GOAT REMOVAL FROM AGUIJAN ISLAND: LESSONS FOR FUTURE EFFORTS

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Abstract: During 1989, feral goats were removed from the island of Aguijan by capture and shooting. A preliminary survey estimated the population at 100-300 goats on this 7.2 km^2 island. Initially, 22 men captured goats over 3 days by driving them into a net corral. Eight of the 31 goats captured were fitted with radio collars and released to assist with hunting efforts. The remainder were removed. Subsequently, 8 individual hunters used 4 different weapons during 6 hunts usually lasting 6 days each. When shooting, hunters were instructed to select adult females before subadults, and subadults before adult males. In 86 man-days of hunting, 158 goats were shot, leaving an estimated population of 40 goats. Comparison of numbers shot with numbers sighted showed that the requested selection was not statistically significant. Analysis of covariance indicated that individual hunter had a significant effect on the number of goats shot/day. Hunting assisted by radio telemetry was not significantly different from unaided hunting. Previous efforts suggest that with the population reduced by about 80%, total effort needed to eradicate the Aguijan goats would be 215 man-days.

Feral goats (*Capra hircus*) have had profound effects on established ecosystems, particularly on islands, as reviewed by Colbentz (1978) and Daly and Goriup (1987). For this reason, control or eradication of feral goat populations is usually desirable. This objective is often not easily reached as goats often attain large populations sizes, become widespread, can be quite wary, and have high a reproductive potential. These difficulties are exacerbated by substantial logistical problems where the goats exist in remote areas and on islands.

A basic choice faced by managers who intend to reduce or eliminate the impact of feral goats is whether to control the population or eliminate it entirely. In insular systems, the latter is much more difficult, but the results are permanent. Although control is usually more feasible, the gains achieved are temporary. Feral goats have showed a density-dependent response of higher reproductive rates as numbers decline. Parkes (1984) estimated a doubling time of just 20 months for a controlled goat population. Similarly, Rudge and Smit (1970) showed that after an 80% reduction, a goat population could return to previous levels in 4 years. Because the ecological objectives of goat removal are long-term, control operations are only effective if they are repeated periodically for an indefinite period. Thus, despite the higher costs incurred in staging eradication efforts, eradication is the preferred strategy wherever it is possible.

Vast amounts of time and money have been wasted on unsuccessful control and eradication efforts (Daly and Goriup 1987). To avoid this, managers must be able to predict if eradication is feasible before committing their resources. There is however, little published information on goat eradication upon which to base such a decision. The purposes of this paper are to describe the goat removal effort on the island of Aguijan, to provide a basis for decisions on the feasibility of eradication on other islands, and to suggest ways to maximize the likelihood of success.

STUDY AREA AND METHODS

The island of Aguijan, also known as Aguijan or Goat Island lies between Tinian and Rota in the Commonwealth of the Northern Mariana Islands (CNMI). At 14°5' and 145°33' E, it covers an area of 7.2 km^2 and is part of the Municipality of Tinian. Generally speaking, there are three levels on the island, two lower benches and a plateau, separated by limestone cliffs or steep slopes. The lowest bench is at 20-40 m elevation, the intermediate bench is at about 70-80 m elevation, and the plateau at about 150 m elevation.

The island was inhabited during Japanese jurisdiction (1914-1945) during which time sugarcane was grown in several areas. As a result, most of the plateau is covered by a mosaic of a mixture of grasses, lantana (*Lantana camara*), masigsig (*Cromoleana odorata*), and vines (*Mikania scadens* and *Calopogonium mucunoides*). The two benches have similar open areas as well as substantial areas of forest. Common forest trees include gulos (*Cynometra ramiflora*), paipai (*Guamia mariannae*), and umumu (*Pisonia grandis*). Fish-kill tree (*Barringtonia asiatica*), fig (*Ficus* spp.), and breadfruit (*Artocarpus altilis*) also occur in some areas. Presumably due to browsing by the goats, forest understory was notably bare, one point intercept transect yielding 97% litter, rock, bare ground, or root, 3% gulos shoot, and 1% woody stem of a vine (500 points). In open areas, common plants include coat buttons (*Tridax procumbens*), masigsig, lantana, *Mikania*, and *Desmodium triflorum*.

