would seem to preclude competition for lying-up places. It seems unlikely that the mink is a potential competitor with the otter in a coastal environment, although any dietary overlap is most likely to occur with the otter cub, when the latter would be most likely to suffer from dietary competition.

APPENDIX 1 : RADIO-TRACKING RESULTS

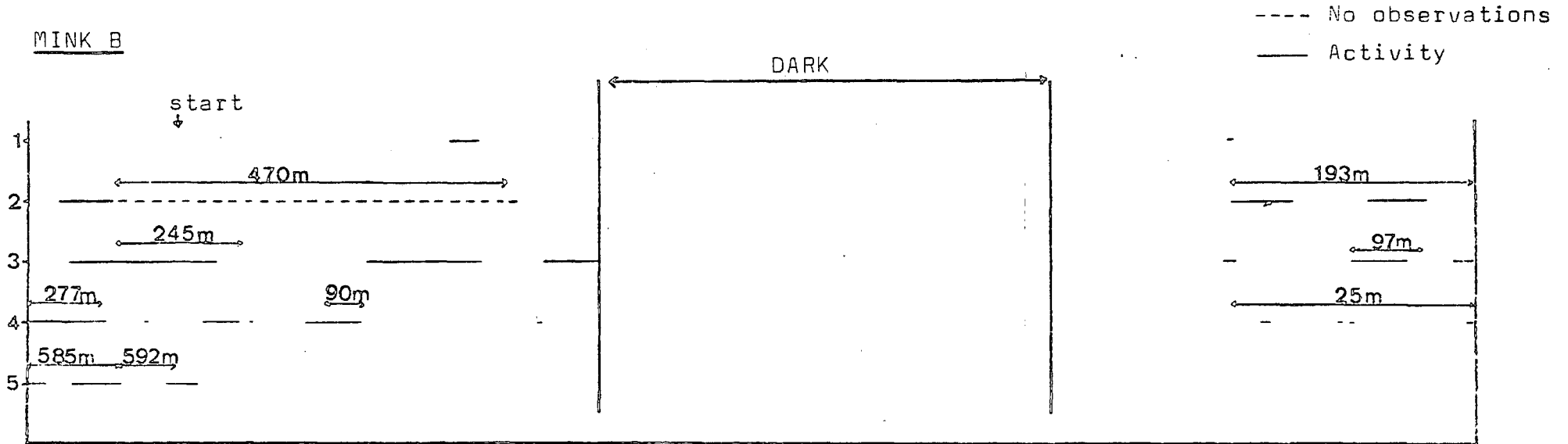
The activity patterns of mink were compiled from two separate periods of radio-tracking. Mink A was tracked continuously for a total of three days in April and Mink B for four days at the end of August. The former was a Silver-Blue adult male and Mink B a Silver-Blue juvenile male. Both were trapped along the same 100 m length of the North Tyne at Chollerford (A at trap 3, B at trap 2, Fig 16) and taken to Durham to be fitted with radio collars.

The animal was anaesthetised using "Vetalar" (ketamine hydrochloride) which took effect within five minutes. A shallow collar of fur was shaved from the neck of the mink and the AVM radio collar containing a SM1 transmitter at 173 MHz was attached. These transmitters had a potential battery life of six months and weighed 12.99 g representing less than 1.4% of the mink's body weight. A Beta light was attached to Mink B's collar to aid location at night.

Mink A remained in captivity for two weeks after capture, whilst B was released after 14 hours, once the effects of the anaesthetic had worn off. Tracking was carried out on foot using a hand-held Yagi aerial, the equipment had a theoretical range of 2 km, but in practice this was reduced to 500 m. A was tracked virtually continuously during the 24 hour period with only a short break of 2 to 2½ hours between 12.30 to 2.30 pm. Mink B was not tracked overnight after observations had shown that there was apparently no activity during this period. N. Dunstone and S. Pickering have kindly made the observations on Mink A

