Aspects of the feeding biology of mink (Mustela Vison Sckreber) on the Ross Peninsula, Dumfries and Galloway, Scotland

David-Peter Moltu

ASPECTS OF THE FEEDING BIOLOGY OF MINK (MUSTELA VISON SCHREBER) ON THE ROSS PENINSULA, DUMFRIES AND GALLOWAY, SCOTLAND

- by -

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B.Sc. Hons.

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Og til slutt men ikke minst til L. Moltu for hennes hjelp.

CHAPTER 1

INTRODUCTION

The North American mink Mustela vison Schreber is an opportunistic generalist carnivore of the family Mustelidae and is the only introduced carnivore in the United Kingdon to have successfully established widespread feral populations.

Mink were first imported into Europe for commercial breeding purposes in the late 1920's (Thompson 1962, 1968). Poor management of these captive animals inevitably led to escapes, and feral populations were reported in several countries, Sweden in 1928 (Gerell 1967), Norway in 1930 (Wildhagen 1956), Britain in 1938 (Thompson 1968), and more recently have become established in Iceland (Gudmunsson 1952), Finland (Westman 1966), and Ireland (Deane and O'Gorman 1969). Over 16000 mink have been deliberately released in Russia since 1933 to provide a commercial fur bearing crop (Novikov 1962, Pavlov 1970).

Feral mink were first confirmed as breeding in the United Kingdom in 1955 from the sighting of a female mink plus kits on the river Teign in Devon (Linn and Stevenson 1980). They suggest that the colonisation of Devon rivers took place in two phases. First an establishment phase, during which the population slowly built up its numbers in the Teign valley,and then an explosive dispersal phase during which a large area of the county was colonised in a very short period.

The presence of coastal mink in the present study area (Kirkcudbrightshire, Scotland) was first reported in 1963

(Lever 1977).

In 1962 the U.K. Government imposed restrictions on the keeping of mink in England and Wales under the Destructive Imported Animals Act 1932 by means of the Mink (Importation and Keeping) Order. At the same time a widespread trapping campaign was initiated by the Ministry of Agriculture, Fisheries and Food. Over 7000 captures were recorded during the decade 1961-1970 and about a 1000 a year have been reported as having been caught subsequently. This is probably a conservative estimate of the number of captures made in recent years (Thompson 1977). However, it became evident that the populations of mink could neither be exterminated nor have their range reduced (Thompson 1968), and by 1969 feral mink were thought to be present in every county of mainland Britain (Deane and O'Gorman 1969).

In size and shape the mink resembles the polecat <u>Mustela putorius L.</u> but in association with its aquatic habits it has partially webbed feet. The natural pelage of the North American mink is a very dark brown, however, selective breeding on fur farms has produced a wide variety of coat colours (Stevenson 1957. Because of this great variety of mutant genes, feral mink from captive stock show more variety of pelage colour than the native North American populations. However feral mink populations tend to approximate to the natural dark brown pelage, with variable white chin and chest spots which facilitate individual recognition (Birks 1981).

Mink exhibit a fairly marked sexual dimorphism of body size, with the ratio of male to female weight ranging between 1.64-1.91 (Moors 1980). In a pilot study of mink in riparian habitats in Devon, Linn and Stevenson (1980) were able to measure and weigh 41 mink. The mean weight of the male mink caught was 935g (range 543g - 1582g), and of females 380g (434g to 704g). The mean head and body length of males was 389mm and of females, 348mm. Mean tail lengths were 191mm and 164mm respectively. These weights and dimensions correspond to those obtained from native North American mink by Burt and Grasenheider (1952) and with feral mink in Scotland (Hewson 1972).

Mink are closely associated with aquatic habitats (lakes, rivers and coastal areas) (Hatler 1971; Southern 1977). They are solitary animals that hold individual territories, with a greater tendency for overlap intersexually than intrasexually (Gerell 1969, 1970; Birks 1981). The size of the area occupied by individuals was expressed as "stream length" by Gerell (1970). Males occupied between 1.05km (juveniles) and 5.0km of stream, and females 1.0 - 2.8km for an "optimal" eutrophic habitat in Southern Sweden. The areas occupied by mink on the oligotrophic and apparently "sub-optimal" river Teign in Devon were approximately 20% larger than those recorded in Sweden (Chanin 1976). This would seem to suggest that the influence of habitat quality may produce variations in the spatial characteristics of territorial systems.

Mink are predominantly nocturnal, although some, notably females, showed diurnal foraging activity at certain times of the year. It was suggested that activity peaks corresponded with peaks in prey activity (Gerell 1969; Birks and Linn 1981).

The mating season occurs in the period February to April with a peak of mating activity in March (Chanin 1976). The female may remain receptive for three weeks after the onset of the photoperiodically-induced oestrus, and during this time, mating will induce ovulation. Mink also exhibit delayed implantation, the minimum period of 'gestation' being 39 days, normal range 45-52 days (Southern 1977). Mink have a promiscuous breeding system and the phenomena of superfoetation and superfecundation apparently ensure that most kits are sired by the last male to mate any female during her period of receptivity (Enders 1952). Parturition occurs in late April early May with litter sizes of between 3 and 6 kits (Gerell 1971; Chanin 1976). The kits remain with their mother until late August when they disperse. Mink are sexually mature and may breed in the spring of their first year (Gerell 1971).

Mink are catholic feeders and their diet includes mammals, birds, amphibia, fish and crustacea which may all form an important part of the diet depending upon season and locality (Gerell 1968). The wide range of prey taken by feral mink, and their tendency to exploit different prey groups in relation to their availability, are both indicators of generalist predatory tendencies, adaptability and opportunism.

The feeding ecology of mink in its native North American habitat has been incompletely studied and was largely based on the analysis of gut contents of mink trapped during the winter trapping season (Dearborn 1932; Hamilton 1936, 1940, 1959; Sealander 1943; Guilday 1949; Errington 1954; Wilson 1954; Korschgen 1958; Hatler 1971). These studies showed generally that mammals accounted for 32%-54% of the mink's diet, with muskrat Ondarta spp. L. being the single most important mammalian prey item taken. Fish was of secondary importance in all the studies except that by Wilson (1954) where fish comprised 60% of the diet. Crustacea and amphibia alternated in tertiary importance. Avian prey was of minor importance in the diet of the mink.

Paradoxically the most extensive studies on the diet of mink have been carried out on feral populations in Europe. The stimulus for this research has been to evaluate the potential effects of mink on native prey species and domestic stock, and any effects upon native carnivores. In Sweden Gerell (1967 ,1968) and Erlinge (1969) in an extensive study concluded that the diet of mink varied with habitat and season. The general conclusion from their separate studies was that fish provided the bulk of the diet, mammals were of secondary importance and anthropods (crayfish), avian and amphibious prey in that order made up the rest of the diet. Fish were of particular importance in the winter and spring diets, the authors suggesting that low water temperatures aided mink in obtaining the slower moving poikilothermic fish. The fish taken were small, usually less than 150mm in fork length. The importance of mammals and crustacea increased during the summer and autumn.

In Britain the first dietary studies were based on analyses of gut contents from mink killed during the 1960's M.A.F.F. trapping campaign in Scotland (Akande 1972), and England and Wales (Day and Linn 1972). Subsequently workers obtained larger samples by collecting and analysing faeces (scats) from various parts of Britain, so enabling them to examine variations in the diet of feral mink between different habitats and different seasons (Wise 1978; Cuthbert 1979; Chanin and Linn 1980). These studies revealed a broadly similar spectrum of prey species, principally comprised of fish, birds, and mammals in varying proportions taken according to their availability. Cuthbert (1979) collected scats from three rivers and a coastal region in Scotland and concluded that fish, mammals and birds in that order were the main constituents of the diet on a yearly basis, with the primary factor affecting mink diet being differences in prey availability, ergo regional studies are rarely comparable.

As part of a broader based study on the diet of mink Rosser (1980) collected scats from the area covered in the present study, mainly from breeding dens during weeks 14, 16 and 18 of 1980. The order of importance of the main prey groups was found to be fish 34.6%, invertebrates (crabs) 26.2%, mammals 21.5%, vegetation 11.5%, and finally avian prey 5.4% with a mean of 2.14 $\pm$ 0.07 prey items per scat and a mean scat dry weight of 0.83 $\pm$ 0.12g.

The greater occurrence of crab Corcinus maemas in the diet could be related to their greater availability during summer (Dere and Edwards 1981). The aforementioned studies show some evidence of temporal variation in the diet, but this is less marked than in similar studies from Sweden.

Generalisations about the specific composition of the diet are valueless unless the prey availability is also considered. When comparing the results from different studies, the methods of analysis and presentation of results must also be taken into account.

This study aims to investigate the diet of coastal mink in Galloway and Dumfrieshire, Scotland and attempt to provide information on prey availability and the size of prey taken, over an eight month study period. Activity patterns and den site selection were also investigated.

CHAPTER 2

STUDY AREA

The study area in Dumfries and Galloway, Scotland, is situated on the west coast of the river Dee estuary. A 4.1km long transect of the coastline was chosen, starting at Mull point (Nat.Grid.Ref. NX64 635446) on the Mull of Ross and ending at Thunder hole (Nat.Grid.Ref. NX64 658441) on the Meikle Ross peninsular (see Fig. 1 and Plate 1).

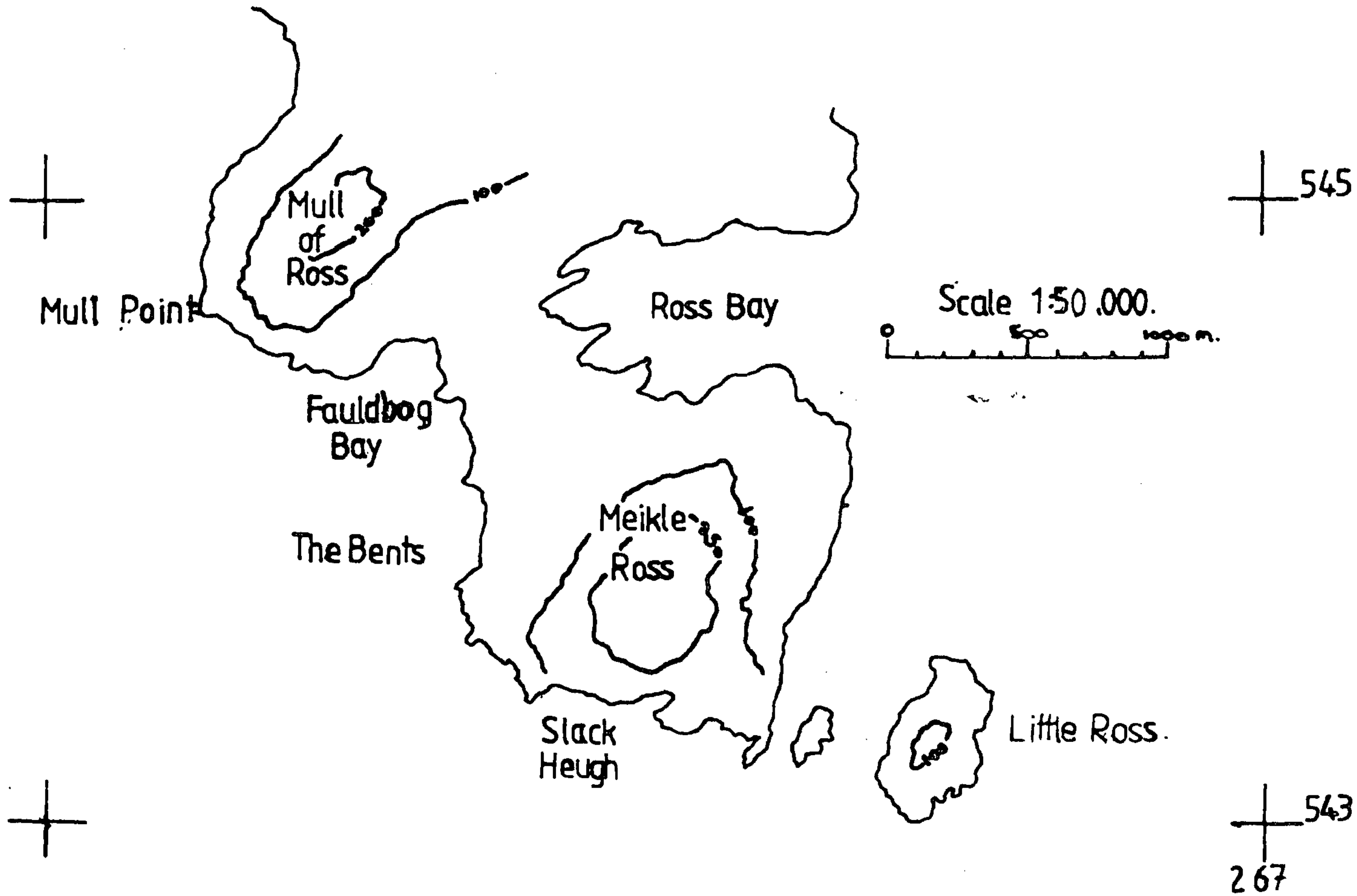
The Meikle Ross peninsula rises to 76m and is primarily rough pasture land, with some arable land used for cereal crop production. There are also three small areas amounting to 1.84 hectares of recently planted (5-10 years) norway spruce Picea abies plantation.

The agricultural land is bordered by a 10-20m wide strip of scrub vegetation, rock outcrops and grassy areas. The scrub vegetation consists mainly of mature hawthorn Crataegus monogyna and gorse Ilex spp. thickets. The eastern shore of Meikle Ross is gently sloping less than 15^{o} and the littoral zone extends for circa 70m at mean low tides, with exposed rockpools accounting for 15%-25% of this area. A large kelp bed including Laminaria digitata (Hudson) and Laminaria saccharina L. extends out towards the island of Little Ross from the low water mark. Seaweeds, Fucus serratus L. and Fucus vesiculosus L. did not form an extensive rock cover, but were present in most rock pools.

At the headland of the Meikle Ross peninsula there is restricted access to the south-west at sea level due to the sheer circa 30m high cliffs. The predominant feature of the

Plate 1. Aerial photograph of study area.

FIG 1 Map of study area



study area is the vertical orientation of the bedding planes in the grey siltstone which forms the bed-rock of the area.

The area from the Bents to Fauldbog bay is a gently shelving storm beach about 100m wide. The beach is strewn with boulders and has numerous igneous intrusions 'dykes', most of the rockpools are situated on or close to these 'dykes' and account for approximately 5% of the beach area. Seaweed cover is not as extensive as on the more sheltered south-east of the headland although F.serratus and F.vesiculosus the dominant species, are commonly found in the rockpools. The beach is bordered by a strip of badly drained rough pasture interspersed with boulders, thickets of hawthorn, and patches of yellow flag Iris pseudacorus.

The ground rises slowly from Fauldbog bay to a height of 60m at the Mull of Ross. Rough pasture land extends down to the strip of boulder strewn exposed rock strata (5-10m) above the littoral zone. Numerous rockpools comprise 10%-15% of the littoral zone area. No kelp beds are visable at extreme low tides along this sector of the coast, although as before F.serratus and F.vesiculosus were commonly found in the rockpools. The study area was terminated at the Mull Point due to the potential disturbance from the many tourists at the Brighouse Bay Caravan Park.

CHAPTER 3 METHODS

PRESENTATION OF RESULTS FOR FAECAL ANALYSIS

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. For bulk analysis 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 are effectively ignored, which may lead to a systematic underestimation of some items.

Most authors presenting data on diet consider the various methods of expressing their results, some in great detail (Englund 1965, Erlinge 1967), but most (Lockie 1959, 1961 and Akande 1972 are exceptions) come to the conclusion that despite its imperfections, frequency of occurrence is the most convenient. Erlinge (1968) has shown that for the otter Lutra lutra at least it gives fairly consistent results. This method is used in this study due to the fact that most work done on the diet of mink has been presented in this form and to use another method would have made comparison difficult. It has been criticised (Lockie 1959; Englund 1965; Erlinge 1967; Day 1968) for underestimating the importance of major constituents of scats while overestimating the importance of prey which occur frequently, but in trace amounts Englund (1965) also considered that the more important an item is, the greater the likelihood that more than one individual will be present in a scat. Therefore, an increase in importance may not be accurately reflected by frequency of occurrence.

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. 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. 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. However, she concludes that bulk estimate is superior to frequency of occurrence in its consistency and superior to the weight of undigested remains in its ease of execution.

FAECAL ANALYSIS

The study involved the collection of whole scats which are items of faecal material consisting of the undigested remains of prey (e.g. bone, fur, feather) bound together with mucus and occasionally containing vegetable matter. Scats were collected at approximately monthly intervals from January 1981 until September 1981 along a 4.1km stretch of coastline comprising the Ross peninsula, Dumfries and Galloway, Scotland, see Fig.1. The collection date, estimated age, location and site of deposition of individual scats were recorded. Table 1 shows the number of scats collected for each month of the study and Fig.2 shows the number of scats collected in the various sectors of the study area. The presence of otter faeces (spraints) within the collection area necessitated that these were distinguished from mink scats usually by their markedly different smell and size. Scats which could not be positively identified were rejected.