The following species wildlife occur on the island and are included on the U.S. Fish and Wildlife Service list of Endangered (status follows scientific name): nightingale reed-warbler (*Acrocephalus luscinia*, endangered); Micronesian megapode (*Megapodius laperouse*, endangered); Mariana gray swiftlet

(*Aerodramus vanikorensis bartschi*, endangered); Mariana fruit bat (*Pteropus mariannus*, proposed); and sheath-tailed bat (*Emballonura semicaudata*, proposed).

Seabirds roost and nest on boulders along the base of the lowest cliffs (brown noddies, *Anous stolidus*) and the top margins of these cliffs (brown boobies, *Sula leucogaster*). Forest birds present include the collared kingfisher (*Halcyon chloris*), bridled white-eye (*Zosterops conspicillatus*), golden white-eye (*Cleptornis marchei*), Micronesian honey-eater (*Myzomela rubratra*), Micronesian starling (*Aplonis opaca*), Mariana fruit-dove (*Ptilinopus roseicapilla*), white-throated ground-dove (*Gallicolumba xanthonura*), and Philippine turtle-dove (*Streptopelia bitorquata*).

Access to Aguijan by sea was complicated by the 20-50 m cliffs along the entire shoreline. Only two suitable landing sites exist and their use is limited to calm or moderate sea conditions. Access by helicopter is easy, albeit expensive.

A preliminary assessment of the goat population was made during a 5-day trip in February 1989. In May 1989, an effort was made to capture as many goats as possible. Eight goats were fitted with radio collars and used as 'Judas' goats (Taylor and Katahira 1988) during hunts.

Goats were then hunted on a monthly basis from July 1989 through January 1990. Hunts were discontinued following the inauguration of a new mayor for the municipality of Tinian who, in contrast to his predecessor, was opposed to further goat reductions on the island.

With the exception of the first effort of 10 days, hunts were for of 5 or 6 days, involving 2-4 people. Hunters were personnel from the CNMI Division of Fish and Wildlife, and the Tinian Department of Natural Resources.

Due to the restrictive regulation of firearms in the CNMI, availability of licensed weapons limited the pool of participants and choice of weapons. Weapons used were 0.223 caliber rifles, 0.22 caliber rifles, and 0.410 gauge shotguns firing slugs.

The island was divided into quarters and each hunter was usually assigned to a specific quarter for a day's hunting. Each hunter was requested to note the location of each goat seen, along with its sex, age, overall color, and whether it was killed or wounded. These data were recorded on standardized forms which had a map of the island on the reverse side for mapping the location. Universal transverse mercator coordinates for each sighting were then taken from the maps. Hunters were also requested to shoot goats in the following priority: adult females; subadults; and adult males.

The following variables were also recorded: day of hunt, number of hunters hunting together, time spent hunting to the nearest half-day, and whether the hunting was assisted. Assisted hunts were those in which radio telemetry was used in locating the goats or, in one case, where a party from a passing boat landed and herded goats into a confined area where they were shot.

The *G* Statistic (Sokal and Rohlf 1969) was used to test for biases in shooting. Stepwise multiple regression was performed on three dependent variables: goats sightings per day, goats shot per day, and goats shot per sighting. The independent variables entered into the model were cumulative number of kills and cumulative number of hunting days. To test for non-linear effects, these two variables were raised to the second, third and fourth powers and also the reciprocal of these exponential transformations were taken and included in the model. Analysis of covariance was employed to investigate the effects of various variables on sighting and shooting of goats.

RESULTS

The pre-hunt capture effort succeeded in capturing 31 goats with about 66 man-days effort, or 0.47 goats removed/man-day. In contrast, there were 2.21 goats shot/man-day during the first 4 hunts (May-October, 52 man-days).

Between May 1989 and January 1990, 6 hunting trips to Aguijan totaled 86 man-days of hunting. Goats were seen but not shot 300 times, 142 were shot and killed, and 16 were wounded. It was thought that in the tropical climate of Aguijan, most wounded goats later died, so goats wounded and killed outright were not distinguished in the analysis. One hundred thirty goats were shot during unassisted hunts (78 man-days), 18 during non-hunter assisted hunts (1 man-day), and 10 during telemetry assisted huts (7 man-days).