FIG 15a A DIAGRAM TO SHOW THE ACTIVITY PATTERNS OF TWO RADIO-TAGGED MINK

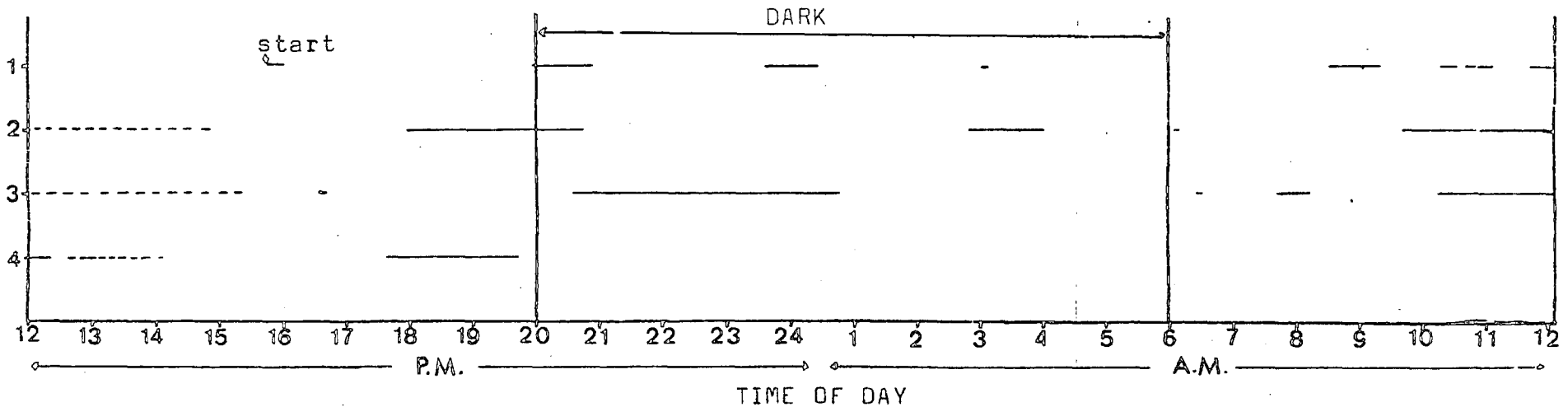
MINK B



(For mink B, figures associated with bouts of activity refer to distance travelled in metres during that period)

MINK A

TRACKING DAYS



available for comparison with those obtained from tracking Mink B.

ACTIVITY PATTERN

Figure 15a shows the activity patterns of the two males over the period for which they were tracked. Activity was calculated as a percentage of time spent inactive, the results are shown in Table 11.

TABLE 11: Activity as a percentage of time spent inactive.

