Rats on Kapiti Island, New Zealand: Coexistence and diet of *Rattus norvegicus* Berkenhout and *Rattus exulans* Peale.

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ABSTRACT

Snap-trapping information and diet analysis were used to investigate the coexistence of Rattus norvegicus and Rattus exulans with one another and with indigenous avifauna on Kapiti Island (1,965ha, 40^{0} 51'S., 174^{0} 56'E.). The period of trapping was one year (May 1983 to April 1984) and a diversity of habitat types were involved. Areas were trapped for a three day period after three days of prebaiting and most areas were trapped three times during the year. Reproductive and morphometric parameters were also recorded for the rat populations and an alternative form of estimating density, nocturnal rat counts, was tested. Attempts were also made to measure the arboreal activity of rats using chalk dust tracking paper.

The density estimate for the combined populations (15.06 rats/100 trap-nights) is high when compared with mainland rat populations. Density varied with habitat and season, the highest density index being obtained in lowland grass, the lowest along a stony beach. A Standard Minimum estimate of 63 rats/ha was derived for the lowland grass area. Changes in density with season varied from area to area although there was a particular tendency for variations in spring. Species composition was different between habitats. Of eight areas trapped R. norvegicus was the predominant species in five. R. exulans was the predominant species in three areas and occurred in six. Seasonal fluctuations in species ratios were observed and in the three R. exulans areas a high negative correlation existed between the abundance of each species. Male R. exulans were heavier ($\bar{x}$=85.92g) than females ($\bar{x}$=78.98g) although the reverse situation occurred in *R. norvegicus*, (male $\bar{x}$=209.76g, female $\bar{x}$=222.07g). Reproduction in both species was seasonal with breeding activity peaking in summer and spring. Length of breeding season, average frequency of litter production and mean foetus number were greater in *R. norvegicus*. *R.exulans* showed greater fluctuations in age structure.

Of the three main food categories measured, invertebrates, vegetation and seeds, the invertebrate fraction was, in terms of mean percentage volume and frequency of occurrence, the most important for both species. *R. exulans* had a less varied diet and was more reliant on invertebrates. Lepidopteran larvae were the most frequently eaten invertebrates with Araneida, Coleoptera, Orthoptera, Dipteran larvae and Chilopoda also occurring. Invertebrates formed a greater part of the diet in summer months. Diet strongly reflected the habitat in which rats were trapped. Distinctly different diets were noted in animals inhabiting forest when compared with those from grassland. The proportion of exotic vegetation and seed was more pronounced in the grassland habitats. Although the overlap in diet was considerable, particularly with the invertebrate types eaten (52 types identified, 17 eaten by only one species) the differences in volumes eaten were substantial. Birds did not feature heavily in rat diet and no instances were recorded of kiore having eaten bird remains. Nocturnal rat counts appear an unreliable alternative to trapping as a density measure and kiore do not appear to forage arboreally.

The changes in species ratio, density and diet with area are discussed in terms of competition theory. It is hypothesised that

R. norvegicus is competitively superior and excludes *R. exulans* from mutually desirable habitats. The mechanisms of the competition are unclear although available evidence suggests that competition for food rather than competition for space is the more likely.

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CHAPTER 1: INTRODUCTION

1.1 - Preamble

Four rodent species exist in New Zealand, Norway rat (*Rattus norvegicus* Berkenhout), kiore (*Rattus exulans* Peale), ship rat (*Rattus rattus rattus* L.) and house mouse (*Mus musculus* L.)[1] and all species have been introduced by man.

All four species have interacted with the indigenous environment and the degree of interaction is of concern to ecologists and conservationists as rodent contact with New Zealand is a biologically recent event. Evidence that rodents have affected indigenous flora and fauna may be obvious yet is largely circumstantial, (e.g. Bettesworth 1972 a, Crook 1973, Daniel 1973, Whitaker 1973, Atkinson 1978, Bell 1978, Campbell 1978, Daniel 1978, Flack and Lloyd 1978, Imber 1978, Ramsay 1978, Whitaker 1978, Moors 1983) and present day effects only can be determined; the greatest impact rodents have had on the New Zealand biota would have occurred not long after their colonisation and that era lacks detailed ecological study. Despite this lack of historial evidence and the often speculative evidence of today, a clearer picture is finally emerging of rodent ecology in New Zealand.

Studies of rodent diet indicate what prey species are affected by rodents although the degree of affect requires an equal knowledge of prey populations. Studies of rodent diet in New Zealand have concentrated on the ship rat (e.g. Best 1969, Daniel 1973, Innes 1977, Clout 1980, Gales 1982); and demonstrate

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[1] Taxonomy of *Mus* in New Zealand is under revision; (WRLG Research Review 4 1984).

that this species has lethal effects on certain bird species. The diet of the Norway rat in New Zealand has been studied by Beveridge and Daniel (1965), Bettesworth (1972 a),Bettesworth and Anderson (1972) and Moors (1979). Campbell (1978) has summarised known plant food and Atkinson (1978) listed known accounts of bird predation by Norway rats. The diet of kiore has been studied on northern off shore islands (Bettesworth 1972b, Campbell et al. 1984) and kiore has been implicated as a predator of lizards and tuatara, (Crook 1973, Whitaker 1973, Whitaker 1978), birds (Bettesworth 1972 b, Atkinson 1978), invertebrates (Ramsay 1978) and seeds (Campbell 1978). Mouse ecology in New Zealand has attracted diverse in depth studies (reviewed in WRLG Res. Rev. 4 1984).

Published studies of Norway rat and kiore diet in New Zealand have one major factor in common; they have all occurred on islands. In the case of kiore, island studies are a reflection of kiore distribution as the only known mainland population of kiore is found in south-west Fiordland. Besides the restrictions imposed by distribution, the study of rodents on islands gives the researcher definite bounds to the area studied (immigration and emigration are more finite), more accurate knowledge of possible predators and competitors and, invariably, a higher density of animals to sample as certain mainland competitors and predators will be absent.

Coexistence of rodent species in New Zealand is more speculated about that understood. Early writers were aware of the disappearance of kiore from the mainland and they associated this with the seemingly concurrent spread throughout New Zealand of the Norway rat, (Meeson 1884, White 1897). Watson (1961) reiterated earlier views adding that "Today in New Zealand, exulans is numerous only on outlying islands where neither of the other two rat species occurs." Greater knowledge of the island distributions for each rodent species, has shown that kiore can and does coexist with the other two rat species singly or in tandem (Atkinson 1978) while Taylor (1975) with knowledge of ship rat, Norway rat and kiore being present on Stewart Island suggested mice, which are absent, may be the most influential competitor of kiore. Taylor (1978) suggested differential mustelid predation may be responsible for the ship rat being the common rat of New Zealand forest, a reversal of the situation in Britain and North America where the Norway rat predominates. Undeniably the questions raised by the disjunct distribution of rodents in New Zealand are complex.

1.2 - Description of rats

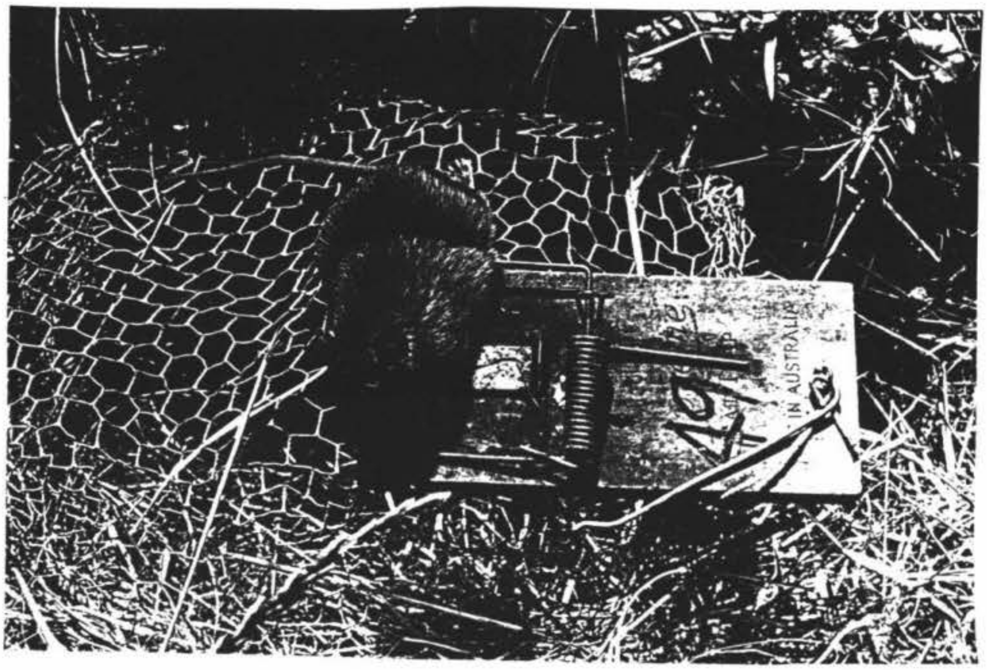
Rodents in general but particularly myomorphs have proved one of the more serious banes of modern mans existence; so much so that rats have been referred to as "the Devil's lapdog", (Canby 1977). Versatile dental morphology, rapid reproductive capacities and developed learning behaviour are typified by the near cosmopolitan Norway rat and the widely distributed kiore.

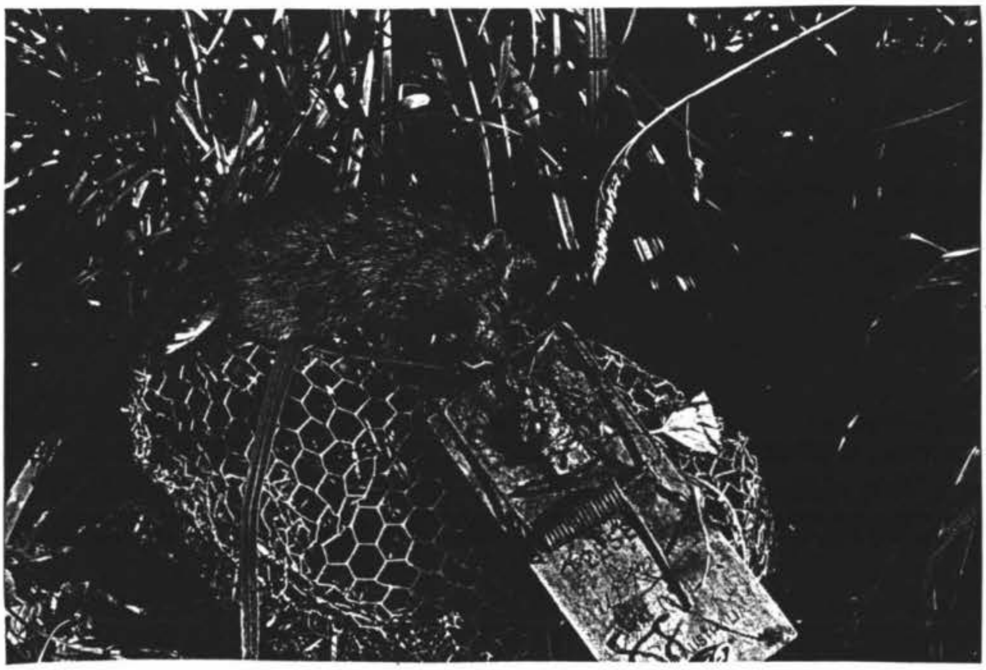
1.2.1 - Norway rats

The Norway rat; also known as the brown rat, water rat, wandering rat, sewer rat, dump rat, house rat and grey rat, originated in northeast Asia. Five subspecies have been described and the species now resides in a large portion of the inhabited world (Southern 1964, Twigg 1975). It arrived in New Zealand along with the first European colonists if not with Captain Cook

PLATE 1: KIORE

PLATE 2: NORWAY RAT


IN AUSTRALIA



and since then it has spread throughout mainland New Zealand and reached some coastal and offshore islands (Atkinson 1973, Atkinson 1978, WRLG Research Review 4 1984).

Of the rodents in New Zealand the Norway rat is largest and weights up to 892 grams have been recorded in England (Barrett-Hamilton 1913), although the heaviest recorded in New Zealand weighed less than 500g (Bettesworth 1972 a). Pooling data from 5 studies (Beveridge and Daniel 1965, Bettesworth 1972a, Bettesworth and Anderson 1972, Baird 1977, Moors 1979), gives an average weight for New Zealand Norway rats of 216.92g, n=590.

The Norway rat is brown dorsally and creamy-grey ventrally. Melanism occurs in Britain (Twigg 1977) but has not been reported in New Zealand. Tail colour and size are useful identification features, tail length being invariably shorter than head and body length combined. The tail is relatively thick, dark dorsally and pale ventrally. Ears are relatively small when compared with those of kiore and ship rat.

Females have twelve nipples, a gestation period of twenty-three days and a litter size ranging from 3-12 (Southern 1964, Hirata and Nass 1974, Pye and Bonner 1980). The species breeds seasonally in New Zealand (Beveridge and Daniel 1965).

The species shows social stratification, at least in certain habitats, with high rank reflected in utilsation of more favourable situations, greater breeding success and larger size. Such differentiation between low and high ranking rats can be so marked that only certain adults successfully reproduce, (Calhoun 1962).

The Norway rat is an adept swimmer and active burrower spending most of its time on the ground although Barrett-Hamilton (1913) stated that "...without being specialists, they are excellent climbers, so that it is difficult to imagine a situation to which they could not penetrate". They are nocturnal omnivores that show "...intimate knowledge of environment and react suspiciously to any change which may inhibit exploratory drive", (Southern 1964).

1.2.2 - Kiore

The kiore (Polynesian, native or Maori rat) originated in Southeast Asia. Its present distribution includes many smaller Pacific islands as well as New Guinea and New Zealand. G. Williams (1973) reviews sub-specific relationships. It is assumed that the kiore arrived in New Zealand with the first Polynesian immigrants either as a stowaway or a source of food. Once common throughout mainland New Zealand it is now restricted to some offshore islands and certain parts of Fiordland, (Taylor 1975, Atkinson 1978, WRLG Res. Rev. 4 1984).

It is the smallest of the three rats in New Zealand seldom exceeding weights of 120g, (Cunningham and Moors 1983).

Colouration is similar to the Norway rat but ear size, foot colour and size and tail shape are distinguishing features. Melanism has occurred in some Pacific islands (Marshall 1962) but no cases have been reported in New Zealand.

Mean litter size, seasonal breeding and size at sexual maturity differ with latitude and habitat, (Watson 1956, Egoscue

1970, G. Williams 1973, Wirtz 1973, Hirata and Nass 1974, Dwyer 1978, Craig 1983). Moller and Craig (in press) provide comparisons of kiore reproduction from Pacific studies.

Kiore are nocturnal, omnivorous and can exist arboreally (Stead 1936, McCartney 1970). They prefer habitats with good ground cover, (Jackson and Strecker 1962, G. Williams 1973, Taylor 1975, Cunningham in litt.). Social organisation within a colony is evidently hierarchial with females dominant over males (L. Davis 1979).

1.3 - Rats on Kapiti

Kapiti Island has the Norway rat and kiore as the only rodents present. The date of arrival of both species is unclear; presumably kiore would have arrived with early Polynesian inhabitants of Kapiti and Norway rats with the first Europeans in the decade 1820-1830.

Cockayne (1907) does not mention the presence of rats on Kapiti yet lists other mammals there; Cowan (1907) likewise makes no mention of rats. Wilkinson (1927) describes "Rats (*Mus decumbus*)..."[2] as being fairly numerous while the Wilkinsons when caretakers of the island (1924-1942) attempted to control the rat population around Rangatira, (Reilly 1936, Wilkinson and Wilkinson 1952).

The first recorded attempt to identify the rat species on Kapiti, occurred in 1959 when four rats were caught by D.S.I.R. staff and positively identified as Norway (3) and kiore (1),

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[2] *Mus decumbus* = *Rattus norvegicus*

(Watson and Wilson 1959). This discovery was important as hitherto understanding of rodent coexistence in New Zealand suggested kiore and Norway rats did not exist sympatrically. Also, prevailing knowledge at the time indicated that the ship rat may have been on the island, a possibility reiterated by Campbell (1965) and Daniel (1969). These authors implied that there is some habitat delineation for the two rat species with Norway more numerous on beaches, kiore in altitudinally higher forests and fire induced grassland. That Norway rats showed a higher relative density has been confirmed by Baird (1977). Baird caught insufficient kiore to add to the existing knowledge of habitat delineation but provided data on morphometrics, diet and reproduction for Norway rats on Kapiti.

1.4 - Kapiti Island

1.4.1 - General description

Kapiti Island (40 ^{0} 51'S.,174 ^{0} 56'E., NZMS 1 KAPITI N156 & PT N157) lies 1.6km off the southern coast of the North Island, immediately to the west of the coastal towns of Waikanae and Paraparaumu Beach. It is a rugged, steep island, 1,965ha in area with a length of 9km and a maximum width of 2.3km. The length of the island is cut by eastward running spurs and streams with the western face of the island exposed cliff. The highest point is Tuteremoana (521m).

Small areas of flat land exist at Wharekohu Bay, Rangatira Point and Waiorua Bay. A more extensive flat area is found at the north-east tip of the island where Okupe Lagoon (8ha) is located. Three smaller islands of 1 to 2 ha lie off the south-east coast of Kapiti; Tokomapuna, Motungarara and Tauhoramurea, (Figure 1, p.10).

1.4.2 - Climate

Kapiti experiences moderate yearly rainfall, warm summers and mild winters with winds predominantly from the north and north-west. Its bulk acts as a wind buffer for the adjacent mainland.

Rainfall averages 1077mm/year (K)[1] the wettest month being July, the driest February. Mean yearly air temperature is 13.3°C; February is the warmest month ($\bar{x}$ = 17.2 °C), July the coldest ($\bar{x}$ = 9.1 °C), (K).

During the study period (May 1983 to April 1984) all months were warmer than usual, the yearly air temperature being 16.4 °C (P)[2]; and September was the wettest month, February and June the driest, (P).

The area receives 82.5 days of wind gusts in excess of 63 km/hr on average,(P).

1.4.3 - Geology

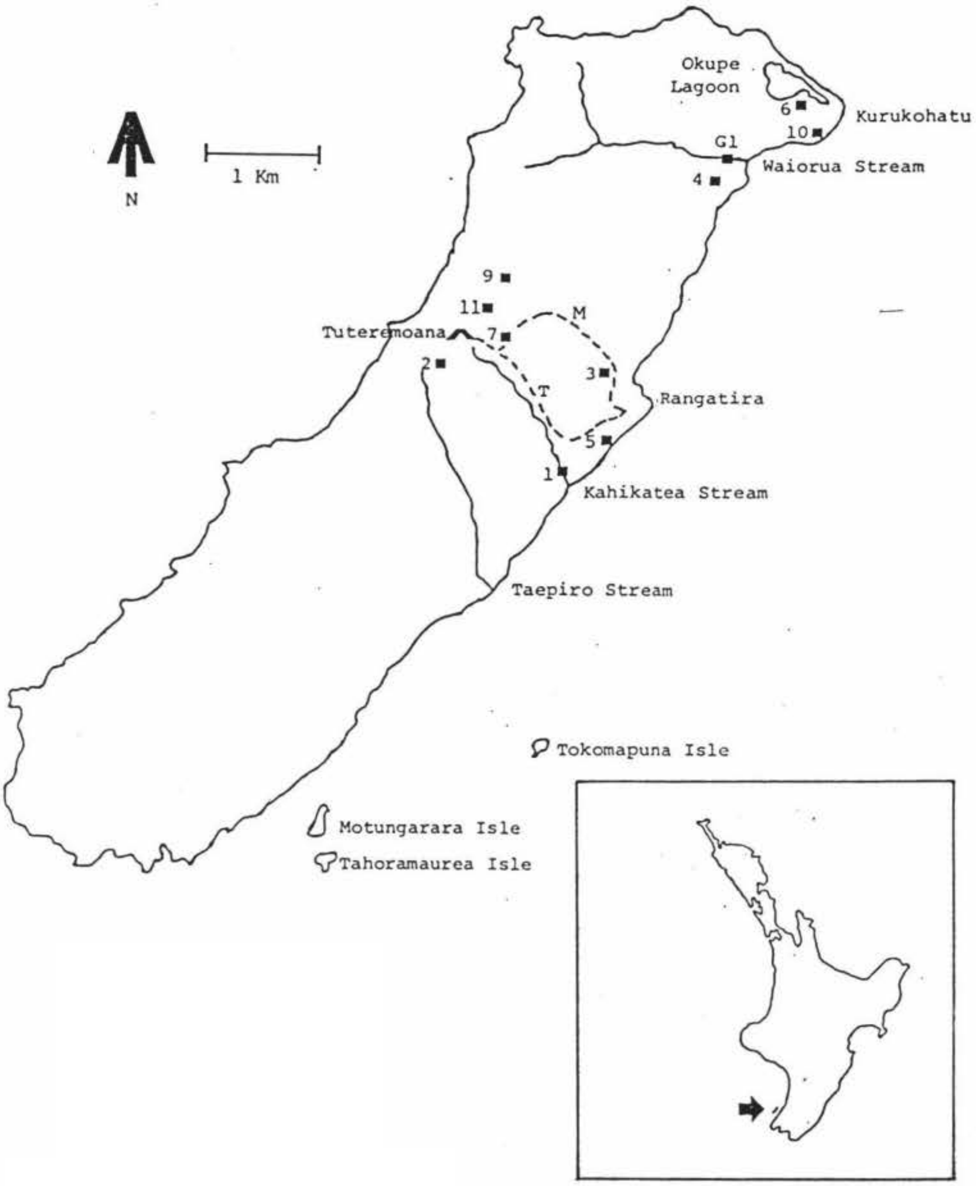
The bulk of Kapiti is composed of argillite and greywacke of Permian or Triassic age with some older phyllorite rocks south of

[1] (K) Kapiti Island data: N.Z. Meterological Service Station E04891.

[2] (P) Paraparaumu Airport data: N.Z. Meterological Service Station E04991.

FIGURE 1: LOCATION OF KAPITI ISLAND AND AREAS TRAPPED DURING THE STUDY.

1-11 = Line numbers, G1 = Grid 1, M = McKenzie Track, T = Trig Track.


N
1 Km
Okupe Lagoon
6
Kurukohatu
10
G1
Waiorua Stream
4
9
11
M
Tuteremoana
7
2
3
T
Rangatira
5
1
Kahikatea Stream
Taepiro Stream
Tokomapuna Isle
Motungarara Isle
Tahoramaurea Isle

Rangatira and on Motungarara and Tauhoramurea Islands. Once part of the mainland and associated with a northern extension of the Wairau Fault, final separation from the mainland was probably 12,000 yrBP, (Ferrar 1928, Fleming and Hudson 1949, McMorran 1977).

Soils on Kapiti are a combination of moderately leached yellow-brown earths, fine rhyolitic ash and, locally, wind borne sands. The steep eastern slopes are dotted with rock screes while the western cliffs have thin coverings of soils in part but are primarily exposed rock. Esler (1967) has given a full description of Kapiti soils.

1.4.4 - Vegetation

The vegetation of Kapiti reflects a number of past and present interacting factors; geology, climate, physiography and modification by man and introduced mammals. Prior to human colonisation of Kapiti the island was covered with mature coastal and podocarp-mixed broadleaf forest. Only remnants of this former forest remain as in the intervening years burning, browsing and grazing has resulted in the wide diversity of vegetation types now present.

Bagnall (1974) defines 17 major vegetation types on Kapiti and describes them in depth, (Appendix 1, p.120). Esler (1967) related such vegetation types to a successional pathway and detailed factors influencing vegetation type distribution. Of 1,622ha mapped in 1965, 183ha were covered by grassland (notably the exotics, sweet vernal Anthoxanthum odoratum, cocksfoot Dactylis glomerata, ryegrass Lolium perenne, Poa pratensis, prairie grass Bromus catharticus interspersed with Coprosma propinqua, Muehlenbeckia complexa and Cassinia leptophylla); 586ha were covered by shrublands (Leptospermum spp., Pseudopanax anomalus and Cassinia leptophylla communities); 499ha were covered by seral forest (five finger Pseudopanax aboreus, heketara Olearia rani, mahoe Melicytus ramiflorus, karaka Corynocarpus laevigatus, tawa Beilschmiedia tawa, kohekohe Dysoxylum spectabile, hinau Elaeocarpus dentatus and rewa-rewa Knightia excelsa), while 354ha were covered by terminal forest (tawa, karaka and kohekohe).

Esler's unmapped area largely comprised the western cliffs which once supported "...beautiful shrubs and trees...", (Wilkinson 1927), prior to the havoc wrought by goats. The cliff vegetation at present is typified by clumps of Phormium cookianum, Muehlenbeckia complexa and scatterings of exotic grasses. The upper reaches of the cliff support stunted forest with canopy of five finger, mahoe and kawakawa (Macropiper excelsum).

