ECOLOGY OF MUSTELIDS IN NEW ZEALAND

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by

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Introduction

"Nothing in connection with the naturalisation of wild animals into New Zealand has caused as much heart-burning and controversy as the introduction of these bloodthirsty creatures"

Thomson, 1922.

Mammalian predators have been liberated on many islands to control pests but the desired results have rarely been achieved. The liberation of mongooses on islands in the Caribbean and Pacific is an excellent example of a liberation which had serious repercussions. These were liberated to control rats which caused serious damage in the sugar cane fields and although they reduced the numbers of rats, they also exterminated many species of small mammals and birds.

Stoats, ferrets and weasels were liberated in New Zealand in the early 1880's to control rabbits. They appear to have had little effect on rabbit populations and stoats quickly spread into forest areas. It is not now possible to determine the effect these predators had on the native bird populations as the changes in fauna and habitat were complex. Unfortunately no studies of mustelids were made until 1948 when Wodzicki (1950) made a brief study as part of his survey of introduced mammals in New Zealand. The two periods of greatest change for mustelids have been during their spread throughout the country in the 1880's and in the early 1950's when rabbits were successfully controlled. There is little information on changes in density or feeding habits of mustelids during these times.

Detailed investigation of the ecology of Mustelids in New Zealand was begun by Dr. W.H. Marshall, Fulbright Research Scholar from the University of Minnesota, with Animal Ecology Division, D.S.I.R. from September 1960 until June 1961. He examined their ecology in the light of his experience of Mustelids in North America where conditions differ markedly from those in New Zealand.

I joined Animal Ecology Division in November 1960 to assist Dr. Marshall throughout the remainder of his study, and continued the work after his return to the United States.

The ecology of stoats, ferrets and weasels has been investigated in terms of their adaptation to food supplies which differ markedly from those in their native range in the Northern Hemisphere.

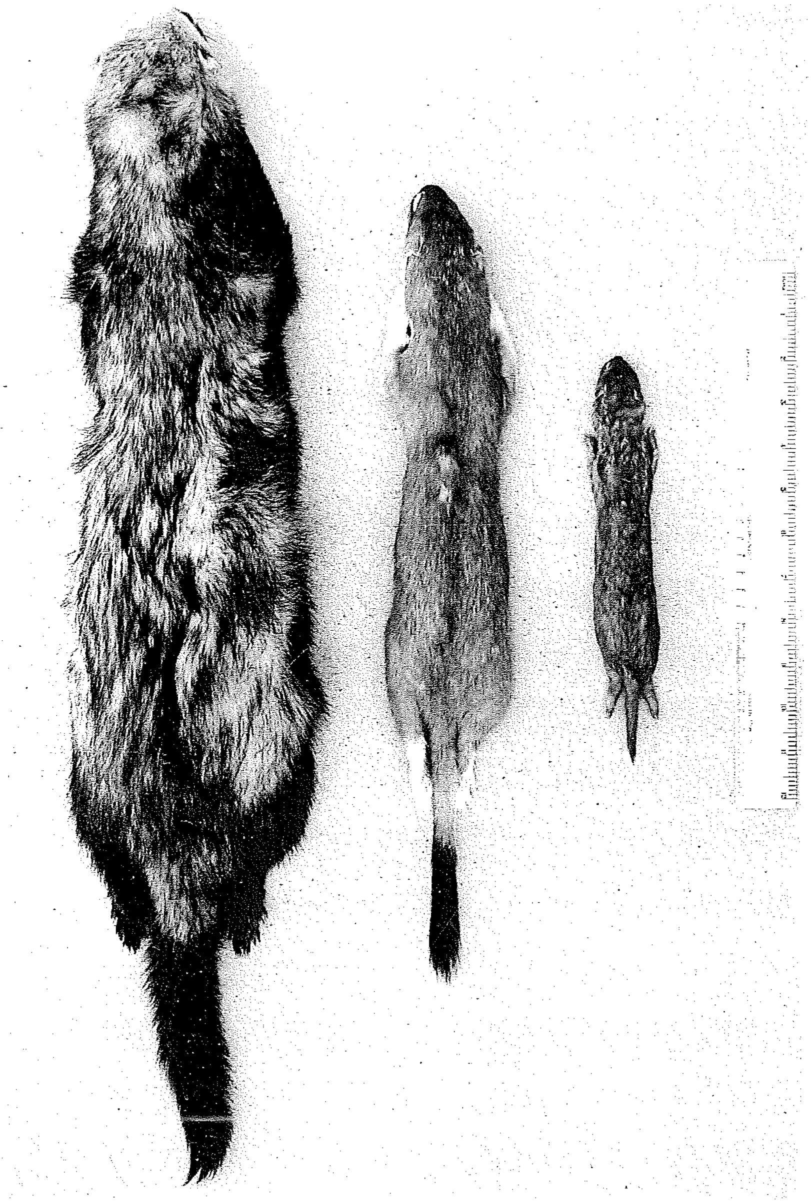

Fig. 1a. Study skins. Dorsal view.

(left to right) Ferret, stoat, weasel.

Description

The family Mustelidae is a group of elongate, short-limbed Carnivora divided into five sub-families, Mustelinae (stoats, weasels, ferrets), Melinae (badgers), Lutrinae (otters), Mellivorinae (honey-badgers) and Mephitinae (skunks). Many species are valuable fur-bearers. (Nomenclature is taken from Ellerman and Morrison-Scott, 1951).

Stoats (Mustela erminea), ferrets (M. putorius furo) and weasels (M. nivalis), introduced into New Zealand in the 1880's, all belong to the sub-family Mustelinae, a group of medium or small carnivores ranging in weight from weasels of 70-150 gms. ($2\frac{1}{2}$-$5\frac{1}{4}$ oz.) to the wolverine of 9-18 kg. (20-40 lb). Many of the group feed extensively on small mammals and the smaller forms hunt in rodent runways and burrows. Mink are adapted to a semi-aquatic mode of life, feeding largely on muskrats but also taking crayfish, fish and birds. Marten climb with agility and may hunt their prey, squirrels especially, in trees. Stoats are also skilful climbers and swim well.

There is frequently confusion in identifying stoats, ferrets and weasels, particularly stoats and weasels which have rather similar coloration, although the stoat's black tail tip is distinctive (figs. 1 a&b).

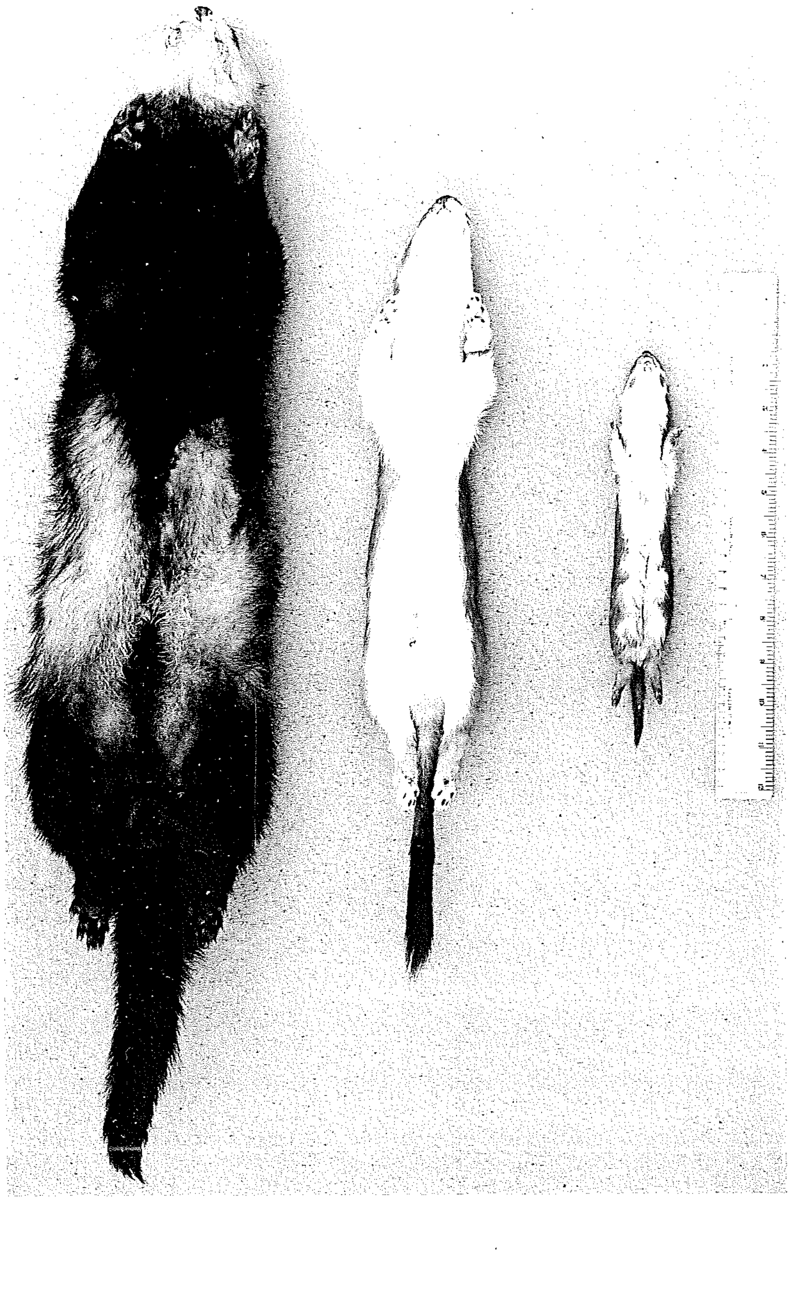

Fig. 1b. Study skins. Ventral view.
(left to right) Ferret, stoat, weasel.

There is marked sexual dimorphism in all three species with males considerably larger than females (tables 1, 2 & 3). This dimorphism is most marked in ferrets where, on average, females weigh 46% as much as males, and least marked in stoats where females average 59% the weight of males (based on mean weights of New Zealand animals). Female weasels are 50% the weight of males. New Zealand stoats and weasels closely resemble British ones in colour and markings.

Stoats are ginger brown with white underparts often tinged with yellow. There is a clear, straight margin between the white and brown hair and the tail is long and bushy with a black tip. Some stoats, particularly females, turn white or partly white in winter but retain the black tail tip.

Weasels are lighter brown than stoats with white underparts. The margin between brown and white hair is less definite than in stoats and there are spots of brown in the white. The tail is short and tapering without a black tip. They do not turn white in winter in New Zealand. Weasels are about one-third the weight of stoats.

Ferrets have black or dark brown guard hairs and buff or creamy-yellow under-fur. The shoulders, flanks, legs and tail are darker than the rest of the body.

Fig. 2. Head of ferret showing facial markings.

The face is distinctively marked with a dark mask across and below the eyes, offset by a ring of buff around the face, muzzle, chin and throat. The ears are also edged with buff (fig. 2). Albinos also occur and, during this study, were collected at Hanmer and Ohoka, Canterbury, Te Anau, and Kourarau near Carterton. Although albinos are bred for ferreting, it is unlikely that the animals caught were escaped domestic ferrets and small numbers of albinos probably occur throughout New Zealand in the feral populations.

Although stoats, ferrets and weasels were introduced from Britain, there are no records of the collection sites and it has been suggested that some animals were possibly caught in Europe (Wodzicki, 1950: 65; McCann, 1955: 152). Lydekker (1896: 121) however, stated that 3,000 stoats and weasels had been sent to New Zealand from Lincolnshire in 1885 and it may have been possible to collect large numbers of all three species in Britain. The colour and external measurements of stoats and weasels are similar to those in Britain (tables 1 & 3) and do not show any consistent differences. The taxonomic position of the ferret, however, is confused and requires investigation. The ferret and all the polecats are grouped as subspecies of <u>Mustela putorius</u> (Ellerman and Morrison-Scott, 1951) with subspecies described from differences in the skull and colour pattern. There has been long discussion as to the ancestor of the ferret, but the problem is not yet solved. Ferrets have been domesticated for many centuries and when bred for rabbiting are selected for albinism and small size. Miller (1912) considered the ferret to be most closely related to the Asiatic polecat (M. p. eversmanni) because of the similar deep constriction of the post-orbital region and similarity in colour. However, others (Pocock, 1936; Tetley, 1945; and Ashton and Thomson, 1955) suggest from similarities in the structure of the skull, especially the shape of the nasals and hooking of the hamular process, that the ferret is more closely related to the European polecat, M. p. putorius. They consider that the difference in post-orbital constriction and the small carnassial teeth of ferrets are a result of domestication and differences in diet. Ferrets show a closer resemblance in colour and markings to the Roumanian and Asiatic polecats than to the English polecat (Pocock, 1936).

There has been some confusion concerning the taxonomy of the ferret (or polecat) in New Zealand. Wodzicki (1950: 48) found that New Zealand ferrets are larger than typical European ferrets and attain the average size of English polecats. They also differ in colour and Wodzicki (1950: 69) suggested that they are possibly either a descendant of an unrecorded polecat importation or a reversion of the ferret to the polecat type. Although they may attain average polecat size, the maximum weight of male New Zealand ferrets is about 400 grams less than that of English polecats (table 4).

McCann (1955) suggested that the animals feral in New Zealand were probably derived from polecats liberated with ferrets, as domestic ferrets would not survive in the wild state. As polecats were comparatively rare in Britain, some were possibly obtained from Europe.

Wodzicki (1950: 69; fig. 15) however, has shown that New Zealand animals are paler than English polecats and are more like Roumanian and Asiatic polecats. Pocock (1936) has pointed out the close resemblance in colour of the English ferret and the Asiatic polecat and from these comparisons it seems likely that the New Zealand ferret resembles that occurring in England.

The behaviour of New Zealand feral ferrets is more like that of domestic ferrets than of polecats. When trapped they can be handled with confidence as they do not struggle or fight; they have little smell and can soon be tamed. In contrast, polecats fight fiercely when trapped, releasing a strong stink, and are very difficult to tame. It is unlikely that polecats would ever survive the long voyage to New Zealand (Dr. T. Poole, Aberystwyth, Wales. pers. comm. 1963).

If, as seems likely, the New Zealand animal is purely a feral ferret, it may be of considerable value in helping to determine the relationships of ferrets and polecats. Ferrets have been present in New Zealand for eighty years and, although some domestic animals may escape and mix with the feral population, many of the domestic stocks have been bred from wild-caught animals. If the differences in the domestic ferret skull are a result of differences in diet and softer foods, they are not likely to be present in ferrets which have been feral for 80 years. These animals should be valuable for comparison with polecats.

TABLE 1.

Stoat Measurements

		NEW ZEALAND			GREAT BRITAIN *		
	Sex	Mean	Range	Sample No.	Mean	Range	Sample No.
Body weight	♂	334	255-416	22	322	200-445	204
	♀	198	125-245	13	213	140-280	99
Total length	♂	396	367-406	22	408	370-439	4
	♀	340	321-382	13	381	337-432	8
Tail	♂	115	106-124	22	111	95-127	4
	♀	96	86-116	13	117	95-140	8

* British measurements taken from Southern (1964).

TABLE 2.

Ferret Measurements

		NEW ZEALAND			GREAT BRITAIN *		
	Sex	Mean	Range	Sample No.	Mean	Range	Sample No.
Body weight	♂	1301	789-1750	16	c.1250	up to c.2150	-
	♀	603	424-885	13	c. 800		-
Total length	♂	566	513-621	16	c. 590		-
	♀	482	551-515	13	c. 490		-
Tail	♂	153	134-170	16	c. 180	"	-
	♀	127	110-145	13	c. 140	"	-

* British measurements from Southern (1964).

TABLE 3.

Weasel Measurements

		NEW ZEALAND			GREAT BRITAIN *		
	Sex	Mean	Range	Sample No.	Mean	Range	Sample No.
Body weight	♂	129	110-151	8	115	70-170	162
	♀	65	52-77	2	59	35-90	36
Total length	♂	266	238-287	8	262	215-295	46
	♀	231	218-230	3	227	205-255	12
Tail	♂	56	51-61	8	60	40-75	46
	♀	49	46-52	3	50	40-65	12

* British measurements taken from Southern (1964).

Liberation and Distribution

Details of the introduction of stoats, ferrets and weasels have been given by Thomson (1922) and Wodzicki (1950). Rabbits, after their initial establishment during the 1860's, increased alarmingly and during the 1870's devastated large areas of farmland. In an attempt to check and reduce them, large numbers of mustelids were introduced. The first record of mustelids in New Zealand is of five ferrets introduced by the Canterbury Society in 1867, but large scale introductions did not start until 1882. Large numbers of ferrets were sent from England for liberation in the areas heavily infested with rabbits. Thomson (1922) records that during 1884 nearly four thousand ferrets were released, most of them in Marlborough. Stoats and weasels were first liberated in 1885 when 183 weasels and 55 stoats were received from London. Further importations were made in the following years and the breeding of large numbers of ferrets was continued until about 1897.

During these large scale liberations very few records were kept of liberation sites and numbers of animals released. However, it appears that they spread rapidly and soon occupied all suitable habitat. They were first seen at Tutira, Hawke's Bay in 1902 and by 1904 they had reached Poverty Bay, over 65 miles further north (Guthrie-

Smith, 1953: 355). Mustelids probably arrived in Fiordland within a decade of their liberation in Otago and Southland (Wodzicki and Bull, 1951: 69) and stoats had reached Resolution Island by 1901 (Henry, 1901). They appear to have had little effect on the rabbit population and did not substantially reduce it as had been hoped (Thomson, 1922: 72).

Distribution

Surveys of the distribution of stoats, ferrets and weasels in New Zealand, based on questionnaire returns from field workers, have been made by Wodzicki (1950) and Marshall (1963). In both cases small numbers of specimens were also collected and helped to confirm the information from questionnaires. There appears to have been little, if any, change in distribution patterns during the twelve years between surveys. However, a sharp decrease in density occurred during this period, following the reduction in rabbit numbers by successful control measures. Mustelids were found in the North and South Islands and on some inshore islands (e.g. Resolution Island, which is separated from the mainland by a narrow channel). They were absent on Stewart Island and all outlying islands.

I have obtained further information on the distribution of mustelids in New Zealand from the large number of dead animals collected for food habit studies. Animals have been trapped by Rangers of the National Parks and by field officers of Wildlife Branch, Internal Affairs. Also, some were caught by private individuals or found killed on roads. In some parts of New Zealand no people were available to collect specimens. These areas have been shaded on the distribution maps and do not necessarily show absence of mustelids. Few specimens were received from the following areas: Northland, Waikato, eastern Bay of Plenty and the East Coast, Nelson, Marlborough and Otago. In other areas, however, adequate numbers of stoats but no ferrets were collected and indicate that ferrets were not present. Numbers on the distribution maps for various localities are given to show the distribution of my collections and do not indicate density.

Stoat

Stoats are widely distributed in all types of habitat throughout New Zealand (Wodzicki 1950; Marshall 1963). Records of mustelids in the Fiordland area indicate that stoats are widespread even in heavy bush. A young male stoat was caught on the shores of Lake Monk in autumn 1957 (Riney _et al_, 1959: 35) and three stoats were trapped in Caswell and George Sounds and Resolution Island (Wodzicki and Bull, 1951: 67). Approximately 19 stoats were destroyed in and about Takahe Valley between

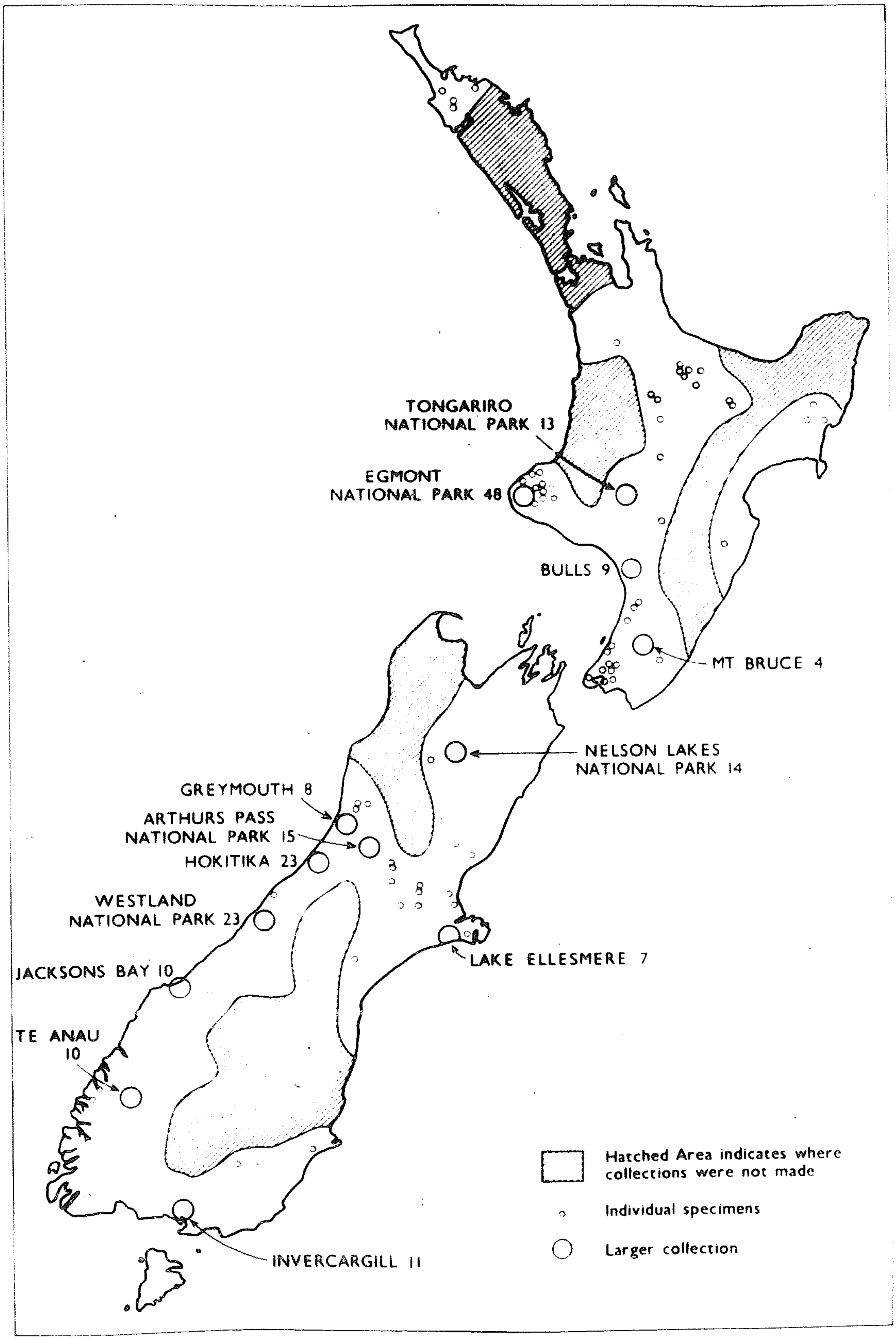

FIG. 3. STOAT DISTRIBUTION

1948 and March 1951 (Williams, 1952: 207).

I obtained stoats from all types of habitat in all areas in which mustelids were collected, even in the wet, heavy bush of Westland and Fiordland (fig. 3). The large number of stoats from the Westland area is more likely to reflect trapping pressure than density. Opossum trapping is intensive here and stoats are often caught in the opossum traps.

Ferret

Ferrets have a much more restricted distribution than stoats and are absent or rare in Northland north of Kaipara Harbour, eastern Bay of Plenty, the East Coast and Poverty Bay, Taranaki, Western Nelson and the West Coast of the South Island (Wodzicki, 1950: 71). In the southwest of the South Island ferrets penetrated Fiordland only as far as did rabbits on the eastern side of the main divide (Wodzicki and Bull, 1951: 69). When rabbits were abundant the heavy and medium ferret populations coincided with heavy rabbit populations and the areas in which ferrets were rare or absent were those with few or no rabbits (Wodzicki, 1950: 71). Even after a great decrease in rabbit numbers Marshall (1963: 17) found a similar distribution pattern and correlated it with a combination of climate and land use. The areas without ferrets were areas of high rainfall and low sheep and rabbit densities.

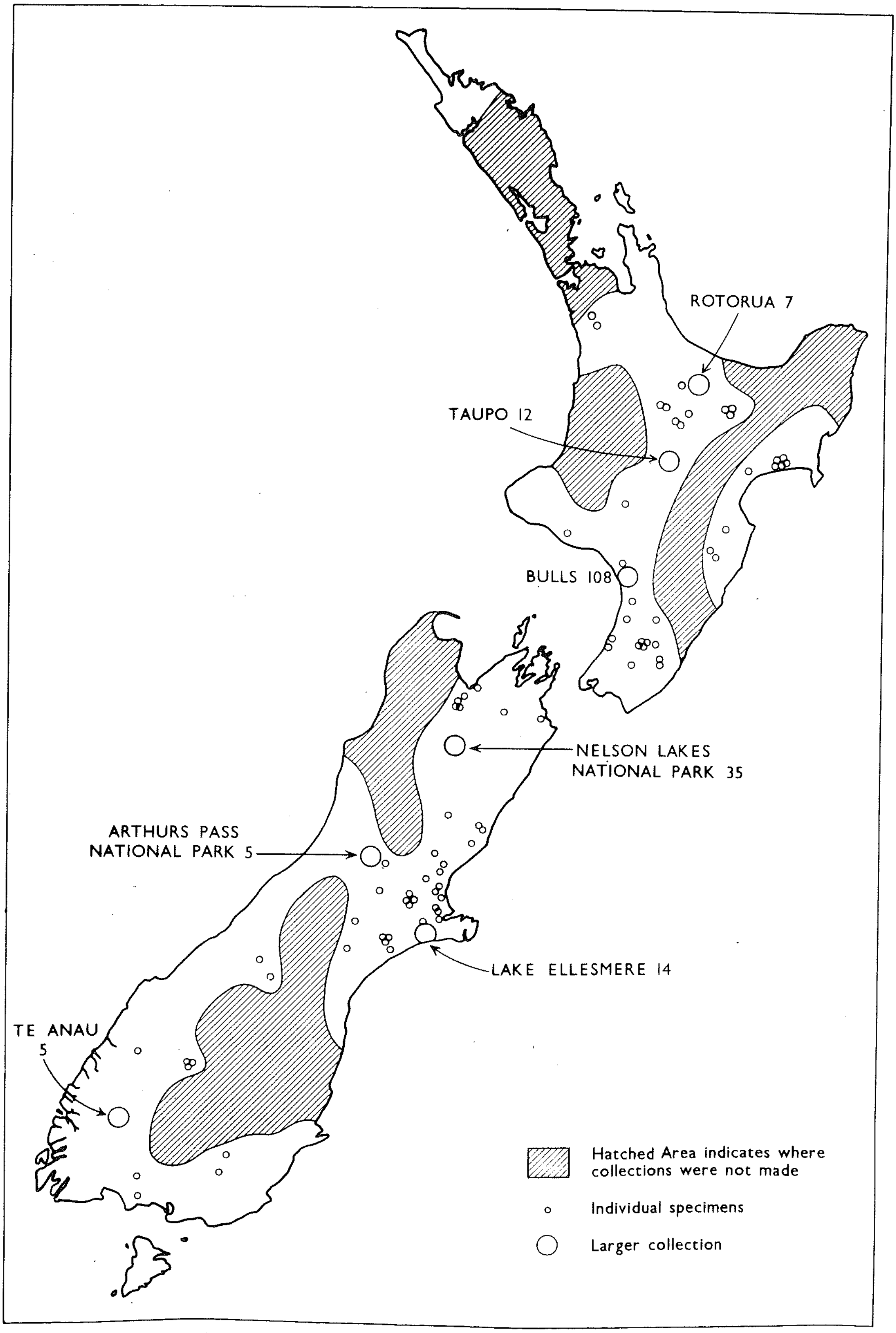

FIG. 4. FERRET DISTRIBUTION

During this investigation ferrets were collected in almost all areas in which they were reported by Wodzicki (1950) and Marshall (1963) (fig. 4). No ferrets were obtained from Taranaki or Westland although large numbers of stoats were collected there. If ferrets were present they would certainly have been caught. In other areas without ferrets few, if any, stoats were collected and the absence of ferrets cannot be shown as clearly as for Taranaki and Westland.

Weasel

The distribution pattern of the weasel has been the most difficult of the three species to determine. Wodzicki (1950) could not make use of questionnaire returns during his survey because the animal was so often confused with stoats. No specimens were obtained but details of two weasels taken in Canterbury in the early 1940's and preserved as study skins in the Canterbury Museum were given (Wodzicki, 1950: 67). Wodzicki (1950) considered that the distribution and incidence of weasels had considerably declined and that they were thinly and rather locally distributed.