Animal	am.	pm.	Night	Day
A	47%	51%	27%	10%
B	11%	36%	—	17%
B*	12%	46%	—	—

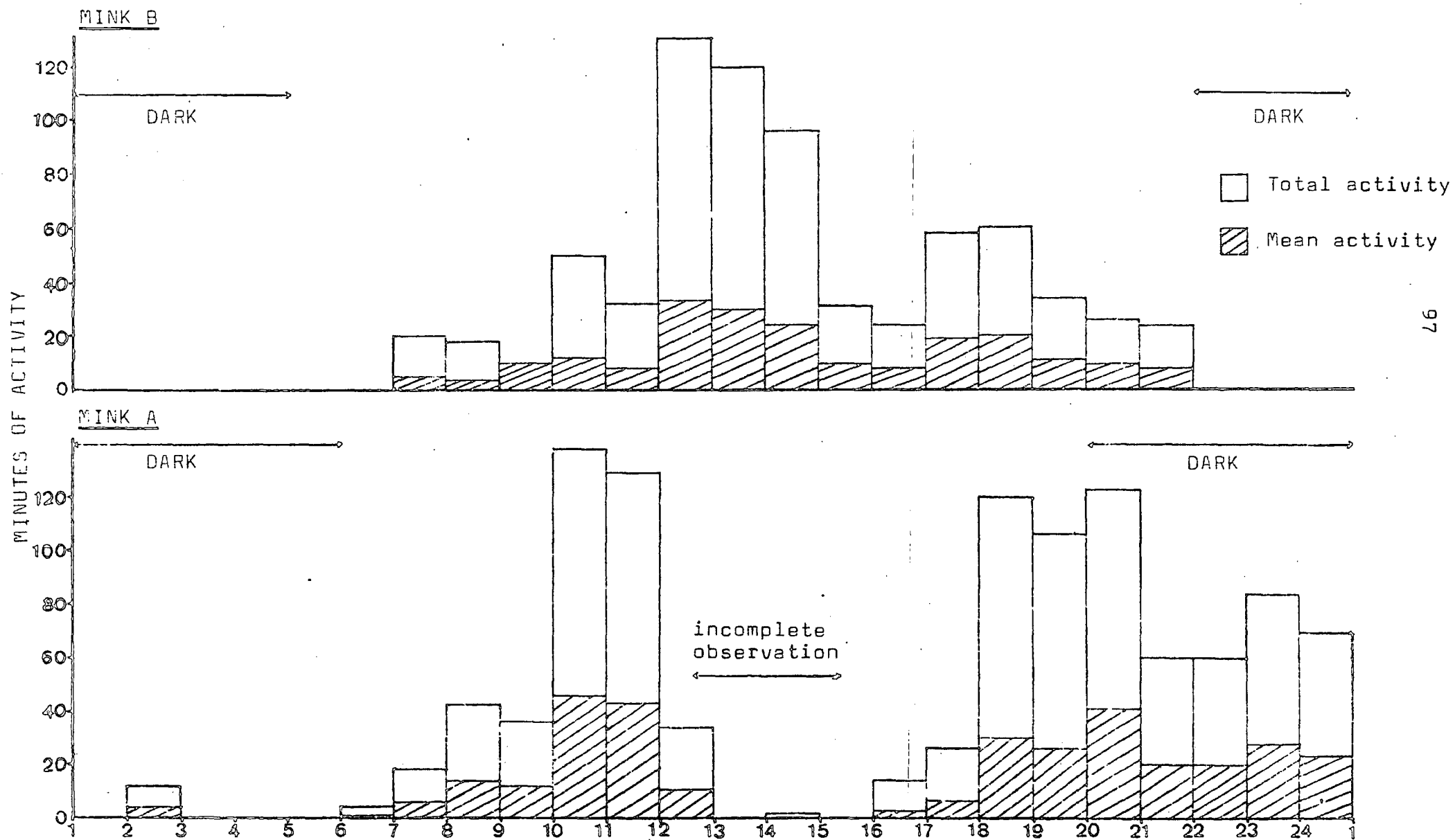
* activity as a percentage of hours of daylight.

The day was arbitrarily divided into two twelve hour periods from 12.01 am to 12.00 pm (am) and 12.01pm to 12.00 am (pm). Mink A was equally active during both periods, however Mink B was markedly less active during the am period. Activity was then calculated as a percentage of time inactive, but divided on the basis of hours of darkness and hours of light, A was relatively more active during the night whilst B was completely inactive during this time.

Figure 15b shows the total activity per hour over the whole tracking period and the mean activity for each hour of the 24 hour period. From both this and Fig 15a it is apparent that Mink B was completely diurnal whilst Mink A was marginally more active at night than he was during the day.

Both mink appeared to have two periods of more

FIG 15b DISTRIBUTION OF TOTAL AND MEAN ACTIVITY THROUGHOUT THE TWENTY-FOUR HOUR PERIOD



intensive activity; Mink B between 1 pm and 3 pm and from 5 pm to 7 pm. Mink A's activity peaks were slightly different, being 10 am to 12 pm and 6 pm to 9 pm with a fairly high sustained level of activity from 9 pm to 1 am. Mink A was tracked during April, the end of the breeding season when males are normally very active.

MOVEMENT

Only the results obtained from tracking Mink B will be discussed. The longest distance travelled during a single bout of activity was 470 m which was covered during a period of seven hours. Contact was lost during this period however, so the exact extent of the journey was unknown. The mean speed was calculated from all those journeys of which the starting and finishing time were known accurately, and was 2.7 m/min. The fastest travel time was recorded when the mink moved 244.6 m in 57 min, giving a mean speed of 4.3 m/min.

In the field the activity pattern seemed to be based on a period during the morning when movement was concentrated around the den site used during the previous night. Around noon, after a short lull, rapid activity was often registered as the mink covered considerable distances along the river bank during periods of continuous movement; it was at this time that most of the day's travelling occurred. Activity invariably decreased again during late afternoon prior to a mid-evening bout which was similar to that of the morning in that activity was concentrated in a single area.

The animal was visible for much of the time that

it was travelling (60-70%), and seemed to prefer a path along the water's edge, hopping between boulders and running along the muddy shore. After each brief period in the water, the animal shook itself dry. On several occasions it was seen to dive and remained submerged for an average of four seconds. Both mink A and B remained within 10 m of the river during the tracking period.

