DEVELOPMENT OF A RODENT CONTROL PROGRAM ON A SOUTH PACIFIC MILITARY BASE

by

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A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

May 1943

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ACKNOWLEDGMENT

Sincere appreciation is expressed to all ex-members of the New Caledonia Rodent Control Unit for aid in making this report possible. In particular, thanks are due to Dr. Wilfred D. Crabb, Mr. Arthur K. Crews, Dr. Arnold J. Nicholson, Dr. Dwain Warner, and Mr. John D. Herron for counsel, cooperation, and companionship.

To Professor R. E. Dimick the writer is indebted for encouragement and for suggestions toward the improvement of this paper.

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DEVELOPMENT OF A RODENT CONTROL PROGRAM ON A SOUTH PACIFIC MILITARY BASE

INTRODUCTION

This report deals with the development of a rodent control program on New Caledonia, a United States South Pacific military base, covering the period of March, 1944, to June, 1945, during which time the writer was a member of a naval rodent control unit and in charge of certain phases of field and laboratory research work.

Rats and mice are of military importance because of their ability to transmit diseases, particularly murine typhus and bubonic plague, and because of their destruction of military supplies. On military bases and within military establishments, rodent populations often increase due to favorable living conditions and adequate food supplies, presenting serious pest problems and a high disease-carrying potential. Most areas selected for military operations have a resident population of rats and mice and rodent-free areas are usually quickly seeded with these animals which are brought in with supplies imported from infested areas. Establishment of a modern military base, which includes clearing of land, building, and the transportation and storage of supplies, has a marked effect upon the rodent population. Certain resident species may either increase or decrease and, in some instances, new species may be introduced and become dominant. It is essential that these effects be recognized

and understood so that control measures may be devised and intelligently applied to reduce property damage and the possibility of disease transmission to a minimum.

On this South Pacific military base, lack of predatory enemies, excellent habitat, and a high resident population of rats and mice, made organized rodent control a necessity.

Objectives:

The objectives of this report of the development of a rodent control program on a South Pacific military base have been:

(1) To record and evaluate the steps in the development of organization for rodent control on this military base from the standpoint of personnel, transportation, equipment, control procedure, and education.

(2) To obtain any information on rodent control on this military base which might be of value in similar areas and/or under similar circumstances and conditions.

(3) To assist in carrying out fundamental research necessary to improve rodent control techniques and results in this area, such as:

(a) Gathering information on the rodent species in the study area, including identification, distribution, spread, economic importance, and general ecology.

(b) Determining food habits and food preferences of individual species in this area; indices of abundance and species population composition, species dominance, and other information essential to the development of efficient control measures.

(c) Developing efficient and accurate methods of evaluating the success of rodent control operations.

(d) Ascertaining how the general rodent control measures of trapping, poisoning, fumigation, and environmental control might be best modified and applied to specific conditions and rodent species present in the study area.

NEW CALEDONIA

The island of New Caledonia, a French colonial possession, ends the southern swing of the Melanesian arc. It lies about 700 miles east of the Queensland coast of Australia, extending from southeast to northwest. It is 220 miles in length, has an average width of 30 miles, and an area, including adjacent islands, of 6,300 square miles--about that of Connecticut and Rhode Island. It lies at the southern border of the tropical zone, about 20° to 22° south latitude, plate 1.

At the ends of the island, two parallel mountain chains enclose open valleys. Over the rest of the island, except for a flat coastal plain on the southwest, these ranges connect to form a confused

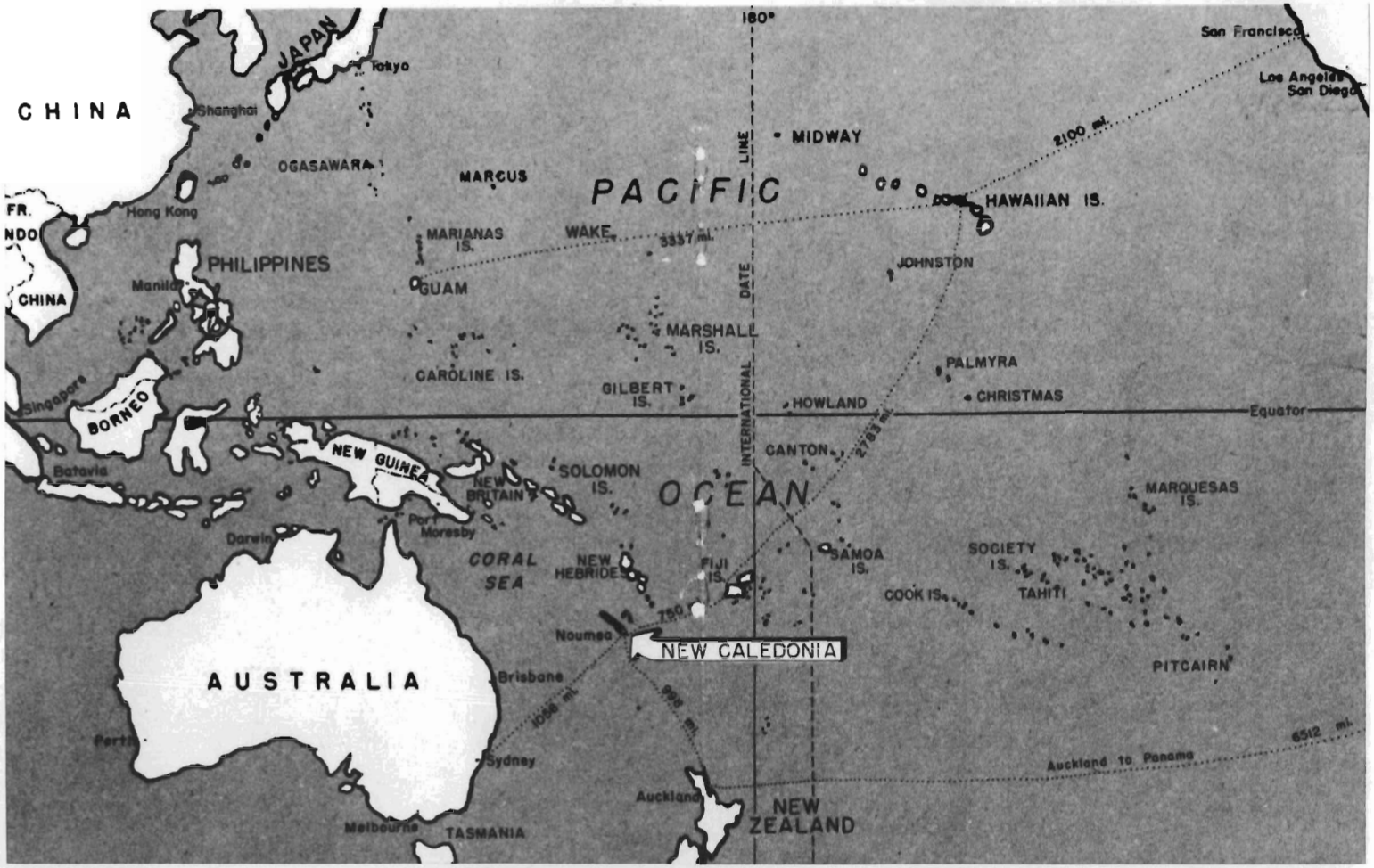

Plate 1. Map of the Pacific Area, showing location of New Caledonia.

tangle of low mountains reaching a maximum altitude of a little more than 5,000 feet, plate 2. There are no active volcanoes. The mountains include ancient rocks like those of New Zealand, rich in minerals, especially nickel. The whole southwestern coast is paralleled by a barrier coral reef at some distance from the shore so that along this coast, there is a protected navigable channel five to eighteen miles wide. The reef on the northwestern coast is not continuous.

Numerous small rivers carry off the abundant rainfall, about 70 inches annually. The climate is sub-tropical, with an ill-defined rainy season from January to June, and a rather hot summer from December to March. Summer temperatures (February-March) average about 86° F. and winter temperatures (July-August) about 75°F.

The forest cover is not as dense as in the New Hebrides or Solomons. Parts of the island are bare and somewhat arid, and some continuous forests exist in the northern mountains, including fig trees, palms, and tree ferns. The most common tree over most of the island, except the higher mountains, is the niaouli or paper bark tree which, according to Morrill (9, p. 20), is closely related to the Australian eucalyptus, Eucalyptus deglupta (Blume). Most of the species of native plants are found only on this island and the area has not been thoroughly surveyed botanically.

According to Carter, Hill, and Tate (1, p. 182), the only mammals native to New Caledonia are five species of bats. The two most common are Pteropus sp., large fruit-eating bats, and Miniopterus

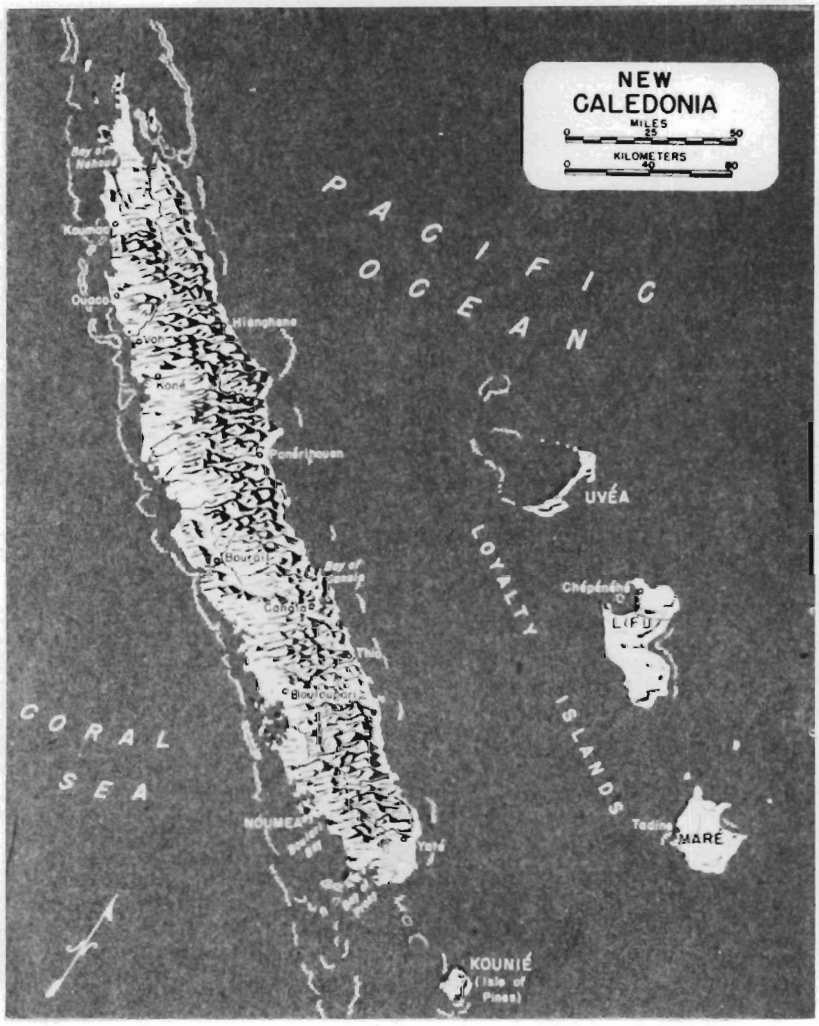

Plate 2. Map of the island of New Caledonia.

sp., small insectivorous bats, figure 1*. Less common are the lobe-lipped bat, Chalinolobus sp., the long-tailed bat, Noctenterus sp., and the sheath-tailed bat, Emballonura sp. Three species of rats and one mouse have been introduced to the island and are now common. These, as illustrated in figure 2, are the brown rat, Rattus norvegicus (Erxleben); the black rat, Rattus rattus rattus (Linnaeus); the Polynesian rat, Rattus exulans hesperk (Grinder); and the house mouse, Mus musculus caracorum (Houck). Another introduced mammal, the Sambar deer, Cervus unicolor (Linnaeus), is very abundant, especially in the northern part of the island, and Reichenbach (13, p. 19) lists an average of 70,000 skins annually as having been exported to Australia prior to 1941. Other introduced species now occasionally found include domestic pigs and dogs, gone wild.

In contrast to the mammal fauna, the bird fauna is very extensive. Mayr (8, p. 149) lists 66 species of birds for New Caledonia**. The most distinctive bird of New Caledonia is the heronlike Kagu, Rhynochetos jubatus (Verreaux and Des Murs), figure 3, which has no near relative anywhere in the world. Mayr (8, p. 149) lists 18 species of birds as endemic to New Caledonia and the remaining

* Specimens of Pteropus and Miniopterus are in the writer's collection at Oregon State College.

** Of this group, some 50 species were collected and prepared as study skin mounts by members of the New Caledonia Rodent Control Unit during 1944 and 1945, figure 6. A few of the specimens are in the writer's collection at Oregon State College and the remainder in the collection of Dr. Dwain Warner at Cornell University.

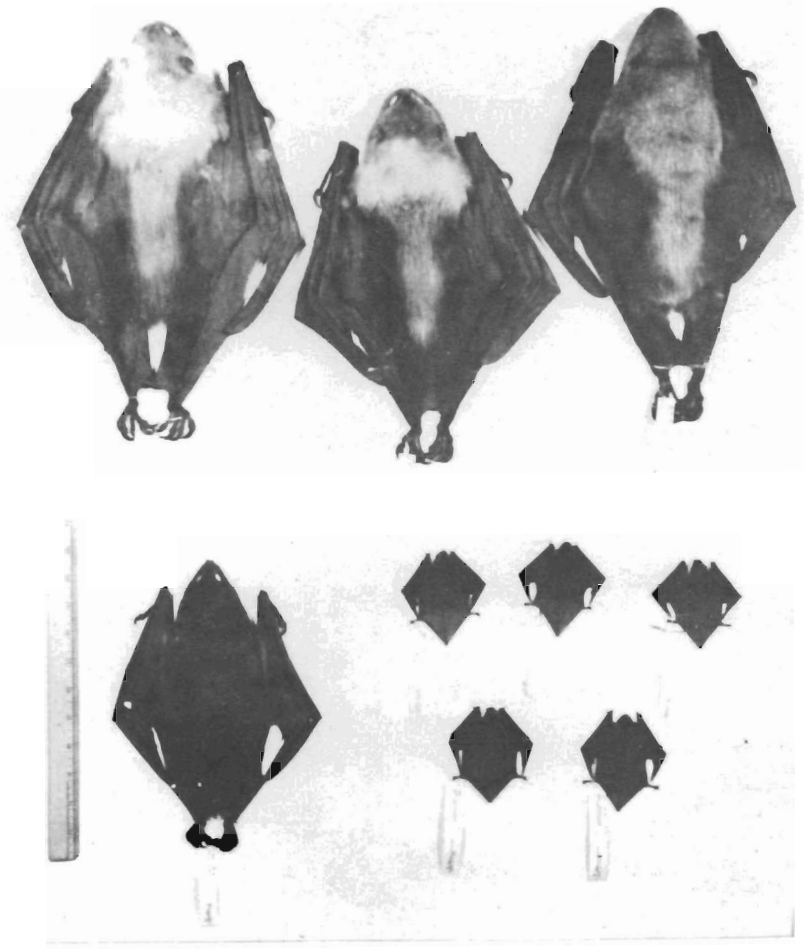

Figure 1. Two common species of bats native to New Caledonia, Pteropus sp. (above and lower left) and Miniopterus sp. (lower right).

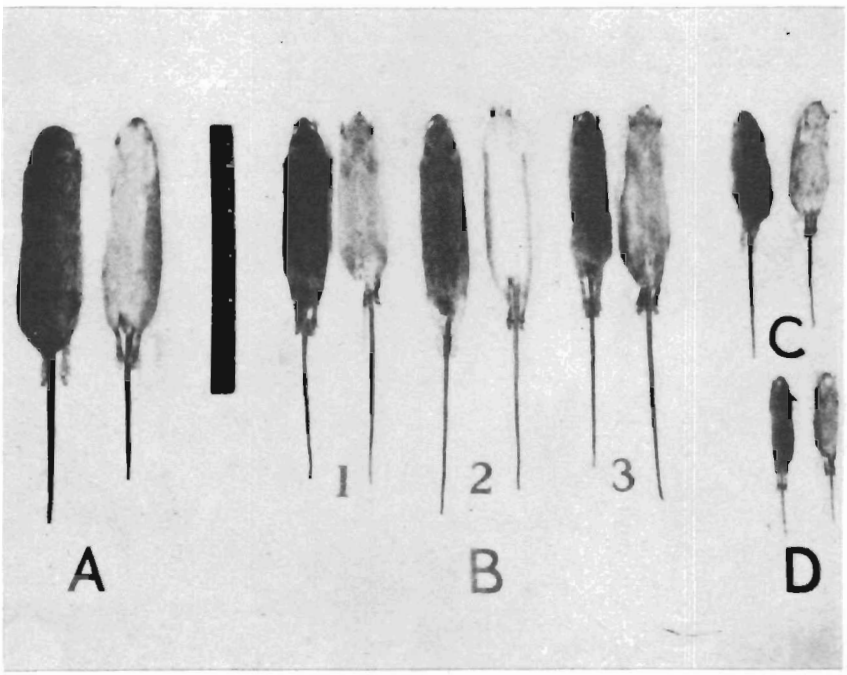

Figure 2. Rodents of epidemic disease and pest importance on New Caledonia.

A. Norway rat (Rattus norvegicus)
B. Black rat (Rattus rattus sp.)
   1. R. r. rattus, black back, gray
   2. R. r. frugivorous, brown back, white belly
   3. R. r. alexandrinus, brown back, gray belly
C. Polynesian rat (Rattus exulans jessook)
D. House mouse (Mus musculus canacorum)

species as being closely related to forms found either in Australia or other South Pacific islands.

The marine life is abundant and varied and resembles that of Australia's great barrier reef. Only a few of the ocean fish enter the mouths of the freshwater streams.

There is no malaria in New Caledonia; the malaria-carrying anopheles mosquito is not known to occur on the island.

According to Osburn (12, p. 97), the natives of New Caledonia, called "Kanakas", now number about 30,000 and are confined to reservations somewhat similar to those of the American Indians. They are referred to by Keesing (7, p. 13) as being of Melanesian or "Ocean Negroid" descent, figure 4. Reichenbach (13, p. 5) states that before the coming of the white men in 1643, the native population was probably much greater. This is evidenced by extensive terracing of the hillsides in many parts of the island, figure 5, indicating that a much greater portion of land was once under cultivation. The white French population numbers about 17,000, most of which live in Noumea, the capital city, located on the southwestern coast. Noumea had a prewar population of about 12,000 people and is by far the largest of the island towns. In addition to the natives and the French, a group of indentured laborers of Javanese and Tonkinese descent number about 8,000, making a total population of about 55,000 for the island. These Javanese and Tonkinese are contract laborers brought in from their native lands to work in the nickel and chrome mines.