Treatment of Scats:

In the laboratory the wet weight of the scats was recorded to the nearest 0.01g prior to drying at 50°C for 24 hours. The scats were then re-weighed and their dry weights recorded. Several authors have advocated crumbling the dry scat prior to analysis (Erlinge 1968, Gerell 1968, Chanin 1976, Wise 1978). However, in order to avoid the possibility of damage to fish vertebrae, the dried scats were soaked in a detergent solution (1% TEEPOL) overnight to remove any binding mucus, washed, sieved (mesh size 0·42mm.),

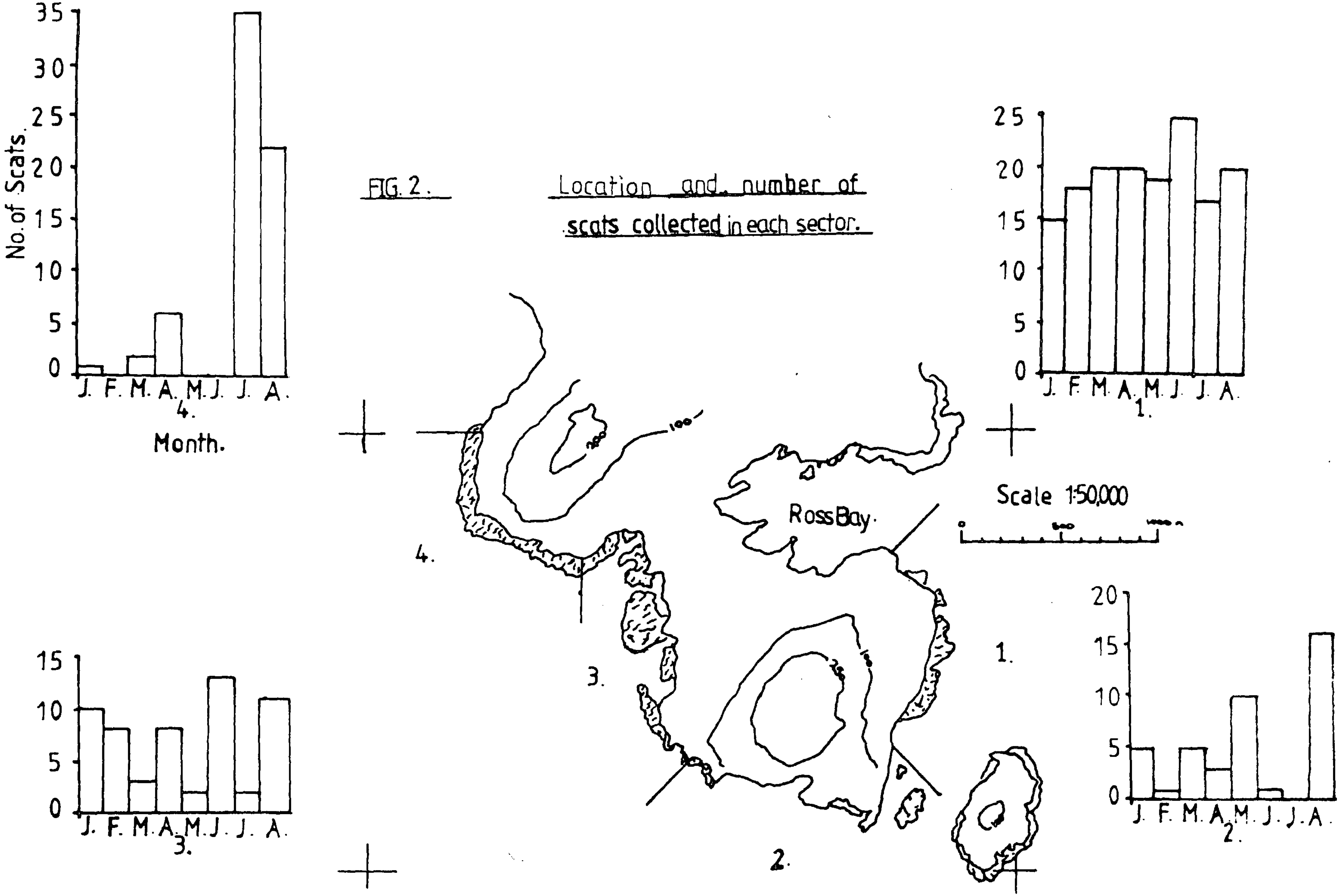


FIG. 2. Location and number of scats collected in each sector.

plated to display content and redried at 50°C.

Table 1 The number of scats collected and the time of collection

Period of collection			Number of scats collected
Week	2	Month Jan	30
	7	Feb	27
	12	March	31
	16	April	36
	20	May	30
	24	June	39
	29	July	61
	33	August	77
Total			331

Identification of Prey Remains:

The undigested prey remains present in each scat were inspected under a binocular dissecting microscope, identified, and the percentage volume of each prey item recorded to the nearest 10%.

Where possible mammalian remains were identified by teeth characteristics (Morris 1966), but in most cases hair characteristics were used as described by Day (1966) and King (1971). A reference collection of teeth and hair proved invaluable for identification purposes.

Avian prey was identified with the aid of the key to feathers, Day (1966). This key was, however, designed for the identification of feather remains in the gut and faeces of stoats Mustela erminea L. and weasels Mustela nivalis L. and did not include the coastal species of birds encountered in this study area. A supplementary reference collection of feathers was therefore also used. Problems were encountered in the identification of some avian prey items in scats because of the lack of the characteristic barbules of covert feathers (presumably from juvenile birds). One instance of egg shell was encountered and this was sufficiently pigmented to be identified as a gull egg (Grieg and Holloway pers.comm.).

Fish prey were identified by vertebral characteristics using a key compiled by Watson (1978). A reference collection of vertebrae from littoral fish species was also used for identification purposes.

Estimation of Fish Prey Size:

Fish are a major item in the diet of mink and the remains in scats often comprise scales, operculae and vertebrae. These structures are widely used for age and growth determinations of fish. Previous studies on the diet of mink (Erlinge 1969, 1972; Akande 1972) estimated prey size by simply comparing fish remains with similar parts from fish of known size, but this method lacks precision and only permits the grouping of fish into a small number of broad size categories. Wise (1980) developed a method which allows a more accurate determination of fish prey size using the basic premise that there is a positive correlation between vertebral length and fish fork length and that this can be expressed by a simple regression. Vertebrae are preferred as they suffer less damage in passage through the intestine, are identifiable to a particular region of the fish and are often identifiable to species or genus of fish. The method requires the preliminary estimation of the regression relationship between centrum length of vertebrae and fork length (the distance between the furthest anterior point of the fish and the fork in its tail) from a number of reference fish of different species, in this instance Common blenny Blenius pholis L., Butterfish Pholis gunnellus L. and the five-bearded rockling Ciliata mustela L.

The littoral fish species were collected, measured to the nearest millimetre, and the wet weight recorded to the nearest 0.01g. The fish were then boiled in water to facilitate dissection of the flesh. Bones were cleaned of any remaining flesh by soaking in a 2% NaOH solution for 15 minutes. The cleaned and dried caudal vertebrae were measured to the nearest 0.1mm using a dial vernier caliper. Caudal vertebrae were selected as they provided the most significant correlations Wise (1980) as well as for their ease of identification in the scats. Fig. 3 shows a typical fish caudal vertebra.

Least squares regression is used, since with this type of regression the predictive equation is fitted to the data so as to minimize the sum of squares of the vertical distances from the data points to the line of regression. The correlation between the two variables is measured by Pearsons product-moment correlation coefficient (R). Although the calculated regression is linear, the variance increases as fish length increases and so 95% confidence limits cannot validly be calculated, Campbell (1974). In order to obtain a measure of the variation for any y estimate (fork length of fish) regressions were calculated using the largest and smallest vertebrae from each fish, thus producing maximum and minimum estimates respectively. All regressions were calculated by a programmable calculator and could be described by the general formula

$$y = mx + c$$

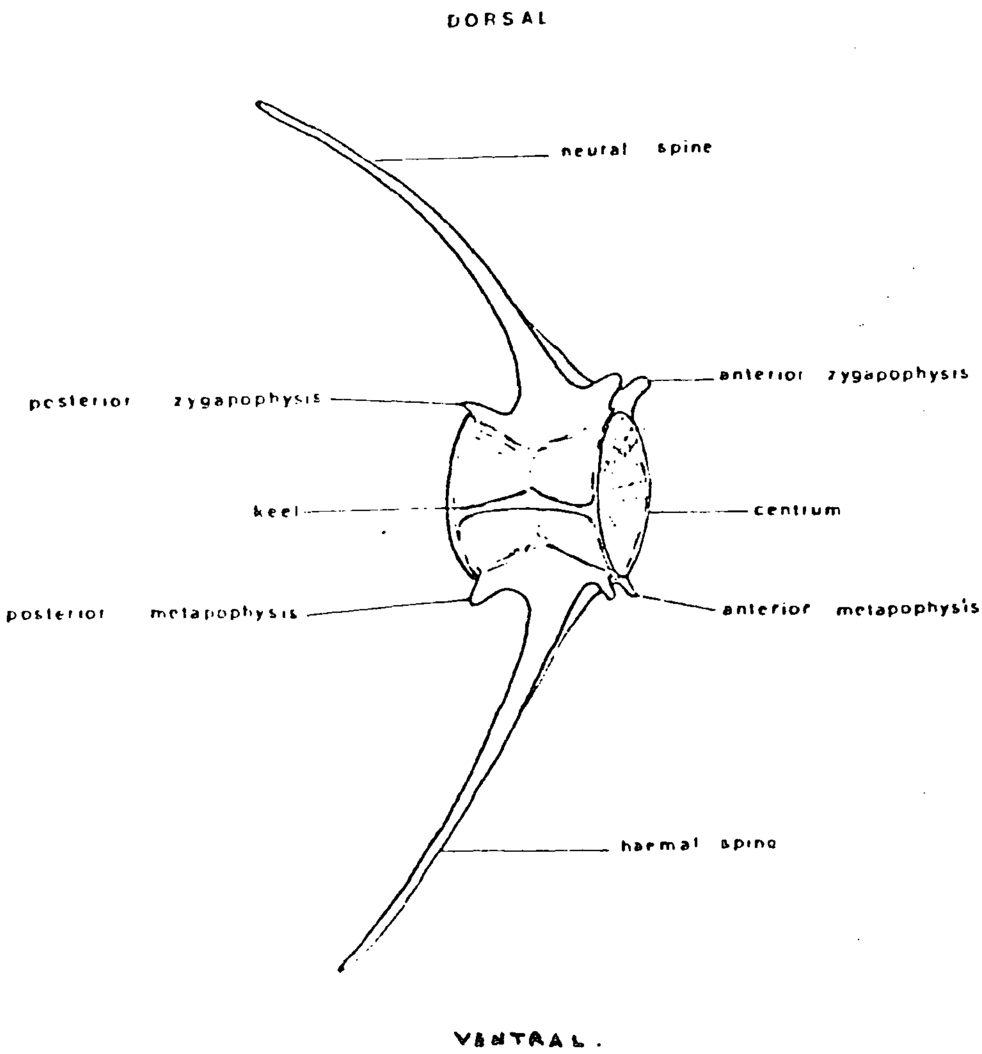
where y = fork length of fish

x = vertebral length

and m and c are the slope and intercept respectively. The correlation coefficient (R) was also calculated in each case.

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 fork 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.

FIG.3. The Caudal Vertebra of a Fish.



RADIO-TELEMETRY

In order to obtain information on the activity patterns and den use by individual coastal mink it was decided to trap and 'radio-tag' individual mink. Two adult males were trapped on one night during May using standard swing-door box traps baited with dead laboratory rats. The traps were concealed carefully close to known dens or in 'runs'. A juvenile male and its mother were trapped in a subsequent trapping session in July. The trapped mink were all anaesthetised with an intramuscular injection of "Vetalar" (ketamine hydrochloride). The mink were then ear-tagged, weighed and sketched/photographed for subsequent identification. Both adult males and the adult female were fitted with A.V.M. radio collars containing a SM 1 transmitter (173 MHz) see Plate 2. The radio collars were attached by first clipping the gaurd hairs and under fur around the animals' necksto approximately 5mm, and then smearing the inside of the collar with a thin layer of adhesive ("Araldite") to prevent it from slipping. The mink were kept under observation for several hours after transmitter attachment and released at the point of capture. All radiotracking was carried out on foot using a hand-held Yagi aerial and a portable AVM LA12 receiver.

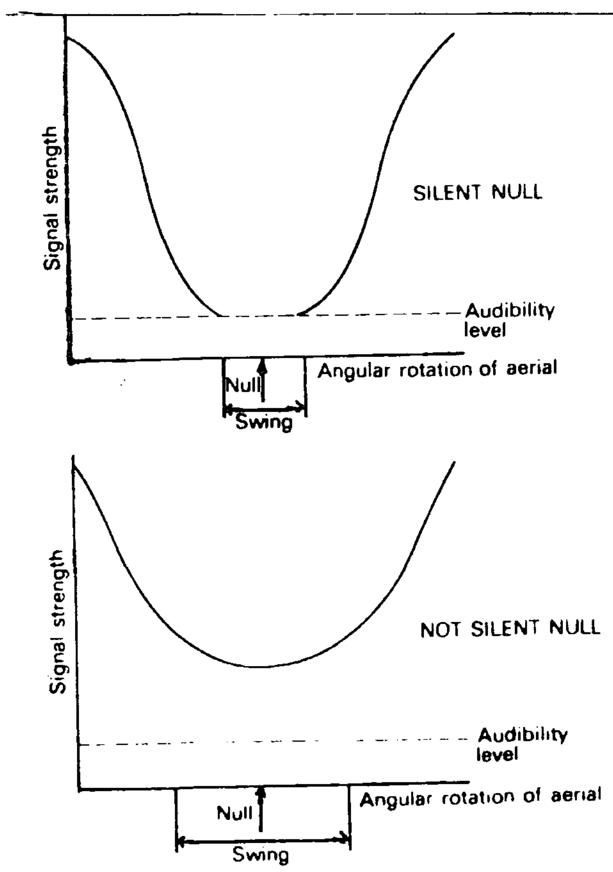
Upon the initial reception of a signal from the transmitter a rough bearing of the animal's position was taken, and approached until a strong signal was encountered. A major course of difficulty in radio-telemetry is the wide variation from place to place in the accuracy of bearings taken with a directional aerial. Bearing errors are caused

PLATE 2

An adult female mink with A.W.M. radio collar attached.

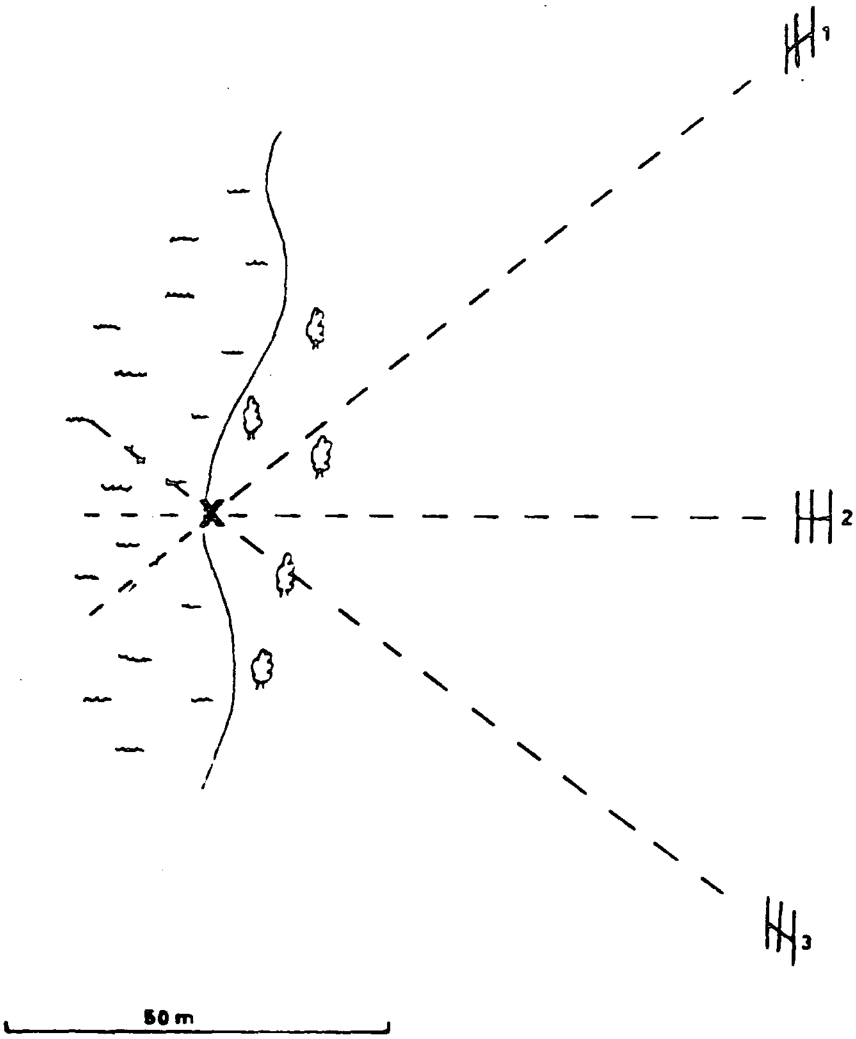
by the reflection, absorption or distortion of radio waves by physical features of the environment, such as large trees, wire fences, power lines and large areas of exposed rock. Another source of difficulty in obtaining an accurate bearing is variation in signal strength caused by movement of the transmitter. When the animal carrying the transmitter moves, changes may occur in both the orientation of the transmitter aerial and its proximity to the ground or other objects, all of which can effect the amplitude of the received signal. Since determining the bearing of a transmitter depends on detecting minute changes in amplitude as the receiver aerial is rotated, any other amplitude changes interfere with this process and prevent or prolong accurate determination of the bearing. However, the above possible sources of bearing error were reduced by taking bearings at close ranges 50m using the null point determination method described by Taylor and Lloyd (1978). The null point being defined as the point of weakest signal as the aerial is rotated. The null may be perceived as the absence of a signal (Silent Nill S) or as weak signals (Not Silent NS) see Fig. **4**. Where the null is silent, the aerial may need to be turned through several degrees before the signal is heard again on each side of the null. This angle is termed the swing of the null. The swing of a silent null is found by turning the aerial slowly from a position where no signal is heard to a point where the signal becomes just audible, and then turning it the other way until the signal is again just audible. The swing between the two points of audibility is then bisected to find the bearing. Finding the null point was repeated several times until consistent readings were obtained. The swing of the NS null is bounded by points where a level or 'flat' signal begins to get louder, but is otherwise determined in the same way as that of the S null.

