Invasive species removal and ecosystem recovery in the Mariana Islands: challenges and outcomes on Sarigan and Anatahan

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Abstract Sarigan Island had a successful eradication of pigs (Sus scrofa) and goats (Capra hircus) in 1998. Following the removal of these species, native forest became blanketed by the invasive vine Opeckula unentrica. Subsequently, the cover from O. ventricosa has stabilized possibly due to competition with two other exotic vine species, drought, and the effects of storms. Native forest cover has increased greatly. Most species of flora and fauna have increased in abundance with native snails and skinks showing some of the greatest gains. Success of the Sarigan ungulate eradication and subsequent responses by native species prompted an attempt to eradicate pigs and goats on nearby Anatahan Island. Support of the project by local inhabitants was gained through education and incentives. Soon after the eradication began, a catastrophic volcanic eruption destroyed the local village and most populations of native species on the island as well as the remaining goats. However, small numbers of other introduced vertebrate species survived. Anatahan Island is still blanketed by ash, is in very early stages of re-vegetation and may one day join Sarigan as a site for bird introductions.

Keywords: Capra hircus, eradication, megapode, Opeckula unentrica, Partula gibba, recovery, Sus scrofa, volcano

INTRODUCTION

Sarigan and Anatahan Islands are two of the fourteen islands that make up the United States possession of the Commonwealth of the Northern Mariana Islands (CNMI) (Fig. 1). The nine northern-most islands of the CNMI are mostly active volcanoes. The islands are typically steep-sided cones rising abruptly out of the ocean and inhabited by fewer species of flora and fauna than the six limestone islands to their south, the sixth island being the US Territory of Guam. Past attempts to populate or otherwise economically utilise the northern islands have met with failure due mainly to volcanic activity, severe typhoons, and difficult logistics. Unfortunately, a remnant of these attempts has been an abundance of feral goats (Capra hircus) and pigs (Sus scrofa) on Sarigan, Anatahan, Alamagan, Pagan, and Agrihan, which compose 87% of the landmass of the nine islands. In addition, Pagan and Alamagan have feral cattle (Bos taurus). Other pest species of concern include: cats (Felis catus) on Anatahan, Sarigan, Alamagan, Pagan, and Agrihan; dogs (Canis familiaris) on Agrihan; and rats on all islands (pers. obs.).

Eradication of pigs and goats have been completed or attempted on Sarigan and Anatahan Islands. In this paper, I describe the methods used on Anatahan and the outcomes recorded after the campaigns on both islands.

The U.S. Fish and Wildlife Service (FWS) Biological Opinion (6 April 1998) recommended that the Navy fund conservation and recovery projects in the Marianas to improve the habitat and population size of the federally listed Micronesian megapode (Megapodius laperouse laperouse) as mitigation for bombing activities on Farallon de Medinilla. To date, the Navy has provided approximately $750,000 in funding for baseline studies and the removal of feral ungulates on Anatahan for habitat restoration. However, no funds were allocated to the removal of other invasive mammals such as cats and rats. The ungulate project is a cooperative effort by FWS, Navy, CNMI-Division of Fish & Wildlife (DFW), and the Northern Islands Mayor’s Office (NIMO).

STUDY SITES

Sarigan (16° 42′N 145° 46′E) is a 500 ha island about 195 km north of Saipan. Over 100 years of grazing by feral ungulates had left patches of bare ground, practically no forest understory, and dry remnants of native forest progressively being replaced by introduced grassland dominated by golden grass (Chrysopogon aciculatus). In 1998, feral goats and pigs were eradicated and within six months there was extensive colonisation by the invasive vine paper rose (Opeckula unentrica) (Kessler 2002). Other species with increased population sizes (detailed elsewhere in the paper) included native skinks, birds, and native tree snails. An additional result of the eradication is that Sarigan has been chosen as the first island for the translocation of bird species from the southern islands as a precaution against future establishment of the brown tree snake (Boiga irregularis). This snake is infamous for its role in the extinction of Guam’s avifauna (Savidge 1987; Fritts and Rodda 1998).

