

# Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands.

C. C. Kessler

4815 Saddle Ave., Flagstaff, AZ 86004. USA

**Abstract** Sarigan Island (c.500 ha) is one of the 15 Mariana Islands in the tropical western Pacific Ocean. The native forest on Sarigan was in an advanced state of decline due to the presence of feral goats (*Capra hircus*) and pigs (*Sus scrofa*). During January and February 1998, 68 pigs and 904 goats were removed by helicopter shooting, ground shooting, trapping, and tracking with dogs. The goal was to stop and reverse the loss of forest and accompanying erosion and thus improve habitat for the endangered Micronesian megapode (*Megapodius laperouse*) and other native species. Follow-up control in 1999 and 2000 removed an additional six goats. Sarigan Island is now considered free of feral ungulates. Vegetation monitoring before and after eradication shows an increase in plant species richness, an increase in tree seedlings, and the rapid expansion of the introduced vine *Operculina ventricosa*. Skinks also increased, but numbers of fruit bats, land birds, and rats have not yet showed change. It is still undetermined as to what effect the vine *Operculina ventricosa* will have on the regeneration and expansion of the native forest.

**Keywords** Vegetation; megapode; *Operculina ventricosa*.

## INTRODUCTION

Of the 11 islands in the Mariana chain (15 islands total) that are uninhabited, the largest five have feral animals. The uncontrolled existence of these populations jeopardises the continued existence of the unique native plant and wildlife species on these islands. Entire forests are disappearing and ecosystems are being changed before they are even understood. Some form of programme, either periodic control or total eradication, needs to be implemented before irreversible damage is done to the entire system.

Sarigan Island had been cultivated and maintained for copra production in 1900 (Fritz 1902). Feral goats (*Capra hircus*) and pigs (*Sus scrofa*) have been present on Sarigan for at least 50 years according to Mr Yamamoto (pers. comm.), a 1940s resident of the island. All residents were evacuated in 1945. In 1950 a request was made to the U.S. Navy administration to let Mr Palacios and company return to the island and commercially harvest goats (J. Johnson pers. comm.); permission was denied. It is believed that ungulate populations were semi-controlled through sporadic harvesting until the 1970s when the most recent attempt at human colonisation was abandoned. Other visitation/harvesting has consisted of brief stops by fisherman or government scientific trips.

The combination of feral goats and pigs has had a severe impact on the native flora and fauna. It appears that the feral ungulates were changing Sarigan from a tropical forest to a grassland habitat (Ohba 1994; unpub. reports CNMI-DFW 1988-1997). This alteration of habitat was believed to be adversely impacting endangered and re-species such as the Micronesian megapode (*Megapodius laperouse*), Mariana fruit bat (*Pteropus mariannus*), and coconut crab (*Birgus latro*) as well as other native species. The primary goal of this project was to remove the feral ungulates from Sarigan Island as a

means to improve habitat (through vegetation recovery) for endangered Micronesian megapodes.

## METHODS

### Study area

Sarigan Island is a relatively small uninhabited island of about 500 ha located 121 miles north of Saipan in the Commonwealth of the Northern Mariana Islands (CNMI) (16° 42' N 145° 46' E). This island is a volcanic cone with steep slopes and no protected beaches. In the central-north-west portion of the island lies a level plateau, which again rises steeply up the main cone. The south and east sides are extremely steep and rise continually to the top of the island (549 m). The vegetation (Ohba 1994) consists of coconut trees (*Cocos nucifera*) with patches of hibiscus (*Hibiscus tiliaceus*) on the lower slopes of the west and north sides. The upper plateau is half native forest (upland mesic climax) and half short grass (*Chrysopogon aciculatus*). The slopes on the south and upper west sides are swordgrass (*Miscanthus floridulus*). The main cone is swordgrass on the southwest and ferns (*Pteris sp.*) on the northeast, with some remnant native forest scattered in ravines and crevices. There are no streams or free-standing water.