Fig.4 Typical relationships between signal strength and angular rotation of the aerial



Once the animal's position had been located by a set of three bearings, see Fig.5. , it was approached to within 20m and followed by sight once activity had started if it was to be continuously tracked. Otherwise the positions of 'radio-tagged' mink were ascertained by twice daily 'fixes' of position using the above techniques. The animals appeared not to be disturbed by being followed cautiously at a distance of 20m and Dunstone (pers. comm.) reports following mink at less than 5m distance in riparian habitats without apparent disturbance of the animal.

Fig. 5. The taking of a 'fix' on mink at position X.



PREY ABUNDANCE

Rockpool Survey:

In order to obtain an estimate of prey abundance in the numerous rockpools of the littoral zone, 30 mid-littoral zone rockpools of varying size were selected for survey, 15 of the rockpools were located on the sheltered shore of the Meikle Ross peninsula and 15 on the more exposed Mull of Ross headland. For the distribution of rockpools surveyed see Fig. **6** . The rockpools were physically emptied of water using a graduated vessel and for each the following rockpool parameteres recorded:- (a) volume of contents, (b) maximum depth, (c) surface area and (d) the presence and size of species known to be prey items of the mink (Rosser, 1980).

Small Mammal Survey:

Two areas of differing habitat type were assessed using Longworth small mammal traps. One area was a recently planted (5 years) norway spruce plantation and the other area consisted of rough pasture with mature hawthorn thickets.

For the location of the trap sites see Fig. **7** . 56 Longworth traps prebaited with wheat and provided with nest material were placed in a 7 x 8 grid, with each trap spaced 5m apart to cover an area of $1052m^{-2}$. The traps were set open for the first three nights and the bait replaced as necessary. On the following four nights the traps were set to catch, and checked at twice daily intervals. No animals were trapped in the forestry plantation, however three Microtus agrestris L. were trapped in the area of rough pasture. In order to obtain a measure of population size a mark and recapture experiment was attempted. The trapped *Microtus* were marked by fur clipping on the rump and released, however, no further successful trappings were made.

No quantitative estimate of lagomorph abundance was attempted, but both rabbits *Oryctolagus cuniculus L.* and brown hare *Lepus capensis L.* were frequently encountered by the author at all times. A record of the number of lagomorph sightings during each scat collection was kept (mean 17 sightings, (range 5-26)/4.1km transect walked).

The different bird species observed on the study area were recorded and used to supplement the species list compiled by Rosser (1980) see Fig. **8**.

Den-Site Selection:

A den was defined here to be any refuge used by an animal regularly or occasionally for resting between bouts of foraging or travelling (Birks 1981 in press), and was usually recognised by the presence of scats at the entrance and/or actual sightings of mink using the den. The position of known dens used by mink was recorded on large scale maps (1 : 25000) and inter-den distances computed from these. The location of the den in relation to high water mark and closest rockpool were also measured.

FIG. 6. Map of study area showing the location of rockpools sampled

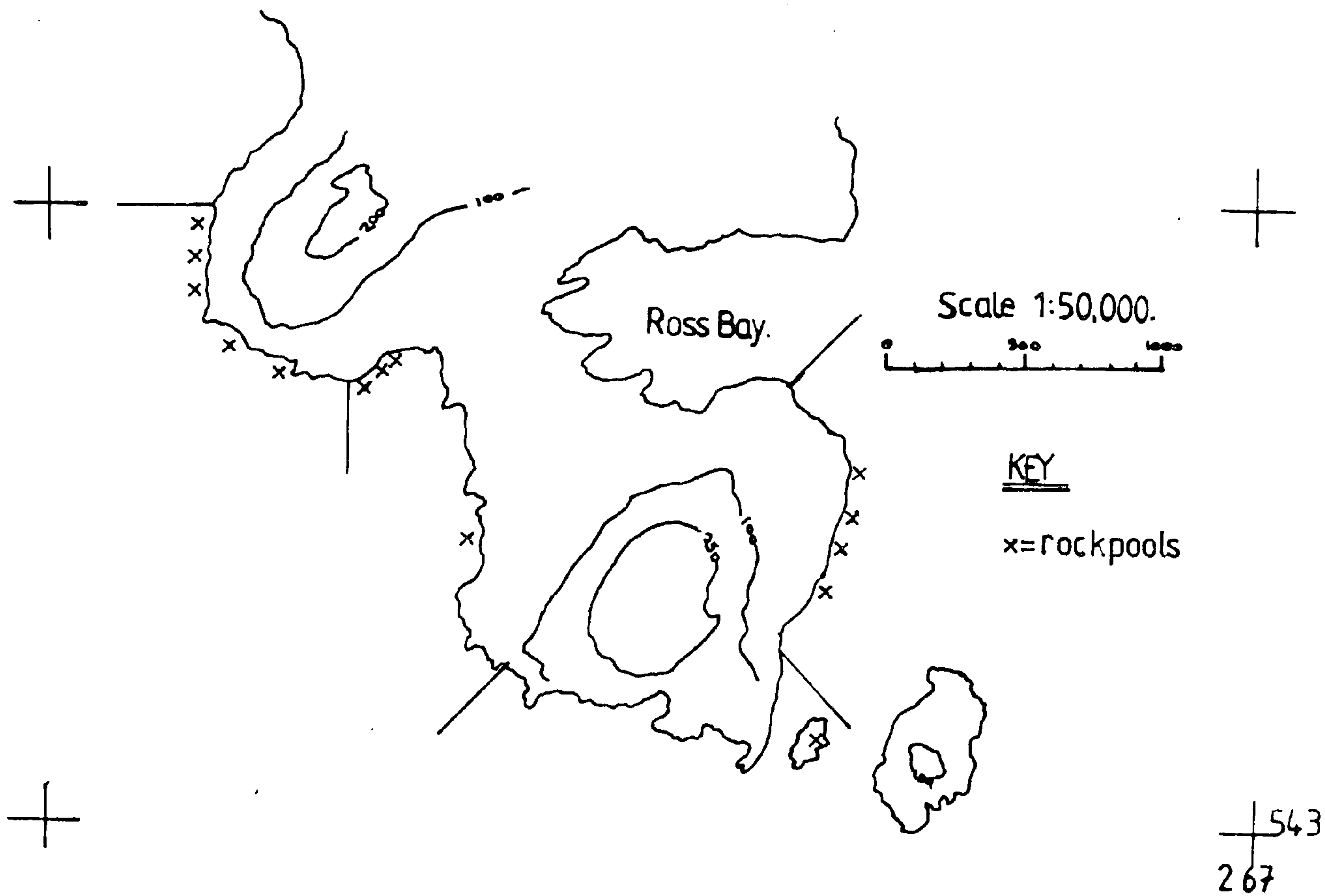


FIG. 7. Map of study area showing the small mammal trapping sites and location of rabbit warrens.

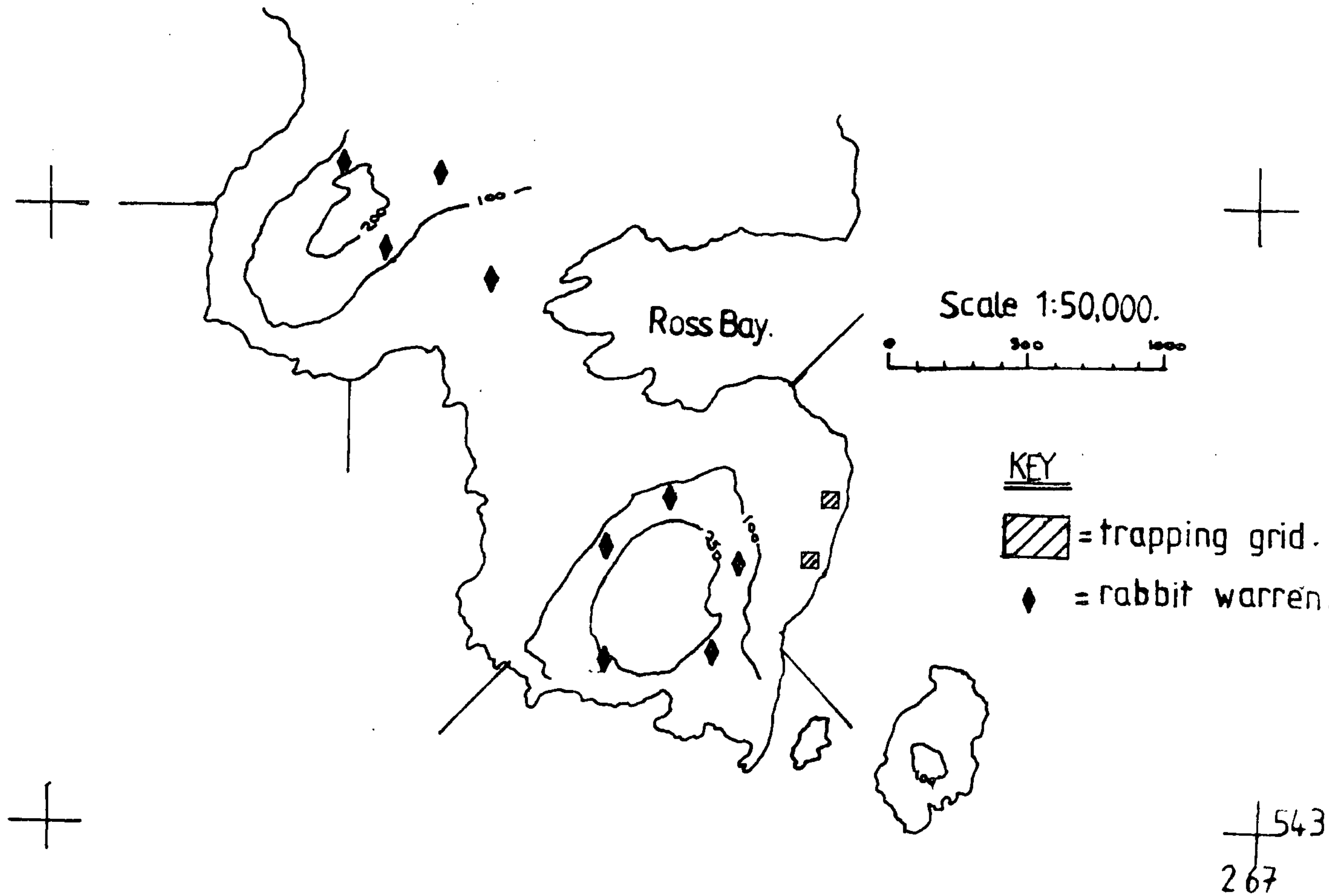


Figure 8. Bird species list

Cormorant	Phalacrocorax carbo.
Shag	Phalacrocorax aristotelis
Kittiwake	Rissa tridactyla
Herring Gull	Larus argentatus
Greater Black-backed Gull	Larus marinus
Oystercatcher	Haematopus ostralegus
Curlew	Numenius arquata
Sandpiper	Tringa hypoleucos
Knot	Calidris canutus
Redshank	Tringa totamus
Rock Dove	Columba livia
Rock Pipit	Anthus spinoletta
Pheasant	Phasanius colchicus
Partridge	Perdix perdix
Pigeon	Columba palumbus
Rook	Corvus frugilegus
Crow	Corvus corone
Raven	Corvus corax
Lapwing	Vanellus vanellus
Woodland bird species	

CHAPTER 4 RESULTS

FAECAL ANALYSIS

A total of 331 scats were collected during the study period from week 2 January 1981 until week 33 August 1981. The total number of prey occurrences was 453 with a mean of 1.38 ± 0.11 prey items per scat; the mean dry weight of the scats was 0.48 ± 0.06g (Table **2**). There was no significant temporal variation in the mean number of prey items per scat (X^2 = 1.32 , 7 d.f N.S.) see table **3.**

The frequency of occurrence of the main prey groups was as follows: mammals 49.1%, fish 26.0%, avian prey 15.7% and finally crab 9.8%, whilst the corresponding figures for the bulk analysis were mammals 48.8%, fish 33.9%, avian prey 13.3% and crab 3.8%, see table **4** and figs.**9,10,11** and **12** . The two methods of faecal analysis were compared by means of the Wilcoxon matched pairs signed rank test which revealed no significant difference between the two methods (T = 17, N.S. $P < 0.05$).

Any amphipods encountered in the same scat as fish were ignored as they are commonly found in the gut contents of fish, especially blennies and were presumably incidentally ingested by the mink, since amphipods were not encountered in any scats not containing fish prey. Avian prey formed the third most frequent prey group in the scats analysed, 15.7% by frequency of occurrence and 13.3% by bulk analysis. As previously mentioned, difficulty was encountered in the identification of feathers lacking the characteristic barbules and it was assumed that these feathers were from juvenile birds. It can be seen from table **5** that during the peak hatching period for

TABLE **2** Results of scat collection

Collection date Week	Month	Prey per scat ± S.E.	Mean scat dry wt. ± S.E. (g)	Number of scats N = 331
2	Jan	1.47 ± 0.11	0.5 ± 0.1	30
7	Feb	1.33 ± 0.14	0.42 ± 0.09	27
12	March	1.13 ± 0.06	0.28 ± 0.04	31
16	April	1.42 ± 0.13	0.2 ± 0.03	36
20	May	1.43 ± 0.15	0.65 ± 0.06	30
24	June	1.36 ± 0.08	0.7 ± 0.08	39
29	July	1.52 ± 0.1	0.55 ± 0.04	61
33	August	1.36 ± 0.07	0.54 ± 0.04	77
Mean		1.38 ± 0.11	0.48 ± 0.06	41.4 ± 6.35

TABLE **3** X^2 test for temporal variation in the polyspecifity of the scats collected

Collection week no.	2	7	12	16	20	24	29	33
Date Month	Jan	Feb	Mar	Apr	May	June	July	Aug
No.of prey	44	35	35	51	44	53	92	99
No.of scats	30	27	31	36	30	39	61	77
Chi square = 1.32. Not significant. 7 d.f.								

Laridae on the Solway (pers.comm. Grieg) unidentified feathers accounted for 30.4% by frequency of occurrence in the scats for June. Overall unidentified feathers represented 7.1% of the diet. Of the identifiable avian prey Laridae (e.g. herring gull Larus argentatus) were the most frequent group, 5.3%; Galliformes, presumably pheasant, Phasanius colchicus were the next most frequent group, 2.6% with Columbiformes (e.g. pigeon Columba palumbus) accounting for the remaining 0.9%. The frequency of occurrence of crab in the scats was 9.6% and represented 3.8% by bulk analysis.

As vegetation is of no nutritional value to mink it was excluded from the dietary analysis. However it should be noted that ingested grass formed 10.2% of the diet by frequency of occurrence and 4.5% by bulk analysis.

