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OBSERVATIONS ON FOODS OF KIORE (*RATTUS EXULANS*) FOUND IN HUSKING STATIONS ON NORTHERN OFFSHORE ISLANDS OF NEW ZEALAND

Summary: Kiore *(Rattus exulans)* carry food to husking stations to feed, where they are sheltered from predators, competitors and rain. On four northern offshore islands of New Zealand remains of plant foods left in husking stations and in the open included seeds, leaf laminae, shoots, bark, flowers and root bases. A wide variety of animal remains were identified in husking station material, from habitats as diverse as tree tops and below the ground. All stages of both small social and large solitary insects were eaten. Use of husking station material is a new technique; the advantages and limitations of which are discussed.

Keywords: Rodent foods; rats; Rattus exulans; Muridae; kiore; offshore islands; terrestrial invertebrates; seeds; technique; husking stations; Burgess Island; Tiritiri Island; Cuvier Island; Hen Island; New Zealand.

Introduction

Despite accumulating evidence that kiore *(Rattus exulans)* have had a significant impact on native flora and fauna (Atkinson, 1972, 1978; Campbell, 1978; Ramsay, 1978; Whitaker, 1973, 1978), quantitative description of kiore diet in New Zealand is limited to analysis of stomach contents of a few individuals collected on two different islands (Bettesworth, 1972; Hicks *et al.,* 1975). Although kiore were at first thought to be exclusively vegetarian (Colenso, 1891; White, 1895; Wodzicki, 1950), it is now known that they also eat a wide range of animal food (Stead, 1936; Atkinson and Campbell, 1966; Atkinson, 1972; Bettesworth, 1972; Hicks *et al.,* 1975).

Little information is known about the foods and feeding habits of kiore so we have compiled our observations from Burgess Island (Moko Hinau group), Hen Island and Tiritiri Island in the Hauraki Gulf, and Cuvier Island off the Coromandel Peninsula. Remains of food items were found in small, dry, semi-enclosed sites where kiore had fed. Campbell (1978) termed these sites "husking stations". Much of our data came from identification of food remains left by kiore in husking stations. This is a new technique for determining kiore foods which has both advantages and limitations.

Study Areas

Burgess, Hen, Cuvier and Tiritiri Islands all have very similar climate, vegetation types and soils because of their geographical proximity (all lie between latitude 35°10' -36°36' S and longitude 174°02' -175°46' E). Three of the studies were made in forest or tall scrub communities and one (Burgess Island) in pasture. The forests contained pohutukawa *(Metrosideros excelsa),* kohekohe *(Dysoxylum spectabile),* mahoe *(Melicytus ramiflorus),* kanuka *(Leptospermum ericoides),* tawa *(Beilschmiedia tawa)* and taraire (*B. taraire)*. Less common species present on all three forested islands included mapou *(Myrsine australis),* puriri *(Vitex lucens),* tawapou *(Planchonella costata),* hinau *(Elaeocarpus dentatus)* and nikau *(Rhopalostylis sapida)*. More detailed descriptions of the vegetation are given by Atkinson and Campbell (1966) for Hen Island, and by Esler (1978) for Tiritiri Island. The forests are typical of many of the islands of the Hauraki Gulf. All have been burnt and all except Hen Island have been further modified by domestic stock or feral goats *(Capra hircus)*.

On all four islands kiore was the only small mammal present. This meant that feeding sign could be more readily attributed to kiore, but evidence was still rigorously checked to distinguish it from chew marks made by parakeets (Aves: *Cyanoramphus* sp.) or wetas (Orthoptera: Stenopelmatidea).

Trapping showed that strong seasonal fluctuations in the density of kiore populations occurred on northern offshore islands (Moller, 1977). Breeding is restricted to spring and summer, so density reaches a peak in autumn (at more than 100 rats/ha on Tiritiri Island) and then declines to low levels in spring.