### Timeline

Between 1995-1997, CNMI-Division of Fish & Wildlife (DFW) formulated a five-phase plan to eradicate pigs and goats on Sarigan:

- Phase I - Reconnaissance and survey
- Phase II - Base camp establishment
- Phase III - Shooting programme

- Phase IV - Removal of remnant populations/individuals
- Phase V - Follow-up monitoring and re-surveying

CNMI-DFW established 13 photo vegetation plots and completed a general aerial reconnaissance (including photographs) in mid February 1997. Phase I was completed with the help of a US Geological Survey-Biological Research Division (USGS-BRD) bird survey crew in March 1997 that resulted in baseline data on vegetation, bird, bat, and lizard populations (Fancy *et al.* 1999; unpub. report CNMI-DFW 1997,1998).

Phase II, base camp establishment, was generally completed by July 1997. During this period four 3 m x 2.5 m x 2.5 m weatherproof containers, purchased by DFW, were flown onto the island by U.S. Navy helicopter. DFW personnel then moved equipment and supplies into these containers over a period of several months.

Zoology Unlimited was contracted (for USD180,000) by the United States Fish and Wildlife Service through an agreement with the U.S. Navy and CNMI, to conduct phases III and IV. We began Phase III on 1 January 1998 with helicopter shooting followed by ground hunts. This gradually shifted into Phase IV by the beginning of February. Phase IV ended by 1 March 1998 when it was believed all ungulates had been removed from the island. All personnel had left the island by 2 March 1998.

Phase V, the monitoring phase, began in August 1998. This first trip was conducted by CNMI-DFW. Three additional monitoring trips in January and July 1999 and July 2000 were made (unpub. report Zoology Unlimited for USFWS-Honolulu 1999, 2000). During these monitoring trips data on habitat and wildlife was also collected by various biologists. Monitoring of wildlife populations and surveillance for any surviving goats or pigs is ongoing.

## Vegetation and wildlife monitoring

### Vegetation

In February 1997, one year before the eradication started, 13 permanent vegetation plots were established. These were marked with steel bars and the Universal Transverse Mercator (UTM) coordinates were located using a Global Positioning System (GPS) (unpub. report Zoology Unlimited for USFWS-Honolulu 2000; unpub. report CNMI-DFW 1997). Photos of the plots were taken which included two 3 m poles spaced five metres apart for scale. All plant species within a 2 m<sup>2</sup> area centred on the rebar were identified. Ground cover within the 2 m<sup>2</sup> area was visually estimated as was canopy cover. Trees were surveyed using the point-quarter method. Plots were spaced 100 metres apart and followed a transect that cut across the centre of the island starting in grassland, continuing through native forest, and ending in the coconut forest. Plots were re-surveyed in August 1998, July 1999, and July 2000 and Laura Arriola of CNMI-DFW did analysis and graphs (unpub. report CNMI-DFW 1998-2000).

### Bats

Fruit bats were surveyed by various biologists using different methods. Fancy *et al.* (1997) and Morton *et al.* (2000) used Variable Circular Plot (VCP) counts. Wiles in 1983 and 1999 (Worthington 2001) and Johnson in 2000 (unpub. report CNMI-DFW 2000) used station counts, individual sightings, and colony counts to estimate populations. These different methods have been combined to form an estimate.

### Birds

Bird surveys on Sarigan were conducted using standard VCP methodology. Different surveyors used either VCP (Fancy *et al.* 1997) or fixed-radius (Morton *et al.* 2000) analytical techniques to estimate densities. Due to the inherent differences between techniques, only the "birds detected per station" were compared. Surveys were done in September 1990, March 1997, July 1999, and July 2000. Dr Justine de Cruz of CNMI-DFW compiled data and conducted the July 1999 and July 2000 surveys (unpub. report CNMI-DFW 1999, 2000).

### Rats

Pacific rats (*Rattus exulans*) were trapped using a large snaptrap baited with peanut butter and set on the ground. Thirty traps, spaced every 25 metres, were set on the ground in two separate transects for a total of 60 traps. Traps were left overnight and checked in the morning. Rat trapping was done in July 1999 and July 2000. Scott Vogt of CNMI-DFW conducted surveys and provided data (pers. comm.).

### Lizards

Glueboard traps were used for catching lizards. A line of 12 traps, with 5 m spacings was set in the morning and picked up in the afternoon. Traps were set in the shade in both the coconut forest and native forest. Catch rates were expressed as the number of lizards captured per trapping hour. Scott Vogt of CNMI-DFW conducted surveys and provided data (pers. comm.).