During the study, mink B used a different den site each night, however, three of these were within 135 m of each other. The first night was spent under a pile of brushwood and fallen trees several metres from the release point (trap 2 on Fig 16). The second night was spent 470 m upstream on the "Island". The final two nights were spent close to the original trap site, and during this period, all activity was restricted to a 309 m length of the river.

PRESENCE OF OTHER MINK

Prior to mink A's capture, an adult female was caught in trap 3 (Fig 16), but subsequently died as a result of mating and trapping injuries. During the April tracking period, two mink were heard screaming and fighting and it is possible that mink A was one of them.

During the four days in August, three mink other than mink B were also seen. A chocolate coloured mink, possibly female (mink C) was observed on August 22 near a small feeder stream (point A, Fig 16) close to mink B's last known position at that time. The following day she was sighted further downstream near trap 2 and was observed attempting to catch a moorhen. The second animal, (mink D) had a dark brown pelage and was smaller than mink B (and thus possibly a female). On two consecutive days this

animal chased mink B out of a clump of sycamore trees, accompanied by much vocalisation, causing mink B to move upstream.

The third animal, mink E, was another Silver-Blue, possibly adult. It appeared from the rushes and came 20 m up the bank passing very close to the observer before entering a den in a dead tree. On emerging several minutes later, it continued downstream, sniffing as though following a trail. On later inspection, the den was found to contain three rabbit carcasses and numerous bird remains. It is possible that it was a breeding den and thus that mink B, C and E were related.

DIET

During the course of the tracking period, mink B was known to have attacked and consumed a rook with a damaged wing. At one point, he was seen to emerge from the river with a fish in his jaws, possibly a minnow. Six hours after his release, he was seen to eat two laboratory mice which been left near the trap site, and whilst in captivity had consumed four one day old chicks. Mink A was observed to catch a juvenile rabbit. Both mink A and B were observed eating vegetation, and both seemed to preface about of activity with a drink from the river.

DISCUSSION OF RADIO-TRACKING RESULTS

During the course of the tracking period, it became abundantly clear that the number of scats present does not give an accurate indication of the number of animals present. Chanin (1976) and Wise (1978) have taken

changes in the number of scats found to be an indication of mink activity, however, this must be viewed with caution and related to the conditions for scat collection, for example, heavy rain is likely to remove scats. Neither are tracks a very reliable indication, as a single mink may cover a large area of river bank in a relatively short time and has been known to track back and forth repeatedly along mud banks producing a number of tracks. As the pad marks of an individual can only be recognised when the ground consistency is favourable and then usually only by an experienced tracker, this can be a very inaccurate method of assessing population size. This must certainly be borne in mind when considering the results of surveys on the rivers Blyth, Wansbeck and Font. Mink have been reported on the river Blyth (Watson, pers. comm. and Richardson, pers. comm.), but no signs of their presence were found.

The most striking result from this study was perhaps, the diurnal nature of mink B's activity pattern. Both Gerell (1969) and Birks (pers. comm.) have reported a mainly nocturnal pattern in the mink which they have tracked, the only exception being a female which became diurnal in the lactation phase. It is possible that mink B, being a juvenile, was still affected by the same factors which prompted Gerell's (1969) female to become diurnal. During the present study, three other animals were also seen during the day and much of mink A's activity occurred during daylight hours. The results from tracking mink A may, however, be unrepresentative as the animal died a few days after the tracking period from an apparent malfunction of the liver, either due to trap stress or as a result of mating stress. Mink A's activity apparently increased just

prior to dusk and decreased towards midnight. From Corbet and Southern's (1977) general account of mammals it appears that the majority of the minks' prey species are either crepuscular or nocturnal.

Apart from the timing of activity, the movements involved also bear some scrutiny. During the early and late bouts of activity mink B remained close to a den site, almost as though foraging within a restricted area. At midday, however, the pattern became very different, large distances were covered at high speed with virtually no interruption, it was at this point that much of the tracking back and forth was apparent. An oscillatory pattern similar to that described by Gerell (1969) was noted. On day two, mink B travelled to the "Island" and once there travelled back and forth in a restricted area prior to moving back to trap 2 on day three. After a brief foray upstream in the morning of day four, he travelled downstream to trap 3 and then back to spend the night at den 5 (Fig 16). On day five, he travelled down to the sycamore trees and oscillated between the trees and an area 200 m further upstream before returning to trap 2.