Of the 331 scats 48% were collected from den sites, 13% from a breeding den and 39% from open areas or on known 'runs' see fig.**13** The scats collected from the breeding den came from a radio-tagged female resident in sector 1 of the study area. The frequency of the main prey items in the scats from this female (and kits) were as follows: mammalian prey 57.7%, fish 15.5%, avian prey 16.5% and crab 10.3%.
The composition of the diet of the breeding female did not differ significantly from the overall diet ($X^2 = 2.96$ N.S.) see figs. **14** and **15**

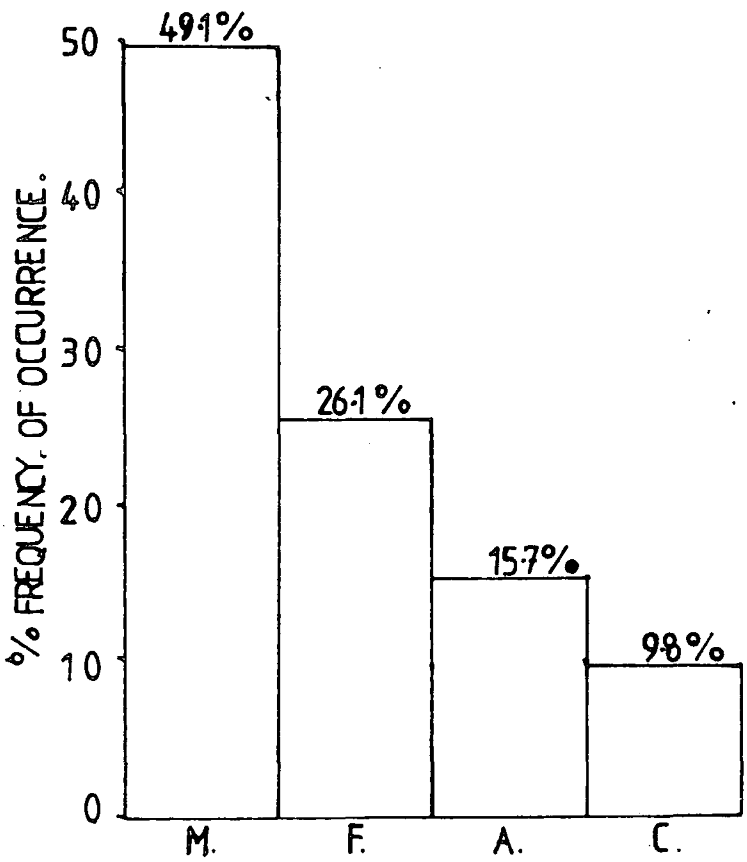
TABLE 4 Percentage frequency of occurrence analysis

Collection Date Week	Month	Mammal Prey	Fish Prey	Crab Prey	Avian Prey
2	Jan	41.4	35.7	11.9	11.9
7	Feb	35.5	58.1	3.2	6.5
12	March	70.6	17.7	2.9	8.8
16	April	69.8	18.6	4.7	7.0
20	May	25.6	30.8	15.4	28.2
24	June	21.7	17.4	17.4	43.5
29	July	69.2	15.4	7.7	7.7
33	August	58.7	14.1	15.2	12.0
Overall Mean %		49.1	26.0	9.8	15.7

Percentage bulk analysis

Collection Date Week	Month	Mammal Prey	Fish Prey	Crab Prey	Avian Prey
2	Jan	49.3	41.1	1.2	8.4
7	Feb	16.2	82.5	0.6	0.6
12	March	68.9	31.9	2.6	3.6
16	April	60.1	33.7	1.3	5.0
20	May	29.0	40.3	4.1	26.6
24	June	26.9	17.5	12.6	43.0
29	July	76.9	12.6	1.1	9.4
33	August	70.1	11.6	6.9	9.5
Overall Mean %		48.8	33.9	3.8	13.3

FIG. 9. Overall diet - Percentage frequency of occurence



T=17 N.S. P >0·05

FIG. 10. Overall diet - Percentage bulk analysis

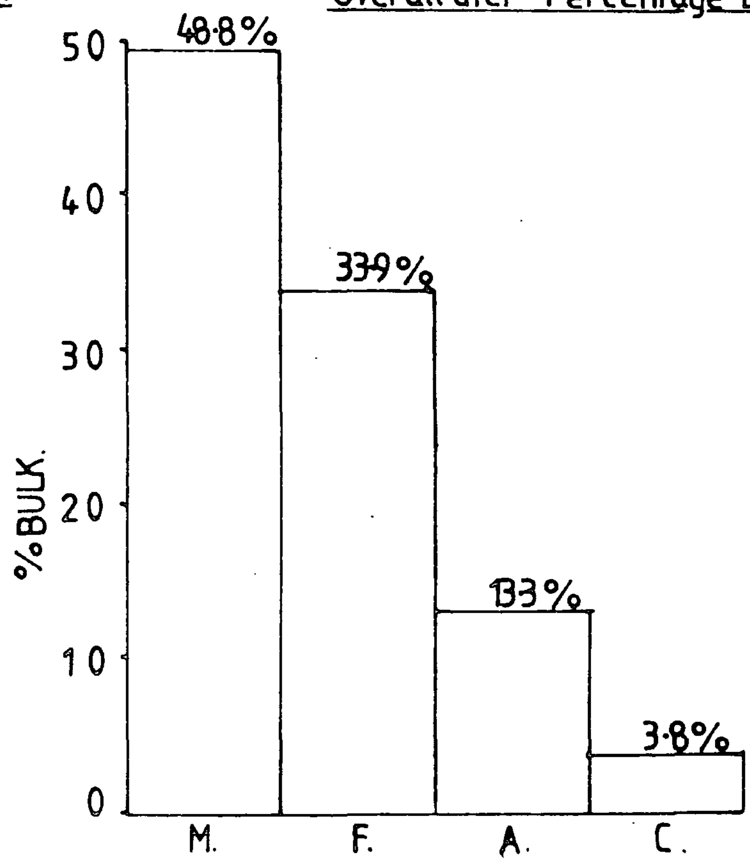


Fig 11. Percentage frequency of occurence of prey items

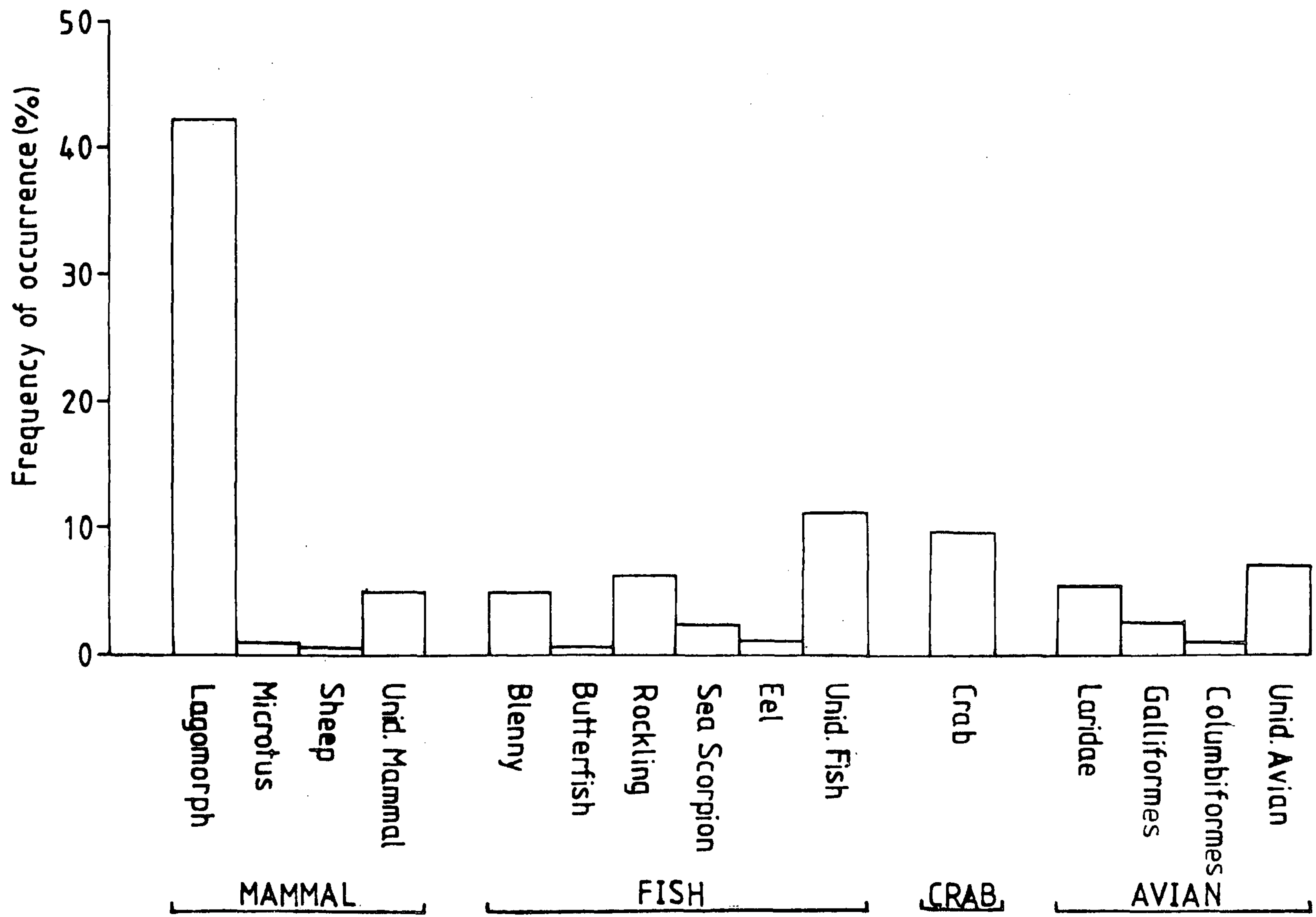


TABLE **5** Percentage frequency of occurrence of prey species in the diet.

Collection Date Week	Month	Lagomorph	Microtus	Sheep	Unidentified mammal	Common blenny	Butterfish	Five-bearded rockling	Sea scorpion	Eel	Unidentified fish	Crab	Laridae	Galliforme	Columbiforme	Unidentified feather
2	Jan	33.3	0	2.4	4.8	4.8	0	19.1	0	0	11.9	11.9	0	0	2.4	9.5
7	Feb	19.4	3.2	0	9.7	16.1	3.2	12.9	12.9	3.2	9.7	3.2	0	3.2	0	3.2
12	March	64.7	0	0	5.9	0	0	8.8	0	0	8.8	2.9	0	2.9	0	5.9
16	April	65.1	0	0	2.3	4.7	0	0	0	0	13.9	4.7	0	2.3	2.3	2.3
20	May	24.3	0	0	0	2.7	0	8.1	5.4	5.4	10.8	13.5	16.2	8.1	2.7	2.7
24	June	13.0	2.2	0	6.5	2.2	0	0	0	0	15.2	17.4	10.9	2.2	0	30.4
29	July	61.5	1.3	0	6.4	3.9	0	1.3	0	0	10.3	7.7	6.4	0	0	1.3
33	August	55.4	0	0	3.3	3.3	0	1.1	0	0	9.8	15.2	8.7	2.2	0	1.1
Mean Overall %		42.1	0.8	0.3	4.9	4.7	0.4	6.4	2.3	1.1	11.3	9.6	5.3	2.6	0.9	7.1

Fig 12 A comparison of the results for the two methods of faecal analysis.

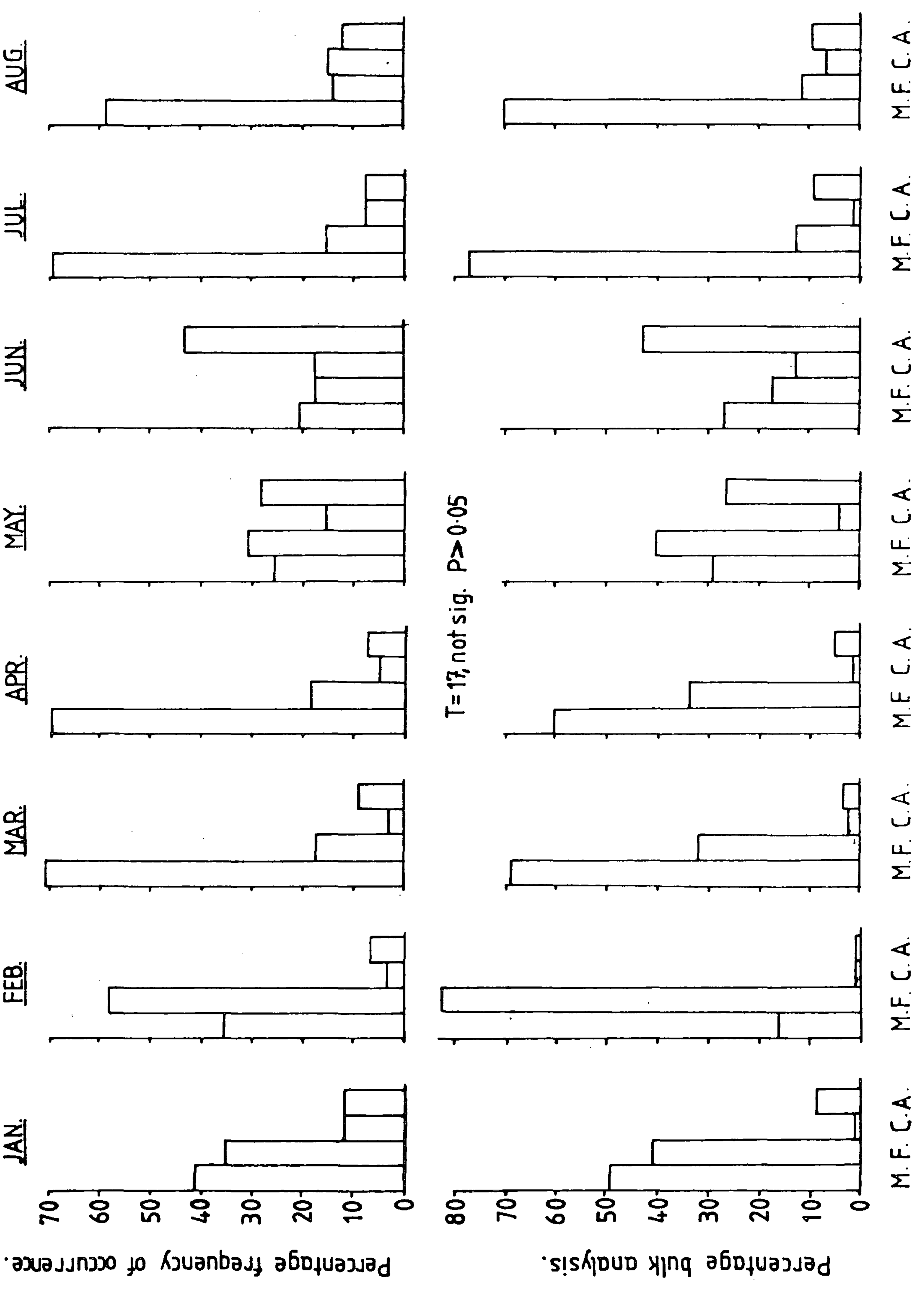


FIG.13 Sites of scat deposition

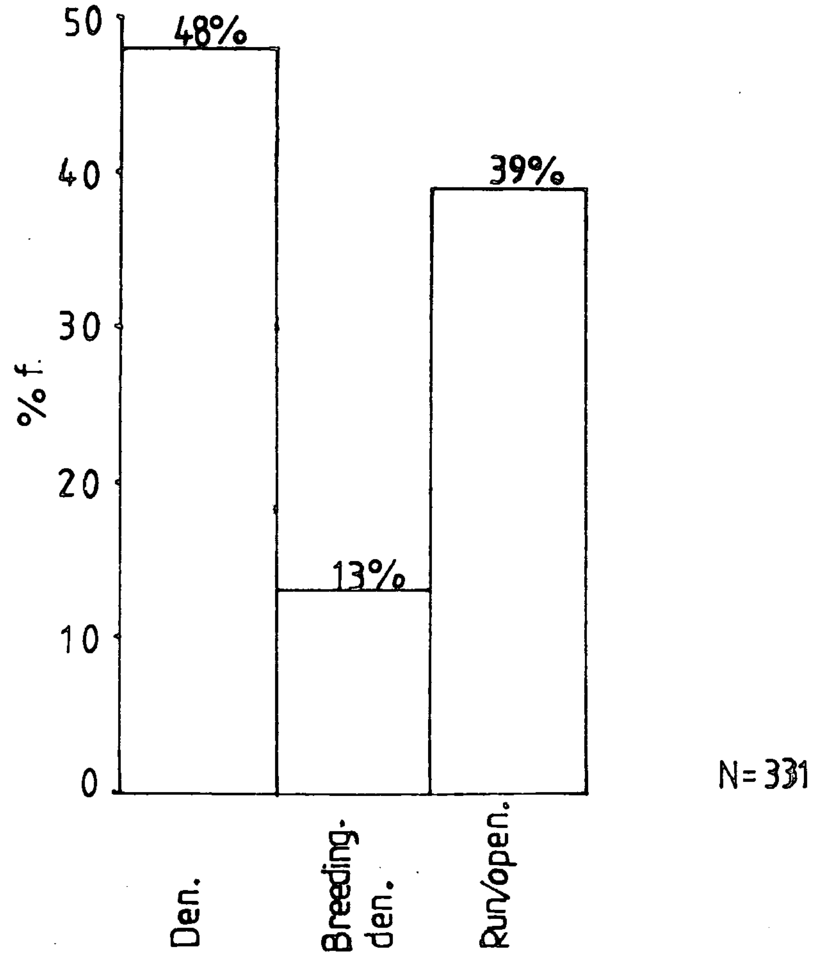


FIG.15 Overall diet

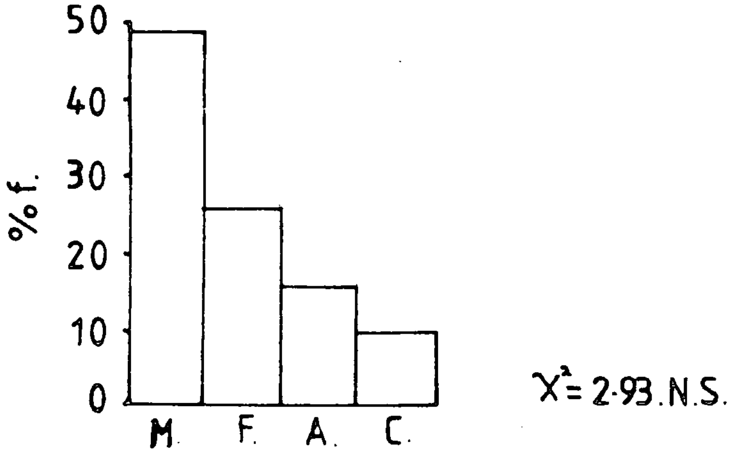
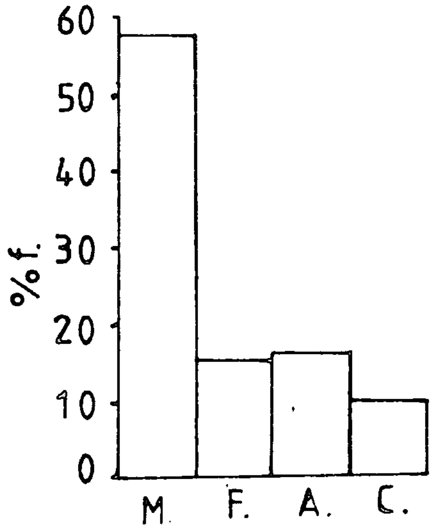


FIG.14 Diet of breeding female



TEMPORAL AND SPATIAL VARIATION IN THE DIET

The composition of the diet for each month during which scats were collected is shown in tables **4,5,**and and figure **9,10,12,**The results have been expressed by both the percentage frequency of occurrence method as well as the percentage bulk method.

Chi-square tests on the data reveals a significant temporal variation in the overall frequency of occurrence of the main prey groups. When present this temporal variation can largely be accounted for by changes in the relative importance of mammalian, fish and avian prey rather than crabs in the diet (see tables **6,7,8,9,10,** and fig.**16**.

