Rat-control procedures on the Pacific islands, with special reference to the efficiency of biological control agents. II : Efficiency of the Japanese weasel, Mustelu sibirica itatsi Temminck & Schlegel, as a rat-control agent in the Ryukyus”

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Rat-control procedures on the Pacific islands, with special reference to the efficiency of biological control agents. II

Efficiency of the Japanese weasel, *Mustela sibirica itatsi* Temminck & Schlegel, as a rat-control agent in the Ryukyus[1]

Teru Aki UCHIDA

Abstract

Effective integrated rat control procedures are of pressing importance to the Pacific islands not only because of extremely heavy rat damage to coconuts but also the consequent transformation of coconuts into larval habitats for mosquitoes, including vectors of Bancroftian filariasis and dengue. Such procedures call for the joint use, against an adequate background of ecological knowledge, of chemical and biological control measures. In controlling rats on large numbers of small, scattered islands, such as those of the Pacific including the Ryukyus, biological control involving the use of predators might be especially important from the ecological and economic points of view. In this connexion, the potentialities of the Japanese weasel, *Mustela sibica itatsi* Temminck & Schlegel, as a rat control agent, were advanced in an earlier contribution (Uchida, 1966). At the same time, attention was directed to the great importance of this field trial in the Ryukyus as a preliminary test to further experimental introduction elsewhere in the tropics.

To appraise whether this weasel merits consideration for field trial in Micronesia or Polynesia for the purpose of evaluating its effectiveness as a rat control agent in coconut plantations, the present study was thus undertaken on several islands of the Ryukyus, into which the predators had been introduced. In consequence, it is concluded that

1) Contributions from the Zoological Laboratory, Faculty of Agriculture, Kyushu University, No. 396. This study was undertaken while the author was serving as a consultant to the World Health Organization (Vector Biology and Control).

further consideration of the possibility of experimental introduction of the weasel into the South Pacific is warranted. *M.* ***sibirica itatsi*** is thus discussed in further detail with special reference to its environmental requirements, the feasibility of establishing it under tropical conditions and its combined use with anticoagulant rodenticidcs. It must nevertheless be emphasized that reasons of nature conservation should preclude any introductions into certain islands set aside as sanctuaries for indigenous animals (especially sea birds), or otherwise of special importance as breeding grounds for such fauna.

Introduction

In previous papers (Uchida, 1966, 1969) it was concluded that the rat-control effectiveness of the monitor lizard, *Varanus indicus* (Daudin) which has been introduced into certain Micronesian islands falls short of expectations. It was submitted, at the same time, that a better candidate biological control agent is the Japanese weasel, ***Mustela sibirica itatsi*** ; the usefulness of weasels as predators upon rats having been established both experimentally and by practical trials on certain islands of Hokkaido and Kyushu, Japan (Inukai, 1949 ; Hiraiwa, Uchida & Hamajima, 1959). Though the weasels feed upon birds to some extent, all data now available herein on their feeding habits (Kishida, 1927 ; Inukai, 1935 ; Yukawa, 1968 ; Kuramoto, Uchida & Nakamura, 1969) clearly indicate that under winter conditions mammals or frogs form the bulk of their food, wild birds being much less commonly eaten. Furthermore, though serious attention must be given to another problem – the relationship between weasels and rabies-it should be emphasized that rabies does not occur either in Japan or in the oceanic islands of the Pacific (WHO, 1966). Soon after my earlier visit to the Ryukyus in December 1965 on the way home from the Carolines, large numbers of weasels were introduced into several widely separated islands of the Ryukyus. Accordingly, close attention was paid to the subsequent development of the rat control programme in the Ryukyus.

Laird (1963, 1966a, 1966b, 1968) drew attention to the special public health hazards caused by rats on certain Pacific islands, where the gnawing of young, growing coconuts by rats leads not just to serious economic loss but also to the consequent transformation of the nuts into larval habitats for mosquitoes, including vectors of Bancroftian filariasis and dengue. The central purpose of the present visit to the Ryukyus from 1 February to 10 March 1967, was to report my views on whether *M.* ***sibirica itatsi*** merits serious consideration for introduction elsewhere in the tropical Pacific as a rat control agent. Further observations were made by the author from 25 December 1967 to 9 January 1968, to follow up the above investigations supported by the World Health Organization. Although the abbreviated article appeared in the Bulletin of WHO (Uchida, 1968), the full text is here reported.

The first aim of using such predators, of course, is to quickly reduce the extent of rat damage. Furthermore, if the predators can be permanently established they may bring about a long-term suppression of the rat population, a new ecological equilibrium being established at a markedly lower level of rat density. Therefore in order to discuss the establishment of the predators on the Pacific atolls and small islands, a general ecological knowledge of this area was of paramount importance, In this connexion, the excellent monographs entitled "Atoll Environment and Ecology" by Wien (1962) and "Pacific Island Rat Ecology" by Storer (1962) helped me to grasp the problems concerned, greatly supplementing my previous personal experience in the Carolines.

History of the introduction of weasels

For a number of years roof rats, *Rattus rattus* (Linnaeus), have been responsible for considerable damage to agricultural products (especially sugar-cane production) all over the Ryukyus, and the introduction of natural enemies against them has been urged. Kikai-jima Island, Amami Group of the middle Ryukyus (Fig. 1) was the first island in the Kyukyus where an encouraging level of rat control has been achieved by introduction of the Japanese weasels in 1942. After that the weasels were introduced into some other islands of the Amami Group. Unfortunately we have no detailed information in this respect, though a few pertinent records have been published (Yotsumoto, 1959 ; Iha, 1966).

Later, under USCAR,[1] the weasels were introduced into Zamami-shima Island (Fig. 1) in 1957 and 1958. Still more recently, heavy rat damage to agricultural products has been reported from many parts of the Ryukyus. Therefore, since December 1965 large number of weasels (a total of 6843) have been introduced into 14 widely scattered islands. Table 1 summarizes the details of weasel introduction though eight of islands involved were not visited during the present survey. It should be mentioned, however, that the weasel introduction into Iriomote-jima Island was unfortunately carried out at own discretion of the local concerned setting at naught my and authorities' advice. I

1) Since the end of World War II in 1945 the southern part of the Ryukyu Archipelago has been administered by the United States Civil Administration, Ryukyus (USCAR). The northern part continues to be administered by Japan.