Gerell (1969) and Chanin (1976) noted that the kits normally remain with the mother until July/August and it is possible that by late August mink B was either attempting to establish a territory or familiarizing himself with the maternal territory prior to dispersion. This speculation is based on the fact that two other mink were seen within a small area in which mink B spent much of his time, yet no signs of aggressive interaction were observed, thus they may have been siblings, whilst further

downstream mink B was chased off on two occasions by mink D.

The use of a different den site each night is in accord with Schladweiler and Storm's (1969) results and may possibly be governed by the availability of shelter close to a "kill". Nights 1,3 and 4 were spent within 150 m of each other and it would presumably have been possible for the mink to return to the same den each night, however, a different one was occupied on each occasion. On day four, mink B was found to have killed an injured rook which had been frequently observed in the area. The carcass was found in a den known to have been occupied by mink B in close proximity to the rook's last known position. Thus it seems likely that, having made a "kill", the mink simply repairs to the closest available shelter. Thus a habitat providing a large number of potential den sites is likely to be favoured; Gerell (1969) and Errington (1946) both note that lack of den sites may restrict mink colonisation.

$$\begin{aligned} \text{Mean C.F.} &= \frac{154.49}{12.08} + \frac{127.98}{6.12} = \frac{282.47}{18.2} \\ &= 15.5 \end{aligned}$$

DISCUSSION

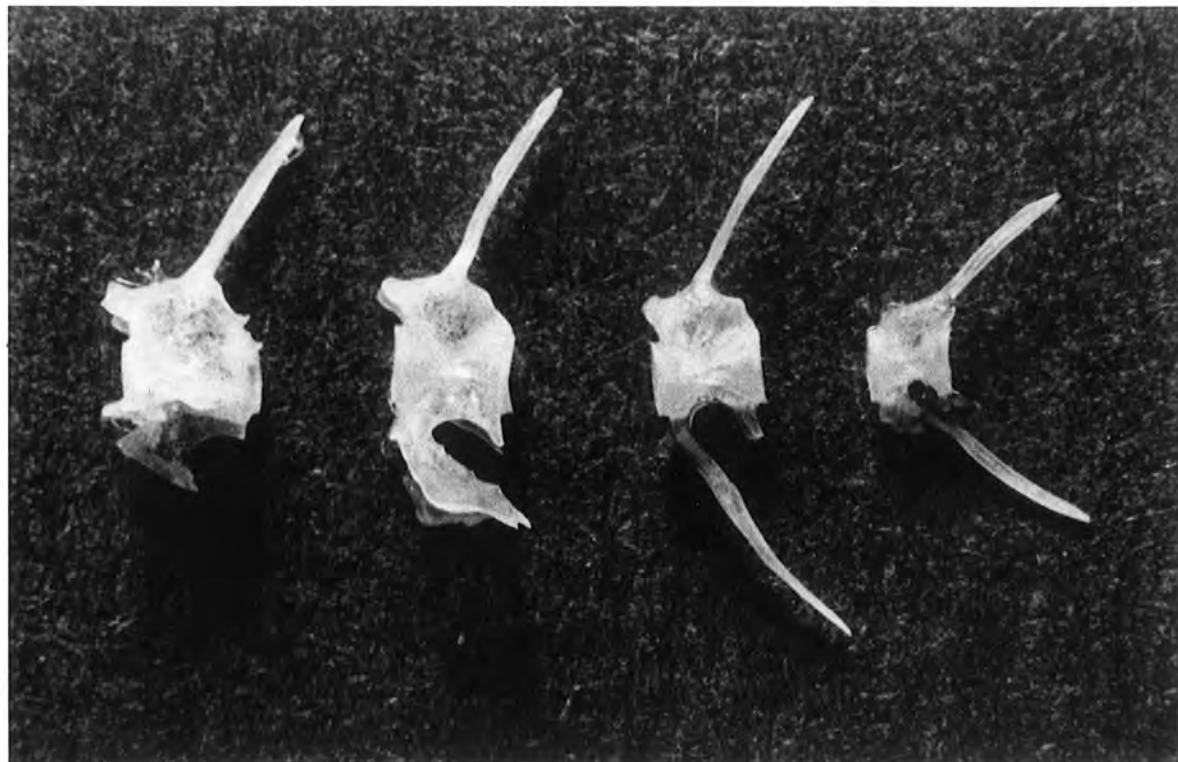
The estimation of a correction factor based on a single feeding trial using only two animals must be viewed with scepticism but is included here for completeness. In this case, the individual mink were observed to use different feeding strategies and this may have either increased the inaccuracy of the method or may have mimicked the situation in the wild. Until there are observations of wild mink feeding on crabs, the efficacy of the method cannot be assessed. The same reservations must, however, apply to previous estimates of Conversion Factors for various prey types (e.g. Wise, 1978).

