Mongooses #7

# CONTROL OF MONGOOSE PREDATION ON ENDANGERED HAWAIIAN BIRDS

## PROGRESS REPORT 1986

by

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Summary:

In 1986, additional knowledge was gained on many aspects of the biology and control of mongooses in Hawaii. Biological studies of mongoose census methods, movements, and population dynamics were continued and considerable information was accumulated on how to reduce mongoose populations in nesting areas of endangered birds during their breeding season. Diphacinone was found to be highly toxic to mongooses and to be lethal with only a single exposure to the toxicant. Mongooses are at least 10 times more susceptible to diphacinone than the next most susceptible animal in Hawaii for which data exist. It is anticipated that levels of 0.0005% diphacinone in bait will give satisfactory control and, at this concentration, diphacinone should not pose primary or secondary hazards to any non-target animals.

The Hawaiian Division of Forestry and Wildlife has supported the mongoose project during the past two years by providing the assistance of Dann Espy. The Division is unable to continue this support in the future and Dann has prepared a final report to the State of Hawaii on his accomplishments while working for them. We are pleased to make his report an integral part of our report this year. Dann is now employed with USDA and will continue working with us on the project.

Introduction:

Mongooses (Herpestes auropunctatus) were introduced into Hawaii in 1883 and now occur on all main islands except Kauai. Their predation on eggs and young are thought to restrict productivity and population recovery in eight species of endangered Hawaiian birds. Effective, safe and practical means are needed to reduce mongoose predation during the breeding season in local areas where these birds nest.

Objectives:

1. To develop methods for assessing mongoose abundance. Techniques are needed to determine relative numbers of mongooses in areas to be protected and to evaluate effectiveness of control operations.

2. To determine the movements of mongooses in selected habitats. Knowledge of movements and home range is required to understand how far mongooses will move to feed on bait, to select proper spacing of bait

stations and to determine the propensity for mongooses to invade areas where they have been removed.

3. To describe the population biology of mongooses in Hawaii. Information on when mongooses breed, their potential for population increase, and how and when they die is needed to develop control strategies.

4. To develop and obtain registration for methods that can be used to control mongooses in Hawaii. This will require identification of the most specific toxicant, the most acceptable bait, the minimum effective level of toxicant in bait, the most effective delivery system, and methods that present the least hazard to the environment.

Accomplishments:

Attempts to develop methods to assess mongoose abundance have not been very successful. Tracks, droppings and sightings of mongooses are too infrequently recorded to be useful. Bait exposed along transects and trap lines rapidly attracts animals from adjacent areas and gives a biased index to mongoose abundance. It was found, however, that single bait spots will attract most animals from the surrounding area. The size of this area is not known, but it should be rather consistent between sites. Subsequent trapping around bait spots appears to give some idea of how many individuals were drawn into the bait and, therefore, provides an index to the relative abundance of mongooses in the area.

Radio telemetry studies have shown that mongooses are nomads and that their home ranges overlap. They are opportunistic feeders and will move a mile or more to utilize new sources of food. Thus, they will tend to quickly invade areas where they have been removed, especially after birds begin to nest. The mean radius of mongoose home ranges was about 725 m for males and 400 m for females in spring and about 325 m for males and 400 m for females in fall. At either season, most mongooses should readily move to bait stations placed 500 m apart.

The peak of mongoose breeding on Hawaii is between January and March, but some pregnant and lactating females are found in every month except November and December. In 1985 many pregnant females were captured, but few young survived to independence. Numbers of mongooses on study areas declined as adult deaths exceeded recruitment of young.

In 1986 only a small proportion of females were pregnant between January and June, but most young they produced survived. More young than adults were caught in the fall, but the total catch was still lower than in 1984 and 1985. Over 400 animals were captured from other areas for necropsy. Data will be analyzed along with live-trapping records to further describe population dynamics in the Hawaiian mongoose. Mongoose densities in native habitats range from about one per 2 ha to one per 25 ha in Hawaii.

Laboratory tests showed that mongooses greatly preferred fresh beef, pork, fish and eggs over any other baits. Beef was selected for use in bait stations as it remained palatable longer than pork or fish. Whole eggs are the bait of choice if bait stations prove ineffective and use of scattered single baits becomes necessary. Acute toxicity trials (single exposure) gave $LD_{50}$ values as follows: compound 1080 (6.0 mg/kg), zinc phosphide (82.0 mg/kg), warfarin (3.0 mg/kg) and diphacinone (0.13 mg/kg). Diphacinone was quite specific to mongooses; it was much more toxic to mongooses than to either rats (3.2 to 5.1 mg/kg) or coyotes (0.6 mg/kg). Wild pigs, which are hunted and eaten by Hawaiians, are much less susceptible (150 mg/kg). In bait concentration trials, diphacinone at 0.0005% killed 80% of mongooses after exposure to a single, 30 g bait. At a concentration of 0.00025%, exposure to a single bait did not cause mortality, but a single bait given on 2 consecutive days killed 89% of animals tested.

Mongooses readily entered and fed from bait stations constructed of 4-inch PVC pipe. Field tests showed dominant mongooses did not restrict other animals from feeding and many different animals fed at stations each day. On two, 0.25 $km^2$ plots, trapping was undertaken before and after beef containing DMCT was exposed at a central bait station (DMCT marked the skulls and long bones of mongooses that fed on bait). Before exposing DMCT bait, 19 animals were caught. Seven of these were subsequently recaptured and all were marked with DMCT. Twenty new animals were also caught after baiting and eleven were marked. Of 19 animals caught before baiting, 12 were not recaptured; however, after baiting 20 new individuals were found on plots. These changes in individuals on plots illustrate both the nomadic movements of mongooses and the attraction of mongooses to bait. Based on this work with DMCT and knowledge of the average radius of a mongoose's home range, bait stations will be placed at 500 m intervals in efficacy trials.

## Reports and Publications:

Keith, J. O., D. N. Hirata and D. L. Espy. 1985. Control of mongoose predation on endangered Hawaiian birds. Progress Report. October 1985. 16 pp. On file at Denver Wildlife Research Center.

Keith, J. O., D. N. Hirata and D. L. Espy. 1986. Control of mongoose predation on endangered Hawaiian birds. Symposium 18 - Poster Session Conference on Science in the National Parks. Colorado State Univ. Fort Collins. July 13-18, 1986.