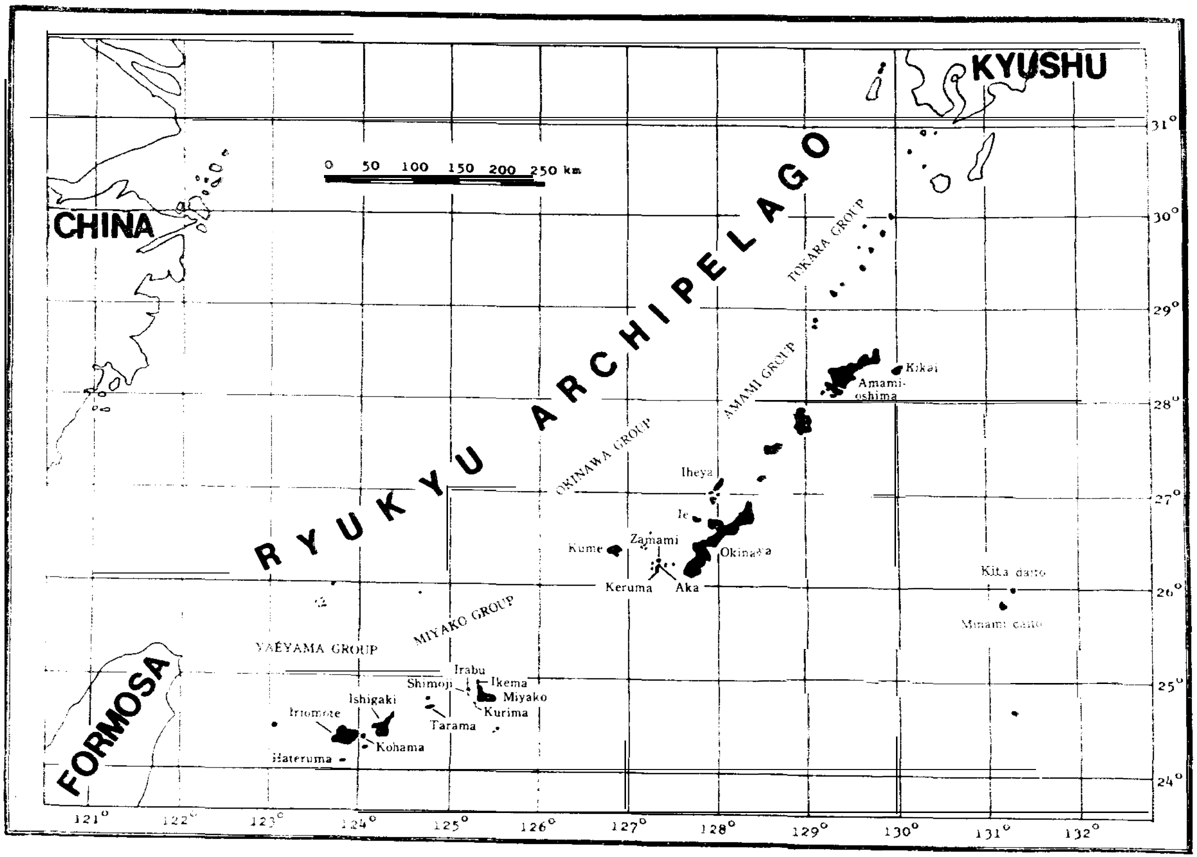

Fig. 1. Location of the islands surveyed.

would hate to introduce them into Iriomote because the fauna of this island is an extremely interesting one and much yet remains to be learnt about it at this stage. The Government of the Kyukyus intends to continue such releases on large islands where the weasel density is still low and agricultural products are being subjected to extremely heavy rat damage.

Relationship between weasel and rat population density

1. Methods

In the first survey, in February -March 1967, I visited the following islands, into which weasels had been introduced, in order to estimate the rat populations : Ishigaki-jims, Miyako-jima, Irabu-Shimoji-jima, Ie-jima, Minami-daito-jima, Zamami-shima, Aka-jima and Keruma-jima (Fig. 1). In the case of Ishigaki it was planned to estimate the actual rat population density following the predator releases and to make direct comparisons between this figure and that estimated in December 1965 prior to the introduction. About nine months later I revisited Ishigaki and Irabu-Shimoji to investigate further changes. Less accurate base-line information being available as regards the other islands, it was obvious that similar comparisons there would be correspondingly less reliable.

To estimate rat populations, the removal method employing snap traps was generally used. On Ishigaki only the mark-release method followed by poisoning was additionally used. The rats were marked individually by tot-clipping. However, due to various reasons, the population estimates were not obtained by this method and those given below were calculated on the least squares (Hayne, 1949) by the removal method. Since snap and cage traps were in grids of 10x5 and 10 x 10 at 10-metre intervals, the experimental site covered an area of 0.5 to 1.0 hectare. Fresh sweet potato was used as trap bait as it was readily available and easy to use. To avoid trap shyness pre-baiting was carried out the day before setting traps.

Since it was necessary to use a rodenticide toxic only to rats and not weasels it was decided to use "norbormide." So far as was known, however, norbormide had not been tested to any extent on weasels. After having confirmed its harmlessness to weasels, even at dosages of 1000 mg, this rodenticide was used for estimating the rat population. Dumplings made of steamed sweet potato and flour formed the base of the poison bait.

2. *Rat population density on Ishigaki-jima*

Ishigaki-jima in the Yaéyama Group of the southern Ryukyus is one of the largest islands subjected to weasel introduction, its area being 25834 hectares. The topographical features are complex and mountainous, the highest point being 525 m above sea level. The mountain range creates many streams. The island is mainly composed of paleozoic strata and some Ryukyu limestone on the southern alluvial plains and barrier coral-reefs around the island. Sugar-cane and pineapple are the main agricultural products, the former being mainly cultivated on alluvial plains and tablelands, and the latter mainly on mountain slopes. Some paddy fields and waste land are also scattered here and there on alluvial plains.

When 1 visited previously the island from 11 – 17 December 1965 on the way home from the Caroline Islands, a census had been made in a sugar-cane field situated in the dry zone near the town at the southernmost end of the island. As this area seemed to have the highest rat population density and the sugar-cane was heavily damaged by rats, this field was chosen for a population estimate. From 13 – 15 December, a total of 300 trap/nights captured 29 roof rats, ***Rattus rattus*** (Linnaeus), per hectare, of which 20 were captured on the first day, six on the second and three on the third. Thus the population density was estimated at about 30 per hectare.

From that time (December 1965) to January 1967, about 1600 weasels were introduced to the island. The period of my first stay was 3 – 17 February 1967. Few rodenticides have been used on this island since weasel introduction. Population estimates were done, using both methods, in sugar-cane fields (Fields Al and A2) near the previous trapping site. In this area rat damage remained heavy and farmers had reduced their agricultural efforts. From 6-8 February a total of 300 trap/nights captured 34 roof rats in Field Al, of which 20 rats were captured on the first day, nine on the second and five on the third. The population density was thus estimated at about 38 per hectare. Simultaneously the mark-release method was used in Field A2 (which is located about 600 m from Field Al). A total of 300 trap/nights captured 15 roof rats (one of which died) and one brown rat, ***Rattus norvegicus*** (Berkenhout). Fourteen roof rats and one brown rat were marked and released. Unfortunately, after poisoning the census area was disturbed. To encourage control, city officials offered a reward for rat tails. This resulted in mutilation and removal of some of the dead rats in the census area by farmers seeking to collect the reward. From a total of 21 roof rats captured, only three marked ones were recovered. It is doubtful whether this is representative. Therefore, it was thought inadvisable to calculate the population estimate in this case. At any rate, the population density remained at least as high as during the previous census despite the introduction of weasels.

Next a census was made in sugar-cane fields (Fields B1 and B2) near a stream, situated in a humid zone about 6 km to the north of Field A. As this area seemed to have the lowest rat population density and the sugar-cane was only sligtly rat-damaged it was chosen as a contrast to Field A. A rodenticide made of a coumarin derivative (warfarin) has been used occasionally from the last year. From 11-13 February a total of 300 trap/nights captured five roof rats per hectare in Field B1, of which four were captured on the first day and one on the third. At the same time, the mark-release method was used in Field B2. A total of 150 trap/nights captured three roof rats per 0.5 hectare, one of which escaped during handling. Two roof rats were marked and released, only one unmarked roof rat being found after the poisoning. In these cases, as stated above, the trapped numbers obtained by both methods were too few to apply Hayne's or Bailey's method. Judging from this, it is certain that the rat population densities in this area are generally low, being a little more than five or six per hectare. In Field B2 I found a weasel's faeces (Faeces No. 2 in Table 2) and the sun-bleached skull of a roof rat which was apparently the remains of a weasel's prey. This indicates occasional weasel action in this area. It is worth noting that there is a considerable difference in the rat population densities between the humid zone (Field B) and the dry zone (Field A), whether a few rodenticides were used or not. This would confirm that weasels are inclined to gather in the humid zone (i.e., forests and river basins, etc.) in search of food.