Table **11** shows the results of chi-square tests for temporal variation in the overall frequency of all prey groups in the monthly scat collections. The scats collected in January (week 2) and February (week 7) did not differ significantly in their composition (X^2 = 5.35 N.S.) In January mammals were the most frequent prey group followed by fish and avian/crab prey in that order. However, in February fish was the most frequent group followed by mammalian, avian and crab prey, the latter two prey items forming less than 10% of the frequency of prey items in the scats collected. The composition of the scats collected during March (week 12) differed significantly from the previous month (X^2 = 11.71 P<0.01) with lagomorphs increasing in their frequency of occurrence to 70.6%, and a significant decrease (X^2 = 4.18 P<0.05) in the frequency of fish prey from 58.1% to 17.7%. The scats collected in April (week 16) do not differ significantly (X^2 = 3.8 N.S.) in their frequency of prey items when compared to the previous months. Although mammalian prey is still the major prey item, its percentage frequency is reduced to 69.8%. Fish is secondary with 18.6% and avian prey and crab together account for less than 12% of the frequency of prey items in the scats. Scats collected in May (week 20) differ in their relative composition of the main prey groups when compared to those collected in April (X^2 = 13.94 P<0.01). This is partially due to the marked increase in the frequency of avian prey from 7.0% in April to 28.2% in May, of the bird species taken Larus spp. accounted for 16.2% of the total diet. The frequency of mammalian prey decreased to 25.6% and fish prey became the prime prey item with 30.8%.

There was not any significant different between the composition of scats collected in May and June (week 24). The frequency of avian prey in the scats continues to increase and forms the major prey item 43.5% - the lack of characteristic feather barbules hindered identification of the avian prey taken by the mink, with unidentified feathers accounting for 30.4% of all prey items taken in June, mammalian prey, fish/ crab in that order make up the remainder of the diet in roughly equal proportion.

By July (week 29) avian prey has become a minor item with 7.7% and mammalian prey has again become the main prey group with 69.2% of the frequency of prey items in the diet. The composition of the main prey items in the scats collected in July differed significantly from the previous month of

TABLE **6** Results of X^2 test for temporal variation in the frequency of mammalian, fish and avian prey in the scats

Collection Date	2	7	12	16	20	24	29	33
Week no. & month	Jan	Feb	Mar	Apr	May	June	July	Aug
Mammals	17	11	24	30	10	10	54	54
Fish	15	18	6	8	12	8	12	13
Avian	5	1	3	3	11	20	6	11

Collection Date Week	Month	7 Feb	12 Mar	16 Apr	20 May	24 June	29 July	33 Aug
2	Jan	N.S. 3.53						
7	Feb		** 11.71					
12	Mar			N.S. 0.089				
16	April				*** 14.68			
20	May					N.S. 3.08		
24	June						*** 31.05	
29	July							N.S. 1.27

TABLE **7** X^2 test for temporal variation in the frequency of mammalian prey

Collection Date Week Month	7 Feb	12 Mar	16 Apr	20 May	24 June	29 July	33 Aug
2 Jan	N.S. 0.36						
7 Feb		N.S. 1.88					
12 March			N.S. 0.04				
16 April				N.S. 3.07			
20 May					N.S. 0.19		
24 June						** 8.97	
29 July							N.S. 0.82

TABLE **8** X^2 test for temporal variation in the frequency of fish prey

Collection Date Week Month	7 Feb	12 Mar	16 Apr	20 May	24 June	29 July	33 Aug
2 Jan	N.S. 0.32						
7 Feb		* 4.18					
12 March			N.S. 0.04				
16 April				N.S. 1.84			
20 May					N.S. 1.25		
24 June						N.S. 0.01	
29 July							N.S. 0.08

TABLE 9 X^2 test for temporal variation in the frequency of avian prey

Collection Date Week	Month	7 Feb	12 Mar	16 Apr	20 May	24 June	29 July	33 Aug
2	Jan	N.S. 1.07						
7	Feb		N.S. 0.4					
12	March			N.S. 0.02				
16	April				N.S. 2.82			
20	May					N.S. 0.45		
24	June						** 9.59	
29	July							N.S. 0.3

TABLE 10 X^2 test for temporal variation in the frequency of crustacean prey (crab)

Collection Date Week	Month.	7 Feb	12 Mar	16 Apr	20 May	24 June	29 July	33 Aug
2	Jan	N.S. 1.07						
7	Feb		N.S. 0.01					
12	March			N.S. 2.4				
16	April				N.S. 0.02			
20	May					N.S. 0.01		
24	June						N.S. 1.18	
29	July							N.S. 0.9

Fig. 16 TEMPORAL VARIATION IN THE FREQUENCY OF THE MAIN PREY GROUPS.

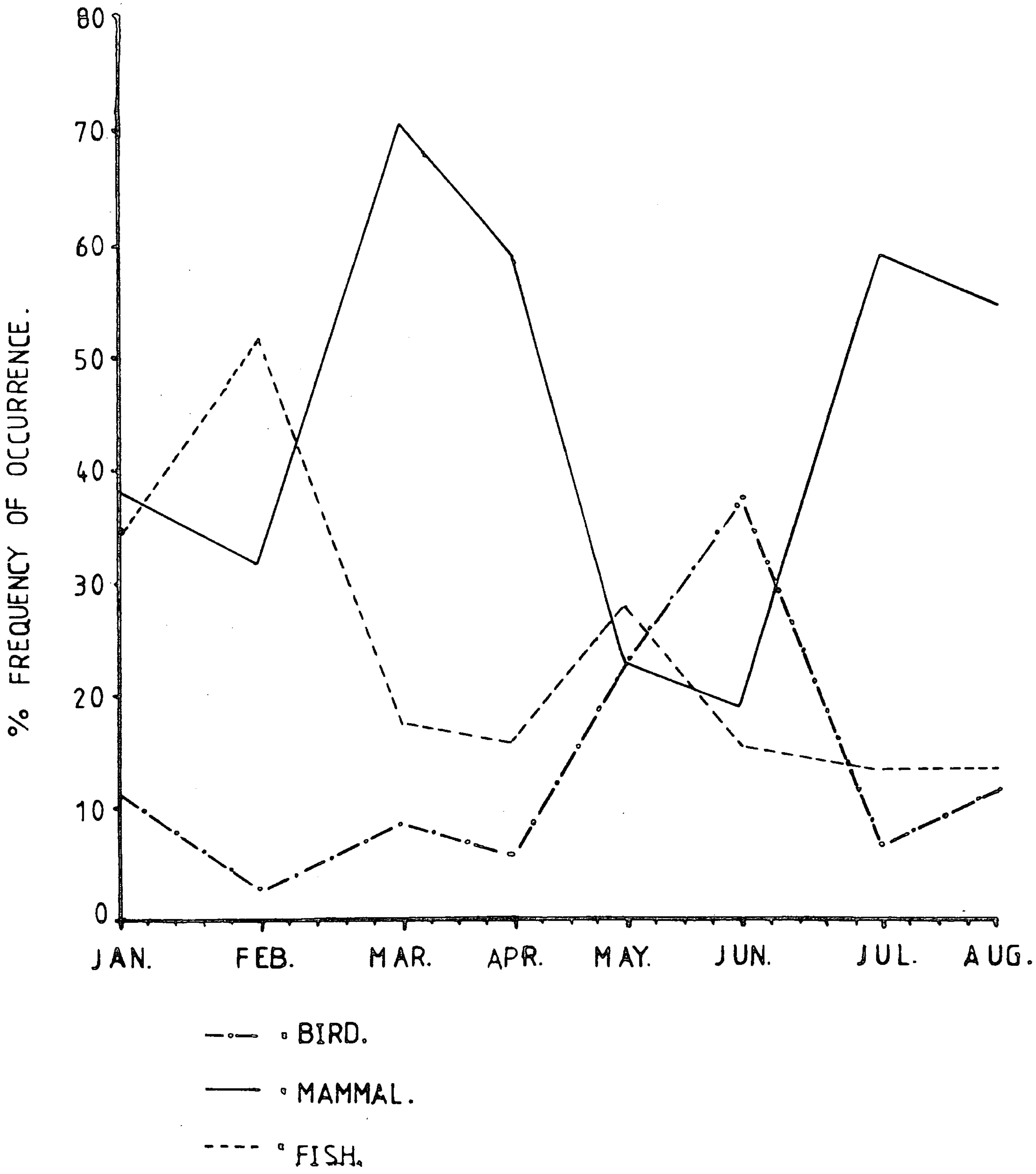


TABLE 11. Results of X^2 test for temporal variation in the diet of coastal mink

Collection Date	2	7	12	16	20	24	29	33	Frequency
Week no. & month	Jan	Feb	Mar	Apr	May	June	July	Aug	Total
Mammals	17	11	24	30	10	10	54	54	210
Fish	15	18	6	8	12	8	12	13	92
Birds	5	1	3	3	11	20	6	11	60
Crabs	5	1	1	8	6	8	6	14	49
No. of scats	30	27	31	36	30	39	61	77	

Collection Date Week	Month	7 Feb	12 Mar	16 Apr	20 May	24 June	29 July	33 Aug
2	Jan	N.S. 5.35						
7	Feb		** 11.71					
12	March			N.S. 3.8				
16	April				** 13.94			
20	May					N.S. 3.13		
24	June						*** 32.8	
29	July							N.S. 3.59

N.S. = Not Significant.

* = P = 0.05

** = P = 0.01

*** = P = 0.001

TABLE **12** Percentage frequency of occurrence analysis

Collection Date Week Month	Mammal Prey	Fish Prey	Crab Prey	Avian Prey
2 Jan	41.4	35.7	11.9	11.9
7 Feb	35.5	58.1	3.2	6.5
12 March	70.6	17.7	2.9	8.8
16 April	69.8	18.6	4.7	7.0
20 May	25.6	30.8	15.4	28.2
24 June	21.7	17.4	17.4	43.5
29 July	69.2	15.4	7.7	7.7
33 August	58.7	14.1	15.2	12.0
Overall Mean %	49.1	26.0	9.8	15.7

June ($X^2 = 32.8$ $P<0.001$) see table **11**.

The final collection of scats in August (week 33) showed no significant difference to the scats collected in July in its composition of the major prey groups with mammalian prey still being the most frequent item (58.7%), followed by crab (15.2%), fish (14.1%) and avian prey (12.0%).

Spatial Variation

The study area was divided into four sections of roughly equal proportions (approximately 1km of shoreline each) see fig. **2** The numbers of scats collected per month in each sector is shown in fig. **17** The overall diet by the frequency of occurrence method was calculated for each sector, see fig. **18** Chi-square tests for spatial variation in the composition of the main prey groups encountered in the scats for each sector are shown in table **13**. It can be seen that scats collected in sector 1 were significantly different from those in sectors 2 and 4 (X^2 - 16.93 and 27.99 $P>0.001$ respectively), but were similar in their composition to scats collected in sector 3 ($X^2 = 2.94$ N.S.).

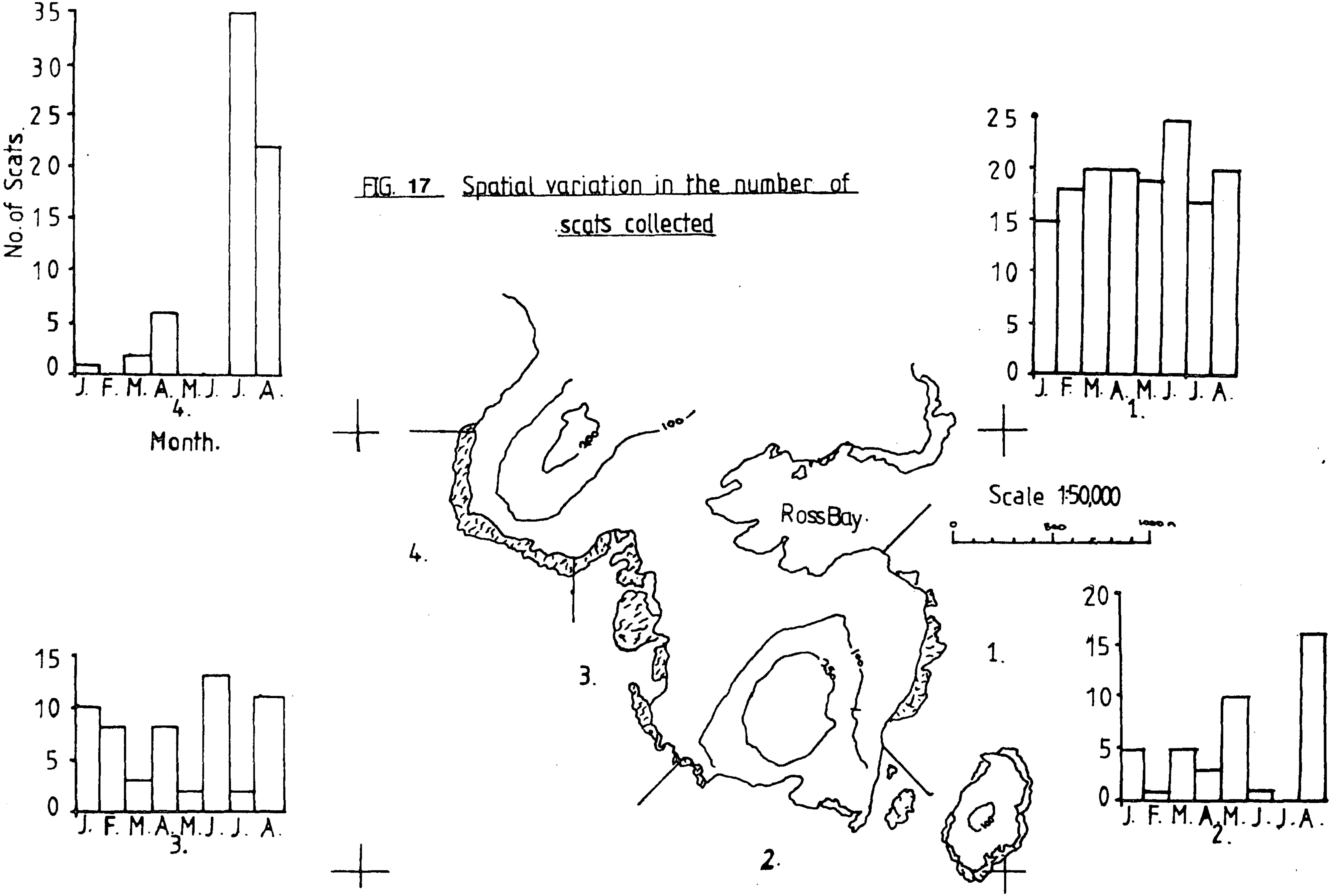


FIG. 17 Spatial variation in the number of scats collected

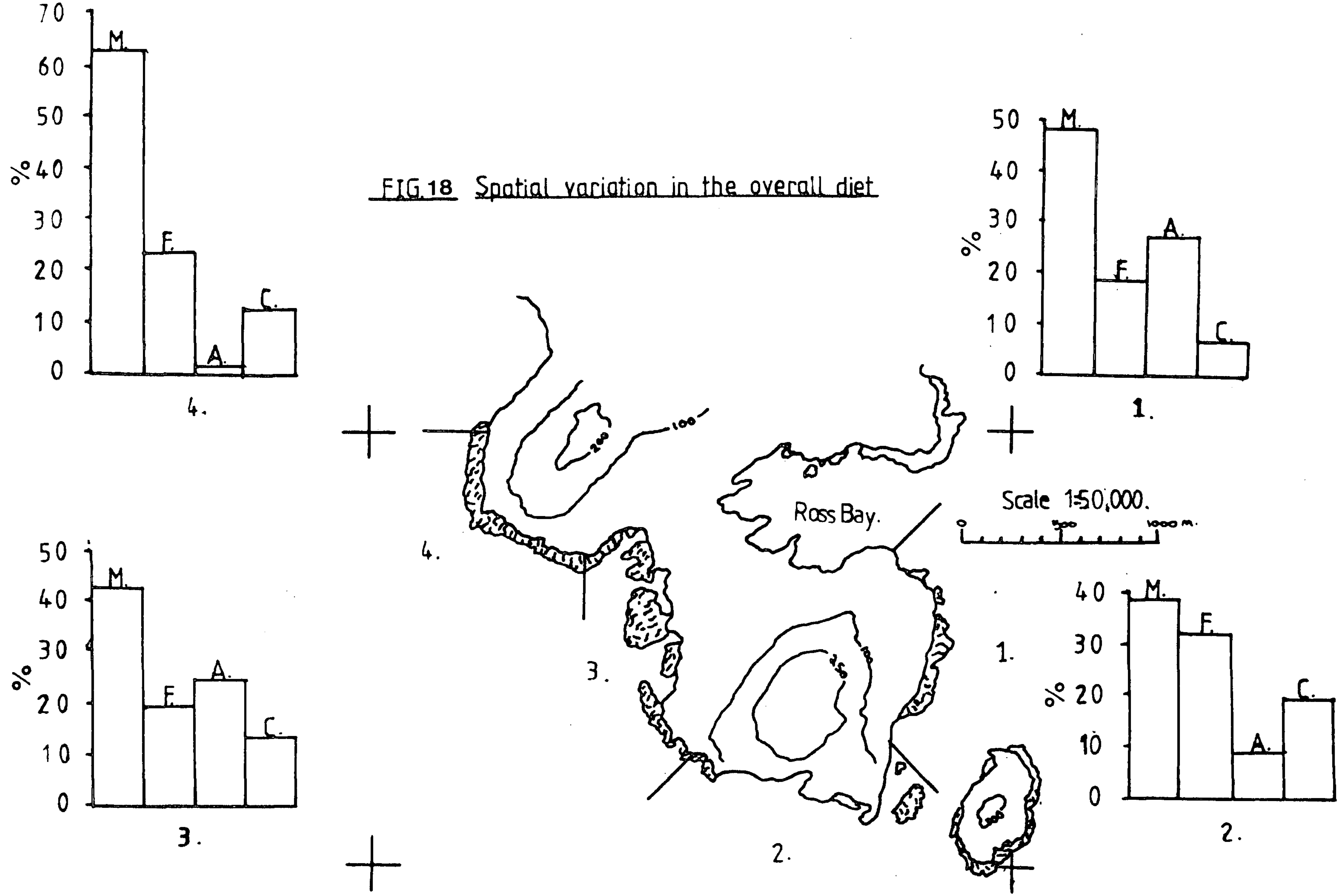


FIG.18 Spatial variation in the overall diet

TABLE 13 X^2 test. Comparison of the frequency of occurrence of the main prey groups in the scats collected in each sampling sector

Sampling Sector	2	3	4
1	16.93 ***	2.94 N.S.	27.99 ***
2	-	6.12 N.S.	10.27 *
3	-	-	22.08 ***

N.S. = Not Significant

* P = <0.05

** P = <0.01

*** P = <0.001

ROCKPOOL SURVEY RESULTS

From table **14** it is clear that the rockpools of the more sheltered Meikle Ross peninsula contained significantly more prey potentially available to the mink than the more exposed Mull of Ross headland, ($t = 3.13$, $P < 0.01$). On average there was 8.73 ± 2.8 prey items representing 143 ± 67g wet weight of prey on the sheltered shore. The exposed shore of the Mull of Ross headland had on average 6.27 ± 0.8 prey items per rockpool representing 86.6 ± 18.4g of prey. The most common prey item available was the shore crab Carcinus maenas with an average of five per rockpool. Common littoral fish species such as the common blenny Blennius pholis, butterfish Pholis gunnelus, five-bearded rockling Ciliata mustela, goby Gobius pholis and sea scorpion were frequently encountered in the rockpools, especially the first three species, with a mean number of occurrences per rockpool being 1.2 for Blennius pholis, 0.5 for Ciliata mustela and 0.33 for Pholis gunnelus.