Methods

Material was collected from 10 husking stations on Hen Island and Cuvier Island in 1964 and 1966 and from two husking stations on Burgess Island in 1966. On Tiritiri Island collections were made from 77 husking stations in April and June 1976 and 20 of those cleared of material in April were revisited in September 1976 to measure the rate of accumulation of food remains.

Field observations of damage to plants (gnawed bark, uprooted seedlings) and scrapes in the ground gave indirect evidence of rodent feeding. A few food items were discovered by direct observations of kiore feeding and from stomach contents examined during autopsy.

Results

Husking stations

Husking stations were found amongst tree roots, within wide fissures in tree trunks at ground level, amongst rock piles, under the enlarged bases of fronds shed from nikau palms, and occasionally up trees. They are characteristically dry places. In fact, an easy way to locate them is to search for dry places during rain. The remains of food items consisted of the hard parts of fruits, seeds (especially tawapou and nikau) and invertebrates, but half-eaten remains of perishable items (e.g. the mushroom *Marasmius orceades)* were occasionally present. Very few entire invertebrates were found, although some woodlice *(Porcellio scaber)* and a pupal case of the moth *Trioxycanus ensysii* were intact, indicating that invertebrates sometimes died or emerged at these sites.

Kiore do not always use husking stations when feeding. Partly eaten remains of all species of fruits (and of snails) were not only concentrated at the husking stations but also were present in the open, often near husking stations or sites used for daytime shelter.

Animal material

Most of the evidence of animal foods (Appendix 1) came from husking stations; 79% of the 77 husking stations on Tiritiri Island (Table 1) contained invertebrates (particularly insects) but only 44% contained tree seeds and other plant material. Many different invertebrates are eaten, from small social insects such as ants to large solitary species such as wetas and moths. Eggs, larvae, pupae and adults of arthropods occurred but large insects (over 12 mm in length) were the most numerous items. The sclerotised head capsules and tibiae of tree wetas *(Hemideina thoracica)* were largely intact but the margins of femora (especially the enlarged hind femora) had sometimes been gnawed away to expose the fleshy muscle within. Tree wetas were eagerly eaten by captive rats on Hen Island in August 1964. Legs and wings of moths were less common and their bodies were probably eaten as remains were never found. On Cuvier and Tiritiri Islands, larval cases of the case moth *(Liothula omnivora)* had been slit open lengthwise. All snail shells were fragmented and the whorls chewed away so that only the columella remained. Kiore were often seen at night on the exposed rocky inter-tidal zone where they forage, and some kiore trapped on the beach had stomachs crammed full of amphipods.

A nestling thrush *(Turdus philomelos)* with its brain eaten was found on Tiritiri Island - a characteristic rat feeding habit (Flack and Lloyd, 1978). Two bird skulls found on Hen Island showed rat tooth marks, probably made by rats removing flesh when the skulls were fresh.

Scrapes in the ground seen on Cuvier and Hen Islands were probably made by kiore searching for earthworms, or ground dwelling insects or their larvae. On Hen Island worms as well as the larvae of the beetle *Stethaspis longicornis* were both greedily eaten by rats that had been captured the previous night. Numerous pupal cases of ants found outside a burrow on Hen Island had the ends nipped off and the pupae extracted.

Plant material

Gnawed seeds were the plant remains most often collected, although damaged leaf lamina, shoots, bark, flowers and roots were found (Appendix 1). Individual localities of each observation have not been listed in Appendix 1, as the plant species do not all occur on each island, and many factors influence whether the item is eaten. The total list records the range of plants and their parts that have- been eaten by kiore.

Kiore strip bark and eat plant stems, especially during winter (Campbell, 1978). Twelve species were attacked on Hen Island in August 1964 and on Tiritiri Island *Coprosma rhamnoides* bark and the growing tips of *Geniostoma rupestre* were severely chewed in May 1977 (J.L. Craig, pers. comm.). On Tiritiri Island, the lighthouse keeper found that root crops such as carrots were uncovered by kiore and partly eaten. On Tiritiri Island some stomachs of kiore trapped in December contained pohutukawa flowers. On Hen Island, in May 1965, seedlings of karaka *(Corynocarpus laevigata)* had been uprooted.