Between 1948 and 1960 ten weasels were added to the Animal Ecology Division collection and two to the Dominion Museum. Marshall (1963) collected further specimens and included all these animals in his distribution map derived

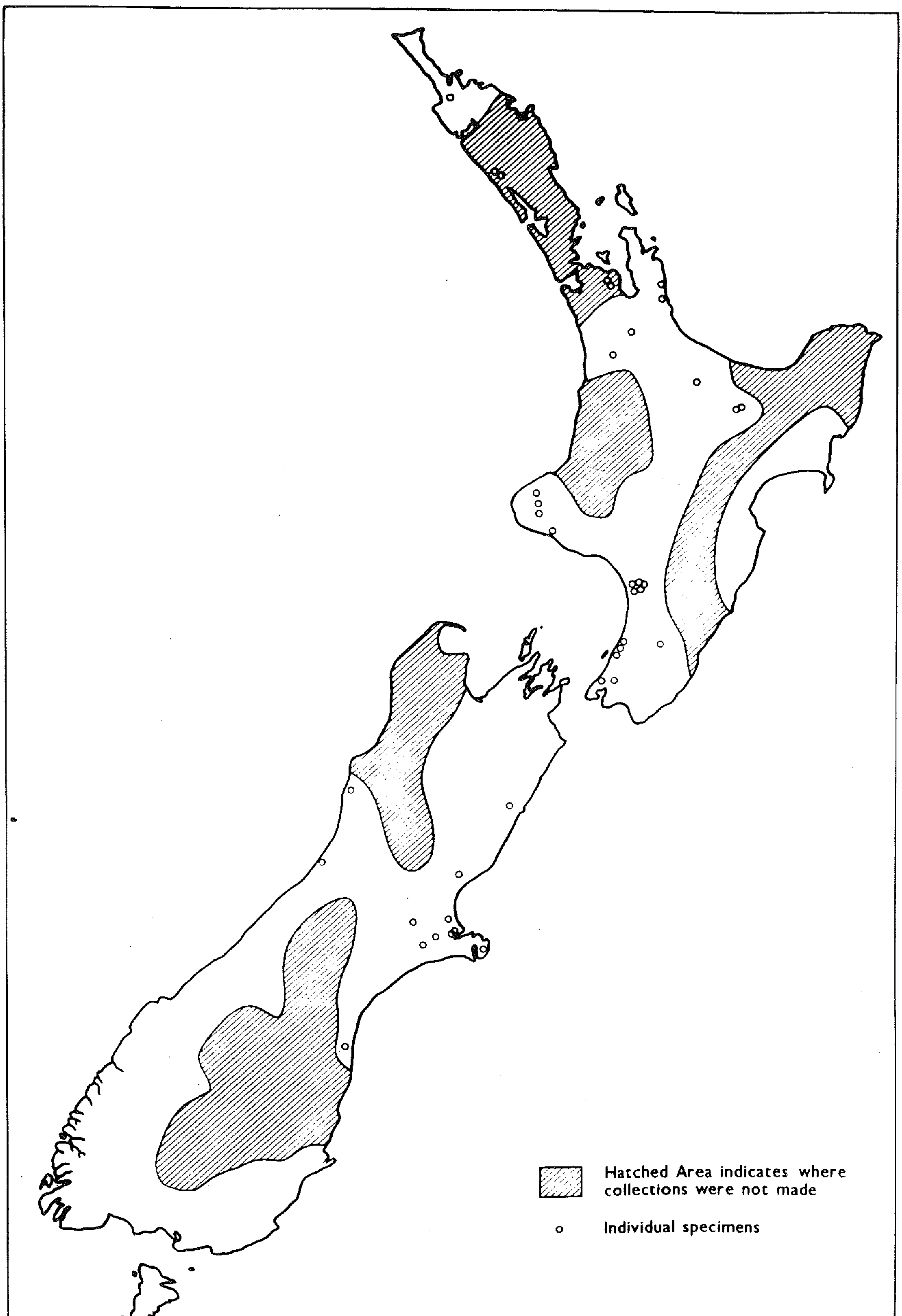

FIG. 5. WEASEL DISTRIBUTION

from questionnaire data. He suggested that the weasel is probably less widely distributed than stoats or ferrets, particularly in the South Island, but as it is the smallest and most difficult of the three species to observe, he considered that this information may be grossly inadequate.

Since the start of Dr. Marshall's survey a total of 32 animals have been collected from scattered localities over much of New Zealand and weasels now appear to be widely distributed (fig. 5). Specimens were collected in Northland, Auckland, Bay of Plenty-Rotorua, Taranaki, Bulls, Manawatu-Wellington, Wairarapa, Kaikoura, Canterbury and Westland. Dr. L. Hartman (pers. comm. 1963) obtained live weasels from Te Awamutu, Mauriceville (Wairarapa) and Leeston (Canterbury). Although two animals were trapped within Egmont National Park and one in scrub at Murapara, most were taken on farmland. It seems likely that, with further collecting, specimens will be obtained from modified habitat in other parts of New Zealand.

Age Determination

It is important in any wildlife investigation to be able to distinguish age classes in the population. In this study the most important distinction made was between young of the year and older sexually mature animals. There is little information on the longevity of stoats, ferrets and weasels in the wild. Linduska (1947) tagged 73 long-tailed weasels (Mustela frenata) on a Michigan farm and recaptured a few one year after their first capture but none at the end of the second year. This suggests that their average life span is relatively short.

Methods of separating the considerable numbers of stoats, ferrets and weasels into age classes were derived with some modification and refinement from previous studies. These have used changes in the skull and dentition with age to distinguish young and adult animals. Hall (1951: 25) recognised four age classes in American weasels, using the degree of fusion of the sutures between nasals and maxillae as an important criterion. His groupings are

(1) juvenile — One or more deciduous teeth present
Birth to 3 months.

(2) young — Sutures widely open
3 to $7\frac{1}{2}$ months

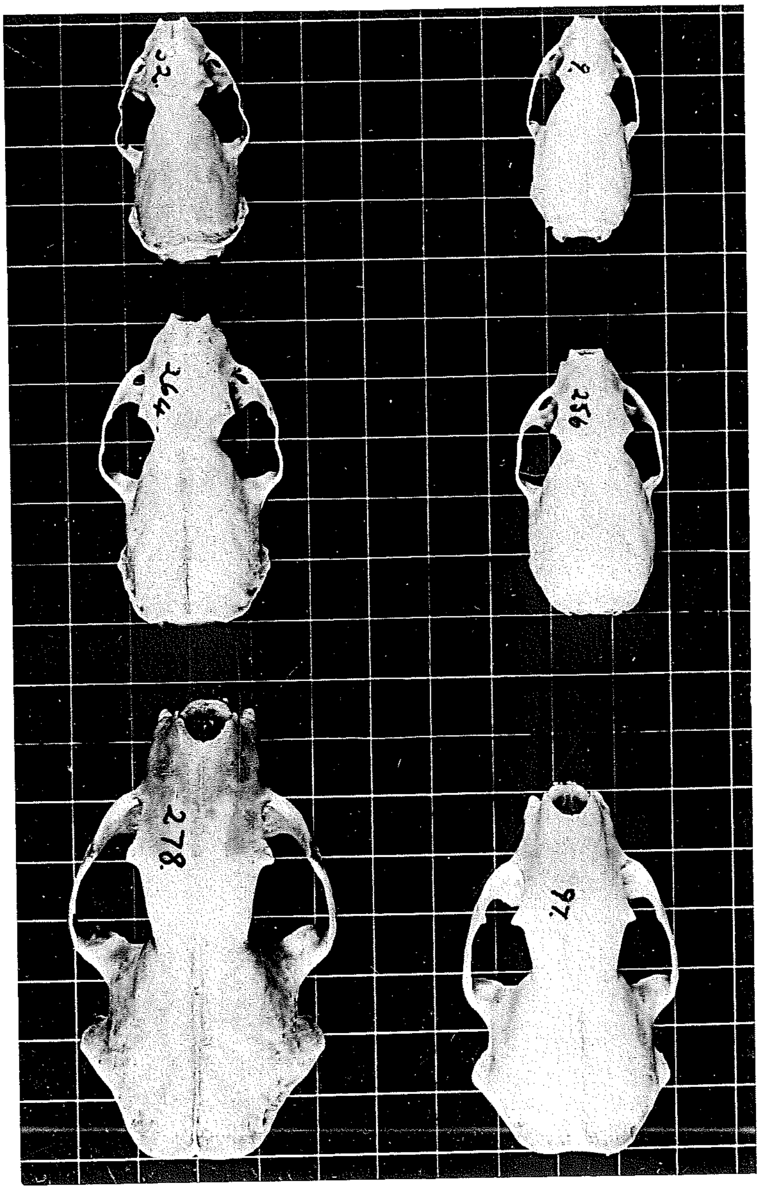

Fig. 6. Skulls showing sexual dimorphism.
Females (right) smaller with saggital
crest poorly developed.
Weasel (upper), Stoat (centre)
Ferret (lower).

(3) subadult Sutures visible but indistinct
$7\frac{1}{2}$ to 10 months.

(4) adult No trace of sutures visible
Over 10 months

The ages given by Hall at which changes in the skull occur do not correspond with other results. Hamilton (1933) found that permanent dentition in M. frenata in north-eastern U.S.A. is completed at 75 days ($2\frac{1}{2}$ months). Permanent dentition in New Zealand stoats is completed at two months and all sutures are closed at five months. A similar pattern of development occurs in stoats in Britain (Deanesly, 1935).

The presence or absence of the sagittal crest has also been used to separate adult and immature age classes in mink (Greer, 1957), pine marten (Marshall, 1951) and other mustelids. In adult males the sagittal crest is always well developed but in adult females it may be poorly developed or absent (fig. 6). Often the temporal ridges do not meet and leave a long V on the skull in place of the sagittal crest.

Body weight can be useful in determining age during the period of active growth but requires calculation of a growth curve from captive animals or recaptured animals of known age. It was not possible to do this adequately in the time available.

The baculum (os penis) shape or weight has been used for many years as a criterion for ageing fur-bearing mammals and has been used for stoats (Deanesly, 1935), weasels (M. nivalis)(Hill, 1939), long-tailed weasels (M. frenata)(Wright, 1947), mink (Elder, 1951; Lechleitner, 1954) and pine marten (Marshall, 1951). At the onset of sexual maturity the baculum undergoes changes in shape and the weight approximately doubles. Dry weight was the most useful measure of these changes.

Increase in the weight of the lens of the eye with age was recently found to be a useful method of ageing cottontail rabbits (Lord, 1959) and this technique has now been applied to a wide range of mammals. Amongst Carnivora it has been used to age gray foxes (Lord, 1961) and raccoons (Sanderson, 1961). However, Montgomery (1963) showed that freezing the lenses of adult and young raccoons for more than one day before fixation, or decomposition for more than two days, reduced their dry weight. Lenses which lost weight showed black rings at the equator and dull surfaces while those without weight loss had smooth shiny surfaces and were a translucent milky white colour. The lenses collected from many of my specimens showed the characteristics of weight loss described by Montgomery and have not been considered further. The relative scarcity of mustelids in New Zealand made it impossible to obtain samples without freezing, preservation and in some cases decomposition.

The age of stoats, ferrets and weasels collected in this investigation has been estimated from the characters of the skull and baculum. The extent of fusion of the following sutures was recorded for all skulls except badly crushed ones

Premaxilla-maxillar
Nasal
Maxilla-frontal
Fronto-parietal
Parieto-occipital
Spheno-basilar
Squamoso-jugal
Maxilla-jugal

Where the skulls of females had been badly crushed, the reproductive condition and size of nipples during the breeding season indicated whether the animal was adult or immature.

A modification of the terms used by Taber (1963: 119) for mammals in general has been used for these age categories. They are

(1) Immature - young of the year (male and female) distinguishable from adults by skull characters.

3 subdivisions

UU	all sutures unfused
UF	some, but not all, sutures fused
CF	all sutures fused and skull chalky

(2) Sub-adult Skull resembles that of adult but baculum has a small head and weight is similar to that of immature animals.

(3) Adult all sutures fused, with skull well calcified and smooth. Baculum has enlarged head and weight is approximately double that of immature animals. Individual is usually sexually mature although female ferrets and weasels may still be sexually immature.

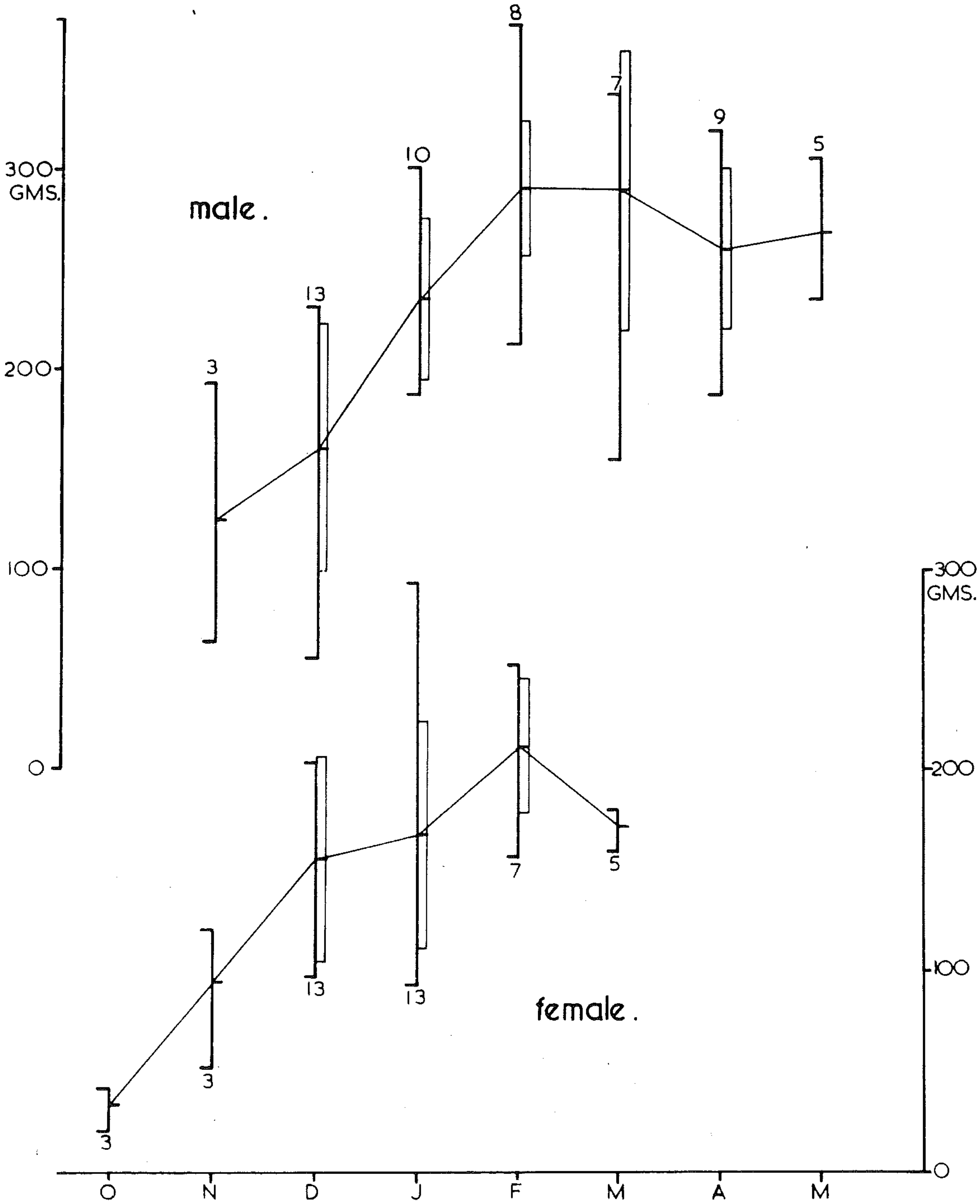

Fig. 7 Body weight of young stoats.

Age Determination in Stoats

As stoats are born during only a short period of the year all young are within a few weeks of the same age. This is evident in the graph of mean monthly body weights of young stoats (fig. 7). Deanesly (1935) described in detail the changes in the skull with increasing age. The skull at three months has open sutures and the bone is chalky in appearance. Male skulls at this age are less developed than females and sutures are more open. At four months the sagittal crest begins to develop although, in females, it may not develop far. At five months the nasal sutures begin to disappear and the skull starts to show adult characters with harder bone and a smooth glossy surface.

The pattern of changes in New Zealand is similar (fig. 8). During December some skulls still had all sutures unfused, while fusion had started in others. Three quarters of the males but only one third of the females in December have UU skulls. In December some females attain adult weight while males continue to grow until February (fig. 7). UF skulls were present from December to March although fusion of sutures was completed in most animals during February. The two UF skulls taken in mid-March had only the squamoso-jugal still open. This is the last suture to fuse.

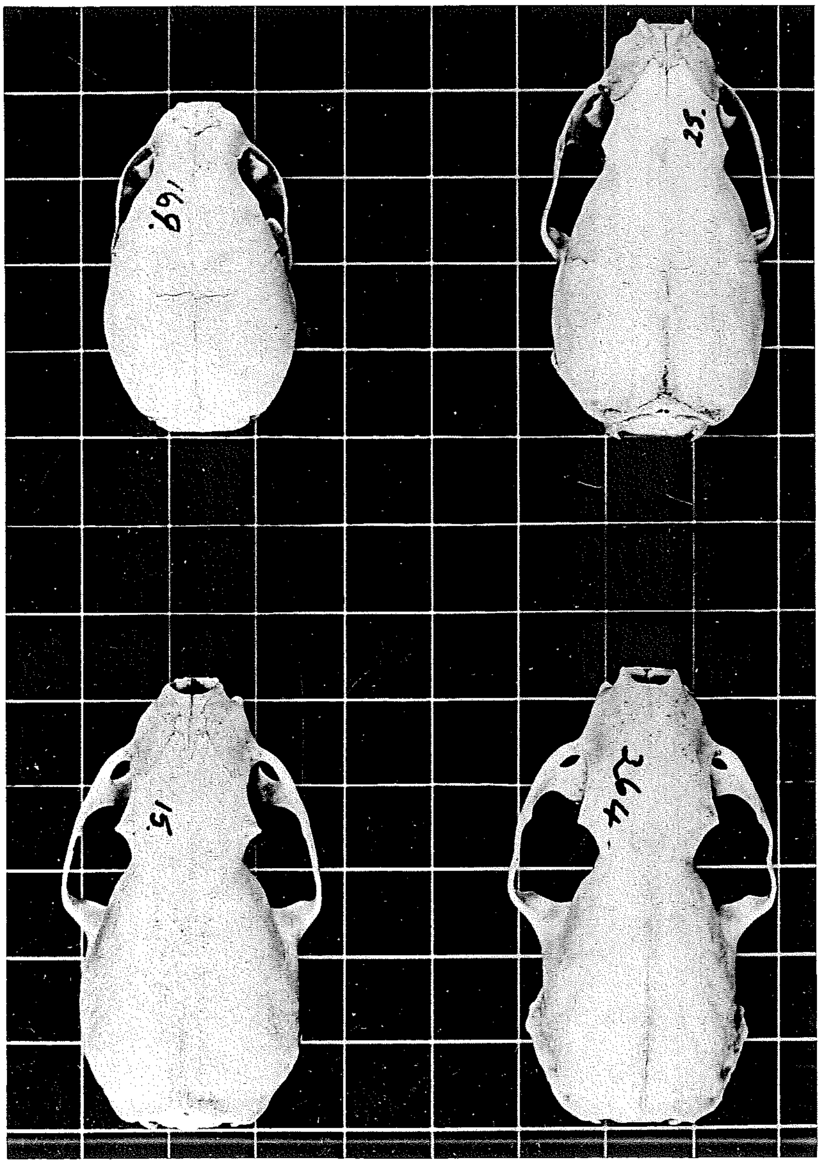

Fig. 6. Male Stoat skull, changes with age.
(upper lsft) UU deciduous teeth still present.
(" right) UU permanent dentition present.
(lower left) UF sagittal crest not yet formed
(" right) Adult skull.

Two females with completely fused CF skulls were collected in January but most skulls were not completely fused until February (table 4). Although some immature skulls could be distinguished until June many males had assumed adult skull characters by the end of April and could only be distinguished from adults by baculum weight. Separation of adult from immature females on the basis of skull chalkiness was a little more difficult than in males as some skulls possibly never become completely smooth. Three females with chalky skulls were found to be more than a year old. One adult in October and another in December still had chalky skulls and the skull of a captive 2½ years old showed signs of chalkiness.

The bacula of male stoats in Britain weigh about 20 or 30 mg. before the first breeding season (i.e. up to about ten months) but the weight doubles as sexual maturity is attained (Deanesly, 1935). Wright (1950) has shown that the baculum in the long-tailed weasel (M. frenata) is stimulated to develop to the adult type by androgens. In castrated males the baculum remains of immature type indefinitely but can be stimulated to increase in weight by injections of testosterone propionate. In M. frenata the baculum of immature males weighs 14-29 mg. and increases in adult males to 53-101 mg. (Wright, 1947). The range of weights in

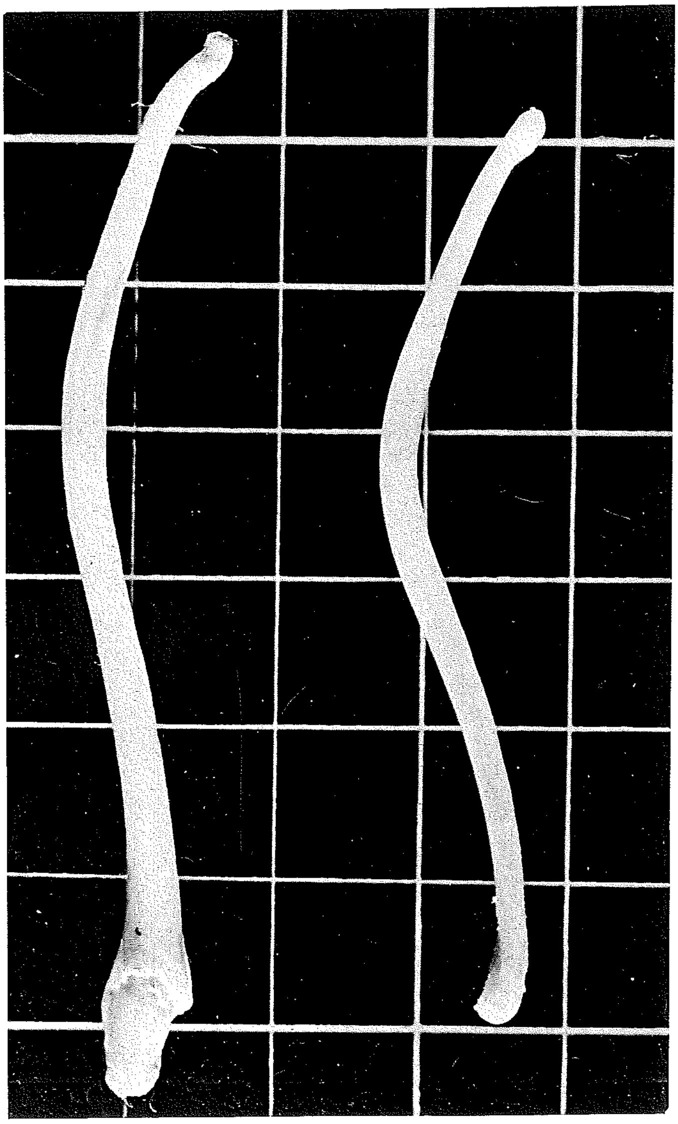

Fig. 9. Stoat bacula
(left) adult 48 mg.
(right) immature 19 mg.

stoats in Russia is 16 to 32 mg. in immature and 33-48 mg. (mean 42 mg.) in adult stoats (Novikov, 1956: 129, quoting V.A. Popov, 1947).

The increase in the weight of the baculum in stoats in New Zealand is rapid during the first four months, while the animal is growing rapidly. It then gains weight slowly through autumn and winter until July when it begins to increase in weight more rapidly. During this month the testes of immature stoats also begin to increase in weight (fig.17). By September the baculum has generally reached adult weight and conformation, with an enlarged head (fig. 9). The lowest baculum weight of adult stoats taken in autumn and winter was 39 mg. and the highest July sub-adult weight was 37 mg. (fig. 10). The division between sub-adult and adult was therefore made at 38 mg. Baculum weight range in sub-adult males was 20 to 38 mgs. Young stoats can thus be separated from adults for six to seven months on the basis of skull characters and in males for ten months by baculum weight (table 5).

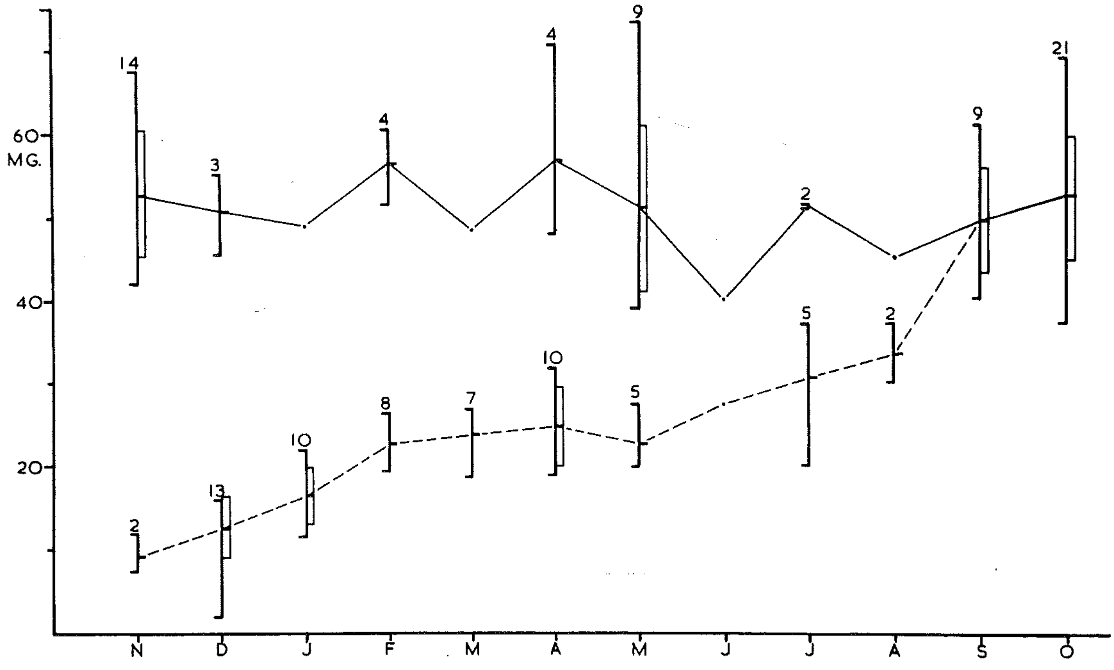

Fig. 10 Stoat baculum weight. —— adult; - - - - immature.

TABLE 4.

Distribution of Immature Stoat Age Groups

	UU		UF		CF		SUB-AD.
	♂	♀	♂	♀	♂	♀	♂
Oct.							
Nov.	2	2					
Dec.	9	5	3	10			
Jan.			10	11		2	
Feb.			4	2	3	5	
Mar.			1	1	5	4	1
April					4	2	6
May					2	1	3
June					1	3	1
July							5
Aug.							2
Sept.							1

TABLE 5.