The success of Sarigan’s ungulate eradication prompted a similar attempt on Anatahan Island (16° 21′N 145° 41′E), 40 km further south. Anatahan is 3200 ha (9 km by 4 km) and rises to 788 m. It has two volcanic craters; the older centre crater forms a vegetated central basin. The smaller eastern crater was characterised by steep vertical slopes with some vegetation and bubbling mud pits at the base. On the lower coastal slopes, Cocos nucifera was managed as a copra plantation from 1900 – 1940 (Fritz 1902; Ohba 1994). Native forest on the steep side slopes is characterized by tropical almond (Terminalia catappa) (Ohba 1994). Toward the tops of the slopes is swordgrass (Miscanthus floridulus) or Chrysopogon aciculatus grasslands, with the endemic giant fern tree Cyathea aramagenensis where fog conditions exist (Ohba 1994). Much of the native forest had been severely degraded by feral goats and pigs (Pratt and Lemke 1984; Reichel 1988; Rice 1992; Ohba 1994; Kessler 1996), leaving many areas of patchy forest with little to no ground cover and large areas of easily erodible loose soil.

Pigs were already established on Anatahan during the late 1890s (Fritz 1902) and goats are thought to have been introduced in about 1960 (Reichel et al. 1988). The pigs mainly preferred the coconut forests, level areas, and those areas that had some standing fresh water. Goats were found throughout and had severe effects on all vegetation types. The extent of forest reduction (60% on the south side) can be observed by comparing aerial photographs taken in 1944 and with those repeated in 1999 (Kessler 2000). In 1995 the goat population was estimated at 5000 to 6000 and at 2001 (Worthington et al. 2001).
METHODS

Methods and results for the eradication campaign on Sarigan were described in Kessler (2002).

Wildlife and vegetation surveys on the island have been undertaken since 1997 when baseline data were collected before the 1998 ungulate eradication. These expeditions were conducted by the CNMI-DFW in 1997, 1999, 2000, and 2006 and include data on changes to vegetation, reptiles, birds, and snails (Fancy et al. 1999; Morton 2000; CNMI-DFW 2000, 2008).

The Anatahan ungulate removal project was modelled after the Sarigan project and was divided into five phases: 1 - Reconnaissance and survey; 2 - Base camp establishment; 3 - Shooting programme; 4 - Removal of remnant population/individuals; 5 - Follow-up monitoring and re-surveying.

Phase 1 started in 1997, with the assessment of the ungulate populations and the establishment of vegetation photo plots, and continued in May 2002 with baseline surveys. Also in May 2002, Phases 2 and 3 began with the transportation of supplies and two weeks of shooting. In January 2003, aerial hunting began on 75% of the island and was to have continued on a monthly schedule. As part of the hunting programme, eight female goats were captured, fitted with radio telemetry collars as “Judas” goats (Taylor and Katahira 1988), and released into their original home ranges.

Initial flora and fauna baseline surveys were completed in May 2002 by CNMI-DFW. The two-week initial ungulate shoot was designed to slow forest collapse and was estimated to have removed half of the goat population. Because feral cats were also present, attempts were made to remove as many as possible during ungulate shooting operations. An agreement made with NIMO required a fence to be built that would constrain ungulates to 25% of the island for use by villagers. Phase 4, which involved ground hunting using eight to ten hunters with dogs, along with a separate crew of fence builders, was organised to begin in June 2003.

In May 2003, without prior warning, the island’s volcano erupted for the first time in recorded history (Truesdall et al. 2005). Eruptions continued sporadically for over two years. The final eruptive episode covered the island in ash, which removed 98% of the vegetation and extirpated all land birds.

After the initial eruption in May 2003, the Governor of the CNMI through the Emergency Management Office (EMO), restricted travel to scientific expeditions, prohibited entry to the village and cancelled construction of the fence. Due to the volcanic hazards, EMO has restricted time spent on the ground and limited eradication operations to aerial hunting. Aerial operations consisted of one trip per month (volcanic conditions permitting) lasting two days. On average, this enabled 12 hours of flight time per month with about four hours of actual aerial searching per day (the additional hours being used for transport). However, a continuous monthly schedule has never been achieved due to environmental conditions, logistics (all fuel must be prepositioned), and funding delays.