Prominent canopy species locally include Northern rata (Metrosideros robusta), kamahi (Weinmannia racemosa), pukatea (Laurelia novae-zelandiae), pigeonwood (Hedycarya arborea) and the tree ferns Cyathea and Dicksonia spp. Understorey species that predominate are kawakawa, hangehange (Geniostoma ligustrifolium), Coprosma australis and lemonwood (Pittosporum eugenioides).

Astelia spp. are common epiphytes of the larger, older trees, Supplejack (Rhipogonum scandens) is common in the mature forests, Clematis spp. and the native passion vine Tetrapathaea tetrandra) less so.

Spleenworts (Asplenium spp.) and ladder ferns (Blechnum spp.)

dominate the lowest tiers of mature forests along with Polystichum richardii, Adiantum cunninghamii and Adiantum fulvum.

The undergrowth is neither dense nor lush, a consequence of the steepness, rockiness and rapid drainage.

1.4.5 - Fauna

The birdlife of Kapiti has been well documented (Cowan 1907, Drummond 1908, Wilkinson 1927, Kikkawa 1960, Atkinson 1979), and is the subject of ongoing N.Z. Ornithological Society surveys. Major studies are being carried out on three bird species; wekas (Gallirallus australis by Tony Beauchamp, Victoria University), saddlebacks (Philesturnus carunculatus by Tim Lovegrove, Auckland) little spotted kiwi (Apteryx oweni by Jim Jolly, N.Z. Wildlife Service).

Herpetology on the island has been little studied. Robb (1980) included Kapiti in her distribution maps of Hoplodactylus maculatus, Leiolopisma zelandicum, Leiolopisma -?- (ex-zelandicum) and Leiolopisma ornatum. Skinks are plentiful around Okupe Lagoon and the raised boulder beaches of Kurukohatu Point.

Invertebrates are largely unknown although Moeed and Meads (1982) have made a preliminary study of invertebrates in selected areas as did Kikkawa (1960), while Beauchamp has acquired considerable knowledge of Kapiti invertebrates.

The long-tailed bat (Chailinolobus tuberulatus) is on the island but numbers and distribution are unclear, (Daniel 1970). A small colony of fur seals (Arctocephalus forsteri) overwinters on the north-west tip of Kapiti. Possums (Trichosurus vulpecula) and the two rat species thrive when not hunted and the north-end may support up to three dogs (Canis familiaris) when the cottage owners are in residence.

1.4.6 - Cultural influences

Knowledge of Maori history prior to the arrival of the Ngati Toa is sketchy although "...Kapiti was associated with the great Polynesian explorer, Kupe...", (Burns 1980). Pre Ngati Toa inhabitants included the Muaupoko and Ngati Apa sub-tribes of the Rangitane.

Ngati Toa's ousting of Ngati Apa and Muapoko from Kapiti in the early 1820's (1822-1823) heralded the way for European contact with the island; Ngati Toa were aware of the benefits Pakeha firearms presented to their warring existence and trade ensued between Maori and European. Trade, intially, was sporadic but the development of the whaling industry resulted in Kapiti providing haven for no less than seven whaling stations. The period of whaling was short; 1829-1839, but during that decade the opportunity for colonisation by Norway rats must have been considerable.

Farming replaced whaling as the next European influence on the island. In 1839 250ha of southern Kapiti was acquired for farming. This, plus farmed leased land and the northern area farmed by the Parata/Webber family resulted in over half the island being farmed by 1890, (Hook 1978).

During the period 1825 to 1890 various mammals were introduced to Kapiti. Pigs (Sus scrofa), goats (Capra hircus), cats (Felis domesticus), sheep (Ovis aries), deer (Dama

dama, Cervus elaphus), possums, dogs, the Norway rat and cattle (Bos taurus) existed on the island for varying lengths of time; all bar the Norway and the possum have been eradicated since - attempts to eradicate the possum are taking place at present.

In 1897 Kapiti was designated a Public Reserve by Act of Parliament and a policy of Government acquisition of land was followed. Today only 13ha at Waiorua and the three small islands remain in private hands.

Human contact with Kapiti nowadays is minimal when compared with the heyday of Maori and early European occupation. Visitors to the island require permits from the Lands and Survey Department and all visitors are made aware of their responsibilities by the resident rangers, Peter and Linda Daniel.

CHAPTER 2: AIMS

This project has three aims.

1. To ascertain the density of rats on Kapiti Island and the fluctuations of density seasonally and with habitat. Understanding of kiore and Norway rat coexistence would be acquired if sufficient numbers of each species were caught and habitat delineation between the two was marked.

2. To provide morphometric and reproductive data on the rat populations.

3. To determine the diet of rat populations and possibly relating dietary differences of the species to their coexistence. Of interest in the investigation of diet is the survival despite the presence of rats of native bird species.

Hopefully examination of these parameters would contribute to an understanding of rat coexistence on Kapiti Island.

CHAPTER 3: METHODS

3.1 - Trapping

Rats were snap-trapped on Kapiti Island over a twelve month period; May 1983 to April 1984. Traps were Australian "eze-set" and all were covered by chicken-mesh bird exclosures secured to the ground with wire pins.

Exclosures were 20cm in height, 20cm in width with a length of 40cm. A small gap was cut in one end facing the trigger plate of each trap. Where possible exclosures were camouflaged with rocks and vegetation in order to minimise accessability to wekas.

Traps were set in either line or grid formation in eleven different localities, (Figure 1, p. 10). Areas trapped were chosen arbitrarily yet were intended to be representative of the varied habitats of the island, (Appendix 1, p. 120). Eight of the eleven localities were trapped more than once (Table 1, p. 18) with a minimum interval of two months between trapping in any one area; the other three although unable to convey seasonal information were selected because of interest in a particular feature of these areas and were primarily used to determine which rat species was present.

Trapping in any one area consisted of an equal effort of pre-baiting; the standard procedure was three nights prebaiting followed by three nights trapping. Grid 1 ("Lower grass") was pre baited and trapped for four nights each and other areas were trapped longer than three nights on occassions if rats appeared

TABLE 1: TRAP EFFORT AND MONTHS TRAPPED FOR EACH AREA

Line# (name)	When trapped (trap-nights).
L1 (Coastal forest)	May (72), July (83), November (129), February (58).
L2 (Upper grassland)	June (90), October (84), February (54).
L3 (Mature kanuka)	June (88:116), October (171), February (131).
L4 (Young kanuka)	July (90), November (134), March (174).
L5 (Beach)	August (90), December (90), April (41).
L6 (Lagoon grassland)	August (90), December (129).
L7 (Tawa forest)	September (90), January (57), April (60:80).
L9 (Cliff)	March (87).
L10 (Gull colony)	December (16).
L11 (Sooty-shearwater burrows)	January (15).
G1* (Lower grassland)	May (251), September (249), January (251), April (256).

(a:b); a = three nights trapping, b = four nights trapping.

* All totals = four nights trapping.

abundant or virtually nonexistent in a particular area with maximising sample size the intention of prolonged trapping. All comparative analysis was done on the results of the first three nights trapping. All traps were baited with peanut butter.

Traps per line varied with availability of traps and the likelihood of catching rats, with areas that showed high density indexes of rats early in the project receiving a greater proportion of the traps available in subsequent trapping. Usual line size was 30 or 45 traps with approximately 15m spacing between traps. One area (Grid 1) was trapped in an 8x8 grid with 15m spacing between traps. It was intended that Grid 1 would provide a more accurate measure of seasonal changes in density with application of the Standard Minimum method (Ryszkowski 1969).

3.2 - Description of study areas

Each area trapped was described by filling out forest reconnaissance ("recce") plot sheets, (F.R.I., Christchurch), at every sixth trap site of any one line. The grid area ("Lower grass") was "recce'd" in an "x" pattern at nine trap sites. Plots were measured at the four corners, the centre, and midway between the centre and each corner. Sheets were mainly used for vegetation description, although physiography, drainage, ground cover, surface stability and mean top height of the canopy were also recorded for each plot measured.

Line 1 ("Coastal forest"; Plate 3, p. 20)

This was the first line trapped during the project and was situated south of Rangatira. It ran up the Kahikatea Stream beginning at the stream mouth, bisecting Track 50 (Appendix 2,p.121)

PLATE 3: LINE 1
Forest type

PLATE 4: LINE 2
Looking north across Taepiro Saddle. Beginning and end of Line arrowed.

)[1] Karaka, mahoe, kohekohe and kawakawa were prominent species with kohekohe dominant in the canopy. Surface stability was generally poor with rock present on the surface. Vegetation ground cover averaged 17.5% from 10 "recce" plots. Bagnall (1974) described this area as "kohekohe forest on a lower slope scree."

Line 2 ("Upper grass"; Plate 4, p.20)

This line ran from the junction of Tracks 60 and 62 down to the Taepiro saddle. This line replicated areas trapped by Daniel (1969) and Baird (1977). Exotic grasses dominated, in particular, cocksfoot and sweet vernal. Stunted forest trees punctuated the northern, upper end of the line (kamahi, mahoe) while Pseudopanax anomalum shrubs dotted the saddle end of the line. Ground cover was nearly all vegetation except for small rock outcrops.

Line 3 ("Mature kanuka"; Plate 5, p.22)

Beginning 100m from the start of the McKenzie track, this line climbed to an altitude of approximately 200m. The lower end of the track is covered by young kanuka forest with coastal tree species, particularly kawakawa and mahoe, dominating the lower forest tiers. Mature emergent kanuka being successionally replaced by kohekohe was the norm for the rest of the line. A belt of northern rata was passed two-thirds of the way up the line. Percentage vegetation cover averaged 14.5 for 10 "recce" plots.

[1] Track x refers to cut tracks used by the possum trappers, (Appendix 2, p.121).

PLATE 5: LINE 3
Forest type

PLATE 6: LINE 4
Forest type

Line 4 ("Young kanuka"; Plate 6, p.22)

This line was situated on the first spur south of the Waiorua Stream, going from near the stream mouth up Track 15. The line followed the track up the spur before sidling. Exotic grasses and weeds at the stream end of the line give way to dense juvenile kanuka with some five-finger, mahoe and lancewood (Pseudopanax crassifolius) more frequent on the sidle. The lower end of the spur is exposed soil and rock and undergrowth is sparse in the purer stands of kanuka. Percentage vegetation cover of the ground averaged 20 from 5 "recce" plots in the kanuka.

Line 5 ("Beach"; Plate 7, p. 24)

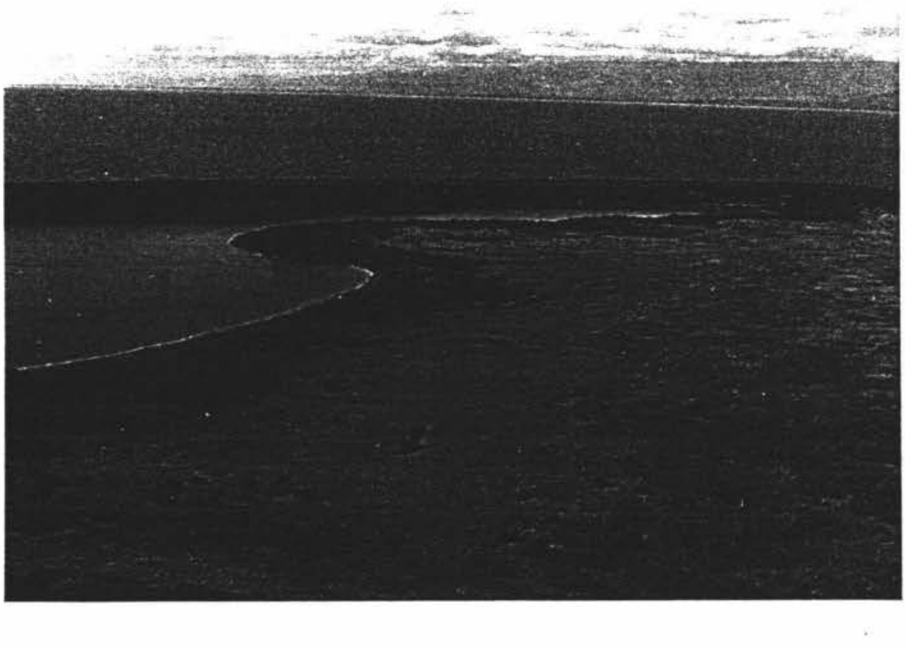
The area trapped was intended to replicate areas trapped by Daniel (1969) and Campbell (1965). The line ran from 50m south of the boatshed at Rangatira to 50m north of the Kahikatea Stream, just above the high tide mark. The nearest vegetation consisted of flax (Phormium cookianum), Coprosma repens, karo (Pittosporum crassifolium) and exotic grasses on the beach/forest ecocline.

Line 6 ("Lagoon"; Plate 8, p.24)

This line begins on the southern junction of Track 100 150m from the lagoon. The line headed towards the east finger of the lagoon, following Track 100, and at the east tip of the lagoon, turned and continued along the small, stony beach of the north shore. Most trap sites were among exotic grasses (cocksfoot, sweet vernal, rye grass, prairie grass and browntop Agrostis tenuis). Closer to the lagoon Leptospermum spp. shrubs and Muehlenbeckia complexa were present.

PLATE 7: LINE 5
Looking south from boat shed

PLATE 8: LINE 6
Beginning and end of line arrowed.



Line 7 ("Tawa"; Plate 9, p. 26)

This line ran from the junction of the McKenzie track and Track 47, down Track 47 to 50m above the Te Rere Stream. Tawa dominated the canopy with hinau, kamahi, heketara and *Cyathea* sp. other canopy species. Putaputaweta (*Carpodetus serratus*), pate (*Schefflera digitata*), *Coprosma australis* and kawakawa were conspicuous seedlings. Average ground cover by vegetation was 28% from 6 "recce" plots.

Line 9 ("Cliff")

This area was trapped once and the line followed one of the recently cut cliff tracks from the head of the Te Rere valley to 1/3 of the way down the western cliffs. The line was always in stunted forest (2-5m) with five finger plus mahoe and kawakawa dominant canopy species. Surface stability was poor and soil very thin. Vegetation cover averaged 21% from 6 "recce" plots.

Line 10 ("Gull colony")

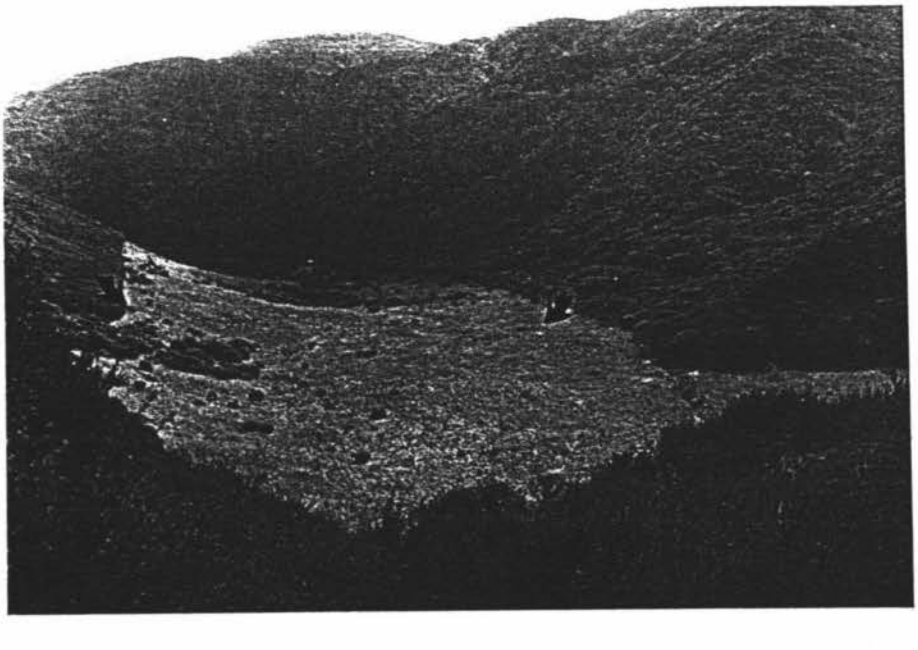
This short line cut across behind the tip of Kurukohatu Point. Reasons for trapping this area revolved around the large adjacent nesting colony of Dominican gulls (*Larus dominicanus*) and the presence of rat burrows amongst the large driftwood piles. The line was on a raised stony beach with *Muehlenbeckia complexa* invading.

Line 11 (Sooty shearwater burrows)

This was more a cluster of a few traps than a line, located on Track 10B with traps placed alongside sooty shearwater (*Puffinus griseus*) burrows. Vegetation was similar to Line 7 with

PLATE 9: LINE 7
Forest type

PLATE 10: GRID 1
Western corner of Grid arrowed



broadleaf (Griselinia littoralis) also present.

Grid 1 ("Lower grass"; Plate 10, p. 26)

This corresponded to an 8x8 grid with its eastern face some 50m west of the barn site in the lower Waiorua valley. All the trap sites were in exotic grass although the northern face of the grid ran within 5m of kanuka scrub.

Vegetation was a mixture of cocksfoot, brown-top, prairie grass, ryegrass, sweet vernal and Yorkshire fog (Holcus lanatus), with small shrubs of kanuka and large sedges (Carex spp.) present. Patches of rush (Scirpus nodosus) appeared on poorly drained soil. Thistles and other weeds were plentiful.

The area encompassed by the grid was damp, generally flat and the Waiorua stream meandered along the northern perimeter. The southern edge ran along the gentle sloping valley side.

3.3 - Field examinations, morphometrics and reproduction

Date and locality, species, gender, stage of sexual maturation, weight, head/body length and tail length were recorded for each rat before freezing and later dissection. A rat was considered caught if a foot or tail was caught alone. Sprung but unsuccessful traps were noted as was any unusual feature of the rat or trap e.g. tail only caught, rat scavenged, trap dragged away. Where possible predators responsible for scavenging and body parts scavenged were noted. Ectoparasites were identified in the first month (May).

Distinction between species became straightforward with practise as small Norway rats differed from kiore in tail size and colour and in foot colour. Sexing of individuals was done by counting the number of holes present in the lower body as female have three holes, (vagina, anus and urethral opening), males two, (anus and urethral opening). Rats were labelled sexually mature if males had scrotal testes and if females had perforate vaginas. Head/body length was measured in millimetres from snout to anus; tail length from anus to tail tip. Rats were weighed to the nearest 5 grams using a spring balance. Weights and lengths were not recorded if some of the carcass was missing as a result of scavenging or injury.

The sole measure of age used in this project was rat size (weight). Rats were classified into weight ranges and the frequency of each weight class tested with season and area. Kiore were grouped into four classes; 0 to 49 grams, 50 to 74, 75 to 99 and 100 plus while Norway rats were grouped into 5 weight classes; 0 to 149, 150 to 199, 200 to 249, 250 to 299 and 300 plus.

3.4 - Laboratory examinations, reproduction and diet

Once thawed, rats were dissected in the laboratory. Stomachs and uteri were removed and stored in 70% alcohol and carcasses then refrozen. Uteri were later examined for the presence of placental scars and foetuses.

Stomach contents were washed through a three tier sieve system of decreasing mesh size; 2mm, 1mm and .25mm. Percentage volume of total food items was visually estimated for each fraction and the three fractions were examined separately under a dissecting microscope.

Percentage volume of eight major food categories; invertebrate, vertebrate, vegetation (leaves/stem), bait, root, wood, seed/fruit and unidentified, was visually estimated. These initial sub-divisions were chosen after canvassing previous rat diet studies.

Percentages for each food item per fraction were combined to give a total food item percentage for each stomach.

Food items from the 2mm and 1mm fraction and at times from the .25mm fraction were kept for later, detailed identification. Bait was not retained and was excluded from subsequent diet analysis. The .25mm fraction was identified in a very broad manner and clues to identification of this fraction required knowledge of the preceding fraction contents of any one stomach.

Invertebrates were keyed down as far as time warranted relying on knowledge of major identifiable features such as wings, scrapers, crotchets, carapace, mandibles and heads. Unidentified invertebrate fragments were sketched and reference slides were made of the common unidentified invertebrates in the hope that more expert entomologists could shed some light on them. In nearly all cases invertebrates, especially insects, were keyed at least to order level.

Vertebrate fractions were classed under three headings; lizard, mammal and bird.

Leaves and stems were further identified by cuticle analysis generally following methods advocated by A. Fitzgerald (1976). Each fraction of vegetation was bleached in a watch-glass containing ordinary household bleach (active ingredient Sodium hypochlorite) for at least two hours. Macerated fractions were then rinsed through a series of watch-glasses before staining and re-rinsing. Staining added clarity to cuticles and a combination of crystal violet and phloroglucin were used. After staining and re-rinsing, plant fragments were spread evenly on a microscope slide, dried using filter paper and a drop of glycerine was then added. Fragments were pounded using the blunt end of a probe, increasing cell layer separation, and a cover slip was placed over the slide. In most instances the vegetation from one stomach could be distributed over one slide although with larger volumes a 40mm clover slip was used rather than the standard 22mm size.

Identification of plant cuticles was achieved by comparing slides from stomachs with a reference collection of slides made using the same technique.

The reference collection incorporated foliage from the major tree species on Kapiti, major ferns and climbers, major grasses and some exotic weeds. Key identification features of cuticles used were epidermal cell shape and size, stomata size and shape, stomata density, the presence of epidermal hairs, the presence of inter cellular gaps and the directional alignment of stomata. All comparisons between slides were made at 400X magnification using a compound microscope.

Seed and fruit were identified to species level in many cases by experts. Unidentified fragments were re-examined at the conclusions of diet analysis and recategorised if necessary. Root and wood were not a feature of rat diet on Kapiti and when they did occur as a food item no further attempt at identification was made.

Stomach nematodes were counted and stored in 10% formalin. Some were sent to experts for identification although most remain identified as "stomach nematodes" only.

3.5 - Arboreality

Two separate attempts were made to obtain information on the arboreality of rats on Kapiti. During October 1983 15 tree trunks along Line 3 ("Mature Kanuka") were circled with black photograph album paper of 10cm width and sprayed with aerosol chalk dust provided by Dr. P. Moors, Wildlife Service. Species, angle to the horizontal and diameter were recorded for each tree banded and each tree was baited with peanut butter above and below the paper band. Bands were set at 1m above the ground. Trapping of Line 3 ran concurrently and each tree banded was the nearest living tree to a trap. Bands were set for four nights; the last two nights of pre-baiting and the first two nights of trapping of Line 3, and re-baited daily.

In November a further 15 trees were similarly banded at the old campsite 50m north of the Kahikatea Stream. In this instance a 20m^2 area was banded without trapping although trapping of Line 1 ("Coastal forest") was carried out concurrently. Rats were or had been present in this area as karaka fruit remains had been hoarded underneath scraps of old corrugated iron in the centre of the area. In addition to the 1m band another band 2m above the ground was set on each of the trees and baited. Disturbed/tracked bands were sprayed with commercial hairspray, which "set" the chalk dust, then replaced and taken to camp for examination.

3.6 - Nocturnal rat counts

On each monthly trip to the island the track system at Rangatira was searched by torch beam and a rat count taken. Three or four searches were carried out per trip and each search took place about one hour after dusk. The position of rats seen was marked on a stylistic map. Weather conditions for each night of searching were noted. The track system searched was approximately 1.3km in length with 200m of that searched twice. 300m of the area searched was coastal forest, the remainder exotic grassland.

In November similar rat counts of the McKenzie-Trig track system began and in each ensuing month one round trip of the system was made (up the McKenzie, down the Trig). The track system searched was approximately 4km in length.

3.7 - Statistics

Standard statistical procedures were used. The restrictions and requirements of each test were met when possible. The information presented in Table 2 (p. 41) did abuse the guidelines of minimum expected cell frequencies for Chi-^{2} , (Hinkle _et al_., Parker 1979) but these results should still give a _relative_ indication of differences in seasonal species ratio between areas.

The multivariate techniques, MANOVA and discriminant function analysis (D.F.A.), were used to most accurately display differences in diet volumes and were calculated using the SPSS computer program outlined by Nie _et al_. (1975). In these tests the three main diet variables were combined and tested for differences rather than univariate testing of each diet class.

Interpretation of Figures 11 (p. 67) and 12 (p. 68) and Appendix 9 (p. 128) requires some knowledge of multivariate analysis. The MANOVA test determines whether a particular comparison is significant; if it is D.F.A. identifies the relative contributions of each dependent variable to the observed variance and therefore enables separation of the levels of the independent variable. Each function (linear combination of the dependent variable) derived by D.F.A. can be thought of as an axis with each level of the independent variable plotted as a group mean along it. This enables graphical display of diet differences.

Although the information of Figure 12B (p. 68) has been graphically displayed using two axes, only one significant function was derived for the comparison of diet between kiore areas. The use of two axes enables easier comparison with Figure 12A (p. 68). The y-axis (2nd function) was not named to emphasise its insignificance. Further qualification of D.F.A. information can be obtained by attaching 95% confidence limits. These can be displayed graphically and are determined by $\sqrt{5.99/n}$ (Hassard pers. comm.).