The mean volumes of the rockpools on either shore did not differ significantly, with the mean volume of rockpools on the Meikle Ross peninsula being 231.1 ± 81.2 l^{-1} and those of the Mull of Ross being 282.3 ± 83.6 l^{-1}.

In order to obtain an estimate of prey abundance in relation to rockpool volume for reference purposes, a linear regression analysis of prey weight and rockpool volume was conducted. The data for both sampling areas was combined to provide a larger sample size ($N = 30$) and the following regression parameters calculated Regression coefficient $R = 0.54$, slope $m = 0.33$ and the y intercept $c = 30.96$.

The estimated percentage area of the littoral zone covered by rockpools on the Meikle Ross peninsula was 20-25% and on the Mull of Ross 10-20%, for the location of the rockpools samples see fig. 6

The mean surface area and maximum depth of the rockpools on Meikle Ross was 1.19 ± 0.26m^{-2} and 287.3 ± 58.9mm respectively, the corresponding figures for the Mull of Ross are 1.37 ± 0.2m^{-2} and 480.1 ± 91.1mm.

TABLE 14. Mean Rockpool Parameters

Rockpool parameter	Ross Peninsula N = 15	Mull of Ross N = 15	t value	P	Overall N = 30
Mean prey wt.(g) ± S.E.	143.09 ± 67.3	86.61±18.4	3.13	**	114.85±34.7
Mean no of prey items ± S.E.	8.73 ± 2.8	6.27±0.8	3.24	**	7.5 ± 1.5
Mean rock-pool vol (l) ± S.E.	231.07 ± 81.2	282.33±83.6	1.7	N.S	256.7 ± 57.5
Mean surface area m^{-2} ± S.E.	1.19 ± 0.26	1.37±0.2	2.14	*	1.28 ± 0.16
Mean (max) depth mm ± S.E.	287.33 ± 58.86	480.1±91.13	6.89	***	383.7 ± 56.22

N.S. = Not Significant

* P = 0.05

**P = 0.01

***P = 0.001

RESULTS : FISH PREY SIZE:

The regression parameters for the centrum length of caudal vertebrae against fork length for three species of littoral fish commonly encountered in the diet of mink are shown in Table **16** and Figures **19,20,21.** In each case, mean, maximum and minimum values are given.

Caudal vertebral length and fish fork length are sufficiently well correlated to enable estimates of prey length to be made from vertebrae present in the mink scats collected.

The mean sizes of the littoral fish species taken as prey by the mink (where calculable) were as follows: common blenny 112 ± 6.8mm (N = 14), five-bearded rockling 107 ± 4.7mm (N = 20). Only a single occurrence of butterfish was encountered during the faecal analysis of the scats, this had an estimated fork length of 100mm.

Table No.15 Fork length of reference fish

Common blenny	Fork length range 47-125mm
Five-bearded rockling	Fork length range 55-150mm
Butterfish	Fork length range 87-125mm

Table No.16 Results of fish fork length estimations (measured in mm) from vertebra centrum length measurements (to 0.1mm) in reference fish

Caudal	Vertebrae	Common Blenny	Five-bearded Rockling	Butterfish
Mean	R	0.894	0.96	0.963
	M	0.014	0.017	0.013
	C	0.257	0.132	-0.263
Max.	R	0.896	0.935	0.958
	M	0.015	0.018	0.012
	C	0.355	0.236	-0.104
Min.	R	0.772	0.951	0.958
	M	0.011	0.017	0.012
	C	0.314	0.006	-0.304

Fig 19

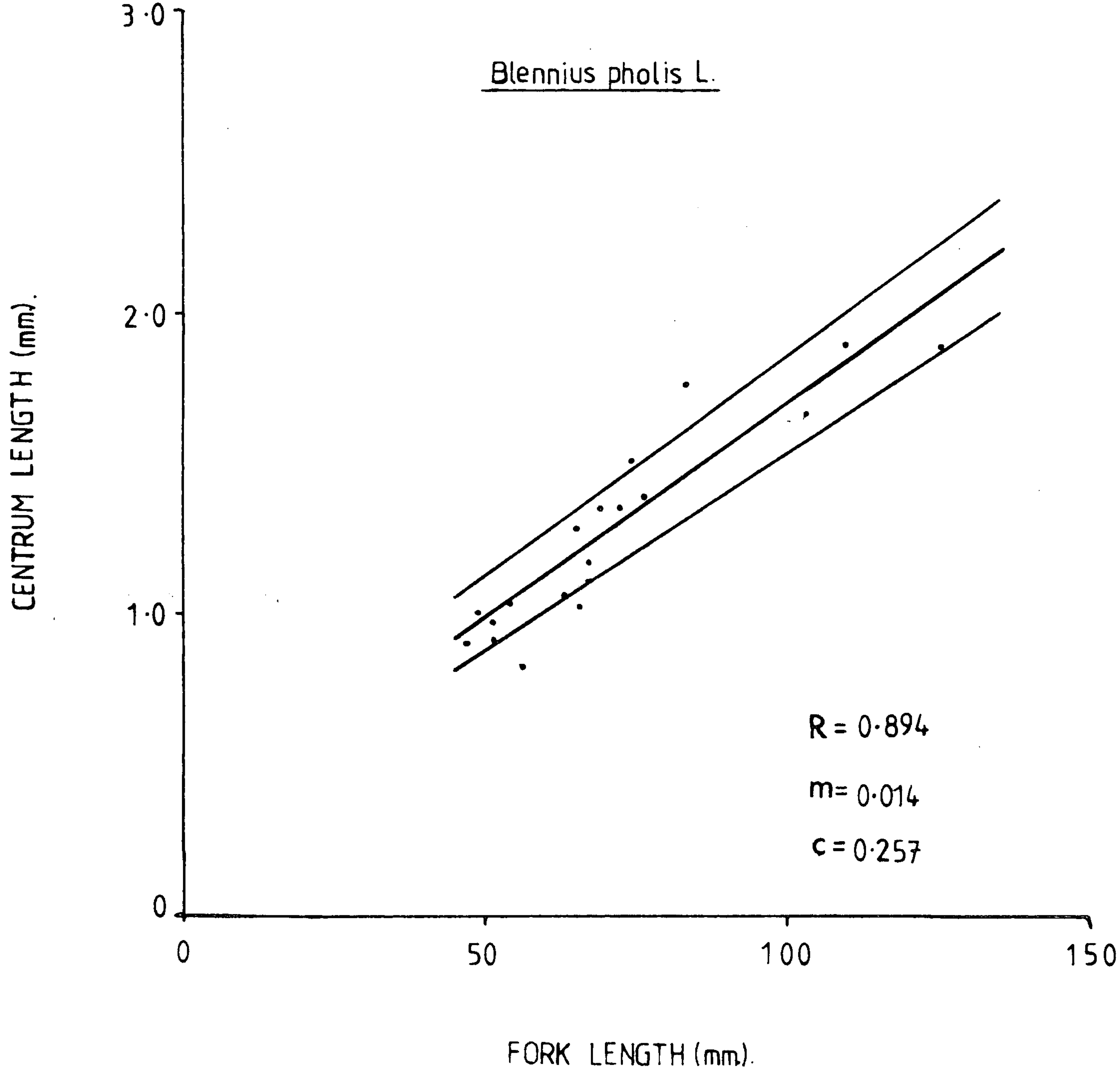
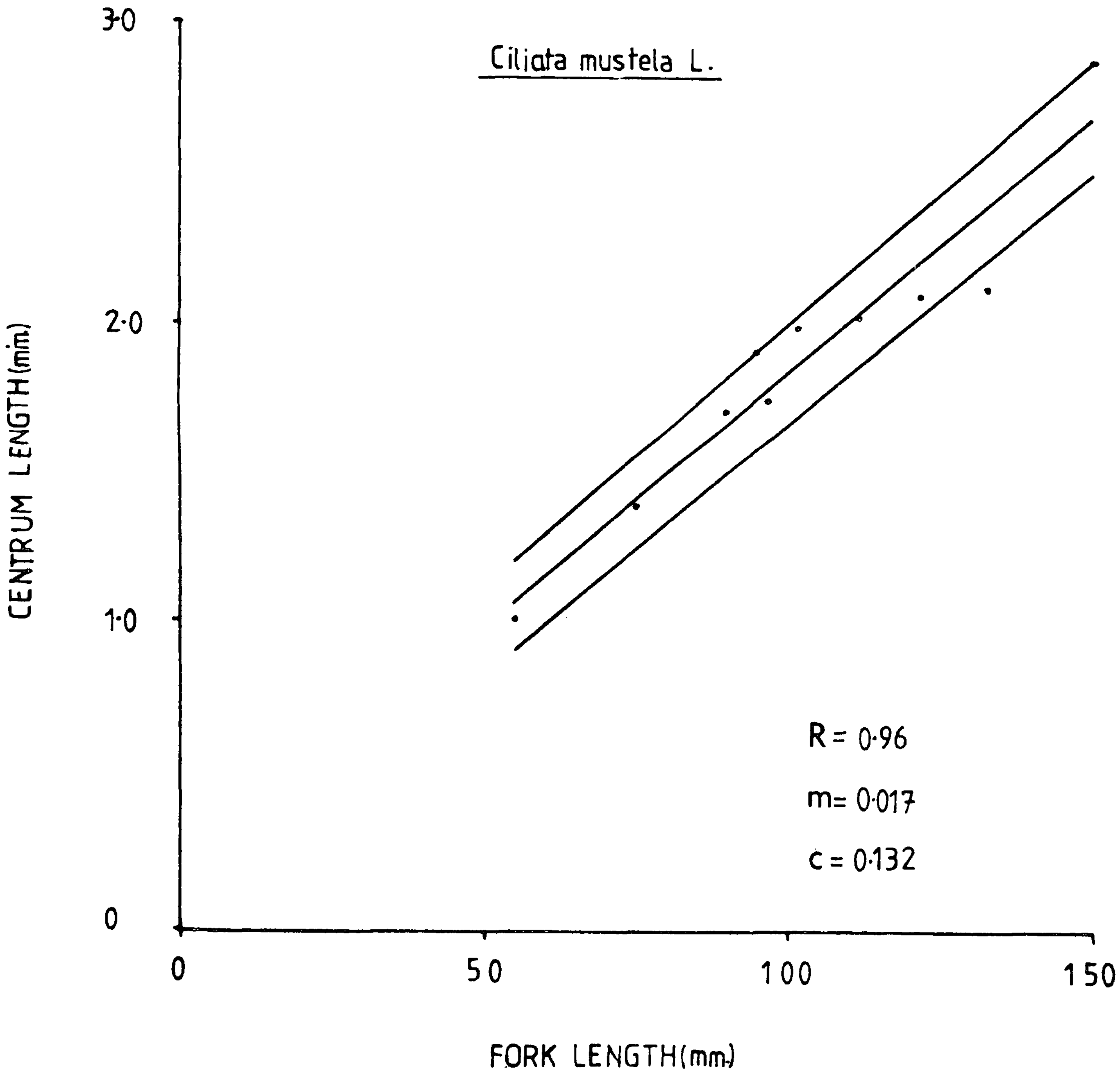
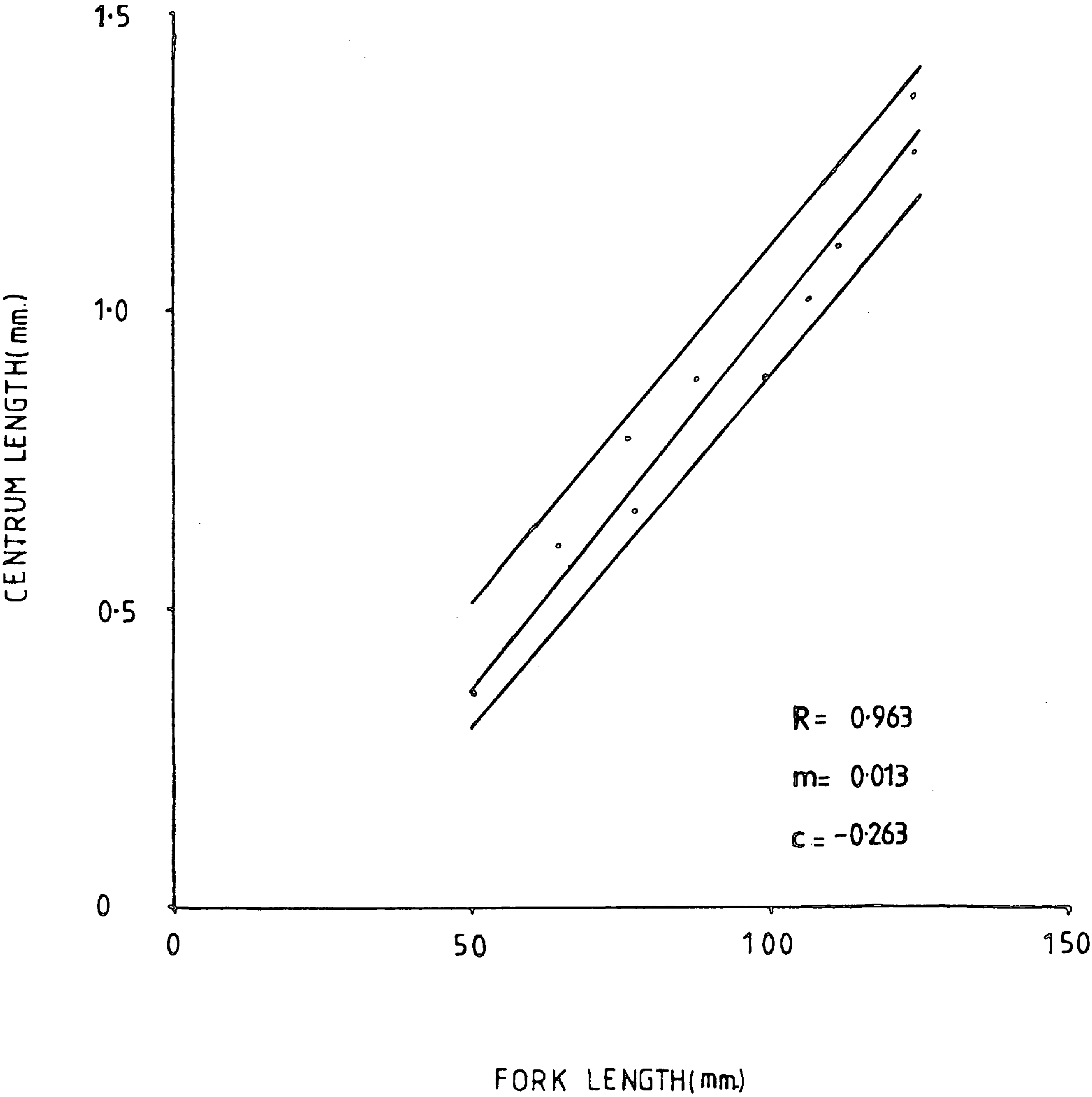

Blennius pholis L.
CENTRUM LENGTH (mm).
3·0
2·0
1·0
0
50
100
150
FORK LENGTH (mm).
R = 0·894
m= 0·014
c = 0·257

Fig 20



Ciliata mustela L.
R = 0·96
m= 0·017
c = 0·132
CENTRUM LENGTH(mm)
3·0
2·0
1·0
0
0
50
100
150
FORK LENGTH(mm)

Fig. 21 Pholis gunnellus L.



RADIO-TELEMETRY RESULTS AND DEN SITE SELECTION

The activity patterns of two mink were compiled from two separate periods of radio-tracking. Mink A, an adult male weighing 930g, was capture on 1.5.81 at Den 1 (see fig.23). Another male mink weighing 1200g was captured on the same night, however no radio-tracking results are presented for this individual as the transmitter became defective soon after attachment. Seven traps were set on that night and the two captures may serve as an indication of the relative abundance of mink in the study area. Mink B, a breeding female weighing 790g, was captured on a subsequent trapping session, 28.6.81, at Den 4 (see fig.23).