## RESULTS

Overall we removed 904 goats (with a sex ratio of 2.38 females to every male of the 383 we sexed), 68 pigs (2.06 females to every male of the 55 we sexed), and two cats in the first 60 days. A further six goats were removed during the four follow-up trips to the island; a density of 1.83 goats/ha and 0.14 pigs/ha. The four follow-up trips were made in August 1998, January 1999, July 1999, and July 2000. Each trip was an average of five search days. These trips accounted for one, four, one, and zero goats respectively (four females and two males). No pigs were ever encountered during follow-up trips.

**Table 1 Effort and feral ungulate kills for Sarigan Island, CNMI. 1 January to 28 February 1998.**

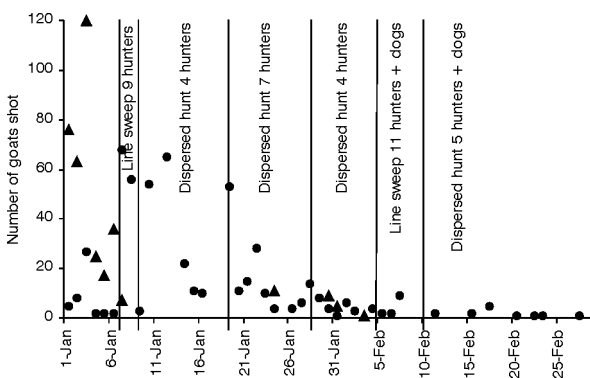
Operational tactic	Hunting effort (estimated)	Goats killed	Pigs killed
Initial aerial	21 hrs flying	344	0
Ongoing aerial	9 hrs flying	26	0
Initial line sweeps	85 man-hours	126	5
Initial dispersed hunt	362 man-hours	382	25
2 <sup>nd</sup> line sweep + dogs	97 man-hours	13	9
2 <sup>nd</sup> dispersed hunt + dogs	424 man-hours	13	22
Pig snares/shooting	20 man-hours	NA	7
Judas goats	20 man-hours	0	NA
Follow-up survey #1	unknown	1	0
*Follow-up survey #2	210 man-hours	4	0
*Follow-up survey #3	380 man-hours	1	0
*Follow-up survey #4	380 man-hours	0	0

\* Includes hours of all wildlife biologists surveying and shooters.

## Aerial shooting

The helicopter (Macaw Helicopter Services, Saipan, R. Crowe-pilot, flying a Hughes 500) was used for about three hours/day over the first seven days of the operation beginning on 1 January 1998, and sporadically thereafter until 22 February 1998. In total 370 goats were shot from the helicopter (41% of the population) in a total of 30 flying-hours, of which 344 were killed during the first seven days in 21 flying-hours.

The overall plan was to shoot as many goats as possible from the helicopter and then follow this with ground hunting. No pigs were ever shot from the helicopter. One to two shooters and a spotter conducted helicopter operations. The spotter was useful in tallying numbers and keeping goats in sight when herds broke up. Shooters were armed with either a semi-automatic rifle with scope and a large-capacity magazine or a bolt action rifle with scope.



**Fig. 1 Goats (*Capra hircus*) shot over time per operational tactic. Black triangles show the number shot from helicopters and black dots the number shot by ground hunting. Sarigan Island, CNMI.**

Helicopter operations concentrated on those areas that had no or little canopy cover. The forested areas were searched, but proved too difficult to shoot through the canopy. Various methods of helicopter deployment were used. These included dropping off a shooter near a cave or dense vegetation and directing the shooter through helicopter surveillance.

## Ground shooting

After the initial seven days of aerial hunting we began the ground hunting part of the operation targeting goats, pigs and feral cats. Our first tactic, used over the first two days, was to use a line formation of nine hunters, without dogs, that searched all forested areas.