Multivariate statistics have assumptions and limitations similar to their univariate counterparts. In that sense the use of non-normal data (volume percentages) is not strictly correct. However there is "...extremely strong evidence..." that multivariate tests are "...extremely robust under violation of assumptions of normality and homogeneity...", (Harris 1975).

CHAPTER 4: RESULTS

4.1 - Trapping

4.1.1 Density indexes

Over the 12 month period of trapping, 390 rats were caught. The corrected density index (Nelson and Clark 1973) corresponds to 15.06 rats/100 trap nights. The density index differed significantly between areas (χ^2=27.15, d.f.=7, P<.05; Figure 2 p. 35, Appendix 3, p. 122 , Appendix 4, p. 123). Raw data used to derive the corrected indexes is presented in Appendix 3 (p. 122).

Seasonal changes in density index were marked for some areas (Figure 3, pp. 36-37 & Appendix 4, p. 123). Only three areas; Lines 2, 5 and 6, displayed constant indexes with season. Those areas that varied showed no clear pattern in their fluctuations. However none of the areas trapped in a winter month showed a marked increase or decrease in rat density. One area, (Line 3), decreased in summer. Grid 1 showed a peak in density in autumn 1984. Spring appeared the season when fluctuations in density were greatest. Lines 1 and 4 peaked in density over spring while Line 7 decreased over that period.

Application of the Standard Minimum method (Figure 4, p. 38) requires a linear decline in rats caught over the trapping period. Only once, in autumn 1984, was this condition met so the density estimation given in Figure 4 is for the accumulated yearly result.

4.1.2 - Species ratio

Of the 390 rats caught 58% of those identifiable were Norway rats, 42% kiore. This ratio of Norway rats caught to kiore caught deviated significantly from unity (z = 3.20, p < .05). The

FIGURE 2: TOTAL DENSITY INDEXES FOR AREAS TRAPPED MORE THAN ONCE.

Reference line = Total density index for all areas combined.

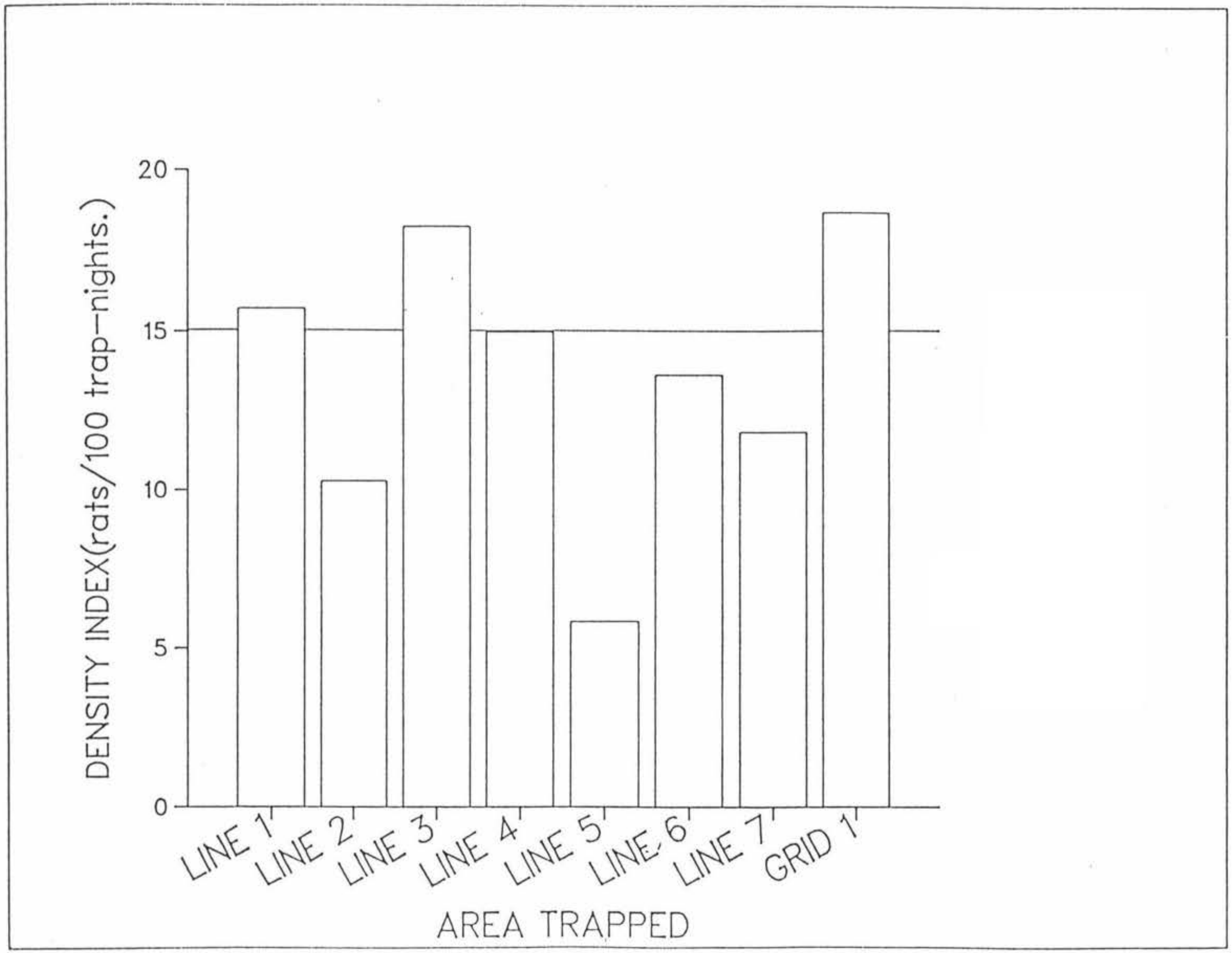

DENSITY INDEX(rats/100 trap-nights.)
20
15
10
5
0
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
LINE 6
LINE 7
GRID 1
AREA TRAPPED

FIGURE 3: SEASONAL CHANGES IN DENSITY INDEX AND SPECIES RATIO: A = Line 1, B = Line 2, C = Line 3, D = Line 4, E = Line 5, F = Line 7, G = Grid 1.

Density; Y = rats trapped/100 trap-nights, corrected (Nelson and Clark 1973). Ratio; Y = ratio of Norway rats to kiore caught expressed as a percentage. A = autumn, W = winter, SP = spring, SU = summer.

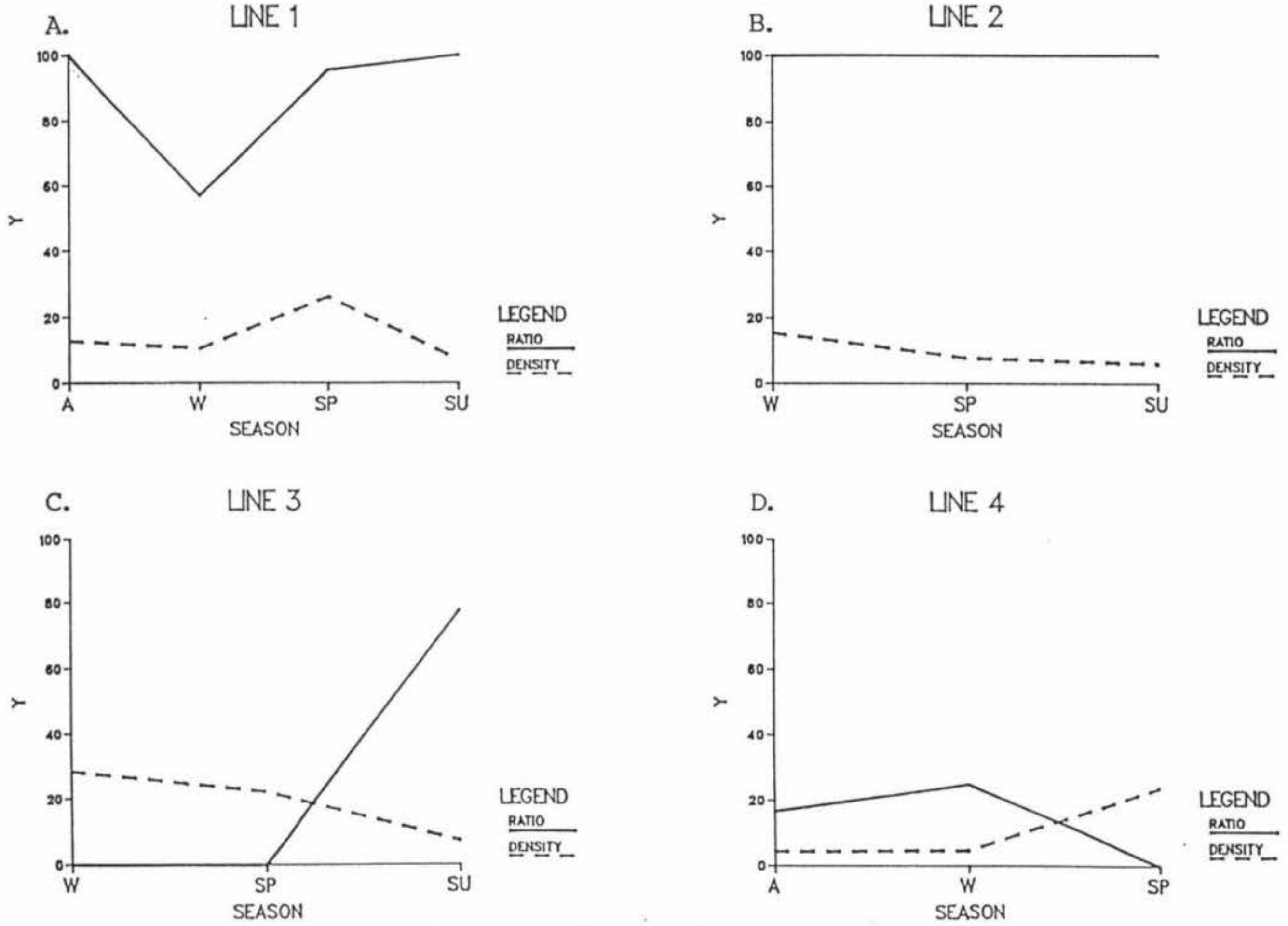

A.
LINE 1
B.
LINE 2
C.
LINE 3
D.
LINE 4
Y
100
80
60
40
20
0
A
W
SP
SU
SEASON
LEGEND
RATIO
DENSITY

FIGURE 3: CONTINUED

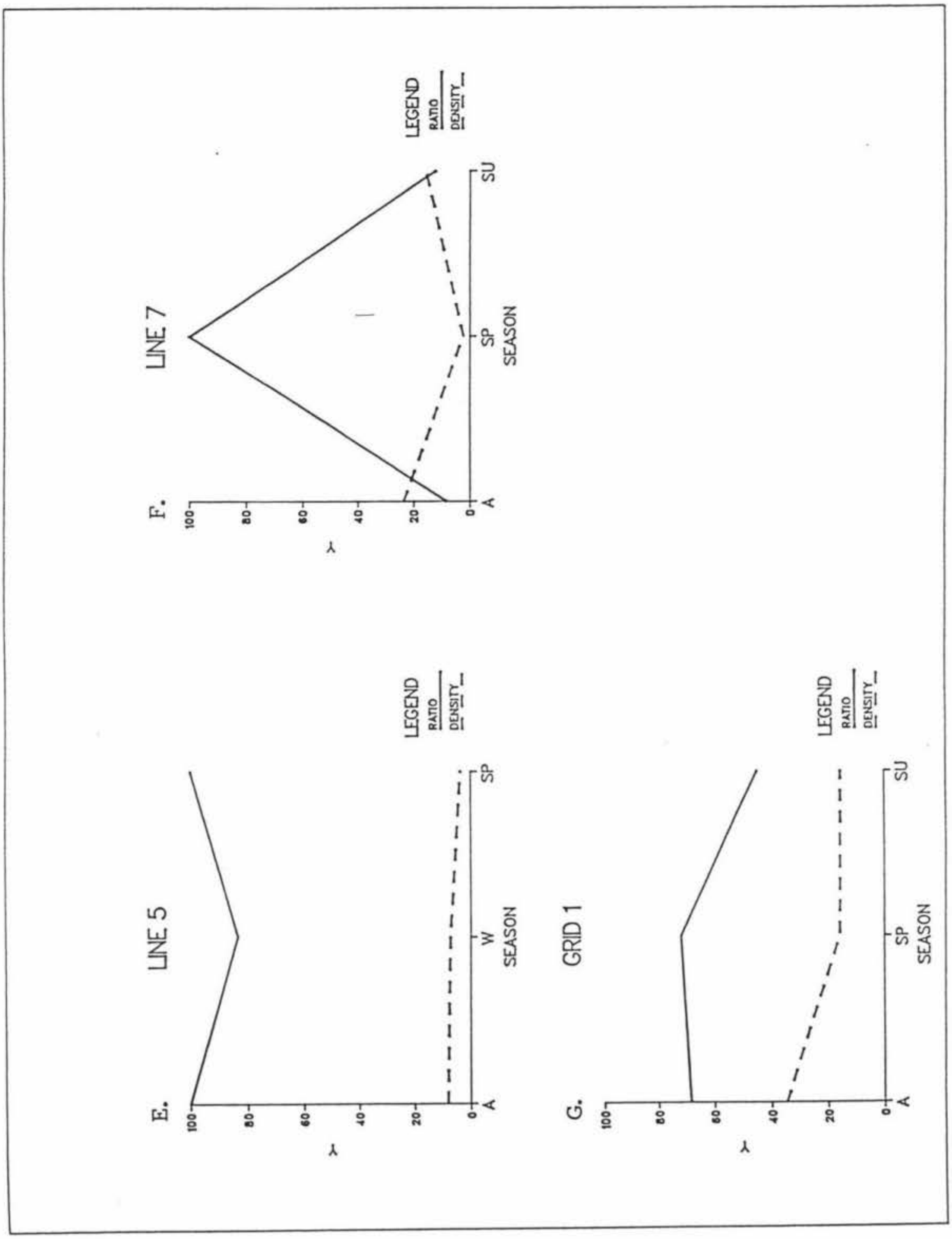
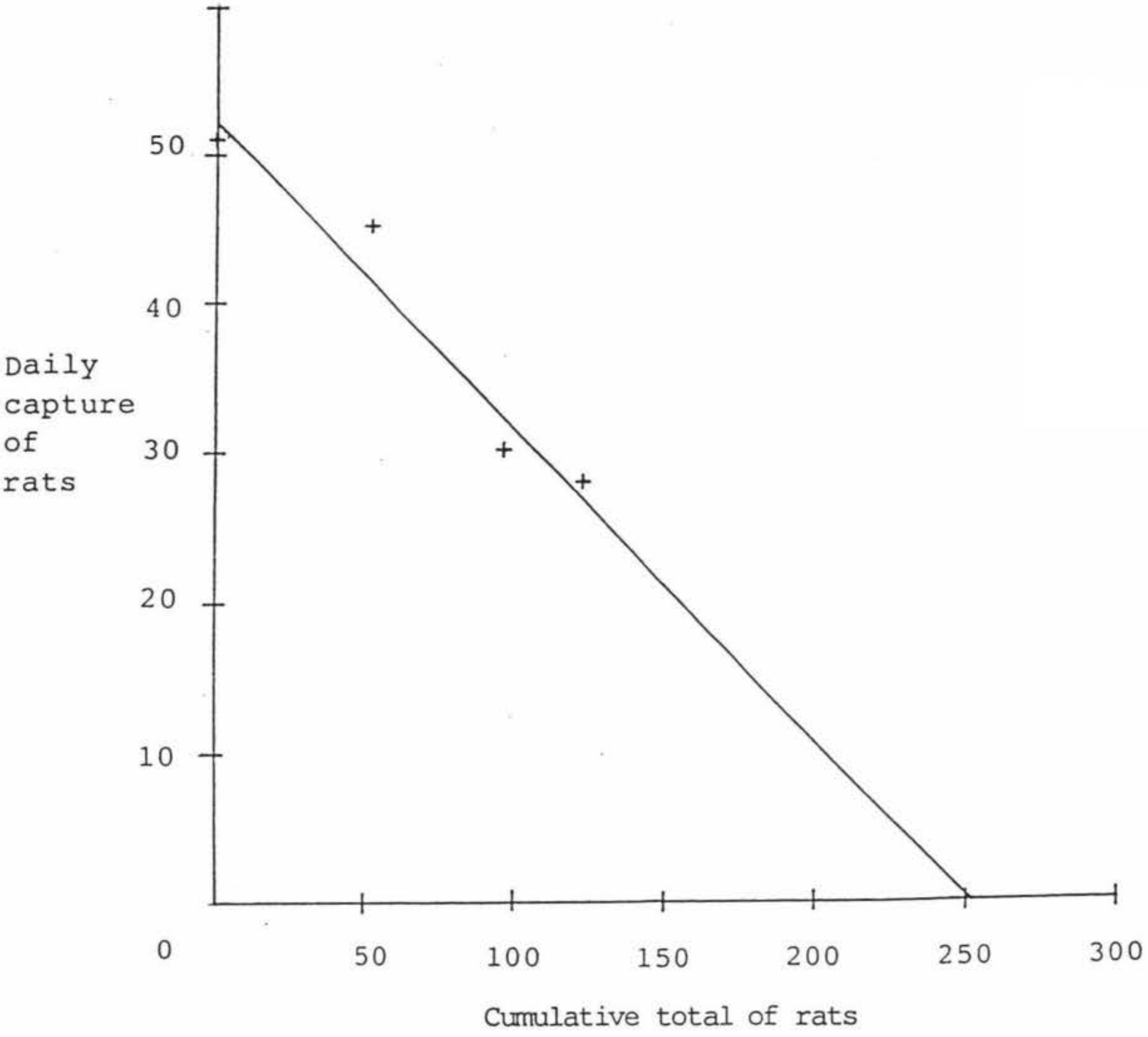

E.
LINE 5
Y
100
80
60
40
20
0
A
W
SP
SEASON
LEGEND
RATIO
DENSITY
F.
LINE 7
Y
100
80
60
40
20
0
A
SP
SU
SEASON
LEGEND
RATIO
DENSITY
G.
GRID 1
Y
100
80
60
40
20
0
A
SP
SU
SEASON
LEGEND
RATIO
DENSITY

FIGURE 4: STANDARD REMOVAL DENSITY ESTIMATE FOR GRID 1



Intercept of y-axis = estimation of rats present within the are = 250.89/4 rats = 62.72/1.1205ha = 61.19 rats/ha.

SEASON	RATS	CAUGHT	PER	DAY
	1	2	3	4
Autumn 83	6	11	11	6
Spring	13	11	2	8
Summer	13	6	6	6
Autumn 84	19	17	11	8
Total	51	45	30	28

caught deviated significantly from unity ($z = 3.20$, $p < .05$). The areas trapped differed largely in their rat species composition, ($\chi^2 = 156.03$, d.f. = 7, $P < .05$; Figure 5, p. 40). Two areas were devoid of kiore, Lines 2 and 6, while no habitat trapped was without Norway rats. Three of the areas trapped, Lines 3, 4 and 7 contained a preponderance of kiore throughout the year. Of the individual areas Grid 1 had the closest ratio to unity as 60% of the rats were Norway.

As with density, species ratio varied with season, (Figure 3, p. 36 & Table 2, p. 41), although seasonal trends were not apparent. Even those areas with major changes in species ratio do not conform to a common seasonal pattern. Line 3 peaked in species ratio in summer while in Line 7 the peak occurred in spring. The winter ratio for Line 1 deviated significantly from the grouped ratio of autumn, spring and summer ($z = 2.37$, $P < .05$). Grid 1 fluctuated from a species ratio of 96.4 in autumn 1983 to 45.5 during summer.

4.1.3 - Correlation between density and species ratio

Visual interpretation of Figure 3 (p. 36) suggests a degree of relatedness between density index in certain areas and species ratio. The interpretation is borne out statistically by Table 3 (p. 41). Those areas having a very high correlation decrease in density as the proportion of kiore within the area drops.

4.1.4 - Density and species ratio of areas trapped once

The three areas trapped once, Lines 9, 10 and 11, were not included in the comparative analysis due to the limited amount of trapping effort involved. Of the three areas the gull colony line

FIGURE 5: TOTAL SPECIES RATIO FOR AREAS TRAPPED MORE THAN ONCE.

Reference line = Total species ratio for all areas combined.

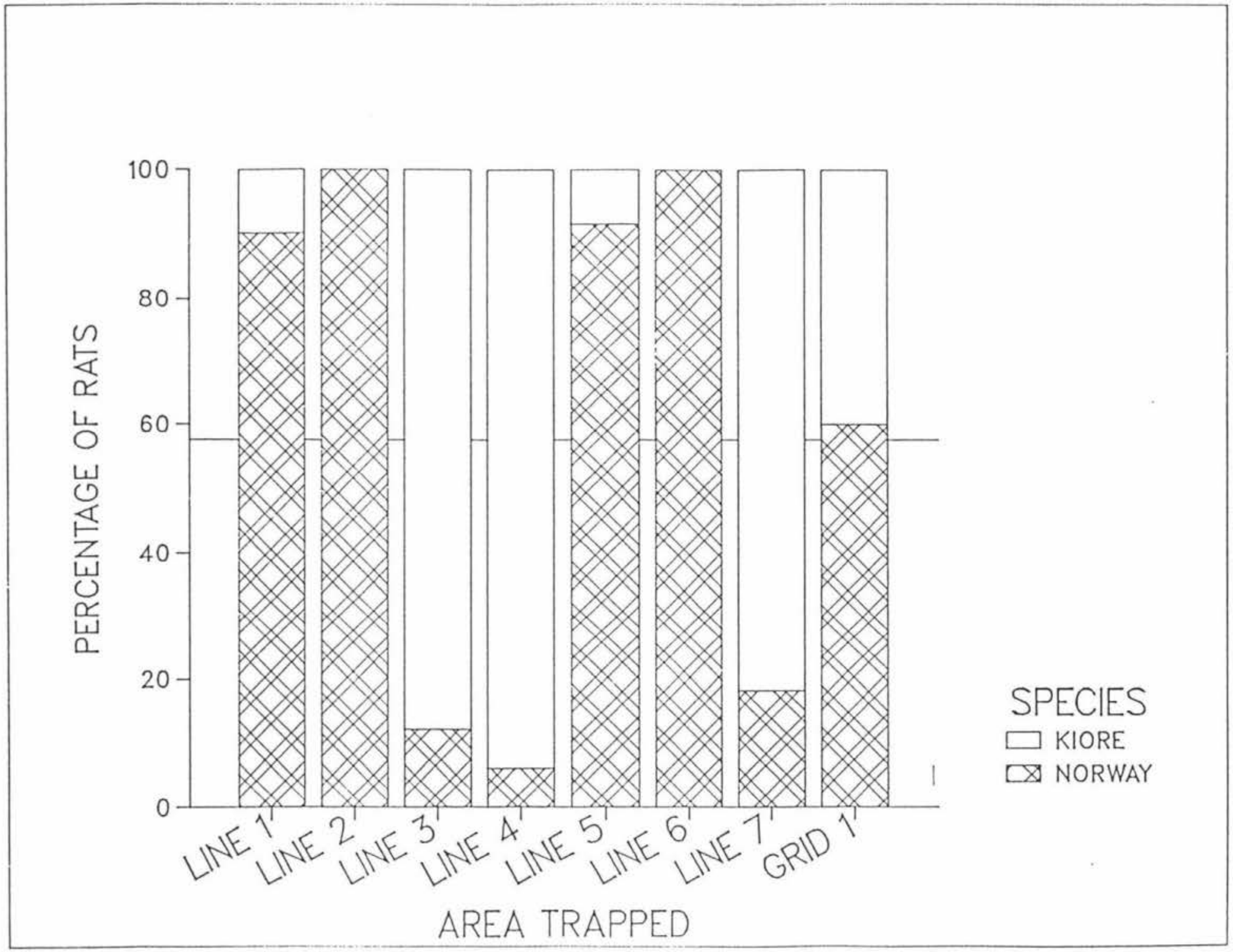

PERCENTAGE OF RATS
100
80
60
40
20
0
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
LINE 6
LINE 7
GRID 1
AREA TRAPPED
SPECIES
☐ KIORE
▨ NORWAY

TABLE 2: SIGNIFICANCE OF SEASONAL CHANGE IN SPECIES RATIO

AREA	χ^2	d.f.	P
L1	9.14	3	$P < .05$*
L2	No difference		
L3	43.34	2	$P < .05$*
L4	5.18	2	$P < .05$
L5	1.09	2	$P < .05$
L6	No difference		
L7	9.95	2	$P < .05$*
G1[1]	3.89	2	$P < .05$

* = Significant.

[1] = Autumn readings combined.

(Ratio = Norway rats to kiore).