All mink were released at the point of capture having been kept under observation for several hours to allow recovery from the anaesthetic used during attachment of radio collars.

Mink A was radio-tracked for six consecutive 24 hour periods from 10.5.81, 0900 hours until 0258 hours on the 17.5.81 by two operators using four hour shifts. Fig. 23 shows the dens used by Mink A during that period as well as the movements between those dens. Mink A was initially located at Den 2 (see fig.23); at 2017 hours the mink became active, denoted by frequent changes in the amplitude of the signal received. Mink A left the Den at 2038 hours and proceeded along the edge of the storm beach, stopping frequently, and arriving at Den 1 at 0213 hours having covered a distance of approximately 375m.

Activity was resumed at 1208 on the second day, and the animal proceeded back to the Fauldbog bay (250m) and was seen to forage in three rockpools, making at least three attempts to catch prey in each rockpool. However, due to the lack of cover for any observer on the storm beach, it was impossible to discern whether Mink A was successful in its foraging. The foraging bout lasted 35 minutes from 1540 until 1615 hours. The animal then returned to Den 2 and was lost from sight until 1850 when it reppeared and defaecated and finally moved back to Den 2 at 1937 hours, having covered a distance of approximately 375m. The animal remained inactive until 0130 hours on Day 3 when Mink B returned to the rockpool by the Fauldbog bay and remained there for one hour and twenty minutes and was known to have visited at least two rockpools before proceeding to Den 3; having covered a distance of approximately 300m by 0518 hours.

Thirty minutes after sunset (at 2143 hours) Mink A left Den 3 and proceeded to the Mull of Ross again stopping frequently. The mink reached a rabbit warren (marked X on fig. 23) some 280 metres distant by 2317, and remained at this warren without reappearing, until 2211 hours on day 5 (May 14th) when it moved back to Den 2 arriving there at 0014 hours, having covered a distance of 160m. (No scats were found by the entrances to the rabbit warren so it is presumed that the mink defaecated within the burrow.)

Activity was resumed at 1814 hours on day 6 when Mink A moved to the western side of Fauldbog bay and was observed to visit five rockpools in the area where some of the rockpool sampling for prey abundance had occurred, remained in the vicinity of the rockpools until 2018 when it departed in the direction of Den 3 and arrived there at 2053 hours, having travelled approximately 215m. Activity was again registered at 0259, but the radio signal was lost at 0317 and the field work terminated.

Fig.22 shows the activity pattern of Mink A over the six day period in relation to low tide and sunrise/sunset as well as the mean activity per hour for the observation period. Activity being expressed as a percentage of the total time observed. On an overall basis Mink A was active for 16.1% of the observation time (being active on average for four hours a day). Of this approximately one third (5.4% overall) occurred during the hours 0.01-1200 and 10.7% during the hours 1201 - 2400. Activity accounted for 25.2% of the period of darkness and only 10.8% of the daylight hours. The mean inter-den movement was 248m (range 160-350m), with a mean speed of1.5m/minute. It is clear from fig. **22** that Mink A is predominantly nocturnal/crepuscular with the majority of activity occurring between the hours of 1800-0500. The three bouts of rockpool foraging observed occurred on or after low tide.

Mink B, the breeding female, was tracked using twice daily 'fixes' of position at 0700 and 2100 hours (which corresponded roughly with sunrise/sunset), in order to provide a general outline of den usage and activity. Observations were taken in the period from 17.7.81 until 21.7.81 and 1.3.81 until 3.3.81. Mink B was observed to have made diurnal movements on three occasions to the forestry plantation and fields in close proximity to her den (see table **17**). On the 1.8.81 she was observed to leave her den (Den 4) at 1511 hours and was located with her kits on the 2.8.81 at 1045 hours in Slack Heugh (Den 5), some 600 metres away, and remained there until 1630 on 2.8.81 when the signal was lost. Mink B was recaptured on the 16.9.81 in close proximity to her original breeding den and was found to have shed her collar and weighed 710g.

Den Site Selection

Of the known den sites in the study area (N = 12) see fig.24, eleven were located in stone crevices or under large stones, whilst only one was located in a hawthorn thicket. The dens had one or two entrances determined by the position of the stones they were located under. All dens were located in the boulder strewn area of exposed rock strata above the littoral zone. The mean distance to high water mark was 14.27 $\pm$ 2.0m and the mean distance to the closest rockpool was 21.35 $\pm$ 3.47m, with a mean inter-den distance of 280.9 $\pm$ 88.8m.

Fig 22. A Diagram to show the activity patterns of a radio-tagged mink.

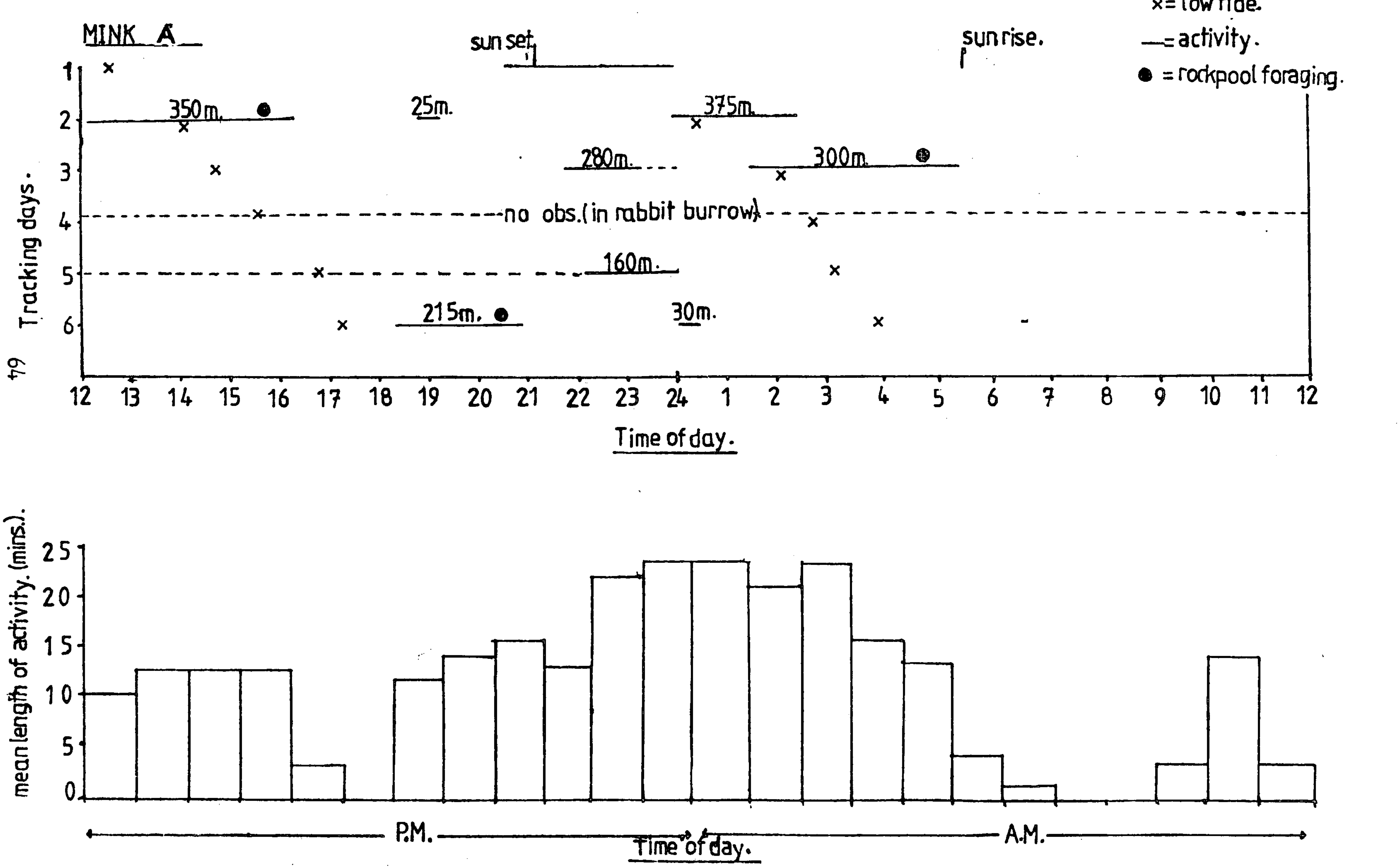


FIG.23 Map of study area showing the location of dens used by radio-tagged mink.

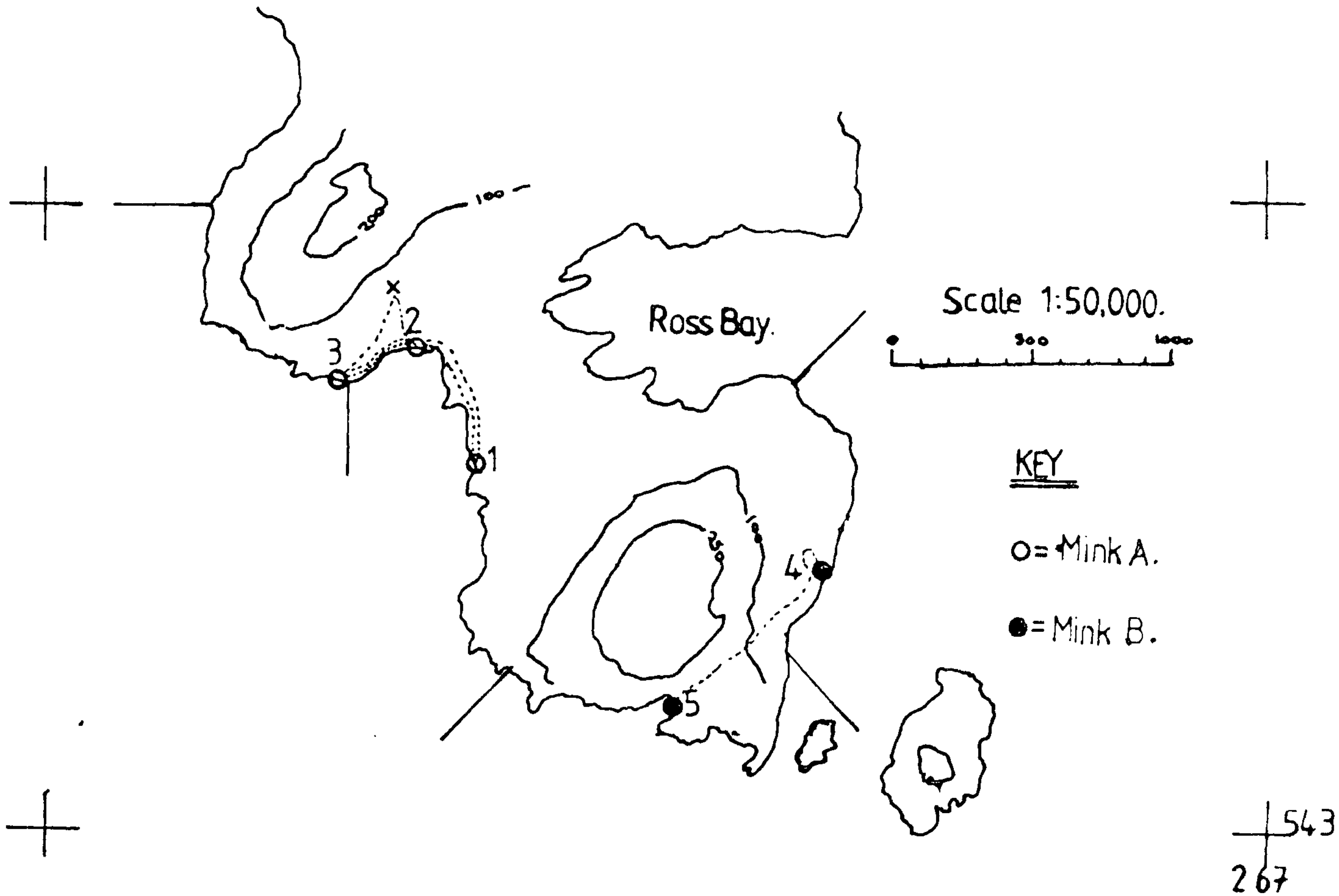


FIG.24. Map of study area showing the location of dens

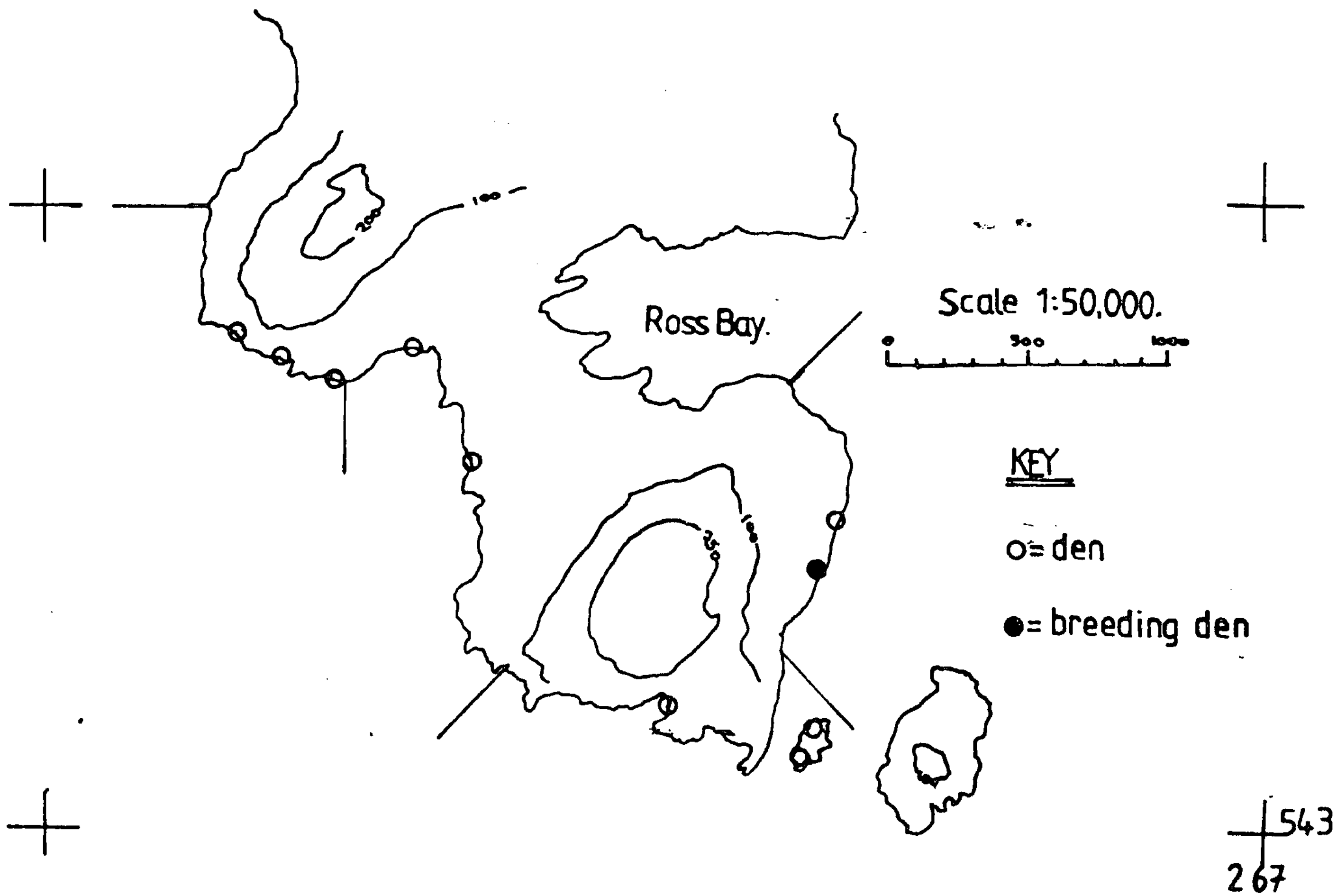


TABLE 17 ACTIVITY OF MINK B

DAY	TIME	SUNSET	HIGH TIDE	ACTIVE	DEN	MOVEMENT	FORAGING
17.7.81	0700	21.42	1247		✓		
17.7.81	2100	-	-		✓		
18.7.81	0700	21.41	0104	✓		✓ 40m	✓
18.7.81	2100	-	1324		✓		
19.7.81	0700	21.40	0141		✓		
19.7.81	2100	-	1404	✓		✓ 150m	✓
20.7.81	0700	21.38	0218	✓		✓ 50m	✓
20.7.81	2100	-	1443		✓		
21.7.81	0700	21.37	0258		✓		
21.7.81	2100	-	1523		✓		
1.8.81	1511	21.18	1325	✓		✓ 600m	
2.8.81	1045	-	0143		✓		
2.8.81	1630	21.16	1409		✓		

CHAPTER 5

DISCUSSION

A number of studies have been conducted on the feeding niche occupied by the mink in those countries where it has established feral populations (Gerell 1967, Chanin 1976, Wise 1978). The diet has been shown to be similar in all studies and generally the same as that reported from its native U.S.A., although it has only been incompletely studied there. This similarity in the feeding ecology of mink throughout their range indicates that any interspecific competition from carnivores native to the countries where mink have become feral has not caused the mink to become either more terrestrial or more aquatic in its feeding habits. This need not imply a lack of competition with native carnivores, but rather that the niche occupied by mink was not previously fully exploited. The wide ecological niche utilised by the mink may serve to reduce its competition with more specialised carnivores. In comparison with some other mustelid species the mink's "specialisation" is in being a "generalist". Weasels and stoats for example are adapted to feeding mainly on small mammals (rodents) and lagomorphs/birds respectively and otters to feeding on fish (Southern 1977). The diet of weasels was found by Day (1968) to be comprised of small rodents (mainly Microtus agrestris, 55%), birds (12%) and rabbit (0.4%). King's (1971) study revealed the following composition for the diet of weasels: small rodents (78%), birds (22%) and rabbit (19%). Studies by Day (1968) and Fairley (1971) found the diet of the stoat to be comprised of the following: 33-45% birds, 28-34% rabbits and small rodents 17-22% respectively. The diet of the otter from various studies (Erlinge 1967, Chanin

1976, Wise 1978) was found to be 67-90% fish with terrestrial prey forming a minor item in the diet.