Aerial shooting involved two hunters and the pilot. One shooter was assigned responsibility to tally kills and record areas searched. Helicopter shooting usually took place in the last hours of the day, but was initially varied to determine the most productive times. One hunter used a 12 gauge shotgun, shooting three inch shells with double-O buckshot and sat behind the pilot. The other hunter was
opposite the first and used a semi-automatic .223 calibre rifle with telescope sight and a bullet catcher. This arrangement allowed the pilot to use either side depending on the winds and terrain. The shotgun was used for calm conditions and getting close to targets and the rifle was used in windy conditions that required shooting from a distance.

Before the eruption, a helicopter was used to transport hunters to the ridge tops. Personnel then moved in a line down slope keeping in close contact by radio and/or sight to ensure total coverage of each section. Ground parties then assembled at a collection point on the coast and were picked-up and transported by small boat to a location that could be accessed by the helicopter. This routine could be done twice daily. During the May 2002 operation, an effort was made to salvage goat and pig carcasses and transport them to the village. Carcasses were dragged to a central location by the hunters, roped together in groups not weighing more than the helicopter’s capacity (~ 300 kg), and slung to the village to be processed by local inhabitants. Freezers and generators were supplied for storage of the meat.

A final hunt was scheduled to include ground hunting with dogs.

RESULTS

Sarigan

Vegetation

Tree and herbaceous species have quickly filled in open areas and the island is no longer an open forest without understorey and areas of grassy fields. Now there is a tangled jungle, closed canopy, and 100% ground cover in areas without trees. Areas once covered with grass are now studded with saplings and covered with vines. The total number of tree species identified in the forested areas has increased between surveys and the overall density of tree species has increased more than tenfold from 1.48 trees/100m² in 1999 to 13.70 trees/100m² in 2006 (CNMI-DFW 2008). The average canopy cover for all forest transects in 2006 was 77%, an approximate 20% increase from 2000 when overall forest canopy cover was 52% for all transects. The range of canopy cover for forest transects in 2006 was 49% to 76% and in 2006 it was 72% to 92%. Canopy cover on a grassy field transect went from 0.4% to 15% (CNMI-DFW 2008).

Wildlife

Native arboreal snail populations on Sarigan were most dense in forested areas dominated by broadleafed native trees. At one station in the native forest, 448 specimens of Partula gibba and 204 of Succinea sp. were encountered within a 25 m² quadrant. (CNMI-DFW 2008).

Three species of skinks were recorded on Sarigan in 1997: snake-eyed skink (Cryptoblepharus poecilopleurus), blue tailed skink (Emoia caeruleocauda), and Slevin’s skink (Emoia slevini). Subsequently, catch rates for E. caeruleocauda increased dramatically and peaked in 2000, then fell slightly in 2006, but were still above catch rates for 1997. Catch rates of the endemic E. slevini also increased, particularly in native forest. In contrast, catch rates of C. poecilopleurus have rapidly declined. This species was found only in the native forest in 2000, but was not captured at all in 2006 (CNMI-DFW 2008).

In 1997, five species of land birds inhabited Sarigan: the endangered Micronesian starling (Aplonis opaca), white-throated ground dove (Gallirallus signicollis), Micronesian megapode (Megapodus lagoperous), Micronesian honeyeater (Myzomela rubrata), and collared kingfisher (Todiramphus chloris). Megapodes and honeyeaters are the two most frequently detected species on Sarigan. Detection rates have increased for both species, but the greatest increase has been for honeyeaters. The starlings and kingfishers have declined slightly in detection frequency, whereas the white-throated ground dove has shown no trend and remains elusive (CNMI-DFW 2008).

Two species have been added to the avifauna of Sarigan. The Marianas fruit dove (Ptilinopus roseicapilla), is apparently a natural colonisation. The bridled white-eye (Zosterops conspicillatus saypani) was purposefully introduced in 2009 to expand its range and reduce the risk of extinction if brown tree snakes become established in the southern islands of the CNMI.