TABLE 3: CORRELATION COEFFICIENTS BETWEEN SPECIES RATIO AND DENSITY INDEX FOR SEASONAL CHANGES

AREA	r	DOMINANT RAT SPECIES WITHIN THE AREA
L1	.193	Norway
L2	Not tested	All Norway
L3	-.958	Kiore
L4	-.941	Kiore
L5	-.351	Norway
L6	Not tested	All Norway
L7	-.947	Kiore
G1	.398	Norway

(Line 10) returned the highest corrected density index (40.0 rats/100 trap nights) although this was derived from only 24 trap nights. The shearwater burrows line also showed a high density index (35.29 rats/100 trap nights) but even less trap nights (15) were used. The cliff line (Line 9) returned a density index of 14.97 rats/100 trap nights from 87 trap nights.

Of these areas, kiore were present only on the "Cliff Line" where 3 of the 11 caught were of this species.

4.2 - Morphometrics

The mean weights of rats caught are given in Table 4 (p. 43) and Table 5 (pp. 44-45). Kiore weight differed significantly with sex ($t = 2.10$, $P < .05$) while Norway rat weight did not ($t = 1.00$, $P < .05$).

Size of rat deviates significantly with area for Norway rats Table 5A (p. 44 ; one-way ANOVA, $F = 2.62$, $P < .05$) and for kiore Table 5B (p.45) when kiore weight is subjected to a two-way ANOVA incorporating gender variation (Appendix 6, p.125). Tail length ($\bar{x} = 154.53$mm, $n = 171$, S.D. = 20.22mm) and head body length ($\bar{x} = 180.32$mm, $n = 165$, S.D. = 26.65mm) showed a high degree of correlation with weight, $r = .800$ and $.780$ respectively, for Norway rats. These correlations were not as great for kiore; TL, $\bar{x} = 144.24$mm, $n = 117$, S.D. = 12.73mm, $r = .566$; HBL $\bar{x} = 140.76$mm, $n = 120$, S.D. = 18.43mm, $r = .518$.

Those areas that were trapped more than once were tested to determine if weight changed with season (Table 6, p. 46). Seasonal changes in weight with area are greater for kiore than Norway rats. Of the Norway areas only Line 2 differed

TABLE 4: TOTAL WEIGHT RESULTS

SPECIES	SEX	n	$\bar{x}$ weight(g)	S.D.
Kiore	Both	119	82.48	21.71
K	Male	60	85.92	23.61
K	Female	59	78.98	19.16
Norway	Both	166	215.84	77.68
N	Male	84	209.76	88.26
N	Female	82	222.07	65.06

TABLE 5: AREA WEIGHT DIFFERENCES TESTED BY t TEST AND ANOVA

A. NORWAY RATS

	t value								$\overline{X}$
	AREA								
	L1	L2	L3	L4	L5	L6	L7	G1	
L1		0.04	2.99*	0.01	0.56	1.35	0.51	1.72	203.33
L2			3.02*	0.00	0.59	1.36	0.51	1.60	202.22
L3				1.84	3.30*	4.32*	1.53	5.12*^{1}	89.17
AREA L4					0.30	0.66	0.37	0.61	202.50
L5						0.59	0.84	0.50	220.00
L6							1.34	0.35	236.77
L7								1.42	176.67
G1									230.55
n	27	18	6	2	11	17	3	73	

* = Significant at .05 level.

1 = Pairs of groups significantly different at the .05 level using Scheffe, (ANOVA)

TABLE 5: AREA WEIGHT DIFFERENCES TESTED BY t TEST AND ANOVA

B. KIORE

		t value AREA						$\bar{X}$
		L1	L3	L4	L5	L7	G1	
AREA	L1		0.53	1.71	0.50	0.07	2.39*	83.33
	L3			2.66*	0.01	0.13	2.46*	85.11
	L4				0.87	1.55	4.50*	98.00
	L5					0.03	0.52	85.00
	L7						1.29	83.92
	G1							73.86
	n	3	44	20	1	13	35	

* = significant at .05 level.

No distinction via Scheffe test at .05 level.

For Table 5 pooled variance estimates of t were used unless the F-ratio of between sample variance had a probability of occurrence of less than .05. If that occurred the t value used is derived from separate variance estimates, (Nie _et_ _al_. 1975).

TABLE 6: SEASONAL WEIGHT CHANGES

AREA	SPECIES	MEAN WEIGHT IN GRAMS (n)				F	P
		SEASON					
		A	W	SP	SU		
L1	N	201.25 (8)	175.00 (4)	222.50 (14)	65.00 (1)	1.29	>.05
L2	N	-	222.73 (11)	268.33 (3)	65.00 (3)	13.72	<.05
L3	K	-	75.25 (20)	90.42 (24)	-	12.08	<.05
L4	K	60.00 (3)	71.66 (3)	102.65 (17)	-	28.02	<.05
L5	N	153.33 (3)	258.00 (5)	-	233.33 (3)	2.04	>.05
L6	N	-	195.00 (6)	-	259.55 (11)	3.91	>.05
L7	K	91.25 (8)	-	-	90.00 (4)	1.21	>.05
G1	N	228.75 (44)	-	248.33 (21)	193.75 (8)	2.23	>.05
G1	K	66.32 (19)	-	76.67 (6)	86.50 (10)	3.44	<.05

Tested using One-way ANOVA

significantly in weight with season while of the kiore areas only Line 7 did not differ significantly.

4.3 - Reproduction

4.3.1 - Sex ratio

The ratio of males to females did not differ significantly with area or season for either species, (Table 7, p. 48).

4.3.2 - Age (weight classes)

Comparisons between weight classes are given in Table 8 (p. 49) and Figures 6 (p. 50) and 7 (p. 51). Fluctuations in weight class are greater in kiore. Large kiore were more apparent in spring, smaller kiore in autumn. Larger rats were caught in Lines 7 and 4 while smaller rats predominated in Grid 1.

Although weight class frequency for Norway rats did not alter significantly with area, Line 1 had a large proportion of young animals. Seasonally, small Norway rats become more prevalent during summer and autumn months while the spring and winter frequencies approximate a normal distribution.

Seasonal comparisons can only be made with areas treated individually. In this instance small samples preclude the use of four and five weight classes, so two weight classes are used for each species; above and below the species mean, (Table 9, p.49).

Of the Norway areas only Line 6 shows a significant change in proportion of large to small rats with season. Kiore changes in population age structure are more marked. Of the kiore areas only Line 7, did not differ significantly in its seasonal ratio of

TABLE 7: SEX RATIOS

	NUMBER OF MALES	NUMBER OF FEMALES	TOTAL	d
NORWAY				
AREA				
LINE 1	17	14	31	0.539
LINE 2	9	12	21	0.655
LINE 5	4	7	11	0.905
LINE 6	8	11	19	0.688
GRID 1	38	42	80	0.447
SEASON				
AUTUMN	37	34	71	0.356
WINTER	12	16	28	0.756
SPRING	25	23	48	0.289
SUMMER	17	20	37	0.493
KIORE				
AREA				
LINE 3	23	26	49	0.429
LINE 4	19	9	28	1.880
LINE 7	5	10	15	1.290
GRID 1	18	21	39	0.480
SEASON				
AUTUMN	18	17	35	0.169
WINTER	11	15	26	0.785
SPRING	34	23	57	1.457
SUMMER	7	12	19	1.147

TABLE 8: SIGNIFICANCE OF CHANGES IN WEIGHT (AGE) CLASS

COMPARISON/TEST OF:	χ^2	DF	P
1. Kiore weight class with season	51.15	9	$<.05$
2. Norway rat weight class with season	24.18	12	$<.05$
3. Kiore weight class with area	30.16	6	$<.05$
4. Norway rat weight class with area	24.82	16	$>.05$

TABLE 9: RATIO OF OLD TO YOUNG RATS

AREA	SPECIES	($> \bar{x} : < \bar{x}$) SEASON A	W	SP	SU	STATISTIC	P
L1	N	4:4	3:1	7:7	1:0	$\chi^2 = 1.69$	$>.05$
L2	N	-	4:7	1:3	3:0	$\chi^2 = 4.65$	$>.05$
L3	K	-	14:6	7:17	-	$\chi^2 = 5.75$	$<.05$
L4	K	-	3:0	0:17	-	Fishers Exact	$<.05$
L5	N	3:0	1:4	-	2:1	$\chi^2 = 5.08$	$>.05$
L6	N	-	5:1	-	1:10	Fishers Exact	$<.05$
L7	K	3:5	-	-	2:3	Fishers Exact	$>.05$
G1	N	18:26	-	6:15	4:5	$\chi^2 = 0.93$	$>.05$
G1	K	17:2	-	5:1	3:7	$\chi^2 = 11.86$	$<.05$

FIGURE 6: CHANGES IN WEIGHT CLASS FREQUENCY WITH SEASON:

A = Kiore, B = Norway rats.

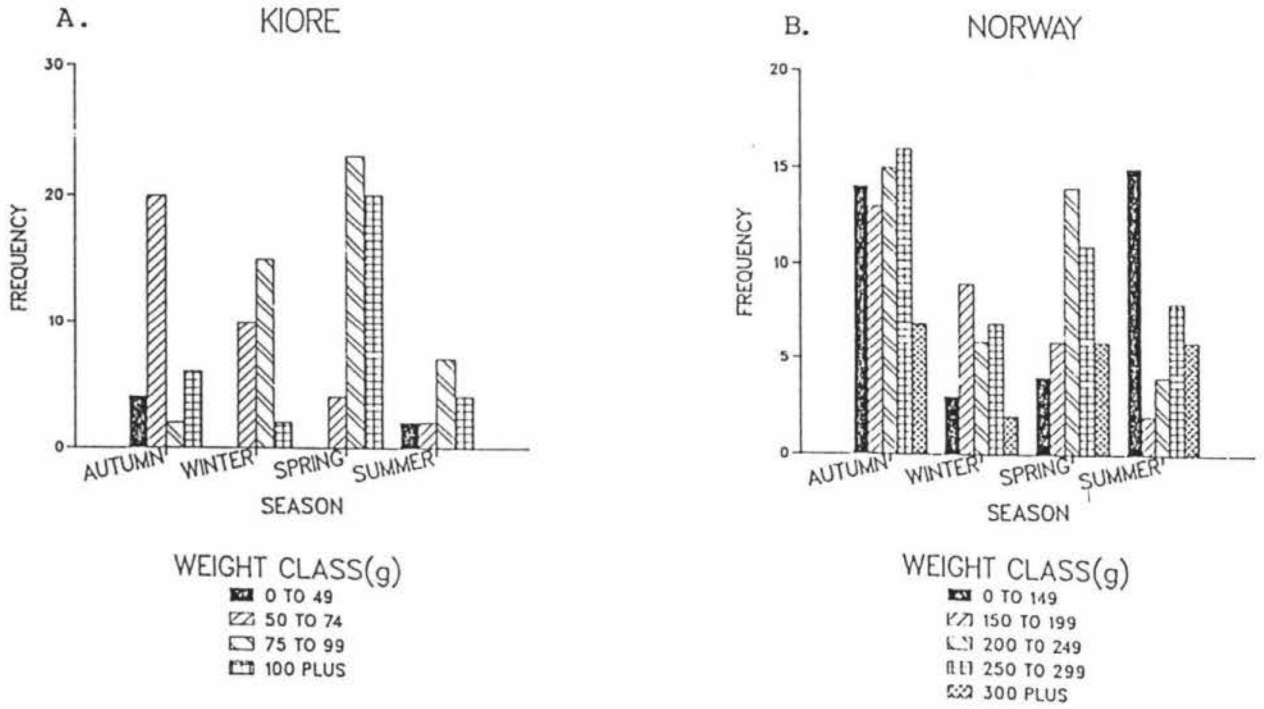

A.
KIORE
FREQUENCY
30
20
10
0
AUTUMN
WINTER
SPRING
SUMMER
SEASON
WEIGHT CLASS(g)
0 TO 49
50 TO 74
75 TO 99
100 PLUS
B.
NORWAY
FREQUENCY
20
15
10
5
0
AUTUMN
WINTER
SPRING
SUMMER
SEASON
WEIGHT CLASS(g)
0 TO 149
150 TO 199
200 TO 249
250 TO 299
300 PLUS

FIGURE 7: CHANGES IN WEIGHT CLASS FREQUENCY WITH AREA:

A = Kiore, B = Norway rats.

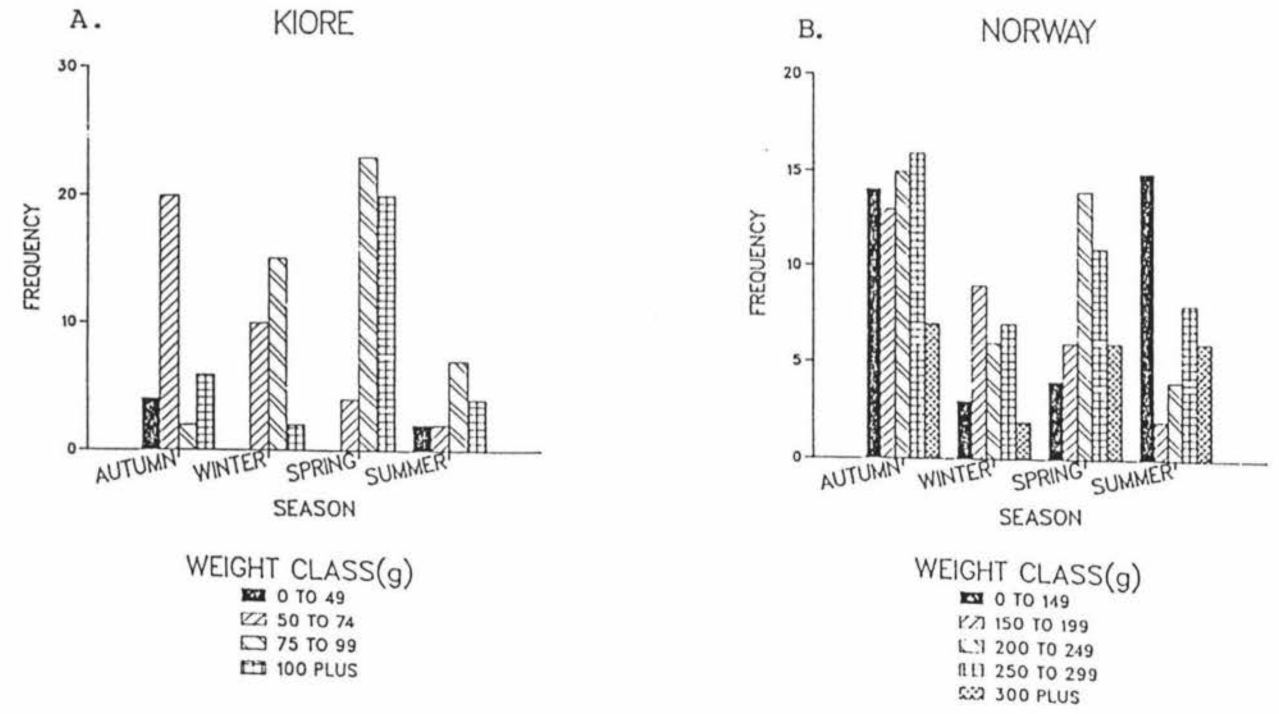
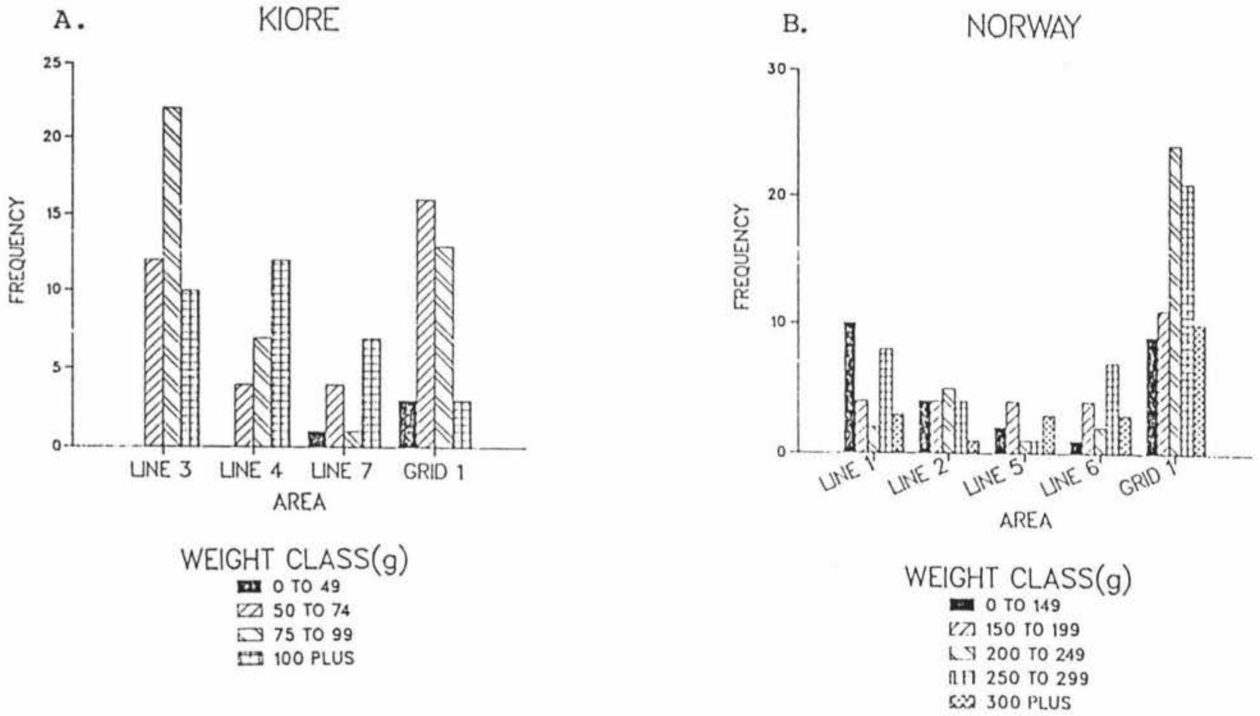

A.
KIORE
30
20
10
0
FREQUENCY
AUTUMN
WINTER
SPRING
SUMMER
SEASON
WEIGHT CLASS(g)
0 TO 49
50 TO 74
75 TO 99
100 PLUS
B.
NORWAY
20
15
10
5
0
FREQUENCY
AUTUMN
WINTER
SPRING
SUMMER
SEASON
WEIGHT CLASS(g)
0 TO 149
150 TO 199
200 TO 249
250 TO 299
300 PLUS

FIGURE 7: CHANGES IN WEIGHT CLASS FREQUENCY WITH AREA:

A = Kiore, B = Norway rats.


A.
KIORE
25
20
15
10
5
0
FREQUENCY
LINE 3
LINE 4
LINE 7
GRID 1
AREA
WEIGHT CLASS(g)
0 TO 49
50 TO 74
75 TO 99
100 PLUS
B.
NORWAY
30
20
10
0
FREQUENCY
LINE 1
LINE 2
LINE 5
LINE 6
GRID 1
AREA
WEIGHT CLASS(g)
0 TO 149
150 TO 199
200 TO 249
250 TO 299
300 PLUS

large to small rats.

4.3.3 - Reproductive activity

Seasonal changes in sexual condition are plotted in Figure 8, (p. 53). Norway rats displayed a summer peak in pregnancies and an autumn low. Pregnant Norway rats were trapped in all seasons. Kiore showed an increase in breeding activity over spring culminating in summer before declining to non-existence in winter.

Only six of the 65 female kiore examined were pregnant. The mean litter size was 4.66 rats, S.D. = 1.36. 11 kiore females had placental scars with a mean scar number of 6.73 (S.D. = 4.54). Of the 88 female Norway rats examined 17 were pregnant and had a mean foetus number of 7.52 (S.D. = 1.68). 39 females possessed scars and had a mean of 17.26 placental scars (S.D. = 11.94). An estimation of average female annual productivity can be derived from other reproductive parameters, (Emlen and Davis 1948). To do this the frequency of litters/female/year is calculated by,

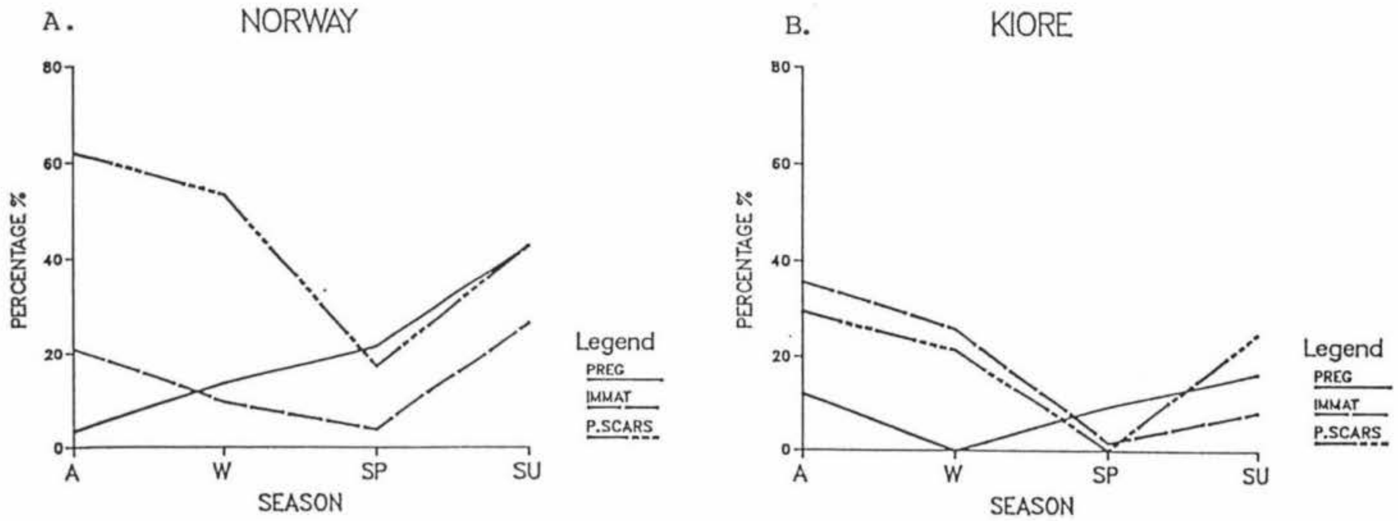
$$\frac{\text{Incidence of pregnancy x length of breeding season}}{\text{duration of visible pregnancy.}}$$

The incidence of pregnancy figure is the proportion of mature females pregnant within a population, the length of breeding season is the number of days from first recorded pregnancy to last recorded pregnancy and the duration of visible pregnancy is taken as 18 days for both rat species (Emlen and Davis 1948, Moller and Craig in press). The incidence of pregnancy is .32 for Norway rats, .18 for kiore. Length of breeding season is taken at 251 days for Norway rats and 139 for kiore (Appendix 7, p. 126). Hence, on average, a mature female Norway rat will have 4.46 litters/year while for kiore the value is 1.39. Multiplying these

FIGURE 8: SEASONAL CHANGES IN REPRODUCTIVE PARAMETERS

A = Norway rats, B = Kiore.

Preg = females pregnant, immat = rats immature, P.Scars = females with placental scars.


A.
NORWAY
PERCENTAGE %
80
60
40
20
0
A
W
SP
SU
SEASON
Legend
PREG
IMMAT
P.SCARS
B.
KIORE
PERCENTAGE %
80
60
40
20
0
A
W
SP
SU
SEASON
Legend
PREG
IMMAT
P.SCARS

figures by the mean foetus numbers of pregnant rats gives the annual productivity of 33.54 and 6.48 for Norway rats and kiore respectively.

4.3.4 - Maturity

Immature rats did not feature heavily in the populations, (Figure 8, p. 53). Considerable overlap occurred in the size of immature and mature rats for both species. Immature Norway rats weighed 40 to 200 grams ($\bar{x}$ = 123.12) while mature rats ranged from 105 to 400 grams ($\bar{x}$ = 244.12). Immature kiore recorded weights of 35 to 75 grams ($\bar{x}$ = 60.87) and mature kiore ranged from 30 to 150 grams ($\bar{x}$ = 89.69).

4.4 - Diet

320 stomachs were examined. Unexamined stomachs were the result of rats being scavenged or tails and feet only being caught. Twenty-four stomachs examined were empty or had contents of bait only and another 18 were ruptured on removal from the carcass and could not be sieved in the standard manner. These last two classes of stomachs were excluded from analysis.

The use of eight food categories becomes superfluous in hindsight. Only three food categories, besides bait, were consistently represented in the diet in reasonable quantities; invertebrate, vegetation and seed, (Tables 10, p.55 & 11, p.56).