Stone, C. P. and J. O. Keith. 1987. Control of feral ungulates and small mammals in Hawaii's National Parks: research and management strategies. pp 227-287. In C. G. H. Richards and T. Y. Ku (eds.) Control of mammal pests. Taylor and Francis. London, N. Y., and Philadelphia.

## Attachments

Project Objectives
Acute toxicity summary
Concentration bioassay summary
Final report to State of Hawaii by Dann L. Espy

# CONTROL OF MONGOOSE PREDATION ON ENDANGERED HAWAIIAN BIRDS

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Objectives:

1. Describe mongoose population biology
   --When do they breed?
   --When is mortality the greatest?
   --What are recruitment and mortality rates?
   --When can control be most efficiently conducted?

2. Describe mobility of mongoose populations
   --Are adults resident or nomadic?
   --When do young disperse?
   --What are reinvasion rates into areas where they have been removed?

3. Develop methods to estimate mongoose abundance
   --To determine when control is needed
   --To evaluate control efficacy

4. Test toxicants for their toxicity to mongooses ($LD_{50}$) and evaluate their registration potential.

5. Determine preferred bait substrates and test their acceptability in the form needed for a bait formulation.

6. Develop a durable and effective formulation of bait and toxicant. Conduct concentration effect bioassays and establish minimum levels of toxicant needed in baits.

7. Assess potential nontarget hazards
   --Primary hazards of baits to mainland corvids and consumption of baits by rodents, other birds, and insects.
   --Secondary hazards of poisoned mongooses and rats to the mainland crow, a buteo hawk, and the short eared owl.
   --Tertiary hazards to man from eating contaminated wild pigs.

8. Develop delivery techniques
   --Use of bait stations vs. use of drop baits.
   --Periodicity and rate of toxicant dispersal.
   --Spacing of baits or bait stations.
   --Use of scents to attract mongooses to baits.

9. Obtain experimental use permits and conduct efficacy trials in habitats of interest.

10. Draft applications for 24 C registration in Hawaii (special local need registration).

11. Assist cooperating agencies with protocols to develop cost/benefit data.
    --How much does mongoose control increase productivity in endangered species?
    --How much does control cost?

6/1/86

Acute toxicity of candidate toxicants against mongooses.

| Test | Toxicant | $LD_{50}$ (95% C.L.) mg/kg |
|---|---|---|
| $LD_{50}$ Probe a/ | Compound 1080 | 6.0 (3.0-12.0) |
| | Zinc phosphide b/ | 25.0 (12.5-50.0) |
| | Warfarin | 3.0 (1.5-6.0) |
| | Diphacinone | 0.13 c/ |
| | Quintox | >200 c/ |
| $LD_{50}$ d/ | Zinc phosphide b/ | 82 (54-124) |

a/ 2 animals/dose level with 4 or 5 levels

b/ most mongooses regurgitated

c/ confidence limits could not be calculated

d/ 5 male and 5 female at each of 5 dose levels

Compilation of 15 Diphacinone concentration - effect bioassays on mongooses.

| Chemical | Bait | Conct.% | Number Animals | Mean Animal Weight (g) | Bait Offered (g) | | Bait Consumed (g) | | Mg/Kg Consumed | | Mortality | Days to Death | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean | Range | Mean | Range | Mean | Range | | Mean | Range |
| Diphacinone | Hamburger | 0.02 | 8 M, 2 F | 702 M, 526 F | 29.75 | 26.45-30.40 | 29.27 | 25.18-30.30 | 9.01 | 7.32-13.26 | 9/10 | 9.2 | 5-17 |
| Diphacinone | Hamburger | 0.01 | 7 M, 3 F | 727 M, 522 F | 29.69 | 29.00-30.55 | 28.76 | 25.62-30.55 | 4.48 | 3.47-6.35 | 10/10 | 9.7 | 6-15 |
| Diphacinone | Hamburger | 0.005 | 6 M, 4 F | 721 M, 508 F | 29.90 | 29.21-30.69 | 29.56 | 27.96-30.11 | 2.43 | 1.90-3.92 | 10/10 | 8.9 | 6-12 |
| Diphacinone | Hamburger | 0.0025 | 5 M, 5 F | 690 M, 516 F | 29.73 | 28.81-30.11 | 29.55 | 28.58-30.00 | 1.31 | 0.79-2.07 | 10/10 | 7.3 | 5-11 |
| Diphacinone | Scrambled egg | 0.0025 | 3 M, 7 F | 669 M, 503 F | 29.54 | 28.29-30.11 | 29.54 | 28.29-30.11 | 1.38 | 0.97-1.70 | 10/10 | 7.8 | 5-12 |
| Diphacinone | Hamburger | 0.001 | 5 M, 5 F | 700 M, 448 F | 29.70 | 28.77-30.82 | 29.32 | 28.37-30.52 | 0.55 | 0.35-0.90 | 10/10 | 7.0 | 4-10 |
| Diphacinone | Hamburger | 0.001 | 4 M, 6 F | 687 M, 471 F | 29.61 | 28.71-30.06 | 29.09 | 26.90-30.06 | 0.55 | 0.36-0.78 | 9/10 | 8.6 | 6-10 |
| Diphacinone | Scrambled egg | 0.001 | 1 M, 9 F | 779 M, 482 F | 29.71 | 29.31-30.33 | 27.21 | 14.50-30.33 | 0.55 | 0.37-0.69 | 9/10 | 9.6 | 5-13 |
| Diphacinone | Scrambled egg | 0.001 | 4 M, 6 F | 662 M, 441 F | 29.76 | 29.12-30.32 | 29.76 | 29.12-30.32 | 0.59 | 0.39-0.85 | 8/10 | 8.0 | 4-11 |
| Diphacinone | Hamburger | 0.0005 | 5 M, 5 F | 794 M, 530 F | 29.91 | 29.01-30.77 | 28.54 | 23.60-30.28 | 0.22 | 0.16-0.31 | 9/10 | 8.0 | 6-11 |
| Diphacinone | Hamburger | 0.0005 | 4 M, 6 F | 646 M, 516 F | 29.94 | 29.30-30.34 | 29.37 | 26.24-30.39 | 0.27 | 0.20-0.32 | 7/10 | 7.3 | 5-9 |
| Diphacinone | Hamburger | 0.00025 | 5 M, 5 F | 752 M, 525 F | 29.84 | 29.20-30.55 | 28.88 | 26.73-30.55 | 0.12 | 0.05-0.15 | 0/10 | - | - |
| Diphacinone | Hamburger | 0.00025 | 4 M, 5 F | 628 M, 473 F | 59.38 1/ | 58.64-60.71 | 59.30 | 58.49-60.71 | 0.29 | 0.18-0.38 | 9/9 | 7.4 | 5-11 |
| Diphacinone | Hamburger | 0.00025 | 3 M, 7 F | 653 M, 498 F | 59.93 1/ | 59.06-62.43 | 59.13 | 56.87-60.31 | 0.28 | 0.22-0.36 | 8/10 | 7.3 | 5-10 |
| Diphacinone | Hamburger | 0.00025 | 4 M, 6 F | 671 M, 464 F | 89.64 2/ | 88.50-91.37 | 89.47 | 88.50-91.37 | 0.42 | 0.30-0.53 | 9/10 | 8.3 | 5-12 |