The period of my second visit was from 25 December 1967 to 4 January 1968. As of January 1968 the number of introduced weasels had reached 2074 (1842 males, 232 females), the density being about eight weasels per 100 hectares. In addition, a large quantity of anticoagulant rodenticides have been used since April 1967 (Table 1). A census was done, using removal method, in the same sugar-cane field (Field Al) as described above. From 27 - 29 December a total of 300 trap/nights captured only one roof rat and two Ryukyu grey musk shrews, ***Suncus murinus riukiuanus***, the former being trapped on the first day and the latter on the second and none on the third. The rat population density was thus dropped markedly to a few rats per hectare. There had, therefore, been a little damage to sugar-cane throughout the island. It must be recalled that in December 1965 and February 1967 the density had been about 30 and 38 per hectare, respectively.

At the same time, another census by removal method, in which traps were in grids at 15-metre intervals, was made in paddy field and a total of 196 trap/nights captured 36 rats (28 brown rats and eight roof

Table 1. Weasel introduction into the

Group	Island	Area of island (ha)	Weasels introduced: Total no.	Sex: M	Sex: F	No. per 100 ha
OKINAWA	Zamami[1)]	594	ca 40 } 83	63	20	7
	Aka[1)]	307	?			?
	Keruma[1)]	ca 100	?			?
	Kita-daito	1 820	178	146	32	10
	Minami-daito[1)]	2 591	381	416	65	19
	Ie[1)]	2 020	360	296	64	18
	Iheya	2 252	472	427	45	21
	Kume	7 065	537	472	65	8
MIYAKO	Irabu-Shimoji[1)]	3 888	733	613	119	19
	Tarama	1 866	472	396	76	25
	Miyako[1)]	14 791	531	443	88	4
	Kurima	262	70	47	23	27
	Ikema	262	62	55	7	24
YAEYAMA	Ishigaki[1)]	25 834	2 074	1 842	232	8
	Iriomote[1)]	32 574	319	288	31	1
	Kohama	1 033	207	180	27	20
	Hateruma	1 496	348	299	49	23
Total[3)]		97 754	6 843	5 920	923	

1) Islands visited.
2) Weasel introduction will be continued until 1971.

Ryukyus in recent years.

Period of introduction	Rodenticide used in addition	Result
Mar. 1957 and 1958	None	No damage ; weasels have become established
	Little	Considerable damage ; weasels failed to become established
	Little	Considerable damage ; weasels failed to become established
Dec. 1965 Feb. 1967	Much	Little damage to crops
Jan. 1966- Feb. 1967	Much	Little damage to crops
Apr.-Dec. 1966	Much	Little effect yet ; should be effective later
Oct. 1967- Jan. 1968	Little	Not yet clear because of the short period since the introduction
Oct. 1967- Jan. 1968[2)]	Much	Little effect yet ; numbers of weasels still too small
Dec. 1966- Jan. 1968	Little	Little damage
Jan. 1967- Jan. 1968	Little	Little damage
Feb.-Mar. 1967[2)]	Little	Little effect; too few weasels and too little rodenticide used
Nov. 1966- Mar. 1967	Little	The effect is expected soon
Oct. 1967- Jan. 1968	Little	Not yet clear because of the short period since the introduction
Dec. 1965- Jan. 1968[2)]	Much	Little damage in spite of insufficient numbers of weasels
Jan. 1966- Jan. 1968	Much	Heavy damage because of scarcity of weasels
Nov. 1966- Jan. 1968	Much	Little damage
Nov. 1966- Jan. 1968	Much	Little damage

3) Excluding the figures for Zamami, Aka and Keruma.

rats) per about 1.5 hectares, of which 11 rats were captured on the first day, 13 on the-second and 12 on the third. This capture pattern seems to have been brought about because of the small number of traps used for such a high rat population density ; it was thus not possible to estimate the density. Simultaneously a survey was done on waste land contiguous to the above paddy field, and a total of 72 trap/nights (four nights without pre-baiting) set at random in a line captured 13 roof rats alone. At any rate, it is very clear that there is still high density in paddy fields and waste land in spite of the scarcity of rats in sugar-cane fields. This is not altogether unexpected because few rodenticides have been used in paddy fields and none on waste land.

The above data indicate that the main cause of the lower rat population density in sugar-cant fields may be due to the effect of rodenticides, although the efficiency of the introduced weasels is partly responsible for it. Moreover. it is considered that such a situation is unstable and temporary since the weasel density is not yet high enough to expect rapid results. The continuation of weasel introduction, together with the application of anticoagulants to paddy fields and waste land, is thus strongly recommended.

3. ***Rat population density on*** *Minami-daito-jima*

Minami-daito-jima of the eastern Kyukyus is a raised atoll, 2591 hectares in area. The bluff surrounds a basin which used to contain a lagoon and is 30 40 m above sea level. There are therefore many ponds and bogs in the centre of the basin. The island's chief agricultural product is sugar-cane. It is cultivated all over the island except forest areas.

Sugar-cane products had been subjected to extremely heavy rat damage (about 20 -- 30 %) prior to weasel introduction, and rodenticides (warfarin and sodium fluoroacetate) had been the sole rat control measure for a long time. Four hundred and eighty-one weasels (416 males, 65 females) were introduced into the island from January 1966 to February 1967, after which the only rodenticide used has been warfarin.[1] The weasel density is about 19 per 100 hectares, which is ideal to expect rapid results, judging from that obtained on Sagi-shima of Kyushu (Hiraiwa et al., 1959). An effective integrated rat control procedure combining weasels with the use of a large quantity of warfarin has been carried out for little over a year.

During my stay on the island from 22 - 28 February 1967 I found hardly any damage in sugar-cane fields except those adjacent to anti-

1) 3-(α-acetonylbenzyl)-4-hydroxycoumarin. This rodenticide "Dethmor" contains it at 0.025 % in optimum, being manufactured by Earth Chemical Company Limited, Japan.

wind forests which were slightly rat-damaged. Although it appeared from improved growing conditions of the sugar-cane that the rat population density was decreasing markedly, a census was practiced in two fields (an undamaged and a slightly damaged field) in order to confirm it using 50 traps in each field. From 25 – 26 February a total of 100 trap/nights captured two roof rats in the slightly damaged field but none in the undamaged field, respectively. As expected, the rat density is very low at present. This integrated control procedure has therefore proved to be effective in the short time it has been in use here and on Kita-daito (Table 1).

4. Rat population density on Zamami-shima

Zamami-shima, Kerama Islands, in the Okinawa Group, was the southernmost island where a significant degree of rat control had been achieved by weasel introduction. This small mountainous island is 594 hectares in area, its highest point being about 140 m above sea level. It is distinguished from the other islands in that its chief industry is fishing. Besides some narrow flat fields, terraced fields on mountain slopes are cultivated with sweet potatoes, wheat, and Irish potatoes. There are also a few sugar-cane fields.

Agricultural produce had been subjected to heavy rat damage prior to weasel introduction in spite of the use of rodenticide (sodium fluoroacetate). About 40 weasels were introduced in March of 1957 and 1958, they having been established since that time. My visit lasted from 4 – 8 March (i.e., 10 years after the introduction). A single survey was carried out in two sweet potato fields, using 50 traps in each field. On 6 March the 50 traps captured one roof rat in one field but none in the other. This proved the rat density to be very low. The effect of weasels upon rat control has begun to be recognized since 1960 – 1961. Attention should be paid to the fact that no rodenticide has been used on the island since their introduction (Table 1).