Kiore may not consume all edible parts of fruits at one sitting. The fleshy mesocarp of fresh tawapou fruit was quickly consumed and the two or three woody seeds were often left together in situ, yet the kernel itself was not eaten until some time later. Karaka kernels (which are toxic) were

Table 1: *Number of different husking stations where items were found on Tiritiri Island. Occurrence of food items in all 77 husking stations at the first visit in April* or *June 1976 is listed in the first column. Occurrence in the sub-sample of 20 marked husking stations visited first in April and revisited in September 1976 are given in the second and third columns respectively.*

	All first visits (n = 77) No.	April first visits (n = 20) No.	September second visit (n = 20) No.
INVERTEBRATES	61		
Mollusca:			
Helix aspersa	1		
Oxychilus cellarius	10		
Insecta:			
Blattodea oothecae	6	1	
Isoptera wing fragments	1	1	
Dermaptera *Anisolabis littorea*	4		
Orthoptera *Hemideina thoracica*	35	12	6
Hemiptera *Amphisalta* sp.	1	1	
Coleoptera	17		
Heteronychus arator	2	2	
Odontria xanthosticta	5		
Trox scaber	1	1	
Agrypnus variabilis	3	2	
Ctenicera sp.	2	1	
Ochosternus zelandicus	9	6	
Trogoderma sp.	1		
Leperina brouni	1	1	
Mimopeus elongatus	1		
Eucolaspis brunnea	1		
Strongylpterus hylobioides	1		
Diptera	5		
Sarcophagidae pupal case	1		
Tipulidae pupal case	4	2	
Lepidoptera	10		
Aenetus virescens	1		
Trioxycanus enysii	3	1	
Liothula omnivora	2		
Gellonia dejectaria	1	2	
Ennominae pupal case	2		
Noctuidae larval skin	1		
Hymenoptera	9		
Ichneumonoidea pupal coccoon	3	2	
Pompiloidea wing fragment	2	1	
Apoidea bee fragments	1	1	
Formicoidea pupal cocoon	1		
Crustacea			
Porcellio scaber	4	2	1
Rat Faeces	29	7	3
Rat Fur	2		
Rat Bones	1		1
PLANT MATERIAL	34		
Dysoxylum spectabile capsule fragments	12	3	
eaten seeds	9	3	
uneaten seeds	6	2	
Beilschmiedia drupe	11		
Vitex lucens drupe	1		1
Metrosideros excelsa capsules	8	2	
Knightia excelsa follicles	1	1	1
Planchonella costata	2	2	2
Elaeocarpus dentatus (endocarp)	2	2	1
Grass seeds	1		1
Fungae: *Marasmius orceades*	2	1	
Unidentified plant material	7	2	

also left uneaten for considerable periods before eventually being gnawed but not totally eaten. On Tiritiri Island, 38% of 53 hinau nuts found in two husking stations were intact.

Rate of accumulation in husking stations
A much lower proportion of the 20 marked husking stations on Tiritiri Island contained the same type of items in September 1976 than at their first visit five months earlier (Table 1). Wetas (*H. thoracica)* accumulated faster than all other items.

Discussion

Husking stations
Husking stations are places where food is eaten rather than stored. The habit of using husking stations is not confined to the kiore; wild *Rattus norvegicus* in captivity withdrew food to the nest and sometimes stored it there (Barnett and Spencer, 1951); the large Australian rock-rat *(Zyzomys woodwardi)* fed on seeds under rock crevices (Begg and Dunlop, 1980); *Rattus rattus* on Big Green Island, Tasmania, fed in sheltered places beneath *Poa* tussocks and beside rock outcrops (Norman, 1970); *Mus musculus* fed within dry holes under large fallen logs on Auckland and Enderby Islands, New Zealand (P. Johns, pers. comm.); rats fed on native *Powelliphanta* snails in an earth chamber beneath a log at Levin (j. Marsden, pers. comm.); and ground squirrels *(Xerus erythropus)* carried food to the burrow entrance before eating it (Ewer, 1965).