1/ = Bait offered over two days.

2/ = Bait offered over three days.

Hawaii Division of Fish and Game

JOB PROGRESS REPORT

State: Hawaii

Project No.: R-11-A

Study No: 6

Cooperator: U.S. Fish and Wildlife Service

Period Covered: January 1, 1985 to September 30, 1986

By: Dann L. Espy

Project Title: State-wide Endangered Wildlife Program

Study Title: Development and Monitoring of Predator Management in Endangered Species Breeding Areas

Job Title: Development-and-Field Testing of Predator Management Techniques for Endangered Species Habitat

## SUMMARY


I spent a total of 298 man-days on activities of the Endangered Species Predator Control Project between August 1, 1985 and September 30, 1986. These activities were: 1) trapping within designated study areas; 110 man-days, 2) monitoring radio-collared mongooses; 60.0 man-days, 3) testing delivery systems; 48.0 man-days, 4) supportive activities, including establishing study areas, mongoose necropsy, data compilation, computer analysis of data, and report preparation; 80.0 man-days. Some results reported here include efforts and results of other staff members of the Mongoose Project.

Endangered species habitats and other study areas were located in Hawaii State lands at Puu Laau (8000 ft.), Pohakuloa (6500 ft.), Kipuka Ainahou (6500 ft.) and Powerline Road (5800 ft.), and in Hawaii Volcanoes National Park at Mauna Loa Powerline Road (5000 ft.), Ainahou Ranch (2400 ft.), Kipuka Nene (2700 ft), and Kalapana (150 ft.), (Figure 1). Other mongoose collection sites include Whittington Beach Park, Waiohinu dump, Kalapana dump, Hilo dump and in North Kona at Honokohau and Makalawena brackish ponds. Investigations were made in these areas to determine mongoose abundance, distribution, movement, and biology.

Mongoose population densities were greatest at coastal elevations and decreased at higher elevation. Mongooses were abundant at Kalapana (150 ft.), the lowest elevation surveyed, and sparsely present at Puu Laau (8000 ft.), the highest elevation surveyed.

Radio-collars were attached to 30 male and 22 female mongooses. Most of these collars were fitted during the breeding season spring-summer 1985. The remaining transmitters were attached to

mongooses during the non-breeding season during fall-winter 1985.

All transmitters were put on mongooses captured and released on the Kalapana and Kipuka Nene grids. Some of these mongooses were located once daily for up to two months. Telemetry locations were plotted on maps. Polygons were drawn to connect peripheral locations and areas enclosed in these polygons were considered to be home ranges of mongooses. Radio-tracking results showed that male mongooses used 8 to 191 hectares during the breeding season and 6 to 100 hectares during the non-breeding season. Female mongooses inhabited 11 to 52 hectares during the breeding season and 16 to 64 hectares during the non-breeding season. Mongooses traveled up to 1600 meters to feed on various attractants.

Systems to deliver poison baits to mongooses inhabiting endangered species habitats have been tested. Selected poisons have been given to target and some non-target species. Baits and lures have been tried along with various designs of bait dispensers. Efforts are now focused on placement of dispensers when eliminating mongoose populations. Tracking tiles and chemical marker dyes have been used to determine which mongooses have fed at dispenser stations.

Necropsy analysis of mongooses trapped within study areas provided information on weight, measurement, sex, age, reproductive status, and body condition.

## OBJECTIVES

1. To minimize endangered species mortality resulting from predation.

2. To develop, refine, and implement optimal predator management strategies by monitoring and testing the effectiveness of various predator management techniques.

## PROCEDURES

Trapping within designated study areas over long periods of time has been started to study mongoose population biology. Capture-release trapping, conducted on grids, was supplemented with radio-telemetry to determine mongoose movements, home range, and seasonal variance. Periodic removal trapping on transects cleared animals from study areas, enabled study of reinvasion rates, and provided animals for necropsy.

The study areas, Kalapana (150 ft.) and Kipuka Nene (2700 ft.) were selected for study of mongoose population biology and movement. Kalapana has uneven pahoehoe lava flows with deep earth-cracks (20 ft.) and lava tubes. The area is vegetated with grasses (0.5 to 2.0 ft.) and some trees and woody shrubs up to 20 feet high. Kipuka Nene has pahoehoe and a'a lava flows, ranges in elevation from 2300 to 2800 feet, and has many small hills. Vegetation is taller and more dense, with three-feet high grasses covering fallen trees, cracks, and lava tubes.

Capture-release trapping grids were established within each area. Grids encompassed one square kilometer with trap stations 100 meters apart (121 stations). Trapping was conducted for five-day periods in January, March, May, July, and September 1985, and January, March, and June 1986 at Kalapana, and in May, July, and September 1985, and January, March, and June 1986 at Kipuka Nene. All mongooses caught were weighed, measured, sexed, aged, examined for reproductive and body condition, marked with ear-tags, and released.

Mongooses were radio-equipped as follows:

| Kalapana | | male | female |
|---|---|---|---|
| 03-15-85 | through 04-16-85 | 8 | 4 |
| 10-09-85 | through 11-08-85 | 9 | 4 |
| **Kipuka Nene** | | | |
| 06-11-85 | through 08-15-85 | 9 | 9 |
| 11-19-85 | through 01-06-86 | 4 | 5 |

Mongooses were located by walking toward the transmitted signal until the location of its source could be identified. The location usually could be determined within an area of 10 meters square. Mongooses were located hiding in lava-cracks or thick vegetation and usually were intercepted during their daily travels. Locations each day were described by measuring azimuths and distances from grid stations.