Stoat age classes from skulls and bacula

Immature	skull UU	Birth to 2 months 11♂ 7♀
	" UF	2 months to approx. 4 months 18♂ 24♀
	" CF	Approx. 4 months to 6 or 7 months 15♂ 17♀
Sub-adult males		baculum less than 38mg. 6 months to 10 months 19♂
Adults		skull fused and smooth Females over 6-7 months 37 Males over 10 months 79

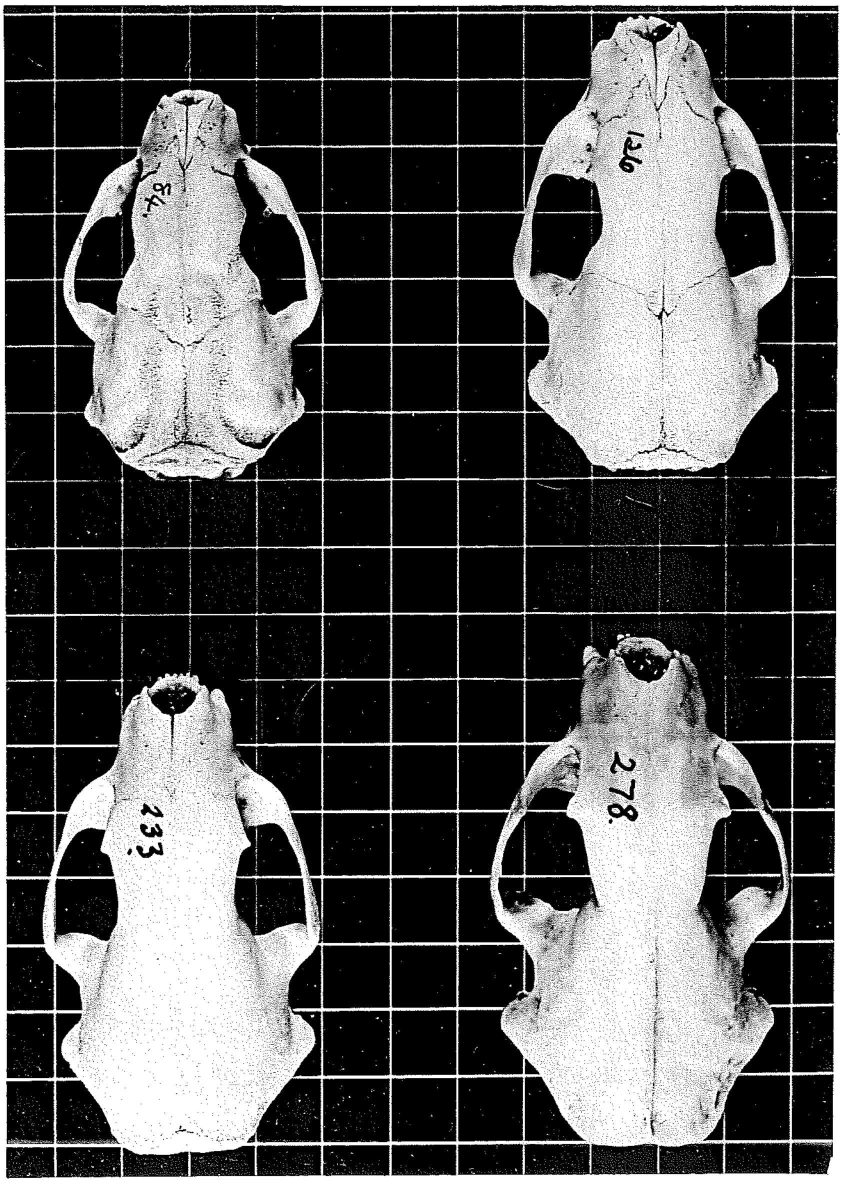

Fig. 11. Male Ferret skulls, changes with age.
(upper left) UU. 9½ wks old.
Deciduous teeth
still present.
(" right) UU permanent dentition
present.
(lower left) UF chalky, sagittal
crest forming.
(" right) Adult.

Age Determination in Ferrets

Methods similar to those used for determining age in stoats were used with ferrets and, as ferrets are relatively easy to breed in captivity, some known age animals were reared at the Animal Ecology Division Animal House, Taita. Unfortunately, a graded series could not be bred in the time available.

All skulls, except those badly crushed, were saved and graded into the classes, UU, UF, CF or adult (table 6 and fig. 11). Most of the skulls with all sutures unfused were trapped in January and February. Two more were taken in March and another in April. The record of one taken in June is doubtful as this animal may have been caught earlier. Partly fused skulls were present in large numbers from January to March inclusive with small numbers present in April and May. One female with a chalky skull was collected in mid-February, but most of the animals with chalky skulls were taken from March to May. Six sub-adult males were collected from March to August. Known age ferrets up to 11½ weeks all had UU skulls with all sutures unfused, suggesting that sutures remain unfused until at least 3 months old. Young ferrets with partly fused sutures (UF) were not obtained until mid-January. If these animals are three months old at this time, they will be

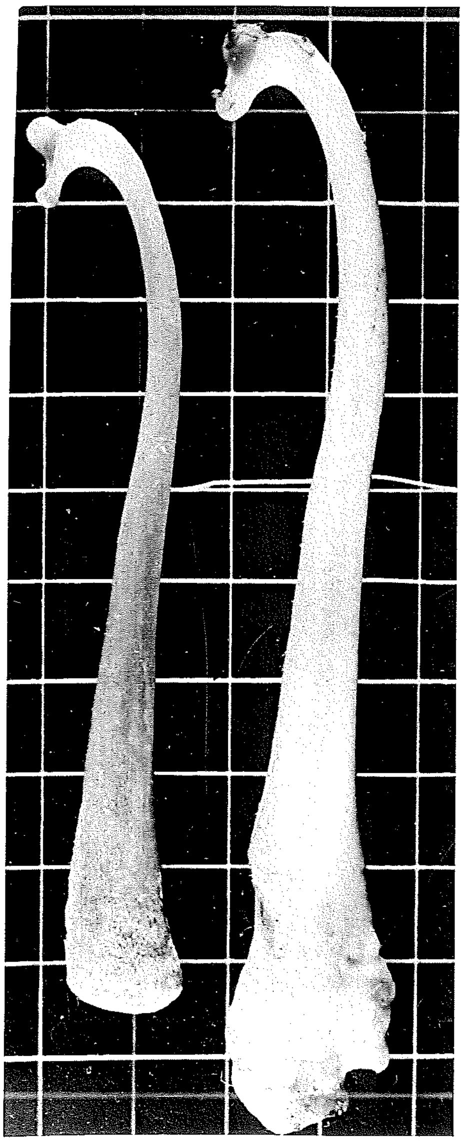

Fig. 12. Ferret bacula.

(left)	immature	162 mg.
(right)	adult	410 mg.

approximately five months old by the time all sutures are fused in mid-March. As breeding extends over a long period in the summer, it was not possible to determine the limits of each grouping from wild caught animals.

The weight of the baculum has been used to age the black polecat (M. putorius) in Russia (Popov, 1943). Immature bacula weigh from 80 to 240 mg., while the mean adult baculum weight is 337 mg. (range 280-470 mg). Bacula of New Zealand ferrets show a rather similar range of weights. Bacula of immature animals weigh from 7 to 254 mg. and the mean adult weight is 395 mg. (range 300-500 mg)(fig. 12). The increase in baculum weight as the animal becomes sexually mature occurs during July and August. The range of weights in monthly samples of immature ferrets is much greater than in stoats and probably reflects the longer breeding season (fig. 13). Baculum weight of captive ferrets appears to be lighter than for wild animals as two 1½ year old ferrets, and another more than two years old, had baculum weights in the range 268-276 mg. This is lighter than any adult wild caught ferret. However, another captive ferret over three years old had one of the heaviest bacula recorded (492 mg)(fig. 14).

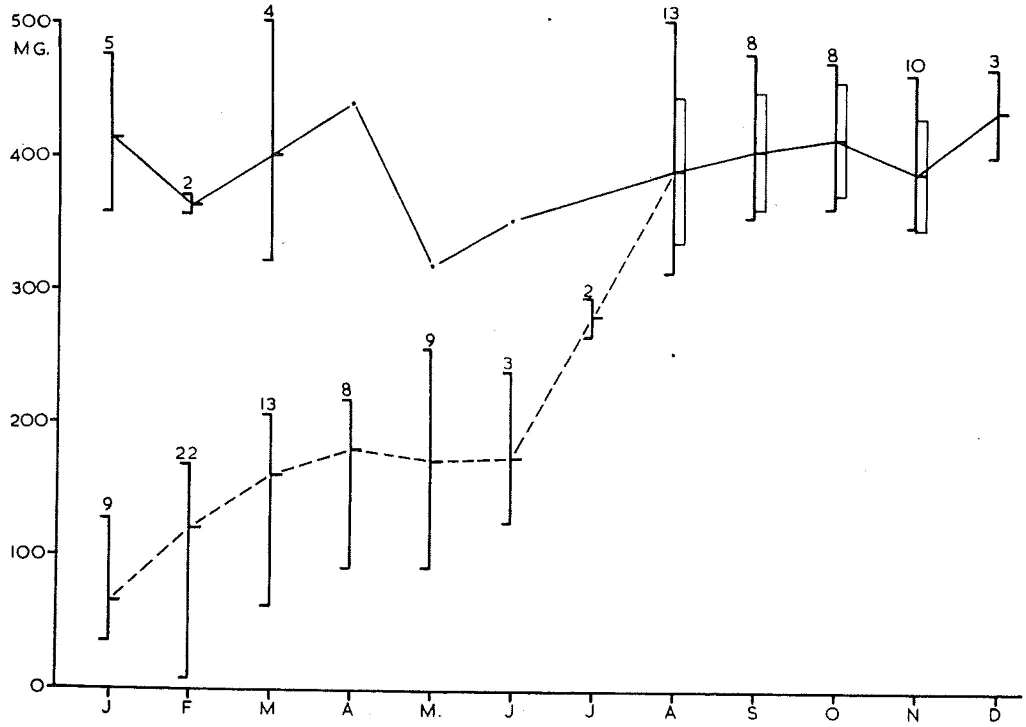

Fig. 13 Ferret baculum weight. ——— adult; - - - - immature.

TABLE 6.

Distribution of Immature Ferret Age Groups

	UU		UF		CF		SUB-AD.
	♂	♀	♂	♀	♂	♀	
Dec.							
Jan.	6	3	2	9			
Feb.	4	4	16	6		1	
Mar.	1	1	4	4	5	9	1
April	1		1	1	4	4	1
May			4	1	3	1	2
June		1					1
July							2
Aug.							1
Sept.					1		
	12	9	27	21	13	15	8

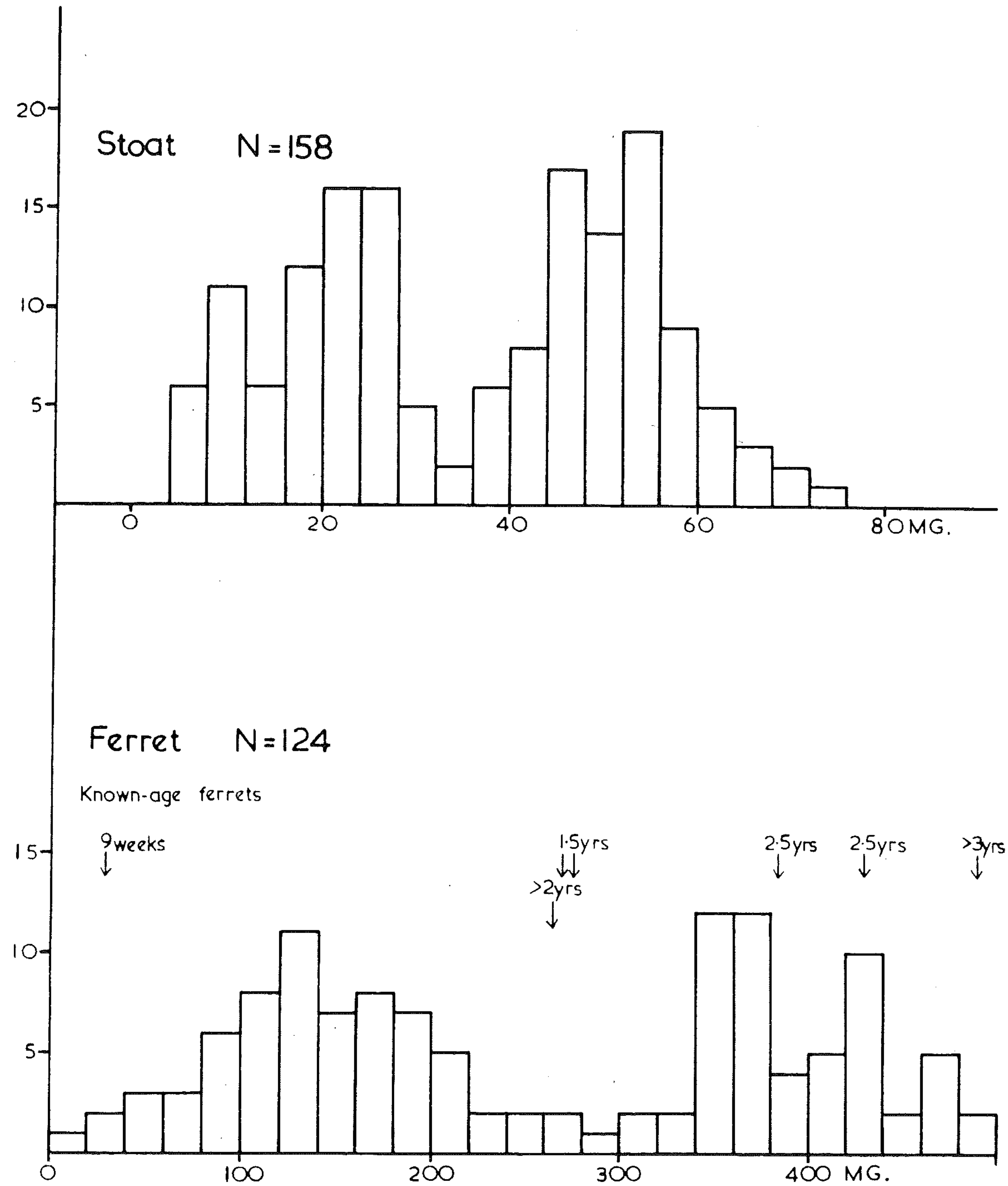

Fig. 14 Frequency distributions of baculum weight.

Age Determination in Weasels

The age of 30 weasels was determined by the same methods as used for stoats and ferrets (fig. 15; 16).

Hill (1939) distinguished adult and immature weasels by skull characters. After fusion of the sutures the skull gradually loses its chalkiness and becomes indistinguishable from adults at seven months.

Of fourteen immature skulls from my collection, eight were UU and were collected between 11 December and 20 March. The long period in which UU skulls were present indicates a long breeding season. Five young male weasels with UF skulls were caught between 13 February and 18 May. The only specimen with a chalky skull was a female taken on 14 April 1963.

In Britain the baculum of the male weasel increases rapidly in weight during the early months of life and then increases slowly (Hill, 1939). However, the use of the baculum as an age criterion is complicated by the early sexual maturity of weasels born in spring. The mean weight of bacula of young weasels in Britain in July and August is 14mg. (range 10-21 mg.) and the weasels at the heavy end of the range (20-21 mg.) are reaching sexual maturity. In contrast, adult weasels

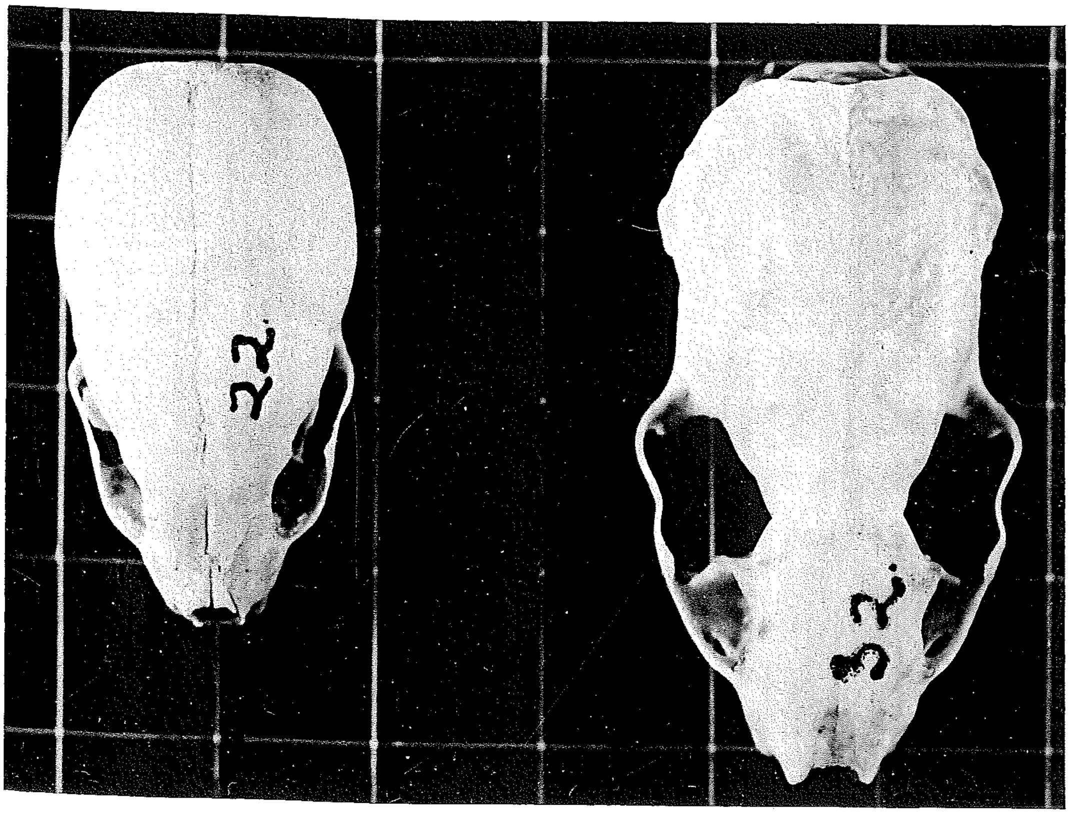

Fig. 15. Male Weasel skulls.

(upper) immature UU

(lower) adult

in full spermatogenesis during March to May had baculum weights ranging from 15 to 59 mg. The low weights, below 20mg, are probably of animals born in late summer and autumn just reaching sexual maturity at 7-9 months (Hill, 1939).

Bacula of eleven immature males collected in New Zealand between December and May ranged from 3-23 mg. in weight. Those of 12 adult males taken between September and May had a mean weight of 45 mg. (range 32-62 mg.). Two young males taken in February with bacula of 19 and 23 mg. had enlarged testes and were approaching sexual maturity. The bacula of these animals probably would not reach adult weight until the following spring.

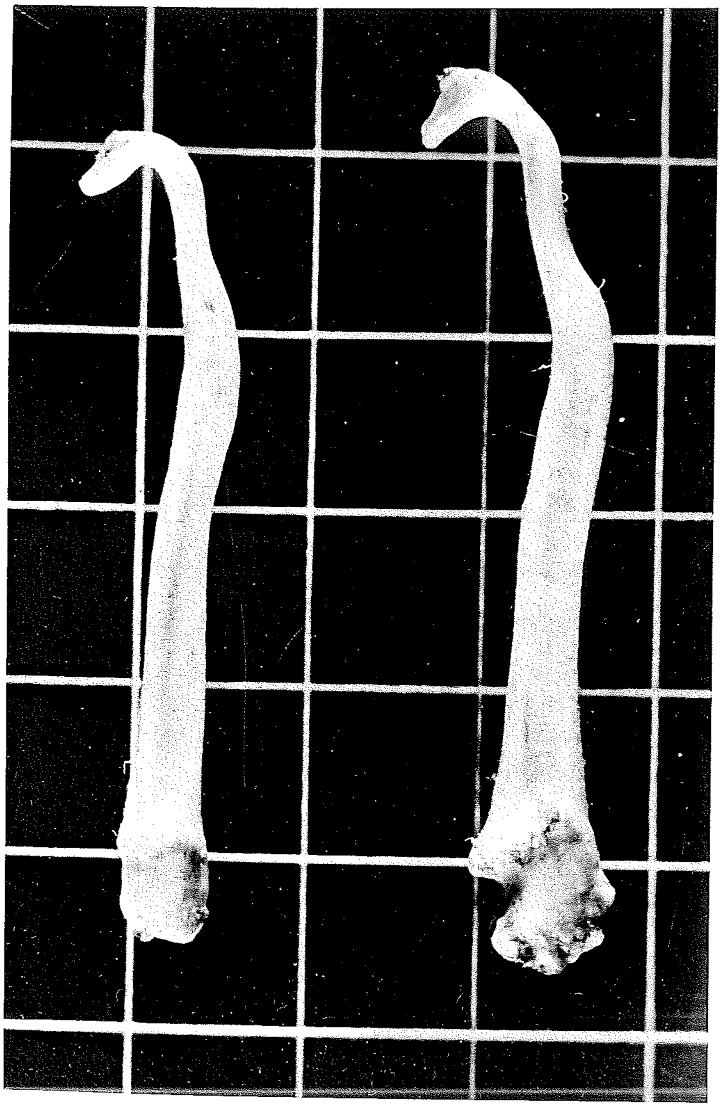

Fig. 16. Weasel bacula

(left) immature reaching sexual maturity 23 mg.

(right) adult 49 mg.

Stoat Reproduction

The family Mustelidae shows considerable variation in reproductive cycles as well as in ecological requirements and food habits. Delayed implantation occurs in a number of species including mink, marten, stoat, long-tailed weasel and badger.

Details of the reproductive cycles of stoats, ferrets and weasels have been described in Britain, Europe and North America and differ from one another quite markedly. As the specimens in New Zealand were collected mainly for a study of food habits, they were not suitably fixed for histological examination. It was possible, however, to show the main outlines of the breeding cycles and to compare them with those in the Northern Hemisphere.

The reproductive cycle of the stoat in Britain has been investigated in some detail (Deanesly, 1935, 1943). Young are born during April and the adult females come into oestrus and mate while still lactating in April and May. The fertilized ova develop to the blastocyst stage and then remain unimplanted in the uterus until the following spring. Young females come into oestrus and mate in May and June when two or three months old, before they are fullgrown. Most matings are fertile and the blastocysts remain quiescent in the uterus for more than ten months in perous stoats and nine months in those breeding for the first time. Just prior to implantation of the blastocysts the uterus undergoes histological changes and increases in weight. There is no evidence of the spring matings found in stoats in Germany (Watzka, 1940). In Britain most stoats become pregnant during March and pregnant stoats are found in March and early April. Litter size, determined from embryo counts, vary from 6 to 13 with an average of 9. Lactation lasts about five weeks. Testes are aspermatic and small during winter from October to March. Sperm is first present in March and testes increase markedly in size and weight, reaching peak weight about mid-April. They remain large until July and then regress rapidly until October when they again become aspermatic.

I examined the reproductive systems of 227 stoats (138 males and 89 females) collected from October 1960 to December 1963. Ovaries and uteri were saved, nipple size was recorded and testes were weighed. No females in oestrus were taken and no examination for unimplanted blastocysts was made. Three females taken in July and early August showed no sign of pregnancy and their uteri weighed 60, 77 and 97 mg. Nipples measured 1mm or less. Two taken on 30 August still showed no obvious signs of pregnancy but had uteri weighing 156 and 185 mg. and had nipples 1mm long. Two pregnant stoats caught on 2 and 30 September had uterus weights of 372 and 309 mg. respectively. Both were early pregnancies, but the one taken on 30 September was slightly more advanced than the first. Another caught on 9 October was at a late stage of pregnancy and the weights of four male foetuses (with membranes) were 1.02, 1.15, 1.13 and 1.22 grams. In the three pregnancies, seven, twelve and twelve embryos were recorded.

The first lactating stoat was caught on 17 October and five taken between mid-October and the end of November were all lactating. During December the size of nipples decreased and some females showed only traces of nipples. Slight nipple enlargement was recorded in some animals until February, although lactation ceased during November.

A young stoat, about five days old, was collected at the den of the lactating female caught on 17 October. The uterus of this female was very enlarged (420 mg.) and twice the weight of late October and November specimens (160 to 210 mg.).

Information on the size of two litters of young was obtained. I received two young female stoats from

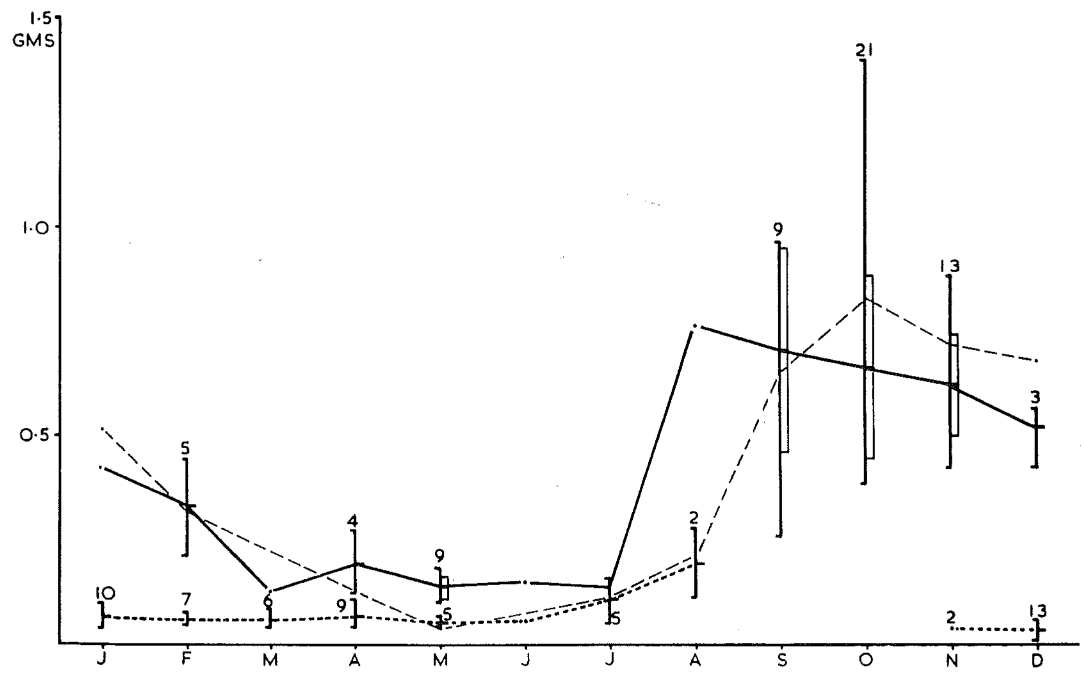

Fig. 17 Stoat testis weight.

a litter of seven young killed at Awapuni Lagoon, Gisborne, on 22 October 1963. Eight young stoats were trapped near a den at Harewood, Christchurch, in late November and early December 1963. A female stoat kept in captivity by Dr. L. Hartman (pers. comm. 1963) gave birth to seven young on 23 August 1963. The unusual date of birth may have been a result of captive conditions. The litter of seven included four females and two males (one not sexed). The pregnant stoat trapped on 9 October contained ten male and two female embryos.

Testes of adult stoats showed a well-marked seasonal variation in weight (fig. 17). The adult testes were small and inactive, weighing about 150 mg. each through winter from March/April to August, but were heavier than immature or subadult testes. In a sample of nine specimens taken in May there was only a small variation in testis weight. Testes increased in weight in August and reached their peak weight in September. The period of active spermatogenesis was not determined but sperm was probably present from August to February. Testis weight gradually decreased from September onwards.

Testes of immature stoats remained small (less than 100 mg.) through autumn and winter. They began to increase in weight in July and more rapidly in August and, by September, were indistinguishable from those of adults. It is likely that by the end of August the bacula of most stoats born the previous spring reach adult weight and subadult animals can no longer be distinguished. Two stoats collected in August and one taken in September were classed as subadult by baculum weight. These subadult stoats taken in August had testis weights of 110 and 270 mg., while the one adult stoat had a testis weight of 750 mg. In a large sample, however, the difference in testis weights during August of subadult and adult stoats may be less. The baculum of only one male out of ten taken in September was in the subadult range and the testis weight of this animal was within the adult range.

The growth curve of monthly samples of immature stoats also shows that young stoats are born during a limited period in spring (fig. 7). This agrees with the results from an examination of pregnancies and lactation. Very small stoats less than 50 gms. in weight were obtained only in October. Body weights of males and females increase rapidly during October and November with the mean body weights of males and females about equal. However, in the following two months, males increased in weight more rapidly than females which were beginning to reach adult size. These changes are also reflected in the characters of the skulls (page 23).

The pattern of sexual changes in New Zealand stoats are similar to those described by Deanesly (1935 & 1943) in Britain. Testes of stoats in New Zealand appear to reach peak weight a month earlier than those of stoats in Britain (fig.17) but the time of pregnancy and births appears to correspond closely in both countries. Unfortunately no information on occurrence of oestrus and unimplanted blastocysts was obtained during this study for comparison with these stages of the reproductive cycle in Britain. However, if New Zealand stoats correspond closely to British animals, as they do for time of birth, adult females in oestrus would occur during October and November, and young females in oestrus during November and December. The three records of embryo numbers in pregnant females falls within the range given by Deanesly (1935).

Although these results for New Zealand stoats correspond closely with those of British stoats, there are some marked differences in the reproductive cycles of stoats (*M. erminea*) between Britain and Germany and the closely related species (*M. frenata*) in the U.S.A. In Britain, pregnant stoats were found in March and April, while in Germany Watzka (1940) found pregnant stoats in April and early May. Pregnancies are thus a month later in Germany. Oestrus cycles occur in lactating and post-lactation stoats during April and May in Britain and in young stoats during June (possibly even in May). In Germany oestrus occurs during late June, July and early August and again in March. Only some of the specimens during August to February have unimplanted blastocysts. The others mate in spring and have direct development taking 8-9 weeks without a delayed stage. The male cycle is very similar in Britain and Germany but, as the oestrus cycle is much later in Germany, many of the July matings may be unsuccessful. Studies on the reproductive cycle of a closely related species (Mustela frenata) in the United States by Wright (1942, a, 1948) have shown that matings occur during July and August and all matings are successful. Implantation of the blastocysts occurs during the following March or April and young are born in April or May. The gestation period of 18 captive stoats ranged from 205 to 337 days (average 279 days) (Wright, 1948). Wright (1948) isolated three females during July-August 1942 and then watched for an early spring oestrus. However, these females did not come into heat until July and August and, after mating, two of the females had a normal delay and gave birth to young the following year. This suggests there is no spring oestrus cycle in M. frenata although Wright

(1942a) had previously recorded two captive females which had not been bred in summer but, in the following spring, showed the enlarged vulva characteristic of oestrus; they were not mated at this time. As sperm is not present in the epididymis until late March, young from spring matings would not be born before late May: Wright (1948) suggested that as there was no evidence of the birth of young after early May, it is unlikely that early spring matings and direct development of young occurs in *M. frenata*.