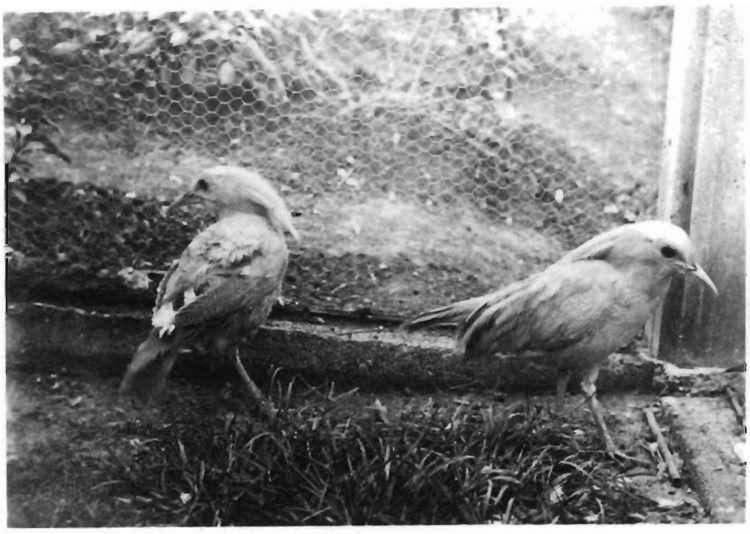

Figure 3. The Kagu, Rhynochetos jubatus (Verreaux and Des Murs) found only on New Caledonia.

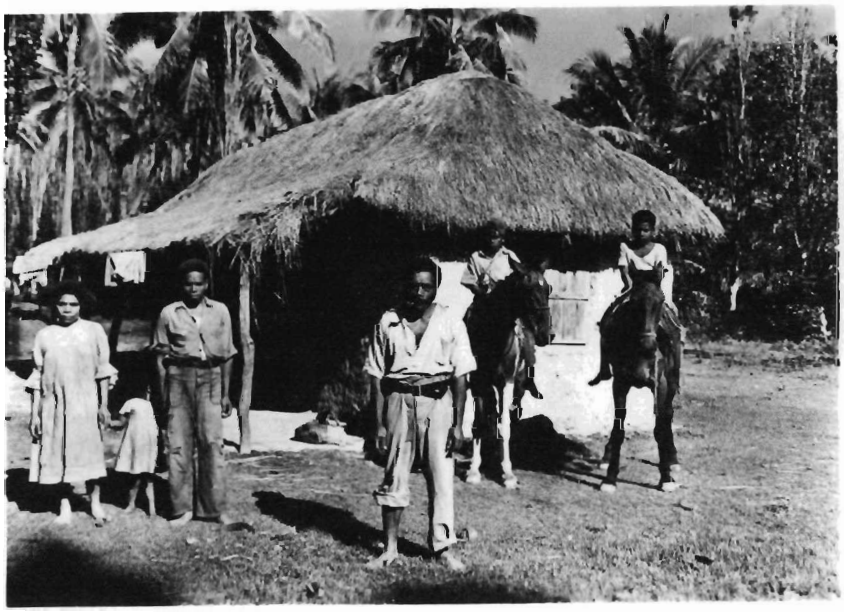

Figure 4. "Kanakas", native New Caledonian Melanesians.

Figure 5. Terracing, as formerly practiced by the "Kanakas".

Figure 6. Species of birds found on New Caledonia.

Principal industries of the island consist of mining, mainly nickel, iron, and chrome; coffee raising; and cattle raising. Bananas, copra, papayas, and citrus fruits are also grown on the island plantations.

Early in World War II, New Caledonia was recognized as a key military area by the Allies and the first United States troops landed on the island in March, 1942. Fortunately, in 1940 when France surrendered, the colonists revolted against the Vichy governor then in power and set up a government to work with the Free French under General De Gaulle, so were receptive to the arrival of Allied troops. Had the Japanese reached the island first, the Allied path across the South Pacific would probably have been blocked and the island would likely have served as a strategic base for an attack on Australia, only 750 miles to the west. Although actual warfare did not reach New Caledonia, the island served as an important staging and hospital area and as command base for the South Pacific area. By 1944, approximately 220 separate military units were established on the island*. These varied in size from a few men in special units to large supply depots and to infantry units of full division strength. Most of these units were located on the southwestern coastal plain with the port of Noumea being the geographical center of military unit concentration, plate 2, as well as the center of activity.

* By March, 1946, when the writer left the area, the military personnel of New Caledonia had been reduced to a garrison force of about 2,000 men.

The rodent control unit with which the writer worked (actually a division of the New Caledonia Malaria and Epidemic Control Unit) was headquartered in offices in downtown Noumea with separate laboratories and storage facilities located in pyramidal tents, figure 7, on the outskirts of Noumea.

ORGANIZATION FOR RODENT CONTROL

General:

At the time of arrival of American troops on New Caledonia, a high resident population of rodents already existed on the island. The city of Noumea had long been an important commercial port and, consequently, was well seeded with several species of rats and mice. These animals had spread to inland towns and native villages and, in the presence of favorable environmental conditions which included a lack of native predators, had, in many cases, formed feral or wild populations not immediately associated with human habitation. Buildings in the more congested part of Noumea were poorly constructed and open sewers and indiscriminate trash disposal contributed to the maintenance of a high rodent population. The Javanese and Tonkinese sections scattered throughout the city carried particularly high rodent populations. Crabb and Nicholson (3, p. 208), in reviewing the history of rodent-borne diseases on New Caledonia, state "The island has experienced periodic outbreaks of epidemic plague, the last major epidemic of bubonic plague occurring in 1914 and claiming 50 lives..."

Figure 7. New Caledonia Rodent Control Unit laboratory.

As American forces rapidly set up supply depots, ration dumps, and other installations with little time, provision (or, apparently, thought), for rodent control, rats and mice immediately moved in, destroyed considerable supplies and established what was apparently a high disease producing potential.

Such was the situation when the New Caledonia Rodent Control Unit began to function in February, 1944, nearly a year after the first American troops had arrived. Realizing the immediate need for control action, W. D. Crabb (3, p. 26), the naval officer in charge of the unit, set up the following priority of procedure:

(1) Establishment of a rodent extermination and control program embracing each organization at the base.

(2) Establishment of adequate ship to shore regulations and barriers.

(3) Institution of fundamental research necessary to improve control techniques and results.

In the absence of an emergency, it is obvious that fundamental research should precede control operations. Actually, here, research was carried out along with control operations and at first consisted primarily of the trial and error type. Complete field notes were kept, however, and gradually a pattern of control operations for each type area and each species began to take form. After ten months of extensive control work, the rodent control problem had been reduced to one of monthly checking of units, control of small reinvaded areas, and pest problems (mostly mice). The epidemic disease poten-

tial was considered to have been reduced to a minimum. After the first five months of intensive control, the effectiveness of control methods had increased to such an extent that considerable time was available for experimental and research work--a portion of which will be described in detail later.

In retrospect, it became obvious that much time had been wasted by using techniques effective only on one species, on the wrong species, or using inefficient methods on species adapted to a particular environment. It was often found that control efforts successfully directed against only one species on an area would not reduce the overall rodent population or greatly reduce the disease potential. As soon as one species decreased through successful control efforts, another species would rapidly multiply and again fill the environment to its capacity. This was especially true in areas where Norway rats predominated, but where a substantial, though relatively inconspicuous, seed stock of black rats and/or house mice existed.

Personnel and Organization:

The New Caledonia Rodent Control Unit consisted of one naval officer and seven enlisted men. Three of the enlisted men were from the Army Medical Corps working on special duty, and four were Navy Pharmacist's Mates. The base was divided into three control areas with one man assigned to each area. Another man answered daily pest complaints and occasionally assisted the area control men when large

areas were to be controlled. Maintenance of the live animal laboratory and the mixing of poisoned baits for the area control men usually occupied the full time of another man. One man was also detailed to check ships for compliance with rodent control regulations, to aid with the control of rats and mice aboard ship, and to live-trap rats for flea index determination.

Transportation:

Sufficient transportation was of vital importance to a unit of this nature. Large areas must frequently be covered and considerable equipment carried. On New Caledonia, one vehicle was necessary for each unit control man and two more were generally in use in procurement of supplies, checking local daily pest problems, and checking ships. Vehicles used by this unit included three quarter-ton and two half-ton vehicles.

Control Procedure on Land-based Units:

After considerable trial and error, it was found that land-based units on the island were best controlled by dividing these into three separate control areas, each small enough to be handled by one man. Each area at this base consisted of from 30 to 70 units, the number in an area depending upon size of the units, distance from base headquarters, and troop concentration on the island. The area control operator visited each unit once each month doing the necessary control work as he proceeded through the area. Very few areas

required monthly control operations.

At small units, the area control operator usually did all actual control work, using whatever method seemed most applicable to the situation. At larger units, working parties were often requisitioned, given instructions, furnished with equipment, and the entire control operation supervised by the area control operator. Military units on this base were required by regulations to furnish one or more men from their unit to assist the rodent control operator on his regular visits. Some larger units had enlisted men attached to Medical Corps dispensary units who worked full or part time on the control of pests.

Each area operator was required to keep a field record book listing the following data for each unit: (1) date visited; (2) personnel contacted; (3) problem encountered and recommendations made for control and ratproofing; (4) control work done; and (5) results.

Three or four days after control work in any major area, a routine visit was made to determine the results. This was necessary to properly evaluate the work. On small, simple pest control problems, results were not determined or recorded until the area was visited the following month.

By keeping the previously mentioned records, a check was maintained on the efficiency of the individual area control operators and, over long periods of time, an evaluation could be made of the effect of specific types of control measures on the different rodent species under varying conditions.

Ship to Shore Rodent Control:

Prevention of any interchange of rodent populations between ship and shore, and shore and ship, was of greatest importance from the standpoint of both introduction of new species and prevention of disease.

At this base, ship to shore rodent control activities were largely a matter of published regulations. However, it was found necessary for the personnel of the rodent control unit to check all ships docked at wharves and piers for compliance with these regulations. The regulations promulgated by the local unit and enforced at this base, as taken from a base memorandum, are as follows:

(1) Rat shields or disks will be maintained on all lines connecting ships with wharves or other ships. Shields will be maintained at all times, so placed that they effectively prevent the use of such lines for rat travel. Consideration in placing the shields will be given to the ability of a rat to jump from one line to another and thereby avoid such shields.

(2) Light clusters will illuminate bow and stern lines at night.

(3) All landing stages and gangways between ships and wharves will be removed or raised between sunset and sunrise unless a guard is present at all times.

(4) Cargo nets will be removed from the wharf during darkness unless cargo is being worked.

Copies of these regulations, along with other sanitary regulations of the port, were given to ships' masters by port boarding officers. Large conspicuous signs, figure 8, placed at the ends of piers also advertised the existing regulations. Properly placed

rat shields and cluster lights are shown in figure 9.

Rodent control unit members first inspected all docked ships daily at sunset and again two or three hours later. After the second inspection, a report of all delinquent ships was made to the dock officers for enforcement of the regulations. This enforcement was prompt. However, it was usually only necessary to call the attention of the ship's master to the violation to bring about immediate compliance. When inspection of ships was temporarily discontinued, violation of regulations increased. Therefore, constant inspection of ships appeared to be essential to the successful control of ship to shore and shore to ship rodent movement. The daily report form for inspection of ships for rodent control appears as table 1.

Educational Program:

Since New Caledonia served as an important staging base, and military units were constantly leaving the island for forward areas, one function of this unit was the training of designated personnel in each transient unit in the methods and techniques of rodent control. Duration of the course of instruction varied from two days to three weeks depending upon size of the unit, time available, and other circumstances. The two-day short course of instruction was based upon practical demonstration of the various control methods on existing rat populations. When practical, the two to three week

Figure 8. Signs used to call attention to existing port rodent control regulations.

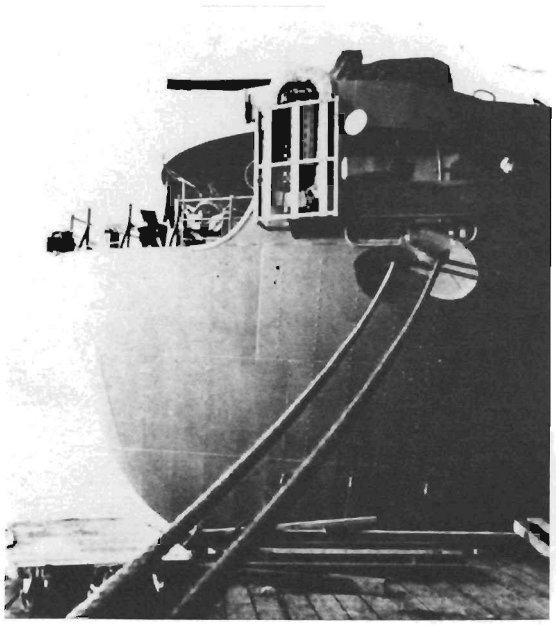

Figure 9. Ship at dock with rat guards and cluster lights properly placed.

Table 1.—Daily Report Form for Inspection of Ships for Rodent Control

MALARIA AND EPIDEMIC CONTROL OFFICE

Rodent Control Division

DAILY REPORT OF INSPECTION OF SHIPS FOR RODENT CONTROL

Date -

Time inspected -

Ships docking at -

Number of ships passing inspection -

Number of ships failing to pass inspection -

NAME OF SHIP	OFFENSE NOTED ON INSPECTION

INSPECTED BY _____

course of instruction covered the following aspects:

Investigation:

- Rodent ecology
- Determination of species
- Collection of scientific specimens
- External parasites of rats
- Flea survey technique
- Rat problem surveys

Control:

- Recommendation for control
- Trapping methods and techniques
- Fumigation methods and techniques
- Poisoning methods and techniques

Equipment and supplies:

- Poisons for rodent control, mixing, handling, uses, and limitations
- Feeder station construction
- Improvising and constructing traps from barrels, cans, and boxes

In connection with training of personnel, two bulletins were prepared by members of the New Caledonia Rodent Control Unit. The first, "South Pacific Rat Control", by W. D. Crabb, A. J. Nicholson, and Jay B. Long, April, 1944, was prepared as a reference guide for rodent control officers and units in the South Pacific Area, while the second, "Rodent Control, South Pacific Area", training manual No. 5 (Crabb and Long), January, 1945, was prepared for distribution to all personnel in the South Pacific Area.

RODENT SPECIES IN THE AREA

Identification of Rodent Species to be Controlled:

As soon as practical after establishing control operations, mammalogists connected with the rodent control unit began collecting series of specimens of the different rodent species including various color phases and age classes. These were carefully measured, essential data was recorded and specimens were prepared as study skin mounts. These were tentatively identified by unit personnel and then forwarded to the National Museum in Washington, D. C., for final determination*. Approximately 225 rodent specimens were forwarded to the National Museum during the first year of unit operation. Many more were sent to other institutions. The writer has a series of skins of the various rodent species in the Oregon State College Department of Fish and Game Management collection.

As previously mentioned, the following rodent species were found at this base: the Norway or brown rat, Rattus norvegicus (Erxleben); the roof or black rat, Rattus rattus rattus (Linnaeus)—with three color phases; the Polynesian rat, Rattus exulans hessnok (Grinder); and the house mouse, Mus musculus connorum (Houck). These species

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* In instances where rodent control is undertaken in a new area without the services of a competent mammalogist, directions for preparation of study skins, scientific data to be recorded, etc., can be obtained from "A Field Collector's Manual in Natural History", Publication 3766, published by the Smithsonian Institute, Washington, D. C., which was specifically prepared for this purpose.

may be distinguished from one another most easily and simply by body size and relative length of tail. Color cannot be depended upon in determining species. The relative length of tail is found by bending the tail sharply forward along the back of the animal and comparing it with the length of the body. A simplified key for identification of these species is found in table 2.

Description*:

Rattus norvegicus, Norway or brown rat

The Norway rat is a fairly large rat, varying in color but usually being some shade of gray brown on the upper parts and gray to whitish gray on the under parts. The line of color demarcation between the upper and the under parts is usually not distinct. The ears are relatively short and narrow; the tail is shorter than the head and body. Size: total length, 40-55 cm.; tail length, 20-25 cm.; hind foot, 4.2-4.5 cm.; ear, 1.4-1.8 cm. Mammary formula: six pairs, three on the chest and three on the abdomen.

Primarily because of frequent reports from military personnel of two pound rats, and rats as large as "small dogs", over 50 of the largest Norway rats taken were weighed. The largest, a pregnant female, weighed 17 ounces. Silver (15, p. 14) lists the heaviest

* Measurements listed include the average of measurements taken by members of the rodent control group on these particular species on New Caledonia, Crabb, Nicholson, and Long (4, p. 3).

Table 2.--Key to Rodents Found on New Caledonia

Length of head and body about 3 inches - House mouse (*Mus musculus*)
Length of head and body about 5 inches - Polynesian rat (*Rattus exulans*)
Length of head and body 6 inches or over:
Tail longer than head and body - Black rat (*Rattus rattus* group)
Tail shorter than head and body - Norway rat (*Rattus norvegicus*)

Norway rat of which the United States Fish and Wildlife Service has record as weighing 25 ounces.

Rattus rattus rattus (and color phases), roof or black rat

This species can readily be distinguished from the Norway rat by size, length of tail, and size and shape of ears. Members of this species are slightly smaller than the Norway rat; the ears are longer and more rounded and the tail is always longer than the combined length of head and body. Three subspecies are usually listed as follows: Rattus rattus rattus, entirely black or sooty black; Rattus rattus frugivorous, brown above and white below, showing a distinct line of color demarcation; and Rattus rattus alexandrinus, grayish brown above and gray below, usually showing no distinct line of color demarcation. Size: total length 43-50 cm.; tail length, 20-25 cm.; hind foot about 4.5 cm.; ear, 2.0-2.3 cm. Mammary formula: almost always five pairs, two on the chest and three on the abdomen.