5. *Situation of rats on Irabu-Shimoji-jima*

Irabu-Shimoji-jima (3888 hectares), about 8 km off Miyako-jima of the southern Ryukyus, consists of two flat islands, i.e., Irabu-jima (2839 hectares) and Shimoji-jima (1049 hectares), separated by a narrow watercourse over which weasels can go across by wading or swimming at low tide. The topographical features are very simple, but the water-table is high, about 1.5 – 2 m below the surface. The land is thus not much dry though the spring-water is not suitable for the weasels to drink as it is brackish. Sugar-cane is cultivated on both islands. One hundred and nineteen weasels (104 males, 15 females) were introduced into the islands in December 1966. I visited the islands on 18 February 1967. Several dead roof rats with their necks severed had been found by farmers in cane fields, and rats were reported to have been decreasing gradually for a month. I was able to find several remains of roof rats in a weasel's nest in a screw pine forest on Shimoji (Fig. 2).

Fig. 2. Weasel habitat in screw pine forst. Nest was found in a hollow formed by limestone and spread roots of screw pine (indicated by an arrow). Note (a) remains of a roof rat killed by weasel and (b) dung masses of weasel found in the nest. Shimoji-jima, 18 February 1967.

I visited again here on 5 – 6 January 1968. Also after my first visit, many weasels have subsequently been introduced and, as of January 1968, the total had reached 732 (613 males, 119 females), the density being about 19 weasels per 100 hectares as well as on Minami-daito. On the other hand, only a few anticoagulants have been used on the islands. Since the weasel introduction roof rats have been markedly decreasing, only a little damage has been caused to sugar-cane. Thus, contrary to the situation on Ishigaki, the predation pressure of the weasels seems to be responsible for the lowering of rat density. The

Fig. 3a and b. A nest (indicated by an arrow in (a)), made in trees, of roof rats driven from their terrestrial habitat by predation pressure of weasels, and its whole shape (b, × 0.3) showing the nest-entrance (indicated by an arrow). Irabu-jima, 5 January 1968.

situation appears to be very stable and of lasting effect as well as on Minami-daito. It is worthy of note that some roof rats, driven from their terrestrial habitat by predation pressure of weasels, were nesting in trees and on sugar-cane stems (Fig. 3a and b). Attention should be directed to the fact that in little over a year weasel introduction with a few anticoagulant rodenticides has been meeting with good results also on the island as well as on Minami-daito (Table 1).

6. *Situation of rats on other islands visited*

I will only briefly touch upon the situation of rats on the other islands I visited because I stayed there once only a short time. Miyako-jima (14791 hectares), in the Miyako Group of the southern Ryukyus, is a large, flat island, its highest point being about 107 m above sea level. The topographical features are very simple : the island has few forests or streams and the land is generally dry except for a few wet zones. Sugar-cane is cultivated over most of the island. Two hundred and twenty weasels (185 males, 35 females) were introduced on 7 February 1967. My visit was limited on 17 and 19 February 1967. Rat damage to sugar-cane had occurred on the southern part of the island from the last year. Fauna which would be useful as weasel prey is poor except in the wet zones. As of January 1968 the number of introduced weasels is five hundred and thirty-one (443 males, 88 females), the density being low, about four per 100 hectares (Table 1). Although weasel introduction into the island would be continued until a high density would be reached, it would be difficult to expect the weasels to be effective over such a very dry, large island without a marked increase of water containers or basins providing drinking water for the weasels.

Ie-jima (2020 hectares), which is about 5 km off Okinawa-jima, has simple topographical features, its highest point being 168 m above sea level. The land is dry and the fauna is considerably poor. Sugar-cane is cultivated all over the island. Three hundred and sixty weasels (296 males, 64 females) were introduced from April to December 1966. I visited the island from 20 – 21 February 1967. A single trapping was carried out in two fields (a fairly damaged and a badly damaged field), using snap traps without pre-baiting. On 21 February the 50 traps captured four roof rats and one mouse (*Mus musculus*) in the fairly damaged field, and 11 roof rats in the badly damaged field. Because only a single trapping was made the population densities cannot be calculated in this case. However, the latter population density compares with that of Field Al on Ishigaki in February 1967. Two of 11 rats caught in the badly damaged field were torn up by an animal, possibly a weasel. On this island a high rat population density persists in spite of the large number of introduced weasels (about 18 per 100 hectares). Probably this is because the use of rodenticides has ceased since their introduction though sodium fluoroacetate had been used previously. As a considerable amount of anticoagulant rodenticides have been recently used. however, the joint use of weasels with chemicals will soon have a good effect (Table 1).

Both Aka-jima (307 hectares ; highest point 193 m) and Keruma-jitna (about 100 hectares ; highest point 154 m), being near Zamami, have similar topographical features and industry to those of Zamami. Though a total of about 40 weasels were introduced into the two islands in March of 1957 and 1958, the weasel failed to become established. When I visited these islands on 7 March 1967, I could not find any evidence of weasel existence and agricultural produce was fairly rat-damaged (Table 1). While the reason why weasels failed to become established on the islands is no clear, the following points should be taken into consideration. Firstly, it is doubtful whether females were among the group of weasels introduced, because of the infrequency of catching live females. Secondly, dogs have been continuously raised on both islands since the weasel introduction. But domestic and feral dogs were exterminated on Zamami before weasel introduction. This difference might be important.

Faeces analysis, *Mustela sibirica itatsi*

The most direct method would have been to analyse stomach contents to examine their feeding habits. However, this would have been unpopular with the inhabitants in view of their acceptance of the weasels. Weasel faeces were therefore collected and analysed. This procedure proved of great help in establishing the relationship between weasels and other animal populations. It is unavoidable that the results of faeces analysis would be slightly less accurate as regards determining the weasels' feeding habits to direct analysis of stomach contents.

Nineteen (Faeces Nos. 1 - 19 in Table 2) and thirteen samples (Nos. 20 - 32) were collected from various islands during the first and second surveys, respectively. With regerd to samples from Ishigaki the bulk of faeces consisted of fragments of various insects,[1], remains of bird (species unidentified) and roof rat being also found in one and two of the six examples respectively. In regard to 11 samples from Irabu-Shimoji. fragments of roof rats were found in eight of them, those of

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1) Identified by Dr. K. Yano of Kyushu University.

Table 2. Weasel **faeces**.

No.	Faeces: Place collected	Weight (g)	No. of mass	State	Date collected	Components: Animal fragments
1	Ishigaki	0.4	A part	Medium	Jan. ? , 1967	Insects (cockroaches, grasshoppers, crickets, ground beetles, gold bugs, crane flies and flies)
2	Ishigaki	ca 5	1	Fresh	Feb. 13, 3967	*Rattus rattus* (fur and teeth)
3	Shimoji	1.0	1	Fresh	Feb. 18, 1967	*Rattus rattus* (fur and fragments of bones)
4	Shimoji (in nest)	ca 23	6	Fresh or medium	Feb. 18, 1967	*Rattus rattus* (fur and fragments of bones)
5	Minami-daito	1.6	1	Old	Feb. 22, 1967	Young toads or frogs (jawbones and fragments of other bones)
6	Minami-daito	1.3	i	Old	Feb. 23, 1967	Young toads or frogs (jawbones and fragments of other bones)
7	Minami-daito	0.4	A part	Old	Feb. 23, 1967	Young toads or frogs (jawbones and fragments of other bones)
8	Minami-daito	0.4	A part	Old	Feb. 23, 1967	Insects (soldier-bugs)
9	Minami-daito	0.4	A part	Old	Feb. 23, 1967	Bird (feathers), young toads or frogs (a few bones) and insects (moth larvae)
10	Minami-daito	2.0	1	Old	Feb. 25, 1967	Young toads or frogs (jawbones and fragments of other bones) and insects (beetles)
11	Minami-daito	0.8	1	Old	Feb. 25, 1967	Young toads or frogs (jawbones and fragments of other bones) and insects (moths)
12	Minami-daito	0.4	A part	Old	Feb, 25, 1967	*Tilapia mossambica* (scales and bones) and young toads or frogs (fragments of bones)
13	Zamami	0.a	1	Old	Oct. 14, 1966	*Crocidura sp.* (fur, lower jawbone and fragments of other bones) and insects (larvae of beetles)
14	Zamami	6.2	5	Old	Mar. 5, 1967	Insects (grasshoppers, cockroaches, crickets and beetles), scolopendrids and small vertebrates' bones
13	Zamami	5.0	3	Medium	Mar. 5, 1967	*Crocidura* sp. (fur, lower jawbone and vertebrae), crabs (fragments of crust), insects (beetles) and scolopendrids

Table 2. Weasel faeces (continued).