Delayed implantation also occurs in *Mustela erminea cicognannii* in Montana (Wright, 1942a), as blastocysts have been recovered from animals caught during winter. The period of mating and birth of young was not determined. Hamilton (1958) flushed seven blastocysts from the uteri of a first year female taken late in July in New York State; it seems likely that oestrus occurred in July-August or earlier.

A significant correlation between the spring moult and spring sexual cycle of *M. frenata* has been described by Wright (1942b). In 13 cases young were born from 35 to 73 days (average 47 days) after the beginning of the moult. Males begin to show signs of sexual activity at the beginning of the spring moult in both *M. frenata* and *M. erminea*. Wright suggests that the spring moult, implantation of blastocysts and onset of male sexual activity may be in response to the secretion of gonadotropic hormone from the pituitary gland. In N.E. Greenland the spring moult occurs in the latter half of May and the autumn moult occurs early in September (Salomonsen, 1939). Here the brown summer coat occurs for three, or at the most four months and it would be of interest to see how the reproductive cycle is adjusted to this brief summer.

Ferret Reproduction

Ferrets have had a long history of domestication and are easily bred in captivity. The reproductive cycle has been studied in captive ferrets but not in feral populations. Nor has the breeding of polecats been investigated in detail.

Ferrets in Britain may have two litters a year with oestrus occurring at the end of March or beginning of April and again at the end of July or August. Animals in oestrus are easily recognised by the enlarged vulva (Marshall, 1904). Ovulation occurs only after mating and, if the ferret is not mated, oestrus is prolonged and may last up to 17 weeks. If mating does not occur in the first two or three weeks of oestrus the follicles degenerate but oestrus persists. Matings after this time induce pseudopregnancy and no ova are shed. Pseudopregnancy shows all the characteristics of pregnancy and lasts for 5½ to 6 weeks.

The gestation period is 42 days and ferrets mated early in the year may rear two litters in 25 weeks or more of the breeding season. Lactation lasts about ten weeks, but if the young die at birth the female comes on heat nine days later (Hammond & Marshall, 1930).

The male sexual cycle in captive ferrets has been investigated by Allanson (1932). Adult males are sexually active from March to July with regression in testis size beginning in August and continuing until October. Testis weight is at a minimum in November and begins to increase again in December but sperm are not present until the beginning of March. Immature males do not become sexually mature until the spring following their birth.

Oestrous cycles in a female ferret caught as an adult at Levin occurred in early September, and again in November and February. Matings were unsuccessful. (McCann, 1955).

I examined the reproductive condition of 219 feral ferrets (65 adult males and 46 adult females). The breeding cycle in New Zealand appears to be similar to that of captive animals in Britain. During July and August females were anoestrous with a mean uterus weight of 26 mg. (range 14-44 mg). Five females taken in September were in oestrus with a mean uterus weight of 54 mg (range 29-72 mg). The uterus of only one of these was in the weight range of July-August anoestrous females. The vulva in this animal was only slightly enlarged and may have been beginning its oestrus cycle. These females were taken from 10-30 September. A ferret caught on 8 October had a swollen vulva and the uterus was enlarged (1.36 gms), but there was no sign of embryos. Two pregnant females were taken in mid-October and another two in mid-January. All were at an early stage of pregnancy. Uteri weighed 4.4, 18.2, 18.6 and 19.6 gms. In the three more advanced ones the embryos were 13-16 mm. long and were probably 2½ weeks old. Uteri of pregnant ferrets weigh 22 gms. at three weeks and 65-85 gms at 5½ weeks (Hammond & Marshall, 1930). Young each weigh about 10 gms at birth.

A feral albino ferret caught near Hanmer, Canterbury, gave birth to six young on 22 November, a week after capture. A post-partum ferret with a uterus weighing 5.5 gms was taken on 12 November and all females taken in November and December were lactating. Two ferrets taken in January were pregnant and six were lactating. One with a uterus weighing 3.1 gms had recently given birth to young. Ferrets were still lactating in February. Litter size from embryo counts were 6, 8, 8 and 11. One resorbing embryo was found in a uterus with eight embryos on 20 October. Young females do not become sexually mature until the spring following their birth.

Male adult feral ferrets in New Zealand (baculum weighing more than 300 mg) show a very great increase

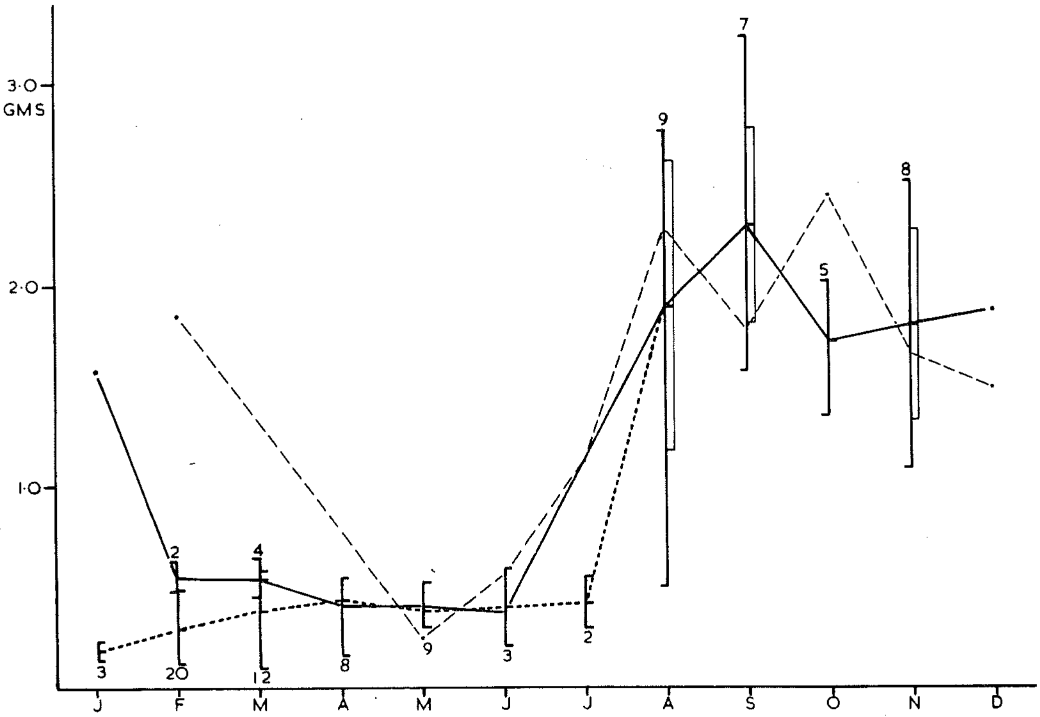

Fig. 18 Ferret testis weight. —— adult; ········ immature
– – – – captive adults [Allanson, 1932.]

in testis weight during August (fig. 18). Unfortunately no adult males were taken in July but two immature animals showed little increase in testis or baculum weight. This suggests that increase in testis weight does not occur until August. Testis weights reached a peak in September and decreased slowly through to January. There is a very marked decrease in testis weight in February and then a gradual decrease to April, with weight remaining low through winter. Testis weights of immature males show a small increase in weight during the period of active growth in autumn and then do not begin to enlarge until the onset of sexual maturity in August. During the winter months the testes of adult and immature ferrets are within the same weight range and, although the samples are small, the pattern and range of weights appear to be relatively constant during this time. The biggest variation in testis weight occurs during August at the onset of sexual maturity.

The breeding cycle of ferrets in New Zealand can be summarised from these results. Females are in oestrus in September and probably again at the beginning of January. Females are pregnant in October and early November and again in January and early February. Males are sexually active from August to January. This is rather similar to the cycle in captive ferrets but in

New Zealand the oestrus cycle may occur a few weeks earlier in relation to the seasons. The period of sexual activity appears to be longer in captive ferrets (fig. 18) but more details are required for both groups to confirm this.

Weasel Reproduction

Little information on the reproductive cycle of weasels in New Zealand could be derived from the small sample of 30 animals obtained during this study. It is possible, however, to interpret the reproductive condition of these specimens in relation to overseas studies. In Britain Deanesly (1944) found pregnant weasels from March until August and two litters might be reared during that time. Although most female weasels probably do not breed until their second year, some born early in the breeding season become sexually mature at about four months and breed in late summer or autumn. Parous first year animals were found in late August, September and October. Litter size from corpora lutea counts of 32 weasels ranged from 4 to 11 with an average of 7.1. Pohl (1910) recorded weasels breeding throughout the year in South Germany. Hill (1939) investigated the male reproductive cycle of weasels in Britain. The testes of adult males are fully active from March to the end of August although fertile males may be found in late February and until mid-October. Sexual activity thus occurs over about eight months of the year and anoestrus is slightly less evident than in stoats and ferrets. At the peak of the breeding season in April, the testis plus epididymis weighs 270 mg. and the lowest mean monthly weight (54 mg) is recorded in January. Males born early in the breeding season (April and May) reach adult body weight quickly and become sexually mature when four months old. Sperm are present in the testes of these males in late July and August. These testes weigh 107-220 mg. Young born later in the season do not attain breeding condition until the following year when eight or nine months old. The baculum of young reaching sexual maturity at four months increases in weight but does not reach the weight of adult male bacula.

As so few specimens were obtained during this investigation, details of the reproductive pattern in New Zealand cannot be determined. However, if the pattern is similar to that in Britain, the reproductive cycles, corrected to New Zealand seasons, would be as follows. Pregnancies would occur from September to February with some parous first year females found during late February, March and April. Testes of adult males would be fully active from September to the end of February with anoestrus most marked during July. Young males born in October and November would be sexually active with enlarged testes during late January and February.

I obtained three adult female weasels. One caught on 5 September showed no sign of pregnancy, while one on 23 February was lactating. The third was a lactating first year animal caught on 14 April. The skull of this animal was still very chalky and it was probably born the previous October or November.

The testis weights of six adult males taken between 23 September and 17 May were in the range 100 to 200 mg. and showed no clear evidence of seasonal variation. However, no animals were caught from June to August when males would be sexually least active. Immature weasels were collected between 9 January and 18 May. Testes of most animals weighed between 20 and 55 mg., but one on 15 February had testes weighing 75 mg. Another on 16 February weighed 130 mg. and both these males were probably attaining sexual maturity. Dr. L. Hartman (pers. comm.) noted signs of sexual activity in the behaviour of a captive immature male weasel. These few results suggest that the sexual cycle of the weasel in New Zealand is similar to that in Britain.

Sex and Age Ratios

At present little is known of the factors influencing the sex and age ratios of mustelids, but comparison of the sex and age structure of the sample collected in New Zealand with those from the Northern Hemisphere shows some striking similarities. Only for stoats, however, is the sample sufficient both here and in Britain for detailed comparison. 227 stoats collected mainly by trapping, between October 1960 and December 1963, are compared with a large series of 640 stoats collected in Britain between November 1930 and October 1934 (Deanesly, 1935). In both cases 61% of the samples were males although the proportion of adult males was higher in New Zealand (table 7). Here the sex ratio in immature stoats was approximately equal but in Britain males predominated even among immature animals (57%). This strong bias towards males in the collections of adult animals is not, however, found throughout the year (Appendix A). Peak collections of adult males were made during October and November, while the highest numbers of adult females were taken in December when more adult females than males were collected. From January to August the proportion of males to females was approximately equal. These changes in the sex ratio are possibly related to changes in the sexual cycle. Testis weight is at its maximum from September to November when large numbers of adult males were trapped and, in Britain, the largest numbers of adult males were taken at the corresponding stage of the sexual cycle. The largest numbers of adult females were taken during the month following oestrus in Britain. It is possible that the same occurred in New Zealand but larger collections and more detailed reproductive studies are needed to check this possibility.

Sex and age ratios of ferrets (table 8) also showed a small predominance of males. The ratio of both male and female adults to immature animals was 1:1. The largest collections of adult males were made from August to November, again the months of peak testis weight, but there is no clear peak in female collections.

The small numbers of weasels collected are inadequate to determine sex and age ratios. They are, however, quite close to the percentage of males given by Deanesly (1944) and Pohl (1910) for Britain and Germany (table 8).

The changes in the proportions of male and female stoats and ferrets caught may be due to differences in their activity, or trap-proneness at different times of the year. This appears to be related to changes in the sexual cycle, particularly in males where largest numbers are caught during the time of greatest sexual activity. Deanesly (1944) suggested that the high proportion of male weasels taken may be due, at least in part, to the reduced activity of females during pregnancy and lactation. Hall (1951) found that there were twice as many males as females in collections of Mustela frenata, and suggested that as males are twice the weight of females, they need to travel twice as far for food and will be much more likely to be caught. Males may also spring traps which females could step on without springing.

However, there seems to be no relation between home range size and proportions of males and females taken. Nyholm (1960) found a large difference in home range size of male and female stoats (males, average 85 acres and females, average 18 acres) whereas in weasels there was little difference between males and females (males 4 acres and females 3 acres). If stoats and weasels in Britain and New Zealand have similar home ranges and Hall's suggestion is correct one would expect the proportion of male stoats taken to be higher than that of weasels.

TABLE 7.

Stoat Sex and Age Ratios

New Zealand

	Total	♀	♂	%♂
Total	227	89	138	61%
Adult	127	37	90	71%
Immature	100	52	48	48%
% Adult	56%	42%	65%	

Britain *

	Total	♀	♂	%♂
Total	640	248	392	61%
Adult	319	110	209	66%
Immature	321	138	183	57%
% Adult	50%	44%	53%	

* Data from Deanesly (1935).

TABLE 8.

Ferret and Weasel Sex and Age Ratios

Ferret

	Total	♀	♂	%♂
Total	319	93	126	58%
Adult	111	46	65	59%
Immature	108	47	61	56%
% Adult	51%	49%	52%	

Weasel

	Total	♀	♂	%♂
Total	30	7	23	77%
Adult	15	3	12	
Immature	15	4	11	
% Adult	50%			

Britain	126♀	327♂	73%♂
Germany	38♀	103♂	73%♂

White Stoats

The characteristic change to white winter coat of stoats in north-temperate and polar regions is well known. Weasels, however, turn white only in the extreme north of their range and white weasels are rarely recorded in Britain.

The change in stoats from brown to white coat may be rapid, particularly in the more northern regions, e.g. Greenland. The white to brown and brown to white changes are effected by a complete moult of hair. If the winter pelage is brown the two moults still occur and the winter pelage may be paler in colour than the summer one. The spring moult from white to brown progresses from the head and back down the sides of the body to the belly, while the autumn moult from brown to white starts at the belly and moves up the sides (Rothschild, 1942). The tail tip remains black in the winter pelage (figs. 19, 20). Rothschild (1944) also reported, in at least some cases, two autumn moults, the first being a brown to brown moult.

There were only two records in the literature of white stoats in New Zealand although more have been collected in recent years (table 9). One caught in West Oxford, Canterbury, in 1910 is now in the

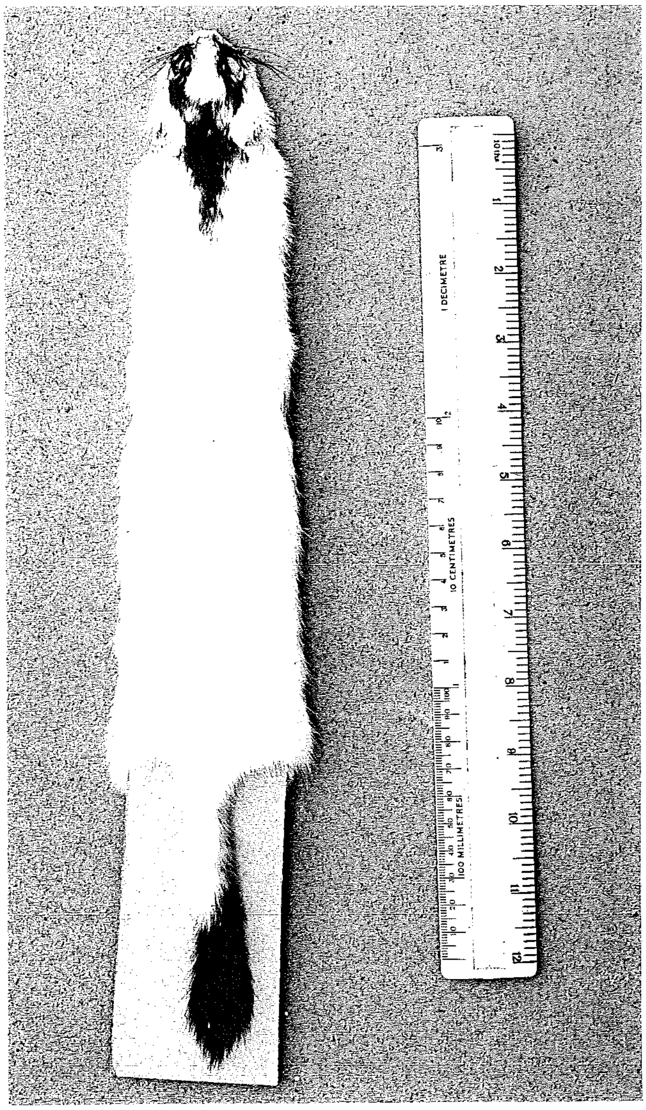

Fig. 19. Study skin of white stoat from Lake Murihiku. 2 August 1963.

Canterbury Museum (Thomson, 1922: 75) and a partly white stoat was trapped at the Blue Mountains, Tapanui in 1948 (Wodzicki, 1950: 65). Study skins of five animals have been examined in the Canterbury, Dominion and Otago Museums and another three animals in white or partly white winter coats were collected during this investigation. All specimens except one were taken from June to September, with specific dates from 5 July to 26 August. One from Mt. Ruapehu in the Dominion Museum, dated 28 April 1954, was almost entirely white with brown on the head and back of the neck. This specimen is anomalous. The moult was complete in a stoat caught on 5 July 1953 while one taken on 11 July 1948 was partly moulted with brown hair on the head and shoulders. In this specimen white hairs were growing amongst the underfur on the shoulders and the moult from brown to white was still progressing.

The stoat taken at Ngahere on 22 July was almost completely white with brown around the eyes and traces of brown on the back of head. There was no sign of new growth of either white or brown hairs. However, the change from brown to white was incomplete in a stoat taken on 2 August. Brown hair was still present on the head and neck and new brown hairs were growing on the head (fig. 19). There was no sign of new white hair.

TABLE 9.

Study Skins of White Stoats

Date	Sex	Locality	Extent	Collection
1912	-	Balclutha	Partial	Otago Mus.
28.4.54.	♀	Mt. Ruapehu	Partial	Domin. Mus
June 1913	-	West Oxford	Complete	" "
5.7.53.	♀	Ohakune	Complete	P. Jenkins
11.7.48.	♀	Tapanui, Otago	Partial	A.E.D.
22.7.37.	♀	Waimakariri R.	Partial	Cant. Mus.
22.7.61.	♀	Ngahere, Greymouth	Complete	A.E.D.
late July 1961	-	Lorneville	Partial (photo)	R.R. Sutton
2.8.63.	♀	L. Murihiku, Southland	Partial	A.E.D.
3.8.63.	-	Gwavas, Hawkes Bay	Complete	Examined by P.C. Bull
26.8.37.	♀	Big River, Reefton	"winter coat"	Canterbury Museum
Sept. 1962	-	Makarora Valley	Partial (salt & pepper)	A.E.D.

The unsexed skin from Makarora Valley, dated September, had almost completed the change from white to brown pelage, with white hairs still noticeable on the shoulders and more densely on the sides of the belly and flanks. The mixture of brown and white hairs gives this skin a "salt and pepper" appearance. Brown hairs were growing out underneath this hair.

This small series of specimens indicates that the white winter coat may occur for two, possibly three months in New Zealand and may be partial or complete. Only some of the stoats turn white, others having brown to brown moults. This is also the case in Britain. During July and August 1948 Wodzicki collected six male and three female stoats. One of the females was the partly white one from Tapanui.

During the winters of 1961, 1962 and 1963 I collected ten male and five female stoats. Two of the female stoats, from Ngahere and Lake Murihiku, had white winter pelage. Two of the brown females were taken on 30 August and possibly had completed their moult by this date. Seven of the white, or partly white, Museum specimens for which the sex was recorded were female, but no white males, were collected. However, two male stoats kept in captivity at Taita, Wellington, have turned partly white, during the winters of 1961 and 1963,

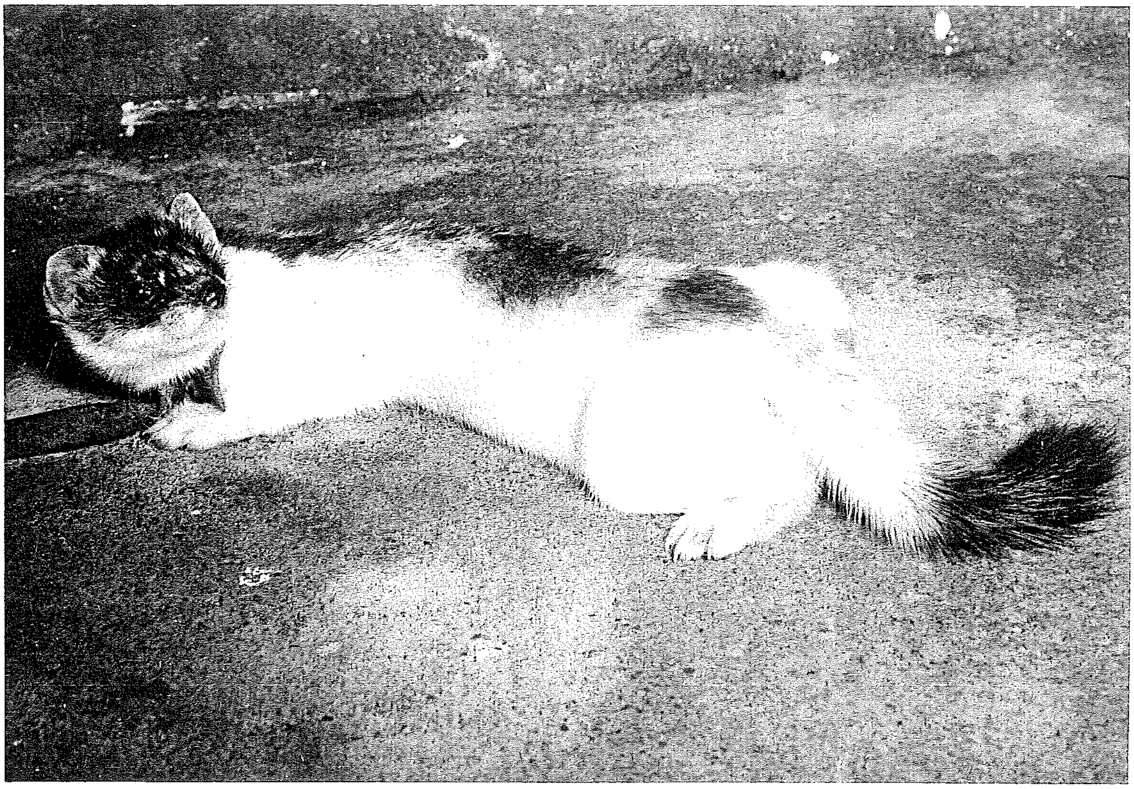

Fig. 2[illegible]. Captive male stoat in partly white winter coat. 15 July 1961.

retaining a brown strip on the head and along the back (fig. 20). One male during winter 1961 began moulting on 23 June and by 11 July was white except for brown on the head and neck and a brown strip along the back. Little change was noticed until 30 August when brown hairs began showing through the white on the sides of the body. The change to brown pelage was complete by 18 September. The moults thus took a little less than three weeks and the white winter coat was present for seven weeks.

A number of studies on the winter colour change of Mustela erminea and M. frenata have been made in the Northern Hemisphere.

Stoats in Britain, excluding northern Scotland, moult slowly with only about 4% achieving a pure white winter coat. About half the population become partly white and many develop a brown winter pelage. This winter moult occurs during the period 1 December to 1 February and the spring moult occurs between 1 February and 1 April. Both males and females are found in white winter coat (Salomonsen, 1939). In areas of the U.S.A. where only part of the population of M. frenata turns white, the white animals are predominantly female (Hamilton, 1933: 302; Hall, 1951: 38).

Stoats in New Zealand turn white for a shorter period in winter than in Britain. The presence of white male and female stoats in Britain, but only white female stoats in New Zealand in the small numbers as yet collected, would suggest that there is a greater tendency to turn white amongst British stoats. This may possibly be correlated with latitude and/or climate.

In north-east Greenland the moult of M. erminea is extremely rapid, and is completed in fifteen days. The white winter pelage is retained for about eight months from September to May. There is a correlation between latitude and duration of the white winter pelage. The white coat is retained longest at high latitudes such as in Greenland and shorter at lower latitudes. (Salomonsen, 1939). In the Netherlands the autumn moult occurs in late November, early December and the moult back to brown pelage occurs in March, early April. Some animals do not turn entirely white (Bree, 1961). Salomonsen (1939) found a close correlation between temperature and time of moult in stoats. Stoats at lower latitudes moult at higher temperatures than those at higher latitudes but take longer to pass through the moult and retain the white pelage for a shorter period. Rothschild (1942) found that in Britain exposure to cold induced a colour change to white winter coat in stoats, but there was great individual variation in extent of the colour change in response to a similar degree of cold. Rust (1962) found that an increase in artificial daylight length induced pelage change from white to brown in *M. erminea bangsi* but found that the time and pattern of moult was modified by temperature. Those kept at 70°F began to moult 8 to 18 days before those kept at 20°F. and moulted more slowly. The pattern of moult also differed.. Those at warm termperatures lost hairs gradually with intermixed areas of brown and white (salt and pepper), while at cold temperatures white hairs were shed in clumps and replaced immediately by brown hairs.

Bissonette and Bailey (1944) have shown that changes in the daily period of light will induce moulting in *M. frenata* and *M. erminea cicognanii*. Decreasing daylength induced moulting and growth of white pelage in *M. e. cicognannii*. Decrease in day-length induced a moult to lighter brown in *M. frenata*, which does not turn white in that part of its range. Rothschild (1944) however, found that *M. erminea* in Britain is less susceptible to light reduction as no stoats changed colour just on light reduction, but one made partial changes for two successive winters when given light reduction at low temperatures. Bissonette and Bailey (1944) suggest that the stimulus for moulting is received through the eyes and acts through the anterior pituitary gland.

There is also a close correlation between the time of the spring moult and the start of sexual activity in *M. frenata*. Testes begin active growth and spermatogenesis at the beginning of the white to brown moult. In females, the white to brown moult occurs about 20 days before implantation of embryos and about 47 days before the birth of young (Wright, 1942b). A similar correlation appears to exist in the stoat in Britain, and probably occurs in New Zealand too as the moult occurs during August and young are born in October. However, more information is required on the time of moult and on the gestation period in New Zealand stoats.

Food Habits - Introduction

Perhaps the most interesting aspect of the ecology of mustelids in New Zealand is, as Marshall (1963) pointed out, their adaptation to food conditions quite unlike those in their native habitats. In Eurasia and North America stoats, ferrets and weasels are largely predators of a wide variety of rodents and lagomorphs. In contrast, the only small mammals available in New Zealand are the house mouse, three species of rats, rabbit, hare and hedgehog.

Methods of studying feeding habits of predators include direct observation, snow-tracking, and gut and fecal analysis (Dice, 1952: 132). These methods have been used in several studies of stoats and weasels in North America (Aldous and Manweiler, 1942; Dearborn, 1932; Hamilton, 1933; and Quick, 1944, 1951) and in many studies of other mustelids. Gut and fecal analyses have been widely used and were the most convenient methods of investigating the feeding habits of mustelids in New Zealand.

Errington (1943: 807) has suggested, with special reference to mink, that stomach analysis probably comes closeest to giving a balanced picture of food habits but has the disadvantage that it is not possible to collect large samples in a given locality at any one time. Also, unless the animals die quickly when trapped, the gut is likely to be empty or contain debris and toes from their own trapped feet. The biggest disadvantage of using gut contents for a study of the feeding habits of a predator is that quantitative analysis is difficult.