Although generally classified as distinct subspecies, it was the opinion of mammalogists connected with the New Caledonia Rodent Control Unit that these forms—at least in the South Pacific—were merely color phases and not distinct subspecies. In breeding experiments in the unit laboratory live rat colony, both the gray-bellied R. r. alexandrinus and the white-bellied R. r. frugivorous were produced in the same litter from R. r. frugivorous parents. Johnson (6, p. 3), on Bougainville Island, noted white-bellied R. r. frugivorous and wholly black R. r. rattus in single litters. He found no ecological differences between the various forms. On New

Caledonia, all three color phases were found occurring in the same areas under the same environmental conditions. Of 163 trapped black rats examined on New Caledonia, 113 were R. r. frugivorous, 39 R. r. alexandrinus, and 11 R. r. rattus.

Rattus exulans jessock, Polynesian rat

This rat is much smaller than either of the previously mentioned species and size alone will easily distinguish it from them. Individual animals may vary in color from a uniform dark brown, to light brown above with buff underparts. Size: total length, 12.5-15.2 cm.; hind foot, about 2.5 cm.; ear 1.3-1.5 cm. Mammary formula: four pairs, two on the chest and two on the abdomen.

Mus musculus castaneum, house mouse

This is a tiny species varying in color from dark brownish gray to bright reddish brown above. Underparts are usually gray. Size: total length, about 15 cm.; tail length, about 7 cm.; hind foot 2.2 cm.; ear 1 cm. Mammary formula: six pairs, three on the chest and three on the abdomen.

General Ecology:

New Caledonia appeared to offer extremely favorable environmental conditions for all species of rats and mice found on the island, both in man-made habitat and in feral populations. The mild climate was particularly favorable to year round reproduction as pregnant females were found each month in the year for all species except the Polynesian rat, Rattus exulans jessock, which species was not

found to breed during the winter months of July and August. As no native mammalian predators existed on the island, the feral rodent populations suffered no predation from mammals. Introduced dogs and cats exerted only a minor effect on populations in and around human habitations. Mayr (8, p. 154-155) lists four species of hawks and one owl for New Caledonia. However, only two of these, the white-bellied hawk, Accipiter haplochrous (Sclater), and the Australian goshawk, Accipiter faciatus (Hotmore), figure 10*, were common and these were not abundant. Three stomachs of the white-bellied and two of the Australian goshawk were examined by the writer. All five of these contained rodent remains, apparently of the Polynesian rat, Rattus exulans lessook. It seems unlikely that the few hawks found on the island could have had much effect on the feral rodent population and, obviously, would have had no effect on populations in and around military installations, native villages, and towns.

Extensive sample trapping by members of the rodent control unit throughout practically all parts of the island indicated that the Norway rat and the house mouse were confined in distribution to areas of human habitation and were not found in true feral populations. The Polynesian rat, however, on New Caledonia was strictly a feral species, only one individual having been taken within the boundaries of a military installation. Roof rats were found in both feral and

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* These specimens are part of the writer's collection at Oregon State College.

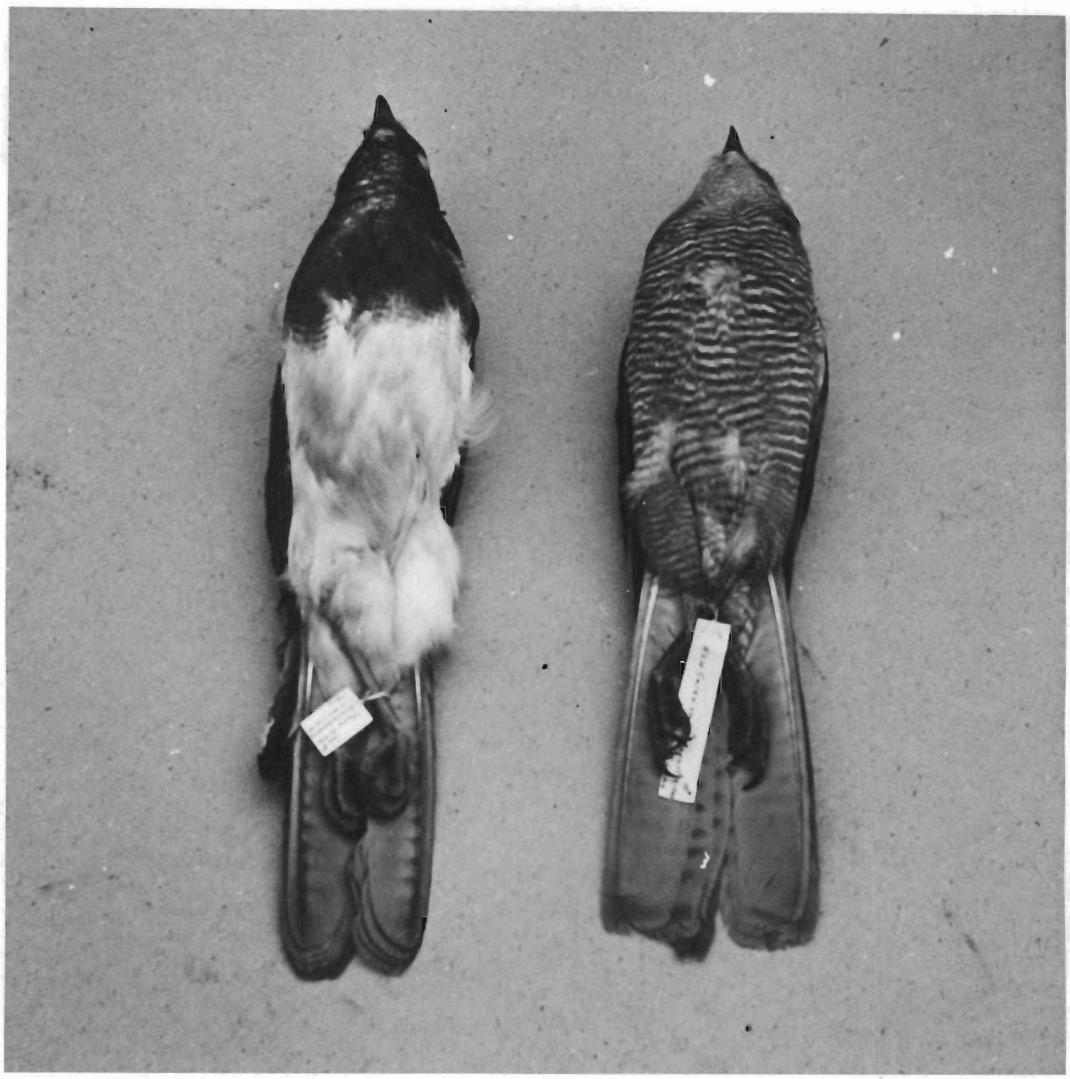

Figure 10. Two common hawks found on New Caledonia, the white-bellied hawk, Accipiter haplochrous (Sclater), and the Australian Goshawk, Accipiter fasciatus (Wetmore).

domestic populations with the bulk of the population being found in the wild state.

Around island towns and military installations, the Norway rat, Rattus norvegicus, was the dominant species. By January, 1945, this rat had been taken through control operations at all but one military installation on the island. This one unit was located approximately 150 miles from Noumea, the greatest distance away of any unit, and was located approximately 50 miles distant from the next nearest military unit. This was one of the few military installations on the island supporting high populations of the roof rat, Rattus rattus. All indications pointed to intraspecific strife with the Norway rat being the dominant species. In no instance were high populations of Norway and roof rats found in the same specific area and in few instances were large house mouse and Norway rat populations found existing together. The tree-living habits of the roof rat, however, --the Norway is a burrowing species which does little climbing-- allowed a small though usually inconspicuous seed stock of roof rats to exist in most areas where the Norway rat was the dominant species. In certain areas such as abandoned forage dumps, roof rats would move in when the Norway rats were taken out by control measures and exhibit an immediate, though usually temporary, population increase. At one particular forage dump, figures 16 and 17, preliminary trapping checks indicated a ratio of fifty Norway rats to ten house mice to one roof rat. The area was poisoned, and trapping checks made before and after poisoning indicated about 86 per cent control success on

the area. Sample trapping on the area three months after control by poisoning indicated a population of about twenty-five roof rats to ten house mice to three Norway rats. Trapping checks eight months after the poisoning showed the Norway rat to have become dominant again, the species ratio being about forty Norway to eight house mice to five roof rats.

The Polynesian rat, Rattus exulans ioassek, was by far the most abundant feral species. Although it was of no importance on New Caledonia from the standpoint of destruction of supplies*, it was found in practically all types of habitat except on the highest mountains where no rat species were recorded. The roof rat was limited in feral populations to areas with abundant tree growths and reached its highest population levels in copra plantations where coconut palms furnished both food and shelter. This rat had penetrated to nearly all parts of the island and was the most abundant rat species in and around most of the inland native villages.

In practically all cases, the house mouse, Mus musculus canacorum, was the first rodent species to make its appearance in newly constructed military installations. Because of the small size of this species, these animals could secrete themselves in packing cases and supplies unloaded from ships or brought in from supply depots and, unless control measures were instituted, would rapidly multiply and become destructive to stored food supplies.

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* Johnson (6, p. 2) reports this species to have been important as pests on Bougainville Island, particularly at camps established in inland areas where other rat species were not present.

Importance:

Although no cases of rodent borne disease occurred on New Caledonia during occupancy by Allied troops, rodents were important as destroyers of food and military supplies and, perhaps, psychologically, to the soldiers from a nuisance and general pest standpoint.

On this base, the Norway rat, because of its high reproductive capacity*, large size, and aggressiveness, was by far the most important rodent species from the standpoint of food and property destruction; however, on the basis of general pest importance to the average individual soldier (and certainly to Army Post Exchanges), the house mouse was most important. Because of its small size and secretive habits, it could live under conditions not tenable to the larger species. Footlockers, drawers in cabinets, and crevices in tent floors, all formed homes for the house mouse and the almost universal habit of soldiers of keeping candy, cookies, and fruit in tents and barracks provided an abundant food supply. A large part of the time expended by the rodent control unit in control operations was directed against this species.

Control operations on board ships soon indicated that the roof rat, probably because of its climbing habits, was much better adapted to conditions on shipboard than the Norway rat. In practically all cases where control operations were carried out on ships, the rodents

* Using the figures of 10 young per litter and 12 litters per year and ignoring the death rate, Silver (14, p. 4) estimates that the progeny from one pair of Norway rats would exceed 350,000,000 in three years.

encountered were the roof rat, Rattus rattus sp. and the house mouse, Mus musculus sp. When abundant, rodents appeared to be of considerably greater economic and pest importance on board ship than on land-based activities.

Although the Polynesian rat was not of importance in destroying food and other supplies on this base, as it was found only in wild populations, it was still of great potential importance from a disease standpoint for, as pointed out by Johnson (6, p. 5), "In the Pacific war zone, rats implicated in unpredictable outbreaks of an endemic disease such as scrub typhus are more likely to belong to native wild species than to commensal species that have a long history of human association..."

Following is a partial list of the more important diseases known to have been carried by rats:

Bubonic Plague:

> Bubonic plague is a highly fatal disease transmitted from an infected rat to man by the bite of a rat flea or, in the pneumonic type, by personal contact, usually with the bodily discharges from an infected person.

Typhus Fever (murine or endemic):

> Like plague, this disease is transmitted from an infected rat to man by the bite of the rat flea or tropical rat mite.

Japanese River Fever (Scrub Typhus):

> This disease is transmitted to man by the bite of a larval mite. Rats and mice serve as hosts for these mites.

Infectious Jaundice (Weil's Disease):

Man contracts this disease by ingesting food or water contaminated with the urine or feces of infected rats, or through the skin by direct contact with the body or excretions of an infected mammal.

Rat Bite Fever:

This disease is transmitted to man by the bite of an infected rat*.

Tularemia (Rabbit Fever):

This disease is transmitted to man by direct contact with the body of an infected mammal or by the bite of a blood-sucking insect or tick which has previously fed on an infected mammal.

Rabies:

This disease is transmitted to man by the bite of a rabid mammal.

Trichinosis:

Man is infected with this disease by eating improperly cooked pork containing the cysts of a roundworm. Rats do not transmit this disease directly to man but are an important factor in spreading the disease among swine, the disease being spread by swine feeding upon infected rats.

Food Poisoning (Salmonella infections):

One of the several means by which man may contract this disease is by eating food which has been contaminated with pathogenic organisms carried on the feet or fur of rats and mice.

Rat populations carrying any of the previously mentioned diseases may show no outward signs of infections. If at any time

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* On New Caledonia, numerous reports were received of military personnel having been bitten by rats.

numbers of sick or dead rats are found within or near military installations, this fact should be immediately brought to the attention of Epidemic Disease Control Units or any available medical or sanitation officer.

FUNDAMENTAL RESEARCH

Many problems confront the personnel of a rodent control unit in a new area. The ultimate success of any control campaign is influenced largely by the intelligent application of data acquired through basic research or investigation. Much of this data may be obtained while personnel are engaged in active control work. Problems to be investigated and important considerations influencing application of research data to control methods are discussed as follows:

Food Habits and Food Preferences:

The success of any trapping or poisoning campaign depends, to a considerable extent, upon the selection of a bait having a high preference or acceptability rating to the rodent species or combination of species in the population to be controlled. Other factors affecting the choice of the bait to be used include availability and rate of spoilage or decomposition of the bait material.

On New Caledonia, investigations began with an attempt to find a bait or baits which would be readily available, remain fresh and attractive for several days, and have a high preference rating for

all rodent species to be controlled. Bait preference tests were made on both free populations and on live-trapped, caged laboratory animals. The general procedure of investigation and the number of trials were limited by time, manpower, and kinds of bait available.

The procedure in laboratory tests was to expose the eight different baits chosen to the various species of caged rodents and to determine preferences by measuring the amounts of the different baits eaten over a period of time extending from 3 p.m. to 8 a.m. Four ounces of each of the selected baits were exposed to individually caged animals in tin containers having eight separate compartments. Papers were placed under the cages to collect any bait materials spilled by the rodents during feeding.

Field trials were carried on in conjunction with normal control operations and consisted primarily of determining bait acceptance and preference through trapping trials. Two or more baits would be tried, these divided equally among the total number of traps used. The number of rodents of the various species taken by the different baits would then be recorded in the control operator's log book. Over a period of several months, results from numerous field trials presented a clear picture of bait preference and acceptance by the various species. These results closely paralleled those obtained from experiments with caged animals. Results of combined experiments are listed in table 3. No attempt was made to record results beyond the general classifications of excellent, good, poor, and undetermined.

Table 3.—Comparative Values of Available Baits for Rats on New Caledonia

Kind of Bait	Norway Rat	Black Rat	Polynesian Rat
Fresh coconut	Excellent	Excellent	Excellent
Fresh meat	Excellent	Excellent	Excellent
Peanut butter	Excellent	Excellent	Excellent
Cheese	Poor	Poor	Undetermined
Salmon	Poor	Poor	Undetermined
Corned beef	Poor	Good	Undetermined
Oatmeal & peanut butter	Excellent	Excellent	Excellent
Copra (dried coconut)	Excellent	Poor	Undetermined

On New Caledonia, fresh coconut proved to be the best bait material for both poisoning and trapping control operations. A combination of rolled oats and peanut butter also met the qualifications of a good bait but did not prove to be quite as attractive to all rodent species as did fresh coconut. Fresh meat proved to be very attractive to both Norway and roof rats but, in the hot, humid climate of New Caledonia, decomposed very rapidly under field conditions and frequently remained attractive to rats for only a few hours. Contrary to popular opinion, cheese proved to be a poor trap bait for Norway and roof rats.

Although no laboratory tests were made to determine the food preferences of mice, field trials indicated that fresh coconut, chocolate candy, and various nut meats were excellent trap baits and that fresh coconut or specially prepared rolled oats were good poisoned bait materials.

Indications of Rodent Abundance and Species Composition:

On New Caledonia, it early became apparent that the success of the rodent control campaign was influenced by the ability of the area control operators to evaluate accurately rodent abundance and species composition at each military installation visited.

During the first few months of operation of the rodent control unit, errors in evaluating indications of abundance and species composition resulted in much misdirected and inefficient control procedure. In certain instances, extensive poisoning campaigns were

instituted in areas where only a few animals were present and where these might have been controlled by trapping by resident personnel of the military installation. In other cases, traps were set for mice in areas where the Norway rat was the species causing damage. Considerable waste of poison and bait materials resulted from using a poison which would have little control effect on the particular species most abundant in the area. Examination of the data compiled in the area operators' log books and evaluation of control operations by trapping checks and other methods eventually resulted in evolving a pattern of procedure which eliminated many of the early errors.

When visiting a military installation, the area control operator would report to the medical officer at the dispensary, on whom rested the responsibility for rodent control in the individual unit. Visits would then be made to the kitchen or galley, the food storage buildings, and post exchanges, and, finally, the living quarters of the troops. Routine questioning of personnel usually indicated whether a problem of rodent pest or rodent damage existed. Such information, however, was often found to be inaccurate as to numbers and species of animals present and it was always necessary for the operator to check the area carefully for rodent sign and actual damage to food or other supplies.

The amount, freshness, and shape and size of rodent droppings were usually found to indicate best both numbers and species of rodents present. Wherever a rat or mouse feeds or rests, it

defecates. Little experience was necessary to determine whether droppings found were fresh or old. Species composition could usually be accurately determined by droppings examination. Droppings of the Norway rat were large in diameter and blunt on both ends, while droppings of the roof rat were slightly smaller in diameter, longer, and sharply pointed on both ends. Droppings of the house mouse could be easily identified by their very small size. As mentioned previously, the Polynesian rat, the droppings of which were shaped like those of the Norway rat only smaller, was not found on New Caledonia within military installations.

Examination of extent and kinds of damage to food and materials also aided in determining species numbers and, to a limited extent, species composition. Rat damage could be distinguished from that caused by mice by the appearance of the incisor tooth marks.

Where Norway rats were living outside or under buildings or tent platforms, the number of underground burrows and trails through the vegetation, figure 11, gave additional evidence of abundance.

Personnel of the units visited would sometimes mention seeing rats in trees or running along the rafters of buildings or electric light wires. In all cases, these animals proved to be roof rats as the Norway rat, while able to climb well, was not found

Figure 11. Forage dump showing rat trails (above) and burrows (below).

in trees and seldom above the first floor in buildings. Destruction of food in footlockers and papers in file cabinets could usually be attributed to house mice as these were the only rodents small enough to obtain access through cracks and similar small openings.

Where time permitted, it was possible to set a number of snap traps, using baits attractive to the different species and to determine relative abundance and species present by the number and kinds of rodents caught. Experienced area control operators seldom found it necessary to use the trapping method of sampling rodent populations.