4.4.1 - Invertebrates

Invertebrates dominated kiore diet in volume and frequency (Tables 10, p. 55 & 11, p. 56). Norway rats often ate invertebrates but the average volume eaten was not as great as

TABLE 10: DIET PERCENTAGE OCCURRENCE RESULTS FOR SPECIES AND AREA

SPECIES	N	K	N	N	K	K	N	N	K	N	K
AREA	All	All	L1	L2	L3	L4	L5	L6	L7	G1	G1
DIET ITEM	% OCCURRENCE										
INVERTEBRATE	81	98	88	100	100	96	100	83	100	73	97
VERTEBRATE	16	2	17	13	5	7	17	11	0	10	0
VEGETATION	57	43	50	75	52	61	33	83	14	49	30
ROOT	3	3	3	4	6	7	4	0	0	0	0
WOOD	5	3	4	6	7	4	17	0	0	3	0
UNIDENTIFIED	13	15	21	25	23	21	33	6	14	10	0
SEED/FRUIT	62	52	38	50	39	46	17	67	14	79	92
n	143	127	24	16	44	28	6	18	14	73	37

TABLE 11: DIET PERCENTAGE VOLUME RESULTS FOR SPECIES AND AREA

	FOOD CATEGORY: MEAN % VOLUME						
	Invertebrate	Vert	Veget	Root	Wood	Unid	Seed
SPECIES							
NORWAY	27.65	4.41	18.86	0.94	1.09	3.21	36.46
KIORE	66.90	0.43	4.33	0.36	0.04	2.79	19.71
AREA							
LINE 1 (Norway)	38.73	8.31	14.77	0.50	0.10	9.25	20.10
LINE 2 (Norway)	33.60	1.34	32.72	1.78	2.80	9.96	11.55
LINE 3 (Kiore)	82.55	1.73	3.32	0.15	0.10	2.51	4.89
LINE 4 (Kiore)	68.43	0.32	6.90	1.43	0.03	4.43	16.52
LINE 5 (Norway)	62.48	5.32	2.06	0.00	16.00	5.17	1.61
LINE 6 (Norway)	27.37	0.20	29.11	0.00	0.00	0.00	39.11
LINE 7 (Kiore)	77.24	0.00	2.99	0.00	0.00	4.47	2.48
GRID 1 (Norway)	21.76	4.16	15.36	0.00	0.02	0.92	54.87
GRID 1 (Kiore)	43.86	0.00	3.20	0.00	0.00	0.00	47.57

that of seed. Lepidopteran larvae were the most common form of invertebrate eaten by both rat species (Figure 9, p. 58). Eighty of 143 Norway rat stomachs examined contained at least one of the seventeen distinguishable types of larvae, whereas out of 127 kiore stomachs, 106 had lepidopteran larvae in them. The variety of lepidopteran larvae eaten by kiore was greater than the variety eaten by Norway rats (Table 12A, pp. 59-60). Caterpillars, as well as spiders and wetas, found in rat stomachs were typified by a lack of hard body parts. Spiders and dipterans followed by wetas then coleopterans were the next most frequent categories of invertebrates found in Norway rat stomachs. In kiore stomachs, spiders were the second most common invertebrate class followed by Diptera then wetas. Centipedes occurred more frequently in kiore stomachs than did coleopterans.

Some spider remains were further identified as ground dwelling (Mygalomorph) or web-spinning (non-Mygalomorph). Legs and abdomen of spiders were eaten but rarely head or thorax. Small, brown, spider eggs occurred occasionally in stomachs. A wide variety of dipteran larvae and some dipteran adults were eaten. Both forms of weta, cave and tree, were collected from rat stomachs. Colouration and scraper patterns were helpful identification features in lieu of head capsules and mandibles. Carabidae were predominant among the coleopteran fraction for both Norway rats and kiore. The centipedes found in kiore stomachs were probably geophilomorphs as opposed to lithobiomorphs, (McColl 1981). Frequencies of other invertebrate forms found in the stomach are given in Table 12A (pp. 59-60).

4.4.2 - Foliate vegetation

FIGURE 9: FREQUENCY OF OCCURRENCE OF NINE MAJOR FOOD ITEMS FOR BOTH RAT SPECIES

Lepidop = Lepidoptera, Coleop = Coleoptera, n.veg = vegetation, ex.veg = exotic vegetation, n. seed = native seed, ex.seed = exotic seed.

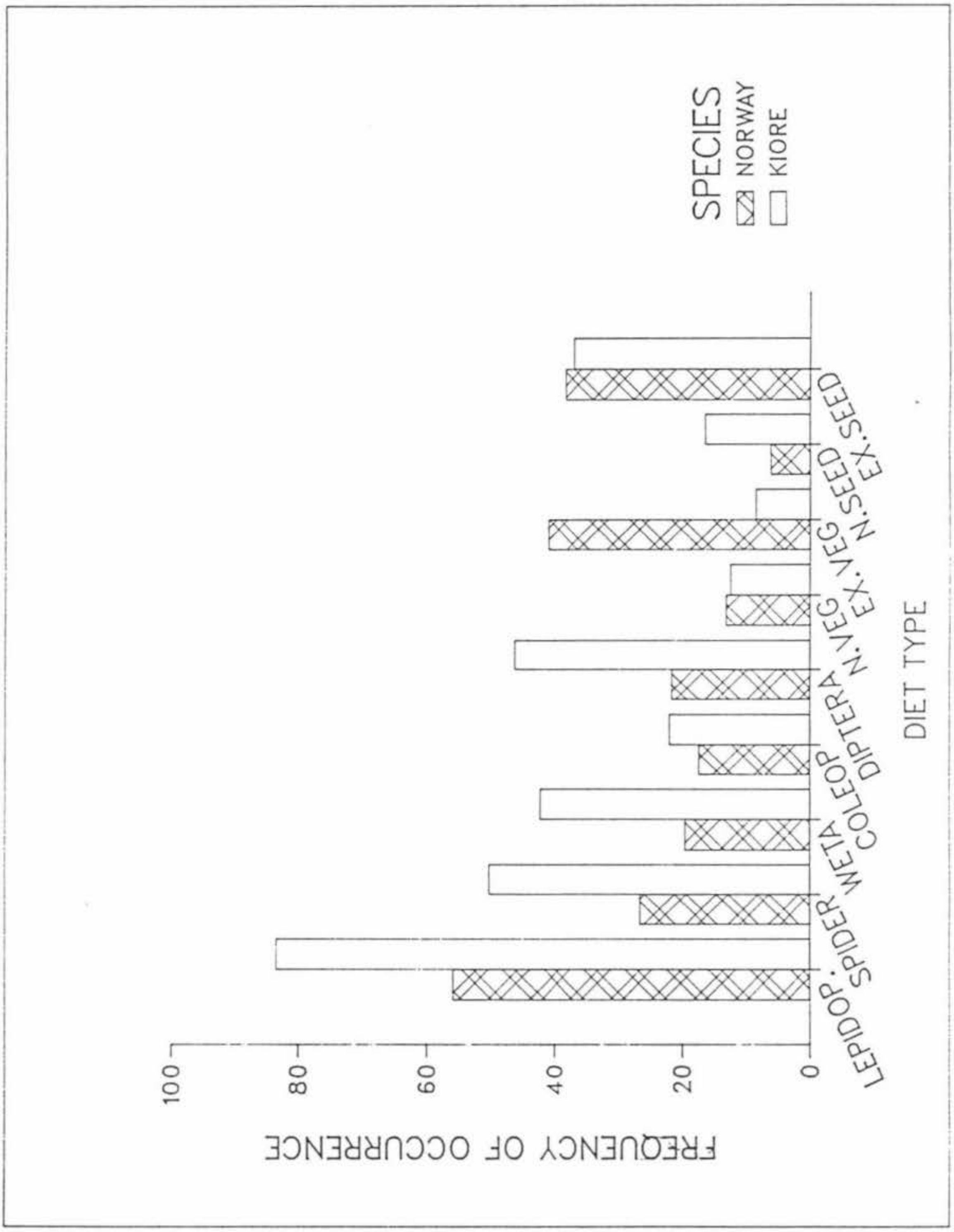

FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP.
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ NORWAY
□ KIORE

TABLE 12A: FREQUENCY OF OCCURRENCE OF INVERTEBRATE FOOD ITEMS

SPECIES	N	K	N	N	K	K	N	N	K	N	K
AREA	All	All	L1	L2	L3	L4	L5	L6	L7	G1	G1
FOOD ITEM											
LEPIDOPTERA LARVAE											
Unidentified	11	6	3	2	3	2	–	–	–	6	–
Type A	3	35	2	–	27	4	–	–	3	–	1
Type B	18	27	–	4	6	9	–	1	1	13	11
Type C	14	9	2	–	1	2	–	1	–	11	6
Type D	18	11	1	4	4	3	2	4	–	6	2
Type E	2	7	–	–	3	–	1	–	2	1	–
Type F	10	18	4	–	8	6	–	2	1	1	3
Type G	11	9	2	–	2	–	–	5	1	4	6
Type H	2	12	1	–	6	5	1	–	1	–	–
Type I	–	4	–	–	2	2	–	–	–	–	–
Type J	1	3	–	–	–	–	–	–	1	1	2
Type K	–	1	–	–	–	–	–	–	1	–	–
Type L	–	3	–	–	–	–	–	–	3	–	–
Type M	4	10	–	1	–	–	1	–	3	–	5
Type N	–	2	–	–	–	1	–	–	–	–	1
Type O	1	–	–	–	–	–	–	–	–	–	–
Type P	1	5	–	–	–	–	1	–	–	–	5
Type Q	2	2	–	–	1	1	–	–	–	2	–
Total	98	154	14	11	61	35	6	13	17	43	42
ARANEIDA											
Unidentified	33	46	7	7	16	7	1	1	6	12	12
Mygalomorph	4	11	1	1	3	2	1	–	2	–	1
non-Mygalomorph	1	8	–	–	2	2	–	–	2	–	2
Total	38	65	8	8	21	11	2	1	10	12	15
ORTHOPTERA											
Unidentified	18	30	2	3	12	13	–	2	3	8	2
Stenopelmatidae	8	7	1	–	8	1	–	2	2	2	–
Rhapidophoridae	2	14	–	–	4	4	1	–	2	–	1
Total	28	51	3	3	24	18	1	4	7	10	3
COLEOPTERA											
Unidentified	11	7	3	1	2	3	2	1	1	4	–
Carabidae	12	14	1	1	3	3	–	–	–	10	6
Scrabidae	1	7	–	–	4	4	–	1	–	–	1
Elateroidea	1	1	–	–	–	1	–	1	–	–	–
Curculionidae	–	1	–	–	1	–	–	–	–	–	–
Total	25	30	4	2	10	11	2	3	1	14	7

TABLE 12A CONTINUED

SPECIES	N	K	N	N	K	K	N	N	K	N	K
AREA	All	All	L1	L2	L3	L4	L5	L6	L7	G1	G1
FOOD ITEM											
DIPTERA											
Unidentified	2	11	-	-	6	4	-	1	-	-	1
Tipulidae larvae A.	2	14	2	-	11	-	-	-	-	-	-
Tipulidae larvae B.	-	2	-	-	1	-	-	-	-	-	-
Tipulidae larvae C.	12	20	-	-	4	10	-	-	-	11	4
Brachycera Syrphidae	1	-	-	-	-	-	-	1	-	-	-
Coleopidae adult	7	1	-	-	-	1	-	4	-	-	-
Brachycera larvae B.	1	1	-	-	-	-	1	-	-	-	1
Brachycera larvae C.	-	1	-	-	-	-	-	-	-	-	1
Dipteran larvae A.	1	-	-	-	-	-	-	-	-	-	-
Dipteran larvae B.	1	-	-	-	-	-	-	-	-	-	-
Nematoceran larvae	-	5	-	-	4	-	-	-	-	-	-
Brachyera larvae D.	6	15	2	2	6	9	-	1	-	-	-
Dipteran larvae C.	2	5	-	-	2	-	-	-	1	-	1
Tipulidae adult	-	3	-	-	-	-	-	-	1	-	1
Unidentified larvae	1	6	-	-	5	-	-	1	1	-	-
Unidentified adult	-	1	-	-	-	-	-	-	-	-	1
Tipulidae larvae D.	2	-	2	-	-	-	-	-	-	-	-
Total	38	85	6	2	42	24	1	8	3	11	10
COLLEMBOLA	4	1	2	1	1	-	-	1	-	-	-
OPILIONE	1	2	-	-	1	-	-	-	1	-	-
CHILOPODA	5	35	1	-	17	9	1	-	2	1	4
MEGASCOLECIDAE	6	14	4	-	12	1	1	1	1	-	-
THYSANURA	1	-	-	-	-	-	-	-	-	1	-
HYMENOPTERA	2	-	-	-	-	-	-	-	-	2	-
BLATTODEA	2	1	-	-	-	1	-	-	-	2	-
MOLLUSCA	4	-	3	-	-	-	-	1	-	-	-
HEMPITERA	1	2	-	-	-	1	-	1	-	-	-
AMPHIPODA	2	1	-	-	-	1	1	-	-	-	-
UNIDENTIFIED	16	13	1	3	2	4	3	3	2	2	4

TABLE 12B: FREQUENCY OF OCCURRENCE OF SEED FOOD ITEMS

SPECIES	N	K	N	N	K	K	N	N	K	N	K
AREA	All	All	L1	L2	L3	L4	L5	L6	L7	G1	G1
FOOD ITEM											
Pseudopanax spp.	-	1	-	-	1	-	-	-	-	-	-
Oxtongue	1	-	-	-	-	-	-	-	-	1	-
Unid. 62	2	-	-	1	-	-	1	-	-	-	-
Prairie grass	45	20	-	-	-	-	-	1	-	44	20
Unid. grass	1	1	-	-	1	-	-	-	-	1	-
Kohekohe	4	16	2	-	9	4	-	1	1	-	1
Unid. weed	1	1	-	1	1	-	-	-	-	-	-
Sweet vernal	3	9	-	2	9	-	-	-	-	1	-
Vicia spp.	3	-	-	-	-	-	-	3	-	-	-
Yorkshire fog	2	4	-	-	-	-	-	1	1	1	3
Rumex acetosella	3	-	-	-	-	-	-	2	-	1	-
Sonchus spp.	1	-	-	-	-	-	-	1	-	-	-
Medicago spp.	1	-	-	1	-	-	-	-	-	-	-
CARYOPHYLLACEAE	3	3	-	-	-	1	-	-	-	3	2
Poroporo	10	6	-	-	-	-	-	1	-	9	6
Unid. native	6	-	6	-	-	-	-	-	-	-	-
Geranium molle	2	-	-	-	-	-	-	2	-	-	-
Fruit like	7	9	-	-	-	1	2	1	3	2	4

TABLE 12C: FREQUENCY OF OCCURRENCE OF PLANT FOOD ITEMS

SPECIES	N	K	N	N	K	K	N	N	K	N	K
AREA	All	All	L1	L2	L3	L4	L5	L6	L7	G1	G1
FOOD ITEMS											
Unid. fern	1	-	-	1	-	-	-	-	-	-	-
Blechnum spp.	1	-	-	-	-	-	-	1	-	-	-
Asplenium spp.	1	-	-	-	-	-	-	1	-	-	-
Kanuka	9	12	-	-	4	8	-	1	-	6	-
Kamahi	-	1	-	-	1	-	-	-	-	-	-
Lemonwood	1	-	-	-	-	-	-	-	-	1	-
Kawakawa	2	-	-	-	-	-	-	-	-	2	-
Cyathodes spp.	2	1	-	-	-	-	-	-	-	2	1
Cassinia spp.	-	1	-	-	1	-	-	-	-	-	-
Meuehlenbeckia	1	1	-	-	-	-	-	1	-	-	1
Titoki	1	-	-	1	-	-	-	-	-	-	-
Aquatic veg.	1	-	-	-	-	-	-	1	-	-	-
Unid. weed	4	-	-	1	-	-	-	1	-	2	-
Clover	12	-	-	4	-	-	-	3	-	2	-
Chickweed	1	-	-	-	-	-	-	-	-	-	-
Senecio spp.	2	1	-	-	-	1	-	1	-	1	-
Vicia spp.	-	1	-	-	-	1	-	-	-	-	-
Plantago spp.	1	-	-	-	-	-	-	1	-	-	-
Moss	3	7	1	1	5	-	-	-	2	-	-
Cocksfoot	1	-	-	-	-	-	-	-	-	1	-
Prairie grass	5	-	-	-	-	-	-	2	-	2	-
Tall fescue	5	1	-	2	-	-	-	-	-	3	1
Yorkshire fog	2	-	-	-	-	-	-	1	-	-	-
Ryegrass	5	-	-	-	-	-	-	-	-	2	-
Uncinia spp.	2	-	-	-	-	-	-	-	-	2	-
Unid. grass	15	1	1	6	1	1	-	-	-	8	-
Unid. plant	10	4	3	2	3	1	-	2	-	3	-

Of the three main diet categories vegetation occurred less often and had a lower mean percentage volume than either invertebrate or seed for both rat species, (Tables 10, p. 55 & 11, p. 56) although it was a much larger proportion of diet in Norway rats than in kiore. In both rat species native vegetation, other than kanuka, was not a feature of the plant fraction. Grasses and weeds characterised the fraction, especially in Norway rats. Identifiable forms of vegetation are given in Table 12C (p. 62).

4.4.3 - Seed and fruit

A variety of seed and fruit was found in the stomachs examined Table 12B (p. 61). Exotic grassland species dominated although kohekohe and poroporo (Solanum aviculare) seeds appeared conspicuously in kiore and Norway rats respectively. Prairie grass seed was a common food item in Grid 1 rat stomachs. Fruit remains were typified by a lack of identifiable features and by seasonal occurrence. They were found in rats caught only in summer and autumn months.

Other evidence of fruit being eaten was obtained. Chewed karaka berries were found hoarded under old corrugated iron lying 25m north of the Kahikatea Stream. This hoarding behaviour is typical of Norway rats (Calhoun 1962, Pye and Bonner 1980). Similarly, poroporo fruit were found hoarded underneath corrugated iron in the lower Waiorua Valley. Partly eaten fruit of native passionvine fruit was found midway up the McKenzie track in June although it is difficult to be certain that rats had been responsible. Likewise a collection of old hinau nuts found neatly pierced in the upper Kahikatea Valley suggests a kiore husking station similar to those described by Campbell (1978).

4.4.4 - Other categories

There was a marked difference between the occurrence of vertebrates in Norway rat and kiore stomachs (Table 10, p. 55). Bird remains were found in eight Norway rat stomachs but in no kiore. Skink, Leiolopisma spp. were present in five Norway rats and one kiore. The remainder of the vertebrate fraction was made up of scavenged possum or rat. Unidentified diet items, although often present in stomachs, were never a large component of the diet (Tables 10, p. 55 & 11, p. 56).

4.4.5 - Diet analysis, species differences

The percentage volume of diet (invertebrate, vegetation and seed) is significantly different for the two rat species on Kapiti Island (Figure 11G, p. 67 & Appendix 9A, p. 128). The invertebrate fraction contributes most to the variation between species. Frequency of occurrence information reiterates the difference between species, when nine classes of food; Lepidoptera, Coleoptra, Orthoptera, Diptera, Araneida, native and exotic vegetation, and native and exotic seed, are compared, $\chi^2 = 61.28$, d.f. = 8, $P < .05$, (Figure 9, p. 58).

4.4.6 - Diet analysis, area differences

Comparisons were made between the diet of rats caught in different areas, (Figure 10, pp. 65-66 , Figure 12, p. 68 , Appendix 8, p. 127 & Appendix 9 K & L, p. 130). The % volume results differ significantly for each species. The variation in diet for Norway rats between areas was due to changes in seed volume and to a lesser extent changes in vegetation volume. Grid 1 stomachs contributed most to the seed variation while Line 5 was of note

FIGURE 10: FREQUENCY OF OCCURRENCE OF NINE MAJOR FOOD ITEMS

IN:

A = Line 1, B = Line 2, C = Line 3, D = Line 4, E = Line 5, F = Line 6, G = Line 7, H = Grid 1.

Abbreviations as for Figure 9. N = Norway rat, K = Kiore.

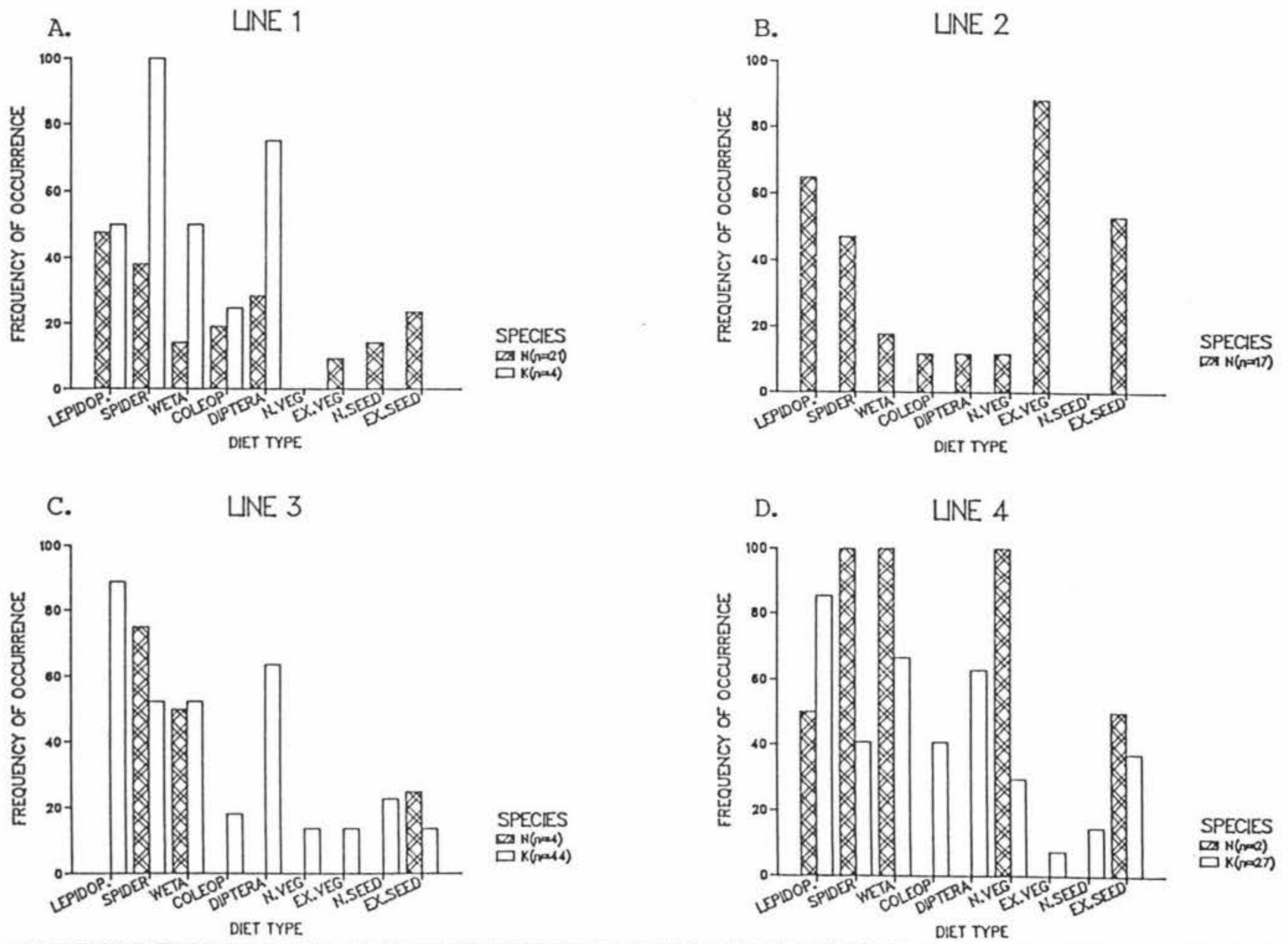

A.
LINE 1
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=21)
☐ K(n=4)
B.
LINE 2
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=17)
C.
LINE 3
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=4)
☐ K(n=44)
D.
LINE 4
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=2)
☐ K(n=27)

FIGURE 10: CONTINUED

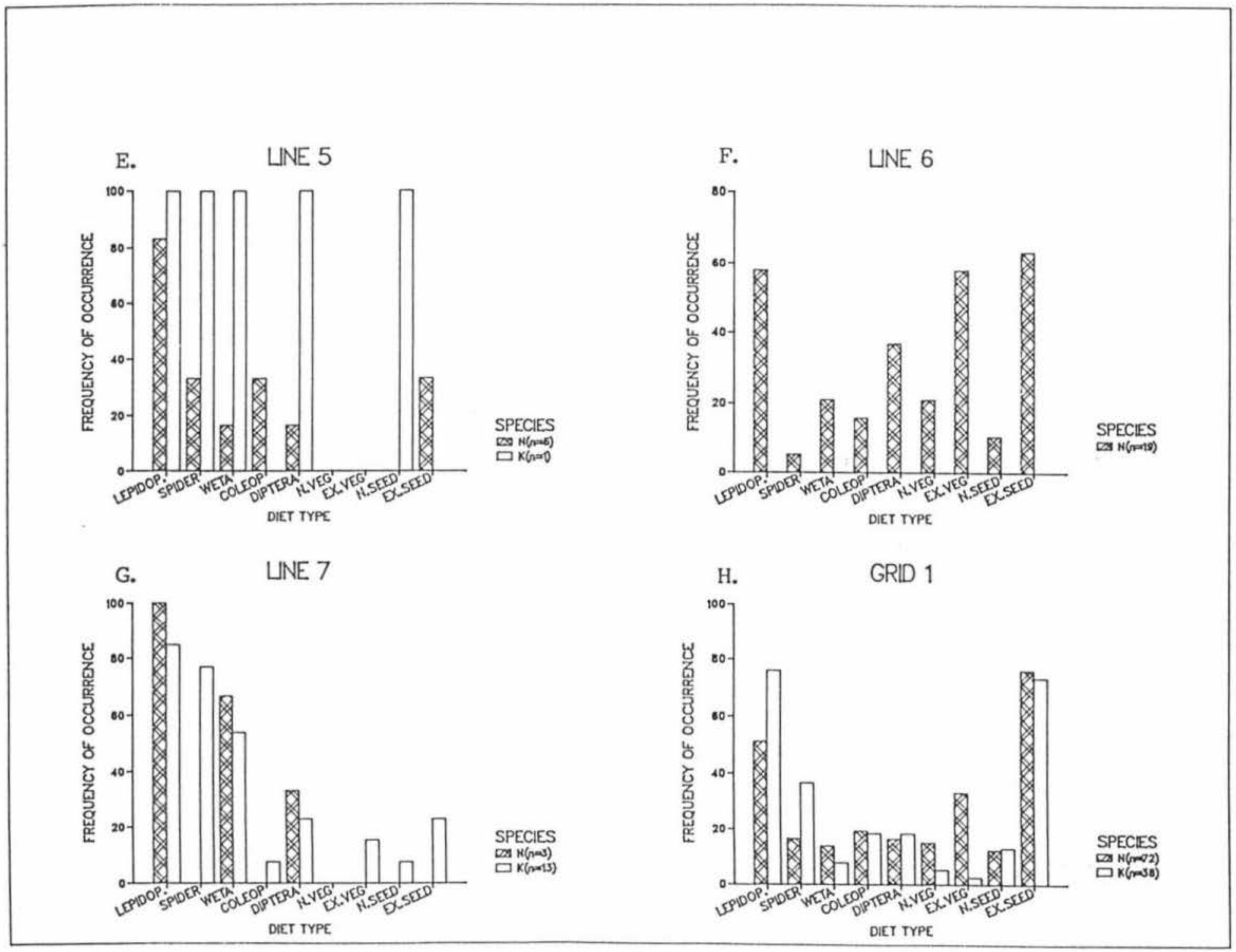

E.
LINE 5
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=6)
☐ K(n=1)
F.
LINE 6
FREQUENCY OF OCCURRENCE
0
20
40
60
80
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=19)
G.
LINE 7
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=3)
☐ K(n=13)
H.
GRID 1
FREQUENCY OF OCCURRENCE
0
20
40
60
80
100
LEPIDOP.
SPIDER
WETA
COLEOP
DIPTERA
N.VEG
EX.VEG
N.SEED
EX.SEED
DIET TYPE
SPECIES
▨ N(n=72)
☐ K(n=38)

FIGURE 11: DIFFERENCES IN THE VOLUMES OF INVERTEBRATE, SEED AND VEGETATION EATEN DISPLAYED AS DISCRIMINANT FUNCTION AXES FOR:

A = Kiore trapped seasonally in Grid 1.