Some radio-collars put onto mongooses detached during the tracking period. Most losses occurred by the collar slipping over the mongoose head (their necks are nearly as large in diameter as their heads). When transmitted signals indicated no movement for several days detached radio-collars were looked for and usually recovered.

Two mongoose removal transects were established in Ainahou Ranch and two along Mauna Loa Powerline Road. Each transect was 2.0 km. long, with 40 stations spaced 50 meters apart. Traps were checked once a day for a five day period. Trapping periods for both areas were February, April, September, and November 1985, and January 1986.

Development of toxicant delivery systems began with investigations of attractants (scent stations). Two scent stations were established in the Kipuka Nene study area August 6, 1985 and were checked each day through August 15, 1985. Radio-telemetry was used to study movement and document mongoose visitations to scent stations. A time-lapse camera was placed at each station.

At each station two bottles, with holes in the lids, contained beef and fish scraps. The bottles were located adjacent to areas (10 feet diameter) cleared of plants, leveled, and covered with a layer of sand. Baits were buried under the sand at each station and leveled smooth. Animals searching for baits or attracted to the areas left sand tracks and diggings which were photographed.

Development of a suitable poison bait is required to meet the objective of controlling mongoose predation upon endangered Hawaiian avifauna. This poison bait must effectively control mongoose populations but not cause hazards to non-target species. Efforts were focused on the possibility of feral pigs consuming poison bait. Feral pigs are especially important due to their use by humans for food. A paramount consideration is not to create any food chain links to man or endangered fauna or animals.

On February 3, 1986, at the experimental feral pig facility located at Hawaii Volcanoes National Park, eight feral pigs (two male and six female) were selected for the initial poison experiment. The first poison to be tested was warfarin, chemically designated 3-(α Acetonylbenzyl)-4-hydroxycoumarin. The feral pigs were divided in two groups. High dose pigs (4) were given 100 mg. of warfarin per day for five days. The warfarin $LD_{50}$ for mongooses was estimated to be 5.0 mg. per kilogram, and the $LD_{99}$ about 20 mg. of warfarin. High dose pigs were receiving the equivalent of five poison baits per day for five days. The total warfarin given to each pig during the five day period was 0.5 grams. A second group of low dose pigs (4) were given 40 mg. of warfarin per day for two days. These pigs received the equivalent of two baits per day for two days. The total warfarin received by each low dose pigs was 80 mg.

The theory behind these tests was that the pigs could possibly consume these levels of warfarin by eating either baits or mongooses poisoned within endangered species habitats. Hunters could then kill these contaminated pigs. The kill could occur either promptly after the pigs had eaten the mongooses or after a longer period. To simulate these conditions the pigs were dosed with poison and 2 high dose and 2 low dose pigs were slaughtered two days and 10 days after the final dosing. Samples of various pig tissues traditionally eaten by humans were taken for analysis. Another anticoagulant, diphacinone, chemically designated 2-diphenylacetyl-3, 3-indandione, is scheduled for feral pig testing during late September 1986.

Beginning on March 11, 1986 experimental methods to deliver mongoose toxicants were investigated. White plastic (PVC) pipe, four inches in diameter, was used to construct four liquid and eight bait dispensers. The liquid dispensers contained a bottle holding a five percent sugar and water solution. The bottles were clamped to aluminum rods inserted into the ground. Tubes projecting from the bottom of the bottles were the source of sugar-water for mongooses. The water stations allowed mongooses a single passage to the water bottles. Bait dispenser stations had two entries and a mid-way service port. Deposited within these stations were about twenty pieces of beef baits. The size of each bait was about three quarters of a cubic inch. Placed before the entry to all stations were tracking tiles (12 $in.^2$ floor tiles). One tracking method employed red chalked tiles. A solution of rubbing alcohol and carpenters chalk was sprayed onto tiles. The animals entering the tubes left prints on the chalked tile or on the tubing. Another technique utilized printers ink which was mixed with mineral oil and brushed in the tube passage-ways. Prints were left on tiles when animals left stations. Both methods were combined to detect tracks of animals which entered the tubes or those that came to tubes but did not enter. Scent lures and baits were sometimes placed at or near the stations to help draw mongooses to them. Some mongooses were captured near the dispenser stations and toe clipped to identify them and document how many later visited stations.

Markers (Rhodamine B and Dimethylchlorotetracycline, DMCT) were placed on baits at delivery stations. Mongooses were free to feed on tainted baits and those later captured were placed under an ultra violet light to see if they had eaten baits. These methods were used at Kalapana where two grids (36 stations each) of 0.5 $km.^2$ were established. Two bait stations were placed in the center of each grid to dispense the bait with markers. These grids were later trapped to determine which mongooses had fed at these stations. This information will be used to determine the correct spacing of bait dispensers when controlling mongoose populations.

Mongoose necropsies were conducted at the Fish and Wildlife Service laboratory in Hilo, Hawaii. All animals were weighed, measured, sexed, and examined for reproductive and body condition. Skulls were removed and saved for age determination and stomachs were removed and saved for food content analysis. All necropsy and telemetry data were entered into Fish and Wildlife Service computers for analysis.

## FINDINGS

### Trapping:

Periodic trapping on study grids is providing data on mongoose population dynamics, movements, and densities. The total catch in both grids tended to decrease over time with a slight increase occurring in March 1986 (Table 1). Juvenile mongooses were seldom captured. Supplemental population dynamics data were obtained by trapping Whittington Beach Park, Waiohinu, Kalapana, and Hilo dumps, and Kamoamoa campground in Kalapana. Grid trapping will be continued through midyear 1987 to identify the timing of peak population increases. Removal trapping on transects located in Hawaii Volcanoes National Park at Powerline Road and Ainahou Ranch indicated a steady influx of mongooses into areas periodically trapped out (Table 2).

### Telemetry:

Data on mongoose movements in Kalapana and Kipuka Nene study areas suggest that males have a spring to summer (breeding season) home range of 8 to 191 hectares and a fall to winter (non-breeding season) home range of 6 to 100 hectares (Figures 2 and 3). Female mongooses tracked during the spring to summer had a home range of 11 to 52 hectares and a fall to winter home range of 16 to 64 hectares (Figures 4 and 5). Males show a much greater home range during the breeding season while females range less but ranges of both sexes are more similar in fall. Mongooses appear to be a nomadic species and the specific area used by each animal changes with time.