Shooters were deployed in a skirmish line spaced roughly 30 yards apart moving across-slope following the general contour. All personnel were in constant communication through the use of hand-held radios. As shooters moved through the forest they stayed in visual contact with the person on either side, helped by the safety requirement to wear orange vests and hats. If they became separated due to terrain or dense vegetation or if they spotted animals, they would use the radios to communicate a desired coordinated action (i.e. stop or slow down). At the end of the day all shooters were debriefed to record the number of animals shot, number seen and in what area, tactical points, and any other items of interest. These line formations worked well for goats but not for pigs because the latter tend to break back through the skirmish line making a shot dangerous.

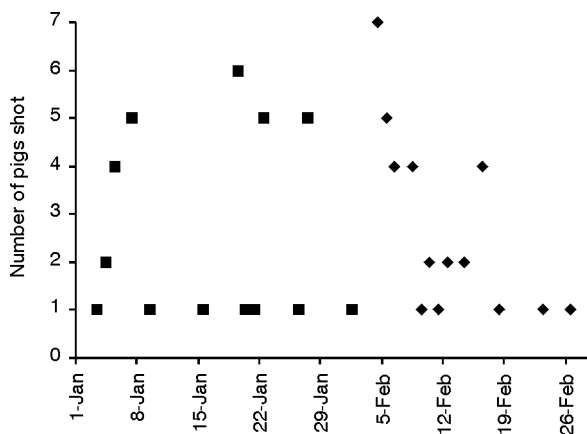
After two days of this large line-shooting operation, the crew was reduced to about five shooters (varied from one to seven). They were deployed in various ways to best exploit the terrain and goat behaviour. Often they would target a specific area, set up one or more spotters/shooters at a strategic point (i.e., a choke point or exit trail), then the rest would disperse through the area. This worked well for the small isolated groups of goats left. Again, radios were essential to keep information flowing as to the progress being made and if help was needed. Positions of the various shooters were continually monitored to ensure coverage and safety. This second tactic continued for about three weeks, after which the crew was again increased to 11 shooters and line sweeps were repeated. At this time we also used dogs. Trained to chase pigs, these dogs also helped with the goats. This greatly increased our coverage and allowed us some certainty that an area was goat or pig-free. After five days of clearance by the second round of line sweeps, the crew was again reduced to five persons. These five were dispersed singularly about the island with the primary mission of detecting goats or pigs. Once detected, help was then radioed for and a coordinated action deployed. The goats' behavioural trait of staying in a home range was exploited and made them vulnerable to this type of operation. Often goats could be detected by the bleating of the kids. Also the goats' habit of going into open areas to feed made them more observ-

able. It should be cautioned that goats could detect loud radios and would flee. Our biggest problem in finding goats was their use of caves. We could sweep an area, but could never fully check all the caves and crevices in the volcanic terrain. Toward the end of the project we would smooth the ground along trails and in caves to be able to better detect animal tracks.

Goats were found in all habitats other than about 100 ha of swordgrass, giving an effective density of two goats/ha. This grass grows in dense clumps to about 3 m in height. As its name implies, it can inflict many slight cuts to exposed skin. This unpleasantness, plus its density and stifling heat, render it practically impenetrable and make for extremely disorienting and strenuous hiking conditions. Thus it was decided to burn off the *Miscanthus*. This was consistent with local agricultural practices. The two main reasons for doing so was to deny fleeing animals cover and allow easier traversal by foot (access into remote areas). *Miscanthus* was usually ignited with a flare shot from a marine signal gun out of the helicopter. In most areas the *Miscanthus* burned quickly, and did not spread into forested areas. It was our practice to go and investigate any carcass we found in the burned areas. We were curious to know if any animals died from the fire. We were always alerted to dead animals by the flies. Our only discoveries were of monitor lizards and geckos. As these were not totally consumed by the fire, it is assumed that anything larger would have left a greater proportion of carcass and would have been discovered more readily. It is therefore our conclusion that no large animals or birds perished in this manner.

## Pigs

Pigs were restricted to the native and coconut forested areas, about 162.5 ha (Morton *et al.* 2000), giving an effective density of 0.42/ha in these habitats. For the first 30 days pigs were hunted opportunistically by personnel, including baiting and snares. This accounted for 54% (37) of the total pigs. At the end of 30 days we concluded that pigs were not being removed efficiently enough to bring



**Fig. 2 Pigs (*Sus scrofa*) shot by hunting without dogs (black squares) and hunting with dogs (black diamonds) over project duration. Sarigan Island, CNMI.**

about a total eradication. Dogs arrived on 3 February 1998 and began hunting immediately. Hunting with dogs accounted for the last 46% (31) of the total. The last pig was killed on 28 February 1998.