Faeces						Components
No.	Place collected	Weight (g)	No. of mass	State	Date collected	Animal fragments
16	Zamami	ca 16	3	Fresh	Mar. 6, 1967	Insects (larvae of spring beetles ; cockroaches and crickets) and scolopendrids
17	Zamami	5.1	4	Old	Mar. 6, 1967	Bird (feathers), scolopendrids and insects (larvae of beetles)
18	Zamami	3.1	1	Fresh	Mar. 6, 1967	Crabs only (fragments of gills and crust)
19	Zamami	2.0	2	Medium	Mar. 6, 1967	Bird (feathers and fragments of bones), *Crocidura* sp. (fur and bones) and crabs (fragments of crust)
20	Ishigaki	0.2	A part	Old	Nov. 30, 1967	Bird (feathers)
21	Ishigaki	0.2	A part	Old	Dec. 29, 1967	Insects (nymphae of dragonflies)
22	Ishigaki	0.3	1	Medium	Dec. 31, 1967	Insects (cockroaches and beetles)
23	Ishigaki	0.4	1	Medium	Dec. 31, 1967	Insects (cockroaches and flies) and bird (feathers)
24	Shimoji	0.15	A part	Old	Jan. 5, 1968	*Rattus rattus* (fur and fragments of bones)
25	Shimoji	0.15	A part	Old	Jan. 5, 1968	*Rattus rattus* (fur and fragments of bones) and bird (feathers and fragments of bones)
26	Shimoji	0.6	2	Old	Jan. 5, 1968	*Rattus rattus* (fur and fragments of bones) and bird (feathers)
27	Shimoji	0.5	1	Old	Jan. 5, 1968	*Rattus rattus* (fur and fragments of bones)
28	Shimoji	0.05	A part	Old	Jan. 5, 1968	*Rattus rattus* (fur and fragments of bones)
29	Shimoji	1.55	3	Medium	Jan. 5, 1968	Bird (feathers and fragments of bones)
30	Irabu	0.8	2	Old	Dec. 8, 1967	*Rattus rattus* (fur, toe, vertebrae and fragments of other bones) and *Crocidura* sp. (fur and fragments of bones)
31	Irabu	0.3	1	Fresh	Jan. 5, 1968	Bird (a feather) and fragments of something
32	Irabu	0.5	1	Fresh	Jan. 5, 1968	*Crocidura* sp. (fur, a foot, vertebrae and fragments of other bones)

bird and shrew *(Crocidura* sp.) being contained in four and two respectively. Thus, contrary to the case on Ishigaki, the frequency of roof rat remains was high here. As stated earlier, I also found remains of several roof rats in the weasel's nest on Shimoji. Most of these remains consisted of the skin, head, limbs and tail, the flesh and internal organs missing. This certainly indicates that the weasels do prey heavily on rats under natural conditions.

On Minami-daito I collected eight samples in sugar-cane fields (Fig. 4). Most consisted of fragments of young toads or frogs and various insects ; birds and fish *(Tilapia mossambica)* were found in one sample respectively. Seven samples containing 19 masses from Zamami (Fig, 4) consisted chiefly of various insects, scolopendrids, crabs, shrew (*Crocidura* sp.) and birds. Thus, on both these islands no rat remains were found in weasel faeces. This indicates, as shown earlier by population estimates, that rats are scarce at present on both islands. The fact that weasels prey on various other animals is worthy of note.

Other observations

1. Relationship between weasel and other animal populations

As shown in the faeces analysis data, *M. sibirica itatsi* preys upon

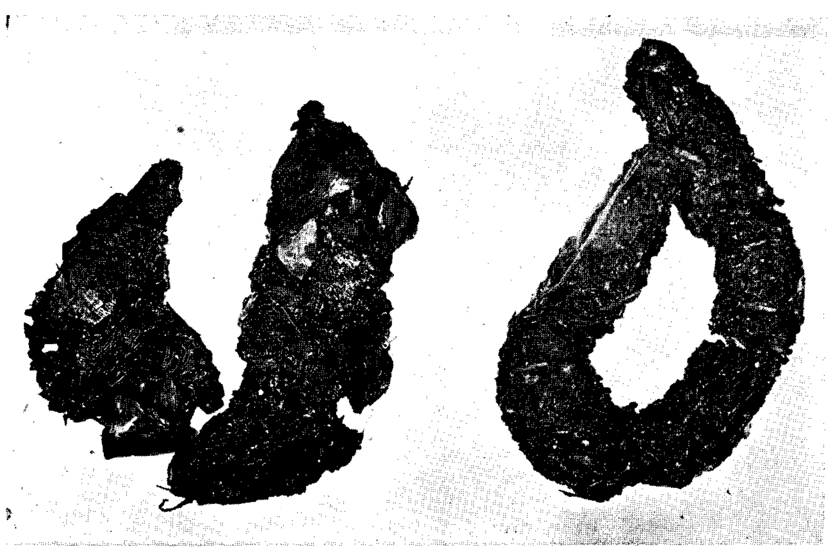

Fig. 4. Weasel faeces, R. H. one from Minami-daito-jima (Faeces No. 5 in Table 2) consisting of the fragments of young toads or frogs only, and L. H. from Zamami-shima (No. 18) consisting of crabs only. × 1.6.

rats, shrews, birds, toads, frogs, fish, crabs, scolopendrids and insects. Also, according to the inhabitants, their predatory activity extends to snakes, lizards and chickens. Zamami is a good example for tracing the consequent fauna1 changes since weasel introduction, because it is now 10 years since their introduction.

The fauna is still very rich on Zamami at present, but was even richer before weasel introduction. Prior to introduction, snakes ***(Natrix pryeri, Opheodrys semicarinatus, Dinodon semicarinatus, Calliophis boettgeri*** and ***Trimeresurus okinavensis)*** and frogs ***(Microhyla ornata, Rana limnocharis*** and ***Rhacophorus japonicus)*** were abundant (Takara, 1962). The inhabitants confirmed that these animals had decreased gradually since weasel introduction. There is no doubt that this phenomenon is due to predation by weasels, as well as rats. However, newts ***(Triturus pyrrhogaster ensicauda)*** are still abundant. As shown in Table 1, no newt remains were found in the faeces. Judging from this, it seems that weasels do not like to eat newts. The damage to frog and snake populations by weasels is therefore as heavy as rats. Furthermore, as shown in Table 1, weasels eat various crabs. I found many clusters of half-eaten crabs (two kinds of sesarmid crabs – ***Helice tridens latimera*** and ***Chasmagnathus convexus***; a kind of marine crab- ***Scylla serrata***)[1] in stream beds near to outfall (Fig. 5).

Fig. 5. A mass of crabs half-eaten by weasels, such masses were found here and there at stream beds near by outfall. Zamami-shima, 6 March 1967.

1) Identified by Prof. S. Miyake of Kyushu University.