Male mongooses seemed less tolerant of human presence than females. When approached within 200 meters, male mongooses either hid in earth-cracks or moved away from the radio-tracker. Females remained active above-ground within 100 meters of the radio-tracker. Females also hid in earth-cracks and were often located in the same area the next day. Mongooses sometimes responded to the radio-tracker by moving away in wide arcs. One female mongoose exhibited this behavior several times.

Mongooses traveled up to 1.6 kilometers to feed on various food sources. In Kalapana mongooses were attracted to fish bait and fish remains left by fishermen, and to food left by a hunter for his lost dog. At Kipuka Nene two mongooses moved up to 1.0 km. to feed on a feral pig carcass.

During the fall-winter telemetry period in Kipuka Nene a mother and her male pup were radio-collared and located each day. The pup was about three months old when radio-collared and was followed for two months. During the tracking period the pup was most often with it's mother but not always. Sometimes the mother was located over two hundred meters away but was always found to regroup with her pup before night. Other recorded mongoose movements have exceeded 2.0 kilometers in less than 24 hours.

During scent station test at Kipuka Nene in August, 1985, radio-telemetry was useful in detecting two visitations to stations by radio-collared mongooses. In one instance the radio-collared mongoose had previously established a home-range over 200 meters west of the scent station. This radio-mongoose was drawn to the scent station but did not dig for bait or leave other evidence of her visitation. Telemetry has also been used to detect movements and fate of two mongooses that ate poison baits. These mongooses died underground and only one carcass with transmitter was recovered.

Delivery Systems:

Delivery systems tests included bait, poison, lures, dispenser tubes, and chemical tracer experiments. These were projects planned and undertaken to perfect safe delivery of mongoose toxicants. Some experiments with scents were useful to Dr. Kay Clapperton, a New Zealand zoologist, who worked with us for 2 months testing mongoose scents as possible lures.

Baits presented to some mongooses during the fall Kalapana grid trapping were rejected in favor of local fruits and berries. Mongooses were hard to catch and later telemetry results show that mongooses stayed in areas densely covered by uulei berries (*Morinda citrifolia*). The seeds from these fruits were identified in mongoose scat samples collected from these areas.

Warfarin poison tests on feral pigs resulted in the rejection of this poison as a suitable mongoose toxicant. Warfarin levels given to the pigs caused toxic effects and some pigs died (Table 3). Further laboratory test of different poisons showed that diphacinone, another anticoagulant, was unusually toxic to mongooses and the low diphacinone levels needed to kill mongooses should not harm feral pigs or other animals. During late September, 1986, a diphacinone test on feral pigs will be undertaken. If these tests go well, then other non-target species will be tested for effects of diphacinone.

On March 11, 1986, four plastic dispenser stations (three bait and one liquid) were established in locations near Kilauea summit, about 4000 feet elevation. Another set of four stations (three bait and one liquid were located on Chain-of-Craters road, approximately 3000 feet elevation. Chalked tiles were arranged before all station inlets. A feline scent, thought to be a potential mongoose lure, was placed on vegetation near every station.

Delivery stations were checked each day. Bait take occurred at only a few stations and liquid dispensers were entered but the sugar solutions were not used to any extent. Rat and mongoose tracks were seen on the tiles and tubes, but were of poor quality due to rain. Rats seemed to use the stations more often than mongoose and the dispensers were moved to Kalapana March 17 to subject more mongoose and less rats to them. The same methods were used and printers ink was added as a tracking medium. At this same time the use of the feline scent was discontinued. Throughout these tests the stations without the feline scent were visited by mongoose more frequently than those with the scent. All stations without the feline scent were entered by mongoose.

On March 29 three stations were visited by dogs which moved the delivery tubes and left foot prints on the chalked tiles. By April 5 all the stations had been visited by dogs. Throughout these test, tracks were made by dogs, mongooses, and rats. No cat tracks were detected, but feral cats are known to frequent these areas. The liquid dispensers lost most of the sugar-water to ants and cockroaches, but mongooses did not use them.

Single entry and smaller diameter delivery tubes were tried next. These stations circulated air less efficiently which decreased their ability to draw mongoose to them.

Marker dyes (Rhodamine B and DMCT) placed on baits inside the dispensers were found in and on the body parts of most mongooses trapped near these stations. Some mongooses appeared to be eating much more of these marked baits than others. The dispenser tubes did not appear to be dominated by individual mongooses and access to the baits was available to all animals.

Baits tainted with DMCT and distributed from dispensers located in the center of the small Kalapana grids were found to have been eaten by 11 out of 15 mongooses captured on one grid. Four out of five mongooses captured earlier on this grid were positive to DMCT along with seven out of ten new captures. Of 12 mongooses captured on the other grid, 11 were DMCT positive. Two earlier captures and nine out of ten new captures were positive. Placing stations 500 meters apart, within endangered species habitat, and rebaiting every few days would seem to ensure that most mongooses would feed from them.

Supportive Activities:

Necropsy data, together with information supplied from study grids and transects, contributed to a gradually increasing data base which will provide information on the biology of Hawaiian mongoose.

## RECOMMENDATIONS

1. Complete trapping in old and new study areas to enlarge data base for features of population biology.

2. Continue studies of toxicants, baits, and draw stations for delivery of poisons to mongoose.

3. Determine the effectiveness of control techniques to be used in endangered species habitats.

TABLE 1.

KIPUKA NENE GRID CAPTURE-RELEASE

| DATE | TOTAL CATCH | NO. OF INDIVIDUALS CAUGHT | | |
|---|---|---|---|---|
| | | Total | New | Old |
| May 85 | 26 | 23 | 23 | 0 |
| July 85 | 22 | 18 | 11 | 7 |
| September 85 | 6 | 6 | 1 | 5 |
| January 86 | 9 | 9 | 8 | 1 |
| March 86 | 16 | 14 | 6 | 8 |
| June 86 | 13 | 12 | 6 | 6 |

KALAPANA GRID CAPTURE-RELEASE

| DATE | TOTAL CATCH | NO. OF INDIVIDUALS CAUGHT | | |
|---|---|---|---|---|
| | | Total | New | Old |
| January 85 | 54 | 37 | 37 | 0 |
| March 85 | 67 | 37 | 16 | 21 |
| May 85 | 34 | 26 | 7 | 19 |
| July 85 | 32 | 23 | 10 | 13 |
| September 85 | 22 | 16 | 2 | 14 |
| January 86 | 11 | 10 | 3 | 7 |
| March 86 | 17 | 16 | 5 | 11 |
| June 86 | 6 | 6 | 3 | 3 |

TABLE 2.