## Control techniques

### Snaring for pigs

Snares were deployed but found to be of limited use. Two kinds were used, a commercial wire snare and a locally-constructed foot snare used with bait. The commercial wire snare was a constricting type equipped with a one-way continually tightening device. These are placed on trails and require that the animal put its head into it. These were not effective due to the lack of defined pig trails. The local snare was moderately successful. This snare was tied to an elastic tree branch, which would be bent down and fastened to a trigger. The snare loop would then be placed on the ground in front of a small semi-circular enclosure made of cut tree limbs that held the bait. The pig would stick its head into the enclosure's opening for the bait while standing in the snare's loop. The pigs feeding would release the trigger, the snare would tighten on one foot, and the branch's action would suspend the foot in the air thus holding the pig. Bait was split coconut. A more effective method was to bait a large area with split coconuts and return at night with the use of a spotlight to shoot any pigs feeding. For the first 30 days snaring, shooting over bait, and hunting were the only methods used for pigs. We had just about reached our limit; that is to say that we were no longer removing pigs, when the pig dogs were brought to the island.

### Dogs

The pig dogs used were a local nondescript breed (mutt or "boonie" dog), about 34 kg apiece, and came from Alamagan Island in the Mariana chain. Dogs worked well, but could only chase a maximum of four pigs in a day before they were tired out. Two pigs in a day was more the norm. Chasing down pigs with dogs is a high-adrenalin pursuit that requires the shooter to strip down to the bare essentials. All gear must be tightly attached to the person, and protective eyewear is recommended. Gear consisted of a radio, canteen, and a short-barrelled semi-automatic rifle. As soon as the dogs signal that they have detected an animal, the shooters must start to run in the general direction so as to keep up. This physically exhausting and mentally nerve-racking run eventually ends in a limited access area. The pig's habit is to run until tired, then turn and face the dogs. When they do this, some natural barrier (such as thick brush or a ravine bank) usually protects their back. The shooter, upon arriving at the scene, is usually found to be blocking the exit path. As soon as the pig becomes aware of the person, it will try to run again and will charge through anything in its way. In this way the shooter is often attacked. Usually the shooter can dispatch the pig before it knows a person is there by slowly approaching. If not, then the dogs will charge in at the move-

ment of the pig and attempt to hold it. This all makes for some seconds of utter confusion. After the pig is shot, a long break is required to rest the dogs and calm the shooter. The dogs usually held smaller pigs. These dogs would also detect and chase goats, although they did not seem as enthusiastic and would stop chasing once the goats reached an area of cliffs, boulders, or sharp rocks.

**Radio-collared goats**

On 12 February six radio-collared goats were released. These were airlifted to different sections of the island. They were heavily marked with water-soluble pink dye on their hair, carried pink flagging in their horns, and a pink-flagging collar for identification at long range. It was feared that these animals would be inadvertently shot, thus the identifying markers. These feral goats were obtained from Anatahan Island. They were deployed for about two weeks and finally removed at the end of the project. The decision to remove the radio-collared goats was made because it was unknown when or if a next trip to the island would be undertaken.

**Rifles**

Two general types of rifles were used. One was the Ruger semi-automatic model mini-14 ranch rifle in .223 calibre with five, 20, and 30 round magazines. The other type was the Ruger bolt action model M-77 in .220 swift calibre with a four shot magazine and fitted with a 3-9 variable Bushnell scope or a 6-20 variable Simmon scope and a bipod. CNMI law regulated the calibre of rifle used.