Also, there are several factors which may bias the results. In a study of the feeding habits of short-tailed weasels in Minnesota, hare and squirrel identified in stomachs were derived from trap bait (Aldous and Manweiler, 1942). Differences in the rate of passage of undigested parts of various prey through the gut may affect the picture of feeding habits when results are expressed as a percentage of the gut contents in which any traces of the prey were found. Prey which takes a long time to be completely eliminated from the gut will be overemphasised and those which pass through quickly will be underestimated. Unfortunately, the rate of passage of various foods could not be determined during this study.

There are also disadvantages in the use of droppings for studies of feeding habits but they can often be gathered in large numbers in a relatively

Fig. 11. Stoat droppings

small area where estimates of the availability of prey species can be made. Difficulties can, however, arise in identifying droppings and in determining the age of droppings found in the field. In New Zealand droppings of stoats, ferrets and weasels may sometimes be difficult to distinguish. Stoat droppings have an average length of about five cm. (range approximately 3.5 to 7.0 cms)(fig. 21). Ferret droppings are larger, and usually more liquid. Weasel droppings are considerably smaller than those of stoats. Associated tracks and prey remains and hairs of the predator in the droppings often help identification. The biggest advantage of droppings in the determination of feeding habits is that it is possible to obtain quantitative results.

There are three main methods of presenting the results of gut and fecal analysis (Dice, 1952: 134; Lockie, 1959). The frequency with which different foods occur in the gut or droppings can be expressed as a percentage of the total number examined (frequency of occurrence). This gives an indication of the proportions of prey taken but does not show the amounts of various foods eaten. Frequency of occurrence tends to overestimate small quantities of prey and to underestimate large quantities. The amount of food present in gut contents varies from large quantities of flesh and hair or feathers to a few hairs or feather fragments.

The amount of a prey species present in droppings or gut contents can also be expressed as a percentage of the total volume of prey. Dearborn (1932) used only frequency of prey occurrences in analyses of the feeding habits of Michigan predators from gut contents and droppings as the extent of digestion of prey varies along the gut. The quantity of food in the gut also depends on the length of time that the animal is trapped before it is killed. Aldous and Manweiler (1942) however, used both percentage of occurrence and percentage volume in an examination of the gut contents of short-tailed weasels in Minnesota and obtained similar results by both methods. Lockie (1959) investigated the accuracy of these methods in a series of feeding trials with red foxes. He found that percentage of occurrence and percentage volume gave considerable and inconsistent results whereas estimated weight of undigested matter gave a consistent error of the weight of original prey eaten. Correction factors for the weight of undigested matter were then calculated for the various prey species. This method has been used in a study of the food habits of marten in Scotland (Lockie, 1961).

In the analysis of the gut contents of stoats, ferrets and weasels I have expressed the results as percentage occurrences (i.e. the number of gut contents in which a particular prey occurred, as a percentage of the total gut contents). In the analysis of droppings collected with den material the results were expressed as "percentage of occurrence" or "percentage volume". "Weight of undigested matter" was not used as the kinds and numbers of prey were determined from the den material.

Stoat Food Habits

Stoats in Britain and Europe, and weasels of similar size in North America, feed mainly on small rodents and take very few birds. Matthews (1952) records small mammals, birds, eggs, lizards and insects as their food in Britain, while Southern (1964) states that rabbits were their staple food before the spread of myxomatosis but when rabbits are absent they take small mammals.

The diet may vary markedly in different areas and at different times, depending on the number of small rodents available. In Russia when rodents are abundant, they form over 90% of the food and shrews, birds and insects are taken in small numbers. When rodents are scarce, stoats feed extensively on insects and berries but do not increase their predation on birds (Novikov, 1956: 131).

Hamilton (1933) and Aldous and Manweiler (1942) found close parallels in the dominant food habits of short-tailed weasels (*M. erminea*) in Minnesota and New York. Mice formed approximately 60% of their food, and shrews about 20%. Small amounts of bird, lagomorph, rat, squirrel and fish were also recorded. Mice and shrews were eaten in direct ratio to their relative abundance (Aldous and Manweiler, 1942: 254). In several other studies of weasel food habits in North America, small rodents, especially Peromyscus and Microtus, were the dominant prey and few birds were taken (Dearborn, 1932; Quick, 1944; 1951).

In New Zealand Marshall (1963) found from questionnaire replies that mammals, especially rabbits, and birds were important foods. The largest number of reports of bird predation were of stoats taking small native birds. A wide range of carrion was also eaten.

Mammals, particularly mice, were the most important prey recorded in the gut contents of 52 stoats (Marshall, 1963: 20). Birds and orthoptera were also important but other insects present were not significant as food. As I assisted Dr. Marshall with these gut analyses and carried out many of the identifications, I have included the results from these animals in my analysis of the gut contents of 257 stoats. This gives larger samples for the comparison of variation in feeding habits with sex, habitat and season.

Aldous and Manweiler (1942) found little difference in the contents of the stomach and intestine of short-tailed weasels in Minnesota. In a comparison of the contents of 119 stomachs and 166 intestines of stoats

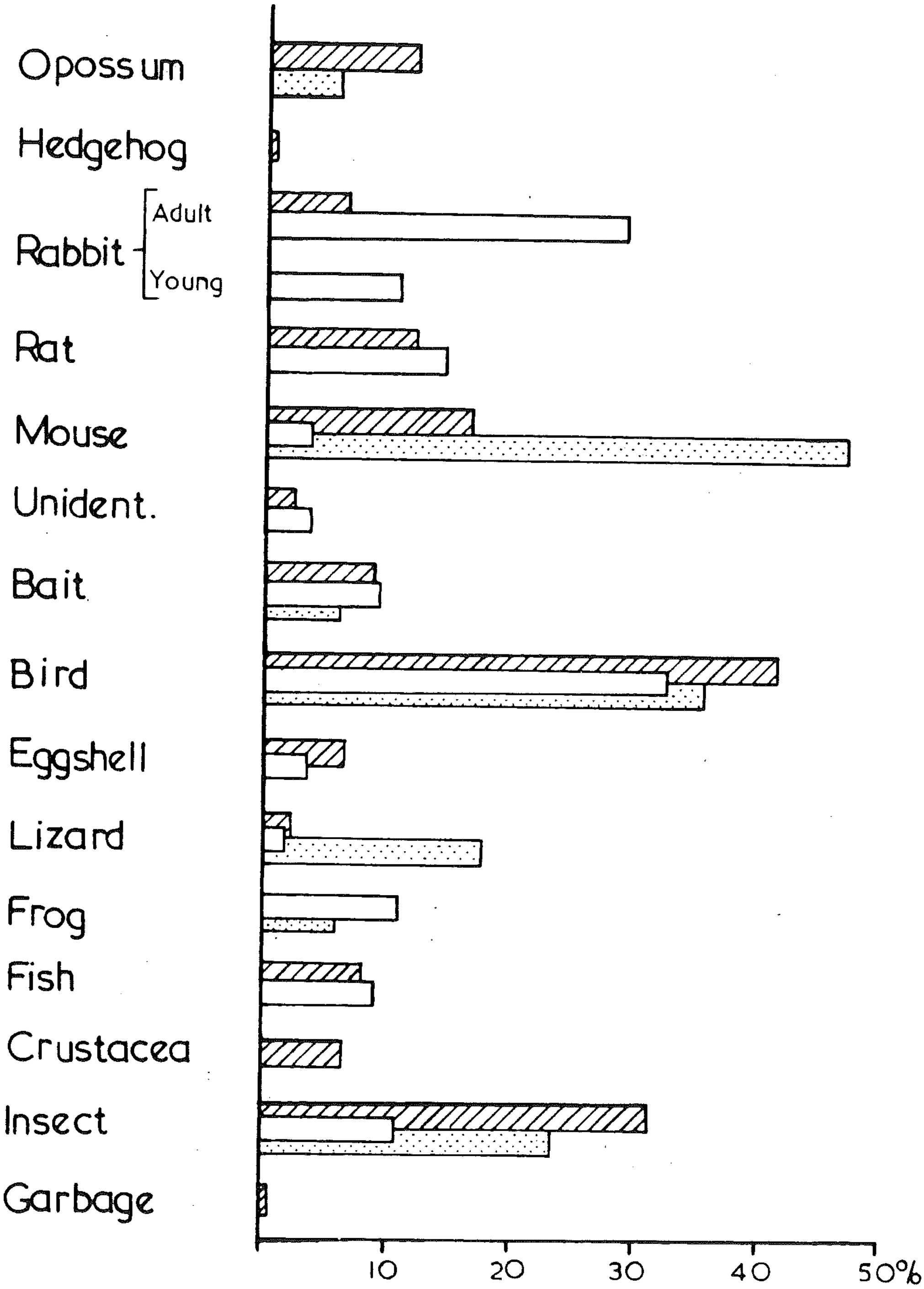

Fig. 22 Gut contents of stoats, ferrets & weasels.

STOAT N = 185

FERRET N = 55

WEASEL N = 17

collected in New Zealand, the only item which occurred in much greater numbers of stomachs than intestines was bait from traps (table 10).

185 of the 257 stoats examined had food items in the gut and 72 were empty or contained just a few stoat hairs (fig. 22). Mammals and birds were the most frequently recorded prey and in most habitats probably provide the bulk of their food. Of the mammals, mice, and to a lesser extent rats, were important prey, with some rabbits also taken. Spines of a young hedgehog were found in one stoat. Opossum hair was probably all derived from carrion or bait.

Birds were an important source of food but in most cases it was not possible to identify the species from feathers and bone fragments present in the gut. Birds eggs were taken from late September to early January. In two cases rotten egg bait had been used to trap the animals and was the probable source of eggeshell.

Skinks were found in four gut contents but there were no records of frogs. Three of the 14 fish were probably derived from bait but in most cases the fish were small and caught by the stoat. Fresh water crayfish were also taken frequently.

Many insects from several orders were found in the gut contents but the only ones of any significance as food were orthoptera (wetas and a few cockroaches) (table 11). Many of the other arthropods, and especially coleoptera, ants, spiders and mites were probably taken accidentally with other foods. Fly eggs and maggots ingested with food which had been dead for some time were found in 12% of the gut contents.

The sample of stoats was sufficiently large to examine for variations in the food habits with sex, habitat and season. This was not possible with the small samples of ferrets and weasels.

Variation with sex.

The difference in size of male and female stoats is so marked, with females approximately 59% the size of males, that males should be capable of catching larger prey than females. Hamilton (1959) found such differences in the feeding habits of mink where 76% of the muskrats and 83% of the cottontail rabbits found in gut contents were taken by males. The small mammals were apparently taken in proportion to their availability. Differences in the feeding habits of weasels of different size are recorded in north-eastern U.S.A. Males of _M. frenata_ average 225 gms and females 102 gms; males of _M.erminea_ average 81 gms and females 54 gms. Differences

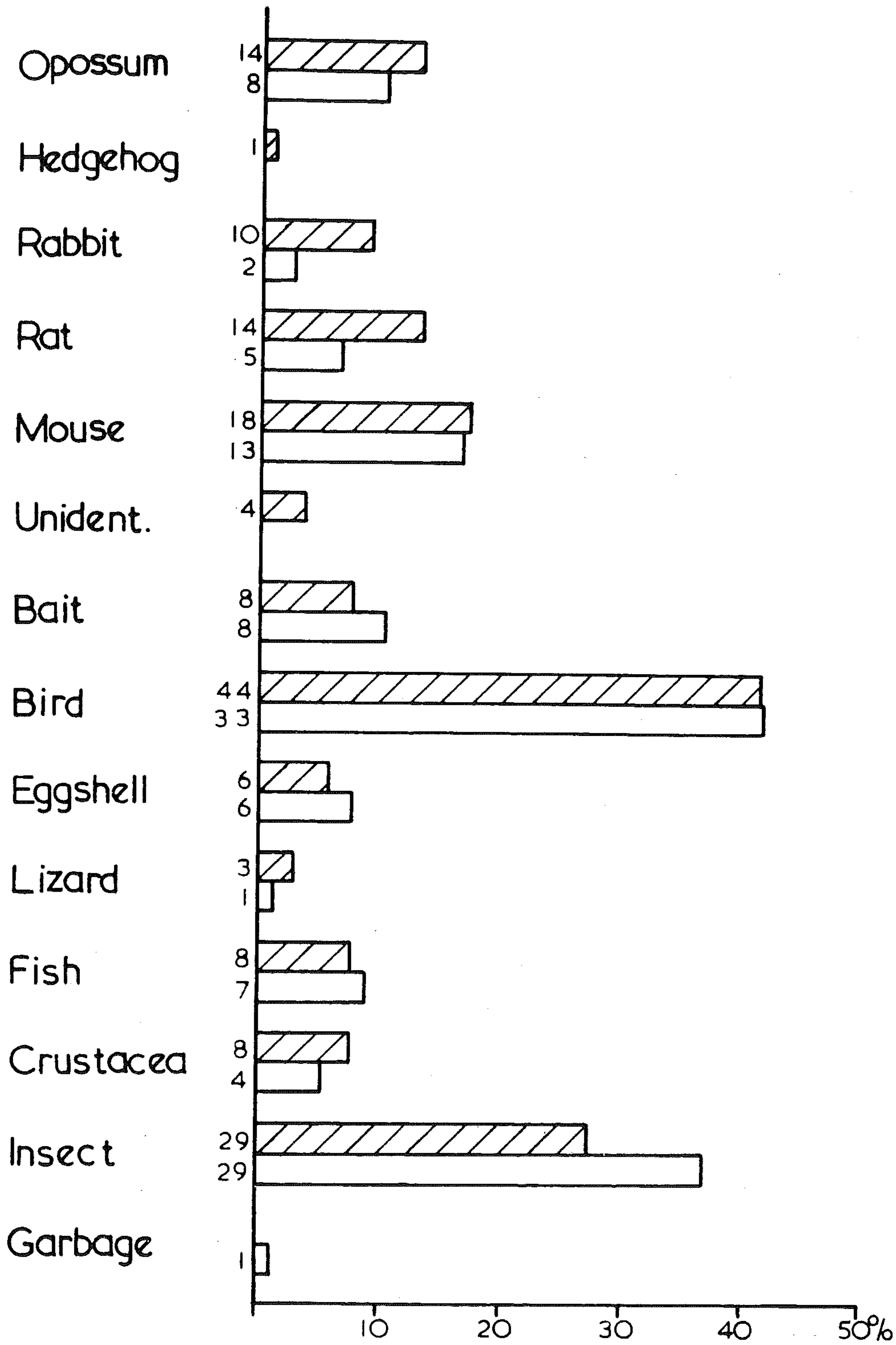

Fig. 23 Gut contents of male & female stoats.

MALE N=106 FEMALE N=79

in the number of occurrences of rats and rabbit (Sylvilagus) in the gut contents of weasels taken in fall and winter appear to be related to differences in size of the weasels. Rabbit was found in 17.3% of M. frenata and 9.0% of M. erminea. Similarly, rats occurred in 9.1% of M. frenata and 4.4% of M. erminea (Hamilton, 1933).

Comparison of the gut contents of 106 male and 79 female stoats collected in New Zealand shows that smaller numbers of rabbits and rats and larger numbers of insects are eaten by female stoats (fig. 23). Other differences in the gut contents of males and females are small. Rabbits and rats were the largest mammals killed and presumably were difficult prey for female stoats to kill. Small insects, not orthoptera, are responsible for the 9% difference in the number of insects in male and female gut contents and an equal percentage of orthoptera were recorded in both cases.

Habitat.

Stoats were collected from a wide range of habitats and a comparison of the differences in the prey taken in two broad habitat categories was made. All animals trapped in National Parks were classed as bush animals, although not all were taken in heavy bush and some were taken around houses in the Parks or in scrub

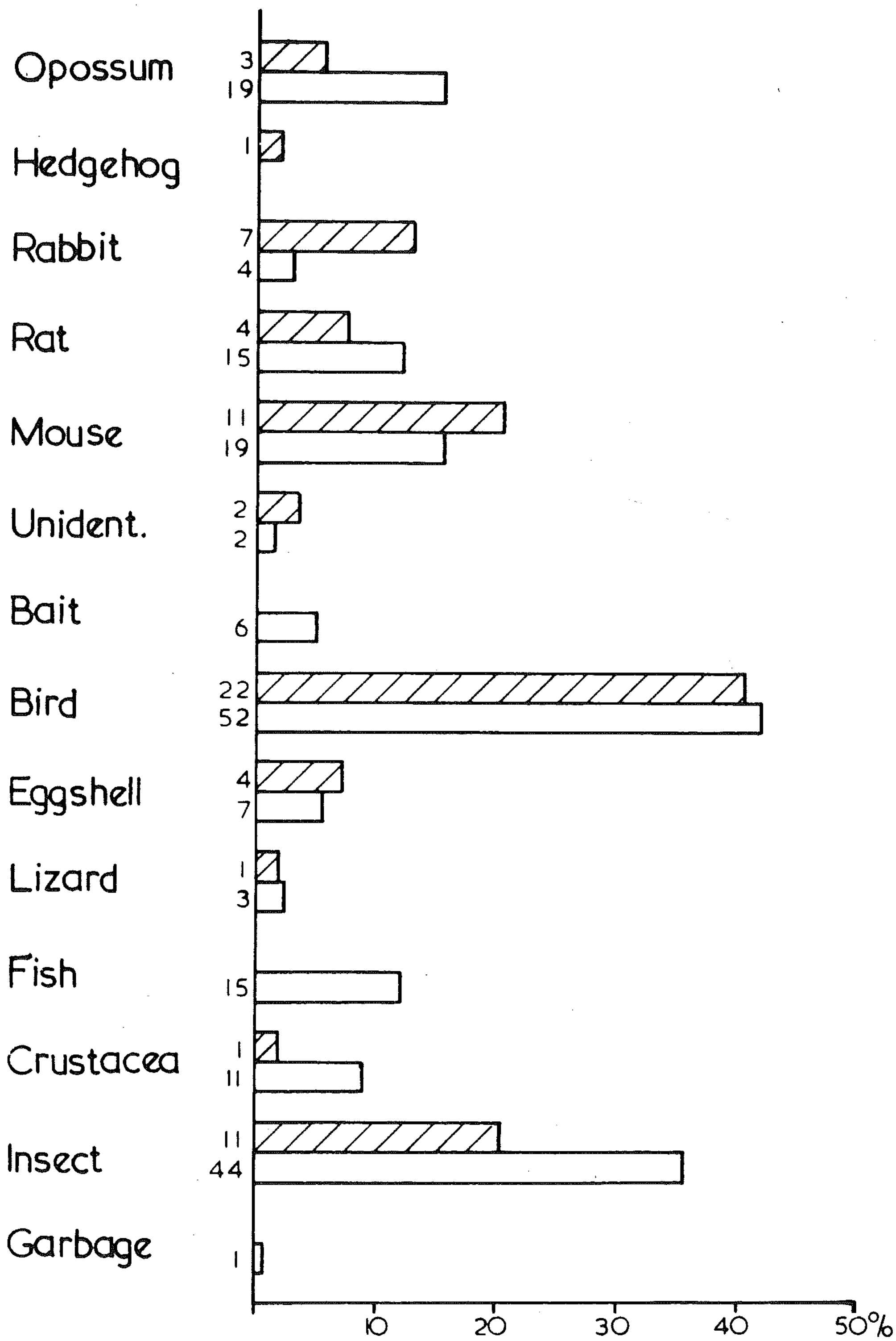

Fig. 24 Gut contents of stoats from farmland and bush.

FARMLAND N =54 BUSH N =124

or tussock grassland. However, in most cases the foods taken in these slightly modified areas appear similar to those from heavy bush areas. Animals from the Hokitika-Greymouth area appear to be taking similar foods to those in heavy bush. Gut contents of 54 stoats from farmland and 124 from bush were compared and show some marked differences (fig. 24) which probably reflect differences in the availability of prey.

Rabbits and mice were found more frequently in stoats from farmland and rats and opossums were found more often in stoats from bush areas. Birds were the largest single item in both habitats, being present in just over 40% of the contents in each case. Fish and Crustacea (freshwater crayfish) occurred much more frequently in the gut contents of stoats from bush areas where these animals were probably more common in the streams. Small insects, probably taken with other foods occurred in approximately equal proportions in stoats from bush and farmland. Wetas, however, were present in almost 20% of the gut contents of stoats from bush but in only 5% of farmland animals.

Although birds are the main prey in both habitats there are some marked differences in the foods taken less frequently, which are related to the availability of these foods.

There are few descriptions of differences in prey taken in different habitats in the Northern Hemisphere. Differences in the occurrences of prey in the gut contents of short-tailed weasels in New York and Minnesota are related to the availability of the prey. Rats were found in 4.4% of the gut contents of stoats in New York but were not found in stoats from Minnesota where rats are not common. Snowshoe hare in Minnesota was replaced by cottontail in New York and differences in the kinds and percentages of occurrence of small mammals were related to their availability. Here one species would be replaced by a similar species in different habitats or areas.

Differences in the feeding habits of marten in the Grand Teton National Park, Wyoming, stress the importance of availability in the feeding patterns of animals in different habitats. In three habitats there were large differences in the mammals and berry-bearing plants available and these differences were reflected in the feeding habits (Murie, 1961). Berries are also a seasonal food available for only a few months in the year.

Seasonal variation.

Seasonal variations in the feeding habits of stoats from bush areas were found in a sample of 150

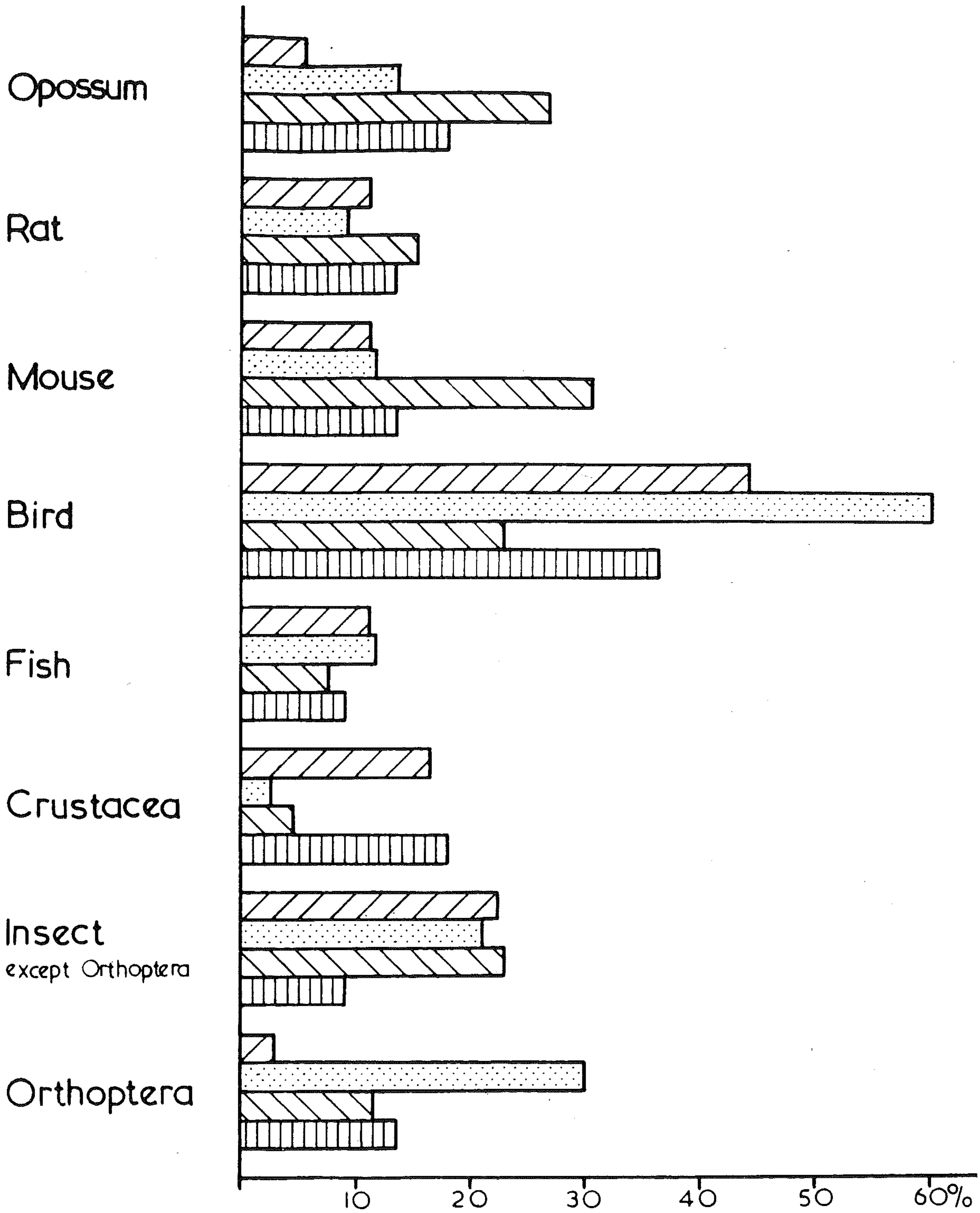

Fig. 25 Seasonal variation in gut contents of stoats in bush areas.

SPRING N = 18 SUMMER N = 43
AUTUMN N = 26 WINTER N = 22

dated animals (fig. 25). This sample was considered sufficiently large to indicate trends in predation. The categories taken were - Spring: August to October; Summer: November to January; Autumn: February to April; Winter: May to July. Some foods, especially rats and fish, showed no marked variation. Twice as many mice were taken in autumn as at any other season and this possibly reflects an increase in mice numbers at this time. Unfortunately, little is known of seasonal changes in mouse populations in New Zealand, but there appears to be a peak in both indoor and outdoor populations in late summer and autumn (Wodzicki, 1950: 105). The changes in opossum occurrences may reflect changes in the amount of opossum flesh used as trap bait or available as carrion. Largest numbers of gut contents contained birds in summer and is possibly related to the number of young birds available at this time. The decrease in birds in autumn is associated with peaks in predation on mice and in the amount of opossum eaten. Also the percentage of empty gut contents was highest in autumn. The marked changes in percentage occurrence of freshwater crayfish is unfortunately based on insufficient material. The pattern of insect occurrences is similar to that found in overseas studies of the food habits of predators. McIntosh (1963) found a similar pattern in the food habits of the fox in Australian farmland. Orthoptera (mainly grasshoppers) were the most important insect taken. Similarly, in New Zealand, wetas were the most frequently recorded with largest numbers taken in summer. These general changes in the seasonal food habits of stoats need to be confirmed by much larger samples. The prey recorded in largest numbers, such as birds, insects and possibly mice, will probably show little change but the frequency of some other groups may alter considerably.

TABLE 10.

Comparison of Stoat Stomach and Intestine Contents

	Stomach		Intestine	
Mammals				
Opossum	9	7.5%	16	9.6%
Lagomorph	7	5.9	10	6.0
Rat	10	8.4	19	11.4
Mouse	15	12.6	28	16.8
Hedgehog	-		1	.6
Stoat	19	15.9	29	17.4
Unidentified	4	3.3.	3	1.8
Bait	16	13.4	2	1.2
Birds				
Feather & bone	49	41.2	66	39.7
Eggshell	10	8.4	5	3.0
Reptiles				
Skink	4	3.3	3	1.8
Fish	10	8.4	12	7.2
Insecta				
Ad.	37	31.1	41	24.7
Maggots & fly eggs	12	9.2	13	7.2
Crustacea	6	5.0	9	5.4
Refuse	-		1	.6
Empty	138	53.6% empty	91	35.4% empty
With Contents	119		166	
Total	257		257	

TABLE 11.

Arthropod Remains from Stoats

	Occurrence	
	No. Gut Contents	No. Individuals
Crustacea		
Paranephrops spp. (Freshwater Crayfish)	12	12
Insecta		
Orthoptera		
Cockroach	2	2
Weta	23	24
Thysanoptera	1	1
Neuroptera	1	1
Coleoptera		
adult	4	7
larvae	2	20
Hymenoptera		
ants	5	8
others	2	2
Diptera		
adults	4	6
maggots and eggs	22	-
Unidentified		
large insect fragments	5	5
small " "	13	13
caterpillars	2	2
Arachnida		
spiders	1	2
pseudoscorpions	1	1
mites	2	3

Ferret Food Habits

There has been little investigation of the food habits of ferrets or polecats in the Northern Hemisphere. The polecat in Britain preys chiefly on rabbits and was exterminated over much of Britain by gin traps used for trapping rabbits (Matthews, 1952). They also eat poultry, young game birds and eggs, snakes, frogs and fish (Southern, 1964). The dark polecat in Russia feeds chiefly on small voles, rats and water voles, and occasionally takes other small mammals. When rodents are scarce it may take large numbers of frogs. The light polecat feeds chiefly on ground squirrels, hamsters, voles and other rodents (Novikov, 1956).

Information from questionnairs in Marshall's New Zealand study (1963) showed that rabbits, particularly young ones, and a wide range of carrion, were eaten by ferrets. Birds were also an important source of food.