REMOVAL TRANSECTS

AINAHOU RANCH

| DATE | TOTAL | ADULTS | JUVENILES |
|---|---|---|---|
| February 85 | 10 | 10 | 0 |
| April 85 | 13 | 13 | 0 |
| September 85 | 12 | 12 | 0 |
| November 85 | 8 | 8 | 0 |
| January 86 | 6 | 5 | 1 |

REMOVAL TRANSECTS

POWERLINE ROAD (Mauna Loa)

| DATE | TOTAL | ADULTS | JUVENILES |
|---|---|---|---|
| February 85 | 2 | 2 | 0 |
| April 85 | 6 | 6 | 0 |
| September 85 | 2 | 2 | 0 |
| November 85 | 5 | 4 | 1 |
| January 86 | 3 | 3 | 0 |

WARFARIN TEST

| Pig No. | Sex | Dose | Date of Death a/ | Wt. loss or gain | Blood Coagulation time | Affected Organs | Cause of death |
|---|---|---|---|---|---|---|---|
| 173 | M | High | 2-25-86 | -9 lb. | 20 min. | liver, lungs and kidneys gray, bleeding from snout | severed jugular vein |
| 166 | F | High | 2-25-86 | -5 lb. | 4 min. | normal looking tissues | shot |
| 155 | F | Low | 2-25-86 | -3 lb. | 3 min. | gray liver, hemorrhaged lungs | shot |
| 172 | M | Low | 2-25-86 | -8 lb. | 8 min. | gray liver, lungs and mesentery tissue | shot |
| 187 | F | High | 2-28-86 | +1 lb. | N.A. | hemorrhaged uterus, gray liver | DOA - hemorrhaged uterus |
| 171 | F | High | 3-02-86 | +8 lb. | N.A. | liver gray, hemmorrhaged renal artery | DOA - hemorrhaged renal artery |
| 138 | F | Low | 3-05-86 | -7 lb. | 2 min. | hemorrhaged lungs | shot |
| 176-7 | F | Low | 3-05-86 | -21 lb. | 2.5 min. | liver, lungs and kidneys gray and firm, hemorrhaged uterus | shot |

a/ Necropsy on date of death, except 187 on 3-1-86 and 171 on 3-3-86.

FIGURE 1.


1. HONOKOHAU WETLANDS
2. MAKALAWENA WETLANDS
3. PUU LAAU
4. POHAKULOA
5. KIPUKA AINAHOU
6. POWERLINE ROAD
7. MAUNA LOA (POWERLINE ROAD)
8. KIPUKA NENE GRID
9. AINAHOU RANCH
10. KALAPANA GRID
11. KAMOAMOA CAMPGROUND
12. KALAPANA DUMP
13. HILO DUMP
14. WHITTINGTON BEACH PARK
15. WAIOHINU DUMP

Map of the island of Hawaii showing mongoose study areas.

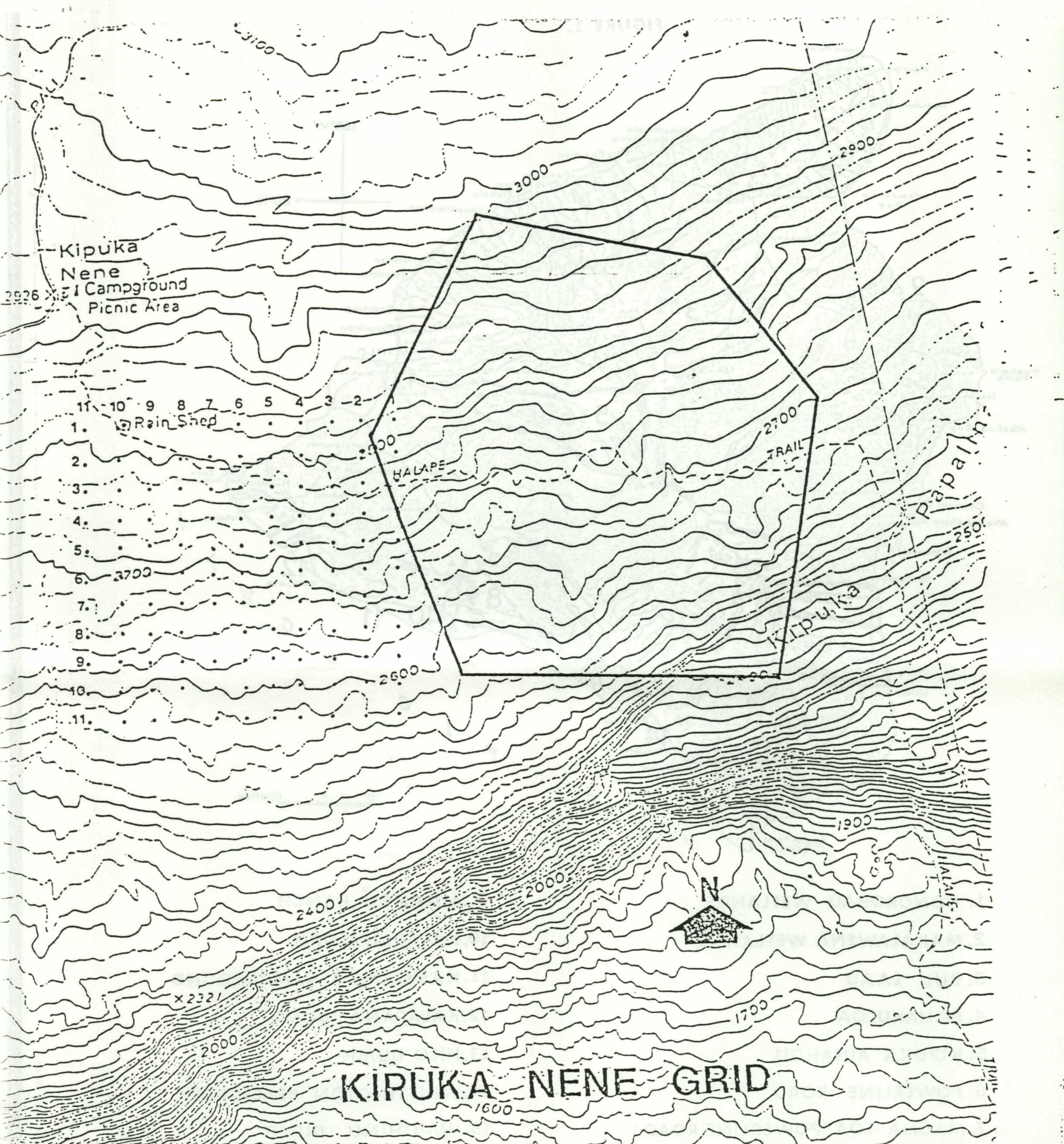


Figure 2. Breeding season range of male mongoose, June 1985.