B = Kiore trapped seasonally in Line 4.

C = Kiore trapped seasonally in Line 3.

D = Norway rats trapped seasonally in Grid 1.

E = Norway rats trapped seasonally in Line 2.

F = Norway rats trapped seasonally in Line 1.

G = Norway rats and kiore.

X Axis = 1st significant function, Y Axis = 2nd significant function (see Appendix 9 pp. 128-130).

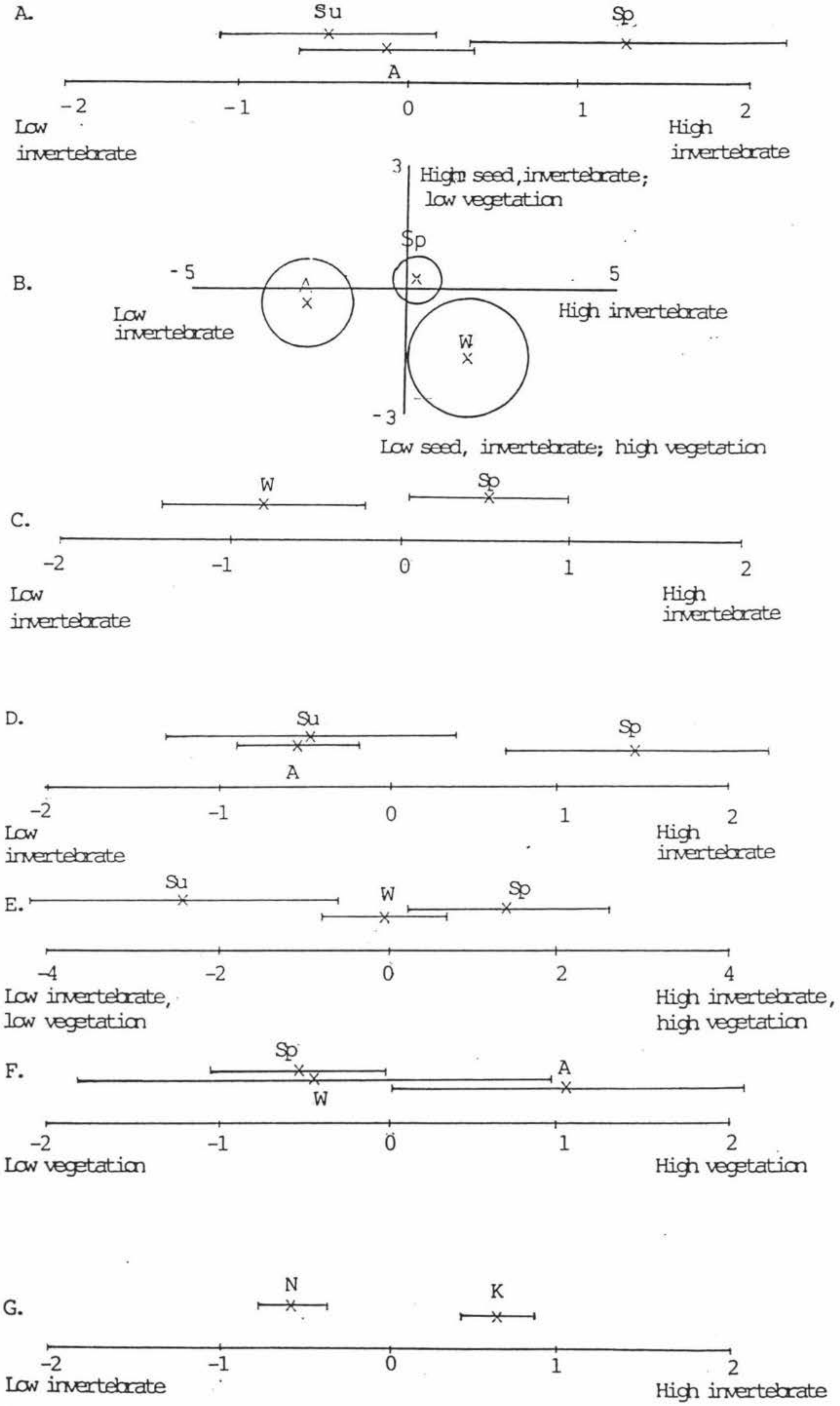
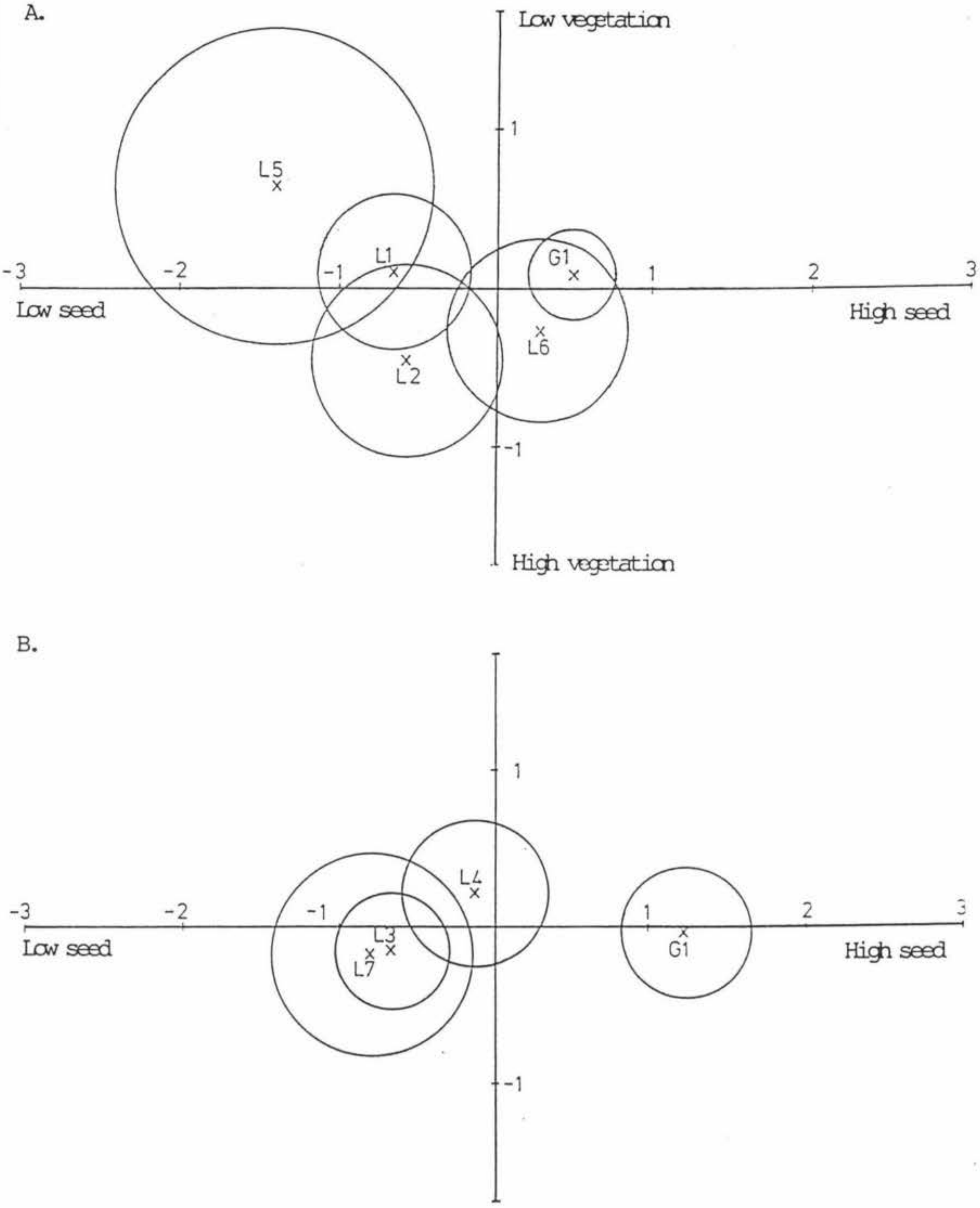

A.
Su
Sp
A
-2
-1
0
1
2
Low invertebrate
High invertebrate
B.
3
High seed, invertebrate; low vegetation
Sp
-5
5
A
W
Low invertebrate
High invertebrate
-3
Low seed, invertebrate; high vegetation
C.
W
Sp
-2
-1
0
1
2
Low invertebrate
High invertebrate
D.
Su
Sp
A
-2
-1
0
1
2
Low invertebrate
High invertebrate
E.
Su
W
Sp
-4
-2
0
2
4
Low invertebrate, low vegetation
High invertebrate, high vegetation
F.
Sp
A
W
-2
-1
0
1
2
Low vegetation
High vegetation
G.
N
K
-2
-1
0
1
2
Low invertebrate
High invertebrate

FIGURE 12: DIFFERENCES IN THE VOLUMES OF INVERTEBRATE, SEED AND VEGETATION EATEN DISPLAYED AS DISCRIMINANT FUNCTION AXES FOR:

A = Norway rats in Norway rat areas.

B = Kiore in kiore areas.

(see page 33 , Appendix 9 pp.128-130).


A.
Low vegetation
High vegetation
Low seed
High seed
-3
-2
-1
1
2
3
1
-1
L5
L1
L2
L6
G1
B.
Low seed
High seed
-3
-2
-1
1
2
3
1
-1
L4
L3
L7
G1

with unusually low vegetation volumes. Variation in kiore areas was due primarily to changes in seed volume and, as for Norway rats, this change was accentuated by the diet of Grid 1 rats.

The frequency of occurrence information confirms % volume results. Kiore areas differed significantly from one another in occurrence of Lepidoptera, Coleoptera, Diptera, Orthoptera, Araneida, vegetation and seed, $x^2 = 5.67$, d.f. = 18, $P < .05$, while Norway rat areas differed significantly from one another in occurrence of Lepidoptera, Araneida, vegetation and seed, $x^2 = 34.98$, d.f. = 12, $P < .05$. The reduction in food classes compared is due to the small expected frequencies computed for when the original nine classes are used.

4.4.7 - Diet analysis, seasonal differences

The frequency of occurrence of diet categories drops to low values when area diet results are subdivided seasonally. Due to the limitations low frequencies imposed upon (Hinkle *et al.* 1979, Parker 1979), only Grid 1 information was statistically analysed. Kiore ($x^2 = 2.03$, d.f. = 6, $P > .05$) and Norway rats ($x^2 = 6.41$, d.f. = 6, $P > .05$) did not differ in the frequency of Lepidoptera, Araneida, seed and vegetation found in rat stomachs seasonally. This was not the case for volume of food class eaten, (Figure 11 A-F, p.67 & Appendix 9, pp.128-130). In spring, for both species, the amount of invertebrate eaten increased markedly.

Only three species/area combinations, kiore in Line 7 and Norway rats in Lines 5 and 6, did not significantly differ seasonally in their diet. Norway rats in Line 1 showed a marked increase in the percentage vegetation in the diet during autumn.

Line 2 rats showed fluctuations mainly in the invertebrate fraction over spring and summer. Kiore in Line 3 also showed large differences in the invertebrate fraction but this difference was most striking in winter. The diet of kiore in Line 4 displayed prominent changes in the invertebrate fraction particularly in autumn while a significant amount of variation in diet for Line 4 rats also occurred where each discriminating variable had nearly equal contributions to the variation.

4.5 - Parasites

Of the sample of fleas, Prof. R.L.C. Pilgrim (Canterbury University) was able to identify two species, Pygiopsylla hoplia and Nosopsyllus fasciatus. Fleas from only one kiore were sent to Professor Pilgrim and Pygiopsylla alone was identified.

Jan McKenzie (Canterbury University) identified the nematode species as Mastophorus muris. Sixty-two of 144 Norway rat stomachs had nematodes in them (43.06%) while 58 of 127 kiore stomachs contained nematodes, (45.67%). This difference between rat species is insignificant, $\chi^2 = 0.19$, d.f. = 1, $P > .05$.

The number of nematodes per stomach differed with rat species. For Norway rats the mean number is 5.01, S.D. = 4.57, while the mean for kiore is 2.01, S.D. = 1.60; $t = 4.86$, d.f. = 76.83, $P < .05$.

4.6 - Arboreality

No chalk bands were disturbed by rats in either of the two areas tested. For the two nights that chalk banding of Line 3 coincided with trapping, nine rats were caught in traps adjacent to banded trees. The Line 1 bands received considerable attention from possums.

4.7 - Nocturnal rat counts

The number of rats seen during counts around Rangatira are given in Tables 13A & B, (p. 72) and the location of rats is given in Figure 13, (p. 73). Although sightings appear clustered the number of sightings did not differ between 200m track subdivision, $\chi^2 = 7.09$, d.f. = 6, $P < .05$.

Visibility and audibility were greater within the bush areas than in the grass area . The sound of rats moving often preceded a sighting although windy nights lessened audibility.

Few rats were seen around the Trig-McKenzie track (Table 13C, p. 72).

4.8 - Miscellaneous results

This section presents information enlarged upon in the discussion.

4.8.1 - Edge Effect

When the years results for Grid 1 are combined the raw trapping index for the 28 perimeter traps is 14.3 rats/100 trap nights. The comparable figure for the inner 36 sites is 15.6. It can be assumed that an edge effect is not in operation.

4.8.2 - Prebaiting

There were 951 first days of prebaiting during the study and

TABLE 13: NOCTURNAL RAT COUNTS

A. Rangatira. Seasonal differences.

Season	Nights	Rats seen
Autumn	7	19
Winter	10	5
Spring	6	3
Summer	4	8

B. Rangatira. Location differences.

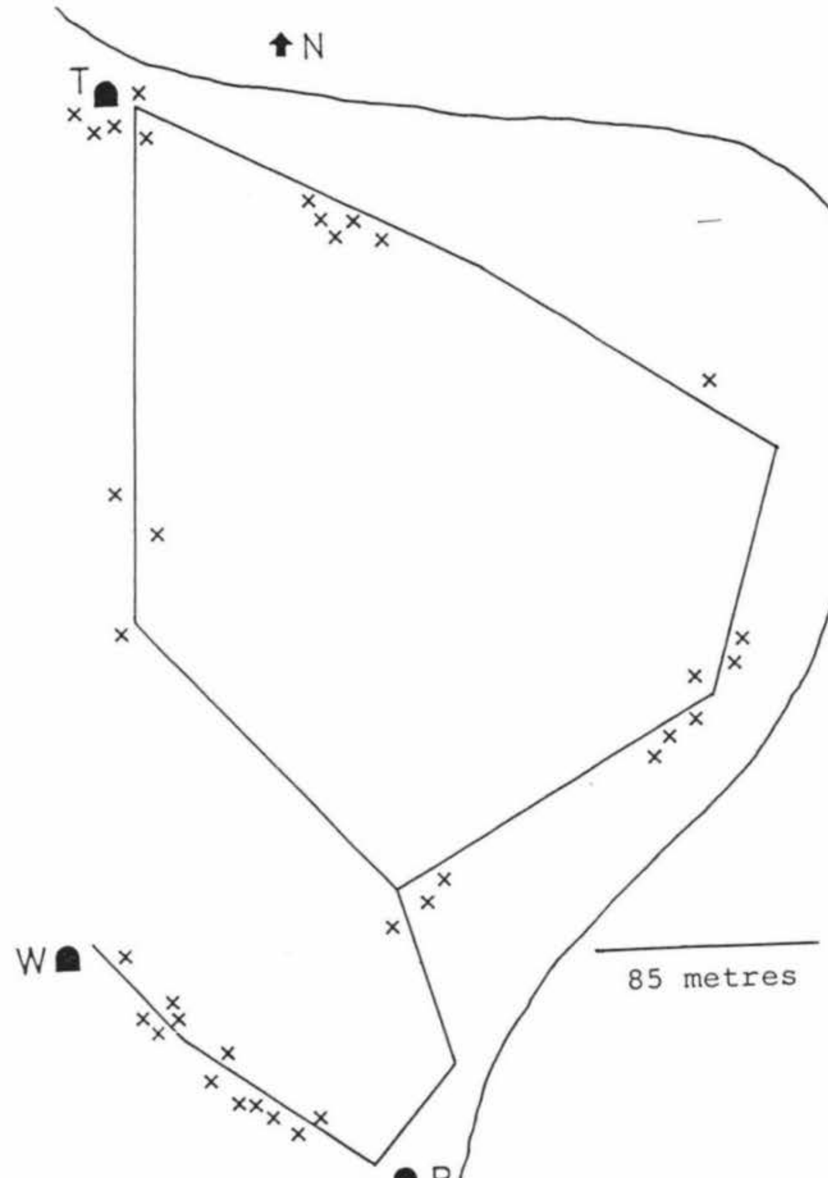
Number of rats seen per 200m starting from the whare:
8, 4, 1, 3, 5, 5, 7.

C. Trig-McKenzie track system. Monthly differences.

Month	Rats seen
November	3
December	1
January	3
February	4
March	1
April	4

FIGURE 13: LOCATION OF RATS SIGHTED DURING NOCTURNAL COUNTS AROUND THE RANGATIRA TRACK SYSTEM.

T = Tri pot, W = Whare, B = Boatshed.


N
T
W
B
85 metres

trap interference occurred on 107 of them. Of 964 first days of trapping 426 traps were interfered with. This difference is significant, ($\chi^2 = 148.72$, d.f. = 1, $P<.05$).

4.8.3. - Post breeding season females

Three female kiore caught in the non breeding season (May to October, Appendix 7, p.126) had placental scars with a mean scar number of 5. For Norway rats 18 females were caught and the mean was 23.3 scars.

4.8.4. - Weight of non pregnant females

The mean weight of female Norway rats that were not pregnant was 213.15g (n=65). This value is larger than the mean weight of male Norway rats.

4.8.5. - Norway rat sex ratio on Line 3

When Line 3 was trapped in summer seven Norway rats were caught. Six of these were males.

CHAPTER 5: DISCUSSION

5.1 - Methods used

5.1.1. - Trapping

Trapping of small mammals circumvents the difficulty of direct observation of behaviour and ecology, and snap-trapping was seen as the most efficient way of collecting rats for autopsy. However, inherent failings of trapping when its findings are applied to the target population include the unequal chance of capture between functional groups and, in some instances, between species (Jensen 1975, Gurnell 1978, 1982), the two dimensionality of trapping which is limiting when arboreal species are studied (McCartney 1970) and a host of often incorrect assumptions when trapping is used for estimating density, (Pelikan 1969, Ryszkowski 1969, Smith et al. 1969, Tamarin and Malecha 1971, Nelson and Clark 1973, Stewart 1979).

Of these failings those that are most pertinent to this study are:

A. The differential trappability of the rat species. Although not quantitatively measured it was observed during the study that the body position of rats caught in traps differed with species. Invariably Norway rats were "just caught" with the bulk of the body out of the trap while kiore appeared to clamber over the trap and were caught in a variety of body positions (Plates 1 & 2, p. 4). This observation indicated a greater wariness or trap-shyness on the part of Norway rats, raising the possibility that the density estimate of Norway rats, relative to kiore, is an underestimation.

B. The assumption of static populations, (Ryszkowski 1969, Smith et al. 1969). The use of snap traps to indicate densities within the trapped area requires the assumption that the area being sampled is not settled by newcomers during the course of trapping. This assumption becomes less true with the increase in duration of the trapping programme (Smith et al. 1969) and is often shown to be invalid by the "edge effect" of trapping grids (Pelikan 1969, Jensen 1975). During this study an "edge effect"; outer lines of a grid catching more targets due to a combination of immigration and increased area of catchability per trap, was not present (p. 71) and such occurrences have been related to the relatively short periods of removal, (Delany 1974).

C. The nature of the density indexes. The format used for the grid during this study was of the minimum advocated size for meaningful results, (Delany 1974), the preferred system being 15x15 trap sites with 2 traps per site. The larger grid was not feasible for this study due to limits of suitable habitat, trap numbers, time and manpower.

Besides these three major shortcomings there are others. The use of the rats/100 trap nights index was standardised for all areas bar Grid 1 by three nights of prebaiting followed by three nights of trapping. However this parameter can be misleading when comparisons are made between studies of varying combinations of nights trapping and/or trap numbers. For example consider two areas with equal rats/trap night indexes where area A was trapped for five nights and area B was trapped for three. If an assumption of static populations holds, the more "diluted" an index becomes as successive trapping nights sample a diminished population. In reality area A has a higher density of rats. Table 14 displays the point with another hypothetical example.

TABLE 14: COMPARISON BETWEEN HYPOTHETICAL DENSITY INDEXES

	Rats caught per night					rats/100tn
Night	1	2	3	4	5	
Area A	10	5	1	not trapped		17.77
Area B	10	5	1	0	0	10.66

30 traps set per night

Prebaiting was seen as a necessity if the aim of trapping was to catch as many animals as possible within three days of trapping. Although not often used in New Zealand prebaiting is recommended procedure when trapping is used for density estimates of small mammals in Europe and North America. That prebaiting does maximise catches is shown by the large difference in trap interference between the first day of prebaiting and the first day of trapping (p. 71). The use of prebaiting further qualifies comparisons of density with other studies that did not include prebaiting.

These limitations ,plus the invariable sprung traps, reduce the effectiveness of trapping as a measure of density, yet alternatives such as census baiting (Chitty and Shorten 1946), complete removal (Dieterlen 1967 cited in Delany 1974) or nocturnal counts as used in this study have even greater limitations.