Sex and Age Determination and Interpretation of Data:

While of less importance from a control standpoint than information on abundance and species composition of rat populations, data were kept on sex and age classes of rodents of different species. Such determinations proved of importance in finding the predominant sex and age groups, ascertaining whether a definite or limited breeding season existed, and in determining whether or not the rodent populations were in vigorous, healthy condition. In most species of rats and mice, the sex ratio at birth appears to be approximately equal*. If a large number of non-breeding females

* Records from field notes list the sex ratio of 203 juvenile and sub-adult Norway rats taken in control operations on New Caledonia as 107 males to 96 females.

or a preponderance of adult males is found, then the population may normally be said to be decreasing. Presence of a large number of adult breeding females or of an equal sex ratio with few non-breeding adults and many juvenile and sub-adult animals usually indicates a healthy population, increasing in numbers.

As previously mentioned, on New Caledonia lactating or pregnant females of the three important rodent species were found during all months of the year. Very few non-breeding females were found at any time and most rodent populations appeared to be in a vigorous, healthy condition.

No difficulty was encountered in sexing breeding animals. The testes of adult breeding males were descended and could be easily seen projecting out from the body at the base of the tail. On breeding females, the teats were evident on the abdomen. Sex was somewhat more difficult to determine on non-breeding and young animals—testes were often not descended on males and in females teats were not always evident. Female rats, however, have three external openings while males have but two. In female rats, the anal opening is found at the base of the tail. The vaginal opening is approximately 1/8-inch anterior to the anal opening and immediately following the vaginal opening is the urethral opening. Only two openings are present in the male—the anal and the urethral openings. These are located in the same regions as in the female.

Age proved to be more difficult to determine than sex. It was possible, however, after considerable practice, to place

readily the animals examined into the age groups of juvenile, sub-adult, and adult. This grouping was most easily made by observing the condition of the hair. Juvenile animals were generally darker and more uniform in color than adults and the hair was soft with no guard hairs being apparent. Sub-adults were frequently nearly as large as adults but the hair still had a soft appearance. Guard hairs were present but were short and not coarse and prominent as in adults. Sub-adults were not as uniform in color as juveniles and a moult pattern might sometimes be observed. Sub-adults were in a non-breeding condition. The guard hairs of adults were coarse, long, and prominent. Adults were usually in breeding condition and the testes of males and teats of females might be seen easily. Adult females were usually either pregnant or lactating and the testes of adult males were usually descended and prominent.

External Parasites and Flea Survey Technique:

As many of the important rodent-borne epidemic diseases are transmitted from infected rats to man by the bite of a rat flea, one of the first projects undertaken upon activation of the New Caledonia Rodent Control Unit was a flea survey to determine how heavily the various species of rats were infested with rat fleas. Rats were live-trapped, killed individually by ether or chloroform fumigation in a quart glass jar, and the fleas were combed from the fur by the use of a fine-toothed comb. According to Crabb and

Nicholson (3, p. 216), during the first three months of control operations, 340 rats were obtained alive, killed, and searched for fleas. An average of 3.9 fleas per rat of the species Xenopsylla cheopis (Rothschild) was found on this collection of rats. No bacteriological examination was made on the rats or fleas collected. Some twelve months later, after the total rat population on the island had been greatly reduced by control operations, a second flea survey was undertaken. A total of 73 rats were live-trapped, killed, and searched for fleas; the average infestation was .9 fleas per rat. This led to some speculation as to the relation of the low rat population to the low infestation of fleas, when compared to the first survey when both rat numbers and flea infestation per rat were greater. The low rat population and the low incidence of fleas found in the second survey seemed to indicate that the control operations of the unit had markedly reduced the possible disease potential of the rodent population on the island.

Both flea surveys progressed slowly due to the difficulty encountered in live-trapping both Norway and roof rats. It was not possible to use dead traps as the fleas would leave the rat's body as soon as the body temperature dropped. Of the several types of live traps tried, the wire cage trap, figure 12, proved most successful. Used in the same areas, however, with the same type bait, these proved only about 10 per cent as effective as the common wooden base snap trap, figure 13. It was particularly

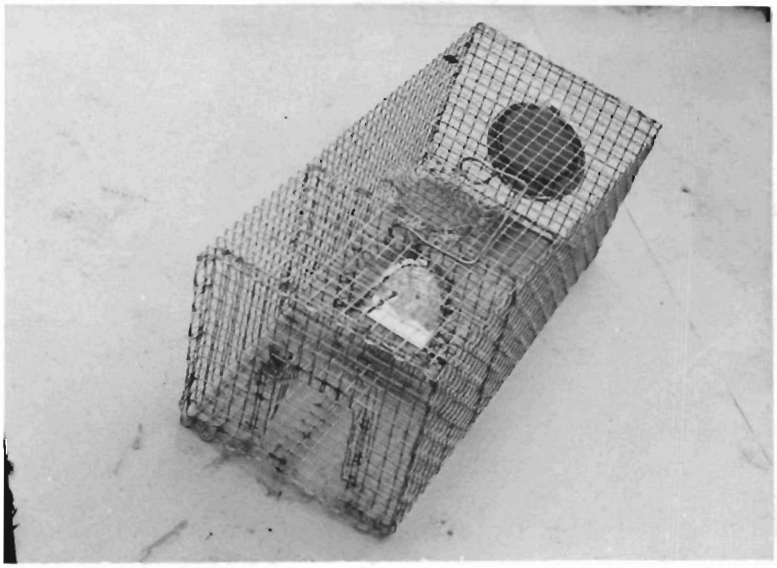

Figure 12. Wire cage trap used in live-trapping rats for flea survey.

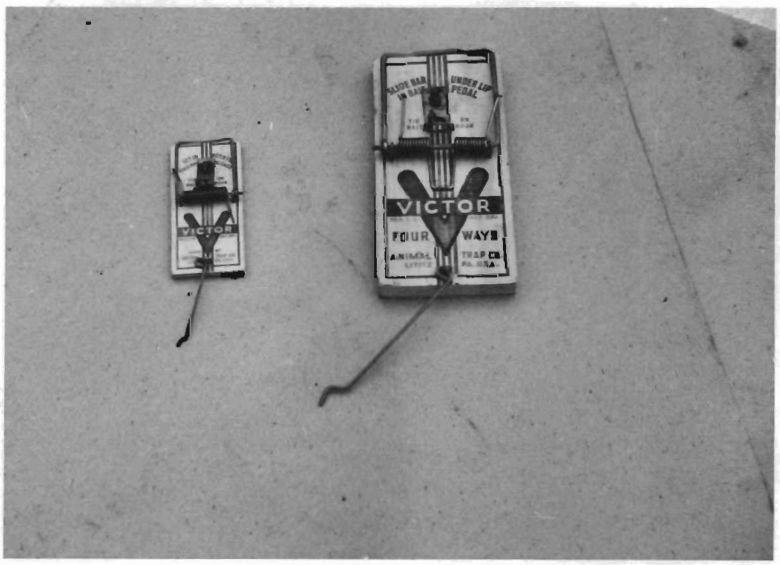

Figure 13. Common wooden base snap traps.

difficult to live-trap rats during the second flea survey due, probably, to the low over-all rat population. An average of only one rat per night per 25 traps was taken during this period. Live traps were found to be most effective when set in dark places near rat runways or burrows and covered with burlap sacks or leaves and brush.

Evaluating Success of Control Operations:

On New Caledonia, the ability of the area control operators to evaluate success of the various control activities improved rapidly with experience. Inexperienced operators, unable to determine accurately percentage of success or failure of control activities, wasted much time, manpower, and supplies by continuing to use inefficient control methods. Later, after a pattern of procedure for determining success of control operations had been evolved, inefficiency and waste of supplies were reduced to a minimum and only the control methods that produced best results were employed.

From one to several of the following methods of evaluating success of control operations were employed after completion of any control activity at military installations: trapping check, feeder station check, damage control check, abundance and freshness of droppings found, continued use of burrows and trails, number of rodents seen by military personnel, number of poisoned baits taken, and number of animals found dead or in traps.

In field trials to evaluate the results of new poisons on the various rodent species on New Caledonia, and whenever an actual percentage figure of control was desired, the trapping check method of determining results appeared to be most accurate.

Procedure in using the trapping check as developed on New Caledonia was as follows: before starting control measures, 100 to 500 snap traps were baited and set in the area*. These were checked the following morning and the number of rodents of different species caught were enumerated. Control measures, usually poisoning or fumigating, were instituted on the area. A few days later, the same number of traps previously used were set in the same places using the same bait. Results were checked the following morning. By comparing the number of animals caught before control with the number caught after control, an actual percentage figure of success could be determined. For example, if 100 rats were caught before control and 10 after control, the percentage of success would be 90 per cent, or 90 per cent of the animals in the area would have been considered killed. Use of the trapping check as a method of evaluating control success was limited by the following factors:

a. This method requires a considerable expenditure of time and manpower.

* Traps were usually set in straight lines through the area a fixed number of feet apart. This was essential if all traps were to be recovered and if trapping procedure was to be constant both before and after control.

b. The area selected must be large enough and have a sufficiently high rat population so that the number of animals caught by trapping will not noticeably affect the total population numbers.

c. Care must be exercised that trapping procedure is constant both before and after control if results are to be considered accurate.

d. Weather conditions during the two trapping nights should be similar as a high wind or heavy rain will spring many traps if these are properly set.

The feeder station check method of determining control success had the definite advantage of requiring a minimum expenditure of time and effort. Probaiting, by employing feeder stations, figure 14, proved to be one of the most effective techniques for control of rats at military installations located within the city limits of Nemea. Fresh, unpoisoned bait was placed in the feeder stations and the supply was replenished daily until the rats learned to visit the stations for food. Usually within two weeks after installation, the total nightly food consumption at these feeder stations would level off as the maximum number of rats in the area began to use the feeder stations. At this time, poisoned bait was substituted for the unpoisoned bait and a high percentage of the rats were usually killed. After approximately 48 hours, the poisoned bait was removed and replaced by unpoisoned bait. By comparing the total amount of unpoisoned bait being taken at the

Figure 14. Two types of feeder stations or bait boxes easily made from available materials.

feeder stations, a few days after poisoning, with that consumed before poisoning, some idea of the success of control might be had. However, it is believed by the writer that any rats having received a sub-lethal dose of poisoned bait would not again use the feeder stations. In laboratory tests with caged animals, it was demonstrated that animals having received a sub-lethal dose of red squill, barium carbonate, or ANTU rat poisons would not only refuse to take again baits containing these rodenticides but would usually refuse unpoisoned food which had been used as bait material in the original tests.

At most small military units or installations, the routine check on success of control operations consisted of determining if rodent damage to food or supplies had been eliminated and if unit personnel still found any evidence of rodent infestation. Elimination of rodent damage was usually considered an indication of successful control.

Determination of the amount of fresh rodent sign found not longer than two weeks after control operations always served as a good method of determining the success of a control operation. Experienced area control operators, when revisiting a recently controlled area, would attempt to remove all rat droppings from certain areas and to fill all burrows with dirt. If no burrows were reopened and no fresh droppings were found when the area was again visited, the control could usually be considered satisfactory.

Two methods often suggested for determining the success of poisoning control procedure are amount of poisoned bait eaten and number of dead animals found above ground. On this base, neither of these proved to be of real value in determining the success of control measures. Except when the rodenticide 1080 was used, very few dead rats were found above ground. Trapping checks frequently indicated high percentages of control success when the average observer might have considered the operation a failure because of the few dead animals actually found. In normal control operations where poisoned baits were used, the amount of bait taken proved of little value in determining control success. In military rodent control operations, volume or cost of bait and poison used is usually not of the same proportionate importance as to a private pest control operator. On New Caledonia, it was found that most efficient results were obtained by saturating the areas to be controlled with poisoned baits so that every rat would have an opportunity to come in contact with a poisoned bait. Under such procedure, trapping checks have indicated excellent control results when only two to five per cent of the poisoned baits were taken.

MODIFICATION AND APPLICATION OF CONTROL MEASURES

Environmental Control:

The potential rodent population density in any area is mainly

dependent upon the food and shelter available. In New Caledonia, it was found that if limitation of food and shelter for rodents was considered in establishment of a military installation, rodent pest problems could be largely avoided. When American forces first arrived on New Caledonia, camps, supply depots, and food storage areas were set up without any apparent consideration being given to limiting rodent food and shelter. Consequently, ideal conditions were often established for rodent infestation and spread. A good example of such a food storage area is illustrated in figures 15 and 16.

After activation of the New Caledonia Rodent Control Unit, an attempt was made to impress upon the officers in charge of incoming military units the importance of considering limitation of food and shelter for rodents when constructing new camps. When proper steps were taken to control the environmental conditions affecting rodent population densities, few of the military installations suffered serious rodent infestation and resultant pest problems. On the other hand, when units were established with no regard for limiting favorable conditions for rodents, pest problems always occurred and frequent control by poisoning, trapping, or fumigation proved necessary to reduce rodent populations. At such units, monthly control procedures were sometimes necessary.

The following principles were set up by Grabb and Long (7, p. 5) as a basis for rodent control by limitation of favorable

Figure 15. Military forage dump area providing ideal cover and food for rats.

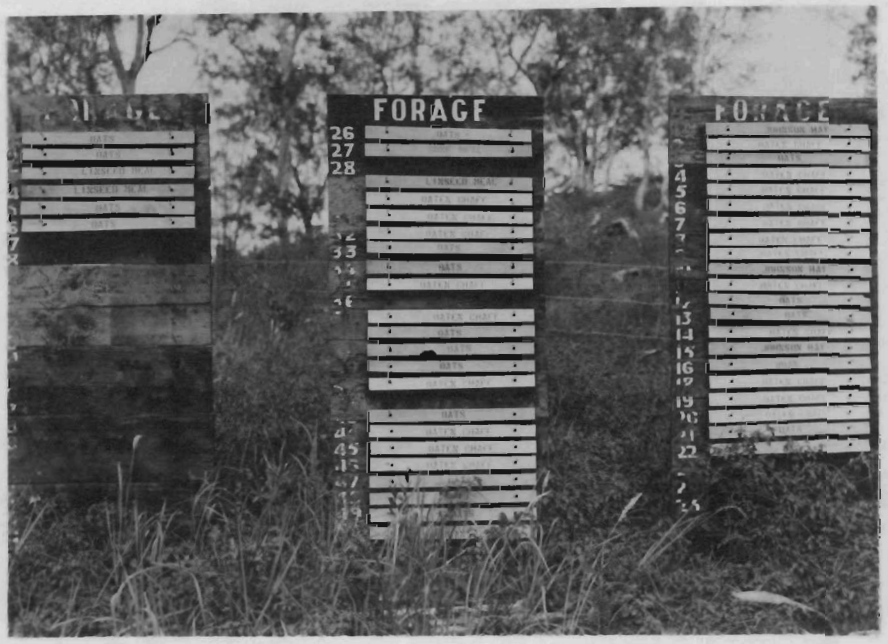

Figure 16. List of foods contained in forage dump.

environmental conditions at military installations:

Limitation of rodent shelter:

(1) All wooden floored buildings should be raised at least 12 to 18 inches above the ground, figure 17.

(2) Concrete floors should be placed under mess halls and food storage buildings, figure 18.

(3) Flies on double-roofed tents should be supported at least six inches above the main roof, figure 19.

(4) All trash and rubbish should be removed from camp areas and then buried or burned, figure 20.

(5) Whenever possible, underbrush should be removed for at least 300 yards around the perimeter of the camp area.

(6) Grass and weeds should be cut short about camp.

Limitation of rodent food supply:

(1) All garbage cans should be kept covered and placed on a platform raised two or three feet above the ground, figure 21, or, if possible, in a screened enclosure, figure 22.

(2) All sewer drains should be made inaccessible to rats.

(3) Food supplies should be stored in rat-proof buildings or on shelves raised at least two feet from the ground, figures 23, 24, and 25.

(4) Mess halls, galleys, and food storage buildings should be rat-proofed, with particular attention being given to fittings of doors and windows, sewer drain openings, and

Figure 17. Tents properly constructed with wooden floors raised at least 12 to 18 inches above the ground.

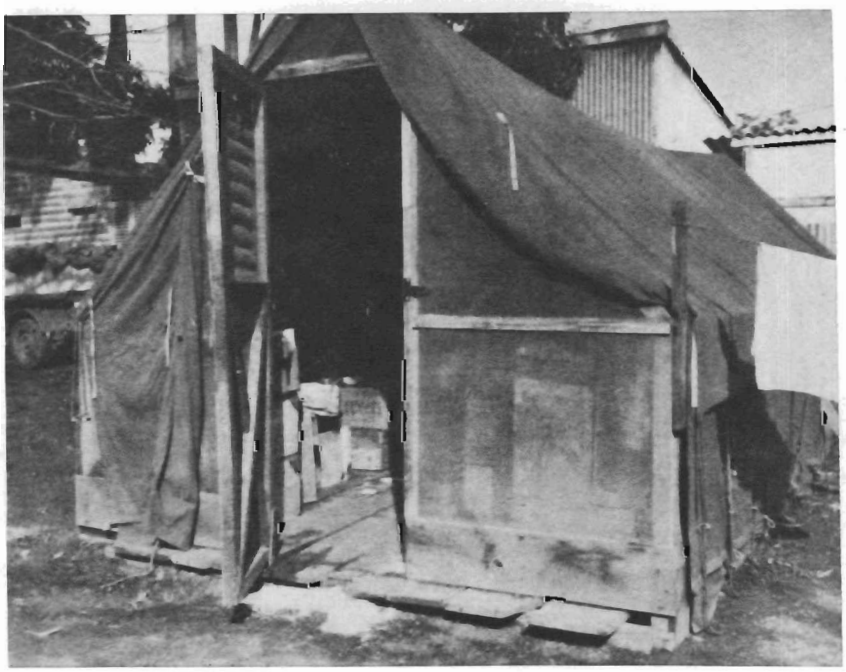

Figure 18. Improperly constructed food storage tent.

Figure 19. Double-roofed tent with properly raised fly, eliminating possibility of rodent shelter.

Figure 20. Garbage disposal trench. Fire destroys burnable material and the remaining debris is covered with dirt by bulldozers.

Figure 21. A simple, easily constructed garbage platform which effectively limits rodent food supply.

Figure 22. Enclosed, rat-proof garbage hut. Screening aids in fly control as in rodent control.

Figure 23. Improper method of storing supplies. Boxes piled together on the floor create excellent rat harbors.