For the kiore this habit was first described by White (1895) who said "It is quite common to see the little heaps of the empty oval cases of the hinau-berry, having a minute hole perforated by the 'Kiore Maori' at one end, through which the kernel has been deftly extracted - a proof that the animal picks up a single berry, and each time returns to a favourite seat, where he makes his feeding place".

Husking stations have not been emphasised or used to study foods eaten before, and where commented on have been interpreted as "food stores" or "food caches". The high proportion of remains bearing obvious marks of gnawing confirms that husking stations are places for eating food rather than storing it. About one third of husking stations also contained faeces, suggesting that the rats probably spent much time at them, rather than simply visiting briefly to store food. This is further confirmed by the absence of quantities of fresh uneaten food items at times when such are abundant and would be expected to be accumulated, e.g. tawapou fruits on Tiritiri Island.

Kiore may use husking stations to shelter from predators (Begg and Dunlop, 1980) or rain while feeding but the habit may also decrease interference from conspecific rodents. Tree wetas and puriri flowers offered to captive kiore were keenly sought and were the object of much pulling and tugging between individuals. Worms were sometimes eaten by two rats simultaneously, starting from either end. Kiore observed feeding naturally were very active, and those without food attempted to rob those with food.

Some species which occur at husking stations (e.g. case moths), only occur in trees or shrubs, so the rats must sometimes descend to the ground with their find before eating it.

Usefulness of husking stations for diet studies
How reliable are remains from husking stations as indicators of rat food? Most plant remains consisted of large, heavy items which could not have been blown into the enclosed space. Almost all of the animal material was fragmented and chewed in ways indicating that rats had eaten it. On the islands investigated, there was no other animals which could have contributed to the food remains in husking stations. Collections from such places give a quick, reliable list of some foods eaten by kiore without the necessity of setting trap lines. They also establish the presence of rodents in an area, and are particularly valuable for identifying many of the invertebrates eaten, since the large fragments which accumulate are more easily identifiable than closely comminuted stomach material.

The slow rate of accumulation of material in the 20 marked husking stations on Tiritiri Island suggests that the remains found on the first visit had collected over long periods. The material apparently decays slowly in the relatively dry confines of a husking station. Therefore analysis of material from husking stations will show foods eaten over a much longer period than can be determined from rat stomachs collected during a brief visit. On the other hand, quantitative analysis of remains from husking stations may give inaccurate indications of kiore diet because of differences in decay rate and because not all food items may be equally likely to be carried there.

The remains of insects from husking stations provided five new locality records from the islands. *Stethaspis longicornis* and *Mimopeus opaculus,* both large, conspicuous beetles, were not previously known from Hen Island (see Watt, 1962): S. *longicornis* is common in Northland and could therefore be expected on Hen Island, but M. *opaculus* was not known north of Cuvier Island. *Sericospilus* sp. had not been recorded on Burgess Island, nor *Mitua tuberculicostata* and *Psepholax tibialis* from Cuvier Island.

Foods eaten by kiore

Although the present study does not quantify the diet of kiore, it does demonstrate the wide variety of plant and animal foods eaten. Plant and animal items of varying sizes and stages of development living in habitats ranging from the tree-tops to under the ground were eaten. In general only the larger species of insect were represented.

Tree wetas were particularly common in husking stations on Tiritiri Island, and they accumulated faster than other items. Tree wetas arc also common foods of *R. rattus* in mainland forests (Best, 1969; Daniel, 1973; Innes, 1979).