**Communications**

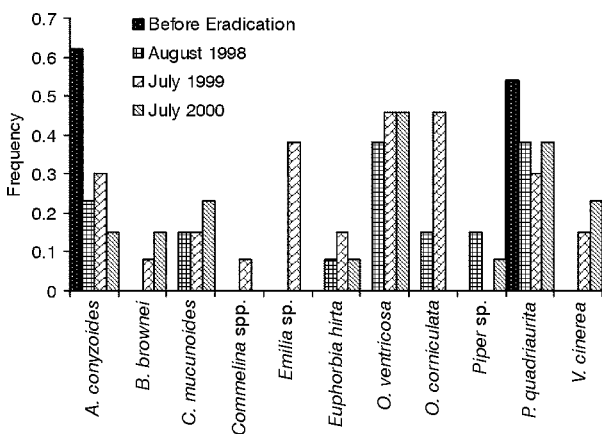
Hand-held radios were a critical link throughout the operation, both for person-to-person and person-to-helicopter communications. Hand-held radios provided coordination between personnel and provided the flexibility to adapt to any situation. It also increased our safety factor

by both preventing dangerous shooting conditions and facilitating rescue for possible accidents. Each person carried a unit plus a spare battery. Some of the units failed due to the high humidity and by getting soaked with perspiration. Waterproof or “integrally safe” type radios are double the standard price, but they may be well worth obtaining. We did lose or otherwise destroy a few units and it is recommended to have extras on hand. Power from a gas generator was used for re-charging. For field operations, radios should be firmly attached to the shooter in a manner that is easy to use (i.e. close to the face) but secure. Plastic ziplock freezer bags or waterproof radio bags should be carried to cover units during rain.

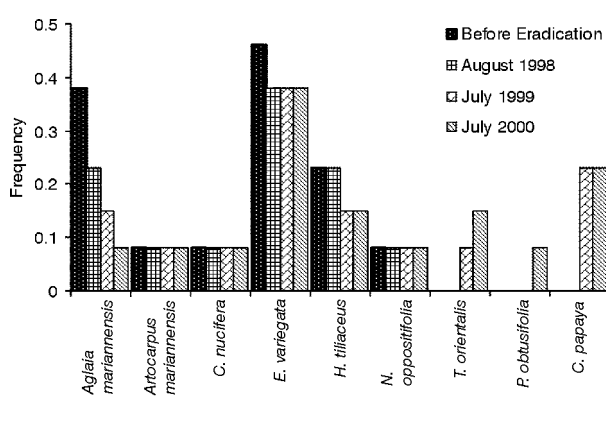
Communications between Sarigan and Saipan (location of closest facilities) were indispensable. A single side band radio was used to communicate with a 24-hour operator (Emergency Management Office) on Saipan. We could also talk directly with Macaw Helicopter’s home base. A long-range radio proved to be a beneficial requirement for logistical planning, weather updates, and emergencies.

**Boat directed**

A small (4.6m) boat equipped with a 12hp outboard was used to move materials from supply boats to shore. It also served as a spotting platform to direct shooters onto animals and to land shooters at otherwise inaccessible areas around the island. Typically, the small boat would depart with an operator and a spotter. Binoculars and radios were needed. The boat would slowly move around the island searching for animals on the steep slopes. Once found, locations would be radioed to ground shooters who had been previously deployed about the island. During these outings we would occasionally see goats close to shore in otherwise inaccessible areas. The small boat would nose in and drop a shooter off. Again radio communications were of the utmost importance. Shooting from the boat was also tried, but the ocean swell made this impractical and usually ended in expended ammo with no gain.



**Fig. 3** Frequency of herbs and weeds on 13 plots before and after feral ungulate eradication. Sarigan Island, CNMI.



**Fig. 4** Frequency of tree species found on 13 plots before and after feral ungulate eradication. Sarigan Island, CNMI.

## Changes in wildlife and vegetation

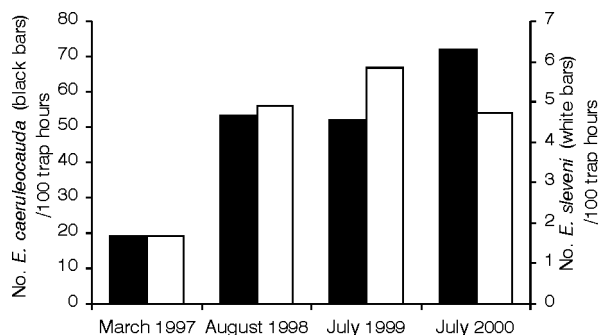
### Vegetation

The vegetation responded immediately to the removal of ungulates. The total number of plant species found in all 13 plots has increased from seven in 1997 to 17 in 1998, 22 in 1999, and 25 in 2000.