The mink also feeds on all of these prey items according to their availability (Gerell 1968). However a consequence of the mink's lack of specialisation is that it should be less effective as a predator on each particular prey group, than those predators specifically adapted to prey on each group. However this should not preclude individual specialisation by certain mink. If mink were to compete directly with any of these predators for a particular food resource, they would probably be outcompeted. However, the wide variety of alternative prey suggests that the circumstances under which direct competition is likely to occur are probably very rare since the mink can switch to alternative prey. Therefore, the wide ecological amplitude of feral mink brings it into potential competition with numerous species of native carnivores, but with each to a lesser extent.

Both weasels and stoats were seen in the vicinity of the study area, but the fox Vulpes vulpes was notably absent from the study area due to pest control by local landowners (pers. comm. landowner). Otter spraints were also found in the study area.

The concern generated by the potential effect of mink upon otter populations in areas where they are sympatric has given rise to numerous dietary studies in an attempt to quantify the competition between mink and otter for food resources (i.e. dietary overlap). Chanin (1976) studied the diet of the otter and mink from two contrasting habitats in Devon. In both areas otters took 90% of their diet as fish, a prey group which comprised only 55% of mink diet, and concluded that there was potential for competition. Wise's (1978) results are similar to those of Chanin (1976). She recorded a dietary overlap of 40%, of which 63% was fish, but with a greater number of large fish consumed by the otter. Cuthbert (1979) in a study of mink and otter diet in Scotland concluded that the selection of main food classes by mink and otters showed no significant difference.

Jenkins (1980) in a more recent study on riparian habitats in Scotland concluded that mink and otters are both opportunistic feeders, each specialising on different prey; whereas otters ate mostly fish, mink preyed upon a wide range of fauna associated with waterways.

Erlinge (1969), in southern Sweden, showed that the diets of the two predators overlapped by 60-70%. Erlinge concluded that in severe winters when food was in short supply, competition between otters and mink took place.

Nine otter spraints were collected during the study period. Although only a small sample, no detectable difference between otter and mink in fish size or species taken could be discerned.

A comparison of the results from the present study of the diet of coastal mink with those of Watson's (1978) study of the diet of coastal otters in Shetland indicates distinct differences in the 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, during the present study over the same months, the mink took 35.9% of its diet as avian prey, 24.1% as fish, 23.7% as mammalian prey and 16.4% in the form of crabs. However variation between the study areas could have a pronounced effect upon prey abundance and render comparison difficult.

Within the fish group the most important species to the otter were, in rank order: butterfish (fork length 100-250mm), Yarrell's blenny (fork length 100-150mm), and five-bearded rockling (fork length 100-150mm), whilst the five-bearded rockling (fork length 107 $\pm$ 4.7mm), common blenny (fork length 112 $\pm$ 6.8mm) and the sea scorpion were the most important fish species to the mink, although contributing a much smaller proportion of the diet overall. Insufficient data is available to evaluate the differences, if any, between the fish size taken by otter and mink in these studies, however there appears to be some overlap. It is also clear from this comparison that the mink is less completely an amphibious animal in its diet than the otter, and may resort to a greater proportion of terrestrial prey than the otter. Competition may also be reduced between the two by spatial separation in that otters hunt for fish amongst kelp beds (Watson 1978) whilst mink were more frequently observed in rockpools foraging for fish (pers. comm.).

The success of feral mink as a generalist opportunistic carnivore is evident from its rapid spread throughout the countries of introduction. Linn and Stevenson (1980) suggest a two stage colonisation, with an initial slow build up of population size followed by dispersal stage to new suitable habitats. The mobility of mink coupled with their territorial system ensures that, depending upon population density and time of year (Birks 1981) there will be a surplus population of non-resident mink available to colonise new areas.

The mink in the present study area are presumed to be descendants of escaped mink from a mink ranch in New Galloway some 30km away and have presumably reached the coast by way of waterways, principally the river Dee where they are still numerous.

Mink in Kirkcudbright in any numbers were first reported in 1963 (Lever 1977). Watson (1978) found the density of otters to be greater in coastal areas than in riparian habitats, suggesting this to be a more "optimal" habitat. Hatler (1971) in a study of coastal mink on the shores of Vancouver island, British Columbia, whilst conceding that potential food sources are widely and abundantly distributed in coastal areas, points out that temporal restrictions are placed on foraging by the tidal cycle, storms and prey migrations, notably that of the kelp crab (Pugettia). He concludes that "mink could fulfil their daily food requirements in less than two hours of foraging in this food rich habitat." On Vancouver island there were between 1.5 - 3 mink/km of shore. The present study area was known to support eight mink as at August 1981, although some were probably non-residents, in other words 2/km of shore. This compared with the 1 mink/3km of river length from Gerell (1971) is a further indication of the "optimal" nature of the coastal habitat.

The large tidal range (mean 8.0m) on the Solway and the numerous rockpools combined with the abundance of terrestrial prey (lagomorphs) in the study area suggests an "optimal" habitat with regard to food abundance. The rock-pools on the comparatively sheltered Meikle Ross peninsula contained on average 8.7 prey items representing approximately 143g wet weight of prey. The rockpools on the more exposed Mull of Ross contained less prey with an average of 6.3 prey items representing approximately 87g wet weight of prey, however the amounts of fish prey in the diet did not differ greatly between the sheltered and more exposed coast. See tables **13**, **14** and fig. **18** A 'typical' mid shore rockpool would have a volume of 257 l^{-1} and may contain up to 40 small shore crabs and perhaps one to two common blennies, or one five-bearded rockling and possibly a sea scorpion or butterfish.

Dens were located close to rockpools on average 21.4 ± 3.5m away, see figure **23** This is probably due either to the fact that the rockpools represent a renewable food resource for the mink, and dens should thus be located close to the resource or that the most suitable and least disturbed den sites for mink were to be found in the area of boulder strewn exposed rock strata just above the littoral zone.

The presentation of results for faecal analysis have been introduced early (chapter **3**). Of the methods available to analyse diet the frequency of occurrence of prey items was particularly suitable since the results are amenable to statistical treatment and allow comparison with other studies. Bulk analysis results have also been included to reduce the underestimation of the importance of prey which occur frequently in the diet but in small amounts or vice versa. Another advantage is that it allows the calculation of correction factors to gain a more accurate estimate of the importance of the prey items in the diet. Many authors have applied correction factors to their data. This is often desirable when a detailed study of the actual food requirements of a carnivore are under study to determine the impact on a particular prey species. However, in this study where it was only the relative frequency of different prey items in the diet that was required, the use of percentage occurrence without correction factors is quite adequate. Although, had time permitted the calculation of correction factors for the main prey groups, then the actual 'importance' of the prey items in the diet could have been ascertained.

The present study of mink diet for late winter, spring and summer reveals that mammals (primarily lagomorphs - rabbit or brown hare which were indistinguishable) constituted 49.1% of the diet and were the primary food source, followed by fish 26.0%, avian prey 15.7% and crab 9.8%. Jenkins (1980) in a dietary study of riparian mink in Deeside, north east Scotland, also recorded a high frequency of lagomorphs and concluded that the main item in mink scats on an annual basis was mammalian prey (lagomorphs approximately 63.5%) and relates this to the 'high numbers' of rabbits now compared with the 1960's when the earlier dietary studies were carried out by Akande (1972) and Day and Linn (1972) where lagomorphs were only minor items in the diet. Cuthbert's (1979) study on the diet of coastal mink living along a 3km length of coastline near Stonehaven in north east Scotland found that Crustacea were the most frequently occurring food item and were almost entirely the share crab Carcinus maemas 33%, fish accounted for 28%, however a high proportion of fish items were fragmented and could not be identified. The main fish items identified were eel Anquila anquila, gadoid and Salmo spp. Avian prey accounted for 16% of the diet and was comprised of Laridae (gulls) 10.1%. Passeriformes (thrushes etc.) 5.0% and Procelloridae (e.g. Manx Sheerwater) accounting for the remainder. Mammalian prey represented 15% of the total diet and comprised lagomorph (8.2%) of the total prey occurrences, Microtus (4.4%) and Rattus norvegicus (1.9%). Molluscs Mytilus and Littorina formed 8% of the total diet, the predators' method of dealing with these difficult prey items would be worthy of further investigation.

Cuthbert's (1979) study was however based on two collections (of unspecified date) of only 78 scats, with no information on where the scats were collected, i.e. dens, breeding dens etc., as well as no mention of prey availability, both of which could obviously have profound effects upon the composition of the diet.

Rosser (1980) in a pilot study of mink diet on the Ross peninsula found that fish prey was the most commonly occurring item (34.6%) followed by crab Carcinus maemas (26.2%), mammals (21.5%) and avian prey (5.4%). Lagomorphs were the single most important mammalian prey constituting 19.1% of the total diet. Microtus, Arvicola, Sorex and sheep all occurred in trace amounts. Of the fish group, littoral fish provided the bulk of the diet, 30.8%, with the common blenny Blennius pholis being the most frequent species. She also noted the large proportion of vegetation in the scats, 11.5%, which did not appear to have been ingested accidentally. Rosser (1980) found Charadriidae (waders) to be the major avian prey item. However in this study the major prey item was Laridae (5.2%), which is in agreement with Cuthbert (1979).

In the present study the overall composition of the diet was similar by both the frequency of occurrence method as well as by bulk analysis, the major difference appearing to be in the contribution of crab to the diet, 9.8% by frequency of occurrence and 3.8% by bulk estimate. This is possibly due to the frequency of occurrence method overestimating the amount of crab in the diet as it occurs frequently in minor amounts in the scats. Depending on size, the whole of the crab may not be eaten, but the carapace broken open and rejected once the soft contents have been devoured (Dunstone pers. comm.) and any carapace found in the scats was probably ingested unintentionally. Application of correction factors to the bulk data would be desirable to provide a more accurate estimate of the importance of crab in the overall diet.

The study area was divided into four sectors of coastline, each approximately 1km in length (see fig. 2). The scats from each sector were analysed and their composition compared. Each sector does not necessarily represent the home-range of an individual mink as there was considerable movement between the sectors. However, section 1 was known to be occupied by a breeding female and sector 2 by an adult male, sectors 3 and 4 by another adult male. Two juveniles were also seen in sector 4. There was a significant difference in the composition of the scats collected from each sector, and this may represent individual preferences in diet. On an overall basis the majority of scats were collected from dens (48%) or on open sites/runways (39%). Only 13% of the scats come from a breeding den, see fig. **13** . The composition of the scats produced by the breeding female (and her kits?) did not differ significantly from the overall scat composition in terms of the proportions of the major prey groups taken, see fig. **14** . The greater frequency of fish and crab prey in the scats collected by Rosser (1980), 35% and 26% respectively from breeding dens differs from this present study, and could possibly be due to the depletion of lagomorph populations in the vicinity of the breeding dens necessitating increased predation on alternative fish prey.

Temporal variation in the frequency of occurrence of the major prey items in the scats collected each month during the study period was largely due to changes in the frequency of the three main prey groups, namely mammalian, fish and avian prey, in the scats, see fig. **16** and tables **7, 8, 9, 10**. Scat samples collected in January and February were similar, with mammalian and fish prey accounting for 77-94% of prey occurrences. However the prey content for the sample collected in March showed a marked increase in the frequency of mammalian prey (lagomorphs 70.6%) with a commensurate decrease in the frequency of fish in the scats (from 58.1% to 17.7%). This increase in the frequency of lagomorphs coincided with the early peak in spring breeding of the rabbit, which starts in early January and lasts until the end of June, reaching a main peak in late April, with a maximum population level attained in June/July (Southern 1977). Successfull rabbit predation is clearly economic in that it provides a secure den site (if the kill is made in a burrow) and a large prey item which will sustain a mink for some time, possibly 3-4 days. Although it is possible that a mink could kill an adult hare it is considered unlikely, and the occurrence of hares in the diet possibly resulted from scavenging.

Avian prey showed a marked increase in May (28.2%) and continued to increase in June to form 43.5% of all prey occurrences, coinciding with the time of peak hatching for lesser black back and herring gulls on the Solway (pers. comm. Grieg). Gerell (1968) also found a peak of bird predation for June in his Swedish study. The avian prey decreased to 7.7% in July and the frequency of mammalian prey (lagomorphs) increased to 69.2% to form the primary prey item taken. The relative frequencies of the four main prey groups in the diet did not alter significantly in the August scat collection.

Akande (1972), Chanin (1976) and Cuthbert (1979) all found rodents, particularly voles, to be the most important mammalian prey item on an annual basis. The low incidence of non-lagomorph mammals in the present study is in contrast to the above studies. The results of the small mammal trapping carried out in this study were inconclusive giving no quantitative estimate of the population size but merely confirming the presence of <u>Microtus agrestris</u> in the study area. Other small mammal prey known to be present in the study area were the common shrew Sorex aroneus L., hedgehog Erinaceus europaeus L. and the common rat Rattus norvegicus. The low incidence of non-lagomorph mammals in the diet may be due to either the relative abundance of these mammal species at the time of year the scats were collected, although this is unlikely since population levels of small mammals should be at their highest (Wise 1978), or that the scats collected provide a biased estimate of the diet due to their collection in areas where lagomorph and fish predation occur, and not in areas where non-lagomorph mammals are important dietary items, e.g. the forestry plantations. A tagged female was observed to have frequented one of the forestry plantations for a longer period (Dunstone pers. comm.) and may have been feeding on small mammals there. The same female was also observed to forage in a small forestry close to her breeding den. However small mammals did not occur in scats collected from the breeding den used by her during that time.

Results from the radiotelemetry show that an individual male mink foraged at low tides in the rockpools. The bouts of rockpool foraging occurred two hours after low tide. However, mink were observed diving into the sea (2m depth) at high tide (Dunstone pers. comm.). Movements made by a male mink occurred at or after sunset and this could be explained by the crepusculor or nocturnal nature of the mink's mammalian prey species (Southern 1977) or to the avoidance of human disturbance caused by the numerous ramblers and fishermen who frequent the study area. However, the radio-tagged breeding female was observed to show diurnal movements on at least three occasions. This could be related to local prey depletion necessitating more foraging activity further away from the breeding den or foraging for less optimal prey, however this does not appear to be the case as the composition of the diet did not differ significantly from the overall diet of the mink. Local prey depletion may lead to an increased amount of foraging in rockpools as these represent a renewable food resource and could possibly explain the greater incidence of fish in the diet found by Rosser (1980) or it could have been simply a case of individual specialisation on rockpool prey.

In the present study it can be seen that mink take a broad variety of prey groups, probably in relation to their abundance, lagomorphs being by far the most frequent prey item taken. Terrestrial prey represented approximately 65% of the total diet. Fish prey was largely comprised of littoral species taken from the rockpools and had an approximate mean fork length of 110mm. Crab was only a minor item in the diet. The diet of a breeding female was found not to be markedly different from the overall mink diet.

Although difficult to quantify in such a limited study, it was felt that the prey taken was of such a catholic nature that competition with the more amphibious otter would not be of great consequence, although some dietary overlap in the fish species and size of fish taken may well occur.

The 4.1km length of coastline was found to have a carrying capacity of at least eight mink, although some of these were probably non-residents. This density compares favourably with Hatler's (1976) study of mink in a coastal habitat considered to be "optimal" and in general it appears that coastal areas can support greater densities of mink than riparian habitats.

The radio-telemetry undertaken in this study, although of a limited nature, did demonstrate that an adult male was primarily crepuscular/nocturnal and foraged in rockpools at low tide, whereas an adult female was more diurnal and this could possibly be related to local prey depletion in the vicinity of the breeding den necessitating greater time spent in foraging or foraging for less optimal prey, or may simply have been individual preference.

In conclusion the incidence of the main prey groups encountered and their varying importance with time demonstrated the generalist and opportunistic nature of mink as a predator.

SUMMARY

1) Mink scats were collected from a 4.1km length of coast at the Ross peninsula, Dumfries and Galloway, Scotland to investigate the late winter, spring and summer diet of coastal mink.

2) The rank order by frequency of occurrence of the major prey groups in the diet was mammalian (largely lagomorph), fish, avian and crab.

3) There was considerable temporal variation in the composition of the diet caused by variations in the frequency of occurrence of mammalian, fish and avian prey. There was some indication that prey were taken in relation to their availability.

4) Of the fish taken, littoral species were the most common and included, common blenny *Blennius pholis*, mean size 112mm, five-bearded rockling *Ciliata mustela*, mean size 107mm.

5) Prey abundance in the rockpools was greater on the sheltered shore than on the exposed shore, with the common shore crab *Carcinus maenas* being the most commonly encountered prey item. Small mammal remains were not common in the scats and a live trapping survey indicated a low abundance of this prey group in the study area, although no quantitative estimate of population size was obtained.

6) A radio-tagged adult male mink showed a largely nocturnal/crepuscular activity pattern and was observed to forage in rockpools at low tides. A radio-tagged breeding female showed

a more diurnal activity pattern.

7) It was concluded from this study that mink were catholic feeders taking a wide range of prey items and were less dependent upon the aquatic habitat for food than the otter.

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