In an examination of 98 ferrets, 55 contained identifiable food items and 43 were empty (fig. 22). A quarter of these animals were collected at Bulls.

Mammals predominated in the gut contents with adult or well grown rabbit the most frequent prey.

Young rabbits were also important and four of the six young rabbits found were small naked ones killed in the stops. Two ferrets caught in rabbit stops have been sent to me and, in both cases, young rabbits were also present. The gut contents of these two animals have not yet been examined and have not been included in the gut content analysis.

Rats also occurred frequently but mice were rarely taken. Bird remains occurred in one-third of the gut contents and eggshell was found in two ferrets caught in November.

Frogs are an important food at times in Britain and Europe and were found in 11% of the ferrets in New Zealand. Only one lizard, a gecko, was found and small fish were also taken occasionally.

Small insects were found and these were mainly Coleoptera which may have been ingested with other food. Diptera and two Lepidoptera, but no large Orthoptera, were also recorded. Fly eggs and maggots were found associated with bait, bird or mammal remains and may indicate carrion or prey eaten some time after it was killed.

Ferret droppings from Kourarau.

The extent to which ferrets will prey on rabbits is also shown in a series of ferret droppings collected in an area of known rabbit density. 85 droppings were collected between June 1961 and January 1962 in a 21-acre rabbit enclosure at Kourarau, Wairarapa, where Dr. J.A. Gibb was carrying out studies on the rabbit population. I made visits to Kourarau in June and late September and Dr. Gibb collected droppings during his monthly visits. Droppings were collected singly, or in numbers, from latrines outside rabbit burrows and from trapped ferrets. Ferrets were live trapped and between June and December 1961 three males and two females were trapped and a white male sighted. Ferrets appeared to do much of their hunting in the rabbit warrens. Cat droppings were also collected and examined for comparison of the feeding habits of these two predators.

Adult and young rabbits were the most important source of food (table 12) and adult rabbit hair and bone was present in all droppings collected from June to August. It was still present in most droppings collected early in September when hair from young rabbits was first found in droppings but, during October, young rabbits formed the largest part of the food. Most of these were taken in the stops and burrows before they were old enough to move out and start grazing.

Rabbit hair was not present in eight droppings collected in November and January and the presence of remains of hedgehog, bird, insect and refuse (food scraps) in these droppings suggests that adult rabbits were now difficult to catch and that ferrets were scavenging. By mid-January there was only one-third the number of rabbits in the enclosure that there had been in June when 160 were counted (Dr. J.A. Gibb, pers. comm. 1964).

Few other foods were found in ferret droppings. Lambswool in four droppings collected early in September was from dead lambs which were a readily available source of food during lambing. Birds and mice were rarely eaten. Oxycanus moth caterpillars were recorded in droppings during June and July and were eaten by both the ferrets and cats. The emerging moths were eaten in very large numbers by cats in October but, in contrast, ferrets were feeding almost entirely on young rabbits in the stops and burrows. Only half the cat droppings collected at this time contained rabbit hair and bone and as adult rabbits had decreased in number and the young were still underground, they were probably less available to cats than to ferrets.

These results indicate that when rabbits are available in sufficient numbers they will be the main source of food, taken in preference to other prey.

TABLE 12.

Ferret Droppings from Kourarau

Date 1961/62	No. droppings	Rabbit adult	Rabbit young	Mouse	Lamb	Hedgehog	Bird	Insect	Refuse	Grass
June 26	11	11						5		3
July 28	25	25		1				6		
Aug. 17	1	1								
Sept. 5	14	9	1		4		2	1		
27	2		2							
Oct. 26	24	2	21					1		11
Nov. 23	1							1		1
Jan. 19	7					2	4		4	4
Totals	85	48	24	1	4	2	6	14	4	19

Weasel Food Habits

There are few references in the literature to the food habits of weasels. Novikov (1956) states that they fed almost exclusively on small field voles and mice with occasional water voles, birds, amphibians, insects and fish. In Egypt, cockroaches are an important source of food for weasels hunting in and about houses in the cities and villages (Setzer, 1958). In Britain they prey mainly on small rodents but also take young rabbits, small birds, eggs, and occasionally poultry (Southern, 1964). Hall (1951) concludes from an examination of the American literature that the closely related least weasel (M. rixosa) eats mice and possibly insects. Criddle (1947) found remains of a large number of voles in a nest in Manitoba, Canada.

One of the few records of weasel food habits in New Zealand is a series of photographs of a weasel killing a young rabbit beside the main Akaroa road, taken in 1961 by Mr. A.C. Maturin of Hawarden.

Gut contents of 26 weasels were examined during this study and, of them, nine were completely empty and two contained only fatty material in the stomach. Seventeen contained food items (fig. 22) with mice the most common prey, occurring in almost half the gut content. Birds were the second most frequent item and, in two, the feathers were sheathed. They were probably from either young or moulting birds. Most of the insects were fragmentary and may have been eaten by the bird or skink associated with them in the gut. A large Hepialid moth caterpillar was the only large insect found. The opossum hair and unidentified flesh was probably from trap bait.

Stoat Dens in New Zealand

Den sites can be an important source of information on stoat food habits, as droppings and prey remains accumulate over a long period, providing information on the relative vulnerability of prey species in the vicinity. In this way, Polderboer, Kuhn and Hendrickson (1941) in Iowa and Quick (1944) in Michigan made detailed studies of long-tailed weasels (Mustela frenata). The term "den" describes any site to which a stoat regularly returns to eat its food, sleep, shelter, or rear young. It generally contains a grass nest (often with large amounts of fur and feathers from prey), uneaten food, and has associated nearby a latrine of droppings. In the Northern Hemisphere dens are most often recorded in the underground burrows of small mammals or in decayed tree stumps but, in New Zealand, there are few species of small mammals and dens are found under logs, timber stakcs, corrugated iron lying on the ground, rubbish piles, in rushes, hollow trees, deserted buildings, haysheds and any dry sheltered site.

There are few references to dens in the New Zealand literature. Thomson (1922) quotes a correspondent who had found weasel nests in heaps of fencing material and rabbit burrows in farmland. These were always made out of skylark feathers. He also found parts of young hares in them, but never a sign of a rabbit. Possibly the observer confused weasels with stoats. F.E. Wilkin at Doubtless Bay about 1930 found a weasel nest lined with at least a dozen mice (Wodzicki, 1950: 71).

Riney et al. (1959) records 14 stoat droppings collected about the hollow bases of several trees on the west side of Lake Monk, Fiordland (table 13). Analysis of these showed that birds were the main food of stoats in the area in summer. Large numbers of wetas were also taken.

Table 13.

Stoat Droppings from Lake Monk

Item	No. droppings	Percentage occurrence
Feathers	11	(78.5%)
Insect (weta)	8	57.1
Eggshell	3	21.4
Mouse	1	7.1

In the present study I received material from several stoat dens collected in a variety of habitats. Examination of these confirms the wide variety of prey shown from gut analysis, although only one or two foods may be important in a particular habitat.

A stoat nest collected by Mr. E.G. Turbott in Thompson Sound, Fiordland, at sea level, on 14/1/58, contained a few skylark body feathers, an insect head (probably weta), bones and one dropping. This dropping contained feather and bone fragments of a small bird. The bones, which were kindly identified by Mr. R.J. Scarlett of the Canterbury Museum are -

Robin (*Petroica australis*)	Left carpo-metacarpus and fragment of ulna
Wren (*Xenicus longipes*) (or Rifleman)	Distal right tarso-metatarsus
Small passerine	Immature left ulna, distal right humerus
Mammal, possibly bat	2 fragmentary limb bones

A stoat den found by Dr. William H. Marshall in October 1960 at Tongariro National Park under corrugated iron roofing sheets contained a nest lined with grass and hair from rabbits and hares. Material was collected from this den in September 1963 by Mr. N.W. Blackbourn, Ranger at Tongariro National Park, although it had not been occupied for some time and the droppings were old and disintegrated. The den was situated near a stream in tussock and sub-alpine scrub containing introduced heather, *Dracophyllum*, *Coprosma*, *Lycopodium* and *Gleichenia* (Umbrella fern). The following material was identified:

Freshwater crayfish (<u>Paranephrops</u> spp) two carapaces and six chelipeds representing three or four animals.

Insects — Small amounts of insect fragment (probably parts of a large moth)

Fish — One fish head (possibly a small trout)

Birds — Remnants of two flight feathers were present in the nest and traces of feathers in the droppings

Mammals

Mouse (<u>Mus musculus</u>). Traces of hair and one molar tooth in the droppings.

Rabbit (<u>Oryctolagus cuniculus</u>). Four skulls and other bones, all of young animals not yet full grown.

Hare (<u>Lepus europaeus</u>). Two skulls, one well grown, and other bones. Several unworn milk teeth found in the droppings may have been from very young leverets killed within a few days of birth. These are not represented by skulls in the nest material and were probably eaten entire.

Mr. Blackbourn considered that there was a moderate rabbit population and a moderate to heavy hare population in the area.

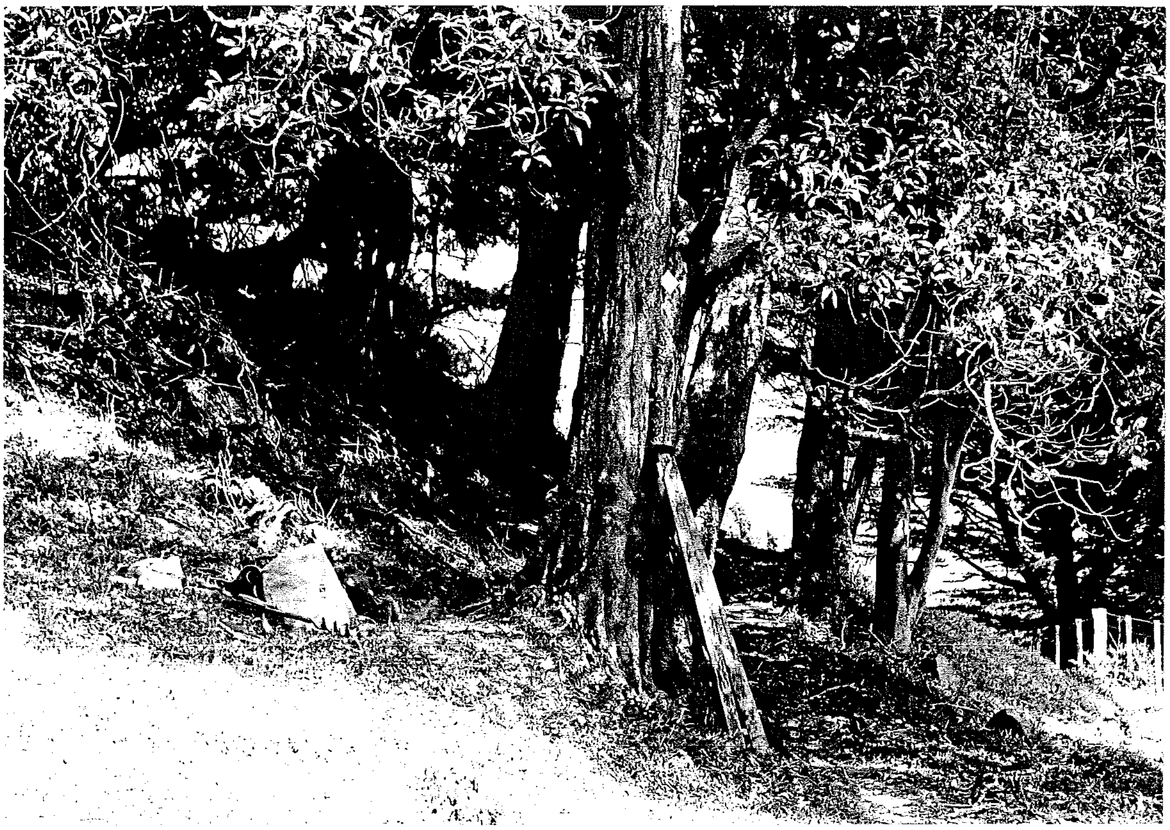

Fig. 26. Hollow Ngaio tree containing stoat den.
Okuti Valley.

Material was collected from a stoat den near the mouth of the Waipaoa River, Gisborne, on 22 October 1963 by Mr. T.P. Fisher, Wildlife Branch, Internal Affairs. It was found under a log in an area of driftwood in farmland with rushes and pasture grasses. Sheep were grazed here and there was a moderate hare population. The nest contained an adult lactating female and seven young; two young collected were estimated at 3-4 weeks old.

Large quantities of hare hair (several handfuls) were present and, amongst it, part of a young hare, a mouse, two upper and one lower hare incisors, and the fragmentary bones, particularly leg bones, of a young hare. Well broken remains of two duck eggs were also present.

Another stoat den was found in a hollow Ngaio tree at Okuti Valley, Banks Peninsula, on 19 October 1963, when a lactating female was seen and trapped. I examined the den site and collected one young stoat about a week old. The hollow tree had contained a starling nest and was about 150 yards from a farmyard in farmland with remnant patches of open bush (fig. 26). The nest contained three mouse tails, mouse hair and a broken starling egg which may have been eaten by stoats.

A few feathers, mostly starling, were present but appeared to be from the starling nest and not from stoat predation.

Field Studies at Birdlings Flat

An area in which more detailed studies of the feeding habits of stoats could be made was selected at Birdlings Flat, southwest of Banks Peninsula, on the east end of Lake Ellesmere spit.

The apit consists of three main habitat types (Wraight, 1957)

(1) sand-dunes along the coast

(2) annual grassland

(3) salt marshes at the lake edge below the 3.25 feet contour line. This area was flooded from late April until late spring in 1963.

Dense annual grassland covers most the the spit and shows very large variation in species composition and yield between successive years under climatic influences. Climate on the spit is of the mediterranean type with adequate winter moisture and termperatures that allow some growth in winter. There are drought conditions with no growth during summer. Plant associations across the spit correlate perfectly with different soils and differences in the species composition of the vegetation along the spit are correlated with differences in the grazing pressure exerted by sheep (Wraight, 1957).

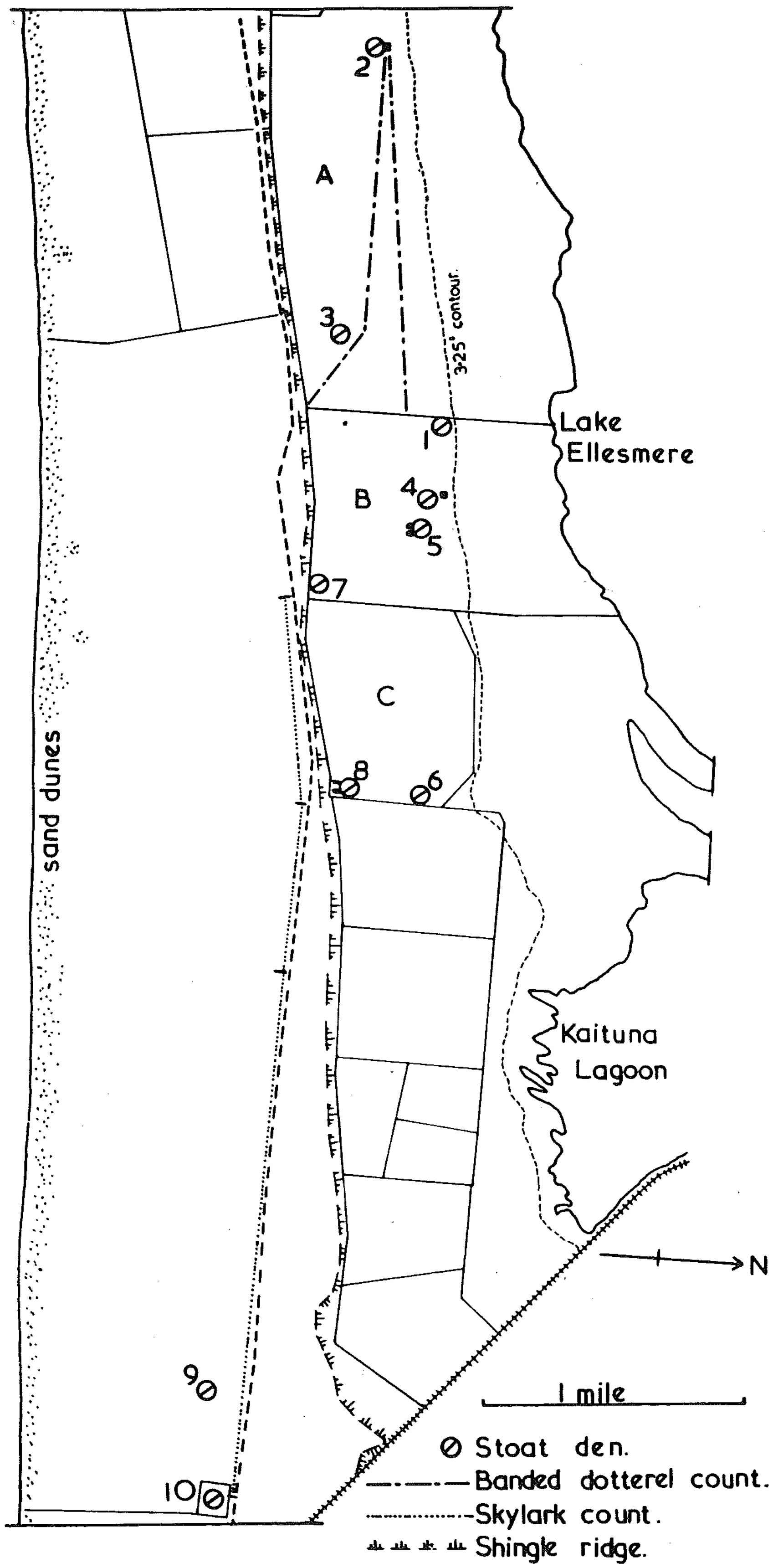

Fig. 27 Study area at Birdling's Flat.

Most intensive studies of stoats were made in an area of approximately 3 square miles along the lake flats on annual grassland but less detailed observations were made over twice that area (fig. 27).

Grazing pressure differed in the three paddocks A, B and C in which most of the stoat dens were collected and was heaviest in paddock A of 1100 acres and lightest in paddock B. A shingle ridge 25 feet a.s.l., extending the length of the spit is an important feature of the landscape. Bracken and matagouri on this ridge provides cover for mammals and birds.

There was very little cover for stoats in the study area, although it was adequate in the sand-dunes and in the rush zone near the lake. Over the remainder of the area stoats were largely dependant on old buildings, rubbish piles and other man-made cover. As the amount of such cover was limited it was relatively easy to find dens and trapping was concentrated around these dens and areas of suitable cover.

Stoats were live-trapped in wooden box traps baited with meat and transferred to a wire holder for weighing and marking (fig. 28). They were marked by toe-clipping. It was possible to identify the occupants

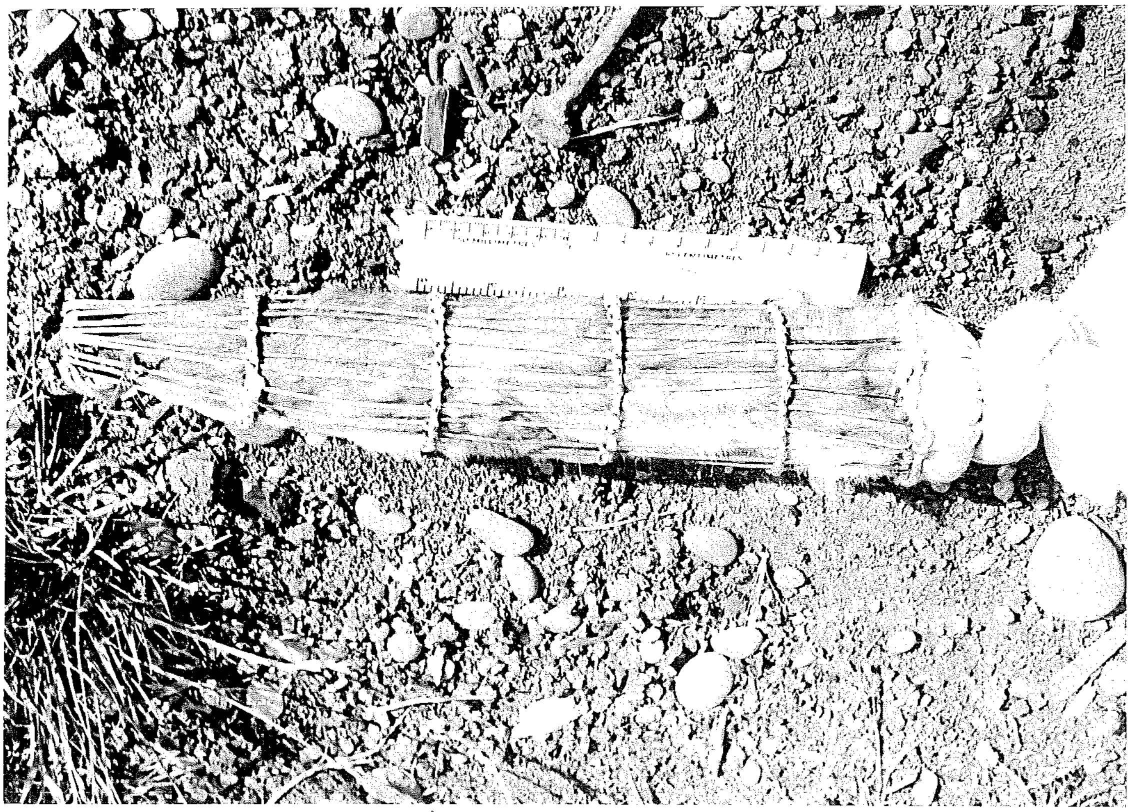

Fig. 21. Live-trapped stoat in holder for weighing and marking

of different dens by this method but the size of home ranges could not be determined. Trapping was carried out between mid-February and early December 1963 and seven males and two females were marked. Stoats were captured or recaptured on 22 occasions but in six cases escaped before they could be examined. Seven stoats were marked in the first five months and the other two were caught in December.

Four marked animals were recaptured and in three cases were caught at the original site of trapping. A male marked on 14 June at den 7 was recaptured three months later almost a mile away at den 8 and two months later was caught again at den 6.

Only one stoat was known to die during the study. This was a sub-adult male caught at den 8 on 14 June and recaptured again on the 27 and 28 June during very cold weather. It lost 40 grams between the last two trappings and appeared to be ill when caught on the 28th. It died shortly afterwards and had no traces of fat in the body cavity. There was no evidence of seasonal weight changes in stoats recaptured.

Only one ferret was caught and this was an adult female trapped nine times between 28 March and 28 June at den 2. During March and April she had enlarged teats and probably had a litter during the summer. Her body weight fluctuated between 465 and 550 grams but no information on her food could be obtained as the few droppings collected from the trap had no identifiable prey remains in them.

Prey Species.

Mammals.

Hedgehogs were found in the sand-dunes and grasslandand twice were caught in stoat traps. There was no evidence of stoats feeding on hedgehogs.

Rabbits and hares were most common in the sand-dunes but hares were also seen frequently on the grassland and lake flats. They were often disturbed from their forms in the tussocks and rushes and in the matagouri and bracken on the shingle ridge. Rabbits were occasionally seen on the lake flats and, in most cases, were living under the buildings.

There was no sign of rats in the area and they were not recorded in stoat droppings. Remains of mice were recorded in stoat droppings from many of the dens and were probably present throughout the area. Only at the hayshed (den 10) was sign of mice evident. Mouse droppings were found and bait in stoat traps was eaten by mice. There was no evidence of seasonal variations in the density of mice but the large numbers recorded from droppings in 1961 and small numbers in 1962 and 1963 suggest that the mice populations fluctuate widely from year to year.

Birds

Birds in the area can be divided into two broad groups of non-prey and prey species. Seabirds and the larger lake birds were not taken by stoats. Gulls and terns often nested on the salt marsh and beach and black-backed gulls nested in both these areas. Black swans nest in very large numbers on the salt marsh along the lake edge and possibly some cygnets are killed by stoats. Ducks and pukekos also nest throughout the area. Remains of two pukekos were found in stoat dens 2 and 8 and may have been carrion but there was no evidence of predation on nests. Harriers were present and usually one or two could be seen hunting over the area. One was seen carrying a young hare on 21 September. White-backed magpies were seen occasionally and in November and early December a flock of up to 31 magpies was seen feeding in the area.

About ten species of birds were present in the area through the year or at certain seasons in sufficient numbers to be available as food, but only two species were preyed on extensively. Skylarks were the most abundant bird resident in the area throughout the year. Counts were made of skylarks on or beside the road from den 8 to den 10 between September and December. An average of six birds per mile was counted in September and October, but at the end of October skylarks began to increase and, early in December, the number had doubled, averaging 13 birds per mile. This increase in numbers may indicate an increase in the population, with young present, or may be due to increased dusting on the road. Two well grown nestling skylarks were found in den 8 on 19 October and would have been flying before the end of the month.

The density of skylarks was greatest in the vicinity of the lake flats and shingle ridge and was over twice that recorded between den 10 and the point where the power lines crossed the road. Counts were made early in December on two sections of road near den 8 gave averages of 26 and 28 birds per mile, while counts from den 10 to the power lines gave counts of 11 birds per mile. Few nests were found so no estimate of nesting success could be made.

The numbers of banded dotterels present altered markedly at different times of the year. They nested from late August to November on the stony areas of the lake flats, among the sand-dunes, and on the shingle beach in the driftwood zone. The most concentrated area of nesting was on the heavily grazed paddock A. From January to April several thousand banded dotterels roosted in flocks on the lake flats in paddock A and were apparently feeding around the lake edge. Towards the end of April their numbers declined but there were still several hundred present until the end of July. During April and May up to 50 birds were counted in paddock B and similar numbers were present in paddock C. Towards the end of July the numbers decreased again and only five to ten were counted in paddock A but increased during nesting in September and October to 20 or 30 birds. Nesting was finished by the end of November and in December only about five birds were counted in paddock A. Nests with eggs were found from mid-September to early November and, of 23 nests found, ten were destroyed, four were known to hatch and the fate of nine was unknown. Stoats were probably responsible for most of the predation as eggs were found in the stoat dens. In no cases were eggs found broken in the nest. The only other likely predators were harriers.

Pied stilts were present on the wet salt marshes and lake edge throughout the year. Between 19 and 37 were recorded on the salt marshes in paddock B in late April and May. Up to 50 were recorded in September and 28 counted early in November.

Pipits were present on areas of sparse vegetation and shingle or sand but were only common in the sand-dunes and on the nearby dry hollows.

Flocks of finches were seen feeding on the lake flats during winter and spring. Goldfinches predominated, in flocks of about 20 to 30 birds from June to early October, but redpolls, yellowhammers and greenfinches were also recorded. One to two hundred yellowhammers were counted in the vicinity of den 8 in July as hay was fed out to sheep here. Few greenfinches were seen until early October when flocks of 50 to 150 birds were seen.

House sparrows were present through the year and six to twelve could be counted around each building. Two occupied nests and several flying young were recorded in February in the building at den 2, and eggs were found in four nests there in early December 1963.

Large flocks of starlings fed in the area on the grassland and salt marsh and over 1000 birds were counted. These birds apparently roosted on the cliffs around Lake Forsythe and the coast of Banks Peninsula. Flocks of several hundred birds were counted through most of the year, with larger flocks in winter. At least two pair nested in the sheds at den 8 in October.

Lizards

Geckos were found in stony areas and skinks were widespread, being particularly abundant in the sand-dunes.

Stoat Food Habits at Birdlings Flat

A large amount of material was collected from stoat dens in the study area during 1963 and some was also obtained during brief visits in 1962. A stoat den found by Mr. K.H. Miers, Wildlife Branch, Internal Affairs, in October 1961 and forwarded to me for examination drew my attention to the area.

If a den did not appear to be occupied when found, all material, including bones, hair, feathers and droppings were collected. Only droppings and flight and tail feathers were collected from occupied dens and the nest left as undisturbed as possible. Where possible the individual droppings were kept separate but in many cases had fused or fragmented. Feathers were identified by comparison with study skins of species known to occur in the area, and counts of distinctive individual were made. The outermost primary (excluding the remicle) on which the outer vane is reduced, and any distinctively marked retrices (tail feathers) were counted. For example, the left and right outermost remix and two outer retrices (5 & 6) of skylarks were counted, and the outermost remix of banded dotterels. The maximum count of any of these feathers (usually the remiges) indicated the minimum number of birds eaten at the den. Details of the analysis of one nest are given (table 14). Hair, bones and teeth of mice were found only in the droppings and in most cases the entire mouse was eaten. Estimates of the number of mice eaten were made from counts of limb bones and incisors (left and right, upper and lower).

Generally, the remains of only one rabbit or hare occurred at a den but, where remains of more than one were present, counts of limb bones, skulls or incisors indicated the number taken. In some cases milk teeth, which were often unworn, showed that very young animals had been taken.

When large numbers of skinks occurred in a series of droppings, an estimate of the number could be made by counting the feet present, as these remained intact.