The evidence for impact of kiore on its prey as inferred by Atkinson (1978), Campbell (1978), Crook (1973), Whitaker (1973, 1978), Ramsay (1978), and Watt (1984) is still fragmentary and circumstantial. Well-planned quantitative comparisons of prey abundance and diversity in the presence or absence of kiore (particularly before and after kiore introduction or eradication from an island) are long overdue. Even such comparisons may not show the full impact of kiore because any species exterminated centuries ago may no longer be available to recolonise a local area, or may have been totally exterminated. The present study shows that a wide range of indigenous plants and animals were and still are potentially vulnerable.

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Appendix 1: *Invertebrate and plant foods eaten by kiore on Burgess Island (B), Cuvier Island (C), Hen Island (H), and Tiritiri Island (T). Location data are given for invertebrate foods only (see text). All food items identified from remains left in husking stations except those marked* (*).

Invertebrates

	Locality
Mollusca	
Pulmonata	
Helicidae	
Helix aspersa (Muller)	C,T
Zonitidae	
Oxychilus cellarius (Muller)	T
Rhytididae	
Paryphanta busby; (Gray)*	H
Rhytida greenwoodi (Gray)	C
Rhytida tarangaensis Powell	H
Schizoglossa novoseelandica (Pfeiffer)	C
Annelida	
Megascolides	
Megascolecidae	
Spenceriella sp*	C
Insecta	
Blattodea	
Blattidae (oothecae)	T
Blattidae	
Celatoblatta sp.	B,C
Platyzosteria sp.	B,C
Isoptera (wing fragments)	T
lsoptera (pupae)	H
Dermaptera	
Labiduridae	
Anisolabis littorea (White)	H,T
Orthoptera	
Stenopelmatidae	
Hemideina thoracica (White)	C,H,T
Phasmida	
Phasmidae	
Clitarchus sp.	H
Hemiptera	
Cicadidae	
Amphisalta sp.	C,T
Pentatomidae	
Dictyotus caenosus (Westwood)	B
Odonata	
Petaluridae	
Uropetala sp.	C
Coleoptera	
Lucanidae	
Ceratognathus irroratus Parry	C
Trogidae	
Trox scaber (Linnaeus)	T
Scarabaeidae	
Heteronychus arator (Fabr.)	T
Odontria sandageri Broun	B
Odontria xanthosticta White	C,T
Sericospilus sp.	B
Stethaspis longicornis (Arrow) (adult)	H
Stethaspis longicornis (Arrow) (larvae)	H
Elateridae (pronotum, elytron)	C,H
Agrypnus variabilis (Candeze)	T
Conoderus sp. d. *maritimus* (Broun)	C
Ctenicera sp.	B,T
Ochosternus zealandicus (White)	C,T
Thoramus sp.	C
Dermestidae	
Trogoderma sp.	T
Trogossitidae	
Leperina brouni Pascoe	C,T
Cucujiformia (pait elytra)	C
T enebrionidae	
Chrysopeplus expolitus (Broun)	C
Mimopeus elongatus (Breme)	B,C,H,T
Mimopeus opaculus (Bates)	C,H
Mitua tuberculicostata (White)	C
Uloma tenebrionoides (White)	C,H
Xylochus sp.	C
Cerambycidae	
Oemona hirta (Fabricius)	C
Chrysomelidae	
Eucolaspis brunnea (Broun)	T
Curculionidae	
Psepholax sulcatus (White)	B
Psepholax tibialis (Broun)	C
Strongylopterus hylobioides (White)	C,H,T
Tychanus gibbus Pascoe	C
Diptera	
Calliphoridae (puparia)*	T
Sarcophagidae (pupal case)	T
Tipulidae (pupal case)	T
Lepidoptera	
Hepialidae	
Aenetus virescens (Doubleday)	C,H,T
Trioxycanus enysii auct. not Butler	T
Wiseana sp.	C
Geometridae	
Gellonia dejectaria (Walker)	T
Pschidae	
Liothula omnivora (Fereday)	C,T
Ennominae (pupal case)	T
Noctuidae (larval skin)	T
Hymenoptera	
Ichneumonoidae (pupal cocoon)	T
Pompiloidea (wing fragments)	T
Apoidea (fragments)	T
Formicidae (fragments)	T
Formicidae (pupal cases)	H
Vespidae	
Vespula germanica (Fabricius)	C
Arachnida	
Araneae	B
indet. (egg mass)	C
Crustacea	
Isopoda	
Porcellionidae	
Porcellio scaber (Linnaeus)	T
Decapoda (1 claw)	B
Chilopoda	
Scolopendridae	
Cormocephalus rubricepes (Newport)	H