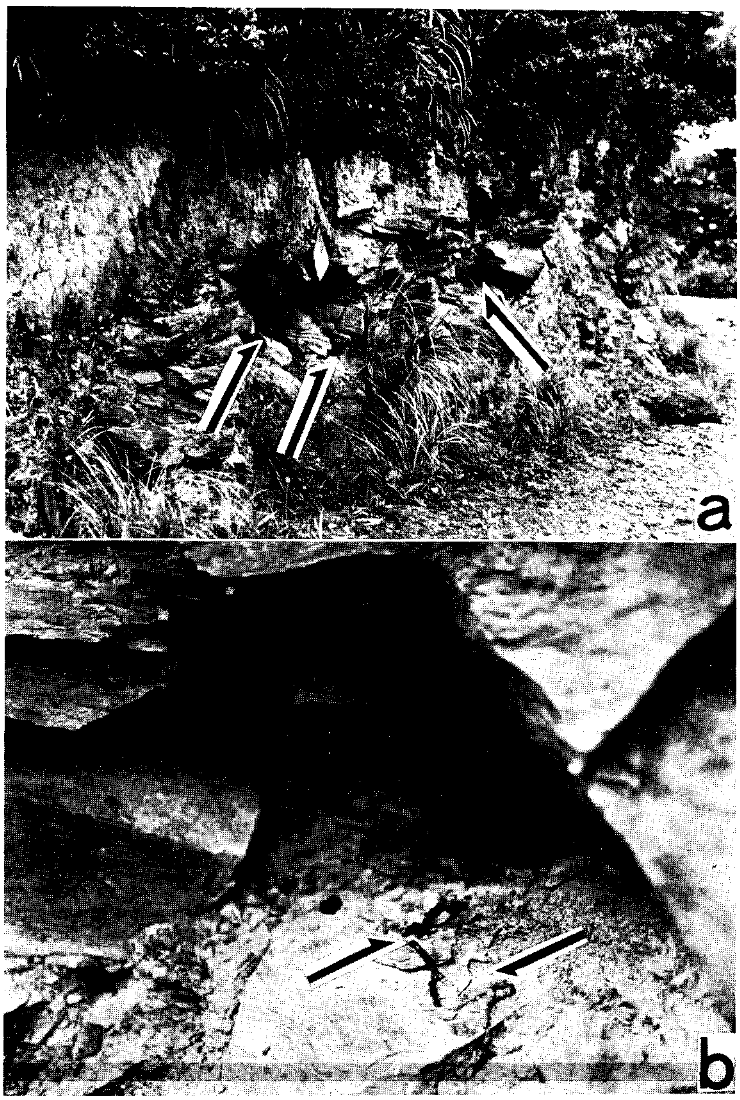

Fig. 6a and b. Weasel habitat along mountain path (a), showing the locations of nest-openings (indicated by arrows). Nest-opening in a crevice of rocky wall (b), showing several faeces masses in front of it (indicated by arrows). Zamami-shima, 6 March 1967.

According to the people, weasels had been seen near the edges of the reef flat or sandy beach at low tide. I found many weasel footprints on stream beds and sandy beaches on this island and also on Irabu-Shimoji. But crabs are still very abundant on Zamami. Incidentally, snails have increased since weasel introduction. on this island, and on Kikai, where, as stated earlier, their introduction had resulted in successful rat control, though the reason is not clear. The decrease in the number of snakes, frogs and rats might be important in this connexion, coupled with certain other factors. I found several weasel nests in crevices of rocky walls along mountain paths, several masses of faeces always existing at nest openings (Fig. 6a and b).

Attention should be paid to the fact that the weasel has been breeding as a terminal animal in the above-mentioned food chain under subtropical conditions since its introduction (1957 – 1958), and that the present situation of ecological equilibrium between weasels and rats (including other animals) has greatly benefited agriculture on Zamami.

As it is not long since weasels were introduced to other islands no great change in fauna was evident. As stated earlier, weasel faeces from Minami-daito contained large amounts of toad and frog remains. Frogs (probably ***Rana limnocharis)*** were introduced into the island from Okinawa-jima about 1921, and toads ***(Bufo melanostictus***) from Formosa in 1935 as insect control agents. The frogs seem to have decreased, probably because of predation by tilapia ***(Tilapia mossambica)*** upon their eggs, or tadpoles, since its introduction in 1955. However, though toads also are decreasing somewhat, their population density remains high. But bones such as jawbones and vertebrae, etc., found in faeces were all small. In this connexion, Mr. Shinko Tamaki of the Agriculture Extension Agency of the Government informed me that a weasel kept in captivity did not eat a large toad. Judging from this, the prey would be young toads or frogs, most probably the former. In only one sample were scales of ***Tilapia mossambica*** found. On Ishigaki I found some remains of half-eaten frogs (bullfrog, ***Rana catesbiana ;*** a kind of arboreal frogs – ***Rhacophorus viridis)*** and crabs (a kind of sesarmid crabs – ***Sesarma dehaani ;*** a kind of land crabs – ***Cardisoma carnifex)*** at stream beds near by outfall. On the island I learned of only one example where much damage had been inflicted upon chickens by weasels, about 90 being killed in an open hen-house. Slight damage was also occasionally inflicted on unpenned chickens on those islands where weasels were introduced. The remains of wild birds were evident in weasel faeces in two samples from Ishigaki, four from Irabu - Shimoji, two from Zamami and one from Minami-daito out of a total of 32 samples. On Ishigaki wild birds such as the Indian water hens (***Gallinula chloropus indica***), etc., were occasionally attacked by weasels. However, on no island had the population of wild birds decreased because of weasels. Therefore weasel damage to chickens and wild birds was not as great in the Ryukyus as was expected, although further studies are desirable in this connexion.

2. Influence ***of weasels against rat damage to agricultural products***

As stated above, the rat most injurious to agricultural products in the Ryukyus is the roof rat, ***Rattus rattus.*** The brown rat, ***Rattus norvegicus,*** on the other hand, is restricted principally to towns, suburban areas (Uchida, 1963) and paddy fields. Rat damage occurs mainly to sugar-cane from the previous October when it begins to accumulate sugar, to March. The roof rats begin to gnaw at the undermost stems of the cane and the damage also extends upwards as the sugar content rises to the upper stems (Fig. 7). On Ishigaki, rat damage extends to pineapples and rice plants. Pineapples are affected both in the early and ripe stages of the fruit season, and rice plants are continuously affected by brown rat, especially in the seedling ear formation and ripe stages.

Fig. 7. Heavily damaged census area (Field AZ) in dry zone, showing sugar-cane stems gnawed by rats (indicated by an arrow). Ishigaki-jima, *6* February 1967.

On Minami-daito, rat damage to sugar-cane fell from 20-30 % to almost nil in the course of a year by the joint use of chemical and biological control measures. This is evident from the fact that the output of sugar-cane was about 97000 tons in 1964 – 1965 (slightly below an average crop), 75000 tons in 1965 – 1966 (bad harvest due to rat damage, before weasel introduction) and 115000 tons in 1966 – 1967 (good harvest after introduction) respectively even though other reasons have to be taken into consideration. Furthermore, it is worthy of note that a rat control procedure using predators only without rodenticides has been successful on Zamami for about three years after weasel introduction. 1 was unable to find evidence of any harm to sweet potato or wheat on the island.

Rat damage to sugar-cane on Ishigaki and Ie was about 30 % in 1966 – 1967, the same as before the weasel introduction. As stated earlier, control with rodenticide (warfarin) was carried out very little on Ishigaki and not at all on Ie after weasel introduction. This would explain the heavy rat damage. On Ishigaki, the density of weasels (about eight per 100 hectares) is low compared to that of other islands, the topographical features being complex and mountainous. These factors would delay the control effect. Attention must also be directed to the fact that although rat damage was heavier in some humid zones than in dry zones before weasel introduction, the reverse is true after introduction. This phenomenon is mainly due to the predation pressure gradient caused by habitat selection of weasels in search of food.