Droppings were examined dry and bones, fur and feathers, etc. separated under a magnifying glass. Identifications were made under a binocular microscope. Estimates of percentage volume of various prey items were made with the intact droppings and occurrences listed for the fused or fragmented droppings.

Fig. 25. Rush containing den 1.

Den 1.

A stoat den was found on 6 October 1963 in a large rush in the rush zone of paddock B (figs. 27, 29) and was typical of the stoat dens found on the lake flats. Recent banded dotterel egg and skylark feathers were visible at the tunnel entrance, but no material was collected. Two old swan skulls (at least 1-2 years old), found at different parts of the rush, may indicate previous or long term occupation. Further signs of activity at the den were seen on 13 October 1963, when eggshell and three fresh orange droppings derived from egg were found. Traps were set near the den for ten trap nights but no stoats were trapped. Nest material and droppings were collected from the den on 4 December (table 14). The nest itself was deep under thick overhanging rush and quite dry. Two tunnels gave access to the nest and one led to an open place within the rush in which there were two latrine sites containing 40 droppings (fig. 30). Feathers, banded dotterel eggshell and a rabbit or hare leg were collected in the tunnels near the nest. Skylarks were the main prey of the stoat occupying this den and both nest material and droppings indicate that other foods were not of great importance.

Fig. 36. Stoat droppings in latrine, den 1.

TABLE 14.

Contents of Den 1 - 4 December 1963.

Mammals:

Rabbit/Hare	2	1 forefoot 1 very small incisor in bone 3 incisors, 2 unworn milk teeth and 2 teeth (In material from old latrine)	

Birds:

Banded Dotterel	1	1st primary left	1
		Eggshell too fragmentary to make count of number of eggs	
Skylark	24	1st primary left	24
		" " right	18
		tail outer left	23
		" right	17
		5th left	18
		" right	17
		hind claws	12
		beak upper mandible	3
		lower "	6
Swan		2 very old skulls	

Droppings: 40 entire	% volume
feather	87.0%
R / H	9.5%
Skink	1.0%
Stoat hair	1.0%
B.D. eggshell *	1.5%

* 3 droppings containing egg found on 13 October 1963.

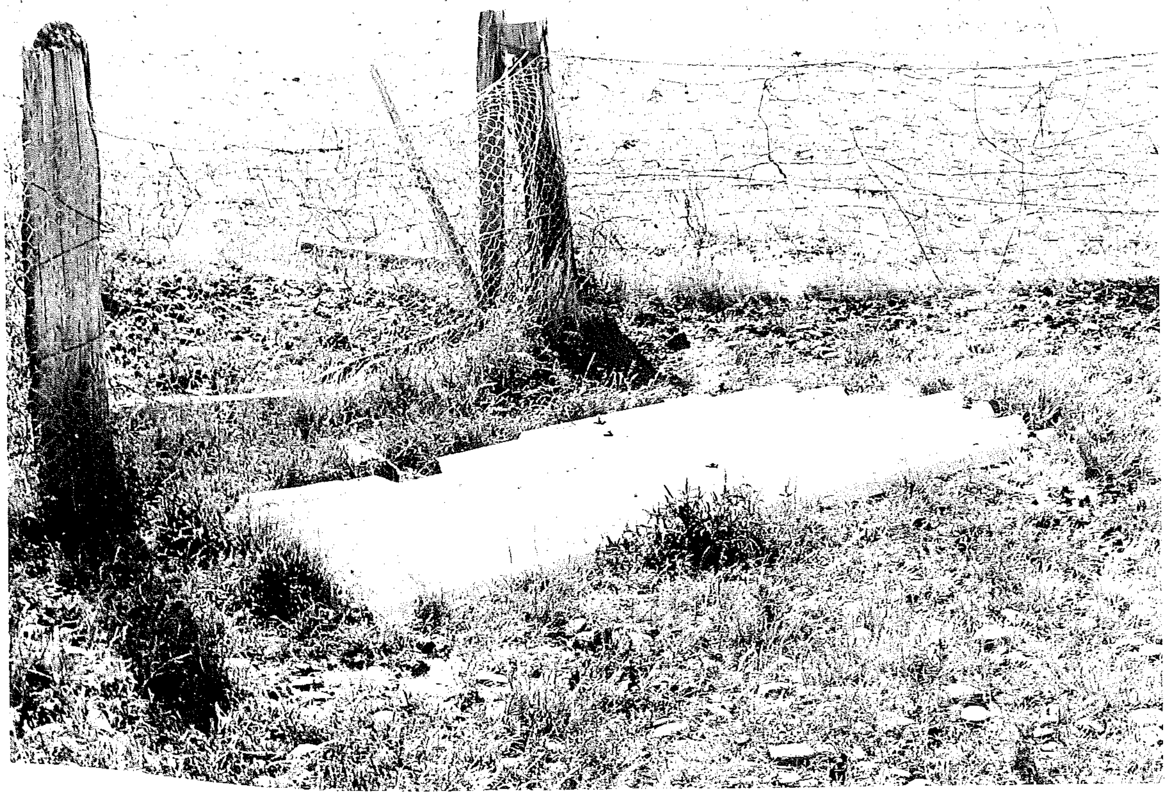

Fig. 51. Den 2 occupied during winter 1963.

Den 2.

This den consisted of a number of sites around a shed and can be considered in four parts. These are

(1) Nest material collected by Mr. K.H. Miers on 2 October 1961, accumulated during spring 1961.

(2) Material collected 3 February 1963 under a stack of corrugated iron, accumulated during spring 1962.

(3) Material collected between 20 June and 2 October 1963 from a nest under a sheet of corrugated gibraltar board (fig. 31). Most of the material accumulated during winter.

(4) Material collected between 15 August and 6 October 1963, from a nest in a rubbish pile of tins, sheet iron and wire, was accumulated during late winter and spring.

An adult male stoat, marked RH_7, was trapped here on 27 July and 5 October and was responsible for the material in parts 3 and 4.

The striking feature of the nest material collected on 2 October 1961 is the large number of mice and small number of skylarks present (table 15). This is reflected in both the food remains and dropping contents. Seventeen mice were counted, in contrast to three in the material accumulated during spring 1962 when many more skylarks and banded dotterels eggs were taken. The droppings in the 1962 material consisted predominantly of bird remains and egg fragments (table 16). The almost complete skeleton of a pukeko was present and could have been taken nearby on the salt marsh or may have been carrion.

Some material and droppings were collected under the stack of corrugated gibraltar board behind the shed on 25 April 1963 (table 17). The female ferret was living here at this time but the material appeared to have been accumulated the previous spring, possibly by stoats (it contained four banded dotterel eggs). Remains of six mice were present in the detritus from old droppings.

Collections of nest material and droppings were made through winter 1962 at a den under a sheet of corrugated gibraltar board (table 18). There was no sign of activity here on 25 April but on 20 June there was a large nest of feathers and 65 droppings were collected. More material was found on 28 June and 30 July but, after this date, the marked stoat RH_7 which occupied the den apparently shifted to the rubbish pile and the previous den was only briefly occupied in September and early October. Material was collected

Fig. 32. Remains of skylarks (upper) and sparrows (lower) from den 2, showing difference in palatability. 30 July 1963.

from the nest in the rubbish pile in August, September and early October (table 19), but there was no further sign of activity at either of these dens after 6 October.

Banded dotterels were the most frequent prey taken in May and early June and remains of eleven were found. At this time banded dotterels were roosting in hundreds on the heavily grazed flats near the rush zone. Two more banded dotterels were found in the den in August and another early in October but at this time predation was concentrated on skylarks. Only seven skylarks were taken in May and June while banded dotterels were preyed upon but, in July, 12 were taken. In August predation on skylarks was still heavy but in September and early October eggs of banded dotterels were being taken extensively. During this time seven banded dotterel eggs were found in the den and eggs disappeared from many nests before they could hatch. Three sparrows were found in the nest on 30 July and were more or less untouched while 12 skylarks had been completely eaten (fig. 32). Another two sparrows were found on 24 September and again were relatively intact. The only other bird taken at this den was a starling found on 20 June.

Rabbits and hares were not taken at all during the winter and the only one was a very young animal found in droppings collected on 20 June. Traces of hair were next recorded on 25 September.

Similarly, no mice were taken during the winter. Four mice were counted in droppings collected on 20 June and no further recently killed mice were found until one was identified in three droppings collected on 24 September. A mouse found in detritus collected with droppings and nest material on 15 August may have been there for some time.

Both the nest material and droppings show that this stoat was feeding almost entirely on birds during autumn, winter and spring, with heavy predation on banded dotterel nests during September and October. During May and early June banded dotterels were preyed on heavily but after this time skylarks were the main source of food.

Table 15.

Contents of Den 2, 2 October 1961.

Mammals			
Rabbit young			1
Mice			17
Birds			
Banded Dotterel			1
" "	young		traces
" "	egg		4
Skylark			2
House Sparrow			1
Droppings			48 entire or part droppings
			% occurrence
Mice	21		43.7%
Birds	19		39.5%
Rabbit	8		16.6%

Table 16.

Contents of Den 2, 3 February 1963.

Mammals		
Rabbit/Hare young		1
Mice		3
Sheep		bones from human food refuse
Birds		
Pukeko		1
Banded Dotterel		2
" " egg		13+
Skylark		14
Skink		traces present in droppings
Droppings		disintegrating or fused and hard
Birds	24.3	
Skink	0.7	
Mouse	1.0	
Eggshell	2.0	
" and down	1.0	
Down	1.0	
Total	30 droppings	

Table 17.

Contents of old nest at Den 2, 25 April 1963.

Mammals	
Hare young	1
Mice	6
Birds	
Banded Dotterel	1
" " egg	4
Skylark	2
Pipit	1
Skink	Traces

TABLE 18.

Contents of Den 2 during Winter 1963.

25 April 1963	No sign of activity
20 June 1963	
Mammals	
Rabbit/Hare very young	1
Mice	4
Birds	
Banded Dotterel	11
Skylark	6
Starling	1
Skink	traces in droppings
Droppings 65	% volume
Bird	68%
Rabbit/Hare	21%
Mice	5%
Skink	4%
Insect	1%
28 June 1963	
Birds	
Skylark	1
Droppings 10	
Bird	100%
Stoat hair traces	

TABLE 18. (continued)

Contents of Den 2 during Winter 1963.

30 July 1963

Birds

Skylark	12
House Sparrow	3 (1♂, 2♀)

Droppings 70

Bird	98% volume

Traces of Rabbit/Hare hair, and stoat hair.

Stoat hair occurred in about 10% of the droppings.

25 September 1963

Bird

Banded Dotterel egg	5
Skylark	2

Droppings 25	occurrence	% occurrence
Bird adult feather	21	65.6
Eggshell	7	21.8
" and down	4	12.5

Traces of insect, rabbit/hare hair and plant fragments.

2 October 1963

Bird

Banded Dotterel egg	1

TABLE 19.

Contents of Den 2 in late winter and spring 1963.

15 August 1963		
Mammals		
Mice		1
Birds		
Banded Dotterel		2
" " egg		traces
Skylark		12
Skink		trace
Droppings		
Bird	50	100%
Skink		traces
24 September 1963		
Mammals		
Mice		1
Birds		
Sparrow		2 (♂)
Droppings	4	
Bird		1
Mouse		3
6 October 1963		
Birds		
Banded Dotterel		1
Skylark		5

Den 3.

This den, under a small loose stack of boards with no surrounding cover in the way of rushes or long grass, was found in paddock A on 27 March. The large gaps between boards made the den rather exposed and it had not been occupied recently. Banded dotterel eggshell indicates that the material was accumulated during spring 1962 (table 20). Remains of one skylark were found here on 13 June and the den was not occupied again before the boards were removed early in spring.

Table 20.

Contents of Den 3.

27 March		
Banded Dotterel	1	
Banded Dotterel egg	7+	(possibly fragments of 1-3)
Mouse	2	hair and 2 tails. No sign of bones or teeth in nest material and droppings
Rabbit/hare	1	hair and bone fragments of a young animal. Includes leg bone fragment, 2 upper and 1 lower incisor.
13 June		
Skylark	1	

Droppings at this den were old, fragmentary and disintegrating. They contained rabbit or hare hair, bone and feathers, and traces of eggshell, but no mouse or skink remains.

During spring 1963 several droppings and banded dotterel eggs were found under two small pieces of iron lying in the paddock. Two small droppings containing feathers were collected with three banded dotterel eggs on 28 September. Two intact banded dotterel eggs found under the tin on 2 October were not eaten until about 10 October and another egg shell was found on 31 October. Two droppings collected under another small piece of tin on 5 December contained down feathers from a banded dotterel chick.

Den 4.

This den, situated halfway between the tower and caravan (fig. 27) under a large sheet of wooden flooring approximately 6 feet square and raised off the ground by 3-inch boards, was not occupied by stoats until 29 March when a young rabbit was found there. The rabbit appeared to have been dead one to two weeks and was not present on 25 February.

A nest of grass containing large numbers of feathers was found on 14 June and had accumulated since 3 May. Three skylarks and a pied stilt were identified in the nest material and remains of three mice were found in the droppings. Remains of birds predominated in 42 droppings found. As this den was occupied only from mid-March to late July, with the majority of the material accumulated in May-June, all prey items are tabulated together (table 21).

Two more skylarks and two droppings were collected on 30 July; after this date the den was not used again and the flooring was removed on 16 August. During June and July the den was very damp, probably because of the high lake level, and this possibly made the den unsuitable.

The pied stilt in this den was the only one known to be taken by stoats during the study, although pied stilts were present along the lake edge and on the wet flats during most of the year. In late April and May I recorded between 19 and 37 pied stilts feeding in a water channel in front of the tower and approximately 160 yards from the den. The mutton bones and fat in the den were probably collected by the stoat from the caravan and shed where duck-shooters had been staying intermittently since 4 May.

TABLE 21.

Contents of Den 4.

Mammals	
Rabbit	1 young collected 29 March
Mouse	3 from droppings 14 June
Birds	
Pied Stilt	1 on 14 June
Skylark	5 - 3 on 14 June 2 on 30 July
Reptiles	
Skink	present in droppings 1 or 2 animals

Refuse

2 cooked mutton bones and fat.

Fat also present in the droppings

Droppings

Total 44

Contents	No. Droppings	% Occurrence
Bird	29.5	67%
Mouse	7.0	16
Skink	3.0	7
Fat	4.0	9
Grass	0.5	1

Den 5.

This den was situated at one of the larger landmarks on the lake flats and appeared to be occupied throughout most of the year. An old caravan and shed provided excellent cover and the stoats lived in the lining of the walls. Unfortunately, I could not collect food remains from the nest within the walls but collected remains of prey eaten outside and old prey scraped out on to the ground in spring. Most of this material was old, probably accumulated during the autumn and winter, and has all been grouped (table 22).

A young rabbit found on 28 March was estimated to have been killed three or four days previously and remains of a young hare found on 24 April were two or three weeks old.

A sparrow and three starlings were found during January and February and the rest of the birds were found during spring. Seven of the 18 skylark remains were almost intact, sometimes with the head or one wing missing. One was a week or two old when found, but the rest were much older. Banded dotterel egg was found at the den between 10 September and 31 October and remains of two of the eggs were found amongst some rushes away from the caravan and shed. Eggshell occurred in fresh droppings collected on 23 and 28

September and in a dropping from a stoat trapped on 5 December. The down feather from a young banded dotterel was found in a dropping on 14 September.

Several large series of droppings collected through the winter have not been examined.

TABLE 22.

Material from Den 5.

Mammals		
Rabbit young	1	
Hare young	1	
Mouse	1	
Birds		
Skylark	18	
Starling	4	
Sparrow ♂	1	
Goldfinch	1	
Banded Dotterel egg	6	
" " young	1	(from dropping)
Droppings		
6 collected 24/4/63 to 15/8/63.		
Feather	5	
Fat	1	
14/9/63 to 5/12/63	total 13	
Rabbit/hare	5.7	
Eggshell	4.5	
Feather	2.5	
Down feathers	.3	

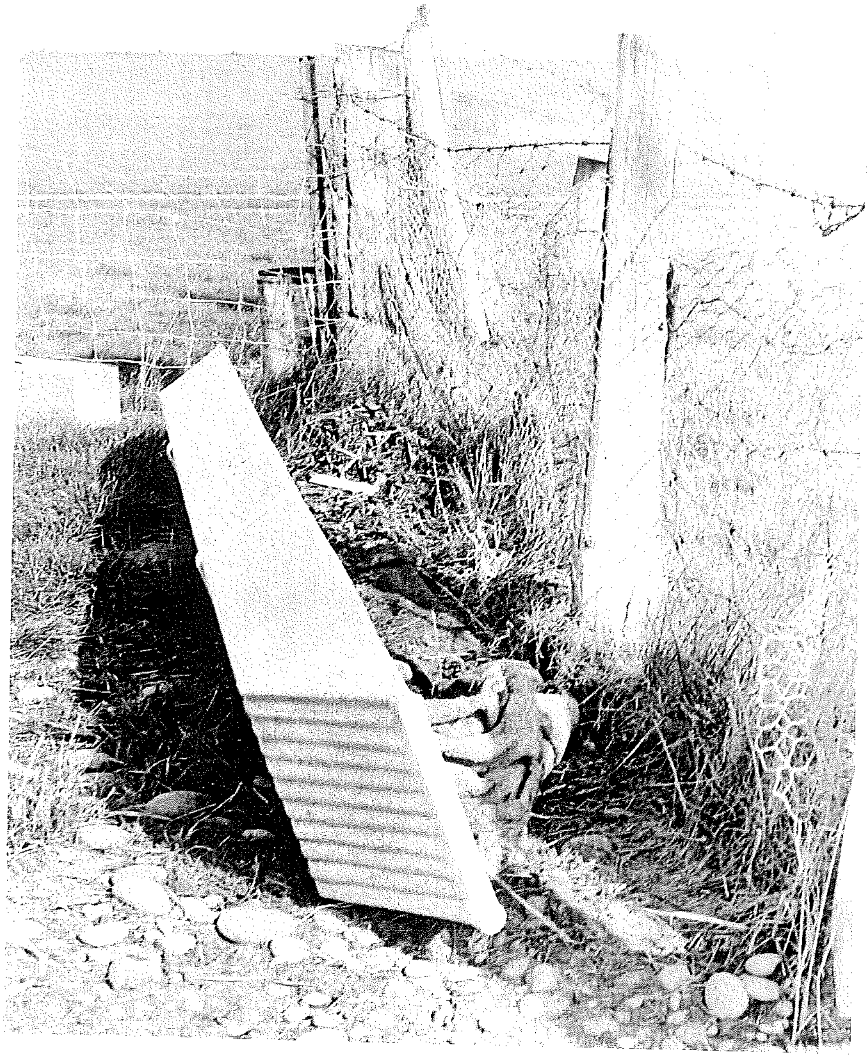

Fig. 33. Den 6 with iron trough turned back to expose nest.

Den 6.

A large stoat nest of feathers was found under an overturned corrugated iron trough in paddock C on 5 October (figs. 33, 34). A marked male stoat previously caught at dens 7 and 8 was caught here on 7 October.

Nest material was collected on 6 October and included large numbers of skylark feathers, five banded dotterel eggs, hare remains and large numbers of droppings (table 23). There was no further sign of activity at this den but a banded dotterel egg taken sometime after 7 October was found under a small piece of iron nearby on 3 December.

TABLE 23.

Material from Den 6.

Mammals	
Hare	2 hind legs and pelvis
Mice	may be present in droppings in small numbers.
Birds	
Skylark	43
Pipit	1
Sparrow	1
Banded Dotterel	2
Banded Dotterel egg	5
Droppings	large series not examined

Fig. 34. Den 6. Detail of nest containing feathers from 45 skylarks.

Den 7.

Even a small area of cover may provide useful shelter for stoats. This was the case at this den where a dense *Plagianthus* bush and a log were often used from January to March. Most of the material was droppings but remains of a young skylark and mouse hair were also collected on 29 January (table 24).

Droppings were collected on the following dates (numbers of droppings in brackets): 3 February (4); 14 February (3); 28 March (12); 2 May (1); 15 August (1). Results of examination of these droppings have been grouped as most of them were collected in February and March.

TABLE 24.

Material from Den 7.

Mouse	1	(from dropping 14 February)
Skylark young	1	
Droppings - total 21		
Rabbit/hare	11.5	
Skink	5.2	
Mouse	2.0	
Feathers	1.3	
Eggshell	1.0	

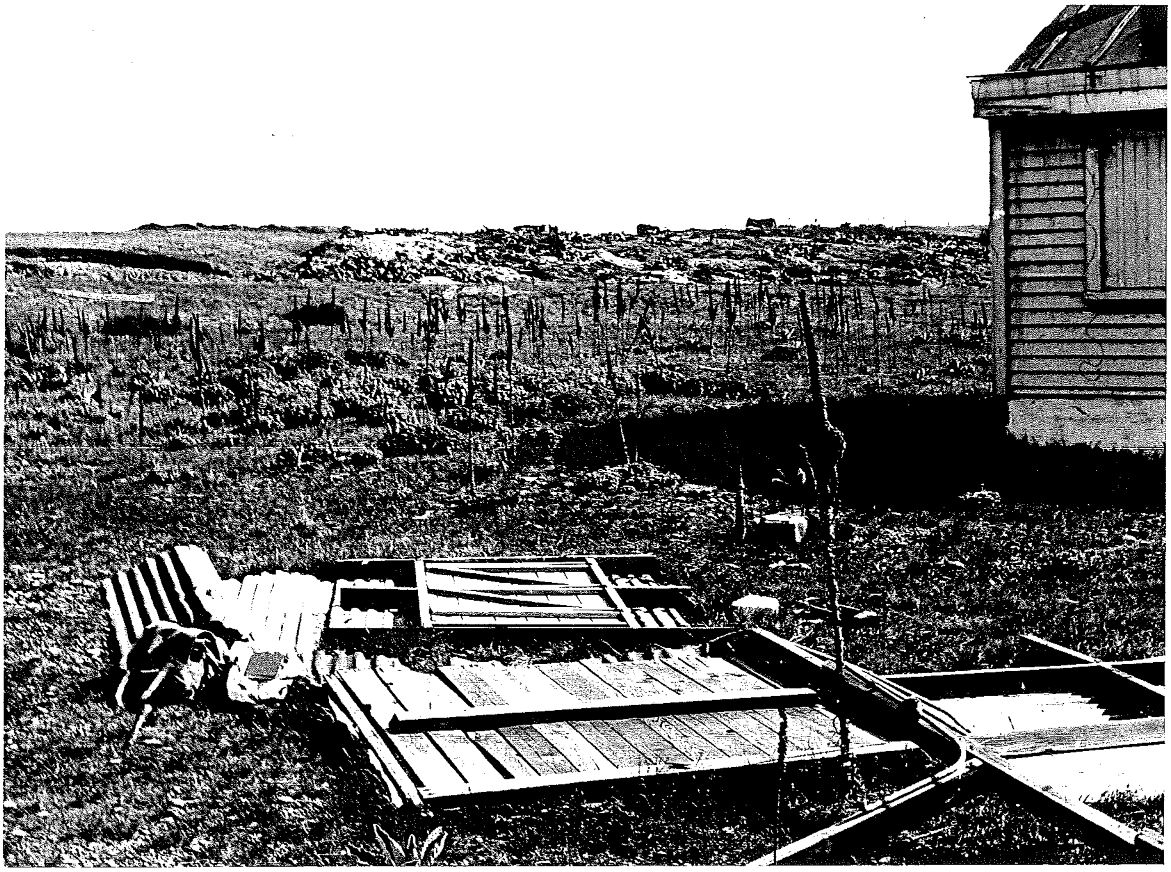

Fig. 35.   Den 8 under corrugated iron and boards

Den 8.

Stoat droppings and food remains were often found at two large sheds and some corrugated iron sheets lying nearby and this den can be best considered as two separate sites. The first was collected in early 1963 amongst hay stored in a shed. The material, including feathers and droppings, had accumulated some time earlier, probably the previous spring as eggshell was present in some of the droppings (table 25).

The second, and more important den, was found under three sheets of corrugated iron a few yards from one of the sheds (fig. 35). Food remains were collected here on six occasions during 1962 and 1963 (table 26). Material was first collected in July 1962 and had accumulated during the previous spring and summer when seven banded dotterel eggs were taken. One pukeko wing was present in the nest and was probably collected as carrion as the nearest pukeko habitat was at least half a mile away from the den.

There was no sign of occupation here during spring 1962 but remains of prey and droppings were collected during the summer. A series of five droppings collected with a rabbit or hare foot on 9 December all contained rabbit/hare hair. Three young and one adult

Fig. 36. Den 8 containing two young and three adult skylarks. 19 October 1963.

skylarks were taken during January and remains of adult and young birds predominated in 37 droppings collected between mid-November and the end of February (table 27). The eggshell trace may have been skylark egg. During the winter one redpoll collected in June was the only remains of prey found and only 12 droppings were collected between March and end of September. Six of these contained bird feathers; four were from rabbit or hare and two contained skink remains. Five of these droppings were collected from trapped animals.

When this den was examined on 13 October there was no sign of occupation. However, when re-examined on 19 October a male stoat was found with the remains of three adult and two young skylarks (fig. 36). Two adult skylarks were entire, the other had been eaten. One of the young skylarks had the head and neck eaten while only the legs, thigh and tail of the other was left. The wing feathers of these were only just showing out of the sheaths. On 5 December a latrine containing 19 droppings was collected and analysed and a further seven droppings gathered. However, there were no further food remains at the nest. These droppings have been grouped for analysis. Feathers predominated in 29 droppings collected between 13 October and 5 December, but eggshell and down feathers from banded dotterels were also present.

TABLE 25.

Den 8 - Material from Hay - Spring 1962.

Mammals	
Rabbit/hare	small amount of hair
Birds	
Skylark	1
Starling	1
Sparrow	5 (3♂, 2♀ or juv.)
Goldfinch	1

Droppings

Old, fused and fragments

Predominantly rabbit/hare with smaller amounts of feather and traces of banded dotterel eggshell, mouse and skink remains.

TABLE 26.

Den 8 - Material Collected Under Corrugated Iron

27 July 1962		
Mammal		
	Rabbit/hare	Young, fragments, probably of one animal.
	Mice	1 or 2
Birds		
	Skylarks	8
	Banded Dotterel	1
	" " egg	7
	Pukeko	1
9 December 1962		
Rabbit/hare		Young, 1 front leg
January 1963		
Skylark		Adult 1
		Young 3
13 June 1963		
Redpoll		1
19 October 1963		
Skylark		Adult 3
		Young 2
Banded Dotterel egg		fragments in droppings

TABLE 27.

Analysis of Droppings from Den 8.

27/11/62 to 25/2/63.

Mammal	
Rabbit/hare	7.5
Mouse	0.6
Bird	
Adult	14.0
Fledgling	8.5
Eggshell	trace
Reptile	
Skink	6.4
Total	37.0 droppings

27/3/63 to 25/9/63

Mammal	
Rabbit/hare	4
Bird	6
Skink	2
Total	12

13/10/63 to 5/12/63

Mammal	
Rabbit/hare	2
Bird	
Feather	21
Down feather	4 (2 with eggshell)
Eggshell	6
Skink	1 (+ 2 trace)
Total	29

Fig. 37. Site of den D in rubbish pile
(set trap in foreground)

Den 9.

This den was found under a pile of old tin and wire on 23 May 1962 and was occupied intermittently throughout the study (fig. 37). When found, the site had not been frequented for some time and all droppings and material were dried and disintegrating. The skull of a young rabbit and a large series of droppings and litter was collected on this date. From the droppings and litter a total of at least 20 mice and two young rabbits were identified (table 28).

There was no further sign of activity until the summer of 1962-63 when remains of four young skylarks were found between 27 November and 3 February. In all cases the wings were still sheathed. Droppings in relatively small numbers were also collected with the skylark remains, but were often in a weathered condition. The small numbers of droppings and their weathered, fragmentary condition made it difficult to determine the pattern of food habits of the stoat or stoats feeding in this area. Birds, rabbits and hares, mice and skinks were all quite important foods. However, during the year December 1962 to December 1963, only the remains of two mice occurred in 40 droppings as compared with 20 mice from approximately 85 droppings on 23 May 1962 and probably accumulated in the summer of 1961-62.

The hind leg of a young rabbit or hare was collected at the den on 2 May 1963. This was from a recent kill but had all the meat eaten off it.

TABLE 28.

Contents of Den 9 - 23 May 1962.

Mammals		
Rabbit (young)		1 skull
		1 from teeth in litter
Mice		20
Droppings		Total 85
Contents	No.	% volume
Mouse	39.5	46.8
Skink	30.7	36.1
R/H	13.5	15.8
Feather	1.0	1.1
Insect traces		

Den 10.