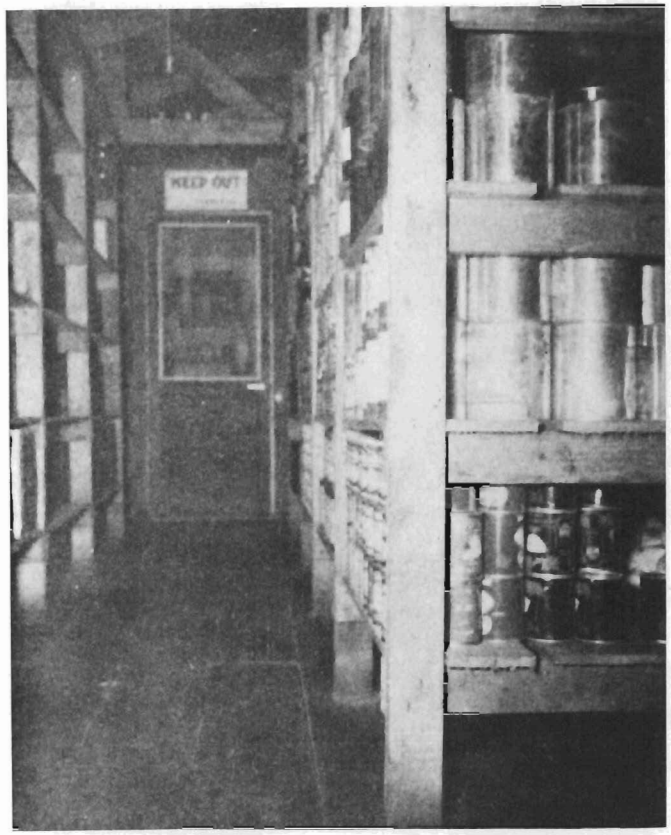

Figure 24. Proper method of storing supplies. Rat harbors are eliminated.

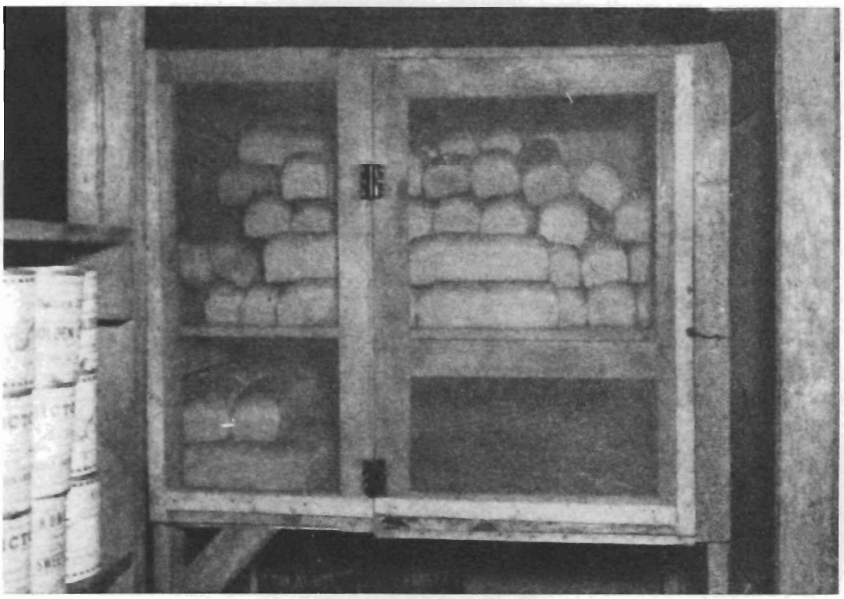

Figure 25. Proper method of storing baked goods in buildings difficult to rat proof.

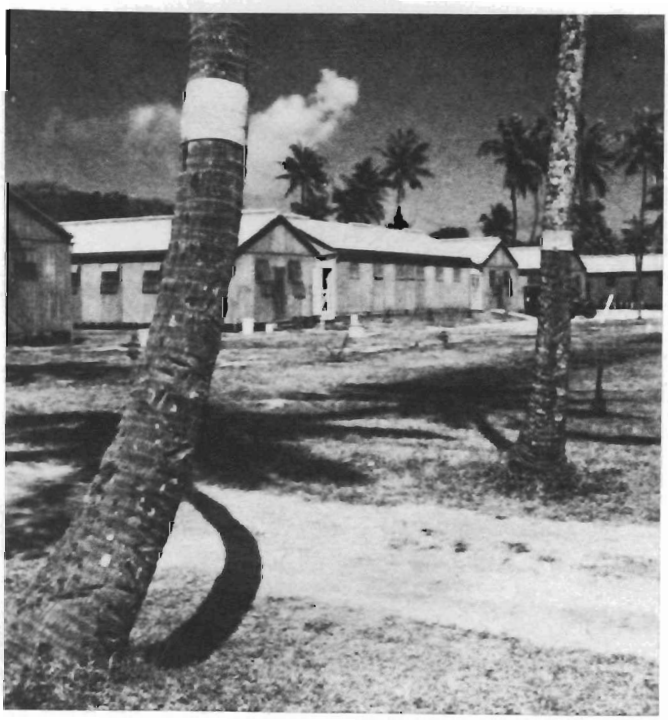

Figure 26. Metal rat bands properly placed on coconut palms.

entrances for electric lines and water pipes.

(5) Personal foodstuffs such as candy, cookies, and fruit should be stored in rodent-tight containers.

(6) Garbage should be disposed of in an area removed from the camp site. Garbage should be burned and the remaining cans, bottles, etc. should be buried.

(7) Where installations are established in coconut groves, fallen coconuts should be picked up from the ground and metal rat bands*, figure 26, 7 to 10 inches wide, should be placed around coconut trees.

Raising wooden floored buildings 12 to 18 inches above the ground virtually eliminated rat shelter under these structures as rats did not feel secure under structures where light penetrated. Camp areas with raised wooden tent floors were virtually free of Norway rats, although a few mice and tree-living roof rats were sometimes found in such areas.

Placing of any wooden floored structure on the ground invited infestation of Norway rats and house mice. The placing of concrete floors under food storage and mess halls largely eliminated rodent shelter. Any animals burrowing under the edges of the concrete flooring were easily and quickly controlled by fumigation.

In the South Pacific, it was the general practice to insulate tents against high temperatures by supporting a fly above the

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* Rat bands may be easily constructed from number 10 or larger tin cans.

regular tent roof. When edges of the fly were allowed to drop against the main roof shutting out the light, roof rats would often find shelter between the fly and the tent roof. When the fly was properly supported on all sides and the light allowed to penetrate, rat shelter was eliminated.

Obviously, the removal of all rubbish piles from camp areas and the cutting of grass and weeds was essential to the removal of rat harbors. If feasible, in non-combat areas where campsite camouflage was not important, the removal of trees and underbrush around the perimeter of the camp area was considered desirable.

Considerable effort and planning was necessary to remove sources of rodent food in and around military installations. In temporary camps, the construction of a raised platform for rodent tight garbage cans resulted in removal of a major rodent food supply source. Such a platform should be constructed away from rodent shelter and the surrounding area should be kept clean at all times. At semi-permanent camps, the construction of a screened, rat-proof garbage hut was desirable. The screening aided in fly control as well as in rodent control.

Proper storage of food and other supplies on shelves or platforms raised above the ground eliminated much of the damage from Norway rats, as well as limiting rat shelter, which was provided whenever sacks and boxes were stacked on the floor. Ratproofing of mess halls and food storage rooms should be considered at

semi-permanent installations. On New Caledonia, it was conclusively demonstrated that rat-proofing, coupled with proper food storage practices, prevented practically all of the damage from rats and definitely reduced damage from mice. A certain amount of mouse control was found to be necessary in practically all food storage rooms as, despite the best efforts of all personnel concerned, mice would be brought in secreted in sacks, boxes, and crates of food supplies. Due to their small size, these animals would utilize cover not adapted for use by the larger rats and, in the absence of control, would soon begin to cause serious damage to food and other supplies.

Efficient garbage disposal proved early to be of utmost importance in controlling rodent populations. On New Caledonia, the efficient methods developed for garbage disposal of burning and burying, practically eliminated food or shelter for rats from this source.

On this base, house mice proved to be of considerable pest importance to soldiers in tent areas. These tiny animals found a ready food supply in the candy, cookies, and other food usually kept in footlockers and desks by the soldiers and, occasionally, damaged valuable equipment in their search for nesting material. In areas where soldiers could be induced to keep food in rodent tight containers, the mouse pest problem was slight. However, it proved difficult to get the individual soldier to cooperate by properly protecting foodstuffs; therefore, control measures were

often necessary.

On New Caledonia, many military installations were established in coconut groves as these areas required little clearing of underbrush and the trees provided some shade. In all such areas, a native population of roof rats existed, living and nesting in the trees and feeding on the fallen coconuts. Damage from these animals could be prevented by proper rat-proofing and food storage methods but these animals would forage around the tent areas at night and their presence presented a definite disease potential. Population numbers of these animals could be greatly reduced by removing all fallen nuts and by placing rat guards, figure 26, on the trees. Thus, when both food and shelter were eliminated, these animals either left the camp area or quickly succumbed to control measures.

On New Caledonia, food and shelter appeared to be the only important limiting factors operating on the rodent populations. As mentioned previously, predation was of very limited importance. Wild rodent populations suffered from predation by hawks and owls and commensal populations, from domestic dogs and cats which were numerous around practically all military installations. However, on this base, despite popular opinion to the contrary, in no instance did dogs or cats, however numerous, succeed in controlling rodent populations where conditions of food and shelter were favorable. Dogs and cats were usually well fed and only occasional individual animals possessed any desire to hunt. Actually, on New

Caledonia, dogs and cats proved more of a hindrance than an aid in rodent control as it was frequently necessary to modify control procedures to prevent their destruction when poisoned baits were used.

Disease and parasitism are important limiting factors affecting animal populations of high density. At no time did these factors appear as limiting influences on rodent populations on New Caledonia.

Inter-specific strife proved to be a factor in determining the specific makeup of rodent populations but did not appear to affect population densities greatly. Intra-specific strife was not noted by the writer as occurring on New Caledonia, probably because in few instances did rodent population densities approach the environmental saturation point.

Fumigation:

On this base, fumigation as a control method had only a limited usefulness, as it was found to be effective on only one species--the Norway rat--and then only under certain specific conditions.

The only fumigant available to the Armed Forces was calcium cyanide dust* and, on New Caledonia, dusting equipment consisted of somewhat inadequate, small, hand-operated pumps, figure 27.

* Commonly known by the trade name "Cyanogas".

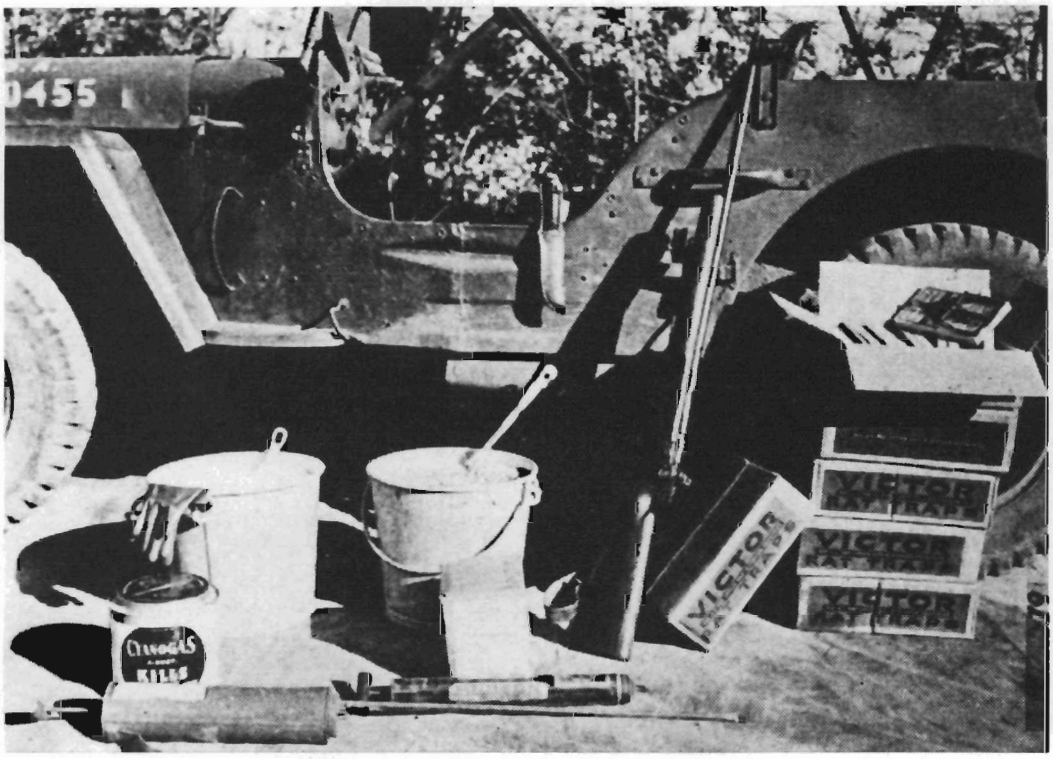

Figure 27. Equipment carried by area control operator.

Calcium cyanide dust gives off hydrocyanic, or prussic, acid gas on contact with the moisture in the air. This gas is extremely poisonous, being destructive to all animal life when proper concentrations are obtained.

The Norway rat, being by habit a burrowing species, could be satisfactorily controlled by fumigation where bank burrows or burrows under cement walks or building foundations were found. Best results were obtained using a two or three man crew in fumigation control procedure. One man would force gas into a burrow with the dust gun while another man stood ready with a bucket of mud or earth to close any other burrows or openings from which the gas might escape. It was found advisable to have a third man armed with a club ready to dispose of any rats attempting to escape from the burrows being fumigated. After completion of fumigation, all remaining opened burrows were filled with earth. By checking the number of reopened burrows the following day, an accurate check could be made on the effectiveness of the control. In the most extensive field trial made at a native "Kanaka" labor camp, 102 bank burrows were fumigated and the openings closed. On checking two days later, ten of the burrows were found to have been reopened, indicating approximately 90 per cent control success.

Because of inadequate pumping equipment available, ineffectiveness on non-burrowing species and because of possible danger to personnel, fumigation was used only to a limited extent on New Caledonia and only by experienced members of the rodent control

unit. The following precautions, as listed by Silver and Carlough (15, p. 19, 20), were carefully adhered to: do not transfer dust from containers to dust guns indoors; avoid breathing gas fumes; wash hands after using dust; after filling dust guns, tightly seal container to prevent deterioration; be sure to empty dust guns after use; store dust containers in a safe place.

Trapping:

Although not as effective as a control method in rapidly reducing high rodent population densities as poisoning, and requiring much more time and labor to secure equal control results, trapping still proved important on New Caledonia under the following conditions:

(1) Where the use of other control methods such as poisoning and fumigation proved impractical.

(2) Where small pest or damage problems involved control of only a few animals.

(3) Where pest or damage problems were caused by house mice, which species proved most vulnerable to control by trapping.

(4) In removing the few animals remaining on an area after control procedure using other control methods.

(5) As a continual suppressive control measure--to be applied by designated personnel of each military installation on the base.

(6) As an aid in sampling an area for species composition and population density before applying other control methods.

(7) In use of the "trapping check" method of determining control success after application of control measures.

(8) In making traps available to the native population of the principal city, Noumea, in an effort to cut down the over-all rat population at this port.

As previously mentioned, in areas where protection of domestic animals and children proved to be of importance, only red squill could be employed safely as a rodent poison. Repeated use of red squill on a rat population resulted in diminishing control returns as certain animals obtained sub-lethal doses or became too suspicious to take baits prepared with this poison. Under such conditions where house mice were implicated as the species to be controlled, the use of red squill in poisoned baits resulted in negligible control as mice did not take red squill baits readily. Under either of the above conditions, trapping was indicated as the preferred control method. Whenever rats and mice were poisoned, and regardless of the specific poison used, a few animals would usually die in inaccessible places, and the resultant odor from their decomposing bodies became extremely unpleasant. Thus, in such areas as living quarters, post exchanges, and food storage depots, when control was considered necessary, trapping was first attempted and other control measures used only if rodent population

numbers were not reduced.

After rodent population numbers had been reduced on an area, constant trapping by designated resident personnel of the unit would usually prevent rapid rodent reinfestation and preclude the re-use of other control measures such as poisoning and fumigation. Frequently, officers aboard ship offered a reward for each individual rat caught. This proved to be an excellent method of stimulating interest in trapping by enlisted personnel and probably, in certain instances, resulted in keeping rodent numbers low.

Traps available to the Armed Forces on New Caledonia consisted of the common wooden base snap traps and wire cage traps, figures 12 and 13. Cage traps were used only for securing live animals for laboratory use and for flea surveys as field trials indicated this type trap to be much less effective than the common snap trap.

During the first five months of operation of the New Caledonia Rodent Control Unit, mouse traps were not available. It was found, however, that the larger rat traps could be used for mice if one side of the tension spring was removed from the bail, figure 28. This decreased the amount of tension on the bait pan necessary to spring the trap. When care was used in setting traps lightly, excellent results trapping mice were obtained.