Appendix 1: *(continued).*

PLANTS					
Name	Common name	Parts eaten	Name	Common name	Parts eaten
Filicales			Malvaceae		
Asplenium oblongifolium (= *lucidum)*	shining spleenwort	Petioles*	*Hoheria populnea*	lacebark	Bark*
			Leguminosae		
			Albizia lophanthus	brush wattle	Fruit*
Polystichum richardii		Petioles*	*Sophora tetraptera*	kowhai	flower
Monocotyledones			Moraceae		
Smilacaceae			*Paratrophis banksii*	milk tree	fruit, bark*
Ripogonum scandens	supplejack	Fruit* , shoot* , rootbases of Juveniles*	Corynocarpaceae		
			Corynocarpus laevigata	karaka	fruit (flesh only)
Agavaceae			Meliaceae		
Phormium cookianum	mountain flax	flowers*, fruit*	*Dysoxylum spectabile*	kohekohe	fruit
Palmae			Araliaceae		
Rhopalostylis sapida	nikau	Fruit* , rootbases of juveniles"	*Meryta sinclairii*	pukunui	Petiole*, bark*, shoot apex*, Fruit*
Cyperaceae					
Cyperus ustulatus		Fruit*	*Pseudopanax arboreus*	fivefinger	Bark*
Scirpus nodosus		Fruit* , rootbases*	*P. lessonii*	houpara	Leaves* , petiole* , shoot apex*
Gramineae					
Anthoxanthum odoratum	sweet vernal	fruit	Sapotaceae		
Bromus cathartic us	prairie grass	fruit	*Planchonella costata* (= *novozelandica)*	tawapou	fruit
Dactylis glomerata	cocksfoot	fruit"			
Paspalum sp.	paspalum	fruit	Oleaceae		
Dicotyledones			*Nestegis apetala*	broad-leaved maire	fruit
Lauraceae					
Beilschmiedia taraire	taraire	fruit	Loganiaceae		
B. tawa	tawa	fruit	*Geniostoma rupestre* (= *ligustrifolium)*	hangehange	Bark*
Monimiaceae					
Hedycarya arborea	pigeonwood	fruit (flesh only)	Apocynaceae		
Piperaceae			*Parsonsia heterophylla*	kaihua, NZ jasmme	fruit
Macropiper excelsum	kawakawa	Fruit* , leaf Petioles* , twigs*	Rubiaceae		
Violaceae			*Coprosma grandifolia*		fruit, bark*
Melicytus ramiflorus	mahoe	leaf lamina (not midrib)*, Seedlings*, fruit* Bark*	*C. aff. macrocarpa*		fruit, bark*, Twigs*, seedlings*
			C. repens	taupata	fruit, bark
Aizoaceae			*C. rhamnoides*		Bark*
Disphyma australe	ice plant	Fruit*	Scrophulariaceae		
Caryophyllaceae			*Hebe parviflora*		Bark*
Silene gallica	catchfly	Fruit*	Verbenaceae		
Proteaceae			*Vitex lucens*	puriri	flowers (nectar disc)* , fruit
Knightia excelsa	rewarewa	fruit			
Passifloraceae			Solanaceae		
Passiflora tetrandra	kohia, native passionfruit	fruit	*Lycium ferocissimum*	boxthorn	Fruit*
			Fungae		
Myrraceae			*Marasmius orceades*		fruiting body
Metrosideros excelsa	pohutukawa	flower	*Secotium porphyreum*		fruiting body*
Elaeocarpaceae					
Elaeocarpus dentatus	hinau	fruit, bark*			