Of the 130 goats shot during unassisted hunting, 89 were adults, 39 were juveniles, and 2 were of undetermined age. Seventy-five were males, 51 were females, and 4 were of undetermined sex. This sex ratio was significantly different from 1:1. For adults shot, the ratio was 57:32 ($G = 7.118, < 0.001$), and for goats sighted but not shot it was 91:43 ($G = 17.582, < 0.001$). Hunters seemed to select adult females and juveniles over adult males (adult male:adult female for those shot (SH) = 1.78, for not shot (NS) = 2.12; juvenile:adult male for SH = 0.68, NS = 0.87), but also selected juveniles over adult females (juveniles:adult female for SH = 1.22, NS = 1.84). None of these differences were, however, statistically significant (*G* test, > 0.05).

With the cutoff for inclusion set at ≤ 0.05, the following equations were obtained from the stepwise multiple regression (Fig. 1): sightings per day = -1.34×10^{-3} {cumulative hunting effort}^{2} + 8.31 ($F = 16.206$, df = 1,74, = 0.0001) and shot per day = -5.57×10^{-6} {cumulative hunting effort}^{3} + 2.37 ($F = 9.320$, df = 1,76, = 0.0031). None of the variables or their transformations were significant for goats shot per sighting for which the mean

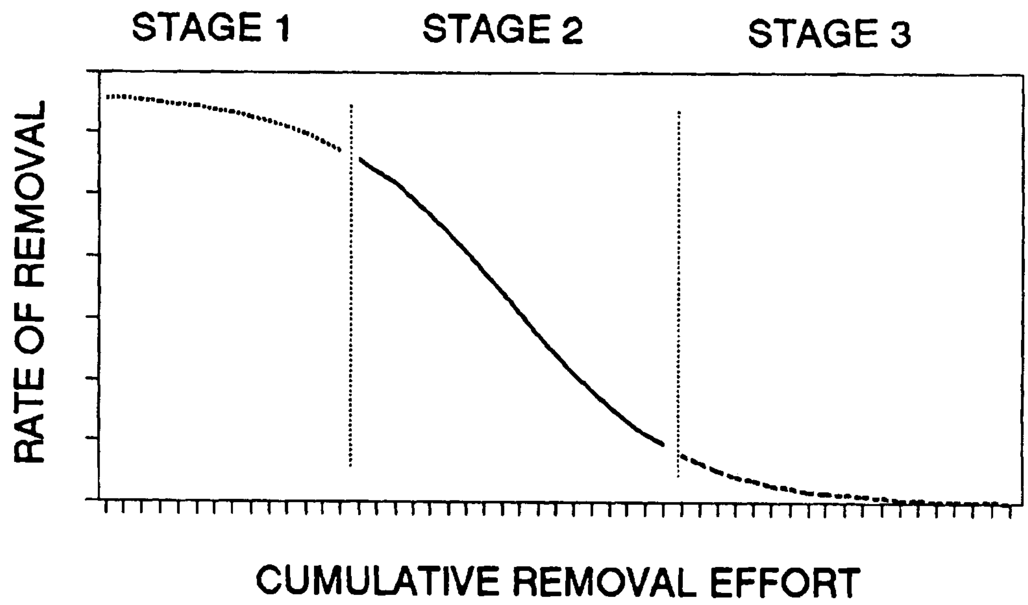

Fig. 2. Hypothetical relationship between removal rate and cumulative removal effort for feral goat removal. (See text for further discussion).

was 0.308 (unassisted hunting, n = 58).

These particular transformed variables were then used in further analysis of covariance with factors and covariates being assessed simultaneously (Table 1). The only significant effects were observed for goats shot per day by hunter and weapon.

DISCUSSION

Comparison of capture and shooting efforts showed that hunting was over 4 times as efficient than as capture. This was despite the fact the Aguijan is relatively favorable for capture. This is because at one site a bench pinches out to a narrow trail. It was therefore easy to drive the goats along the bench in into a corral set up on the bench near this constriction. The major compensation for the extra effort required for capture is that it supplies live goats.

Attempts to preferentially shoot goats of a particular sex and/or age did not appear to be effective. Thus, employing such a policy in our goat removal program was of questionable value.