As stated before, the success of trapping as a control measure depended, to a great extent, upon the proper choice of bait used. Bait preferences of rodents on New Caledonia, as determined through field trials and feeding tests with caged animals,

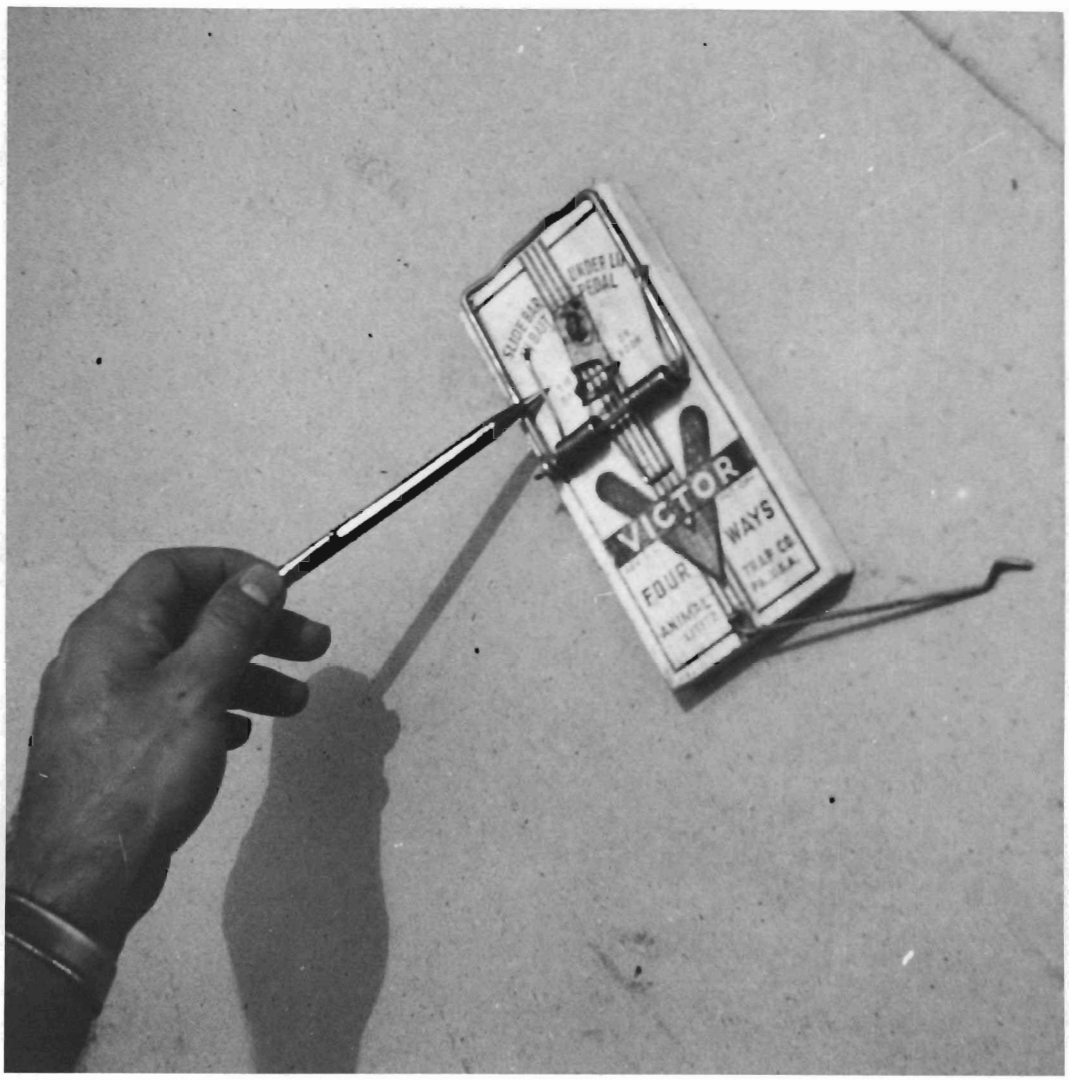

Figure 28. Removing tension on trap spring so that rat trap may be used for mouse control.

are listed in table 3, page 39. Extensive field experience on New Caledonia indicated that a satisfactory trap bait should meet the following qualifications:

(1) Be easily obtainable in the area.

(2) Have a high food preference rating for all species found in the area.

(3) Be of such nature or consistency as to be easily and firmly attached to the trap pan without necessity of tying.

(4) Remain fresh and attractive to rodents for at least 48 hours.

(5) Be easily and completely removed from the trap pan as traps are gathered up.

The three trap baits most nearly meeting these qualifications for New Caledonia, in order of their preference, were: fresh coconut, a mixture of peanut butter and rolled oats, and fresh meat—preferably beef. Fresh coconut, as listed in table 3, page 39, had a high food preference rating for all species, including house mice, as well as meeting all other arbitrary qualifications. The mixture of peanut butter and rolled oats did not cling to the trap pan as well as coconut or meat but was somewhat more difficult to remove completely later. The carnivorous and cannabalistic tendencies of all species of rats on New Caledonia were evidenced by free rats commonly feeding on trapped animals. Fresh meat proved to have a particularly high preference rating for Norway and roof rats, although slightly less so for Polynesian rats and house mice.

However, under the humid, hot, semi-tropical climatic conditions of New Caledonia, fresh meat decomposed very rapidly and remained attractive to rodents usually for not more than 12 hours. All three of these baits were easily obtained at this base. The most attractive and effective bait for house mice, as stated earlier, proved to be chocolate candy, although field trials indicated this bait to be only slightly more effective than fresh coconut. It was found particularly important to use a trap bait with a high food preference rating in areas where rodents had free access to other foods such as at a forage dump.

The recommendation is usually made that bait be tied to the trap pan when trapping rats. Under conditions on New Caledonia, particularly when several hundred traps were used in a trapping control operation, this procedure was found to be time-consuming and not conducive to appreciably better control results. The preferred trap baits such as coconut and fresh meat could be easily and rapidly secured to the V-shaped hook on the trap pan without necessity of tying with thread.

As standard operating procedure, traps being used continuously were cleaned and deodorized weekly by being dipped into a can of boiling water, figure 39, and then scrubbed with a wire brush.

Under military conditions where large numbers of traps were used, trap loss was relatively high; a loss of from two to five per cent of traps in a single control operation was not unusual. In addition to those traps set and not found, traps would frequently

Figure 29. Cleaning and deodorizing traps by dipping in boiling water.

be dragged away by rats caught by the tail or legs. It was found essential, in order to cut down trap loss, to have the same crew both set and pick up the traps.

Before beginning trapping control operations, an attempt was made to remove all food in and around the area. In all cases, a large number of traps were used to make the control efforts short and decisive. The best places to set traps were found to be wherever fresh rat droppings or trails were found and wherever rat damage had occurred. Inexperienced trappers frequently made the mistake of setting traps under low tent floors or boxes where the bail would strike when the traps were sprung. On occasion, as many as 20 per cent of the traps were made ineffective by this mistake in setting. Although seemingly simple, the proper adjustment of the trap trigger to insure springing of the trap with a minimum of pressure on the trigger required considerable practice. In setting the trap, the bail should be held down with the left thumb, figure 30, while the trap trigger is adjusted for tension with the thumb and forefinger of the right hand. As long as this procedure is followed, the operator's hands will not be injured. In springing traps set on the ground level, the bail should be depressed with the toe of the foot, figure 31. This disengages the trigger wire from the trigger and allows the trap to spring when the foot is removed. When this method is used, the hands need not touch the trap until after it is sprung. Before these methods of trap setting and springing were adopted by all members of the

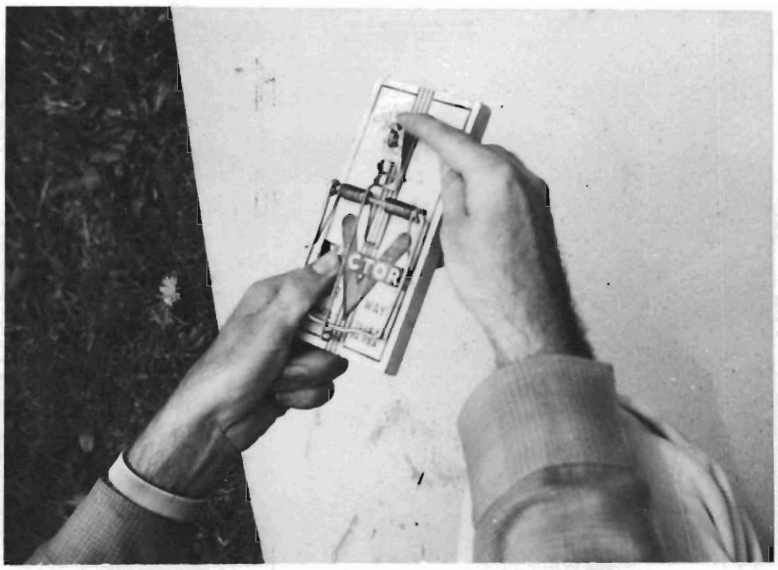

Figure 30. Method used in setting snap traps.

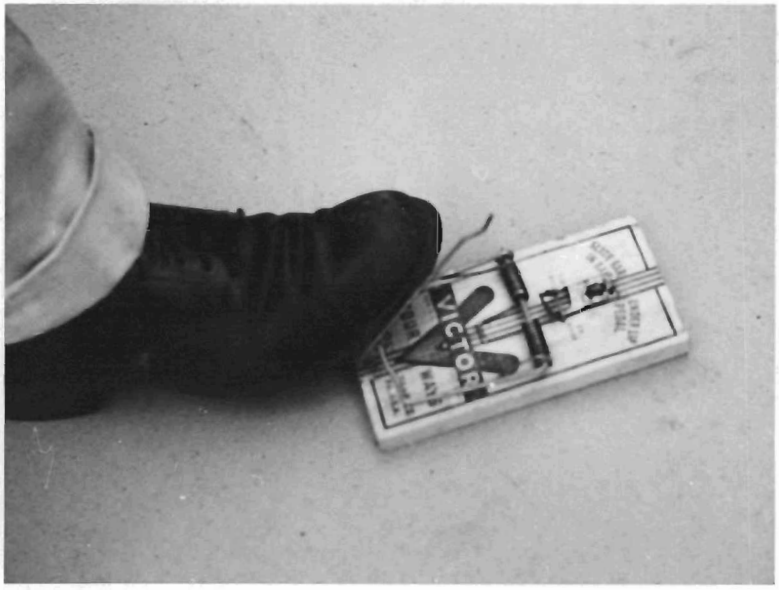

Figure 31. Method used in springing snap traps.

rodent control unit, several individuals received painful and temporarily incapacitating injuries to the hands as well as considerable shock to the nervous system.

Field notes on 1,431 trap nights on New Caledonia for all species indicate a 10.2 per cent trapping success ratio—or about one rat or mouse caught per ten traps set. In considering this figure, it should be borne in mind that, in most control procedures, a large number of traps was used so that every animal in the area would be exposed to a baited trap. If smaller numbers of traps had been used, the trapping success ratio would have been much higher. This statement is substantiated by records of high percentages of trapping success on areas where a fewer number of traps were set to sample the population for species composition and population density.

The use of trapping as a control method proved of particular value when used as a continual suppressive measure by designated personnel of each military installation on the base. In selecting such personnel, it was found to be very important to find individuals with a natural interest in trapping. Such individuals often developed a high degree of skill and, on occasion, trapping by these men proved so successful that use of other control measures was found unnecessary.

Poisoning Control Procedure:

On New Caledonia, the use of rodenticides or rodent poisons was found to be the most efficient method of control for most rodent populations. The use of poisoned baits required less time and manpower than other control methods and usually resulted in rapid and effective control results. However, rodent poisons, other than red squill, were always potentially dangerous to control operators, resident military personnel, and domestic animals and pets. The fact that no effective antidote had (or has) been found for thallium sulfate, 1080*, and ANTU**, greatly increased the potential danger from the use of these poisons. Additional hazards accompanying the use of thallium sulfate and 1080 resulted from the danger of secondary poisoning, resulting when cats or dogs fed on rodents killed by these rodenticides. No casualties among military or civilian personnel occurred on this base, although numerous cats and dogs were killed, mostly from secondary poisoning. As previously mentioned, regardless of the poison used, at least a few rodents would usually die in inaccessible places, and the stench from their decomposing bodies often proved highly objectionable, particularly around living quarters, mess halls, or galleys, and food storage rooms or depots.

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* The code number "1080" was assigned by the U. S. Fish and Wildlife Service to designate the chemical, fluoroacetic acid.

** The letters "ANTU" are commonly used to designate the chemical formula for Alpha-naphthylthiourea.

The use of rodenticides in rodent control on New Caledonia, as probably in other military areas, was limited largely by availability of the various poisons. The only rodent poisons available during the first two months of operation of the New Caledonia Rodent Control Unit were barium carbonate and an inferior grade of red squill. Thallium sulfate and strychnine became available in April, 1944; ANTU in November, 1944; and 1080 in January, 1945.

Results from field trials indicated that 1080 and thallium sulfate were the most effective rodenticides for all rodent species where conditions were such as to permit their use. Red squill was the preferred poison where safety of human beings and domestic animals were of primary concern. Strychnine was used only as a mouse poison.

On New Caledonia, frequently all three of the important commensal rodent species were found in areas to be controlled by poisoning. Thus, where possible, it was essential to use a bait which would be attractive to all species of rodents in the area, as well as a poison effective on all species.

After approximately six months of field and laboratory experimental work with different bait materials, control procedures were standardized, using four poisoned bait formulas. These formulas are listed in table 4, page 82. Three of these formulas were effective on all rodent species when used in conjunction with the proper poison. The fourth formula was used only in mouse control.

Table 4.—Effective Poisoned Bait Formulas for New Caledonia*

Fresh Baits - to be mixed and used at once

Formula No. 1	Bread crumbs or rolled oats	10 pounds
	Fresh ground coconut	10 pounds

If selected poison is water soluble, dissolve in water or coconut milk and use to moisten bait prior to distribution. If poison insoluble in water, sprinkle on ground coconut before mixing with bread crumbs or cereal.

Formula No. 2	Bread crumbs or rolled oats	10 pounds
	Fresh ground hamburger	10 pounds

If selected poison is water soluble, dissolve in water and use to moisten bait prior to distribution. If poison insoluble in water, sprinkle on hamburger and knead well before mixing with bread crumbs or cereal.

Stable Baits - may be mixed in quantity and stored until needed

Formula No. 1	Bread crumbs or cereal	32 pounds
	Peanut butter	7 pounds

Mix bread crumbs or cereal thoroughly with peanut butter and store in rodent and insect proof containers in a dry place. If selected poison is water soluble, dissolve in water and use to moisten bait material prior to distribution. If poison is not water soluble, mix with flour and sprinkle over bait material as it is being mixed with water prior to distribution.

Formula No. 2	Rolled oats	10 pounds
	Heavy corn syrup	1/2 pint
	Gloss starch	1 tbsp.
	Baking soda	1 ounce
	Glycerine	1 tbsp.
	Powdered strychnine alkaloid	1 ounce

Mix starch in one-fourth (1/4) cup of cold water and stir in three-fourths (3/4) pint of boiling water to make a thin, clear paste. Mix the strychnine alkaloid with baking soda and stir into the starch. Stir in corn syrup or glycerine. Apply to oats and mix thoroughly to coat each kernel. Spread on paper to dry. Store in a dry, tight container. (This poisoned bait was used for mice only, hence only strychnine alkaloid was used as the selected poison.)

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* For proportion of different poisons to be used with bait, see table 5, page 89.

The choice of bait materials coincides closely with the list of foods given high preference rating in table 3, page 39, "Comparative values of available baits for rats on New Caledonia". Of the three "all purpose" bait formulas, two were fresh baits to be mixed and distributed at once, while the third, a mixture of peanut butter and rolled oats or bread crumbs, was a stable bait which could be mixed in large quantities, and stored until needed. It was found essential to keep a supply of stable bait on hand at all times for small control operations, for distribution to individual unit personnel in charge of rodent control at military installations or on board ships, and for any purpose where it was inconvenient to prepare a fresh bait. Of the two fresh bait formulas, the fresh coconut-bread or bread crumb mixture, had a definite advantage over the fresh hamburger-bread or bread crumb mixture in that it remained attractive to rodents usually for several days.

To facilitate rapid and thorough mixing of poisons and bait materials, a quonset hut tub and garden rake, figure 32, were generally employed. Moist baits were found to be more acceptable to rats than dry baits and were also much easier to distribute, as moistened baits could be formed into small balls with the hands. These bait balls could be tossed easily under platforms, into burrows, onto shelves or thatched roofs, and other places where effective distribution of dry bait would have been difficult. Since best results were obtained with fresh baits, attempts were made to distribute baits in the late afternoon and to prepare them as short

Figure 32. Mixing poisoned bait in quonset hut tub.

a time before distribution as was practical.

When rodenticides having a definite taste and/or odor such as red squill, barium carbonate, or ANTU were used, good control results in a specific area were usually obtained only the first time the poison was employed and not thereafter. No such conditioned aversion to 1080 and thallium sulfate poisons by rodents was noted; probably this was because these poisons have little taste or odor and are so potent as to be lethal to rats and mice when used in relatively minute quantities with bait*. It early became apparent that when using such poisons as red squill, barium carbonate, or ANTU, if a high degree of success were to be expected, nearly the whole rodent population must be killed the first time the poison was used. Especially when using red squill, an attempt was usually made to saturate the area completely with poisoned baits so that every rat would have an opportunity to come in contact with a poisoned bait. Such control procedure was practical on military bases where the exigency of the service required that such animals be destroyed and where cost of destruction was of secondary consideration. Since red squill did not prove harmful to human beings or domestic animals, it was not generally necessary to attempt to remove from the area poisoned baits which were not eaten.

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* Table 5, page 89, illustrates concentrations of the various poisons (parts poison to parts bait) used in poisoning operations on New Caledonia. In several instances, these do not agree with concentrations recommended by the U. S. Fish and Wildlife Service for use in control operations within the United States.

When any rodenticide other than red squill was used around camp areas, an attempt was made to direct poisoning operations in such a manner as to minimize danger to personnel and pets. Usually, at least one week before the date of control operations, notices were posted on the camp bulletin boards advising all personnel of the pending poisoning control operation and warning them to confine all pets until at least three days after the date of poisoning. In such cases, all uneaten poisoned bait was removed from the area the day following distribution. To insure that all bait was removed, bait boxes or feeder stations were used—or bait was prepared as "torpedoes"* and set out at well marked baiting stations. When bait boxes, figure 1/, were used, these were usually staked to the ground so that only rodents could reach the bait. Poisoned bait prepared for bait boxes or feeder stations was not moistened as, being dry and crumbly, uneaten portions could not easily be removed by rodents. When torpedoes were used, a fixed number of baits was deposited at each bait station and the uneaten baits removed the following morning. When either 1080 or thallium sulfate was the designated rodenticide, the area was also carefully checked for dead rodent carcasses to reduce the possibility of secondary poisoning to cats and dogs.

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* When referring to rodent control procedure, the word "torpedoes" indicates the use of baits wrapped individually in waxed paper as in "candy kisses". The use of this technique is sometimes precluded by lack of man power.

In most literature on rodent control, it is suggested that "pre-baiting" be employed prior to poisoning operations to insure success in reducing rodent population numbers. In pre-baiting procedure, the area is seeded for several nights preceding poisoning with several kinds of unpoisoned baits, the object being to ascertain what kinds of bait might be most acceptable to the rodent population and also to overcome any hesitancy the animals might have in accepting the baits. Such procedure was not found to be of practical value on New Caledonia except where permanent feeder stations, as previously described, were used. Pre-baiting trials required excessive expenditure of man power and failed to appreciably increase the control success. Acceptability of baits had already been determined, as only baits having a previously proven high food acceptance rating were used.

Rubber gloves were worn by all control personnel in mixing and distributing all poisoned baits, except red squill. Gloves were worn to protect control personnel from exposure to the poison and not to protect the baits from human odor. It is the writer's opinion that commensal rodent species do not find human odor objectionable or they would be unlikely to be found around human habitation. In field work, no appreciable difference in trapping success was noted between freshly decontaminated and dirty traps as long as both types were in good working order.