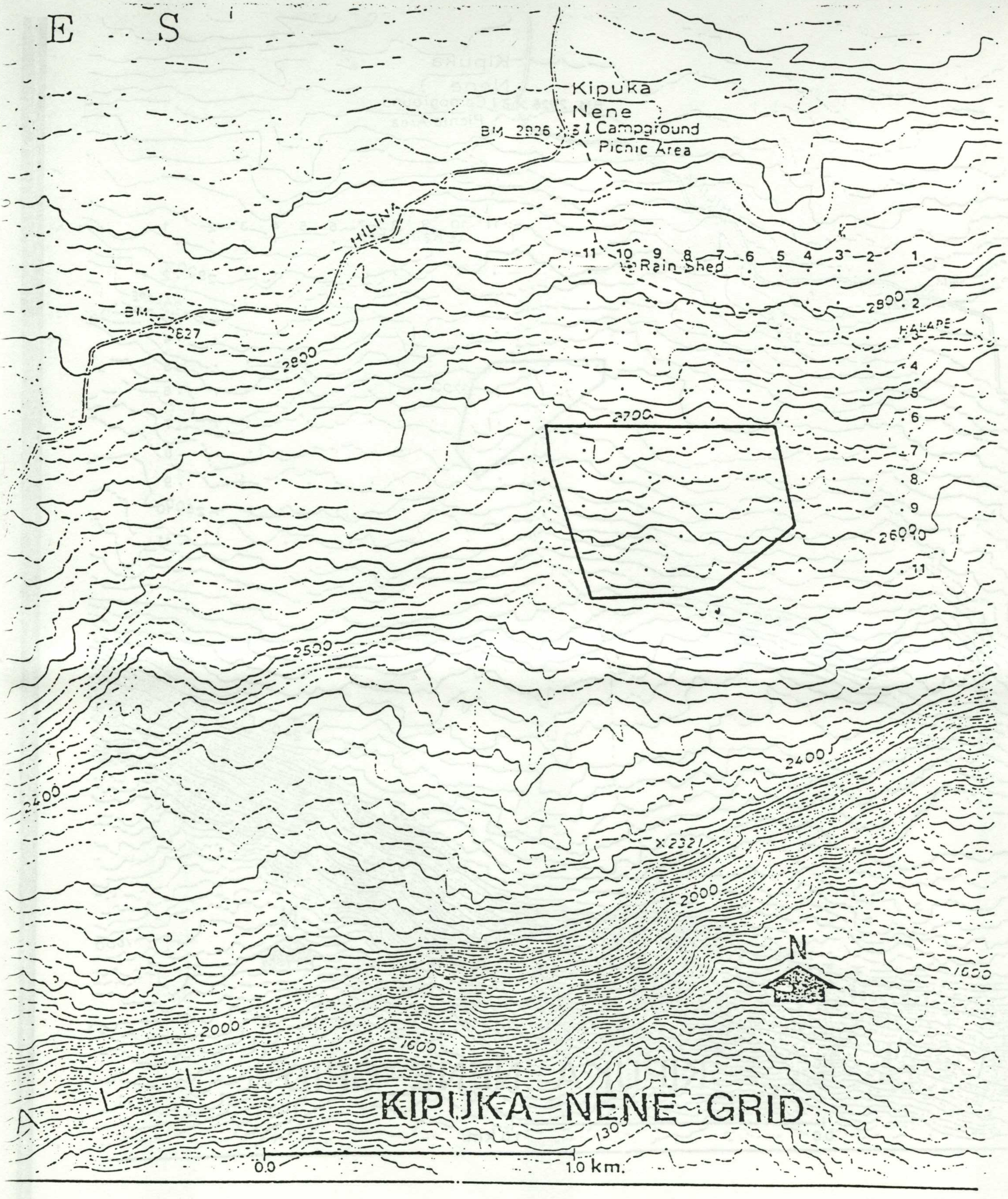


Figure 3. Non-breeding season range of male mongoose, November 1985.