One of the two animals ate the crabs complete, crunching the carapace, whilst the other attempted to kill the crab with a bite in the carapace and then removed the carapace and ate only the contents.

APPENDIX 3 CHARACTERISTIC VERTEBRAE

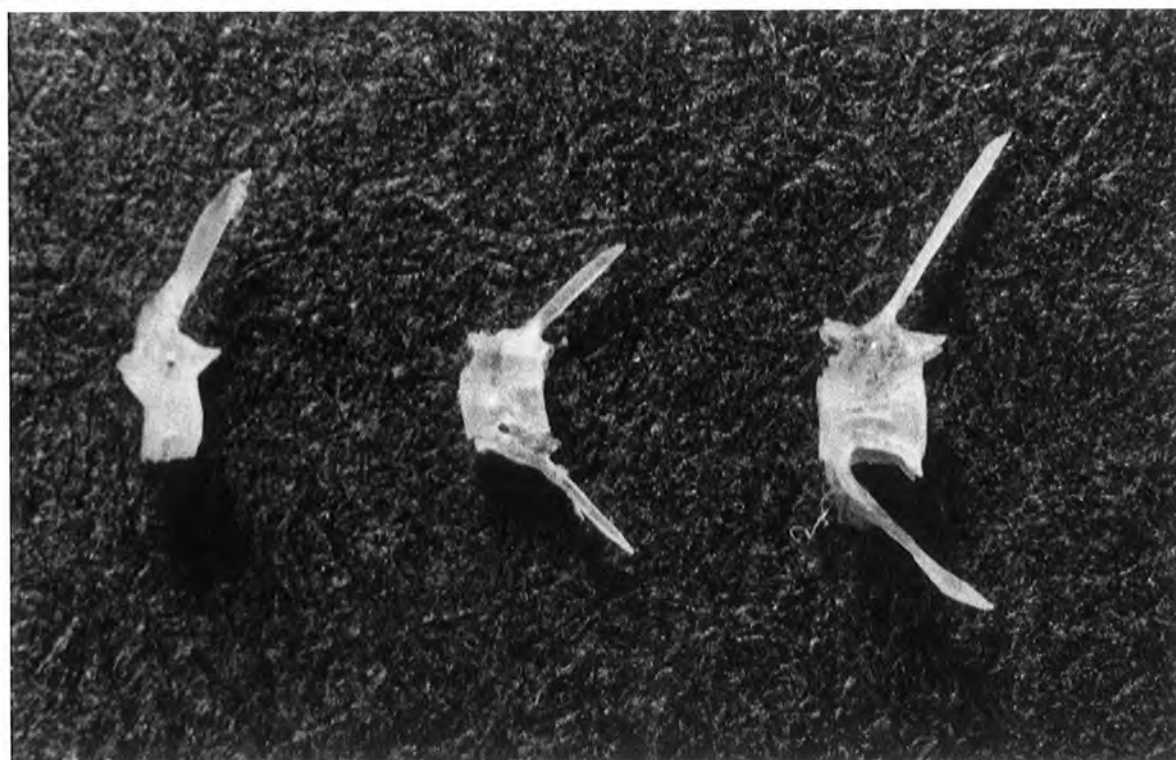
VERTEBRAE FROM THE COMMON BLENNY

Anterior abdominal to posterior caudal vertebrae, from left to right.