Effectiveness of Available Poisons:

Barium carbonate:

Barium carbonate is a heavy white mineral salt, lethally poisonous when ingested in sufficient quantities, slow in action, and inexpensive. Despite manufacturers' claims that this rodenticide is odorless and tasteless, rats are able to detect its presence in poisoned baits and, after having recovered from a sub-lethal dose, refuse again to take baits containing this poison. Barium carbonate proved best as a "single operation" poison. On New Caledonia, it was found necessary in order to obtain lethal concentrations, to use one part of this poison to four parts bait--as compared, for example, to the highly toxic 1080 at one part poison to 160 parts bait, table 5. Moistened barium carbonate baits appeared to sour quickly and, therefore, rapidly became unpalatable to rats. This poison was used extensively on New Caledonia during the early months of 1944 with fair control success against rats. At this time, it was the only rodenticide available to Armed Forces on New Caledonia in large quantities. As soon as other more efficient rodenticides were available, the use of barium carbonate was discontinued. This poison proved ineffective against mice on New Caledonia as these animals would not readily accept baits containing lethal concentrations of poison. Ingestion of dead rodent carcasses did not result in lethal secondary poisoning to dogs and cats; however, domestic animals and human beings may be killed by eating sufficient quantities of poisoned baits.

Table 5.—Proportion of Poison Used with Bait on New Caledonia

Kind of Poison	Killing Time (Hours)	Parts Poison (By weight)	Parts Bait (By weight)
Red Squill	24 - 100	1	9
Barium Carbonate	24 - 36	1	4
Thallium Sulfate	36 - 100	1	64
Strychnine Alkaloid	1/4 - 2/3	1	160
ANTU	16 - 48	1	30
1080	3 - 24	1	160

Red Squill:

Red squill is a vegetable poison in powder form which is derived from the bulb of the red squill plant Urginea maritima; the principal source of supply is the Mediterranean area principally along the North African coast. Red squill is the only rodenticide which may be said to be "specific" for rats. Its acrid taste proves objectionable to most animals with the exception of rats and, in addition, red squill usually acts as an emetic when taken in dangerous quantities. Rats have no vomiting reflex and, thus, are killed upon ingesting lethal amounts of this poison. Different lots of powdered red squill may vary in toxicity and the rodent control operator should make certain that the squill he is using is of standard potency. The U. S. Fish and Wildlife Service standard of potency is 600 mg./kg., which simply means that the ingestion of 600 milligrams of poison per kilogram of body weight will result in killing most rats. Nearly all manufacturers of red squill state the mg./kg. potency of their product. If the potency of a lot is not known, a sample may be forwarded to the U. S. Fish and Wildlife Service for analysis. If this is not practical, potency may be tested by feeding poisoned baits to caged animals and checking results, as was done with the first red squill available on New Caledonia. Red squill is normally used in the proportion of one part poison to nine parts bait. Most red squill having at least a 600 mg./kg. potency rating has been "fortified" by the addition of red squill extract to the powdered bulb, thereby

increasing its potency.

Red squill was in very short supply during the first few years of the war but, after the North African coast was wrested from the Axis powers by the Allies, red squill "chips" were sent to the United States in quantity and by July, 1944, shipments of fresh, fortified red squill became available for use by the Armed Forces in the South Pacific.

On New Caledonia, red squill proved to be one of the most useful rodenticides. With this specific poison, it was possible to undertake extensive poisoning campaigns not only within military installations, but also in sections of the city of Noumea and the outlying Javanese village, figure 33, where no other poison could be used because of danger to children and domestic animals. Population numbers of the Norway rat were reduced approximately 65 per cent in the Javanese village area by a single "saturation" poisoning campaign using red squill with the hamburger-bread bait formula*. An intensive trapping campaign was then instituted in this area and this, combined with bi-monthly red squill poisoning operations, served to keep the rodent population at a relatively low level. However, it should be noted that, as in most other field trials with red squill, only the first poisoning control procedure produced measurable control results. This poison proved

* This formula, table 4, page 62, proved to be the most effective for use with red squill poison, particularly for the Norway rat.

Figure 33. Javanese village, Noumea.

of little value as a mouse poison on New Caledonia as these animals would not readily accept red squill poisoned baits containing lethal amounts of poison.

Red squill is insoluble in water. It was found that this poison could be most easily and thoroughly mixed with bait by the use of a quonset hut tub and garden rake, figure 32. While one man sprinkled the red squill poison onto the bait in the tub, another man raked the poisoned bait until thorough mixing resulted. Two of the rodent control personnel on New Caledonia proved quite sensitive to the effects of red squill powder. One, on coming into contact with the powder, broke out in a red rash on the hands, arms, and sometimes other parts of the body. This rash, although disagreeable, persisted usually for less than an hour. On breathing red squill powder, which usually occurred when mixing poisoned bait, another member of the unit reacted with severe coughing and sneezing symptoms, somewhat similar to those exhibited by a hay fever sufferer. Symptoms seldom persisted for longer than thirty minutes.

Thallium sulfate:

Thallium sulfate is a heavy, white, metallic powder, not readily soluble in water. It is odorless and tasteless, and is a powerful, cumulative, slow-acting poison. Due to its chemical stability in the body of a poisoned animal and its potency and cumulative effect, danger from secondary poisoning to dogs, cats (and other rats) is great. Danger to control personnel is increased

by the cumulative effect of the poison and the possibility of absorbing this poison through the skin or through abrasions or cuts on the hands. Thallium sulfate has long been known as a very efficient rat and mouse poison where dangers attending its use can be overcome. Rodents on New Caledonia did not "learn" to detect the presence of thallium sulfate in poisoned foods and laboratory animals receiving a sub-lethal dose of poison showed no aversion to other bait materials in which this poison was incorporated. Thus, it was possible to use thallium sulfate in repeated control procedures on the same area without markedly reducing the percentage of control results.

Since the principal source of supply of thallium sulfate was from Europe, and particularly Germany, importation of this poison into the United States ceased at the beginning of the war. Since, at that time, thallium was admittedly the best rodenticide known, it was adopted for use in military rodent control by the Army and Navy. In order to guarantee the needs of the Armed Forces, thallium was placed under control of the War Production Board and civilian supplies were largely cut off*. Fortunately, reserve supplies of thallium proved adequate for military rodent control purposes until, in 1944, other efficient new rodenticides such as 1080 and ANTU became available.

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* Thallium was taken off allocation by the War Production Board in August, 1945, and at present, no restrictions exist on supplies which may be obtained by users.

Thallium sulfate was extensively used on New Caledonia by the rodent control unit until the poison 1080 became available. In areas where it could safely be used such as forage dumps, supply depots, and along the fenced and patrolled waterfront and dock area of Noumea harbor, it proved highly effective on all species of rodents. This effectiveness was due, in part, to the secondary poisoning effect resulting from the cannabalistic tendencies exhibited by, particularly, the Norway rat species. Symptoms shown by rats obtaining a sub-lethal dose of thallium included loss of hair. On several occasions, rats were trapped in areas where thallium poisoned baits had previously been distributed which had lost portions of their hair.

Thallium was also used on New Caledonia to a limited extent to control ants around and in food storage warehouses. A mixture of thallium and syrup or honey proved very attractive to these insects and good control results were usually obtained. Many roaches were killed incidentally in thallium poisoning operations around dock and waterfront areas.

Due to its insolubility and heavy weight, proper mixing of this poison with bait materials proved difficult. Thallium could most easily be mixed thoroughly with the hamburger, bread mixture, table 4 page 82, which was the bait formula most generally used with this poison. Best results were obtained in sprinkling the powder evenly over the hamburger and kneading the mixture with a spoon or, if wearing rubber gloves, with the hands. The hamburger

was then mixed with the bread and the whole moistened to proper bait consistency by the addition of water.

Because of lack of an effective antidote*, high potency, cumulative effect, and possibility of absorption through the skin, great care was taken by all rodent control members when using thallium to avoid accidental poisoning. Despite all precautions taken, numerous cats, and a few dogs, died from secondary poisoning resulting from eating carcasses of thallium poisoned rodents.

Thallium sulfate is much more expensive by weight, or in actual use, than any of the other common rodenticides. This, however, was of little concern under conditions of military rodent control.

Strychnine:

Alkaloid strychnine is a light, white powder, extremely poisonous and very bitter in taste. On New Caledonia, strychnine was used only as a mouse poison. Supplies of this poison at this base were very limited, and previous experimentation by the U. S. Fish and Wildlife Service and other agencies had indicated strychnine to be a poor rat poison. It has been suggested that strychnine poisoned baits are not readily accepted because of the extremely bitter taste. Since rats eat very slowly and strychnine works rapidly, the effect of the poison may possibly be felt

* No effective antidotes have been found for poisoning by thallium, 1080, or ANTU. Emergency measures include emetics, purges, and general symptomatic treatment.

by the animal before lethal amounts of the poison have been ingested. Strychnine, however, proved to be an excellent mouse poison on New Caledonia. While extremely poisonous, strychnine is less dangerous to human beings than certain other poisons because of the existence of effective antidotes. In addition, this poison is so physiologically changed after entering the body of a rodent that the possibility of secondary poisoning is minimized. Mice did not seem to object to the acrid taste of strychnine and, because of their very small size, were killed upon ingesting very small portions of poisoned bait. Although both thallium and 1080 were excellent mouse poisons, strychnine was the poison of choice for mice as it was the least dangerous of the available poisons which would still give good control results.

ANTU (Alphanaphthylthiourea):

ANTU is a fine, bluish gray powder, relatively light in weight, insoluble in water and having somewhat variable properties of taste and odor. In general use, ANTU has proved to be a good poison for use in control of the Norway rat but of only slight value as a control agent for other species. It is not an effective mouse poison. In rats, ANTU causes death by changing the permeability of the blood vessels in the chest area, and the animal dies from drowning in its own body fluids which accumulate in the pleural cavity around the lungs. According to records of the National Research Committee (10, p. 1), it is about five times more toxic to Norway rats than to members of the roof rat group and

considerably more toxic to adult than to young Norway rats. Other disadvantages include the rapid build-up in rats of a tolerance that follows eating a non-lethal dose, its non-solubility in water, and lack of a good antidote for cases of accidental poisoning of human beings. A rat poisoned but not killed by ANTU may subsequently refuse to eat any bait containing this poison for a period of several months. Relative toxicities of ANTU to animals other than rats are listed in table 7, page 101.

ANTU has proved effective on Norway rats in poisoned food baits and, according to the U. S. Fish and Wildlife Service, as a tracking or dusting poison. ANTU may be dusted along rat trails or into rat burrows. The powder acts as an irritant and is ingested in lethal quantities when the rat licks its feet or fur. The formula suggested for dusting is: 20 per cent ANTU, 2 per cent DDT, and 78 per cent pyrophyllite. This formula will tend to control the rats and the rat fleas at the same time. The Fish and Wildlife Service suggests that ANTU in poisoned bait formulas be used in the ratio of one part poison to 100 parts bait for Norway rats, or one part poison to 25 parts bait for roof rats or mixed populations of Norway and roof rats. Because of its insolubility, ANTU is not a good water poison.

The use of ANTU as a rat poison was discovered by Dr. Curt P. Richter, Johns Hopkins Hospital, Baltimore, Maryland, in 1942, while working on a grant from the Office of Scientific Research and Development. ANTU is covered by a public patent made out to the

Secretary of War and is being produced commercially by E. I. DuPont de Nemours and Co., Wilmington, Delaware.

The first shipment of ANTU for use by the New Caledonia Rodent Control Unit arrived late in 1944--with no instructions regarding toxicity or use except the suggestion that it be tried in poisoned bait formulas at the relative strength of one part poison to 30 parts bait. Accompanying the shipment was a request that field trials be made on this base and all information relayed to the National Research Council, Washington 25, D. C.

The writer was placed in charge of the experimental work with ANTU and limited laboratory and field trials were instituted*.

Live-trapped, caged rats and mice were used to determine effective lethal concentrations of poison to bait, average killing time, and effect of poison on bait palatability. At the time of the experiment, only three rodent species were available: Norway and Polynesian rats and house mice. Unfortunately, all laboratory roof rats had recently been disposed of in a secondary poisoning experiment with thallium sulfate. Specific results of laboratory experiments using the poison ANTU are listed in table 6, page 100. General results from the limited data obtained from laboratory

* The New Caledonia Rodent Control Unit, at this time, had no information regarding the toxicity or use of ANTU except the suggested strength for poisoned bait formulas.

Table 6.--Results of Laboratory Experiments Using ANTU

Rodent species	No. of animals in trial	Bait used	Parts bait to poison (by weight)	Av. amount eaten (in grams)	Killing time (hours)
Rattus norvegicus	1	Dry rat food mixture	1 to 10	8.85	18
Rattus norvegicus	1	Dry mouse poison mixture	1 to 25	1.77	7
Rattus norvegicus	3	Dry rat food mixture	1 to 40	1.18	39
Rattus norvegicus	3	Dry rat food mixture	1 to 50	1.18	23
Rattus norvegicus	3	Dry rat food mixture	1 to 100	1.77	34
Rattus exulans	1	Wet rat food mixture	1 to 20	1.18	46
Rattus exulans	1	Dry rat food mixture	1 to 25	1.77	48
Rattus exulans	1	Dry rat food mixture	1 to 50	1.18	48
Mus musculus	4	Dry mouse poison mixture	1 to 25	2.95	3

(Note: Rat food mixture was the balanced diet regularly fed to the experimental animals consisting of cornmeal, "Vimax" cereal, powdered milk, powdered egg, salt, and cod liver oil. The mouse poison formula is listed under table 4, page 82.)

Table 7.—Estimated Minimum Amounts of ANTU Required to Kill 100% (= LD 100) of Certain Animals and Birds When Given by Mouth*

Animal or Bird	Amount of ANTU in mg./kg. of body weight
Laboratory rat, adult (Rattus norvegicus)	6 - 8
Norway rat, adult, wild (R. norvegicus)	10
young, wild (R. norvegicus)	20 - 50
Domestic dog (Canis familiaris)	50
Pig (Suis scrofa)	50
Roof rat (R. rattus subspecies)	250 or higher
Squirrel (S. carolinensis)	50 - 250
Rabbit (Lepus)	400 or higher
Guinea pig (C. cobaya)	400
Domestic cat (Felis libyca domestica)	1000
Domestic chicken (Barred Plymouth Rock)	5000
Monkey (Macaca mulata)	5000

* Data from National Research Council (10, p. 2).

poisoning experiments with the poison ANTU indicated the following*:

(1) ANTU proved extremely toxic to the Norway rat, Rattus norvegicus, and the house mouse, Mus musculus. All animals taking poisoned baits died.

(2) ANTU, while apparently not as toxic to the Polynesian rat, Rattus exulans, as to the above-mentioned species, was still effective against this rat as all animals taking poisoned baits eventually died.

(3) Addition of ANTU to the food mixture regularly fed to experimental animals did not seem to affect palatability as, in all cases, the poisoned food was readily accepted. (Animals were not starved prior to exposure of poisoned food.)

As the Norway rat was the most important species at this base, from the standpoint of both disease potential and destruction of supplies, it was decided to direct field trials with ANTU against this species.

An Army controlled native labor camp was selected as a satisfactory area in which to carry out field trials using the poison ANTU against the Norway rat. This area, about 200 by 300 yards, included grass-thatched, floorless barracks, a food storage room, mess hall and garbage hut, large, scrap lumber pile and rock-walled

* Flesh of three different ANTU poisoned rats (1 part poison to 30 parts bait) was later fed to three caged Norway rats to determine secondary poisoning effect. No evidence of secondary poisoning was observed in any of these animals nor in subsequent field trials with this poison.

drainage ditch. Rat infestation was fairly heavy with numerous burrows under buildings, along ditch banks and hillside areas. No trees were found in the area and the rat population was predominantly Norway, with an occasional house mouse being found.

As numerous dogs and goats ranged in the area, it was decided to use wooden feeder stations which would be pre-baited and later poisoned. These feeder stations were provided with hinged tops and were staked to the ground to prevent disturbance of the bait by domestic animals.

In order to check poisoning results, trapping checks were made prior to and after the actual poisoning. In addition, the natives were recruited to search the area thoroughly and to pick up all dead animals.

Chronological procedure and results of the field trials with ANTU on this area were as follows:

First day - A trapping check was made using 100 traps baited with fresh beef; 14 Norway rats were caught.

Second day - Ten feeder stations were set up and pre-baited with fresh unpoisoned bread.

Sixth day - A check on feeder stations indicated that rats were readily taking pre-bait (bread).

Seventh day - All old bread was removed and feeder stations were poisoned with broken pieces of fresh bread dusted with dry ANTU--approximately one part poison to 30 parts bait. Approximately 20 pounds of bread were used.

Fifteenth day - Feeder stations were checked. About 50 per cent of the poisoned bait had been taken from feeders. Twenty-seven dead Norway rats had been found by members of the camp. Feeder stations were rebaited with poisoned food in the same manner as above.

Twenty-fifth day - Feeder stations were again checked. About 25 per cent of the poisoned bait had been taken by rats. All remaining poisoned bait was removed from feeders. Nineteen additional Norway rats were picked up by natives between the 15th and 25th days, making a total of 46 dead rats found during the experiment.

Twenty-sixth day - A second trapping check was made using the same number of traps and same techniques as before. One house mouse was caught outside one of the native barracks and one juvenile Norway rat was caught on the hillside just inside the area boundary.

Summary of results from field trials:

(1) A total of 46 dead Norway rats were picked up in the area.

(2) Trapping checks indicated approximately a 90 per cent reduction of the rodent population in the area.

(3) Although dogs and goats ranged freely over the area, no case of poisoning or of disturbance of the feeder stations was noted.

Although both laboratory and field trials listed previously indicated favorable results from ANTU as a rodenticide on New Caledonia, subsequent field experience suggested, as later

substantiated by the U. S. Fish and Wildlife Service, that this poison was not very effective on mixed rodent populations as ANTU poisoned baits were not readily accepted by house mice and were not highly toxic to roof rats, table 7, page 101. Although experimental work by the Fish and Wildlife Service and other agencies later ascertained that ANTU was not as toxic as other poisons such as 1080 and thallium to cats, dogs and, probably, human beings, table 8, page 106, this was not known at the time this rodenticide was used on New Caledonia. Thus, ANTU was considered to be a dangerous poison and was so treated. The only advantage of ANTU over other effective poisons such as 1080 and thallium, suggested by limited experimental work on New Caledonia, was the lack of secondary poisoning effect exhibited by animals feeding on ANTU poisoned rodents. Since this was a fairly important consideration at units located inside the city of Noumea, ANTU was used to a limited extent as a poison in conjunction with permanent feeder stations, as previously described. Since the predominant rodent species in Noumea was the Norway rat, success with this poison in conjunction with pre-baited feeder stations or boxes was excellent and no cases of secondary poisoning to cats or dogs were reported.