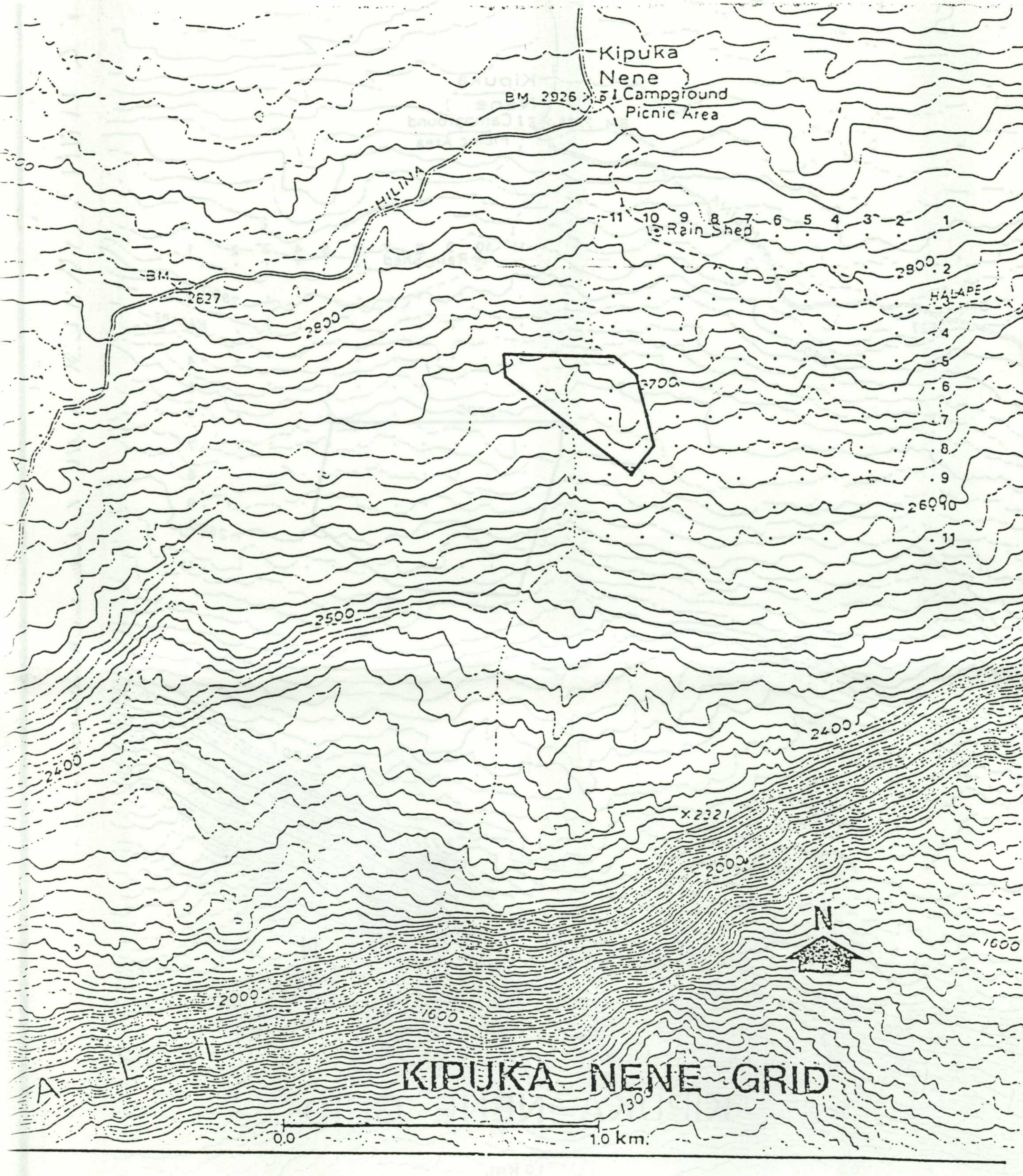


Figure 4. Breeding season home range of female 2c, June, 1985.

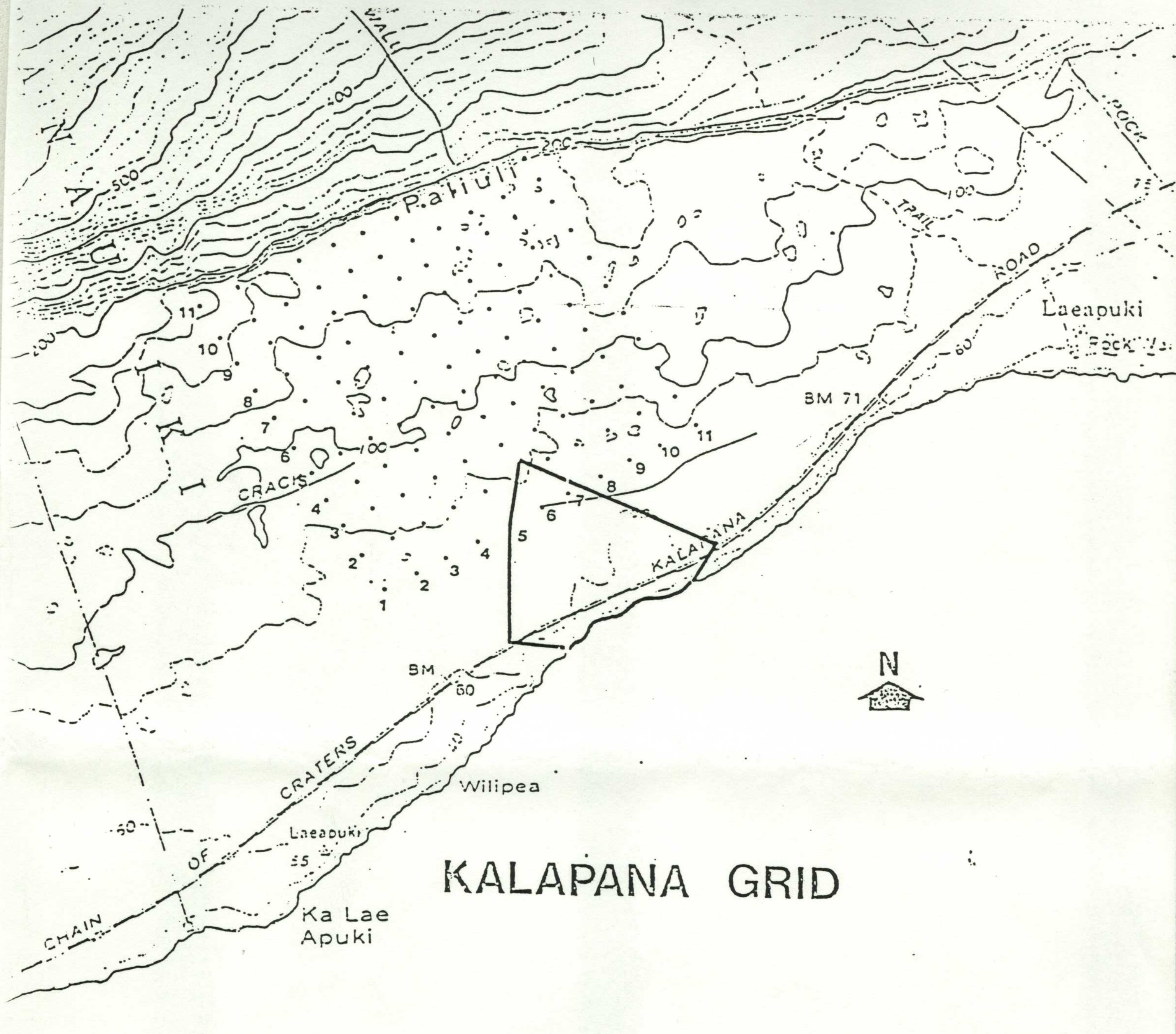


Figure 5. Non-breeding season home range of female, October, 1985.