On Ishigaki, however, the use of a large quantity of anticoagulants since April 1967 and continuation of weasel introduction, have produced a good result. When I revisited Ishigaki, therefore, a little damage to sugar-cane was done throughout the island. This resulted in more than 100000 tons in yield for 1967 – 1968 ; that for 1966 – 1967 was about 62000 tons. Also on Irabu-Shimoji, the crop for 1967 – 1968 was 45000 tons because of weasel introduction at high density (19 per 100 hectares) with a few anticoagulant rodenticides ; the yield in 1966 – 1967 was 31000 tons. Attention must be directed to the fact that also on some other islands where the integrated rat control procedure by joint use Of weasels and anticoagulant rodenticides was carried out, rat damage has markedly decreased ; especially on Kohama-jima and Hateruma-jima the crop of sugar-cane *(1967* – 1968) showed an increase of about 80 and *20 %* over the yield of last year, respectively (Table 1).

3. *Attitude of the islanders concerning these weasel introductions*

Judging from the data mentioned above, it is evident that weasels are effective as rat control agents on smaller islands, especially when jointly used with a rodenticide, such as coumarin derivatives (e.g., warfarin). However weasels occasionally attack chickens. Nevertheless, the islanders do not regard this as important in view of the fact that the weasels are effective against rats. Again, agricultural produce (mainly sugar-cane and pineapples) is more important to the local people than poultry farming. They are certainly pleased with the weasel introduction. It might be expected also that weasels would be useful in controlling poisonous snakes, such as ***Trimeresurus flavoviridis***, ***T. elegans*** and ***T. okinavensis,*** by their predation on young snakes directly or by cutting off indirectly snake's food chain by their predation on rats.

The islanders feel that weasels are of great help in controlling rats. The weasels are therefore protected by law. However, dogs seem to be a danger to weasels. From experience on a small island, Sagi-shima in Kyushu, Japan, it is known that dogs hinder the establishment of weasels, especially on small islands (Hiraiwa et al., 1959). Before the introduction of weasels on Zamami, dogs were exterminated for the purpose of protecting the weasels. Also on Minami-daito a periodic round-up of wild dogs was carried out, sparing only those dogs that were chained.

On islands besides Ishigaki, Zamami and Minami-daito, the land is generally dry and there are hardly any streams or ponds. Thus on Irabu-Shimoji and Ie many concrete water containers ($2\times1\times$ 1 m) and several large basins were placed or dug throughout the islands.

The weasel introduction project will be strongly implemented by the Government of the Ryukyus and the local authorities, though the cost per head ($ 20) is very expensive. Half the expense is covered by Government subsidy, the other half being provided by the farmers through fund raising campaigns and subsidy by the local authorities concerned. It is obvious from this that the islanders are enthusiastic about weasel introduction.

Discussion and conclusions

The following points should be considered as causes of notable rat population increases in recent years in the Ryukyus :

a) environmental changes, e.g., variations in land use due to labour shortages, and alteration of the sugar-cane strain (from POJ-2725 to NCO-310) causing increased foliage which hampered field maintenance causing an increase in cut stems and foliage left on the field. This was further aggravated by the prohibition of burning waste.

b) the lack of indigenous carnivorous mammals which is typical of small Pacific islands such as the Ryukyus (Marshall, 1957 ; Johnson, 1962;

Wiens, 1962 ; Uchida, 1963 ; Kirkpatrick, 1966 ; Wodzicki, 1968), is the reason why predator introductions are advisable in these areas. In this connexion, the death of cats accidentally killed by insecticides used for mosquito control on Ishigaki, and rodenticides on Minami-daito, is partially responsible for the increase in rat populations. There were many stray cats on both islands before chemicals were used.

Needless to say, the objective of using weasels is to prevent rat damage as quickly as possible. However, the time required before their effect is noticeable varies according to the number of weasels introduced, topographical features, and the use or not of rodenticides. A further aim of their introduction is to permanently suppress the rat population by establishing an ecological equilibrium between predator and prey, as on Sagi-shima of Kyushu, Japan (Hiraiwa et al., 1959) and Zamami-shima. In this connexion, questions such as whether wild animal resources useful to weasels as food, are abundant (this depends on whether the island is wet or dry), and whether predators against weasels (such as wild dogs) exist, are relevant in deciding whether the weasels become established. The smaller the island, the sooner it will be possible to assess the results. Therefore, the weasel introduction project into large islands such as Ishigaki and Miyako must be watched patiently.

It must be recalled that although rodenticides had been used as a rat control measure for a long time on Minami-daito and Irabu-Shimoji, whose areas are about 2600 and 3900 hectares respectively, the extent of rat damage to sugar-cane reached 20 – 30 % prior to weasel introduction ; however, in addition to the use of anticoagulants, many weasels, the density being about 19 per 100 hectares, were introduced into both islands, and in little more than a year the rat control procedures have been effective. On the other hand, rat control by a biological procedure (weasel introduction) only could be effective on small islands such as Sagi (about 100 hectares) and Zamami (594 hectares). It is clear from the above data that eventual success in rat control will not be achieved by the use of rodenticides alone, without a biological control procedure, on crop-cultivated or coconut-planted islands lacking effective predators, whether the islands are large or small. It would be thus necessary to introduce about 20 weasels per 100 hectares to achieve rapid effects, judging from the weasel density obtained on Sagi, Minami-daito and Irabu-Shimoji. The smaller the island, the easier it should be to attain an ideal weasel density. In this connexion, it is fortunate that the area of one islet, being a minimum unit of an atoll, is usually small.

Besides the great contribution they have made to rat control, it must be recalled that weasels have proved capable of adapting themselves to the subtropical climates on Zamami, which lies not far north of the Tropic of Cancer, and also that weasel damage to chickens and indigenous birds was generally not as much in the Kyukyus as was expected. Furthermore, as regards environmental conditions in the Pacific area (Marshall, 1957; Wiens, 1962; Storer, 1962), weasels seem to become established on atolls and small islands as long as these are not too dry. Thus, the Japanese weasel is recommended as a biological control agent meriting attention for further tropical field trials against rats. Though Zamami-shima is best as the sources of supply of weasels for the Pacific because its weasels, which have been breeding there for 10 years, will be more adaptable to tropical climates than those from Japan itself, unfortunately I could not obtain approval of the Government of the Kyukyus as regards capturing weasels alive by reason of embargo on the exportation. Thus the southern Kyushu in Japan must bc unwillingly chosen as their supply sources.

The possibility of secondary toxicosis of warfarin to weasels should be mentioned. So far as I know, warfarin had not been tested to any extent in this respect on weasels, though it was felt that there would be little danger to them and there is no record of weasels having died as a result of secondary toxicosis by this rodenticide on any islands into which weasels had been introduced. However, cats often die because of direct toxicosis. An attempt was therefore made to clarify this point. My experiment with the secondary toxicosis of one male Korean weasel, ***M. sibirica coreana*** (Domaniewski), revealed that it was eventually harmed after eating rats poisoned with warfarin[1] for a prolonged period. This weasel ate 25 poisoned rats (20 brown rats and five roof rats) during 24 days (from 14 May to 6 June 1967), and died on 8 June. Anatomical inspection showed symptoms of warfarin toxicosis. Thus attention should be paid to the fact that warfarin may cause secondary toxicosis in weasels. As stated in footnote, the percentage of warfarin contained in the rodenticide is very high, which might account for its having killed the weasel rather quickly (Price-Evans & Sheppard, 1966). It is unlikely, however, that weasels contiguously eat poisoned rats for such a length of time under natural conditions even though they may eat one per day.