Compound 1080 (Sodium Fluoroacetate):

Compound 1080 is the wartime code number designated by the U. S. Fish and Wildlife Service for the chemical, sodium fluoroacetate. 1080 is a light, fluffy, white powder, highly soluble in water but relatively insoluble in animal or vegetable

Table 8.--The Comparative Toxicities to Man of Seven Rodenticides*

Poison	Poison conc. in bait	Estimated LD50 in mg./kg.	LD50 for 70 kg. man (mg.)	Poison in bait mg./oz.	LD in terms of bait used in field
1080	1:1600	5**	350	17.7	19.8 oz.
	1:454	5	350	62.4	5.6 oz.
	1:266 (water)	5	350	105.1	3.3 oz.
Tl_2SO_4	1:65	20	1,400	436.5	3.2 oz.
Zn_3P_2	1:50	40	2,800	567.0	4.94 oz.
$BaCO_3$	1:5	800	56,000	5,670	9.9 oz.
Arsenic	1:33	1.5-15	105-1050	860	0.12-1.22 oz.
Strychnine	1:320	1	7	88.5	
ANTU	1:20	4,000***	280,000	1,425	197 oz.

* Data from National Research Council (11, p. 2).

** On the basis of an LD50 for monkeys of ca. 5 mg./kg.

*** On the basis of data from monkeys, supplied by Dr. Curt P. Richter. This extrapolation to man must be taken as a very tentative estimation due to peculiar physiologic action of ANTU. The correct LD50 figure for man may be much lower.

fats or oils. Compound 1080 is the most toxic rodenticide in use at the present time and has been found to be highly poisonous to all animals on which it has been tested*. It is also considered to be very toxic to man**. When used properly, it is a very effective rodenticide.

Advantages of 1080 as a rodenticide include high toxicity to all species of rodents, excellent acceptance of poisoned bait due to lack of objectionable taste and odor, and non-toxicity and non-irritation to the unbroken skin of workers. 1080 is not cumulative in toxic effect. Rats do not develop any tolerance on ingestion of sub-lethal amounts and do not seem to "learn" to detect the presence of the poison in bait. Compound 1080 is very easy to mix with bait as it may be dissolved in water and this poisoned water used to moisten the bait material to obtain proper consistency prior to distribution of poisoned baits. When this poison is used in control procedures, a higher surface kill of rats and mice results than with the use of any other poison. According to U. S. Fish and Wildlife Service records (5, p. 3), because of its toxicity, 1080 is an excellent "water poison" when used in the

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* The toxicity of 1080 to various animals is listed in table 9, page 109.

** The comparative toxicities to man of various rodenticides are listed in table 8, page 106.

ratio of one-half (1/2) ounce of 1080 per gallon of water*.

Disadvantages inherent in 1080 as a rodenticide include its high solubility in water, which may result in the poison being washed out of the baits by rain. The hazard of accidental poisoning to human beings is increased by reason of 1080 being a white powder without distinctive odor or taste. The rapidity of absorption of this poison in the gastro-intestinal tract heightens the danger to human beings as it makes symptomatic treatment in cases of accidental poisoning difficult. As previously mentioned, no antidote for 1080 poisoning is known. Greater danger to cats and dogs exists in 1080 poisoning campaigns than when any other poison is used. These animals are many times more susceptible to 1080 poisoning than rats, table 9, and may be killed by ingesting very small quantities of poisoned bait or by feeding upon carcasses of 1080 killed rodents. However, as demonstrated in field trials on New Caledonia, the secondary poisoning effect of 1080 may increase its effectiveness on carnivorous or cannibalistic rodent populations.

At present, sodium fluoroacetate, or 1080, is being manufactured by one company, the Monsanto Company, Phosphate Division, St. Louis 4, Missouri. The policy of this company is to release this

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* When used as a "water poison", water containing 1080 is usually put out for rats in three-fourth (3/4) ounce waxed paper souffle cups wherever rat sign or rat damage occurs.

Table 9.--Lethal Dose Figures of Compound 1080 to Various Animals and Birds*

Animal or Bird	Amount of 1080 in milligrams per kilogram of body weight	Per cent killed
Albino rat	5-7	50%
Norway rat, wild (Rattus norvegicus)	3-7	50%
Roof rat (R. rattus subsp.)	1-4	50%
Cat	0.35-0.5	50%
Dog	0.1-0.2	50%
Goat	0.7	50%
Pig	0.3	50%
Horse	1	50%
Monkey (rhesus)	5-7.5	50%
Chicken (domestic)	10-30	50%
Mourning dove (Zenaidura macroura)	10	33%
English sparrow (Passer domesticus)	2.7	100%

* Data from National Research Council (11, p. 3).

poison only to State and Federal agencies and to professional pest control operators. As yet, 1080 has not been made available to the general public.

According to U. S. Fish and Wildlife Service records (5, p. 1), the toxicity of one of the organic fluorine compounds was discovered by three Polish investigators in 1939. In 1942, this secret was disclosed to the British who, after some preliminary investigation, prepared a quantity of the chemical, which later became known as 1080, and shipped a quantity to the United States.

Shortly after the start of the war, a long-time project of the Fish and Wildlife Service Research Laboratory (at Denver) to search for new and better poisons for control of animal pests was intensified because of the acute wartime shortage of several rodenticides such as thallium sulfate, red squill, and strychnine. Sodium fluoroacetate was first tested at the Patuxent, Maryland, Wildlife Research Laboratory on June 8, 1944. It received the designation "1080" as that was the invoice number given to it when it was received at the Patuxent Laboratory. After further study at the Denver laboratory, lots of the poison were sent out to various military areas to be used in rodent control operations.

The first lot of 1080 arrived on New Caledonia in January, 1945. Accompanying this lot was a brochure describing the properties of the chemical and a request that field trials be made and all information on results of the use of 1080 as a rodenticide be

forwarded to the U. S. Fish and Wildlife Service and the National Research Council, Washington, D. C.

Very limited preliminary tests made on caged, wild, Norway rats on this base with 1080 poisoned baits produced excellent results. When trials were made by feeding flesh of 1080 poisoned rats (poison to bait ratio - 1:160) to other caged, wild Norway rats, all experimental animals died*. Since this secondary poisoning effect on other rats was desirable, field trials were instituted using this proportion of poison to bait**.

A large isolated Army forage dump was selected as a satisfactory area in which to carry out field trials using rodenticide 1080 on the principal rodent species found on New Caledonia. This area, about four acres in extent, included 45 tarpaulin-covered forage stacks, each averaging about 30 feet in length by 12 feet in width. These forage stacks contained oats, oaten chaff, Johnson hay, bran, bone meal and linseed meal, figures 15 and 16. Bales of forage had been stacked on low boards or pole platforms only a few inches off the ground, and covered with tarpaulins which usually touched the ground on all sides of the forage pile. This combination of abundant food and suitable shelter established ideal conditions for the existence of a heavy rodent population.

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* Only three rats were used in the secondary poisoning experiment.

** Ratio of poison to bait recommended by the U. S. Fish and Wildlife Service (5, p. 4) is one (1) part poison to 448 parts bait.

Five months previous to the beginning of field trials with 1080, this area had been controlled using thallium sulfate poison with ground coconut-bread bait. Comparison of trapping checks made before and after poisoning had indicated approximately a 70 per cent reduction in the rodent population. At the beginning of 1080 poison trials, the rodent population on this area was considered to be relatively low in comparison to former rodent numbers. However, numerous rat burrows and well worn trails through the vegetation were evident, figure 11.

Field trials in this area with poison 1080 covered the period from February 28 to March 26, 1965. The rodent population on the area consisted primarily of Norway rats and house mice with an occasional roof rat* being found.

Chronological procedure and results of the field trials with 1080 on this area were as follows:

First to third day - the pre-poisoning trapping check was made. 200 traps were set each night for three nights, half being baited with fresh beef and half with fresh coconut. A total of 22 Norway rats and two house mice were caught**.

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* Only two roof rats, Rattus ratlus subsp. were taken in the area during both thallium sulfate and 1080 poisoning procedure field trials.

** Trapping conditions on two of the three nights were unfavorable; heavy wind and rain were responsible for springing a large number of traps. Of the 600 traps set, 217 were sprung.

Fourth day - a total of 48 pounds of poisoned bait was distributed in the area during the late afternoon. This consisted of 25 pounds of fresh meat and bread bait (50 per cent fresh ground beef, 50 per cent bread) and 23 pounds of coconut and bread bait (50 per cent fresh ground coconut and 50 per cent bread). Rodenticide 1080 was used in the ratio of one (1) part poison to 160 parts bait.

Fifth day - a check on results of the poisoning operation indicated approximately 20 per cent bait acceptance. A total of 84 dead or sick rodents was found in the area. Of these, 29 were rats--28 Norway and one roof rat--and 55 were house mice. All of these animals were picked up within 16 hours after distribution of poisoned bait.

Tenth to Thirteenth day - the post-poisoning trapping check was made using the same techniques, including the same number of traps and same bait as in the pre-poisoning trapping check. A total of five rats were caught--four Norway and one roof rat*.

Twenty-eighth day - the area was thoroughly checked for rodent sign. Very few fresh rodent droppings were found; most trails and runways were disappearing due to new growth of vegetation.

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* Relatively favorable trapping conditions existed during the three trapping nights. However, 88 of the 600 traps set were sprung.

Summary of results from field trials:

(1) A total of 84 dead or sick animals were picked up in the area. Poisoned bait acceptance was estimated to be 20 per cent.

(2) Comparison of results of pre-poisoning and post-poisoning trapping checks indicated approximately an 83 per cent reduction in the rodent population.

(3) A thorough check on the area 20 days after poisoning revealed very little fresh rodent sign, indicating that actual control success might have been in excess of the 83 per cent shown by the trapping checks.

(4) The greatest rodent mortality occurred within 16 hours after the poisoned bait had been distributed.

Following laboratory and field trials with 1080 on New Caledonia, this rodenticide was chosen as the preferred poison for use in all areas where thallium sulfate had previously been employed.

Reasons for preference of compound 1080 over thallium sulfate as a rodenticide on this base were as follows:

(1) Compound 1080, being highly soluble in water, proved much easier to mix with bait than the relatively heavier, insoluble thallium sulfate.

(2) A higher surface kill resulted with the use of 1080 than with any other poison and fewer animals appeared to die underground or in inaccessible places.

(3) Since 1080 was not a cumulative poison such as thallium sulfate, it was thought that it could be handled with greater safety by control personnel.

(4) As 1080 was used only in areas where danger to domestic animals was not a serious problem, its greater secondary poisoning effect on cannibalistic rodents was believed to be advantageous.

Compound 1080 was not used as a water poison on New Caledonia. The humid climate and relatively heavy rainfall provided a plentiful water supply for rodents, resulting in poor acceptance of poisoned water baits.

Little difference could be detected between control success on ants when using 1080 or thallium sulfate poisons with syrup baits. Both poisons were very effective.

Because of its high toxicity, great care was taken by all personnel to prevent accidental poisoning when using 1080. Rubber gloves were worn by all personnel when mixing and distributing poisoned baits. A special set of bait buckets was reserved for use with 1080 poisoned baits alone, and all supplies of this rodenticide were kept locked in the poison cabinet.

On this base, rats and mice seemed to become partially paralyzed and inactive shortly after ingesting 1080 baits and, although these animals might not die for several hours, they seldom moved far from the place where the poison was eaten.

One instance demonstrating the high toxicity of 1080 to dogs was observed when a Canine Corps German shepherd was inadvertently brought into an area which had been poisoned with 1080 baits. This dog took only one "torpedo" bait from a bait station and although emetics and a morphine injection were administered and artificial respiration applied, the animal died in convulsions approximately 45 minutes after having taken the poisoned bait. This dog weighed about 70 pounds and the bait ingested was less than half the size of a golf ball. Compound 1080 was used in this poisoned bait mixture in the proportion of one (1) part poison to 160 parts bait.

SUMMARY AND CONCLUSIONS

Introduction

This study deals with the development of a rodent control program on New Caledonia, a United States South Pacific military base, covering the period of March, 1944, to June, 1945, during which time the writer was a member of a naval rodent control unit and in charge of certain phases of field and laboratory research work.

Rats and mice are of military importance because of their ability to transmit disease, particularly murine typhus and bubonic plague, and because of their destruction of military supplies.

The objectives of this report of the development of a rodent control program on a South Pacific military base have been:

(1) To record and evaluate the steps in the development of organization for rodent control on this military base from the standpoint of personnel, transportation, equipment, control procedure, and education.

(2) To obtain any information on rodent control on New Caledonia which might be of value in similar areas and/or under similar circumstances and conditions.

(3) To assist in carrying out fundamental research necessary to improve rodent control techniques and results in this area.

New Caledonia

The island of New Caledonia is a French colonial possession, lying about 700 miles west of the Queensland coast of Australia. The island is 220 miles in length, has an average width of 30 miles, and an area of 6,300 square miles. It lies at the southern border of the tropical zone about 20° to 22° south latitude. New Caledonia had a pre-war population of about 55,000, including native "Kanakas", French, and Tonkinese and Javanese indentured laborers. The first United States troops landed on the island in March, 1942, and by 1944, approximately 220 separate military units were established on this base. This island served as a staging and hospital area and as command base for the South Pacific area. The center of military unit concentration was the capital city of Noumea. As this city had long been an important port, the island was well seeded with several species of rats and mice.

Organization for Rodent Control

The high rodent populations existing within military installations on New Caledonia by 1944 made organized rodent control a necessity. The New Caledonia Rodent Control Unit began to function in February, 1944, with the primary purpose of reducing the disease potential and the damage to military supplies resulting from rodent infestation on this base.

Rodent control personnel consisted of one naval officer and seven enlisted men. Sufficient transportation for rodent control was found to be of utmost importance as activities were carried out over a large territory and considerable equipment was transported. Control of rodents on land-based units was found to be best accomplished by dividing the island into three control areas, each containing from 30 to 70 military units. A rodent control operator was placed in charge of each of these areas and all units were visited once each month. After ten months of intensive control operations, the rodent control problem was reduced to one of monthly checking of units, control of small, reinvaded areas, and pest problems (mostly house mice). Ship-shore rodent control proved to be mainly a case of enforcing published regulations regarding placement of rat guards and cluster lights on ships to prevent interchange between ship and shore rodent populations.

An educational program was put into effect to train individual personnel of transient units headed for forward areas in the techniques of rodent control.

Rodent Species in the Area

Four rodent species were found on this base. The two most important, from the standpoint of damage to military supplies, were the Norway rat, Rattus norvegicus, and the house mouse, Mus musculus connacorum. Of less consequence in destroying supplies but

still of importance from a potential disease carrying standpoint were the roof rat, Rattus rattus subsp., and the Polynesian rat, Rattus exulans jessook. The Norway rat and the house mouse were found only around human habitations while the roof rat was found both in commensal and feral populations. The Polynesian rat, on New Caledonia, was strictly a feral species, not being found within the boundaries of military installations. The roof rat, a climbing species, was the only rodent found commonly living above the ground level. Because of its high reproductive capacity, large size, and aggressiveness, the Norway rat was the dominant species within military installations on New Caledonia. Control operations on board ships indicated that the roof rat, probably because of its climbing habits, was better adapted to conditions on shipboard than the Norway rat and, therefore, was usually the species encountered. When abundant, rodents appeared to be of considerably greater economic and pest importance on board ship than on land-based units.

Fundamental Research Data

Rodent food preference studies indicated the best available baits for trapping and poisoning control procedures to be, in order of effectiveness, fresh coconut, a mixture of peanut butter and rolled oats, and fresh meat.

Rodent population densities and species composition were most easily and accurately determined by observing abundance, freshness,

and shape and size of rodent droppings.

An attempt was made to determine the predominant sex and age groups making up the rodent populations. Lactating or breeding females of all species except the Polynesian rat were found during all months of the year. The Polynesian rat did not appear to breed during the winter months of July and August. Very few non-breeding females of the other three species were found at any time and most rodent populations appeared to be in a healthy, vigorous condition.

When an actual percentage figure of control success or population reduction was desired, the "trapping check" method of evaluating control results appeared to be most accurate. Elimination of rodent damage in an area usually was considered as evidence of good control success.

Two flea surveys were undertaken at 12-month intervals. The first, in 1944, showed an average infestation of 3.9 fleas per rat of the species Xenopsylla cheopis, while the second, made in 1945, after a marked reduction in the over-all rodent population due to intensive control procedures, showed an average infestation of only .9 fleas per rat. No case of rodent borne disease was reported on New Caledonia during occupation by Allied Armed Forces.

Modification and Application of Control Measures

Environmental control by elimination of rodent food and shelter around military installations proved to be of primary importance.

Trapping proved to be an important control method, particularly where conditions prevented use of other control procedures. Trapping as a constant suppressive measure when practiced by designated personnel in each unit on this base often precluded use of other control measures. Live-traps proved to be only about ten per cent as effective as wooden break-back traps.

Fumigation, as a control method on New Caledonia, had only limited use and proved applicable and effective on only one species, the Norway rat, and then only under certain specific conditions.

The use of rodenticides was found to be the most efficient method of control for most rodent populations. After completion of field and laboratory trials with all available poisons, including the new rodenticides, ANTU (Alphanaphthylthiourea) and compound 1080 (Fluoroacetic acid), the following conclusions were reached: Compound 1080 was the preferred poison when consideration of safety of personnel and domestic animals did not preclude its use. This poison appeared to be superior to thallium sulfate in ease of mixing with bait materials, in safety of handling, and in lethal, secondary poisoning effect on cannibalistic rodent populations. In addition, use of 1080 resulted in a higher surface kill of rodents

than that accruing from the use of any other poison. Red squill proved to be the most useful rodenticide where poisons more toxic to human beings and pets could not be used. Alkaloid strychnine was considered the safest poison for use in mouse control, which would still give good control results. Although ANTU gave excellent control results on Norway rats, no advantage could be attributed to its use in place of thallium sulfate or 1080 except that less chance of secondary poisoning of dogs and cats resulted when this poison was used.

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