Anatahan

Eradication

In May 2002, the initial shoot from helicopters removed 1740 goats, 32 pigs, and five cats over 31.5 hunting hours. The highest one-day kill rate for was 106 goats/hour, while the overall average was 55 goats/hour. Concurrently, the ground crew removed 681 goats, 30 pigs and one cat in approximately 344 man-hours and with two hours of helicopter transport time. The combined aerial and ground shooting total over 14 days was 2421 goats, 62 pigs, and six cats.

In January 2003, the eight “Judas” goats with radio collars were deployed around the island, following which an additional 144 goats and one pig were removed in six hours of aerial hunting. Ground crews removed an additional 40 goats and five pigs over approximately 75 man-hours.

During the pre-eruption period of January through April 2003, while using “Judas” goats, 784 goats, 47 pigs, and one cat were removed during 30 aerial hunting hours. The highest one-day kill rate from the helicopter dropped to about 40 goats/hour and the average was about 25 goats/hour.

During the two years of active eruptions, there was some limited aerial shooting as conditions permitted. However, once activity ceased (December 2005), no goats were found and they are now considered eradicated. Some pigs had persisted with another 18 removed through aerial hunting. By January 2010, only three pigs were estimated to have survived. Only one cat was removed during this period.

Meat Salvage

About 50 goats and five pigs were moved to the village after helicopter recovery before villagers become overwhelmed by the processing effort and the transfers were stopped. Approximately two hours of flight time was wasted at US$1200/hr in addition to the cost of two generators and freezers and the field time of six staff. Although the task of saving meat was overwhelmed by the physical effort required, it did stop the complaints about “wasted meat.” A greater number of skinners with better skills and determination might have yielded different results. However, the fact that most goats were shot in extreme terrain would have limited the salvage to < 300 animals.

DISCUSSION

Sarigan

Based on survey results, the trend of increasing tree species richness and density should continue as species sighted, but not yet detected on transects, become more
established. Forest composition is changing toward a more native and diverse ecosystem and areas of bare soil now have ground cover. Introduced short grasses are declining in extent as they are replaced by forest and the canopy closes. With less solar irradiation reaching the forest floor, there is better moisture retention and higher humidity near the ground surface.

The effects of these changes are illustrated by the increasingly abundant land snails, where there appears to be a direct relationship between abundance and percent canopy cover. Native forest on Sarigan now supports the largest arboreal snail populations known from the Mariana Islands. For example, Partula gibba on Sarigan attains the highest densities recorded for the species, and Succinea sp., which may be extinct in the southern islands, may be more abundant than the partulids (CNMI-DFW 2008).

Likewise, Enoia slevini, which is the only reptile endemic to the Marianas, has quadrupled in number since the eradication. This species is presently known from five islands in the chain: Alamagan, Asuncion, Guguan, Pagan and Sarigan. Catch rates for this species are now higher on Sarigan than on any other island (CNMI-DFW 2008). Because of this, Sarigan is vital for the survival of this species and could become a source population for future reintroduction efforts.

Bird numbers also appear to be changing. Increased detection frequencies for megapodes are probably linked to increased forage area, especially areas of closed canopy, and an increased prey base in deep forest litter. The reduction in erosion and the addition of leaf litter will further increase forage areas. Similarly, the increase in honeyeaters is probably directly linked to the increased spread of Erythrina trees which bloom during a period when other sources of nectar used by the birds are scarce. Since the eradication, abundant Erythrina saplings are colonising areas that were once over-grazed grasslands.

Increased cover by native species of plants has been accompanied by increased areas of introduced vegetation. The invasive vine Operculina ventracosa is an unplanned consequence of ungulate eradication and had apparently been suppressed by goats. In recent years, the rapid spread of this species has been slowed and may have reached an equilibrium as a result of extended drought during the dry season, intolerance to salt (which can cover the island in the form of salt spray during storms), and competition for sunlight. Two other invasive vines, the mile-a-minute vine (Mikania micrantha) and perennial soybean (Neomotonia wightii) as well as native trees (including Erythrina), all effectively compete with O. ventracosa for sunlight.