A plausible hypothetical relationship between hunting effectiveness and cumulative hunting effort would have three stages (Fig. 2). During Stage 1, hunting success does not decrease sharply as goats remain easy to locate and kill. As goat density drops, however, and goats become more wary, kills per unit effort drops steadily (Stage 2). Lastly (Stage 3), with low densities of very wary goats, hunting effectiveness remains low for an extended period until eradication is achieved. The regression equations for goats shot and seen per day (Fig. 1), showing a downward inflection, suggest that the Aguijan program reached the end of Stage 1, or perhaps the early part of Stage 2.

The use of telemetry to track 'Judas' goats did not significantly increase hunting success (Table 1). However, this would likely change as goat densities dropped and goats became more wary (i.e., during Phase 3). This is, in fact, when the use of 'Judas' goats is intended to be employed (Taylor and Katahira 1988).

Hunting in pairs or trios did not affect hunting effectiveness (per man-day, Table 1). However, we usually hunted alone (57 solitary man-days, 15 in pairs, and 3 in trios). A more rigorous test involving more equitable sample sizes would be appropriate before drawing conclusions on this issue.

There was no evidence that hunting effectiveness was affected by day of hunt (Table 1). Consequently, there is no discernable reason to change the structure of hunting trips from one week in length.

Both individual hunter and weapon influenced the number of goats shot/day, but not sightings/day or goats shot/sighting. A direct test of which of these variables primarily determines hunting success is not possible because we did not rotate weapons frequently. However, both hunter and weapon showed a stronger effect on sightings/day than on goats shot/sighting (values of 0.209 and 0.190 versus 0.589 and 0.560 respectively, Table 1). One would expect that sightings/day would be determined by hunter, not weapon, whereas goats shot/ sighting would be more likely affected by weapon. Therefore, although no direct statistical test is possible, it seems likely that the effect of individual hunter was most important in determining the number of goats shot/

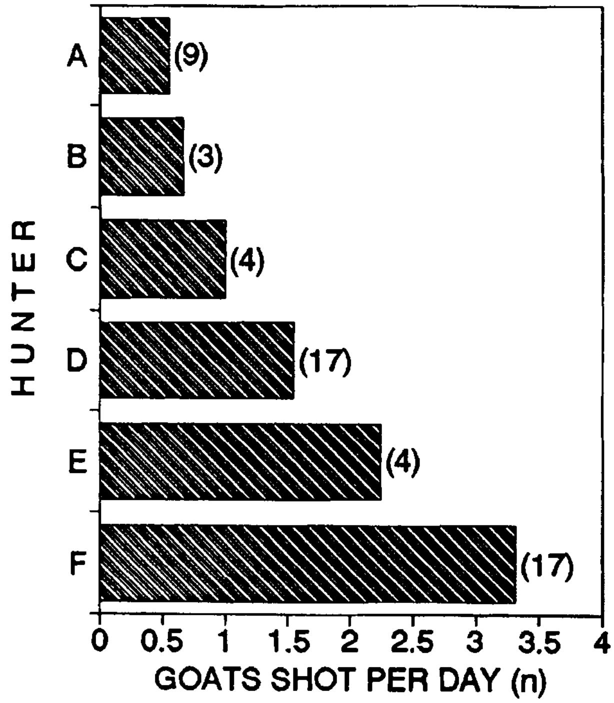

Fig. 3. Mean number of goats shot per day by hunter on Aguijan.

day (Fig. 3). The best strategy then, is to select and include good hunters. What particular weapon they use seems to be of lesser importance.

Given our experience with this experimental goat removal, some assessment of the prospects for eradication can be made. According to Parkes (1989), eradication on Raoul Island (New Zealand) was achieved with an final hunting intensity of 1 hunter-day/2 ha of forest. In contrast, on Great Barrier Island (Parkes 1989), one effort of 1 hunter-day/9 ha nearly eliminated the entire population (930 goats killed). We expended 86 man-days over a 9-month period, equivalent to 107 man-days per year for the 720 ha island or about 1 hunter-day/year/7 ha, suggesting our efforts were within the range of other successes.

With an estimated 40 goats left on the Aguijan, and 158 having been shot, we are roughly 80% of the way to eradication. In the course of the much more lengthy eradication of goats on Raoul Island (Parkes 1984), when 80% of the goats had been shot, the effort was 40% completed. We might then expect an Aguijan effort to entail about 215 man-days, or 129 more than already expended. As the Aguijan goat population has no doubt increased since reductions ended in January 1990, this must now be considered a conservative estimate.

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