A hayshed, situated near the main Christchurch-Akaroa highway in a more complex plant community than the main study area, showed signs of stoat activity throughout the year but no stoats were trapped here. Hay was stored here throughout the study although the amount varied and most of it was fed out to sheep during July. Mice were probably more common here and this was the only site where mice ate the bait in stoat traps.

A large amount of material from a stoat nest was uncovered while hay was being fed out to sheep in July. It included feathers, rabbit/hare remains and droppings (table 29). Some of the material was very recent (two yellowhammers and one greenfinch), but remains of a skylark and a rabbit or hare were much older, possibly several months. At this time the hay was being fed to sheep in the vicinity of the shed and flocks of yellowhammers and greenfinches were feeding on seed from the hay. It was hard to determine the age of the droppings and they were difficult to analyse quantitatively as many were broken, particularly those containing the remains of skinks. From estimates of the percentage volumes of the droppings, rabbits or hares were the most important food with mice and skinks taken to a lesser extent. Fourteen mice and 29+ skinks were counted.

Twelve fresh droppings were collected at this den throughout the year. Eight were found on the hay and four at a nearby rock pile. The droppings were collected in May (1), June (4), August (6) and December (1). Five mice were counted in the droppings and small amounts of feathers were the only other prey remains in these droppings (table 30).

TABLE 29.

Contents of Den 10.

25 July 1963

Mammals	
Rabbit/hare	young 1 (pelvis and hind legs)
Mice	14
Birds	
Skylark	1
Greenfinch	1
Yellowhammer	2
Skink	29+
Droppings	% volume
Rabbit/hare	44.9
Mice	13.9
Skink	31.0
Feather	10.0

TABLE 30.

12 Fresh Droppings Collected at Den 10.

Mice	10.9
Feather	1.1
Total	12.0

Discussion

Examination of stoat dens showed that extensive predation on birds occurred with large numbers of skylarks taken. Banded dotterels were important prey in autumn and during nesting. Other birds were rarely taken (table 31).

Rabbits and hares taken were all young, with the tibia still unfused and in most cases were less than half-grown. There were insufficient animals to indicate seasonal variations in predation.

Although the remains of 82 mice were found in stoat droppings, 39 of these are derived from two dens accumulated in 1961. Seventeen mice were recorded from den 2 collected in October 1961 and twenty were found in old nest material collected at den 9 in May 1962. Nineteen mice were found in droppings from den 10 at the hayshed in 1963. Mice were more common here than on the lake flats. Only 24 mice were identified in den material from the lake flats in 1963. The large number of mice found in den material accumulated in 1961 suggest that mice were much more common then than during 1962 and 1963. In the three dens containing large numbers of mice there was little evidence of predation on birds. In den 10 (tables 29 and 30) only one skylark, a greenfinch and two yellowhammers were found and only a small percentage of the droppings consisted of bird feathers. Similarly, in den 9 only traces of feathers were found (table 28). When mice occurred in large numbers in the droppings at den 2 only one banded dotterel, two skylarks and a house sparrow were found (table 15). In 1962 when only three mice were found, two banded dotterels and 14 skylarks were taken (table 16) and more banded dotterel eggs were taken. This was also the case during the winter and spring of 1963 (tables 18 and 19).

Skylarks were the most readily available bird on the lake flats throughout the year, probably both in numbers and in ease of capture. The only other ground feeding and ground roosting birds present were banded dotterels, which were abundant from late summer to early winter on paddock A. In May and early June they were taken in preference to skylarks by a stoat at den 2 and, as they were roosting in large flocks, may have been easier to catch than skylarks. The other birds were relatively uncommon or fed in flocks and roosted outside the area.

It is also possible that some species are relatively unpalatable. This may be the case with house sparrows as three were collected from den 2 in July 1963 and had not been completely eaten (fig. 32). In contrast, all that remained of 12 skylarks were the wing tips and sometimes the legs. Altogether, of 13 house sparrows found in den material, five were not eaten. Two of the six starlings found in dens were not eaten completely and may be less palatable than skylarks. In cases where prey was killed but not eaten, the head was often chewed about and the brains eaten. Only seven skylarks were found which had been killed and not eaten, out of a total of 161 adult and 10 young skylarks. These seven were all found at den 5 in spring 1963 when six were scraped out of a nest in the wall of the caravan. They were all dried and had probably been killed in autumn. The seventh had been dead for a week or two.

There is a correlation between the edibility of the flesh and the visibility of the plumage in birds (Cott, 1947). The most palatable birds are cryptically coloured and the least palatable species are conspicuous in plumage and habit. Skylarks are probably more palatable than sparrows or starlings, but one would expect banded dotterels to be relatively unpalatable as it is conspicuous. Contents of den material at Birdlings Flat did not suggest this as all dotterels had been eaten completely. There are also differences in the palatability of the eggs of birds (Cott, 1953). Banded dotterel nests were heavily predated in the study area and remains of 58 or more eggs taken by stoats were found. The only other birds nesting in large numbers on the lake flats which might also be predated were skylarks but no definite evidence was found of this.

Although geckos and skinks were both present in the area only skinks were recorded in stoat droppings. Differences in their behaviour may make geckos relatively inaccessible to stoats, or possibly geckos are unpalatable.

Predation on the nests of banded dotterels was heavy during 1963. Twenty three nests were found from 24 September to 31 October (two were re-nestings) and eggs in only four nests known to hatch. In ten cases the eggs went missing from the nests before hatching and the fate of nine is unknown. Remains of 34 dotterel eggs were found in stoat dens in paddocks A, B and C during spring 1963.

There is little information on the food requirements of stoats but Howard (1957) found that a male long-tailed weasel in captivity required a daily food intake of 21 to 33% of its body weight. Weasels (M. nivalis) have similar food requirements (Linn, quoted by Southern, 1964). Den 2 was occupied throughout winter in 1963 and the nest material on 30 July was known to have accumulated in the previous 32 days (table 18). Twelve skylarks were eaten in this time, and three uneaten sparrows were also present. It was thought that this was the total food eaten during this period as remains of stoat prey were rearely found away from the dens. The weight of a male skylark from Lake Ellesmere was 30 grams and, assuming this as an average weight for skylarks, the 12 taken provided 360 grams of food for 32 days, or 11.2 gms per day. The stoat in this den weighed 280 grams and a daily food intake of 11.2 grams would provide the stoat with 4% of its body weight per day. This low food intake may be highly inaccurate if the stoat was also occupying another den, possibly in the nearby rushes, during this time and did not take all its prey to the den. However, Dice (1952, 141) has pointed out that animals may eat more when food is plentiful than when it is scarce and may be able to exist for long periods of time on a diet below that required to maintain the best state of health. Errington (1943: 822) has shown that the number of muskrats eaten by a mink may vary from two adult-sized animals per day to one in nine days. This minimum was believed by Errington to be sufficient to maintain a mink in satisfactory health although, more commonly, mink on a straight muskrat diet consumed two or three per week.

TABLE 31.

Total Numbers of Prey Recorded from Stoat Dens, Birdlings Flat.

Mammals		
Lagomorphs		
Rabbits		4
Hares		3
Unidentified		9
Rodents		
Mice		82
Birds		
Pukeko		2
Banded Dotterel		24
Pied Stilts		1
Skylark	adult	161
"	young	10
Pipit		2
Greenfinch		1
Goldfinch		2
Redpoll		1
Yellowhammer		2
House Sparrow		13
Starling		6
Eggs		
Banded Dotterel		58+
Reptiles		
Skink		many taken

Discussion

It is not now possible to determine the effects of Mustelids, and particularly of stoats, in New Zealand during the first decade after their liberation. As Marshall (1963) has pointed out, the factors involved in the changes in the New Zealand avifauna are complex. The clearing of bush and burning of tussock, the introduction of disease, presence of grazing mammals and liberation of predators, all had an effect on the bird life. Some birds showed a marked reduction in numbers even prior to the liberation of Mustelids. The New Zealand quail was extinct by 1875 (Williams, 1962), largely as a result of fires which destroyed food and cover, although dogs, cats and rats may also have been contributory factors. Other birds showed a marked decrease in numbers and the bellbird had disappeared from large areas of New Zealand by 1873 (Oliver, 1955). The disappearance of some birds from forested areas may be attributed to rats and/or stoats and this is particularly the case with the more specialised ground-feeding birds such as the saddle-back. The damage to the avifauna has been least where there has been little or no settlement or modification of the vegetation and no introduction of mammals (Williams, 1962). Rats have been an important factor in reducing bird populations. Bull (1946) found that rats were the most important cause of nest mortality amongst blackbirds and thrushes at Mangere, Auckland. After an extensive rat-trapping campaign nest mortality was reduced. Rats were present in New Zealand much earlier than Mustelids and were reported at times in plague proportions. Nothing is known of the effect of the introduction of Mustelids on the rat populations.

A balance between predators and prey was probably soon struck and, although predators may still be an important cause of mortality, they are not now likely to have long term effects on the population size of species. Quality of the habitat is probably the most important factor controlling bird populations, as has been stressed in several recent studies of game birds in New Zealand. The numbers of Californian Quail are largely controlled by methods of land use (Williams, 1952). Similarly, pheasant populations are as high as the habitat can support and the only way to increase their numbers is by habitat improvement (Westerskov, 1956). It is probable that this also applies to native bush birds. At Birdlings Flat one species, the skylark, suffered most of the predation and other birds were not often taken. Here availability of prey was the important factor controlling predation, although palatability may also be a factor. It is probable that in forests one species may suffer most of the predation and this species is likely to be the most common one, or one of the more common ones which, from its behaviour, is readily available to stoats. The species on which predation is concentrated possibly may change through the year.

Under some circumstances predation may be severe and conspicuous. This is particularly the case in nesting seabirds. Mr. J.R. Jackson (pers. comm. 1962) found 15 dead black-billed gulls in a nesting colony of about 200 birds on the Ashburton River bed in December 1962. All had been killed by a stoat or ferret and had been bitten about the back of the head and neck. Predation on eggs and chicks of black-backed gulls has also been reported (R.A. Fordham, pers. comm. 1964). In a colony of about 70 nests all eggs and almost all chicks were taken in a three week period by a female ferret and four young. Nothing is known at present of the effects of such predation on the populations.

Although Mustelids were introduced into New Zealand to control rabbits it seems that they had little effect on rabbit populations and were, in fact, largely dependant on them. When rabbits and hares are plentiful they are taken in preference to birds and this was the case in stoat dens from Tongariro and near the Waipaoa

River Gisborne. High rabbit densities maintained large mustelid populations and when rabbit populations were reduced markedly by control measures in the early 1950's, the numbers of Mustelids also decreased (Marshall, 1963). The repercussions of a sudden and marked reduction in rabbit numbers in Britain, following myxomatosis, have also been noted. Fewer stoats than usual were seen throughout the country after rabbit numbers decreased (Thompson, 1956), and trapping records also indicated a decrease. Between 136 and 302 stoats were trapped yearly on 4,000 acres in Hampshire prior to myxomatosis but after myxomatosis the numbers dropped to between 13 and 58. In contrast there was no appreciable change in the numbers of weasels trapped before and after myxomatosis (Southern, 1964).

Weasels appear to be too small to prey on rabbits and hares to any extent and are dependant on small mammals. This explains, at least in part, the stability of weasel trap records before and after myxomatosis in Britain, and rarity of weasels in New Zealand where there are few small mammals.

Stoats, ferrets and weasels occupy distinct ecological niches which differ, at least in stoats, from those in the Northern Hemisphere. This is reflected in both the distribution and food habits of the three species. Stoats are widespread throughout New Zealand and take a wide variety of prey. This adaptability allows them to exist in diverse habitats, and mice and rats, rabbits, hares and birds are all utilized as important sources of food. Weasels have a restricted distribution and were collected mainly in farmland from scattered localities. The large number of weasel gut contents containing remains of mice suggest that mice are the most important food. It is possible that weasels, because of their small size are not able to utilize larger mammals and birds to maintain their population. The absence of small mammals other than the house mouse and rats probably explains the rarity of weasels in New Zealand. The distribution of ferrets coincides with that of rabbits and rabbits were the most frequently occurring prey found in ferret gut contents. Ferrets appear to be largely dependant on rabbits and possibly cannot exist in their absence.

The adaptability of stoats is shown in the results of liberation of stoats and weasels on the island of Terschelling, off the coast of Holland (Wijngaarden and Morzer Bruijns, 1961). They were released in an attempt to control water voles which were a serious pest in crops, gardens and forest. Within six years of the liberation of predators water voles were extinct and weasels had died out although other small mammals were still present. Stoats increased greatly after liberation and, after voles died out, preyed heavily on rabbits. These were rapidly reduced in number and stoats began to prey on birds, even climbing on the roofs of houses to take sparrows and starlings. Gradually the numbers of stoats declined and now fluctuate in numbers with the rabbit, which appears to be their main food. The situation on Terschelling shows some similarities with New Zealand in that stoats adjusted to feeding largely on rabbits or birds when small mammals were scarce. Weasels were unable to expoit these sources of food.

The reproductive potential of stoats and weasels may be another factor of some importance in their ecology in New Zealand. Although stoats may take a wide variety of foods in New Zealand, both weasels and stoats in the Northern Hemisphere prey largely on small mammals. Studies at Birdlings Flat indicate that when mice are available in New Zealand they are taken in preference to other foods. Comparison of the reproductive potentials of these two species shows that weasels are able to respond more quickly than stoats to increases in mice populations. The average litter size of stoats in Britain is nine and there is only one litter each year (Deanesly, 1935). The average litter size of weasels is seven, with two litters possible each year. In addition, the young of the first litter may breed in autumn (Deanesly, 1944). Thus, excluding losses of young, a pair of weasels may produce double or even treble the number of young produced by a pair of stoats in a season. There is little mention of fluctuations in weasel populations in Britain or Europe although Southern (1964) mentions much larger numbers trapped during a year of mouse and vole abundance than in other years and suggests that dependence of weasels on small mammals may cause their numbers to fluctuate more than those of stoats. There is no evidence at present of such fluctuations in New Zealand but its ability to respond rapidly to changes in the density of mice may explain its persistence at low densities.

Summary

1. Stoats, ferrets and weasels are described and their weights and measurements compared with those of animals in Britain. The taxonomic position of the ferret is discussed.

2. The three species were liberated in the early 1880's and soon occupied all suitable habitat. The distribution patterns are described. There appears to have been no change in distribution during the last 15 years.

3. Age criteria, based on fusion of the skull sutures and weight of the baculum of males were used to determine age classes. The skull assumes adult characters at about six months. The baculum increases greatly in weight as sexual maturity is reached.

4. The reproductive cycles of the three species were investigated briefly and appear to be similar to those in Britain. Stoats probably have delayed implantation of the blastocyst and one litter a year is born in October. Ferrets may have two litters a year in spring and summer. Young become sexually mature the following spring.

Weasels also have two litters but young born in spring may become sexually mature in autumn.

5. The sex and age ratios of samples of 227 stoats, and 319 ferrets are compared with British samples and suggestions made to account for differences in the sex ratios of stoats, ferrets and weasels, and for variations in the ratio through the year.

6. White stoats collected during winter have been examined. White females were recorded from late June to September. No white males were found.

7. Examination of the gut contents of 185 stoats, 55 ferrets and 17 weasels showed that foods taken in New Zealand differ from those in the Northern hemisphere. Birds are important in the diet of all three species in New Zealand. Rats and mice, birds, fish and invertebrates are all preyed on by stoats. Ferrets prey largely on adult and young rabbits. Rats, birds, fish and frogs are also taken. Mice are the most important food of weasels but birds, lizards and insects are also eaten. Variations in the food of stoats with sex, habitat and season were found. Analysis of droppings confirmed the importance of rabbits in the diet of ferrets.

8. Material from stoat dens from several localities was examined and showed the importance of availability of prey in governing the feeding habits of stoats. Field studies at Birdlings Flat showed seasonal variation in predation. Detailed descriptions of the stoat dens found are given and the habitat and prey species available described briefly. Mice were taken when available. The most important prey species were skylarks which were taken throughout the year. Banded dotterel were taken while roosting in flocks and predation on dotterel nests was heavy. Small numbers of rabbits and hares were taken during the year. Other birds in the area were rarely taken. Availability of prey appears to be the most important factor governing predation although palatability of prey may also have an effect.

9. The ecology of stoats, ferrets and weasels in New Zealand is discussed in terms of their food habits, distribution and reproductive potential. Their effect on native bird populations is also discussed briefly.

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References

(Where possible, abbreviations follow the "World List of scientific periodicals", Butterworth, London. 1058 pp.)

ALDOUS, S.E. and J. MANWEILER. 1942. The winter food habits of the short tailed weasel in N. Minnesota. J. Mammal. 23(3): 250-255.

ALLANSON, M. 1932. The reproductive processes of certain mammals. III. The reproductive cycle of the male ferret. Proc. roy. Soc. Ser. B. 110: 295-312.

ASHTON, E.H. and A.P.D. THOMSON. 1955 Some characters of the skulls and skins of the European polecat, Asiatic polecat and domestic ferret. Proc. zool. Soc. Lond. 125(2): 317-333.

BISSONETTE, T.H. and E.E. BAILEY. 1944. Experimental modification and control of molts and changes of coat color in weasels by controlled lighting. Ann. N.Y. Acad. Sci. 45: 221-260.

BREE, P.H.J. Van. 1961. A note on the date of molt in the stoat (Mustela erminea) from the Netherlands. Saugetierk. Mitt. 9(1): 8-10.

BULL, P.C. 1946. Notes on the breeding cycle of the thrush and blackbird in N.Z. Emu 46: 198-208.

COTT, H.B. 1947. The edibility of birds. Proc. zool. Soc. Lond., 116: 371-524.

COTT, H.B. 1953. The palatability of the eggs of birds : illustrated by experiments on the food preferences of the ferret (<u>Putorious furo</u>) and the cat (<u>Felis catus</u>): with notes on other egg-eating carnivora. Proc. zool. Soc. Lond. 123 (1): 123-141.

CRIDDLE, S. 1947. A nest of the least weasel. Canad. Fld. Nat. 61(2): 69.

DEANESLY, R. 1935. The reproductive processes of certain mammals. Part IX. Growth and reproduction in the stoat (<u>Mustela erminea</u>). Phil. Trans. B, 225: 1-62.

DEANESLY, R. 1943. Delayed implantation in the stoat. Nature, Lond. 151: 365-66.

DEANESLY, R. 1944. The reproductive cycle of the female weasel (<u>M. nivalis</u>). Proc. zool. Soc. Lond. 114(3): 339-49.

DEARBORN, N. 1932. Foods of some predatory fur-bearing animals in Michigan. Univ. Mich. School Forestry and Conservation, Bull 1: 1-52.

DICE, L.R. 1952. Natural communities. Univ. of Michigan Press. 547 pp.

ELDER, W.H. 1951. The baculum as an age criteria in mink. J. Mammal. 32(1): 43-50.

ELLERMAN, J.R. and T.C.S. MORRISON-SCOTT. 1951. "Checklist of palaearctic and indian mammals." British Museum (Nat. Hist.) 810 pp.

ERRINGTON, P.L. 1943. An analysis of mink predation upon muskrats in North Central United States. Iowa Agr. Exp. Sta., Res. Bull 320: 793-924.

GREER, K.R. 1957. Some osteological characters of known-age ranch mink. J. Mammal. 38(3): 319-330.

GUTHRIE-SMITH, H. 1953. Tutira. 3rd ed. Wm. Blackwood and Sons, Edinburgh. 444 pp.

HALL, E.R. 1951. American weasels. Publ. Mus. nat. Hist. Univ. Kans. 4, 1-466.

HAMILTON, W.J. Jnr. 1933. The weasels of New York. Amer. Midl. Nat. 14(4): 289-344.

HAMILTON, W.J. Jnr. 1958. Early sexual maturity in the female short-tailed weasel. Science 127: 1057.

HAMILTON, W.J. 1959. Foods of mink in New York. N.Y. Fish and Game J. 6(1): 77-85.

HAMMOND, J. and F.H.A. Marshall. 1930. Oestrous and pseudopregnancy in the ferret. Proc. roy. Soc. Ser. B. 105: 607-630.

HENRY, R. 1901. Resolution Island. N.Z. Dep. Lands Survey Rep. 1900-1. pp. 132-6.

HILL, M. 1939. The reproductive cycle of the male weasel. Proc. zool. Soc. Lond. 109.B.: 481-512.

HOWARD, W.E. 1957. Amount of food eaten by small carnivores. J. Mammal. 38: 516-17.

LECHLEITNER, R.R. 1954. Age criteria in mink *Mustela vison*. J. Mammal. 35(4): 496-503.

LINDUSKA, J.P. 1947. Longevity of some Michigan farm game mammals. J. Mammal. 28(2): 126-129.

LOCKIE, J.D. 1959. The estimation of the food of foxes. J. Wildl. Mgmt. 23: 224-7.

LOCKIE, J.D. 1961. The food of the pine marten. Proc. zool. Soc. Lond. 136(2): 187-195.

LORD, R.D. 1959. The lens as an indicator of age in cottontail rabbits. J. Wildlife Mgmt. 23(3): 358-360.

LORD, R.D. 1961. The lens as an indicator of age in the Gray Fox. J. Mammal. 42(1): 109-111.

LYDEKKER, R. 1896. British Mammalia.

McCANN, C. 1955. Observations on the polecat (*Putorius putorius*) in N.Z. Rec. Dom. Mus., Wellington. 2(3): 151-165.

McINTOSH, D.L. 1963. Food of the fox in the Canberra district. C.S.I.R.O. Wildl. Res. 8(1): 1-20.

MARSHALL, F.H.A. 1904. Reproduction in the ferret. Quart. J. micr. Sci. 48: 323-345.

MARSHALL, W.H. 1951. An age determination method for the pine marten. J. Wildlife Mgmt. 15: 276-83.

MARSHALL, W.H. 1963. The ecology of mustelids in New Zealand. N.Z. Dep. sci. industr. Res. Inform. Series No. 38. 32 pp.

MATTHEWS, L.H. 1952. British mammals. New Naturalist, Collins. Lond. 411 pp.

MILLER, G.S. 1912. Catalogue of the mammals of Western Europe. British Museum (Nat. Hist. 1019 pp.

MONTGOMERY, G.G. 1963. Freezing, decomposition and raccoon lens weight. J. Wildlife Mgmt. 27(3): 481-83.

MURIE, A. 1961. Some food habits of the marten. J. Mammal. 42(4): 516-521.

NOVIKOV, G.A. 1956. Carnivorous mammals of the fauna of the U.S.S.R. Moscow and Leningrad. Keys to the Fauna of the U.S.S.R. No. 62. Translation 1962 by Israel Program for Sci. Trans.

NYHOLM, E.S. 1960. On stoat and weasel and their winter habitat. Suom. Riista, 13: 106-16.

OLIVER, W.R.B. 1955. New Zealand Birds. 2nd edition. A.H. & A.W. Reed. 661 pp.

POCOCK, R.I. 1936. The polecats of the genera Putorius and Vormela in the Biritish Museum. Proc. zool. soc. Lond. (3): 691-723.

POHL, L. 1910. Wiesel Studien. Zool. Beob: 51(8): 234-241.

POLDERBOER, E.B., L.W. KUHN and G.O. HENDRICKSON. 1941. Winter and spring habits of weasels in Central Iowa. J. Wildlife Mgmt. 5(1): 115-119.

POPOV, V.A. 1943. A new age index in mustelidae. C.R. Acad. Sci. U.R.S.S. 38: 258-68.

QUICK, H.F. 1944. Habits and economics of the New York weasel in Michigan. J. Wildlife Mgmt. 8(1): 71-78.

QUICK, H.F. 1951. Notes on the ecology of weasels in Gunnison County, Colorado. J. Mammal 32(3): 281-290.

RINEY, T., J.S. WATSON, C. BASSETT, E.G. TURBOTT and W.E. HOWARD. 1959. Lake Monk Expedition - an ecological survey in Southern Fiordland. N.Z. Dept. sci. industr. Res. Bull. 135. 75 pp.

ROTHSCHILD, M. 1942. Change of pelage in the stoat (M. erminea L.). Nature, Lond. 149: 78.

ROTHSCHILD, M. 1944. Pelage change of the stoat. Nature, Lond. 154: 180-181.

RUST, C.C. 1962. Temperature as a modifying factor in the spring pelage change of short-tailed weasels. J. Mammal. 43(3): 323-328.

SALOMONSEN, F. 1939. Moults and sequence of plumages in the Ptarmigan (Lagopus mutus Martin). Vidensk. Medd. dansk. naturk. Foren. Kbh. 103: 1-491.

SANDERSON, G.C. 1961. The lens as an indicator of age in the raccoon. Amer. Midl. Nat. 65(2): 481-485.

SETZER, H.W. 1958. The mustelids of Egypt. J. Egypt. publ. Hlth. Ass. 33(6): 199-204.

SOUTHERN, H.N. ed. 1964. The handbook of British mammals. Blackwell. 465 pp.

TABER, R.D. 1963. Criteria of sex and age in wildlife investigational techniques. 2nd ed. H.S. Mosby ed. Wildlife Society.

TETLEY, H. 1945. Notes on British polecats and ferrets. Proc. zool. Soc. Lond. 115: 212-217.

THOMPSON, H.V. 1956. Myxomatosis - a survey. Agriculture, Lond. 63: 51-57.

THOMSON, G.M. 1922. The naturalisation of animals and plants in New Zealand. C.U.P. 607 pp.

WATZKA, M. 1940. Mikroscopisch anatomische unter suchungen uber die ranzzeit und trogdaner des Hermelins (Putorius ermineus). Z. mikr.-anat. Forsch. 48: 359-374.

WESTERSKOV, K. 1956. Productivity of New Zealand pheasant populations. Wildlife Publ. No. 40B. N.Z. Dept. Int. Affairs. 144 pp.

WIJNGAARDEN A. and M.F. MORZER BRUIJNS. 1961. The Ermines Mustela erminea of Terschelling. Lutra. 3(3): 35-42.

WILLIAMS, G.R. 1952a. Notornis in March 1951. Notornis 4: 202-208.

WILLIAMS, G.R. 1952b. The California Quail in New Zealand. J. Wildl. Mgmt. 16(4): 460-485.

WILLIAMS, G.R. 1962. Extinction and the land and freshwater-inhabiting birds of New Zealand. Notornis 10(1): 15-32.

WODZICKI, K.A. 1950. Introduced mammals of New Zealand. N.Z. Dep. sci. industr. Res. Bull. 98. 255 pp.

WODZICKI, K.A. and P.C. BULL. 1951. The small mammals of the Caswell and George Sounds area. In New Zealand-American Fiordland expedition. N.Z. Dep. sci. industr. Res. Bull. 103 Expedition. pp. 62-9.

WRAIGHT, M.J. 1957. The ecology of Lake Ellesmere spit. M. Ag. Sc. unpubl. Thesis. Lincoln Agricultural College.

WRIGHT, P.L. 1942a. Delayed implantation in the long tailed weasel (M. frenata) short-tailed weasel (M. cicognani) and the marten (Martes americana). Anat. Rec. 83(3): 341-353.

WRIGHT, P.L. 1942b. A correlation between the spring moult and spring changes in the sexual cycle in the weasel. J. exp. Zool., 91(1): 103-110.

WRIGHT, P.L. 1947. The sexual cycle of the male long-tailed weasel (Mustela frenata). J. Mammal. 28(4): 343-352.

WRIGHT, P.L. 1948. Breeding habits of captive long-tailed weasels (M. frenata). Amer. Midl. Nat. 39: 338-44.

WRIGHT, P.L. 1950. Development of the baculum of the long-tailed weasel. Proc. Soc. exp. Biol., N.Y. 75: 820-822.

Appendix A.

Details of Monthly Samples

Stoat

Month	♂			♀	
	Im.	Subad.	Ad.	Im.	Ad.
January	10		1	13	4
February	10		5	8	1
March	7	1	1	5	1
April	4	6	4	2	4
May	2	3	9	2	3
June		1	1	3	5
July		5	2		1
August		2	1		4
September		1	9		2
October			21		4
November	2		14	2	2
December	13		3	16	7
Undated	6		14	4	10
Totals	54	19	85	56	47

Details of Monthly Ferret Samples

Month	♂			♀	
	Im.	Subad.	Ad.	Im.	Ad.
January	9		5	13	8
February	22		2	11	2
March	12	1	4	15	2
April	7	1	1	5	4
May	7	2	1	2	3
June	2	1	1	1	4
July		2			3
August		1	13		5
September			9		5
October			8		3
November			10		3
December	2		3		4
Undated	14		9	14	5
Totals	75	8	66	61	51

Details of Monthly Weasel Samples

Month	♂ Im.	♂ Ad.	♀ Im.	♀ Ad.
January	2		3	
February	3	2		1
March	2			
April	1	1		1
May	1	1		
September		2		1
October		1		
November		2		
December	1	1	1	
Undated	1	2		
Totals	11	12	4	3