**Anatahan**

The use of “Judas” goats with radio transmitters early in the project greatly assisted with locating the remaining animals. “Judas” goats used for the Sarigan project, came from another island and were apparently unable to socialise with the local animals. However, those for Anatahan were local animals released back into their home ranges. These were later readily found from the helicopter and cohort animals dispatched.

Support of the local inhabitants was vital for this project to proceed. There were only a few permanent residents on Anatahan but they all had extended families on Saipan. These members shared in the resources obtained on Anatahan and held an intention to return to their home island. Shooting the main meat source on the island was thus unpopular and a hard choice for a publicly elected mayor. Discussions with family elders about restoring more culturally desirable natural resources, such as coconut crab (Birgus latro) and fruit bat (Pteropus mariannus), proved decisive. Anatahan residents understood that crabs and bats need fruiting trees, that goats eat the trees, and that pigs also eat fruit and crabs. Photos showing changes over time helped to convince the residents as did elders’ memories of enjoying the shade of forest that had since vanished. In addition, the proposed construction of a fence to contain a sizeable part of the island for goats was acceptable.

After the eruption, the island became uninhabitable and permission was obtained from the residents to remove all ungulates. The eruption not only destroyed the village but apparently also the families’ dreams of returning. The residents also accepted that recovery of the island’s forest would be more rapid in the absence of ungulates. The CNMI - DFW must now ensure that ungulates are not reintroduced sometime in the future.

Initially, estimated costs for the eradication were about US$2,000,000. So far, the project has cost about US$750,000. After the eruption, operations continued, but funding from the Navy dwindled as the project was delayed due to the eruption, typhoons, governmental bureaucracy and changes to policy. In 2010, the project was in the last year of available funding and only time will tell if pigs will be eradicated. Restrictions on funds and lack of political will have meant that there are no immediate plans for the eradication of other invasive species on the island.

The eruption of Anatahan’s volcano seems to have completed the eradication of goats, which have not been observed in four years. The loss of six of the eight radio-collared goats in the initial eruption and the loss of the remaining two in subsequent eruptions support this. Feral pigs were heavily impacted by the eruptions but some large adults (>100 kg) did survive. There were at least four dogs on island before the eradication. After the eruptions, two survived, but are believed to have died out within the year. One cat was shot after the eruptions and sign of more is still being observed. Within the cat’s stomach were two rats (Rattus exulans) showing that these rodents had also survived. Chickens (Gallus gallus domesticus), along with all terrestrial bird species, did not survive. Finally, monitor lizards (Varanus indicus) thought to be introduced by ancient Chamorro (Pregill and Steadman 2009), also survived; one was collected in December 2005.

It is estimated that 98 percent of the original forest has been severely altered or totally removed by the eruption. Ground cover was completely buried under at least two meters of ash across the island. Five species of resident land birds were eliminated: Micronesian starling, white-throated ground dove, Micronesian megapode, Micronesian honeyeater, and a unique breeding population of the common buzzard (Buteo buteo). The coconut crab (Birgus latro) an important resource species is also gone. The Marianas fruit bat, which was one of the largest colonies in the archipelago at about 2000 animals (Worthington et al. 2001), was reduced to fewer than ten individuals, but has since increased to about 150 (pers. obs.).

Anatahan Island is now practically a “clean slate” and serious thought should be given about developing it into a more desirable pest free environment. There is some interest in continuing bird relocations to Anatahan Island in the future as the forest recovers, in which case the removal of cats and rats should be considered. At present, the most effective method would be an aerial broadcasting of rodenticide with the secondary goal of cat removal. With the current reduced vegetation cover there is a good chance of success. Also without people wanting to return to the
island, and the lack of resource species such as the coconut crab and fruit bats which would be a concern, there will be no health or non-target issues. Additionally, a rodent removal operation on Anatahan could be combined with projects on nearby Sarigan and Farallon de Medinilla Islands, with cost savings realized through economy in scale. The removal of rodents and cats from islands in the Marianas would start a new chapter in their recovery and greatly enhance our efforts in protecting and promoting the natural conditions and resources of this unique tropical island system.

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