Many of these new species are herb and weed species (one species in 1997 vs 11 in 2000). Two species originally found on the plot, the fern *Pteris quadriaurita* and the colonising weed *Ageratum conyzoides* have both declined (Fig. 3). Species found on the plots since 1998 include; *Blechnum browneii*, *Calopogonium mucunoides*, *Operculina venricosa*, *Euphorbia hirta*, *Oxalis corniculata*, *Oplismenus undulatifolius*, *Veronica cinera*, *Emilia* sp., *Piper* sp., and *Commelina* sp. These species are widespread throughout the tropics and have been observed in the Mariana Islands since the early 1900s (Merrill 1981).

Grasses and sedges have increased from one species in 1997 to four in 2000. Tree species have increased from a total of four in 1997 to nine in 2000 (Fig. 4) and have shown a steady increase in the number of seedlings on the plots. These tree species are *Aglaia mariannensis*, *Artocarpus mariannensis*, *Cocos nucifera*, *Erythrina variegata*, *Hibiscus tiliaceus*, *Neisosperma oppositifolia*, *Trema orientalis*, *Premna obtusifolia*, and *Carica papaya*. All are native species to the Marianas, except for *C. papaya*, which is from the Americas but considered naturalised (Raulerson and Rinehart 1991).

Along with the increase in vegetation there has been an increase in canopy cover and a decrease in ground cover (from shading) on those plots near or within the forest. Plots located on grasslands have shown an increase in ground cover from near zero (bare dirt) in 1997 to 100% cover in 2000.



**Fig. 5** Catch rates (# lizards/100 trap hours) for *Emoia caeruleocauda* and *Emoia slevini* before and after feral ungulate eradication. Sarigan Island, CNMI.

### Wildlife

Fruit bats' populations appear to be stable at about 175 and showed no apparent changes. It is assumed that fruit bats are linked to the number of flowering/fruit producing trees, so that any change in bat numbers would require a number of years until the trees mature. Likewise there is no apparent change in rat populations, although only a few rats (<6/year) were ever caught. Rat trapping was done in 1999 and 2000.

There were no significant changes in bird detections. There appears to be a slight increase in the number of megapodes detected from about one per station to two per station. Kingfisher (*Halcyon chloris*) populations also show a slight increase. Micronesian starling (*Aplonis opaca*) detections went up in 1999 but decreased in 2000. Honeyeater (*Myzomela rubratra*) detections have declined in 2000. It is likely that it is too soon to see changes in these species and the slight variations detected could be due to seasonal foraging differences, observer variance, or to El Niño/La Niña events.

Catch rates for blue-tailed skinks (*Emoia caeruleocauda*) and the endemic Slevin's skink (*Emoia slevini*) have greatly increased (Fig. 5).

## DISCUSSION

### Eradication

#### Goats

The helicopter shooting worked well as a means to remove large numbers of goats in open or steep terrain. Calculations show that we killed 38% in approximately 21 hours of shooting. After this the numbers shot dropped off sharply. The goats quickly learned to recognise the sound of the helicopter. The helicopter was also useful in surveying remote areas for the absence of goats.

Line sweeps with a number of shooters was a good way to clear dense sections of forest. At first try, the line was difficult to keep straight and gaps and holes would form presenting dangerous conditions and incomplete coverage. Once the method was practiced a number of times it became very efficient. Walking in a line would force the animals to either try to get through or go around the top or bottom of the line. Pigs usually went through, goats went around. Spotting goats using binoculars and directing shooters to the location by radio was another method that was successful; especially in very steep terrain when the spotter could be offshore on a boat.

The "Judas goats" (Taylor and Katahira 1988) did not work for us. In reviewing the project, I believe that the failure of this operation was due to association problems between goats already present (with established herds and ranges) and the newcomers. The collared Anatahan goats were bigger and hairier than the small short-haired goats on Sarigan. I suspect that over a longer period of time they