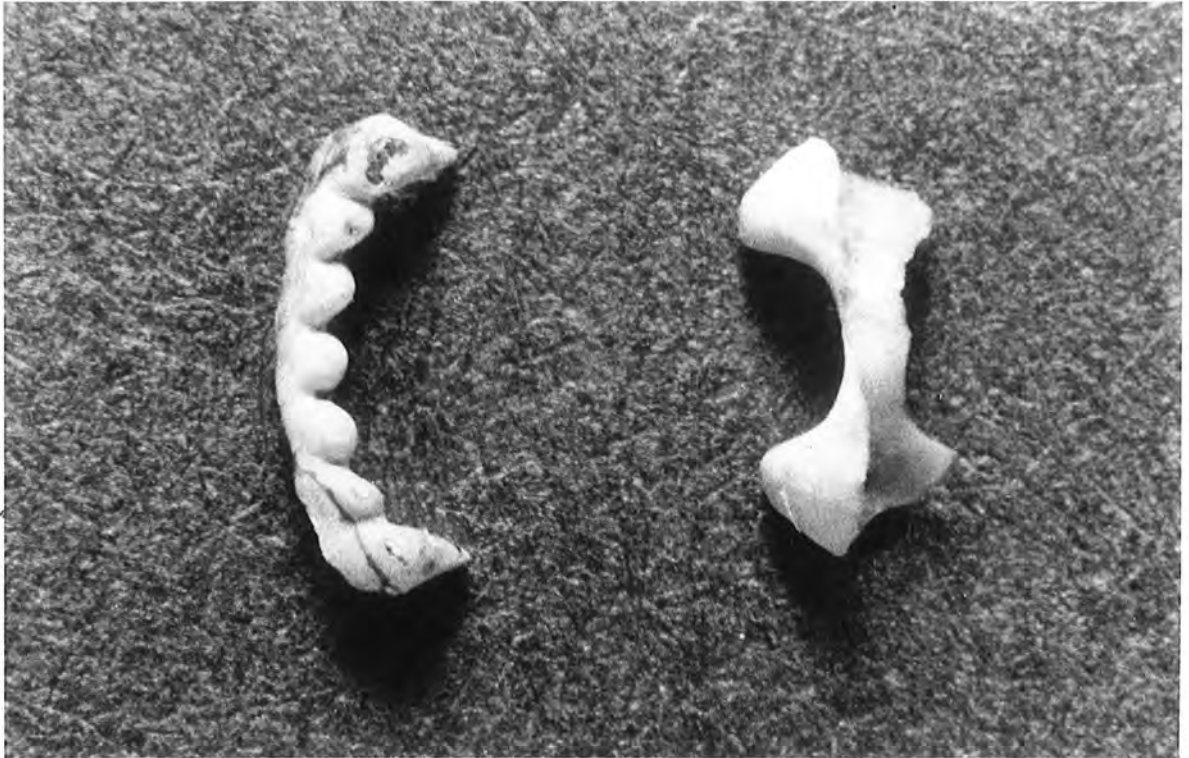


VERTEBRAE FROM THE BUTTERFISH

Anterior abdominal to caudal vertebrae, from left to right.



PARTS OF THE ORAL SUCKER OF THE BROOK LAMPREY



Photographs from P.Wheeler.

SUMMARY

1. Mink scats were collected from two riparian areas in Northumberland and a coastal site in Galloway, in order to investigate the spring and summer diet of feral mink.
2. The order of importance of the major prey groups in the riparian habitat was:- mammal, fish, bird, amphibian.
3. There was seasonal variation between spring and summer, as the diet changed from a predominance of fish to one of mammal, with a decrease in the importance of amphibians.
4. On the coast, the main prey groups in order of importance were:- fish, crab, mammal and bird.
5. There was temporal variation in the coastal diet over the three collection periods in June and July, the mammal group becoming increasingly important.
6. Half the riparian diet was composed of terrestrial species, with aquatic and semi-aquatic species providing the remaining two quarters respectively. On the coast, the three types were equally represented.
7. As few scats were collected initially, an individual was trapped and radio-tracked in an attempt to ascertain how much time mink spent close to the water course.
8. The juvenile male tracked exhibited a diurnal activity pattern, remaining within 20 m of the river, and displaying much exploratory behaviour.
9. It was concluded that mink and otter did not compete during spring and summer in the riparian habitat and that they would be unlikely to do so on the coast were they sympatric.

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