However, in using norbormide both direct and secondary toxicosis to weasels need not be considered. As pointed out by Gratz (1966), its high cost coupled with its genus specificity excludes norbormide

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1) The rodenticide used, "Yasomin" contains warfarin at 0.2% and is manufactured by Dai-ichi-noyaku Inc., Okinawa, Ryukyus. The reason this rodenticide was used in my experiment is that it has been already distributed to some islands of the Ryukyus where weasels have been introduced.

from use in the Ryukyus.

From the above, although the use of anticoagulants on small islands n-here weasels have been introduced is not the best solution, it is preferable to the use of rodenticides other than anticoagulants, except norbormide. If the problem of cost were solved, norbormide would be best for such an application, though this poison is less toxic to the roof rat than to the brown rat. However, at present, it is recommended that an integrated control procedure consisting of the joint use of weasels and anticoagulants be employed because there is little danger of secondary toxicosis of anticoagulants to weasels under natural conditions.

A further point concerning the use of warfarin should be pointed out, i.e., the occurrence of resistance to warfarin in the brown rat, though this was discovered only in the United Kingdom and Denmark (Lund, 1966). Fortunately, no resistance in roof rats has been reported from any country so far. However, resistance may occur in roof rats in the future, especially in view of its occurrence in the house mouse in the United Kingdom. As warfarin has not been used for long in the Ryukyus, its joint use with predators would diminish this hazard by quickly suppressing rat populations.

As stated in previous papers (Uchida, 1966, 1968), however, the introduction of any biological control agent must be carefully considered in all aspects. The greatest care must be taken for the proper conservation of endemic animals (especially sea birds) when considering the introduction of such a predator as a weasel which will be a terminal animal in a certain food chain. In fact, Wodzicki (1968) is of the opinion that liberation of exotic predatory animals into the Pacific islands should not be permitted except on an experimental basis and under strict supervision. In this connexion, Laird[1] (1968) pointed out that Atafu Atoll in the Tokelau Islands administered by New Zealand, particularly because there are no terrestrial birds except a few resident examples of the widespread Pacific pigeon and occasional New

1) While this paper was in press, in a personal communication (dated on 10 June, 1969) Prof. Laird informed me that our hoped-for plans for an experimental introduction of the weasel into Atafu, Tokelau Islands, failed to materialize through opposition from New Zealand, and suggested that we continue to urge the scientific appropriateness of an experimental weasel introduction on a small South Pacific atoll against the eventual possibility of (1) finding a new field site where the responsible authorities favour such a project, or (2) bringing about a change of attitude among those concerned in New Zealand, believing that the main obstacle that now has to be overcome is that of the attitude of conservationists who, after all, can point to many instances of unfortunate end results of introduction of predacious mammals into new areas.

Zealand long-tailed cuckoos as seasonal migrants, and because of the great amount of ecological background information now available there, would represent the ideal introduction site. Predators should certainly not be introduced into islands which are wild-life sanctuaries or are otherwise of special importance by reason of their fauna.

It is thus concluded that further consideration of the possibility of experimental introduction of the Japanese weasel, *Mustela sibirica itatsi* Temminck & Schlegel, into tropical Pacific islands, e.g., in the Tokelaus, would be very pertinent. It is submitted that urgent suppression of rat population on small, isolated islands is possible by an effective integrated rat control procedure consisting of the joint use of weasels and anticoagulants such as warfarin, etc.

Acknowledgements

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Résumé

11 est indispensable et urgent de mettre en oeuvre un ensemble intégré de mesures pour détruire les rats dans les iles du Pacifique, non seulement parce que ces animaux font des dégats très importants dans les plantations de cocotiers, mais encore parce qu'ils transforment les noix de coco en gites larvaires pour les moustiques, notamment les moustiques vecteurs de la filariose bancroftienne et de la dengue. Un tel ensemble doit cornporter à la fois des mesures de lutte biologique et des mesures de lutte chimique en fonction des données Ccologiques.

Pour détruire les rats lorsqu'on a affaire à un grand nombre de petites iles disséminées comme celles du Pacifique (y compris les iles Ryu-kyu), les méthodes biologiques reposant en particulier sur l'emploi d'animaux prédateurs présentent peut-être un intérêt spécial au double point de vue Ccologique et Bconomique. Dans une étude précédente (Uchida, 1966), l'auteur a appelé l'attention sur la belette japonaise, *Mustela sibirica itatsi* Temminck & Schlegel, comme agent possible de destruction des rats. A cet égard, une grande importance doit être attachée à l'essai pratique entrepris dans les îles Ryu-kyu, qui mériterait d'être suivi de nouvelles experiences du méme genre dans d'autres regions tropicales.

La présente étude a donc été menée dans plusieurs îles Ryu-kyu où ce prédateur avait été introduit, le but visé étant de voir s'il vaudrait la peine d'envisager d'autres essais en Micronésie et en Polynésie pour déterminer l'efficacité de la belette comme agent de destruction des rats dans les plantations de cocotiers. Elle a permis de conclure qu'un essai d'introduction de la belette dans la region du Pacifique sud serait justifié pour plusieurs raisons. Tout d'abord, on a constaté que la densit6 des populations de rats *(Rattus rattus)* était tombée à quelques unités par hectare, voire à z&o, dans l'île de Minami-daito-jima sous l'effet de mesures intégrées de destruction des rats (mesures biologiques et mesures chimiques combinées), dans l'année qui a suivi l'introduction de la belette. En second lieu, dans l'île d'Irabu-Shimoji-jima, des rats (*Rattus rattus)* ont été considérablement réduits en un peu plus d'un an principalement par la mesure biologique (i.e., l'introduction de la belette). En troisième lieu, l'effet du prédateur sur les rats a commencé, d'après les rapports, à se faire sentir environ trois ans après l'introduction de la belette dans l'île de Zamami-shima en 1957 - 1958, alors qu'aucune mesure chimique n'était venue renforcer son action. En quatrième lieu, l'analyse des excreta des belettes a montré que celles-ci avaient détruit un nombre considérable de rats et relativement peu d'oiseaux sauvages. En cinquième lieu, la production agricole a accusé, par rapport à l'époque précédant la dératisation, une nette augmentation dans les îles de Minami-daito-jima, de Kita-daito-jima, d'Irabu-Shimoji-jima, de Kohama-jima, de Tarama-jima et de Zamami-shima (20 - 30 % en moyenne dans les premières quatre de ces îles et 80 % clans l'île de Kohama-jima). En sixième lieu, il est probable que les belettes sont capables de s'habituer aux zones tropicales, maintenant que leur installation à Zamami-shima a apporté la preuve de leur faculté d'adaptation aux climats subtropicaux. En septième lieu, les populations locales ne sont pas hostiles à ce prédateurs, car s'ils attaquent de temps en temps les volailles et les oiseaux sauvages, ils contribuent considérablement à la destruction des rats.

L'auteur discute alors de l'emploi de ***M. sibirica itatsi de*** divers point de vue : conditions de milieu indispensables à ce prédateur, possibilité pratiques de son installation en climat tropical, problème que pose l'emploi simultané de rodenticides anticoagulants. I1 serait nécessaire, afin d'aboutir rapidement au but, d'introduire à peu près *20* belettcs par 100 hectare. Plus petite est une île, plus facilement la densité ci-dessus de belette atteindrait ce niveau idéal. A cet Cgard, c'est une chose bien heureuse qu'une ile, qui est l'unité minimum d'un atoll, est toujours de petites dimensions. 11 faut souligner, toutefois, que, pour des raisons de protection de la nature, il ne saurait être question d'introduire cette belette dans certaines iles classées comme reserve de la faune indigene (oiseaux de mer, en particulier) ou présentant une importance spéciale pour la reproduction des animaux sauvages.

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