5.1.2 - Reproduction

The reproductive parameters used in this project are not wholly accurate in what they are professed to measure. The use of weight as a linear correlate of age has been widely used yet the relationship is not entirely linear (Calhoun 1962, Wirtz 1973, Bishop and Hartley 1976, Hardy et al. 1983). Alternative aging measures of eye lens weight (Hardy et al. 1983, Moller and Craig in press) and teeth wear (Jackson and Barbehenn 1962) are claimed to be more accurate.

The use of vagina perforation to denote sexual maturity is not strictly correct (D. Davis 1953, Calhoun 1962, Moller and Craig in press) as it tends to overestimate the number of mature females. Microscopic examination of uteri enhances maturity predictions. The presence of macroscopically visible tubules in the cauda epididymis of males adds to maturity information gained by the testes position, (Jackson 1962). Placental scars give a reliable indication of production in kiore (Moller and Craig in press) although distinction between resorption and term scars in Norway rats could not be made by Conaway (1955) so placental scars are probably an overestimation of viable offspring. Placental scar clarity varies with scar age. Determination of pregnancy is limited to microscopically visible foetuses (Perry 1945 cited in Bettesworth 1972a).

Despite the limitations outlined above the methods used are an adequate compromise between greater accuracy and time available. The refinements mentioned also have inherent limitations and while some reproductive information appears mandatory for most ecological studies the emphasis of this project lies elsewhere.

5.1.3 - Diet

Analysis of stomach contents has been the usual criterion for determining rodent diet (Drodz 1975) although alternatives do exist, (Phillipson et al. 1983, Campbell et al. 1984).

Stomach content analysis requires little applied laboratory techniques with petri dish and binocular microscope sufficient for superficial results. More detailed results can be derived using cuticle analysis, reference collections of possible diet items and stains. The techniques used here have limitations (Hansson 1970, Watts and Braithwaite 1978, Phillipson et al. 1983) but they were less severe than other techniques for the purposes of this study. The subjectivity of visual volume estimates are unavoidable (Hansson 1970, Bettesworth 1972a). Improvement in my ability to identify fragments was countered by the repeated examination of stomachs.

Cuticle analysis has been criticised as a technique for determining deer (Nugent 1983) and possum (Dunnet et al. 1973) diet but few practical alternatives exist for analysing vegetation in small mammal stomachs. Its use is best suited to herbivourous, small mammals existing in a simple vegetation habitat. Initially, a chromic-nitric acid solution was used for macerating purposes (A. Fitzgerald 1976) but because of the difficulty of keeping trace of fragments in the dark solution while rinsing, macerating solution was replaced by bleach, (Williamson pers. comm.).

Stains were used for macerated plant fractions and enhanced cell delineation when cell layers were separate. Staining is considered advantageous by O. Williams (1962) and Hansson (1970) although Williamson finds identification of bleached cuticles easier when they are not stained. The three tier sieve system aided identification of contents by excluding "interference" fragments of differing size. However it is possible three sieves compounded the subjectivity of volume estimates.

Greater emphasis in diet studies should be put on the usefulness of detailed reference collections. The difficulty in identifying fine diet fragments without these tools was major.

5.2 - Density and species ratio

Variations in rodent density are the result of a number of factors operating on the population; intraspecific and interspecific competition (Twibell 1973, Heske et al. 1984, L. Davis 1979), food quality and availability (Flowerdew 1972), the availability of cover, nests and shelter (Barnett 1963, Southern 1964), predation (Andersson and Erlinge 1977), infectious diseases (Barnett 1963), climate and weather (Delany 1974, Moors 1979) and latitude (Moller and Craig in press). These factors act by changing rates of reproduction, mortality and movement.

The total corrected density estimate agrees with observations that rodent populations in New Zealand attain higher levels when major predators are absent (Beveridge and Daniel 1965, Daniel 1978, M. Fitzgerald 1978). Daniel (1969) observed high numbers of Norway rats previously on Kapiti as did Beveridge and Daniel (1965) on Mokoia Island and Bettesworth (1972a) on Whale Island. Factors, other than the absence of predators, operate on island population density as Moors (1979) attributes drought as the cause of low population levels of Norway rats on Otata Island.

Moller and Craig (in press) described large populations of kiore on Tiritiri Island and listed known kiore density indexes from other New Zealand studies.

Both density and species ratio differ with habitat yet interpretation of habitat preference as a correlate of high and low densities and presence or absence of either species is incorrect. A quite plausible outcome of competition between two rodent species when some habitat component is in short supply is the displacement of one species to a less favourable habitat (Schoener 1982). Consequently it would be presumptuous to state that because they are at higher densities in Line 7 kiore prefer mature tawa forest to high altitude grassland (Line 2). A statement of preference may be made with greater certainty if comparisons are made between the various predominantly kiore areas and predominantly Norway rat areas. An order of habitat preference may then be supported; kiore prefer areas of mature kanuka/coastal forest to young kanuka/coastal forest which is in turn more favoured than higher, damper, mature forest. Norway rats find the damp, lower Waiorua Valley, where there is a good cover the most supportive habitat, while the stony beach is least preferred.

These findings differ from the habitat delineation previously observed on Kapiti. Daniel (1969) found Norway rats more numerous in the lower forested areas and on the beaches while kiore dominated numerically in the Taepiro and Te Rere grasslands. Baird (1977) caught no kiore on traplines and found Norway rats most numerous at Rangatira Point (grassland) and in a forested area similar to Line 7 of this study. Campbell (1965) caught a kiore at an altitude of 253m, between my Lines 3 and 7, and found

Norway rats numerous along the shoreline. This information and comparable results from other studies (Table 15, p. 83) suggests that few precise parallels exist in habitat preferrences. However a general picture is that kiore prefer dry grassland areas of good cover while Norway rats do not favour existence in forests.

From the foregoing it appears that both species covet grassland habitats yet it is the Norway rat that not only dominates these areas but in fact was the only species present in two of the three grassland areas studied. The implication is that Norway rats exclude kiore from areas suited to the survival of both species and kiore then have to move to alternative areas to continue to exist. This hypothesis is broad and general and is unable to explain the seasonal changes in species ratio, the past distribution of rodent species, the high number of Norway rats in Line 1 and the closeness to parity of numbers in Grid 1. However competition does appear to be a feature of rats on Kapiti Island and this is reflected in disjunct distribution over different habitats. The possible mechanisms of this competition will be discussed further.

Seasonal changes in rodent density are the norm in New Zealand, (M. Fitzgerald 1978, Craig and Moller in press), with concurrent changes in the food supply being the major determinant of population size (Daniel 1978). On Kapiti little parallel existed in seasonal density changes between Norway rat areas apart from a low in summer. Even less consistency was apparent for kiore areas. It is possible that this accurately reflected the density dynamics yet the limited trapping periods per area are cause for caution. Also, seasonal comparisions ignore differences between the monthly extremes of a season; for example the density

TABLE 15: DESCRIPTION OF PREFERRED HABITATS

A. NORWAY

HABITAT	PREFERENCE/DENSITY	STUDY
Wet, lower grass	High density	Present Study
Coastal forest/gully	↓	
Dry, lower grass	↓	"
Dry, upper grass	↓	"
Beach	Low density	"
Grass	High density	Bettesworth (1972)
Scrub	↓	
Bush	Low density	"
Beach/Sand-dunes	High density	Bettesworth & Anderson (1972)
Pohutukawa bush/gully	↓	
Puffinus burrows	↓	"
Grass/sedge/manuka	Low density	"
Beach/bush edge	High	Beveridge & Daniel (1965)
Bush	Low	
Beach, low altitudes	High	Daniel (1969)

B. KIORE

HABITAT	PREFERENCE/DENSITY	STUDY
Mature kanuka, coastal	High	Present Study
Forest/lower	↓	
Young/kanuka lower	↓	"
Mature upper forest	Low	"
Grasslands/2 growth/ lower altitudes	Preferred	Jackson & Strecker (1962)
Flax and bush fringes	High	Hicks *et al.* (1975)
Secondary bush	High	Watson (1956)
Climax forest	Low	"
Dry, good cover	Preferred	J. Williams (1973)
Grassland	Preferred	Taylor (1975)
Arboreal	Preferred	McCartney (1970)

estimate of Grid 1 in September is considered directly comparable to that of Line 1 in November.

The density estimate gained by the Standard Removal method is extremely high when compared with the estimates of rodent density listed by Delany (1974) yet this method is more likely to underestimate than overestimate the population.

5.3 - Morphometrics

The standard body measurements taken add quantitative information about geographic differences in populations. In this study, weight also provides an indication of age.

The mean weight of Norway rats trapped agrees well with the combined mean for other New Zealand studies (p. 5). Even though the difference was not significant it is unusual for female Norway rats to be heavier than males (Calhoun 1962, Hirata and Nass 1974). This difference remains even if pregnant females are not included in the analysis (p.74). The body measurements of Norway rats are smaller on Kapiti, and New Zealand generally, than their British and North American counterparts. Differences in body size between rodent populations has been related to environmental factors, e.g. nutrition, (Jackson and Barbenhenn 1962), stress and intraspecific competition (Barnett 1955) and social ranking (L. Davis 1979). Assuming an equal incidence of density dependent factors in rat populations, different environmental factors appear likely for the reduced size of New Zealand Norway rats.

When considering weight differences between the separate habitats trapped on Kapiti a combination of the above factors may be operating. However weight differences with age may also be of importance and the low mean weight of Norway rats caught in Line 3 (Table 5A, p. 44) implies high recruitment of young animals rather than a severely disadvantaged population. The Line 3 result also indicates the bias involved when comparisons are made between population parameters of separate seasons as all Norway rats caught on Line 3 came from one sample of the three taken (Appendix 3, p. 122).

Kiore weight also differs with geographic location, (J. Williams 1973). The kiore from Kapiti tend toward the upper weight limit of the species. Barnett and Dickson (1984) explained similar increases in weight in laboratory mice (Mus musculus) as a genetical response to colder climates. Moller and Craig (in press) found seasonal weight loss in individual kiore with the loss varying between habitats. They hypothesised that this loss may be due to changes in the food supply. On Kapiti, weight differed between areas and seasonally within areas. Similar causes of food supply changes may be in effect on Kapiti but the individuality of the changes coupled with the unknown effect of age prevents reasonable deduction.

5.4 - Reproduction

5.4.1 Norway rats

The seasonal changes in breeding, with highest activity over spring and summer, support the findings of other New Zealand studies. Bettesworth (1972a) observed a peak in the percentage of mature females pregnant in spring while Beveridge and Daniel (1965) observed a summer breeding peak on Mokoia Island. Daniel (1978) further defined the breeding season for ship and Norway rats in mainland New Zealand forests as occurring for 6 to 7 months "...but can continue into autumn and winter...". The small percentage of immature rats and females bearing placental scars in spring reflects the lack of winter breeding on Kapiti, (Figure 8, p. 53).

The number of embryos per pregnant female (7.5) was higher on Kapiti than on Whale Island (6.5; Bettesworth 1972a) and on Waewaetorea Island (6.9; Moller and Tilley 1984) although no distinction was made between resorbing and viable embryos in my study. This figure (7.5) was close to the minimum number recorded for embryos in north hemisphere studies reviewed by D. Davis (1953) while Beveridge and Daniel (1965) found a higher litter size on Mokoia.

Daniel (1978) considered 30 young/female/year close to the maximum productivity of Norway rats in New Zealand. On Kapiti the high value of 33.5 was computed with two sources of error a) the use of placental scars to denote maturity and, b) the unknown degree of embryo mortality, although these errors tend to negate each other.

Moller and Craig (in press) found a similarity between the mean placental scar number for females caught after the close of the breeding season and their estimated productivity results. The parallel did not exist on Kapiti as the mean placental scar number for post breeding season females was 23.3. It is possible that the estimation of the breeding season was too generous as although two pregnant rats were caught in August none were found in September. The percentage of mature females pregnant was greater on Kapiti than on Mokoia Island (Beveridge and Daniel 1965). The mean number of placental scars is higher on Kapiti than on Otata

Island (Moors 1979) while Baird (1977) caught two pregnant females in February. The incidence of pregnancy figure (4.46) appears about midway in the range reported by D. Davis (1953) when perforate vagina is used to determine maturity.

High productivity (high incidence of pregnancy) has been linked with increasing and, surprisingly, decreasing rat populations (D. Davis 1953). If this holds for Kapiti the age structure information may indicate the state of the population. An increasing rodent population should have a greater proportion of young than stable and decreasing populations. Although the age structure results (Figures 6, p. 50 & 8, p. 53) reflect the input of young during the breeding season they do not make up a large proportion of the total population. Before discarding increasing populations as an explanation of high productivity rates the likely bias in trapping towards older animals must be considered. Also, in the absence of previous years age structure information the relative importance of young in the present population cannot be determined. That one area (Line 1) did have a large proportion of young rats suggests productivity is, in part, habitat dependent.

Other rodent studies have indicated a negative correlation between breeding activity and density, (D. Davis 1953, Tamarin and Malecha 1971, Bettesworth 1972a). Such a comparison can not be made directly in this study but it follows that peaks in population density should be highest in autumn and lowest in summer. Of the Norway rat areas only Grid 1 recorded a significant increase in density during autumn (1984) while the increase in density in Line 1 during spring when breeding activity is quite high suggests that on Kapiti the correlation between density and breeding is not strong.

5.4.2 - Kiore

The breeding season for kiore extended from November to April which was longer than that on Tiritiri Island (Moller and Craig in press). The litter size of 4.66 falls about midway between the two extremes reported (2.5 on Ponape Island, Jackson, 1962; 6.7 on Tiritiri, Moller and Craig in press) and both the annual number of litters and the annual productivity of Kapiti kiore were lower than the seven studies with comparable figures reported by Moller and Craig. These results contradict Moller and Craig's use of altitude and latitude to explain changes in litter sizes and length of breeding season.

The low value of mean placental scars for non breeding season females (p. 74) supports the productivity findings of less than 1.5 litters per season per female although the small sample size of non breeding females with placental scars requires cautious interpretation.

The low productivity of kiore and the deviation from a high litter size predicted by latitude may be due to one of two causes. First, the population may be stable and hence have low productivity a possibility suggested by D. Davis (1953) for Norway rats and second, the population may have reached a maximum and a concurrent increase in social stress and competition has retarded reproduction as proposed by Calhoun (1962) for Norway rats. Because the density of kiore on Kapiti is evidently higher now than demonstrated by Daniel (1969) and Baird (1977) the second explanation is perhaps the more plausible. Stable populations resulting in low incidence of pregnancy could not of course be discounted as an explanation, as age structure information is limited. That crowding and stress lead to physiological and behavioural changes in reproductive parameters and mortality is well supported (Calhoun 1962, Vaughan 1972, Myers and Krebs 1974, Brewer 1979, Swanson 1983) but its existence on Kapiti could only be determined by constant monitoring of the population. If the second hypothesis, that lowered productivity on Kapiti for kiore is due to the repercussions of high densities, a lowering in the density levels followed by an increase in the reproductive parameters, would be apparent over the next breeding seasons. The inability to determine mortality frustrates further attempts to qualify this suggestion.

5.5 - Diet

5.5.1 - Introduction

The diet of an animal results from numerous factors. Behaviour, physiology and morphology impose limits to what food a species can eat. The need for energy, water and nutrients influences diet with these needs differing with age, sex and health. Hunger gives individuals less choice in diet while level of hunger is itself determined by a host of factors. Fluctuations in availability and abundance of suitable prey items will be reflected in diet changes while large fluctuations exert selective pressure on animals to adopt a generalist foraging pattern.

5.5.2 - Kiore

The importance of invertebrates in the diet of Kapiti kiore is at variance with the findings of a number of writers which indicate that kiore are predominantly herbivorous, (Watson 1959, Kami 1966, Fall *et al*. 1971). J. Williams (1973) considers that the importance of plants in kiore diet is a consequence of a low protein requirement in comparison with sympatric rodents. This consideration assumes protein requirement is a dictating factor of kiore diet yet Barnett (1963) and Reichman (1977) suggest that energy needs are the most important determinant of rodent diet. Kiore are more omnivorous than earlier writers have suggested and this is evidenced by the findings of Bettesworth (1972b), Fleet (1972), Crook (1973), Whitaker (1973), Hicks et al. (1975), Whitaker (1978) and Campbell et al. (1984), where, in instances, birds, reptiles and invertebrates feature heavily as diet components. Many Pacific island studies of kiore diet show a predominance of vegetation eaten and this reflects, in part, the habitat in which rats were trapped. Kami (1966), Fall et al. (1971), Mosby et al. (1973) and Twibell (1973) were studying rats in association with crops. Another possible explanation of greater herbivory in the tropics is the more reliable nature of plant food. In temperate New Zealand seasonality, and hence availability as a food source, of plant is more apparent.

On Kapiti habitat influenced kiore diet. The distinction between diet in grassland as opposed to forest was marked. If kiore from Grid 1 were used solely to describe diet on Kapiti the conclusions would be that kiore were fundamentally herbivorous. Strecker and Jackson (1962) found little variation in diet with habitat on Ponape Island. Bettesworth (1972b) and Hicks et al. (1975) examined stomach contents from the Red Mercuries although different islands were sampled (Korapuki and Red Mercury respectively). The collection of samples in different years and seasons confounds this example yet differences in diet were apparent between the two habitats.

Kiore can exist in an artificial grassland habitat away from crops (e.g. Grid 1) which suggests habitat destruction was not as important as the introduction of predators and competitors in determining the present distribution of kiore. They can quite readily adapt to an exotic source of food such as prairie grass seed.

Season affected kiore diet on Kapiti and notable changes occurred in Grid 1 where an increase in the volume of invertebrates eaten was apparent in spring. This increase was mirrored by Norway rats in the same area suggesting a change in food availability was the cause rather than changing needs or preferences. Kami (1966) and Wirtz (1972) both report seasonal changes in kiore diet. In Hawaiian cane fields grass seeds and insects increase in frequency over summer (Kami 1966) while on Kure Atoll insects peak in their representation in the diet over summer, (Wirtz 1972).

The frequency of invertebrate type eaten by kiore on Kapiti differs from that found by Campbell et al. (1984) on Tiritiri Island. There wetas were the most common invertebrate remains at husking stations followed, in decreasing frequency, by Coleoptera, Mollusca, Lepidoptera and Diptera. The presence of the harder invertebrate body parts in husking stations on Tiritiri explains the absence of hard body parts in the stomachs (p. 57).

Of the native foliate vegetation occurring in stomachs only kanuka appeared of importance. Campbell (1978) lists kawakawa and mahoe leaves as being edible for kiore but no evidence was found of either of these species in kiore stomachs despite the prevalence of these plants on Kapiti.

No bird remains were found in kiore stomachs and this suggests that this species is less of a danger to the birdlife of Kapiti. Fleet (1972) showed that kiore predation of red-tailed tropic birds resulted only when the primary food source of the rats was in short supply. This evidence plus that mooted by Atkinson (1978) implicates kiore as a possible predator of ground nesting birds. Past influences of kiore may have been a major cause in the present composition of the avifauna but the coexistence of kiore with the bird species on Kapiti at present (with the possible exception of saddleback, Lovegrove pers. comm.) suggests if kiore were having an effect on the birds it was not major.

5.5.3 - Norway rats

On Kapiti the larger rat species appears a more balanced omnivore with less dependence on any one food class. Even within the invertebrate types, Thysanura, Hymenoptera and Mollusca, were found only in Norway rat stomachs.

As with kiore, habitat and location are important factors in determining Norway rat diet in New Zealand. Bettesworth and Anderson (1972) noted that the stomach content of rats changed when samples taken progressed from the shore inland on Whale Island. Intertidal invertebrates and insects were most important diet components of beach foraging rats while petrel flesh was more important inland. Plant food, particularly seed and fruit, featured in the diet of rats from Mokoia Island (Beveridge and Daniel 1965). A wide variety of invertebrates was also eaten on Mokoia with grassgrubs (Melolonthinae) a frequent diet item. Moors (1979), like Bettesworth and Anderson (1972), found shoreline invertebrates, insects and plants, especially Solanum, in rat stomachs from Motuhoropapa Island. On Whale Island petrels are an important source of food (Bettesworth 1972a). Density of petrel burrows varies with habitat and this variation is reflected in the diet. The presence of grass and seed in the rat diet also differed with habitat on Whale Island.

On Kapiti some of the above observations of diet from other New Zealand studies were not apparent. The absence of littoral invertebrates, particularly molluscs and crustaceans, was unexpected in light of these previous studies. Moors (1979) suggested that the littoral zone may be an essential source of food for island rats although on an island as large as Kapiti, where only a small proportion of individuals could be expected to include foreshore in their home range, this is not a reasonable supposition. Even those rats caught on the beach (Line 5) did not contain intertidal invertebrate types although one rat had eaten an amphipod, (Table 12A, pp. 59-60). Absence of petrel flesh within the rat diet on Kapiti mirrors the absence of petrels. Plant and seed when combined are more important than invertebrate alone, a finding shared by Beveridge and Daniel (1965). Of the records of plant food eaten by Norway rats in New Zealand (Campbell 1978) Kapiti rats only appeared to eat karaka, kohekohe, poroporo, clover (Trifolium repens) and possibly native passionvine and hinau. However they did eat plants not listed by Campbell (1978), (Table 12C, p. 62).

Habitat related differences alone do not explain differences between samples as season exerts an influence on diet. Some areas however did not appear to differ with season (Lines 5, 6 and 7) and this is probably due to trapping artefacts. Diet in two of the areas (Line 6 and Line 7) was compared between two seasons only while the small sample sizes of Line 5 casts doubt on its results. Stability in the availability and abundance of food does not appear a viable explanation.

Bettesworth (1972a) observed seasonal changes in diet particularly in the volumes of petrel flesh, inkweed seeds and grass. Daniel (1978) stated that seed and fruit are the main source of food in autumn and winter for New Zealand forest populations of ship and Norway rats. This observation does not hold on Kapiti. In autumn and winter the combined mean volume of fruit/seed and plant eaten by the Norway rats in coastal forest (Line 1) is less than the mean volume of invertebrates eaten in either sample (Appendix 10, p. 131).

Although fruit and seed in coastal forest did not dominate the diet over autumn and winter there was a seasonal aspect to the occurrence of fruit alone. Fleshy fruits, presumably native, occurred only in autumn and summer months further contradicting Daniels (1978) observation.

The most noticable trend in seasonable changes in diet, for all areas that displayed a change, is the upsurge in the representation of invertebrates in spring samples.

5.5.4 - Lepidoptera larvae and prairie grass seed

Kikkawa (1960) and Moeed and Meads (1982) provided indications of the relative abundance of invertebrates in various habitats and at various forest layers. Moeed and Meads (1982) found beetles and weevils, Collembola, amphipods, acari and larval insects to be the most numerous invertebrates within the litter. Although

Kikkawa's results are more superficial they do point to Lepidoptera larvae not being abundant. Despite not being able to determine the availability of these invertebrate types, the consistent domination of the invertebrate fraction by Lepidoptera larvae suggests their occurrence in the diet is a result of being preferred and actively sought rather than a consequence of their availability and abundance. The other major invertebrate types are eaten less fequently than Lepidoptera and the fact that their order of importance changes with area, suggests their occurrence in the diet is more a reflection of availability and abundance. Moeed and Meads (1982) observe that rats are responsible for low numbers of large invertebrates on Kapiti. Despite this the authors suggest modified behaviour of larger invertebrates enables reasonable sized populations to survive on rat inhabited islands with modifications taking the shape of greater wariness. This can be seen as another explanation of the high frequency of Lepidoptera larvae in the rat diet as the escape abilities of larvae appear restricted.

Prairie grass seed was a major part of the diet of rats in Grid 1 yet its infrequent occurrence in Line 6 rats is surprising, as prairie grass was known to be present in both Line 6 and Grid 1 and may have been present in Line 2. Although prairie grass may have been more abundant in Grid 1 it was not the dominant member of the sward. If differences in abundance was not the cause of the large difference in occurrence between the areas then an explanation involving different, subjective preferences for discrete populations could not be discounted.

5.5.5 - Summary

The diet of the Kapiti rats could be appropriately described as opportunistic. The diet appears to reflect the availability of a wide variety of invertebrates, plants and seed to the rats. However, the frequent occurrence of Lepidoptera larvae in the diet in all areas suggests that preferences do exist contrary to availability. Norway rats are the better opportunists.

5.6 - Arboreality and nocturnal rat counts

Inconclusive data was gained from the nocturnal rat counts and the chalk bands. This does not auger well for future use of these approaches in rodent research. Hicks et al. (1975) indicated that night counts can be an effective means of determining changes in relative density but this technique would be useful only when density fluctuations are high. Certainly for the effort involved trapping, regardless of its failings, is a more efficient method of determining density.

Paper tracking has proven successful in providing information about the movements of some New Zealand rat populations (Innes 1977, Innes and Skipworth, 1983). This was not the case on Kapiti primarily because of the limited effort and time involved in pursuing the subject of arboreality. However as baited traps on the ground were able to entice kiore into investigating the traps of Line 3 it should follow that the baited tracking paper would do likewise if kiore were arboreal in their habits. The fact that none of the chalk papers were tracked does not indicate that kiore are not arboreal although it is evidence which suggests that they forage more readily at ground level than in trees.

5.7 - Coexistence and competition

The coexistence of kiore and Norway rat on Kapiti yet the strong habitat delineation between the two suggests competition may be an active force on these populations.

Interspecific competition has been frequently observed in small animal populations (Jaeger 1974, Turner et al. 1975, Pontin 1982, Schoener 1982, Heske et al. 1984) and Grant (1972) asserts that "...competitive interaction for space is a general phenomenon among rodents...". Depsite this, interactions of Pacific populations of rodents have not been subjected to rigorous applications of competition theory although that competition between Rattus species in the Pacific is a real occurrence has been supported by the observations of J. Williams (1973), Twibell (1973) and Kami (1966). In New Zealand, Watson (1956, 1961) and Taylor (1975, 1978) have proffered explanations involving competition to account for rodent distribution. Taylor's (1978) assertions are the accepted state of the field (p. 3).

The ability of kiore and Norway rats to coexist has been doubted (Barrett-Hamilton 1913, Watson 1961) yet they are known to coexist on a number of New Zealand offshore islands (Atkinson 1978, Moller and Tilley 1984, WRLG Res. Rev. 4 1984). They are the only rodents on some of the Tonga islands where the more aggressive Norway rat competes for habitat with kiore, (Twibell 1973). Competition between the species occurs on Kapiti and is evidenced by the marked habitat delineation. Allopatry rather than sympatry appears the norm. Competition is not the only possible cause of the disjunct distribution as Rosenzweig (1973) and Morris (1984) have shown that different habitat preferences can occur in sympatric rodent populations. This latter explanation is unlikely given the low number of kiore present in grassland habitats which other studies indicate are preferred habitats for this species (Daniel 1969, J. Williams 1973, Taylor 1975, Cunningham pers. comm.).

A broad pattern emerges of the species interaction and can be summarised by the following statements:

A. The Norway rat has a competitive advantage over kiore.

B. This competitive advantage is reflected in the exclusion of kiore from habitats favoured by both species.

C. Kiore are able to survive and even reach high densities in suboptimal, refuge habitats.

D. The strength of the competition is not constant.

The first three statements are straightforward interpretations of kiore presence and absence. It might be expected that a higher density of kiore in three of the four forest areas (Lines 3, 4 and 7) indicates a reversal of the competitive advantage. However Norway rats increased their presence in these areas at least once during sampling and a concurrent decrease in the presence of kiore was observed. This suggests the competitive advantage is still with Norway rats. I suspect that the absence of Norway rats from these areas reflects the exclusion of them by an unsuitable habitat rather than their exclusion by kiore.

The fourth of the above statements is needed to qualify some of the anomalies if the other three are considered alone. For example, kiore appear to coexist in Grid 1 despite the relatively high Norway densities of that area. A clearer understanding of the resource responsible for the competition may clarify this apparent contradition.

Exploitation of the same foods when some or all are limited in their availability and negative behavioural interactions due to limited space- are two commonly cited causes of interspecfic competition among rodents, (Grant 1972).

In the heavily studied microtine rodents of North America behavioural aggression related to changes in reproductive states has been seen as a major cause for disjunct distribution (Stoecker 1972, Turner et al. 1974, Heske et al. 1984). The intensity of competition would depend upon season and density; the greater the density the greater the contact between individuals while if aggressive behaviour is related to reproductive state seasonal breeding will have a noticeable effect. If this phenomenon is occurring on Kapiti then it would be expected, at the very least, that the areas with the highest densities would be least likely to support both species and that if density was constant a reduction in coexistence would be observed in the breeding season.

On both counts, Grid 1 did not support these predicted changes in coexistence. During summer, the peak of Norway rat pregnancies on the island, the ratio of Norway rats to kiore was close to 1:1 (Figure 3G, p. 37) while there was little correlation between density and species ratio in Grid 1.

Exploitation of similar food sources is probably the commonly appraised example of competition although evidence of its occurrence in rodent populations is not great, (Grant 1972). This in part, reflects the difficulty of measuring competition for food. If food is the resource that the Kapiti rodents compete for then the coexistence of Grid 1 rats implies food is not limited in its availability in this area. One reason why availability may not be a problem is that the diet preferences are different for this area. This seems unlikely as a corollary is that different diet preferences in other areas would enable coexistence. A more plausible explanation is that available food was abundant for both species and as a consequence competition was not a significant factor in determining populations structures. Obviously other causes of competition may exist such as competition for nest sites and shelter. However evidence for these possibilities is less apparent. The view that food limitation may be the source of competition is enhanced by the unlikeliness of aggressive interactions being the source.

This discourse is speculative yet offers plausible explanations for the habitat delineation between species. That kiore areas receive an influx of Norway rats at some stage may reflect dispersal of Norway rats to escape population pressures in preferred habitats, this dispersal tendency of Norway rats having been observed by Barnett and Prakash (1975) and Kendall (1984). That the rats caught in Line 3 in summer were predominantly young males (p. 74) supports this.

Overlap in the diet of the two species neither confirms or denies food limitation as a source of competition although level of overlap has often been associated with intensity of competition, (Jaeger 1972). An overlap in food eaten does not necessarily imply that species are competing. More precisely the fact that diet of the different species is significantly different in volumes of seed, invertebrate and vegetation eaten does not imply food is not being competed for although Whitaker and French (1984) suggest that is the case for diet volume in sympatric shrew species. A statistical difference in diet and the difference needed for coexistence of small mammals are not neccessarily equivalent. Also, a difference in the volumes of food types eaten may be the result of active competition; food eaten may not be preferred but may be all that competitors have left available. The diet data does support one aspect of the proposed mechanisms of competition operation. The more generalist eating habits of the Norway rat indicates that they are better adapted to compete for food.

The mechanisms of the competition and coexistence of the rats will not be understood fully until detailed knowledge of behaviour and food availability is gathered and removal experiments with artificial interference in species composition are used. That competition is not constant and may even be nonexistent or unimportant particularly in certain areas at certain times, could explain the continued presence of kiore on Kapiti.

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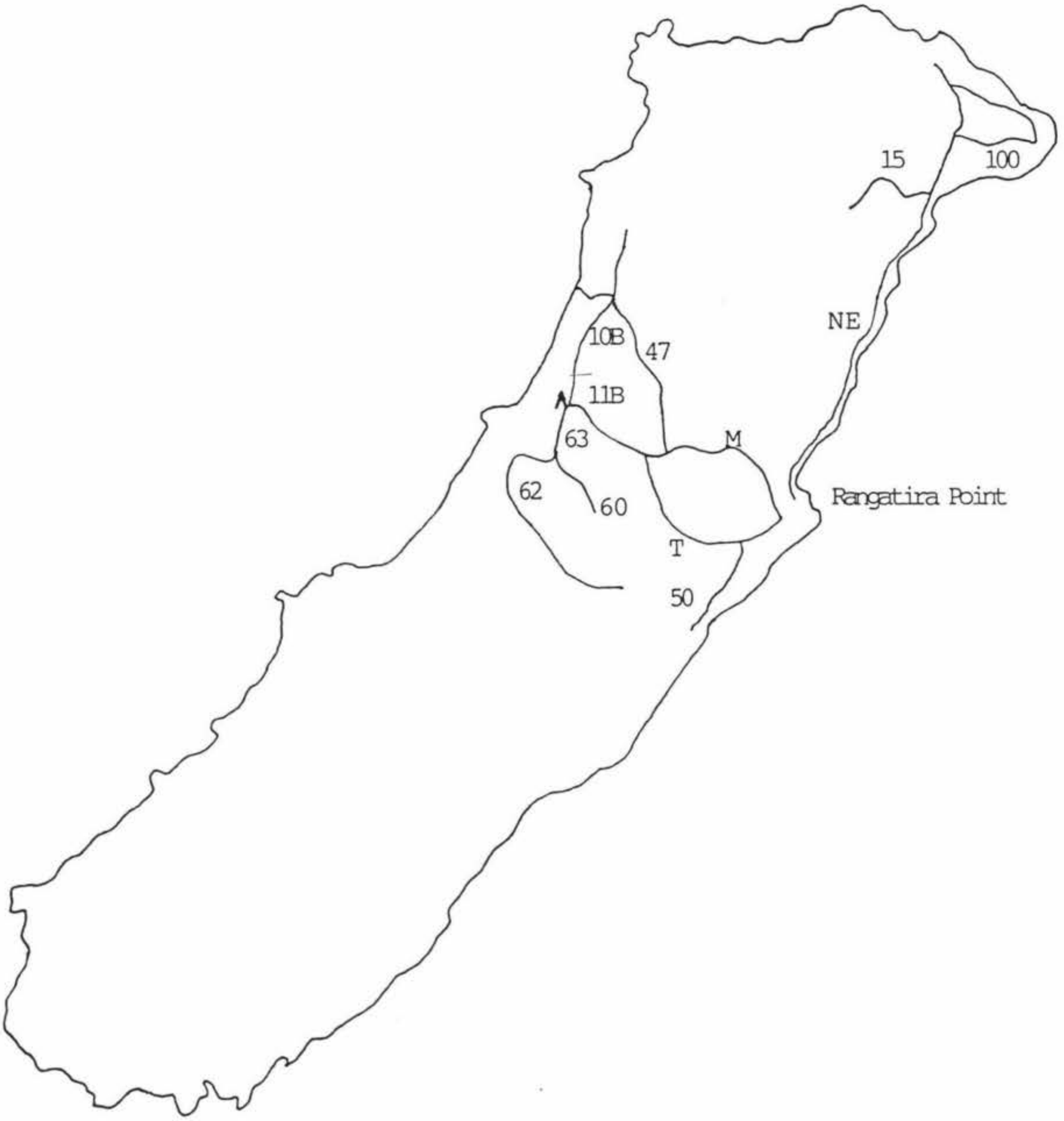
APPENDIX 1: VEGETATION TYPES OF KAPITI ISLAND

(after Bagnall 1974)

VEGETATION TYPE

1.	*	Grassland on upper slope.
2.	*	Grassland on lower flat.
3.		*Pseudopanax anomalus* shrubland on upper slope.
4.		Mature manuka on lower slope.
5.	*	Young kanuka on lower slope.
6.		Flaxland on lower slope.
7.		Five-finger on lower slope.
8.		Mature kanuka on upper slope.
9.	*	Mature kanuka on lower slope.
10.		Mid-seral cloud forest.
11.		Mid-seral forest on upper slope.
12.		Late-seral cloud forest.
13.		Mid-seral forest on lower slope.
14.		Kamahi cloud forest.
15.		Kohekohe forest on moderate upper slope
16.	*	Tawa forest on upper slope.
17.	*	Kohekohe forest on lower slope scree.

* = vegetation types trapped in during this study.



APPENDIX 2 : LOCATION OF POSSUM TRAP LINES MENTIONED IN THE TEXT.

T = Trig track, M = McKenzie track, NE = North end track.

A	M	R	T/N	S	N:K
1	5	8	72	11	100.0
99	5	28	191	46	96.4
2	6	12	90	13	100.0
3	6	19	87	22	0.0
1	7	8	84	9	57.1
4	7	4	90	12	25.0
5	8	6	90	6	83.3
6	8	11	90	14	100.0
99	9	26	186	18	72.0
7	9	2	90	8	100.0
3	10	30	171	44	0.0
2	10	6	84	8	100.0
1	11	23	129	61	95.7
4	11	23	134	51	0.0
6	12	12	129	64	100.0
5	12	3	90	8	100.0
10	12	5	24	18	100.0
99	1	25	191	39	45.5
7	1	8	57	6	12.5
11	1	3	15	10	100.0
1	2	3	57	26	100.0
2	2	3	54	6	100.0
3	2	9	131	19	77.8
4	3	6	174	80	16.7
9	3	11	87	16	72.7
99	4	47	192	70	51.1
7	4	12	60	7	8.3
5	4	3	41	5	100.0

APPENDIX 3: RAW TRAPPING DATA

Results from first three nights of trapping. A = area expressed as line number, 99 = Grid 1; M = month, R = rats caught, T/N = total trap nights, S = sprung but unsuccessful traps, N:K = percentage of identifiable rats that are Norway rats.

APPENDIX 4 : DENSITY INDEXES WITH CONFIDENCE LIMITS

AREA	CORRECTED DENSITY INDEX (Rats/100 trap-nights)	95% C.I.
L1	15.70	11.84 - 19.55
L2	10.29	6.35 - 14.23
L3	18.27	14.43 - 22.11
L4	15.00	11.50 - 18.51
L5	5.84	2.75 - 8.93
L6	13.65	9.10 - 18.20
L7	11.86	7.46 - 16.27
G1	18.71	15.94 - 21.48

APPENDIX 5: SEASONAL DENSITY INDEXES WITH CONFIDENCE LIMITS

Rats/100 trap-nights (± 95% C.I.)

	SEASON			
AREA	AUTUMN	WINTER	SPRING	SUMMER
L1	12.80(±7.72)	10.59(±6.59)	26.44(±7.61)*	7.06(±6.65)
L2	-	15.48(±7.48)	7.79(±5.75)	6.06(±6.37)
L3	-	28.57(±9.50)	22.39(±6.25)	7.69(±4.51)[1]
L4	4.58(±3.11)	4.88(±4.45)	22.39(±8.52)*	-
L5	8.11(±8.35)	7.14(±5.32)	-	3.55(±3.82)
L6	-	14.19(±7.21)	-	13.19(±5.84)
L7	23.76(±10.77)	-	2.36(±3.12)[1]	16.00(±9.52)
G1	18.18(±5.47)	-	15.85(±5.25)	15.72(±5.17)
G1	41.96(±13.51)* = Autumn 1984			

* = significant peak in density index.

[1] = significant low in density index.

APPENDIX 6: TWO-WAY ANOVA OF KIORE WEIGHT WITH SEX AND AREA

Source of variation	DF	F	P
Sex	1	4.866	0.030
Area	5	5.295	0.000
Two-way (Area and Sex)	4	3.633	0.008

APPENDIX 7: MONTHLY FEMALE SEXUAL CONDITION

	NORWAY				KIORE			
	n	perf.	preg.	p.s.	n	perf.	preg.	p.s.
MONTH								
MAY	17	16	0	12	-	-	-	-
JUNE	6	5	0	5	13	10	0	2
JULY	3	1	0	1	1	1	0	0
AUGUST	6	5	2	2	1	1	0	1
SEPT.	11	10	0	2	2	2	0	0
OCT.	2	2	1	1	11	11	0	0
NOV.	7	7	4	1	10	10	2	0
DEC.	13	9	4	4	-	-	-	-
JAN.	8	6	4	2	11	10	2	3
FEB.	2	4	1	1	1	1	0	0
MAR.	2	2	0	2	1	0	0	0
APRIL	12	11	1	6	16	12	2	5

perf. = perforate vaginas.

preg. = pregnant.

p.s. = placental scars.

n = number of females examined.

APPENDIX 8: RELATIVE FREQUENCY OF OCCURRENCE FOR NINE FOOD CLASSES

A. NORWAY RATS

		INVERT					VEGE		SEED	
AREA	n	L	S	W	C	D	N	Ex	N	Ex
L1	21	47.6	38.1	14.2	19.1	28.6	-	9.5	14.3	23.8
L2	17	64.7	47.1	17.7	11.8	11.8	11.8	88.2	-	52.9
L3	4	-	75.0	50.0	-	-	-	-	-	25.0
L4	2	50.0	100.0	100.0	-	-	100.0	-	-	50.0
L5	6	83.3	33.3	16.7	33.3	16.7	-	-	-	33.3
L6	19	57.9	5.3	21.1	15.8	36.8	21.1	57.9	10.5	63.2
L7	7	100.0	-	66.7	-	33.3	33.3	0	-	-
G1	72	51.4	16.7	13.9	19.4	16.7	15.3	33.3	12.5	76.4

B. KIORE

		INVERT					VEGE		SEED	
AREA	n	L	S	W	C	D	N	Ex	N	Ex
L1	4	50.0	100.0	50.0	25.0	75.0	-	-	-	-
L3	44	88.6	52.3	52.3	18.2	63.6	13.6	13.6	22.7	13.6
L4	27	85.2	40.7	66.7	40.7	63.0	29.6	7.4	14.8	37.0
L5	1	100.0	100.0	100.0	-	100.0	-	-	100.0	-
L7	13	84.6	76.9	53.9	7.7	23.1	-	15.4	7.7	23.1
G1	38	76.3	36.8	7.9	18.4	18.4	5.3	2.6	13.2	73.7

DIET CODE

L = Lepidoptera
S = Spider
W = Weta
C = Coleoptera
D = Diptera

N = Native
Ex = Exotic

APPENDIX 9: MANOVA AND D.F.A. PARAMETERS

A. HYPOTHESIS: Diet of kiore = diet of Norway rat.
MANOVA: Wilks Lambda, F=34.84, P <.05, d.f.=3,266.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda = .780, χ^2 =88.316, P <.05, d.f.=3.

STANDARDISED COEFFICIENTS	
INVERT	0.85283
VEG	-0.38980
SEED	-0.02774

GROUP MEANS		
NORWAY	(n=143)	-0.58852
KIORE	(n=127)	0.66267

B. HYPOTHESIS: Diet of Norway rats in Line 1 does not change seasonally.
MANOVA: Wilks Lambda, F=2.34, P <.05, d.f.=9,43.96.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda =.386, χ^2 =18.545, P <.05, d.f.=9.

STANDARDISED COEFFICIENTS	
INVERT	-0.08012
VEG	0.95807
SEED	-0.17222

GROUP MEANS		
AUTUMN	(n= 5)	1.06139
WINTER	(n=3)	-0.42758
SPRING	(n=15)	-0.54871
SUMMER	(n=1)	4.20639

C. HYPOTHESIS: Diet of Norway rats in Line 2 does not change seasonally.
MANOVA: Wilks Lambda, F=2.80, P <.05, d.f.=6,24.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda =.347, χ^2 =13.777, P <.05, d.f.=6.

STANDARDISED COEFFICIENTS	
INVERT	1.00436
VEG	0.88437
SEED	-0.43152

GROUP MEANS		
WINTER	(n=11)	-0.07532
SPRING	(n=4)	1.41232
SUMMER	(n=2)	-2.41037

D. HYPOTHESIS: Diet of Norway rats in Line 5 does not differ with season.
MANOVA: Wilks Lambda, F=14, P >.05, d.f.=6,2.

E. HYPOTHESIS: Diet of Norway rats in Line 6 does not differ with season.
MANOVA: Wilks Lambda, F=2.38, P >.05, d.f.=3,15.

APPENDIX 9: CONTINUED

F. HYPOTHESIS: Diet of Norway rats in Grid 1 does not differ with season.
MANOVA: Wilks Lambda, F=8.37, P <.05, d.f.=6,136.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda =.533, χ^2 =43.388, P <.05, d.f.=6.

STANDARDISED COEFFICIENTS	
INVERT	1.10297
VEG	0.22897
SEED	0.18672

GROUP MEANS	
AUTUMN (n=45)	-0.51754
SPRING (n=19)	1.50085
SUMMER (n=9)	-0.58076

G. HYPOTHESIS: Diet of kiore in Line 3 does not differ with season.
MANOVA: Wilks Lambda, F=3.36, P <.05, d.f. 6,78.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda =.632, χ^2 =18.373, P ,>05, d.f.=6.

STANDARDISED COEFFICIENTS	
INVERT	0.78435
VEG	-0.58068
SEED	0.16194

GROUP MEANS	
WINTER (n=17)	-0.80154
SPRING (n=26)	0.52526
SUMMER (n=1)	0.22940

H. HYPOTHESIS: Diet of kiore in Line 4 does not differ with season.
MANOVA: Wilks Lambda, F=7.00, P <.05, d.f.=6,46.
DISCRIMINANT FUNCTION ANALYSIS: 2 significant functions derived,
Func. 1, Wilks Lambda = .238, χ^2 =31.146, P <.05, d.f.=6.
Func. 2, Wilks Lambda = .679, χ^2 =9.300, P <.05, d.f.=2.

STANDARDISED COEFFICIENTS	Func.1	Func.2
INVERT	1.69776	0.70587
VEG	0.95924	-0.66406
SEED	1.17801	0.57792

GROUP MEANS	Func.1	Func.2
AUTUMN (n=5)	-2.36646	-0.39855
WINTER (n=3)	1.45205	-1.68812
SPRING (N=20)	.37381	0.35285

I. HYPOTHESIS: Diet of kiore in Line 7 does not differ with season.
MANOVA: Wilks Lambda, F=1.80, P >.05, d.f.=3,9.

APPENDIX 9: CONTINUED

J. HYPOTHESIS: Diet of kiore in Grid 1 does not differ with season.
MANOVA: Wilks Lambda, F=3.02, P <.05, d.f.=6,64.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived Wilks Lambda =.608, χ^2=16.434, P <.05, d.f.=6.

STANDARDISED COEFFICIENTS	
INVERT	1.15289
VEG	0.26798
SEED	0.16693

GROUP MEANS	
AUTUMN	-0.15403
SPRING	1.39650
SUMMER	-0.58357

K. HYPOTHESIS: Diet of Norway rats does not differ with area.
MANOVA: Wilks Lambda, F=3.47, P <.05, d.f.=21,382.5.
DISCRIMINANT FUNCTION ANALYSIS: 2 significant functions derived.
Func 1: Wilks Lambda = .606 χ^2 =68.299, P <.05, d.f.=21.
Func 2: Wilks Lambda = .842 χ^2 =23.422, P <.05, d.f.=12.

STANDARDISED COEFFICIENTS		
	Func.1	Func.2
INVERT	0.27187	0.56199
VEG	0.69424	-0.65711
SEED	1.31654	0.31673

	GROUP MEANS	
	Func.1	Func.2
L1 (n=24)	-0.64377	0.10591
L2 (n=16)	-0.56131	-0.46369
L5 (n=6)	-1.40932	0.64679
L6 (n=18)	0.28328	-0.25303
G1 (n=73)	046861	0.09738

L. HYPOTHESIS: Diet of kiore does not differ with area.
MANOVA: Wilks Lambda, F=6.69, P <.05, d.f.=12,317.78.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda =.551, χ^2=72.656, P <.05, d.f.=12.

STANDARDISED COEFFICIENTS	
INVERT	0.05145
VEG	0.08105
SEED	1.04298

GROUP MEANS		
L3	-0.64550	-0.13449
L4	-0.11301	0.22886
L7	0.76673	0.18023
G1	1.22898	-0.04570

M. HYPOTHESIS: Diet of Grid 1 rats does not differ with species.
MANOVA: Wilks Lambda, F=5.40, P <.05, d.f.=3,106.
DISCRIMINANT FUNCTION ANALYSIS: 1 significant function derived, Wilks Lambda =.867, χ^2=15.146, P <.05, d.f.=2.

STANDARDISED COEFFICIENTS	
INVERT	0.87126
VEG	-0.46707
SEED	0.11482

GROUP MEANS	
NORWAY	-0.27577
KIORE	0.54409

APPENDIX 10: SEASONAL % VOLUME RESULTS FOR THE INVERTEBRATE, VEGETATION AND SEED FRACTIONS

AREA	SPECIES	SEASON	INVERT.	VEG.	SEED	n
L1	N	AUTUMN	45.49	35.43	0.00	5
		WINTER	47.02	0.00	14.97	3
		SPRING	37.41	4.05	29.17	15
		SUMMER	100.00	0.00	0.00	1
L2	N	WINTER	23.74	40.04	12.71	11
		SPRING	64.13	33.23	2.64	4
		SUMMER	10.00	0.00	40.00	2
L5	N	WINTER	100.00	0.00	0.00	1
		SUMMER	48.00	6.19	0.00	2
		AUTUMN	29.76	0.00	3.23	3
L6	N	WINTER	41.81	37.35	20.92	7
		SUMMER	24.14	17.74	54.80	12
G1	N	AUTUMN	9.78	17.94	65.33	44
		SPRING	56.31	13.96	28.73	19
		SUMMER	9.81	7.35	65.04	9
L3	K	WINTER	69.816	7.78	5.58	17
		SPRING	91.214	0.54	3.58	26
		SUMMER	73.85	0.00	26.15	1
L4	K	WINTER	72.30	27.70	0.00	3
		SPRING	77.04	5.01	15.27	20
		AUTUMN	31.67	1.96	31.41	5
L7	K	SUMMER	86.45	5.98	2.86	7
		AUTUMN	68.03	0.00	2.09	7
G1	K	AUTUMN	37.99	5.47	50.93	18
		SPRING	82.92	2.41	14.68	7
		SUMMER	29.86	0.27	61.72	12